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RECONNAISSANCE ASSESSMENT OF POTENTIAL BEDROCK AGGREGATE

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ABSTRACT

In 1988, a reconnaissance assessment of the aggregate potential of bedrock in the Clarenville and Gander areas was undertaken. Natural aggregates (sand, gravel and crushed stone) are nonrenewable mineral commodities that are being continuously depleted by the rapidly increaseing demand of the construction industry for aggregate use in cement, concrete, asphalt, railway ballast, armour stone, gravel roads and fill material.

A total of 294 sites were visited and 243 samples were collected. Of the 294 sites visited, 187 sites were identified as showing potential for bedrock aggregate; 62 sites were identified as marginal aggregate sites and the remaining 45 sites were considered to be of poor quality for aggregate use.

Geotechnical properties of the bedrock, including geological structures, deleterious substances, abrasion, soundness, petrographic analysis for potential alkali-reactivity and petrographic number are presently under study.

INTRODUCTION

During the 1988 field season, an evaluation of bedrock aggregate potential in the Clarenville and Gander areas was undertaken. This assessment was conducted to determine the quantity and quality of bedrock aggregate for industrial use in the area. This inventory should help to eliminate the use of poor quality rock (e.g., alkali-reactive rocks that react destructively in concrete, and friable rock as a form of armour stone) (Plates 1 and 2).

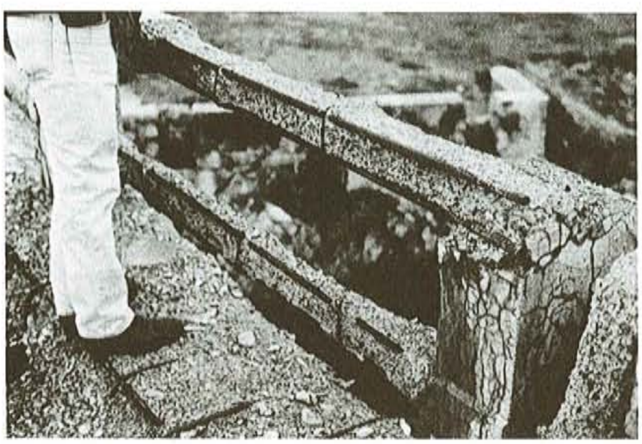

Plate 1. *Bridge deterioration that is believed to be caused by alkali-reactive rocks.*

The field area covers sixteen 1:50,000 map sheets (Figure 1) and because of time and staff limitations, only road traverses were carried out.

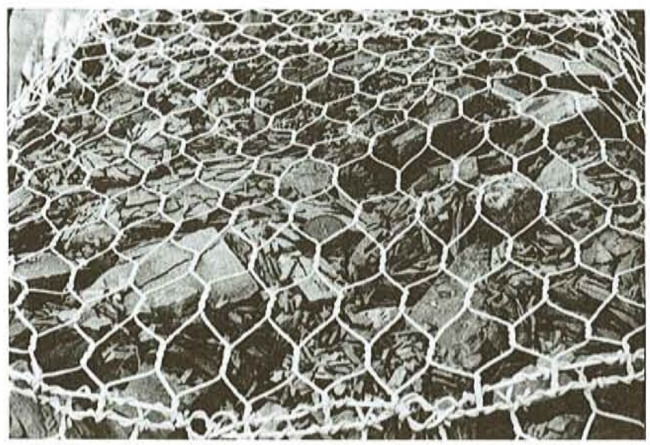

Plate 2. *Friable shale used as a form of armour stone.*

FIELD WORK

Field work consisted of a detailed examination of all rock quarries, road-cuts and natural outcrops along all highways and side roads in the study area. Each site investigation entailed rock identification, representative sampling, determination of overburden type and thickness, and the recording of all geological features present; these site investigations are described below.

Rock Identification

Rocks were identified according to their genetic origin as being either sedimentary (a rock formed by the deposition

