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PETROGRAPHIC EXAMINATION OF CONSTRUCTION AGGREGATES OF NEWFOUNDLAND

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ABSTRACT

Petrographic examination of construction aggregates originates with onsite visual observation and finishes with a thin-section examination of representative samples from the source area, to obtain a reliable quality assessment of the material and thus a credible petrographic number (P.N.) and petrographic rating (P.R.). However, this is often not the case and a questionable quality assessment of the material may frequently result. The P.N. system has four different quality classes, which are used to determine the physical quality of a potential aggregate source.

The petrographic numbering system for construction aggregates was established in Ontario in the late 1940s–early 1950s and many improvements have been added to the petrographic number system since then. One of four different quality classes or factors are assigned to individual rock types that are found in an aggregate deposit; these are good (factor 1), fair (factor 3), poor (factor 6) and deleterious (factor 10). Based on Ministry of Transportation (MTO) and American Society for Testing and Materials (ASTM) standards, a revised P.N. classification consisting of the four different quality classes and using continuous numbers from 1 to 10, may minimize or eliminate the subjectivity of the P.N. and reduce the margin of error, thus giving a reasonably close or same P.N. for the same sample or similar samples.

The P.R. system has four different quality classes of potential cement–aggregate reactivity; non-reactive (rate 1–low), marginal tending toward non-reactive (rate 2–slight), marginal tending toward reactive (rate 3–moderate) and reactive (rate 4–high) to predict the potential alkali-aggregate reactivity of a sample.

A total of 7100 samples were examined over a 15-year period, and of those, 600 representative samples of the different rock types of various durability and quality are presented in this report.

INTRODUCTION

Petrographic examination of potential construction aggregate deposits originates in the field with an onsite visual observation of the aggregate source, whether a gravel pit (Plate 1) or rock quarry (Plate 2), and finish in the laboratory using the petrographic microscope for thin-section investigation of representative samples from the source.

The field investigation for an aggregate deposit should contain imformation on the type of deposit (e.g., sand, gravel or any combination of sand/gravel); the origin of the deposit (glacial, glaciofluvial, marine, colluvial, eolian, fluvial and lacustrine); gradation of the unprocessed material; amount of oversized material (boulders) present; amount of silt or sand lenses present; general estimate of different rock type present and their distribution; and degree of weathering and particle shape. This information is crucial to the process of obtaining representative samples of the source to be investigated.

The field investigation for a rock quarry consists of rock identification (rock type or types and amount), degree of weathering (fresh, slight, moderate and high) and representative sampling and recording of any geological features (e.g., faults, folds, joints, dykes, fractures, cleavages, bedding thickness, grain size, flow structures, alteration zones and mineralization; Bragg, 1989).

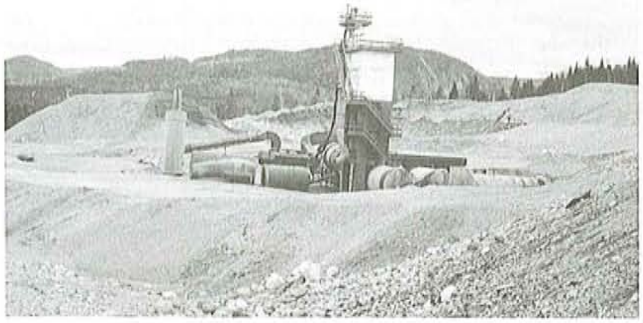

Plate 1. *Gravel pit, Gallants, western Newfoundland.*

Plate 2. *Rock quarry, Avondale, Avalon Peninsula, Newfoundland.*

Any deposit that is being considered for use as construction aggregate should initially be rated on the basis of the amount of deleterious substances present and petrographic number. Deleterious substances are materials or features that occur in or on the rock surface that are capable of causing adverse effects, resulting in premature deterioration of the rock, asphalt or cement binder used in concrete. Some commonly found deleterious substances include clays, organic matter, mica, iron and manganese oxide staining, sulphides, encrustations, mineral alterations, micro-fracturing and highly weathered rock.

A petrographic number (P.N.) is determined for each sample. The P.N. measures the initial physical quality of the material for potential use as construction aggregate. The P.N. is the sum of petrographic factors for each percentage of rock type present, and can range from 100 to 1000 (Table 1 shows how a P.N. is calculated). Each rock type may be assigned a petrographic factor of either 1,3,6 or 10 (Ministry of Transportation, 1994) (Table 2) or assigned a petrographic factor between 1 to 10 (Tables 3 and 4).

Table 1. Procedure for determining petrographic number of a sample following Ministry of Transportation (1994) standard and Bragg (1986)

Number	% Samples	Petrographic Factor	Petrographic Number	Classification
Granite	25	1.1	27.5	Good
Gabbro	10	1.0	10.0	Good
Sandstone	35	1.5	52.5	Fair
Shale	10	5.0	50.0	Poor
Gneiss	10	2.2	22.0	Fair
Clay lump	5	10.0	50.0	Deleterious
Gneiss	5	1.2	6.0	Good
			P.N. = 218.0	Fair

Table 2. Rock types and petrographic factors

Rock Type	Classification	Factor
Carbonates (hard)	good	1
Carbonates (sandy, hard)	good	1
Sandstone (hard)	good	1
Gneiss (hard)	good	1
Quartzite (coarse grained)	good	1
Greywacke-arkose	good	1
Volcanic (slightly weathered)	good	1
Granite–diorite	good	1
Trap	good	1
Magnetite	good	1
Pyrite (disseminated in trap)	good	1
Iron-bearing quartzite	good	1
Sedimentary conglomerate (hard)	good	1
Carbonates (slightly weathered)	fair	3
Carbonates (sandy, medium hard)	fair	3
Sandstone (medium hard)	fair	3
Crystalline carbonates (hard)	fair	3
Crystalline carbonates (slightly weathered)	fair	3
Gneiss (soft)	fair	3
Chert and cherty carbonates	fair	3
Granite (friable)	fair	3
Volcanic (soft)	fair	3
Pyrite (pure)	fair	3
Flints and jaspers	fair	3
Carbonates (soft, slightly shaly)	poor	6
Carbonates (soft, sandy)	poor	6
Carbonates (deeply weathered)	poor	6
Carbonates (shaly clay)	poor	6
Carbonates (ochreous)	poor	6
Chert and cherty carbonates (weathered)	poor	6
Sandstone (soft, friable)	poor	6
Quartzite (fine grained)	poor	6
Crystalline carbonates (very soft, porous)	poor	6
Gneiss (friable)	poor	6
Granite (friable)	poor	6
Encrustations	poor	6
Cementations	poor	6
Schist (soft)	poor	6
Ochre	deleterious	10
Shale	deleterious	10
Clay	deleterious	10
Decomposed volcanic rocks	deleterious	10
Slates	deleterious	10
Talc-gypsum	deleterious	10
Iron formation (very soft)	deleterious	10
Sibley formation	deleterious	10

A petrographic factor (P.F.) of 1 indicates the highest quality, whereas a petrographic factor of 10 indicates the lowest quality. Thus, the lower the petrographic number the higher the rock quality (e.g., a clean, hard, fresh, fine-grained granite would normally have a petrographic factor of 1 and a petrographic number of 100, whereas a soft, friable shale would have a petrographic factor of 10 and a petrographic

Table 3. Petrographic factors for some common rock types (after Bragg, 1986)

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

number of 1000). The petrographic number of any particular rock type may be affected by texture, degree of weathering and hardness as shown in Appendix I.

In the past, only trivial attention has been paid to the importance of petrographic examination of construction aggregates in Newfoundland and it has cost the province millions of dollars to replace or repair damaged roads (Plate 3), bridges (Plate 4) and retaining walls (Plate 5) caused by premature deterioration of these structures, often due to the use of inferior aggregates. Dolar-Mantuani (1983) gives an excellent account of the importance of petrographic examination of aggregates for use in construction.

