Preliminary Report on Bedrock Aggregate Research in the Eastern Cobequid Highlands

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Introduction

Bedrock aggregate potential is one of the most important components of aggregate resources in Nova Scotia. When sites are properly selected, the deposits produce high quality stone products which are used throughout the construction industry. The crushed stone from the quarries is particularly important for the development of infrastructure such as highways and concrete bridges, which require superior materials to make the structures safe, long lasting and cost effective. Over the last couple of decades quarries have supplanted glacial sand and gravel deposits as the primary source of construction aggregate in Nova Scotia. This largely reflects the depletion of gravel deposits in many areas, as well as the bedrock sources ability to produce higher quality materials. Approximately 6-10 Mt of crushed stone are produced annually for domestic use in Nova Scotia, which represents about 60-65% of the aggregate consumed in the province. As glacial sand and gravel deposits continue to be depleted and materials standards tighten, it is anticipated that crushed stone will play a greater role in the aggregate industry in the future.

In spite of the expanding need for large volumes of high quality bedrock aggregate, there are issues which will have serious implications for the future of the resource. Factors such as competing land uses, zoning bylaws, increasing land values, pit and quarry regulations, population increases and residential sprawl are continually making the resource land more difficult to access for quarry development. The result is that large areas of strategically located bedrock with aggregate potential have been sterilized, while others face the threat of a similar fate in the future.

The greatest concern is the loss of the resource land in the areas which are the primary stone markets. The Halifax-Dartmouth area, for example, requires more than 3 Mt of crushed stone each year. Because these nonrenewable materials are rarely recycled, the total stone reserves (remaining in the ground) in the metro quarries are shrinking by an amount approximating the annual production rate. Although difficult to predict with certainty, it is reasonable to expect that the demand for stone in an area such as Halifax-Dartmouth and the surrounding suburbs will accelerate in the future. If the population continues to expand it will require a larger and more complex infrastructure to accommodate this growth (e.g. new highway connectors and improved access to the city core area) in addition to the maintenance and replacement of existing structures. The eventual outcome of continually extracting large amounts of stone is the exhaustion of these finite reserves and the need for new quarries to replace them. However, the land-use issues and population growth in the region will most likely push the new quarries into more remote areas where there are fewer pressures on the resource land. The inevitable increased distance from quarry to construction site will mean longer truck hauls to carry the millions of tonnes to the Metro stone markets. Transportation costs for these heavy, bulk materials are the single largest component in the price of the stone that is landed at the construction site. Each additional kilometre that a tonne of stone has to be transported from the quarry gate to its destination means higher costs for the materials, greater fossil fuel consumption, greater air emissions and additional wear on equipment and highways. This will have significant socioeconomic implications for communities and negative impacts for the environment (Prime and

Prime, G., 2011: *in* Mineral Resources Branch, Report of Activities 2010; Nova Scotia Department of Natural Resources, Report ME 2011-1, p. 123-129.

Bonner, 2007.) Other populated areas in the province will face similar concerns in the future. Resistance to the permitting of new quarries near small communities has already been experienced in some areas of the province.

Nova Scotia Department of Natural Resources's Bedrock Aggregate Research

In spite of the strategic value that crushed stone has in the province, the remaining usable resource land continues to shrink and grows more vulnerable to sterilization each year. If present trends continue, the bedrock aggregate resource may go from being a 'resource at risk', to one that disappears entirely in some of the key areas where the stone is needed the most. This will leave the province with expensive choices in order to meet future demands for these irreplaceable materials.

The bedrock aggregate resource is considered a priority in the research under Nova Scotia Department of Natural Resources's (DNR) Aggregate Program. Over the last couple of decades, several resource evaluation studies have been conducted in the province with the objective of producing resource maps which identify and assess the bedrock potential. Bedrock studies have been undertaken as part of regional overviews that have looked at all aspects of the aggregate resource including surficial potential (Prime, 1992, 2005, 2009, 2010). Other research has exclusively examined the bedrock potential in focused areas that are considered strategic to public works agencies and communities (Prime, 1994, 2001; Prime and Bonner, 2007). There have also been research efforts focused on specific lithologies or stratigraphic packages of rock (Prime, 2008; Prime and White, 2007). The ongoing and long term goal of the research is to locate the remaining usable resources throughout the province.