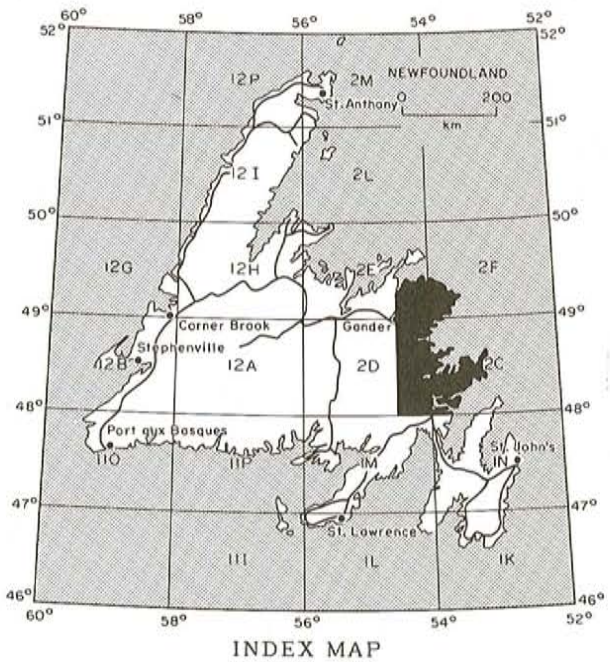

Figure 1. *Location of study area.*

of sediment), igneous (a rock or mineral that solidified from molten or partly molten material), or metamorphic (rocks that have been changed or deformed by high temperature and pressure within the earth's crust). Identification was usually made on site with the aid of a hand lens, but a later more detailed laboratory examination using a petrographic microscope was made, to enable a more precise and accurate rock classification.

Representative Sampling

Sampling is the most critical aspect of the investigation because unless a sample is representative of the site, any testing or analysis undertaken would be clearly, of no value.

A minimum of one representative sample (1 kg) was collected from each quarry or sample site. However, where the quarry or sample site was large (greater than 300 m^2), had a number of different rock types exhibiting varying degrees of weathering and where veining or alteration zones were observed, between 2 and 5 samples were commonly collected. In the latter instances, much larger samples (about 50 kg) were collected at random for more extensive laboratory analyses.

Overburden Type and Thickness

The predominant type of overburden observed in the assessment areas was a veneer (< 1 m) of till (observed at about 80 percent of sites), however, locally, thicknesses ranged from 0.5 to 3.5 m. The remaining sites are thinly vegetated with shrubs and trees.

Geological Structures

The main geological structures that were studied during the field investigation included faults and dykes (Plate 3), fractures (Plate 4), joints (Plate 5) and cleavage (Plate 6). These control the breakage pattern of the bedrock and hence the cost of quarrying, by determining the amount of explosives required and the amount of waste products (such as excessively oversized or undersized blast material).

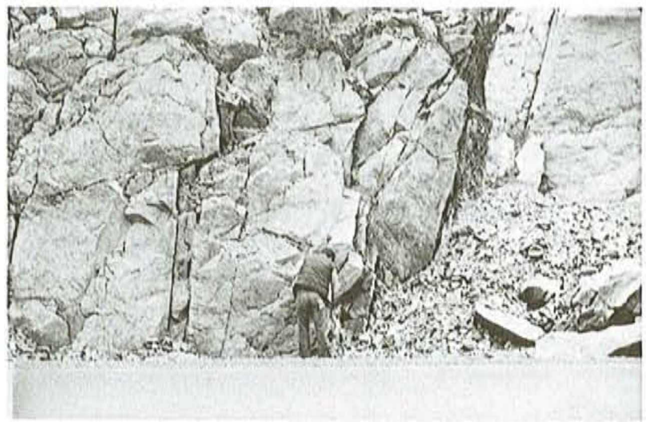

Plate 3. *Road-cut showing a mafic dyke (darker colour); dyke is also offset by a fault.*

Plate 4. *Numerous fractures in a road-cut.*

Other characteristics that are examined in the field include:

1) grain size—generally, the finer the grain size the harder the rock;

2) bedding structures—important because rocks tend to break more easily along bedding planes and laminae;

3) flow structures—in igneous rocks these tend to be planes of weakness;