The P.N. system has being used extensively in Ontario since the late 1940s–early 1950s (Rogers, 1991). It was not used in Newfoundland until 1978, when the author began using the Canadian Standards Association, 1973 version adapted from the Ministry of Transportation, Ontario (MTO) and ASTM, 1985, to give a quick quality assessment of potential aggregate deposits in Newfoundland. The P.N. was used informally by the author and the Department of Works,

Table 4. Revised version of petrographic factors for the most common rock types found in Newfoundland (after Bragg, 1993)

Rock Type	Petrographic Factor Range	Usual Factor
1. Sandstone	1.0–6.0	1.1
2. Shale	3.5–8.5	5.0
3. Mudstone	1.0–6.0	1.5
4. Siltstone	1.0–6.0	1.1
5. Argillite	1.0–6.0	1.5
6. Conglomerate	1.2–8.5	2.5
7. Arkose	1.0–6.0	1.1
8. Greywacke	1.0–6.0	1.1
9. Arenite	1.0–6.0	1.1
10. Chert	1.0–6.0	1.3
11. Limestone	1.1–8.5	1.1
12. Dolomite	1.1–6.0	1.1
13. Quartzite	1.0–4.5	1.0
14. Granite	1.0–7.5	1.2
15. Gabbro	1.0–4.5	1.0
16. Diorite	1.0–4.5	1.0
17. Granite-diorite series	1.0–4.5	1.0
19. Felsic volcanic rocks	1.0–4.5	1.0
20. Rhyolite	1.0–4.5	1.0
21. Mafic volcanic rocks	1.0–5.0	1.0
22. Basalt	1.0–5.0	1.0
23. Intermediate volcanic rocks	1.0–4.5	1.0
24. Andesite	1.0–4.5	1.0
25. Porphyry	1.0–4.5	1.1
26. Pyroclastic rocks	1.1–8.5	1.5
27. Tuffs	1.1–8.5	1.5
28. Metavolcanic rocks	1.1–6.0	1.2
29. Gneiss	1.1–8.0	1.2
30. Schist	1.5–8.5	3.5
31. Phyllite	2.0–8.5	3.5
32. Marble	1.1–6.0	1.2
33. Slate	2.0–8.5	3.5
34. Metasediments	1.1–6.5	1.2
35. Psammite	1.1–6.5	1.3
36. Pelite	1.1–8.5	1.5
37. Semipelite	1.1–6.5	1.3
38. Amphibolite	1.1–7.0	1.5
39. Ultramafic rocks	1.0–7.5	2.5
40. Iron formation	3.5–8.5	4.5
41. Friable rock	10.0	10.0

Services and Transportation since 1978, and in 1983 it was put into the specifications for coarse aggregate by the said Department.

The apparent subjectivity of the P.N. evaluation or test was often the result of unqualified personnel conducting the test. Samples were often collected by unqualified personnel, therefore doubting the representativeness of the sample, and rarely was the person doing the petrographic examination responsible for the collection the sample; these factors often resulted in the P.N. for the same or similar samples being significantly different (>30). It is very important that the person who is doing the P.N. analysis be qualified and be

Plate 3. *Premature deterioration of asphalt pavement, Bay d'Espoir Highway, Newfoundland.*

Plate 4. *Premature deterioration of concrete bridge, Norris Arm, central Newfoundland.*

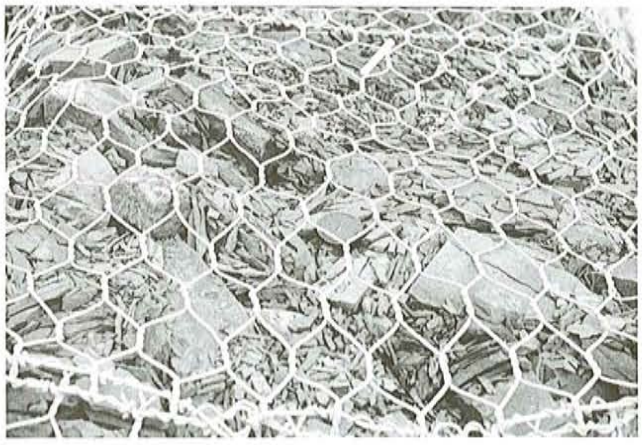

Plate 5. *Premature deterioration of bedrock used as rip-rap in retaining wall, eastern Newfoundland.*

able to obtain a representative sample of the deposit or quarry. It is hoped with this report that the margin of error or subjectivity would be significantly reduced in Newfoundland by using the revised P.N. classification derived from representative samples in Newfoundland.

GENERAL GEOLOGY

The geology of Newfoundland is very complex and consists of a variety of different sedimentary, igneous and metamorphic rock types, which have undergone various degrees of deformation and alteration caused by a number of different orogenies. Figure 1 shows a simplified geology map of Newfoundland and Table 4 shows a simplified revised version of the P.F. for most rock types found in Newfoundland and was developed by using 600 representative rock types with the P.F. as shown in Appendix I.

Sedimentary rocks, because of their diversity, may or may not be suitable for aggregate use. These rocks are usually the first choice of the contractor because they are usually softer than igneous and most metamorphic rocks, thus allowing for less wear on their production equipment.

Sandstone, siltstone, mudstone, greywacke, arkose, argillite, arenite, limestone and dolomite are sedimentary rocks that are generally suitable for aggregate use when they are fine to medium grained, fresh, hard to medium, hard and siliceous. They usually have a P.F. between 1.0 to 1.3 when hard, fresh and durable, but may range from 1.0 to 6.0 depending on their hardness, freshness, mineral content, cement type and grain size, which all affect their durability.

Conglomerate, shale and porous limestone are generally unsuitable for aggregate use other than as fill material. They usually have a P.F. ranging from 2.5 to 3.5, but may range from 1.2 to 8.5 depending on hardness, cement type and freshness. However, conglomerate, when consisting of siliceous cement and hard durable fragments, may be suitable for use as construction aggregate having a P.F. of 1.2.

Igneous rocks are generally suitable for aggregate use and are subdivided on the basis of coarseness; medium- to coarse-grained rocks are called plutonic (intrusive), fine-grained rocks are called volcanic (extrusive).

Plutonic (intrusive) rocks such as granite, diorite, gabbro, monzonite, syenite, pegmatite, tonalite, granodiorite, anorthosite and norite have a usual P.F. in the range of 1.0 to 1.3 when fresh, hard and fine to medium grained. The P.F. increases in the range of 1.3 to 7.5 with degree of weathering, hardness, grain size and percent of deleterious substances present, such as mica.

Volcanic (extrusive) rocks such as mafic to felsic volcanic (rhyolite, andesite, basalt, dacite and associated tuff) have a usual P.F. range from 1.0 to 1.5 when fresh to slightly weathered and hard to medium hard, but may range from 1.0 to 8.5 depending on degree of weathering, hardness and alteration. Unweathered volcanic rocks are usually excellent aggregate materials, but care should be taken when using these