Eastern Cobequids Study

The bedrock aggregate potential of the eastern Cobequid Highlands (Fig. 1) has been selected as the next area of study in the bedrock evaluation process. It was chosen because of its strategic location between the Truro and the Oxford/ Springhill/Amherst aggregate markets. Although these areas currently have thriving aggregate industries with adequate supplies of crushed stone and glacially-derived materials to meet demand, DNR research approaches the resource from the perspective of future community needs. Through field work, sampling and the preparation of databases, the resource can be located and its quality determined. It is anticipated that this information will help government agencies and industry locate the best construction materials available to do the work in the future. This will have important implications for the cost of infrastructure. Under the current conditions of unchecked sterilization of resource land, this research may also be an opportunity for governments and planners to take proactive measures to protect the resource for future use.

There may also be a strategic value to the aggregate resource in this region because of its proximity to the primary rail line that connects to the Halifax-Dartmouth area. Previous studies by Prime (2001) and Prime and Bonner (2007) suggested that the Halifax-Dartmouth area will face challenges to meet its aggregate needs in the future. If new quarries cannot be permitted near this market, the anticipated long truck hauls of these bulk materials from distant sources could be very costly for taxpayers and the environment. The railway transport of stone can be as little as one tenth that of truck haulage costs (Barker and Harben, 2002). If sources of stone can be identified in proximity to the rail line traversing the Cobequid Highlands in the Folly River area, it may present a cost effective method of transportation for materials to reach the Halifax-Dartmouth aggregate market. This method of delivery would require a centrally located unloading site or distribution yard near the rail line, as well as trans-shipping by trucks from the stockpiles to the final destination, however it may be a competitive option to longer haul trucking. The rail link also connects to the Sydney area, the second largest population base in the province, which will face similar resource land issues in the future.