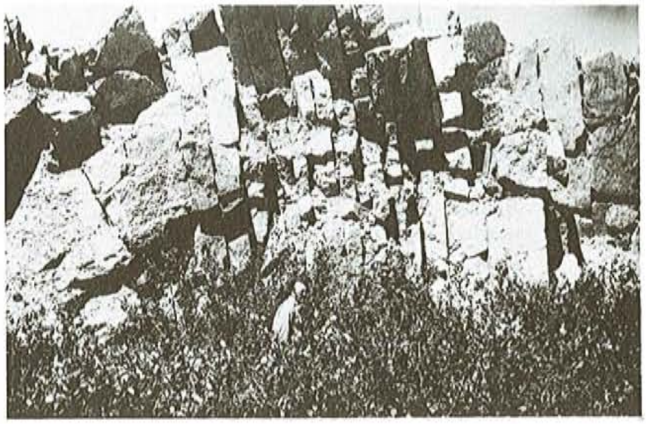

Plate 5. *Vertical jointing in granite.*

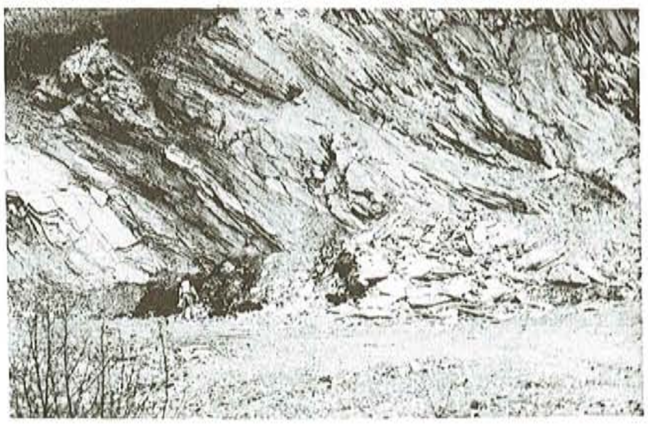

Plate 6. *Metasediments, showing schistosy and prominent cleavage.*

4) mineral alignment–in metamorphic rocks these tend to be planes of weakness and thus important with regard to excessive rock breakage when blasting, crushing and during blending of crushed stone with cement or asphalt binders;

5) mineralization, veining and alteration zones were also noted because of their deleterious affect on asphalt or concrete; and

6) weathering–the degree of weathering (fresh, slight, moderate and high) is important because it affects the durability of the aggregate (i.e., the more weathered a rock, the weaker it would be and thus less durable).

GENERAL GEOLOGY

The Gander area consists primarily of Ordovician sedimentary rocks, sandstone, and shale having varying degrees of metamorphism and psammitic and pelitic rocks of the Gander Group (McGonigal, 1973), and also sedimentary rocks (shale, siltstone, sandstone, limestone) of the Davidsville Group (Kennedy and McGonigal, 1972). The area is intruded by a series of plutonic rocks (granites, granitic-gneiss) of Ordovician (Hare Bay Gneiss, Blackwood, 1982), Silurian (Cape Freels and Middle Brook granites, Strong *et al.*, 1974) and Devonian (Ragged Harbour Pluton and Deadman's Bay Granite, Strong *et al.*, 1974) age.

The Clarenville area consists of Precambrian sedimentary rocks (siltstones, sandstones, graywackes, shales and conglomerates) of the Connecting Point and Musgravetown groups (Hayes, 1948), and minor amounts of felsic to mafic volcanic rocks of the Bull Arm Formation (McCartney, 1958). Precambrian volcanic rocks (basalts, rhyolites, tuffs and breccia) of the Love Cove Group (Jenness, 1958), and minor Cambrian shales of the Adeyton Group (Jenness, 1958) were also noted.

Rock Types and Uses

Rock types in any given area that are being considered for aggregate use should initially be rated on the basis of the amount of deleterious substances present, and the petrographic number.

Deleterious substances are materials that occur in or on the rock and are capable of producing adverse effects (e.g., chemical reactions with other minerals), resulting in a deterioration of the rock or cement binder used in concrete or asphalt. Some commonly found deleterious substances include clays, organic matter, mica, iron and manganese oxide staining and cherty or fine grained siliceous material. Alteration zones, encrustations and the degree of weathering are also factors that are considered to be deleterious to the rock.

A petrographic number is calculated for each site and this measures the initial quality of material for aggregate purposes. The petrographic number is calculated by sampling 100 clasts and assigning a petrographic factor to each clast. The petrographic factor ranges from 1 (best) to 10 (worst) depending on rock type, freshness, hardness and weathering. The petrographic number is the sum of the petrographic factor for each clast and thus can range between 100 and 1000. Each rock type is given a petrographic factor of 1, 3, 6 and 10 (CSA standard A23.12) (Table 1) and a revised version (Table 2; Bragg, 1986) are factors given to different rock types that indicate the initial assessment of the rock for aggregate use. A petrographic factor of 1 indicates the highest quality, whereas a petrographic factor of 10 indicates aggregates of the lowest quality. Thus, the lower the petrographic number the higher the rock quality, which is expressed in the range of 100 to 1000 (e.g., a clean, hard unweathered granite would normally have a petrographic factor of 1, and a petrographic number of 100, whereas a friable, soft shale would have a factor of 10 and a number of 1000). The quality is usually affected by degree of weathering of the rock (Table 3). Table 3 shows the range of petrographic numbers of the different rock groups that were sampled during the field season.