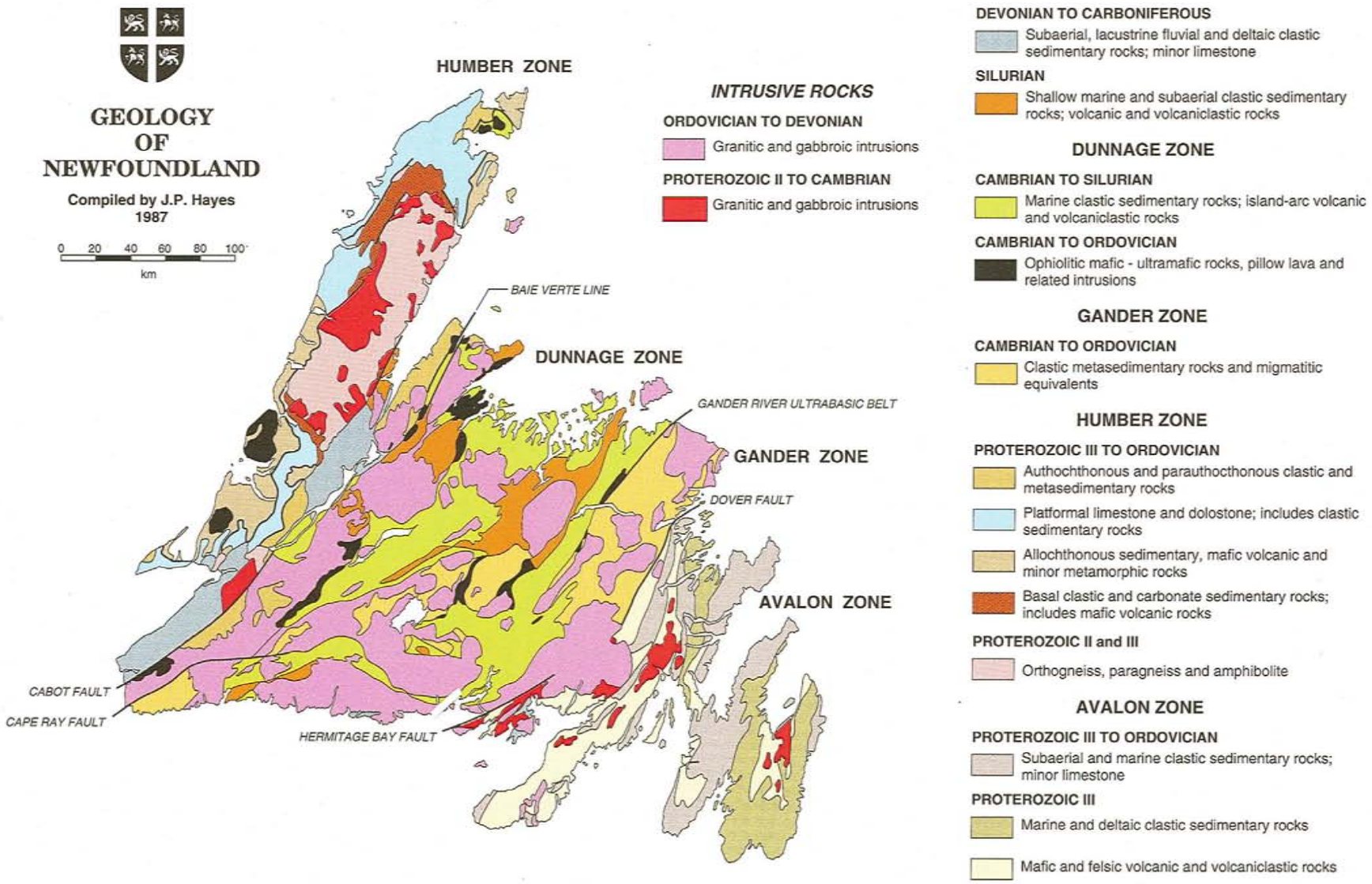

Figure 1. *Geology of Newfoundland (Hayes, 1987).*

rocks in concrete. Highly siliceous volcanic rocks may react chemically with the cement paste, resulting in progressive deterioration of the concrete.

Metamorphic rocks, because of their diversity, may or may not be suitable for use as construction aggregate. Fresh, hard and durable gneissic rocks have a usual P.F. range of 1.1 to 1.3 and are usually a good source for aggregate material; these rocks may have a P.F. range of 1.1 to 8.0 depending on degree of weathering, hardness and amount of deleterious substances (mica, chorite). Schist has a usual P.F. of 3.5 and a P.F. range from 1.5 to 8.5, phyllite has a usual P.F. of 3.5 and ranges from 2.0 to 8.5 and slate has a usual P.F. of 3.5 and may range from 2.0 to 8.5; these rock types are usually not suitable for most construction aggregate use if present in large quanities, but may be used as fill material.

Tables 5 through 13 show the number of samples and their petrographic number from different rock groups and formations in Newfoundland. Figure 2 is a generalized bedrock aggregate geology map of Newfoundland based on Colman-Sadd *et al.*, 1990 and petrographic number data from the different rock units in the above tables.

PETROGRAPHIC NUMBER SYSTEM

The P.N. was developed as a screening test and is best when assessing the initial quality of a potential aggregate source. The P.N. alone should never be used as a rejection or acceptance test of an aggregate because sources that have an unacceptable or high P.N. may pass other relevant tests (ASTM, 1989a and 1983) and thus may be suitable for some applications; also, sources that have an acceptable or low P.N. may fail other criteria and prove to be unacceptable for some applications. Sometimes, the P.N. may be the only available test to determine the quality of an aggregate source. For example, it is the only test able to detect small but significant amounts of deleterious substances (e.g., rotten or weathered rock, mica, micro-fracturing, organic matter, encrustations, staining, alterations and slaty cleavage) in a potential source that could cause premature deterioration of the concrete structure or asphalt pavement.

The P.N. system used in Newfoundland (Table 4) is based on a system developed in Ontario, and reflects the rather large diversity of different rock types found in Newfoundland. The revised system should help to minimize or eliminate the subjectivity or margin of error by using continuous numbers from 1.0 to 10.0 similar to Hudec (1983), instead of discreet and selected whole numbers (1,3,6 and 10).

Table 4 shows the petrographic factors for most common rock types in Newfoundland. Sandstone, siltstone, mudstone, argillite, arenite, arkose and greywacke are generally good for construction aggregates having a usual P.F number of 1.1 but may range from 1.1 to 6.0; in fact, most clastic sedimentary rocks have a P.F. range of 1.1 to 6.0 depending on hardness, degree of weathering, grain size, cement type, mineral content and presence of deleterious substances. Shale and conglomerate being the exceptions; shale has a usual P.F. of 3.5 and may range from 3.5 to 8.5 and conglomerate has a usual P.F. of 2.5 and a range of 1.2 to 8.5.

The carbonate sedimentary rocks (limestones and dolomites) have a usual P.F. of 1.0 to 1.1 and a P.F. range of 1.0 to 8.5 depending upon hardness, degree of weathering, grain size, mineral content and presence of deleterious substances.

Metamorphic rocks (gneiss, schist, psammite, pelite, phyllite, marble, slate, quartzite, metasediment and metavolcanic rocks) may or may not be suitable for construction aggregate and have a P.F. range of 1.0 to 8.5 depending on hardness, mineral content, degree of weathering, banding, cleavage, mineral alteration and deleterious substances.

Igneous rocks are generally excellent for use as construction aggregate and have a usual P.F. of 1.1 but may range from 1.0 to 8.5 depending on grain size, crystal texture, degree of weathering, hardness, banding, mineral content and deleterious substances.

Shale, slate, clay lumps, talc, gypsum and friable rock are all unsuitable for most construction aggregate purposes having a P.F. range of 3.5 to 10.0; however, they may be used as a fill material. It should be noted that shale and slate, although deleterious petrographically, sometimes pass the Los Angeles Abrasion and Magnesium Sulfate Soundness tests thus giving a false impression of their durability. It is necessary to know what the material is going to be used for, because a shale or slate, which is deleterious for must construction purposes, may be a excellent raw material for lightweight aggregate, a specialized commodity in the construction industry.

Unconsolidated aggregate deposits (sand and gravel) may have a wide range of petrographic numbers due to the amounts and dispersion of different rock types found in these deposits, degree of weathering of the different rock types, mineral content, and the amount and dispersion of deleterious substances present for each deposit. These factors are not only important for different aggregate deposits but may cause significant P.N. ranges for the same deposit. Fifteen samples were examined from the same aggregate deposit; these were collected at different times by different people within a one year period. The results of the analyses show significant P.N. ranges from 115.3 to 178.5, but the actual or true representative P.N. for the deposit is 130; thus stressing the importance of representative sampling by qualified personnel.

PROCEDURE FOR PETROGRAPHIC NUMBER ANALYSES

Table 1 shows how a petrographic number (P.N.) is determined following Ministry of Transportation (1994) procedure or test, and Bragg (1986). The first and most important step in the procedure is the obtaining of a representative sample or samples.

Table 5. Petrographic number (P.N.) of samples collected from different groups/formations on the Avalon Peninsula

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Signal Hill Group	30	110-350	21	9	125	Good
St. John's Group	56	110-1000	8	48	230	Fair
Conception Group	77	110-800	49	28	120	Good
Holyrood Pluton	17	100-325	13	4	110	Good
Harbour Main Group	59	110-330	38	21	130	Good
Connecting Point Group	17	110-350	10	7	125	Good
Musgravetown Group	22	110-1000	10	12	200	Fair
Bull Arm Formation	26	110-320	18	8	115	Good
Random Formation	1	120	1	0	120	Good

Table 6. Petrographic number (P.N.) of samples collected from different groups/formations on the Burin Peninsula

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Love Cove Group	32	130-350	4	28	250	Fair
Marystown Group	23	125-325	3	20	268	Fair
Burin Group	6	130-335	1	5	275	Fair
Inlet Group	3	310-1000	0	3	565	Poor
Mortier Bay Group	25	100-375	13	12	155	Fair
Long Harbour Group	7	120-150	5	2	130	Good
St. Lawrence Granite	2	110-130	2	0	115	Good
Swift Current Granite	8	110-140	5	3	125	Good
Cross Hills Complex	1	145	0	1	145	Fair
Spanish Room Formation	3	130-300	2	1	186	Fair
Belle Bay Formation	4	130-250	3	1	160	Fair