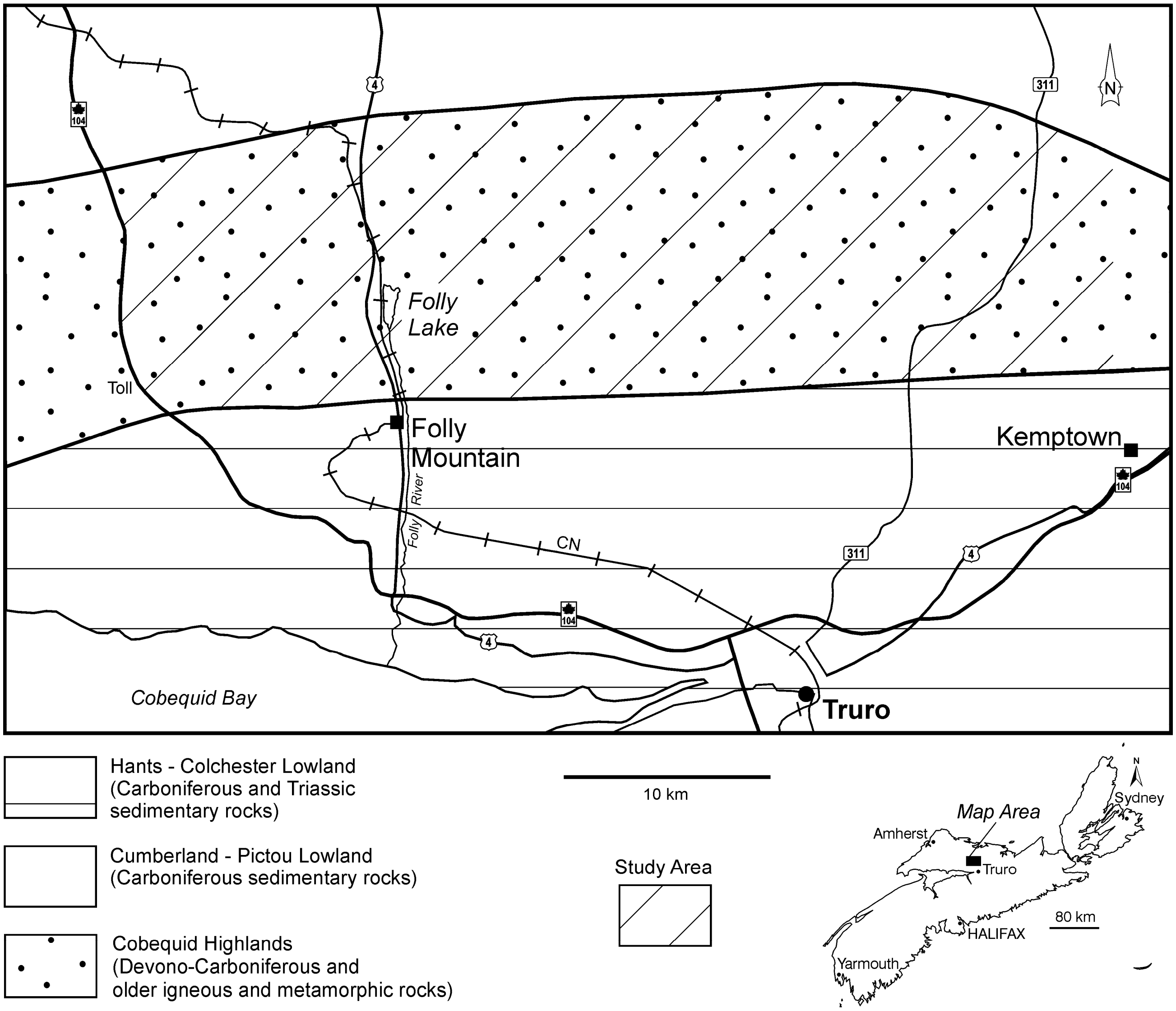

Figure 1. Outline of the study area in the eastern Cobequid Highlands north of Truro being evaluated for bedrock aggregate potential.

Study Area

The area selected for study (Fig. 1) is based on a combination of geology, physiography and stone materials research. The physiographic subdivisions in the region (and Nova Scotia in general) are a very accurate predictor of where to find bedrock aggregate deposits. The rock characteristics which determine susceptibility to erosion and topographic relief are the same properties which are used to distinguish construction stone potential. The unmetamorphosed sedimentary rocks that occur to the north and south of the Cobequid Highlands produced lowland areas because they were easily eroded. The soft, porous and layered nature of these rocks also makes them unsuited for the production of durable, weather resistant aggregate particles. Conversely, the highland area between the lowlands consists of an igneous-metamorphic assemblage of rocks that are commonly hard and erosion resistant. This durability and resistance to water penetration make many of these rocks highly suited to bedrock aggregate exploration.

The east-west trending contact between the Carboniferous lowland areas and the older geology of the Cobequid Highlands defines the northern and southern limits of the study area (Fig. 1). The specific area of the highlands selected for investigation is near the Truro aggregate market and the railway corridor along Folly River. The eastern boundary is a north-south trending line in approximate alignment with Kemptown and the western boundary is Route 104 in the area called the Cobequid Pass Toll Highway.

Methodology

Land-Use Issues Affecting Resource Potential

Evaluating the bedrock aggregate resource in the study area combines geological and land-use investigations. Understanding which rock types and areas may have potential for the production of crushed stone must be undertaken in conjunction with identifying land uses compatible with extractive resource development. There is little value, from the perspective of stone resource analysis, in finding a high quality rock deposit which can never be quarried because of conflicting land-use issues (e.g. parks, protected places and wind farms) or impediments to site access. The primary objective of the research is to focus on bedrock in areas which appear to be best suited to future resource development and avoiding areas where land-use conflicts are anticipated. (Note: In the unlikely event that future land-use changes or municipal zoning favour aggregate resource development in areas that are currently considered off limits using the criteria defined here, the data from this study can be used to indicate aggregate potential in these areas as well.)

An examination of the documented land-use issues, accompanied by an initial examination of the study area, lead to the conclusion that the best potential for future quarry development are areas currently under forestry management and being used for wood harvest. With the exception of local areas, where there are cottage developments (near lakes), these fairly isolated areas have very low levels of human activity. The large blasting setback distances from residential dwellings (800 m) is just one example of the value of focusing on resource land which is found in these more isolated locations. The extensive network of haulage roads which provides access to these mountainous areas is also significant from the perspective of a commodity that depends on truck haulage.

Site accessibility is also important in terms of the impacts that stone haulage can have on communities. If the road connection from a new quarry to the major highways unavoidably requires truck haulage through residential areas, a proposed development site can quickly become a focal point of community concerns during the permitting process. Other land uses and natural barriers that can affect truck access to a site include rivers, steep mountain slopes, railway lines and divided highways. Securing travel routes that can access or cross these barriers can vary from costly to an insurmountable task. Although these potential land-use and geographic barriers did not eliminate aggregate potential from being evaluated, they will be highlighted in the final report as potential concerns or obstacles to development.