Table 1. Rock type 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 volcanics	deleterious	10
Slates	deleterious	10
Talc-gypsum	deleterious	10
Iron formations (very soft)	deleterious	10
Sibley formation	deleterious	10

Sedimentary rocks, because of their variability, may or may not be suitable for aggregate use. The sedimentary rocks of the Gander–Clarenville area that are suitable for aggregate use are massive sandstone, silicious siltstone and graywacke of the Musgravetown and Connecting Point groups provided they are hard, dense, fresh and free of deleterious substances.

Sandstone, siliceous siltstone and graywacke have a petrographic factor range of 1 to 6 with a usual factor of 1 when fresh and hard. These rock types may all be used as crushed stone aggregate for roads, concrete, breakwaters, asphalt, canals, dams, retaining wall construction and railway and road ballast. The sedimentary rocks in the Gander–

Table 2. Revised petrographic factors for some rock types

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. Argillite	3-6	6
8. Graywacke	1-6	1
9. Chert	1-3	1
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 volcanics	1-6	1
18. Mafic volcanics	1-6	1
19. Intermediate volcanics	1-6	1
20. Felsic-mafic volcanics	1-6	1
21. Pyroclastics	3-6	3
22. Metavolcanics	3-6	3
23. Gneiss	1-6	3
24. Schist	3-10	6
25. Phyllite	6-10	6
26. Marble	1-6	1
27. Slate	10	10
28. Amphibolite	6-10	6
29. Ultramafic	6-10	6
30. Metasediments	1-6	3
31. Iron formation	6-10	6
32. Drift deposits	Any or all of the above	Any or all of the above

Clarenville area that are usually unsuitable for aggregate use are shales and conglomerates of the Davidsville Group and the Brigus and Bonavista formations. Shale, which has a high petrographic factor of 10, because of its softness, friability and mineral content, is not used in most applications as an aggregate. However, it may be used extensively as a raw material in portland cement, as a lightweight aggregate and also as a fill or ballast for road construction. Conglomerate has a high petrographic factor range of between 1 and 10, and a normal factor of 6 when fresh. It is not used normally as an aggregate, because of its weak internal cement, which may break down during handling of the rock. Nevertheless, some cemented homogenous conglomerates (e.g., those consisting of predominantly volcanic or granitic clasts having a silica cement), maybe used as armour stone, for breakwater construction.

Igneous rocks mainly from the Gander area are subdivided on the basis of coarseness. Medium to coarse-grained rocks (granite, diorite and gabbro) are generally plutonic (intrusive), and the finer grained rocks (rhyolite, andesite, basalt and pyroclasts (tuffs and breccias)) are volcanic (extrusive). These igneous rocks have petrographic factors ranging from 1 to 6 and a normal factor of 1 when fresh.

Table 3. Affect of weathering on petrographic factors

Petrographic Factor	Weathering Grade	Final Petrographic Factors
1	1, 2	1,2
	3	3,4,5
	4, 5	6,7,8,9
	6	10
3	1, 2	3,4,5
	3, 4	6,7,8,9
	5, 6	10
6	1, 2	6,7,8,9
	3, 4, 5, 6	10
10	1, 2, 3, 4, 5, 6	10

The medium- to coarse-grained intrusive rocks of the Georges Pond, Middle Brook, Ragged Harbour, Big Round Pond and Warehams granites are all from the Gander area and are all excellent sources of aggregate material, and can be used for both industrial and architectural purposes. The industrial use include crushed−stone road construction, dams, bridges, pavement, retaining walls, railway ballast and foundation blocks. Architectural uses include dimension stone for ornamental and structural use in monumental structures, private, residential, commercial and institutional building complexes. The intrusive rocks that were generally unsuitable for aggregate are from the Newport Granite suite and parts of the Hare Bay Gneiss.

Fine grained extrusive volcanic rocks of the Bull Arm Formation are excellent aggregate materials, but care should be taken when used in concrete. Highly siliceous rocks may react chemically with high-alkali cements, resulting in progressive deterioration of the material. The extrusive rocks of the Love Cove Group are generally not suitable for aggregate material due to their intense alteration and weathering.

Metamorphic rocks may be both suitable or unsuitable for aggregate use depending on their mineralogical characteristics. The metamorphic rocks in the field (Hare Bay Gneiss), which are suitable for aggregate use, consist of granitic-gneiss which are hard and have a normal petrographic factor of 1. The unsuitable metamorphic rocks are slates, pelites, phyllites and schists of the Gander, Mustravetown and Connecting Point groups because of their mineral content, distinct cleavage and softness, and have a petrographic factor of 10 for slate and pelite, 6 for phyllite and schist. These rocks are normally used as fill material.