Table 7. Petrographic number (P.N.) of samples collected from different groups/formations in eastern Newfoundland (Clarenville–Gander area)

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Love Cove Group	11	100-350	8	3	150	Fair
Musgravetown Group	106	110-600	78	28	125	Good
Connecting Point Group	52	110-450	34	18	135	Good
Georges Pond Pluton	1	125	1	0	125	Good
Middle Brook Granite	2	110	2	0	110	Good
Hare Bay Gneiss	11	130-325	4	7	170	Fair
Brigus Formation	1	350	0	1	350	Poor
Bonavista Formation	1	600	0	1	600	Poor
Ragged Harbour Granite	1	120	1	0	120	Good
Big Round Pond Granite	1	125	1	0	125	Good
Random Formation	4	110-210	1	3	145	Fair
Gander Lake Group	9	110-350	4	5	185	Fair
Davidsville Group	9	100-600	3	6	355	Poor
Bull Arm Formation	16	115-350	10	6	165	Fair
Wareham Granite	6	100-250	5	1	125	Good
Canning Cove Formation	9	130-300	6	3	155	Fair
Newport Granite	5	100-210	1	4	180	Fair
Deadman's Bay Granite	4	100-130	4	0	115	Good
Cape Freels Granite	4	110-210	3	1	135	Good

Table 8. Petrographic number (P.N.) of samples collected from different groups/formations in central Newfoundland (Gander–Grand Falls area)

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Botwood Group	3	130-275	1	2	195	Fair
Davidsville Group	13	300-1000	0	13	650	Deleterious
Dunnage Melange	15	110-350	2	13	235	Fair
Fogo Batholith	17	100-130	17	0	110	Good
Gander Group	4	110-350	1	3	215	Fair
Gander River Complex	10	110-135	10	0	120	Good
Goldson Group	8	125-180	3	5	145	Fair
Horwood Formation	4	250-350	0	4	275	Fair
Lawrenceton Formation	5	135-325	1	4	215	Fair
Loon Bay Granodiorite	9	115-145	8	1	125	Good
Loon Harbour Volcanics	2	150	0	2	150	Fair
Mount Peyton Intrusive	18	100-210	15	3	130	Good
New Bay Formation	7	115-190	3	4	145	Fair
Sansom Formation	16	110-350	13	3	135	Good
Stoneville Formation	14	110-375	3	11	275	Fair
SummerFord Group	19	110-325	17	2	125	Good
Tims Harbour Formation	8	125-600	5	3	275	Fair
Twillingate Granite	21	100-300	17	4	135	Good
Wigwam Formation	22	115-1000	13	9	210	Fair
Undivided Unit	27	110-1000	17	10	220	Fair

Table 9. Petrographic number (P.N.) of samples collected from different groups/formations in west–central Newfoundland (Grand Falls–White Bay area)

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Lawrenceton Formation	8	130-210	3	5	155	Fair
Robert's Arm Group	22	120-230	11	11	140	Fair
Topsails Granite	3	100-110	3	0	105	Good
Springdale Group	9	125-210	3	6	165	Fair
Flatwater Pond Group	7	135-310	3	4	175	Fair
Betts Cove Complex	8	110-155	8	0	125	Good
Birchy Complex	4	210-330	0	4	250	Fair
Rattling Brook Group	32	115-450	5	27	275	Fair
Old House Group	17	230-310	0	17	260	Fair
Garden Cove Group	3	200-220	0	3	213	Fair
Pigeon Island Formation	3	210-270	0	3	240	Fair
White Bay Group	6	200-250	0	6	245	Fair
Pacquet Harbour Group	15	110-310	10	5	121	Good
Dunamagon Granite	4	100-110	4	0	105	Good
Cape Brule Porphyry	16	110-120	16	0	115	Good
Cape St. John Group	29	110-135	29	0	120	Good
Burlington Granodiorite	16	110-215	13	3	130	Good
Loon Bay Batholith	6	110-125	6	0	120	Good
Snook's Arm Group	3	125-155	2	0	135	Good
East Pond Metam. Suite	9	215-350	0	9	265	Fair
Buchans Group	13	110-120	13	0	117	Good
Goldson Group	6	150-175	0	6	165	Fair
Sansom Formation	7	110-130	7	0	120	Good
Dunnage Melange	9	110-350	2	7	260	Fair
Halls Bay Pluton	4	110-115	4	0	112	Good
New Bay Formation	11	115-190	5	6	153	Fair
Exploits Group	9	115-600	3	6	230	Fair
Lush's Bight Group	21	110-375	11	10	185	Fair

Table 10. Petrographic number (P.N.) of samples collected from different groups/formations on the Great Northern Peninsula, Newfoundland (Deer Lake to St. Anthony)

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
St. Georges Group	1	110	1	0	110	Good
Catoche Formation	11	115-325	10	1	130	Good
Boat Harbour Formation	15	110-155	13	2	123	Good
Watts Bight Formation	20	110-145	15	5	121	Good
Southern Arm Formation	5	110-120	5	0	113	Good
Petit Jardin Formation	33	125-175	23	10	134	Good
March Point Formation	20	110-185	13	7	141	Fair
Labrador Group	8	110-625	5	3	210	Fair
Hawkes Bay Formation	3	120-250	2	1	168	Fair
Forteau Formation	23	115-455	17	6	128	Good
Bradore Formation	2	155-180	0	2	167	Fair
Cow Head Group	4	185-255	0	4	206	Fair
Table Head Group	15	110-165	13	2	117	Good
Long Range Complex	3	100-115	3	0	108	Good
Melange	10	310-450	0	10	375	Poor
Maiden Point Formation	43	115-450	9	34	210	Fair
Epine Cadoret Formation	4	185-210	0	4	195	Fair
Northwest Arm Formation	1	110	1	0	110	Good
Goose Tickle Group	1	350	0	1	350	Poor
Goose Cove Formation	11	125-265	3	8	165	Fair

Table 11. Petrographic number (P.N.) of samples collected from different groups/formations in western Newfoundland (Corner Brook to Port Aux Basques area)

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Rose Blanche Granite	8	110-250	5	3	125	Good
Port aux Basques Gneiss	65	110-310	50	15	115	Good
Port aux Basques Granite	3	110-120	3	0	113	Good
March Point Formation	5	120-155	4	1	125	Good
St. Georges Group	31	110-130	31	0	115	Good
Table Head Group	35	100-310	29	6	115	Good
Humber Arm Group	15	115-500	5	10	280	Fair
Indian Head Group	12	100-220	10	2	120	Good
Codroy Group	4	150-400	2	2	285	Fair
Anguille Group	2	175-250	0	2	212	Fair
Mount Musgrave Group	30	110-350	10	20	250	Fair
Burgeo Granite	30	110-255	27	3	115	Good
Georges Brook Formation	26	110-130	26	0	112	Good
Bay Du Nord Group	10	110-350	8	2	130	Good
Spruce Brook Formation	7	130-600	2	5	350	Poor

Table 12. Petrographic number (P.N.) of samples collected from different groups/formations on the southcoast of Newfoundland (Bay D'Espoir to Burgeo area)

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
Bay D'Espoir Group	17	110-600	5	12	250	Fair
Burgeo Group	20	110-230	13	7	120	Good
François Granite	13	100-250	5	8	210	Fair
Grey River Enclave	9	100-210	7	2	120	Good
McCallum Granite	8	100-150	7	1	115	Good
Gaultois Granite	9	110-210	1	8	165	Fair

Table 13. Petrographic number (P.N.) of samples collected from different groups/formations on the Port Au Port Peninsula, Newfoundland

Group/Formation	Samples	P.N. Range	P.N. <135	P.N. >135	Av. P.N.	Classification
St. George Group	56	100-850	48	8	120	Good
Table Head Group	15	110-850	12	3	120	Good
Petit Jardin Fm.	5	110-600	3	3	350	Poor
Long Point Fm.	8	100-250	6	2	130	Good

A representative sample should always be taken by a qualified geologist or a well-trained technician familiar with geotechnical properties of an aggregate deposit and the different rock types in the area. It is also recommended that the person who is collecting the sample be the one determining the P.N.

