CHAPTER 1. INTRODUCTION

Aggregate is defined by the American Society for Testing and Materials (1988) as "a granular material of mineral composition such as sand, gravel, shell, slag or crushed stone, used with a cementing medium to form mortars or concrete, or alone as in base coarses, railroad ballasts, etc". Its primary uses are in the construction of roads and buildings and, as such, it is a critical material in the development and maintenance of our Nation's infrastructure. Production statistics for 1988 estimated that total aggregate production for Canada exceeded 450 Mt with a product value FOB of $2.5 billion (Canadian Aggregates Magazine, 1989).

In Nova Scotia the industry is an integral part of the Province's economy. Within the mining sector aggregate annually ranks second or third in terms of product value and employment. Annual production is currently in the range of 15 Mt with a product value of $67 million and requiring a work force of 900 individuals (MacLellan, personal communication). The indirect impact of aggregate is much wider with jobs in several other industries being dependent upon these materials. This includes sectors such as concrete manufacture, highway construction, trucking and equipment manufacture. Furthermore, because aggregate is tied so closely to the construction industry, the economics of the resource impacts Province-wide.

Aggregate production in Nova Scotia has increased substantially in recent years (Fig. 1). However, problems such as selective depletion of reserves and sterilization of the resource lands have accompanied this growth. The result is that the aggregate industry is facing new challenges in order to maintain the supply and quality of their materials.

To address these problems the Nova Scotia Department of Mines implemented an aggregate program in the early seventies to evaluate the resources. The focus of the program has been the building of an information base to: (1) assist industry in meeting its aggregate needs; (2) promote growth in the aggregate industry; and (3) ensure proper management of the resource in the future. Among the achievements of the program to date are a series of granular aggregate maps on a Provincial and more detailed regional scale (Fig. 2). The aim of the present project is the continuation of detailed mapping by examining the aggregate potential in northern Nova Scotia.

The northern Nova Scotia region, as defined for this study, comprises Cumberland and Colchester Counties (Fig. 2). Although the region contains some of the

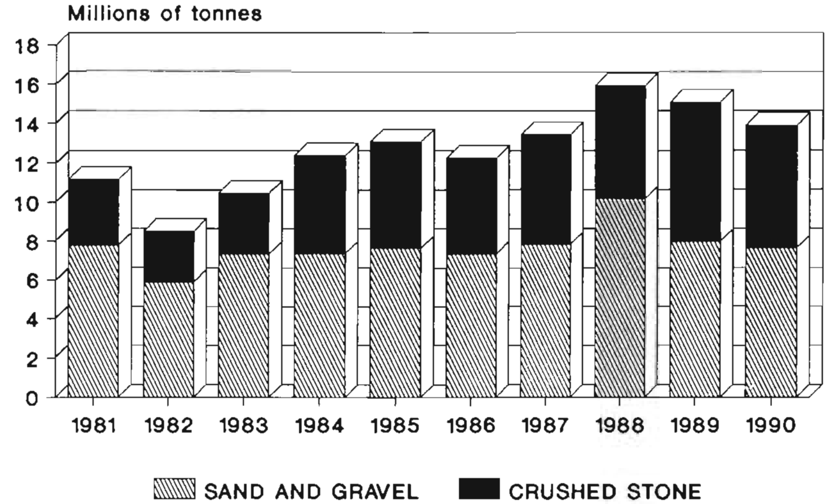

Figure 1. Annual aggregate production for Nova Scotia (compiled from Nova Scotia Department of Natural Resources statistics).

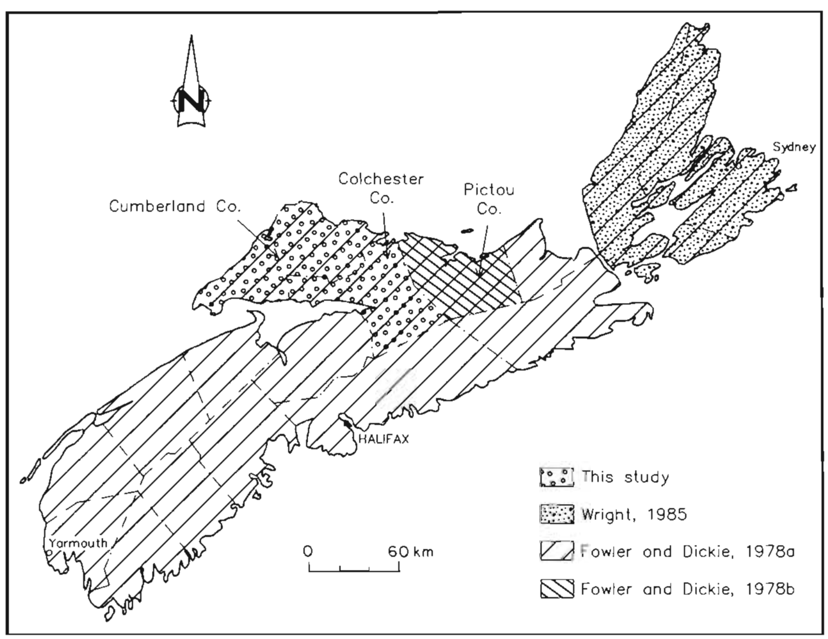

Figure 2. Granular aggregate studies completed by Nova Scotia Department of Mines and Energy.

highest concentrations of sand and gravel in the Province (Fowler and Dickie, 1978a), there are problems associated with the resource. They are summarized as follows:

(1) The quality of the deposits varies widely, with many of the materials being substandard for the production of concrete and asphalt, both of which are required throughout the region.