LABORATORY INVESTIGATION

Petrographic examination (ASTM method C-295.65, 1973) and CSA standard tests A23.2.30 (1973) were carried out on all hand specimens and thin sections made from them. Petrographic examination involves a detailed investigation to determine the quality of the rock sample by identification of such features as microfractures (fractures in the crystal) (Plate 7), porosity in the rock (Plate 8), strained quartz (Plate 9), mineral alteration (Plate 10) and iron-oxide staining in fractures (Plate 11), all of which are deleterious to the rock. Soundness and abrasion tests are being carried out on select samples.

Plate 7. *Microfractures in a quartz crystal; field of view is 5 mm.*

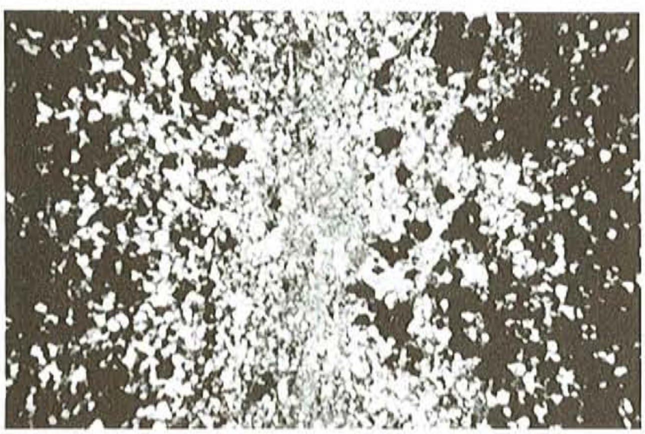

Plate 8. *The darker spots are void spaces that indicate high porosity; field of view is 5 mm.*

Plate 9. *Strained quartz showing undulating extinction; field of view is 5 mm.*

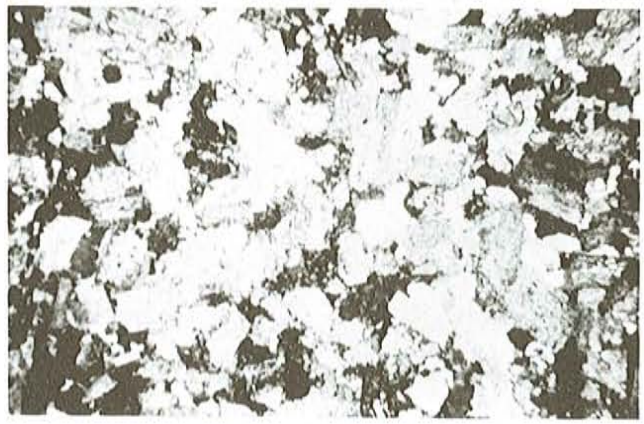

Plate 10. *Feldspars altered to clay minerals; field of view is 12 mm.*

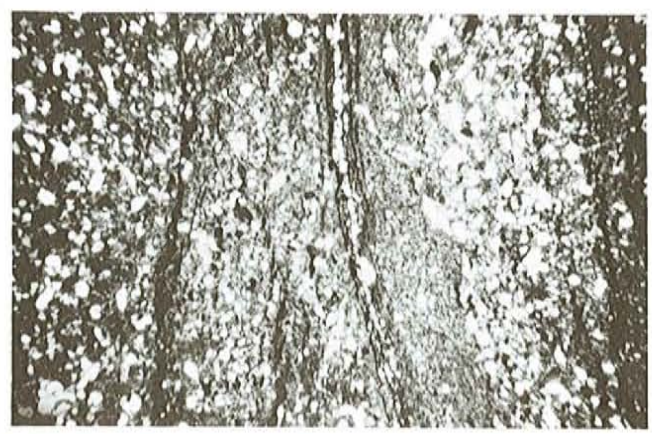

Plate 11. *Iron-oxide staining in fractures; field of view is 12 mm.*

SUMMARY

A total of 294 sites were visited and 243 samples were collected during the field season. Thin sections were made of all samples and petrographic analyses is presently continuing.

A more comprehensive report is scheduled for publication later in 1989, and will give descriptions of each site and sample. This will eliminate certain sites for aggregate use and promote others. The report will provide a data base for the exploitation of bedrock for aggregate use.

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