Next, the sample should be quartered and 2000 gm of the sample collected and washed. The percentage of each rock type is determined by identifying the individual particles and a petrographic factor (P.F.) is assigned to each rock type. The weight percent of each rock type is multiplied by the appropriate factor and the P.N. is the sum of the products. Another way of determining the P.N. is by randomly counting 100 to 200 pebbles from the sample and then determining the frequency percentage of the different rock types and assigning a P.F. to each type; the P.N. is calculated in the same way. The author has used both methods in determining the P.N. and has found very little or marginal differences in the results for the sample. There were no samples where significant differences (>30) existed in the final P.N. for the same sample.

Petrographic Rating System

Petrographic rating is a system developed by the author (Bragg and Foster, 1992; Bragg, 1993) to give a quick initial assessment or screening of a potential aggregate deposit on its potential alkali-aggregate reactivity based on petrograhic examination.

Alkali-aggregate reactivity is a chemical reaction between the alkalies in the cement paste and certain types of silica in the aggregate to form a expansive silica gel in the concrete, (see Canadian Standards Association, 1994, Appendix B for more imformation about this reaction in Canada).

The petrographic examination to determine a samples potential alkali-reactivity consists of using a petrographic microscope to examine hand samples and thin-sections of the material. The potential reactivity of a sample or deposit may be determined by the amount, the type of known reactive minerals, and the rock types (Dolar-Mantunai, 1983). One must be cautious however when examining known reactive rock types because experience has shown that a particular rock type in one area may be reactive and non-reactive in another area. For example, greywacke found in certain areas of eastern Newfoundland seem to be reactive while greywacke in certain areas of central Newfoundland seem to be non-reactive. The same has been found for certain siliceous siltstones–sandstones and rhyolites.

A petrographic examination is performed on the material to determine the amount of potentially reactive rocks or minerals and based on the results of the petrographic examination, a rating system as shown in Table 14, is established. Material rated 1 (low) or 2 (slight) are usually not reactive and material rated 3 (moderate) or 4 (high) are usually potentially reactive.

This is a crude but often effective way of screening potentially reactive rocks and was used extensively on the Avalon Peninsula to predict potentially reactive rock units (Table 15).

CONCLUSIONS

Petrographic examination when done by a qualified person can be a valuable tool in predicting the quality or durability of a potential aggregate source; in fact, in some cases, it may be the only tool to predict the quality of an aggregate source or deposit.

Petrographic examination of which the P.N. is part of should only be used as a screening test, and as a screening test it is the best to give a quick durability evaluation of a potential aggregate deposit. The use of a revised classification will reduce the subjectivity of the P.N. In fact, with proper training and the use of a standard detailed petrographic factor table such as the one in Appendix I of this report, the subjectivity of the test can be reduced significantly.

Unfortunately, the P.N. is only as good as the person who does the test, so it is very important that the person doing the test be a geologist, experienced in construction aggregate properties or a well-trained technician with geological and engineering experience. Although the test is a screening test and should always be used in conjunction with other tests for acceptance or rejection of an aggregate, there are times when the P.N. may be the only test to determine the suitability of an aggregate source.

The petrographic number/factor for a particular rock type should be the same or similar, irrespective of its location (i.e.,

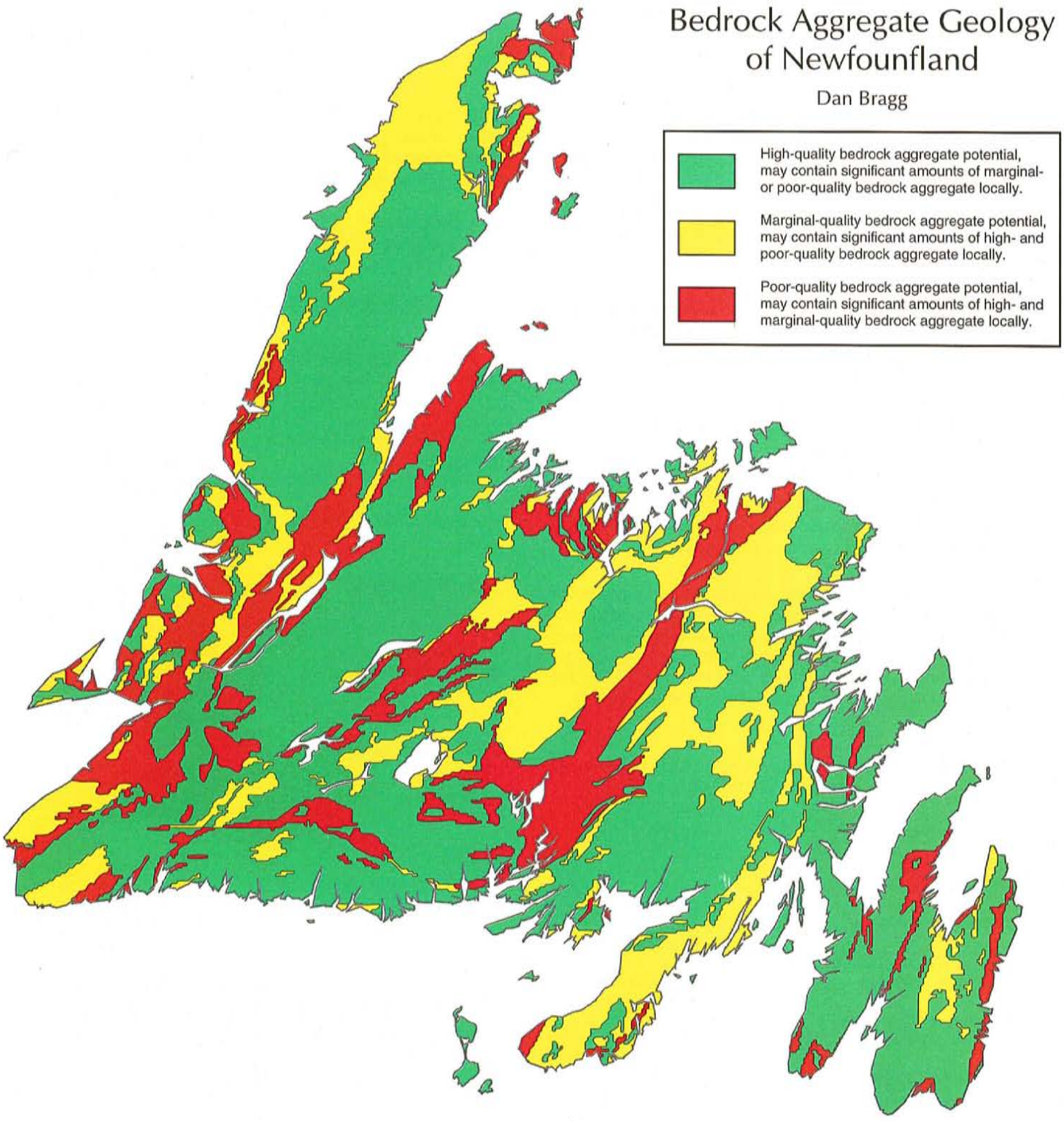

Figure 2. *Generalized bedrock aggregate geology map of Newfoundland.*

Newfoundland or Ontario), however, this is only true if the particular rock type has similar properties such as grain size, hardness, degree of weathering and mineral content.

Petrographic rating is a system used fairly effectively by the author to determine the potential alkali-aggregate reactivity of a particular rock sample or aggregate deposit.

Table 14. Petrographic rating system of aggregates for their potential alkali-aggregate reactivity after Bragg (1993)

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

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

** Some reactive rocks and minerals show 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 or is over, which can be from 5 to 50% for some rock types and less than 1% for certain minerals.