Geological Parameters Affecting Resource Potential

The geological component of the investigation is being conducted using the geological maps of the Cobequid Highlands by Donohoe and Wallace (1982a, b). When the maps are used in conjunction with the data and research knowledge acquired under the Aggregate Program, it permits focus on the rocks which tend to make the best aggregate. The aggregate study of northern Nova Scotia (Prime, 1992) and the diamond drilling program conducted in the Cobequid Highlands to the west of the study area (Prime, 1994) are particularly useful in this respect. The discussion which follows will describe the geological characteristics considered important in the evaluation of bedrock aggregate potential in this study.

Based on past research and field experience, the rock types given the highest priority are the fine- to medium-grained igneous rocks which tend to be hard, durable and resistant to water penetration. These include the plutonic rocks and some of the thick volcanic deposits which are uninterrupted by interbedded units of sedimentary rock. Fine-grained sedimentary rocks, such as shale and siltstone, are usually considered to be deleterious materials unsuited for the production of construction-grade aggregate. The presence of small percentages of these rocks as interbeds would have negative implications for a volcanic deposit that is being considered for a crushed stone quarry. Although these 'mixed lithology', stratigraphic units cannot be dismissed as potential, they would require detailed, site specific evaluations which were beyond the scope of this study.

Rocks with a metamorphic fabric, such as slaty cleavage or schistosity, were avoided because the layering is a plane of weakness in the aggregate particles. Stone applications such as highways must use aggregate that is not prone to breakage due to stresses associated with heavy traffic load and volume. During the crushing and screening process, rock with a pronounced fabric commonly produces stone with a high proportion of platy- or tabular-shaped clasts. Materials specification tolerances for these particle shapes can be quite low in certain aggregate products. Depending on the intensity of the fabric and the composition of the metamorphic minerals, the plane of weakness can also be a path for water entry which leads to freeze-thaw damage in weather-exposed aggregate products. The minerals responsible for layering also tend to be soft and subject to high abrasion wear in many construction aggregate applications. Easily abraded rock can also be a problem in the processing stage if large amounts of fines are generated during crushing and screening activities. Excessive fine materials can require expensive wash systems and cause financial burden associated with the storage and disposal of these waste products. The metavolcanics in the study area are an example of rocks that may contain unacceptable amounts of soft minerals. Although these rocks were generally avoided in the evaluation process of this study, they probably contain site specific areas where the rocks have little, if any, fabric. The metavolcanics are being considered for followup investigation at a later date.

Another important characteristic to consider in the identification of bedrock aggregate potential is the thickness of the surficial deposits which overlie the solid bedrock. During the most recent ice advance and eventual deglaciation more than 10,000 years ago, glacial till was deposited over much of the province. Some areas also contain the remnants of older tills from previous stages of glacial advance. The result is that till can reach tens of metres in thickness in some areas of the province. It is important to identify and avoid areas where there are thick accumulations of till deposits because of the high overburden stripping costs to access the underlying bedrock. Areas of minor glacial cover or scoured bedrock are ideal for quarrying.

Areas of highly weathered bedrock or saprolite can have negative implications for bedrock aggregate potential. These highly fractured, altered rocks tend to be friable, lack durability and perform poorly in aggregate testing, making them unsuited for the production of high quality construction aggregate. Previous work under the Aggregate Program (Prime, 1992, 1994) indicated that these weathered rocks are quite common in the plutonic rocks of the Cobequid Highlands. Although it has been suggested that the saprolite should be treated as overburden which needs to be removed to access the solid rock beneath (e.g. Barksdale, 1991), it is the opinion of the author that these areas should be avoided when searching for bedrock aggregate potential. The transition of this bedrock from friable rock at the surface to solid rock beneath is commonly gradational. The apparent solid bedrock at the base of a pit, where the overlying materials have been removed by ripping equipment, probably contains the characteristics that permitted the weathering to take place (i.e. fractures, fluids and alteration). These are the same features that make the rock deleterious for the purpose of aggregate. These areas should be approached with extreme caution if they are being considered for quarrying construction grade aggregate. They were avoided in this study because the weathered rock was not considered suitable for sampling.

Field Results For 2010

Beginning in late April 2010 reconnaissance field work was conducted in the study area to determine, (1) where the best geological targets for bedrock aggregate potential are found, and (2) where representative samples of the rock could be collected for aggregate testing. Approximately 75 potential sample sites were identified where samples could be easily extracted. They include natural bedrock exposures, quarries (active or abandoned), road cuts and ditch cuts. The selected sample sites were entered into a GPS unit and the sampling began in late May. The samples consisted of two 20 litre pails containing approximately 40 kg of bedrock that was reduced to small pieces using wedges and hammers. Fifty samples were collected for storage.