Table 15. Petrographic rating of most rock units on the Avalon Peninsula, Newfoundland

Group/Formation	Rating	Comments
SIGNAL HILL GROUP		
Blackhead formation	1	Non-reactive
Gibbert Hill formation	3	Marginal (tending towards reactive)
Cuckold Cove formation	4	Reactive
Quidi Vidi formation	3	Marginal (tending towards reactive)
Cappahayden formation	1	Non-reactive
Ferryland formation	2	Marginal (tending towards non-reactive)
Cape Ballard formation	1	Non-reactive
Flat Rock formation	2	Marginal (tending towards non-reactive)
Bay de Verde formation	2	Marginal (tending towards non-reactive)
ST. JOHN'S GROUP		
Renews formation	1	Non-reactive
Fermeuse formation	2	Marginal (tending towards non-reactive)
Trepassey formation	1	Non-reactive
CONCEPTION GROUP		
Briscal formation	1	Non-reactive
Drook formation	4	Reactive
Gaskers formation	3	Marginal (tending towards reactive)
Mall Bay formation	4	Reactive
Mistaken Point formation	3	Marginal (tending towards reactive)
HOLYROOD INTRUSIVE SUITE		
Undivided	1	Non-reactive
HARBOUR MAIN GROUP		
Undivided—Mafic volcanic	1	Non-reactive
—Felsic volcanic	4	Reactive
CONNECTING POINT GROUP		
Undivided	3	Marginal (tending towards reactive)
MUSGRAVETOWN GROUP		
Big Head formation	3	Marginal (tending towards reactive)
Crown Hill formation	2	Marginal (tending towards non-reactive)
Heart's Content formation	1	Non-reactive
Heart's Desire formation	1	Non-reactive
Maturin Ponds formation	1	Non-reactive
Trinny Cove formation	2	Marginal (tending towards non-reactive)
BULL ARM FORMATION		
Mafic volcanic	1	Non-reactive
Felsic volcanic	3	Marginal (tending towards reactive)
RANDOM FORMATION		
Quartzite	4	Reactive
Arkose	3	Marginal (tending towards reactive)

Usually, if the rock type is siliceous (high silica content) or has a silica cement content for sedimentary rocks, then the rock is usually potentially alkali-reactive.

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APPENDIX I

Petrographic factors for most rock types in Newfoundland

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Sandstone	(Fine grained, fresh, hard)	1.0	Good
	(medium grained, fresh, hard)	1.1	Good
	(coarse grained, fresh, hard)	1.2	Good
Sandstone	(Fine grained, slightly weathered, hard)	1.1	Good
	(Medium grained, slightly weathered, hard)	1.15	Good
	(Coarse grained, slightly weathered, hard)	1.25	Good
Sandstone	(Fine grained, moderately weathered, hard)	2.5	Fair
	(Medium grained, moderately weathered, hard)	2.7	Fair
	(Coarse grained, moderately weathered, hard)	3.0	Fair
Sandstone	(Fine grained, severely weathered, hard)	3.5	Poor
	(Medium grained, severely weathered, hard)	4.5	Poor
	(Coarse grained, severely weathered, hard)	5.5	Poor
Sandstone	(Fine grained, fresh, medium hard)	1.1	Good
	(Medium grained, fresh, medium hard)	1.2	Good
	(Coarse grained, fresh, medium hard)	1.3	Good
Sandstone	(Fine grained, slightly weathered, medium hard)	1.15	Good
	(Medium grained, slightly weathered, medium hard)	1.25	Good
	(Coarse grained, slightly weathered, medium hard)	1.35	Good
Sandstone	(Fine grained, moderately weathered, medium hard)	3.0	Fair
	(Medium grained, moderately weathered, medium hard)	3.5	Poor
	(Coarse grained, moderately weathered, medium hard)	4.0	Poor
Sandstone	(Fine grained, severely weathered, medium hard)	4.5	Poor
	(Medium grained, severely weathered, medium hard)	5.0	Poor
	(Coarse grained, severely weathered, medium hard)	6.0	Poor
Sandstone	(Fine grained, fresh, soft)	3.0	Fair
	(Medium grained, fresh, soft)	3.5	Poor
	(Coarse grained, fresh, soft)	4.0	Poor
Sandstone	(Fine grained, slightly weathered, soft)	3.1	Poor
	(Medium grained, slightly weathered, soft)	3.8	Poor
	(Coarse grained, slightly weathered, soft)	4.5	Poor
Sandstone	(Fine grained, moderately weathered, soft)	3.5	Poor
	(Medium grained, moderately weathered, soft)	4.5	Poor
	(Coarse grained, moderately weathered, soft)	5.0	Poor
Sandstone	(Fine grained, severely weathered, soft)	5.0	Poor
	(Medium grained, severely weathered, soft)	5.5	Poor
	(Coarse grained, severely weathered, soft)	6.0	Poor
Sandstone (Porous)	(Fresh, hard)	1.5	Fair
	(Slightly weathered, hard)	2.0	Fair
	(Moderately weathered, hard)	3.5	Poor
	(Severely weathered, hard)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Sandstone (Porous)	(Fresh, medium hard)	2.0	Fair
	(Slightly weathered, medium hard)	2.5	Fair
	(Moderately weathered, medium hard)	4.5	Poor
	(Severely weathered, medium hard)	6.5	Deleterious
Sandstone (Porous)	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.0	Poor
Sandstone (Micaceous)	(Fresh, medium hard)	2.5	Fair
	(Slightly weathered, medium hard)	3.0	Fair
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor
Sandstone (Micaceous)	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Sandstone	(Friable)	10.0	Deleterious
Arkose	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Arkose	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Arkose	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Arkose	(Friable)	10.0	Deleterious
Arenite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Arenite	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Arenite	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Arenite	(Friable)	10.0	Deleterious
Greywacke	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Greywacke	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Greywacke	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Greywacke	(Friable)	10.0	Deleterious
Conglomerate	(Fresh, hard)	1.2	Good
	(Slightly weathered, hard)	1.25	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Conglomerate	(Fresh, medium hard)	2.0	Fair
	(Slightly weathered, medium hard)	2.3	Fair
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	6.0	Poor
Conglomerate	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	5.5	Deleterious
	(Severely weathered, soft)	8.5	Deleterious
Conglomerate	(Friable)	10.0	Deleterious
Shale	(Fresh, medium hard)	3.5	Poor
	(Slightly weathered, medium hard)	4.0	Poor
	(Moderately weathered, medium hard)	5.0	Poor
	(Severely weathered, medium hard)	6.5	Deleterious
Shale	(Fresh, soft)	4.5	Poor
	(Slightly weathered, soft)	5.0	Poor
	(Moderately weathered, soft)	6.5	Deleterious
	(Severely weathered, soft)	8.5	Deleterious
Shale (slaty cleavage)	(Fresh, hard)	1.2	Good
	(Slightly weathered, hard)	1.35	Good
	(Moderately weathered, hard)	3.5	Poor
	(Severely weathered, hard)	4.5	Poor
Shale (slaty cleavage)	(Fresh, medium hard)	3.0	Fair
	(Slightly weathered, medium hard)	3.5	Poor
	(Moderately weathered, medium hard)	5.0	Poor
	(Severely weathered, medium hard)	6.0	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Shale (slaty cleavage)	(Fresh, soft)	5.0	Poor
	(Slightly weathered, soft)	5.5	Poor
	(Moderately weathered, soft)	6.5	Deleterious
	(Severely weathered, soft)	8.5	Deleterious
Shale	(Friable)	10.0	Deleterious
Mudstone	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.2	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Mudstone	(Fresh, medium hard)	1.2	Good
	(Slightly weathered, medium hard)	1.25	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Mudstone	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	3.8	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Mudstone	(Friable)	10.0	Deleterious
Siltstone	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Siltstone	(Fresh, medium hard)	1.2	Good
	(Slightly weathered, medium hard)	1.25	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Siltstone	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	3.8	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Siltstone (slaty cleavage)	(Fresh, hard)	1.2	Good
	(Slightly weathered, hard)	1.3	Good
	(Moderately weathered, hard)	3.0	Fair
	(Severely weathered, hard)	4.5	Poor
Siltstone (slaty cleavage)	(Fresh, medium hard)	1.5	Fair
	(Slightly weathered, medium hard)	1.7	Fair
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	6.0	Poor
Siltstone (slaty cleavage)	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.5	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.5	Deleterious

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Siltstone	(Friable)	10.0	Deleterious
Argillite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Argillite	(Fresh, medium hard)	1.2	Good
	(Slightly weathered, medium hard)	1.25	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Argillite	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	3.8	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Argillite (slaty cleavage)	(Fresh, hard)	1.2	Good
	(Slightly weathered, hard)	1.3	Good
	(Moderately weathered, hard)	3.0	Fair
	(Severely weathered, hard)	4.5	Poor
Argillite (slaty cleavage)	(Fresh, medium hard)	1.5	Fair
	(Slightly weathered, medium hard)	1.7	Fair
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	6.0	Poor
Argillite (slaty cleavage)	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.5	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.5	Poor
Argillite	(Friable)	10.0	Deleterious
Chert	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.2	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	6.0	Poor
Chert	(Friable)	10.0	Deleterious
Limestone	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor
Limestone	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.3	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.0	Poor
Limestone (argillaceous)	(Fresh, medium hard)	1.25	Good
	(Slightly weathered, medium hard)	1.35	Good
	(Moderately weathered, medium hard)	3.25	Poor
	(Severely weathered, medium hard)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Limestone (argillaceous)	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.3	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.5	Deleterious
Limestone (arenaceous)	(Fresh, medium hard)	1.15	Good
	(Slightly weathered, medium hard)	1.2	Good
	(Moderately weathered, medium hard)	3.25	Poor
	(Severely weathered, medium hard)	4.5	Poor
Limestone (arenaceous)	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.3	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.5	Deleterious
Limestone (dolomitic)	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.25	Poor
	(Severely weathered, medium hard)	4.5	Poor
Limestone (dolomitic)	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.3	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.0	Poor
Limestone (porous)	(Fresh, medium hard)	2.5	Fair
	(Slightly weathered, medium hard)	3.0	Fair
	(Moderately weathered, medium hard)	4.5	Poor
	(Severely weathered, medium hard)	7.0	Deleterious
Limestone (porous)	(Fresh, soft)	4.5	Poor
	(Slightly weathered, soft)	4.7	Poor
	(Moderately weathered, soft)	5.5	Poor
	(Severely weathered, soft)	8.5	Deleterious
Limestone	(Friable)	10.0	Deleterious
Dolomite	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	2.5	Fair
	(Severely weathered, medium hard)	4.5	Poor
Dolomite	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Dolomite	(Friable)	10.0	Deleterious
Marble	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Marble	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.1	Poor
	(Moderately weathered, soft)	4.0	Poor
	(Severely weathered, soft)	6.0	Poor
Marble	(Friable)	10.0	Deleterious
Quartzite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Quartzite	(Friable)	10.0	Deleterious
Quartz Pebble	(Fresh)	1.1	Good
Granite	(Fine grained, fresh, hard)	1.0	Good
	(Medium grained, fresh, hard)	1.15	Good
	(Coarse grained, fresh, hard)	1.35	Good
Granite	(Fine grained, slightly weathered, hard)	1.1	Good
	(Medium grained, slightly weathered, hard)	1.2	Good
	(Coarse grained, slightly weathered, hard)	1.4	Fair
Granite	(Fine grained, moderately weathered, hard)	2.5	Fair
	(Medium grained, moderately weathered, hard)	2.6	Fair
	(Coarse grained, moderately weathered, hard)	3.0	Fair
Granite	(Fine grained, severely weathered, hard)	3.5	Poor
	(Medium grained, severely weathered, hard)	4.5	Poor
	(Coarse grained, severely weathered, hard)	6.0	Poor
Granite (biotite/muscovite) (1-5%)	(Fine grained, fresh, hard)	1.15	Good
	(Fine grained, slightly weathered)	1.2	Good
	(Fine grained, moderately weathered)	2.5	Fair
	(Fine grained, severely weathered)	4.5	Poor
Granite (biotite/muscovite) (1-5%)	(Medium grained, fresh, hard)	1.25	Good
	(Medium grained, slightly weathered)	1.3	Good
	(Medium grained, moderately weathered)	2.5	Fair
	(Medium grained, severely weathered)	4.5	Poor
Granite (biotite/muscovite) (1-5%)	(Coarse grained, fresh, hard)	1.35	Good
	(Coarse grained, slightly weathered)	1.4	Fair
	(Coarse grained, moderately weathered)	3.0	Fair
	(Coarse grained, severely weathered)	5.5	Poor
Granite (biotite/muscovite) (5-10%)	(Fine grained, fresh, hard)	1.2	Good
	(Fine grained, slightly weathered)	1.35	Good
	(Fine grained, moderately weathered)	2.5	Fair
	(Fine grained, severely weathered)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Granite (biotite/muscovite) (5-10%)	(Medium grained, fresh, hard)	1.3	Good
	(Medium grained, slightly weathered)	1.5	Fair
	(Medium grained, moderately weathered)	3.5	Poor
	(Medium grained, severely weathered)	5.0	Poor
Granite (biotite/muscovite) (5-10%)	(Coarse grained, fresh, hard)	1.35	Good
	(Coarse grained, slightly weathered)	1.5	Fair
	(Coarse grained, moderately weathered)	3.5	Poor
	(Coarse grained, severely weathered)	5.5	Poor
Granite (biotite/muscovite) (10-20%)	(Fine grained, fresh, hard)	1.5	Fair
	(Fine grained, slightly weathered)	1.8	Fair
	(Fine grained, moderately weathered)	3.5	Poor
	(Fine grained, severely weathered)	5.0	Poor
Granite (biotite/muscovite) (10-20%)	(Medium grained, fresh, hard)	1.8	Fair
	(Medium grained, slightly weathered)	2.0	Fair
	(Medium grained, moderately weathered)	3.5	Poor
	(Medium grained, severely weathered)	5.0	Poor
Granite (biotite/muscovite) (10-20%)	(Coarse grained, fresh, hard)	2.0	Fair
	(Coarse grained, slightly weathered)	2.1	Fair
	(Coarse grained, moderately weathered)	4.5	Poor
	(Coarse grained, severely weathered)	6.0	Poor
Granite (biotite/muscovite) (> 20%)	(Fine grained, fresh, hard)	2.5	Fair
	(Fine grained, slightly weathered)	2.7	Fair
	(Fine grained, moderately weathered)	3.5	Poor
	(Fine grained, severely weathered)	5.5	Poor
Granite (biotite/muscovite) (> 20%)	(Medium grained, fresh, hard)	2.7	Fair
	(Medium grained, slightly weathered)	3.0	Fair
	(Medium grained, moderately weathered)	4.5	Poor
	(Medium grained, severely weathered)	6.0	Poor
Granite (biotite/muscovite) (> 20%)	(Coarse grained, fresh, hard)	3.0	Fair
	(Coarse grained, slightly weathered)	3.5	Poor
	(Coarse grained, moderately weathered)	5.5	Poor
	(Coarse grained, severely weathered)	7.5	Deleterious
Granite	(Friable)	10.0	Deleterious
Granodiorite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Gabbro	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Gabbro	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.2	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Gabbro	(Friable)	10.0	Deleterious
Diorite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Diorite	(Friable)	10.0	Deleterious
Syenite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Syenite	(Friable)	10.0	Deleterious
Monzonite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Monzonite	(Friable)	10.0	Deleterious
Tonalite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Tonalite	(Friable)	10.0	Deleterious
Anorthosite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Anorthosite	(Friable)	10.0	Deleterious
Norite	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Volcanics (felsic)	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Volcanics (felsic)	(Friable)	10.0	Deleterious
Rhyolite	(Fresh, hard)	1.0	Good
	(Slightly, weathered)	1.1	Good
	(Moderately, weathered)	2.5	Fair
	(Severely, weathered)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Rhyolite	(Friable)	10.0	Deleterious
Porphyry	(Fresh, hard)	1.0	Good
	(Slightly, weathered)	1.1	Good
	(Moderately, weathered)	2.5	Fair
	(Severely, weathered)	4.5	Poor
Porphyry	(Friable)	10.0	Deleterious
Volcanics (mafic)	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Volcanic (mafic)	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.0	Poor
Volcanic (mafic)	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	8.5	Deleterious
Volcanic (mafic)	(Friable)	10.0	Deleterious
Basalt	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Basalt	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.0	Poor
Basalt	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	8.5	Deleterious
Basalt	(Friable)	10.0	Deleterious
Volcanic (intermediate)	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.1	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Volcanic (intermediate)	(Fresh, medium hard)	1.1	Good
	(Slightly weathered, medium hard)	1.15	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.0	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Volcanic (intermediate)	(Friable)	10.0	Deleterious
Andesite	(Fresh, hard)	1.0	Good
	(Slightly weathered)	1.1	Good
	(Moderately weathered)	2.5	Fair
	(Severely weathered)	4.5	Poor
Andesite	(Friable)	10.0	Deleterious
Dacite	(Fresh, hard)	1.0	Good
	(Slightly weathered)	1.1	Good
	(Moderately weathered)	2.5	Fair
	(Severely weathered)	4.5	Poor
Dacite	(Friable)	10.0	Deleterious
Trachyte	(Fresh, hard)	1.0	Good
	(Slightly weathered)	1.1	Good
	(Moderately weathered)	2.5	Fair
	(Severely weathered)	4.5	Poor
Trachyte	(Friable)	10.0	Deleterious
Volcanic (vesicular)	(Fresh, hard)	1.5	Fair
	(Slightly weathered)	1.8	Fair
	(Moderately weathered)	4.0	Poor
	(Severely weathered)	8.5	Deleterious
Pyroclastic	(Fresh, hard)	1.1	Good
	(Slightly weathered, hard)	1.25	Good
	(Moderately weathered, hard)	3.5	Poor
	(Severely weathered, hard)	4.5	Poor
Pyroclastic	(Fresh, medium hard)	1.35	Good
	(Slightly weathered, medium hard)	1.5	Fair
	(Moderately weathered, medium hard)	4.5	Poor
	(Severely weathered, medium hard)	6.0	Poor
Pyroclastic	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	6.5	Deleterious
	(Severely weathered, soft)	8.5	Deleterious
Pyroclastic	(Friable)	10.0	Deleterious
Tuff	(Fresh, hard)	1.1	Good
	(Slightly weathered)	1.25	Good
	(Moderately weathered)	3.5	Poor
	(Severely weathered)	4.5	Poor
Tuff	(Fresh, medium hard)	1.35	Good
	(Slightly weathered)	1.5	Fair
	(Moderately weathered)	4.5	Poor
	(Severely weathered)	6.0	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Tuff	(Fresh, soft)	3.5	Poor
	(Slightly weathered)	4.0	Poor
	(Moderately weathered)	6.5	Deleterious
	(Severely weathered)	8.5	Deleterious
Tuff	(Friable)	10.0	Deleterious
Metavolcanic (altered)	(Fresh, hard)	1.1	Good
	(Slightly weathered, hard)	1.2	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Metavolcanic	(Fresh, medium hard)	1.2	Good
	(Slightly weathered, medium hard)	1.25	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor
Metavolcanic	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Poor
Metavolcanic	(Friable)	10.0	Deleterious
Metasediment (altered)	(Fresh, hard)	1.1	Good
	(Slightly weathered, hard)	1.15	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Metasediment	(Fresh, medium hard)	1.25	Good
	(Slightly weathered, medium hard)	1.35	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor
Metasediment	(Fresh, soft)	3.0	Fair
	(Slightly weathered, soft)	3.5	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.0	Deleterious
Metasediment (slaty cleavage)	(Fresh, hard)	1.2	Good
	(Slightly weathered, hard)	1.25	Good
	(Moderately weathered, hard)	3.0	Fair
	(Severely weathered, hard)	4.5	Poor
Metasediment (slaty cleavage)	(Fresh, medium hard)	1.25	Good
	(Slightly weathered, medium hard)	1.3	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.0	Poor
Metasediment (slaty cleavage)	(Fresh, soft)	4.0	Poor
	(Slightly weathered, soft)	4.5	Poor
	(Moderately weathered, soft)	5.0	Poor
	(Severely weathered, soft)	6.0	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Metasediment	(Friable)	10.0	Deleterious
Gneiss	(Fresh, hard)	1.1	Good
	(Slightly weathered, hard)	1.15	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Gneiss	(Fresh, medium hard)	1.25	Good
	(Slightly weathered, medium hard)	1.35	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor
Gneiss	(Fresh, soft)	2.5	Fair
	(Slightly weathered, soft)	2.8	Fair
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	8.0	Deleterious
Gneiss	(Friable)	10.0	Deleterious
Schist	(Fresh, medium hard)	1.5	Fair
	(Slightly weathered, medium hard)	2.5	Fair
	(Moderately weathered, medium hard)	3.25	Poor
	(Severely weathered, medium hard)	4.75	Poor
Schist	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	5.0	Poor
	(Moderately weathered, soft)	5.5	Poor
	(Severely weathered, soft)	8.5	Deleterious
Schist	(Friable)	10.0	Deleterious
Phyllite	(Fresh, medium hard)	2.0	Fair
	(Slightly weathered, medium hard)	4.0	Poor
	(Moderately weathered, medium hard)	5.5	Poor
	(Severely weathered, medium hard)	6.5	Deleterious
Phyllite	(Fresh, soft)	5.0	Poor
	(Slightly weathered)	5.5	Poor
	(Moderately weathered)	6.5	Deleterious
	(Severely weathered)	8.5	Deleterious
Phyllite	(Friable)	10.0	Deleterious
Psammite	(Fresh, hard)	1.1	Good
	(Slightly weathered)	1.15	Good
	(Moderately weathered)	2.5	Fair
	(Severely weathered)	4.5	Poor
Psammite	(Fresh, medium hard)	1.25	Good
	(Slightly weathered, medium hard)	1.35	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor

Petrographic factors for most rock types in Newfoundland *(Continued)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Psammite	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	3.75	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.5	Deleterious
Psammite	(Friable)	10.0	Deleterious
Semi-pelite	(Fresh, hard)	1.1	Good
	(Slightly weathered, hard)	1.15	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Deleterious
Semi-pelite	(Fresh, medium hard)	1.2	Good
	(Slightly weathered, medium hard)	1.25	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.0	Poor
Semi-pelite	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	3.75	Poor
	(Moderately weathered, soft)	4.5	Poor
	(Severely weathered, soft)	6.5	Deleterious
Pelite	(Fresh, hard)	1.1	Good
	(Slightly weathered, hard)	1.15	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Pelite	(Fresh, medium hard)	1.2	Good
	(Slightly weathered)	1.25	Good
	(Moderately weathered)	3.5	Poor
	(Severely weathered)	5.0	Poor
Pelite	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	5.5	Poor
	(Severely weathered, soft)	8.5	Deleterious
Pelite	(Friable)	10.0	Deleterious
Slate	(Fresh, medium hard)	2.0	Fair
	(Slightly weathered, medium hard)	2.3	Fair
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	5.5	Poor
Slate	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	5.5	Poor
	(Severely weathered, soft)	8.5	Deleterious
Slate	(Friable)	10.0	Deleterious
Amphibolite	(Fresh hard)	1.1	Good
	(Slightly weathered, hard)	1.2	Good
	(Moderately weathered, hard)	3.0	Fair
	(Severely weathered, hard)	6.0	Poor

Petrographic factors for most rock types in Newfoundland *(Concluded)*

Rock Type	Texture/Weathered/Hardness	Petrographic Factor	Classification
Amphibolite	(Friable)	10.0	Deleterious
Ultramafic	(Fresh, hard)	1.0	Good
	(Slightly weathered, hard)	1.15	Good
	(Moderately weathered, hard)	2.5	Fair
	(Severely weathered, hard)	4.5	Poor
Ultramafic	(Fresh, medium hard)	1.15	Good
	(Slightly weathered, medium hard)	1.25	Good
	(Moderately weathered, medium hard)	3.5	Poor
	(Severely weathered, medium hard)	4.5	Poor
Ultramafic	(Fresh, soft)	3.5	Poor
	(Slightly weathered, soft)	4.0	Poor
	(Moderately weathered, soft)	5.5	Poor
	(Severely weathered, soft)	7.5	Deleterious
Ultramafic	(Friable)	10.0	Deleterious
Clay lumps	(Friable)	10.0	Deleterious
Iron formations	(Friable)	10.0	Deleterious
Talc	(Friable)	10.0	Deleterious
Gypsum	(Friable)	10.0	Deleterious

Definition of Terms

Hardness

Hard —Cannot be scratched with a knife.
Medium Hard —Can be scratched with a knife, but not with a new shiny penny.
Soft —Can be scratched with a new shiny penny.

Weathering

Fresh —No surface weathering or staining.
Slightly weathered —Minor surface weathering and/or staining.
Moderately weathered —Iron-oxide penetrating inward along cracks and fractures, 10 to 15 percent minerals altered. Cannot be broken by applied hand pressure.
Severely weathered —Intensive iron-oxide staining and weathering, greater than 15 percent minerals altered to clay minerals. Breaks rather easily with applied hand pressure.
Friable —Most minerals are altered to clay minerals and/or the cement holding minerals or rock fragments together in sedimentary rock is weak or altered, causing the rock to break or crumble fairly easily when handled.

Classification

Good (P.N.100–135) —excellent for major asphalt/concrete construction.
Fair (P.N.136–300) —may be used in minor construction (gravel roads, house foundations, minor retaining walls, low traffic asphalt roads) if it passes other required specifications.
Poor (P.N.301–600) —should only be used as fill material.
Deleterious (P.N.601–1000) —unsuitable for aggregate use.