The samples collected were from the following geological units mapped by Donohoe and Wallace (1982a, b): Carboniferous-aged monzogranite, Frog Lake Pluton diorite, Byers Brook Formation rhyolite, Diamond Brook Formation basalt, Devono-Carboniferous diorite and Hart Lake-Byers Lake Pluton monzogranite. These rock types appear to have the best potential for producing construction grade aggregate. Although the focus was sites containing high quality stone, a few locations were selected for sampling because they contain sheared and faulted rock. The deformed rock associated with these structural features is very common in the upland areas in the province which have been subjected to a lengthy, complex tectonic history. At least a minimal level of deformation can be expected within the dimensions of any aggregate deposit found in the Cobequid Highlands, and therefore it is important to understand how the deformed rocks affect aggregate quality.

Further sampling at a later date is required, however the samples collected in 2010 are reasonably representative of the bedrock aggregate potential in the study area. Future samples will include more of the structurally deformed rocks and the metavolcanic rocks to gain further insight into the effects that features such as shearing, brecciation and fabric have on stone quality.

At the time of preparation of this report the samples were in storage awaiting laboratory preparation and analysis later this winter. A final report will be prepared at a later date. Questions regarding this research or any other aspect of aggregate resources in Nova Scotia can be directed to the author by phone at 902-424-8146, by e-mail at primega@gov.ns.ca or my office location on the 3rd Floor of Founders Square at 1701 Hollis St., Halifax.

References

Barksdale, R.D. (ed.) 1991: The aggregate handbook; National Stone Association, Washington, D.C., 771 p.

Barker, J. M. and Harben, P. W. 2002: Industrial mineral transportation - an overview; *in* 38th Forum on the geology of industrial minerals; Missouri Department of Natural Resources, Geological Survey and Resource Assessment Division, p. 16-21.

Donohoe, H. V. and Wallace, P. I. 1982a: Geological map of the Cobequid Highlands, Colchester, Cumberland and Pictou counties, Nova Scotia; Nova Scotia Department of Mines and Energy, Map 82-8, Sheet 3 of 4, scale 1: 50 000.

Donohoe, H. V. and Wallace, P. I. 1982b: Geological map of the Cobequid Highlands, Colchester, Cumberland and Pictou counties, Nova Scotia; Nova Scotia Department of Mines and Energy, Map 82-9, Sheet 4 of 4, scale 1: 50 000.

Prime, G. 1992: Aggregate potential of Cumberland and Colchester counties, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Economic Geology Series 92-2, 162 p.

Prime, G. 1994: A diamond drilling program near the Amherst market, investigating bedrock aggregate potential in the northwestern Cobequid Highlands, Nova Scotia; Nova Scotia Department of Natural Resources, Mines and Energy Branches, Paper 94-1, 38 p.

Prime, G. 2001: Overview of bedrock aggregate potential in the Halifax-Dartmouth metropolitan area, Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Economic Geology Series ME 2001-1, 74 p.

Prime, G. A. 2005: Aggregate program activities in 2004; *in* Mineral Resources Branch, Report of Activities 2004, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2005-1, p. 93-99.

Prime, G. 2008: An overview of the industrial mineral potential of the North Mountain Basalt; *in* Mineral Resources Branch, Report of Activities 2007, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2008-1, p. 81-104.

Prime, G. 2009: Progress report on the Annapolis Valley Stone Resource Project; *in* Mineral Resources Branch, Report of Activities 2008, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report ME 2009-1, p. 121-128.

Prime, G. 2010: 2009 progress report on the Annapolis Valley Region Stone Resource Project; *in* Mineral Resources Branch, Report of Activities 2009, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report ME 2010-1, p. 99-111.

Prime, G. and Bonner, F. J. 2007: Bedrock aggregate development potential in western Halifax Regional Municipality; Nova Scotia Department of Natural Resources, Mineral Resources Branch, Economic Geology Series ME 2007-1, 51 p.

Prime, G. A. and White, C. E. 2007: Bedrock aggregate potential of the Meguma Group; *in* Mineral Resources Branch, Report of Activities 2006, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2007-1, p. 123-136.