(2) There is a depletion of materials in areas of high consumption. In most areas the better deposits are consumed first, which leaves the producers searching for new sources.

(3) There is an absence of materials in some areas where the surficial cover and bedrock have characteristics which make them unsuitable as sources for aggregate.

(4) The industry is facing competition for the resource land, primarily in the areas of urban development, agriculture and recreation.

(5) Environmental regulations have restricted the development of many deposits partially or entirely. This includes beach deposits and gravels adjacent to streams and rivers.

The overall effect of these factors is increased haulage distances in order to obtain suitable materials, which means higher transportation costs and higher prices for the product. Thus there is a negative impact on both producer and consumer. Two locations where the effects of these problems are most noticeable are Truro and Amherst, the two major centres of aggregate consumption in the region. The Truro area has had a long history of problems stemming from population growth and encroachment on the resource land. The Amherst area has no aggregate deposits, forcing them to haul materials long distances at considerably higher costs.

The goals of this study are to address these problems by defining and evaluating the aggregate potential in Cumberland and Colchester Counties. This includes the search for new granular deposits and the identification of alternative sources of aggregate.

PREVIOUS STUDIES

The earliest general examination of the **surficial geology** of northern Nova Scotia was conducted by Chalmers (1885). Approximately a half century later, Wickenden (1941) studied some of the glacial deposits in the region. The first mapping of surficial deposits which included the study area was conducted by the Nova Scotia Research Foundation (MacNeill, 1956). The result was a Provincial series of 1:50 000 maps indicating the location of till, ice contact stratified drift and glacial outwash deposits. The first complete coverage of the Quaternary geology for an area within the region was produced for the Shubenacadie area by Hughes (1957).

The earliest detailed sedimentological examination of glacial deposits in the region was provided by Swift and Borns (1967). They interpreted the lowland gravel deposits along the northern shore of the Minas Basin as being remnants of glacially derived outwash deltas. Wightman (1976; 1980) conducted mapping of the glaciofluvial and glaciomarine deposits along the entire northern shore of the Minas Basin, providing a detailed sedimentological interpretation of the deposits.

The Nova Scotia Department of Mines and Energy conducted the most recent Quaternary study in the area with 1:100 000 maps of Cumberland and Colchester Counties (Stea et al., 1986; Stea and Finck, 1988).

A series of **soil surveys** covering the Province were conducted by the Federal government, providing mapping and descriptions of the soil types and identification of glaciofluvial sand and gravel. Initially the Dominion Department of Agriculture produced a report covering Colchester County (Wickland and Smith, 1948). A later report was provided for Cumberland County by Agriculture Canada (Nowland and MacDougall, 1973). Most recently reports have been produced by Agriculture Canada on Colchester County (Webb et al., in preparation), the Minas Basin area (Webb et al., 1989) and the Northumberland Shore area (Patterson and Thompson, 1989).

Water resources studies in northern Nova Scotia were carried out by two Provincial departments. The Nova Scotia Department of Mines produced groundwater reports in the areas of Brookfield (Hennigar, 1968) and Truro (Hennigar, 1972), both containing detailed surficial geology maps. More recently, the Nova Scotia Department of the Environment examined the groundwater resources in the Amherst-Oxford-Springhill area (Vaughan and Somers, 1980), including a description of many of the gravel deposits. In addition to their value for the detailed mapping which was accomplished, these reports also provide valuable information on water well data.

One of the earliest **aggregate reports** completed in the Province was a land use study conducted near Truro by Simmons (1971). Precipitated by land use conflict in the North River area, the study provides early insight into the problems facing the aggregate industry. The study evaluated the aggregate resources, identified areas of concern and provided suggestions as to how problems might be avoided in the future.

The Nova Scotia Department of Mines became involved in aggregate resource management in the Province in the early seventies. They produced a series of 1:50 000 sand and gravel maps covering the Province, providing information on pit location and size gradation of the materials (Fowler and Dickie, 1978a). Subsequently more detailed studies have been produced for Pictou County (Fowler and Dickie, 1978b) and Cape Breton Island (Wright, 1985) (Fig. 2).

Many published and unpublished maps on **bedrock geology** are available for northern Nova Scotia, however only those relevant to this study are identified here. The Cobequid Highlands igneous and metamorphic rocks were mapped by Donohoe and Wallace (1982). Maps recently have been produced covering the Devono-Carboniferous rocks north of the Cobequid Highlands in the Cumberland Basin by the Nova Scotia Department of Mines and Energy at scales of 1:10 000 (Ryan et al., 1988a; 1988b; 1988c; Deal et al., 1988; Boehner et al., 1988) and 1:50 000 (Ryan et al., 1990a; 1990b; Ryan et al., 1990; Ryan and Boehner, 1990). To the south of the Cobequids, there are maps available for Truro (Stevenson, 1958) and Shubenacadie (Stevenson, 1959; Giles and Boehner, 1982).

METHODOLOGY

The research for this report was conducted from 1986 to 1989, including three summers of field investigation. Initially a literature search was carried out to obtain background information. This was followed by aerial photographic interpretation in conjunction with field investigation. The air photo study was conducted using 1:10 000 coloured photos and 1:50 000 infrared photos. The 1:50 000 infrared photos were preferred in this study because of scale and relief enhancement. During the field investigation all exposures were examined and described in detail. The exposures included shorecuts, roadcuts, streamcuts, ditches, outcrops, pits, quarries and other excavation sites. Those deposits with the best potential were sampled including newly identified deposits and previously known, yet untested deposits. Samples representative of size gradation and composition were collected when possible. Laboratory analyses of the samples were conducted to determine quantitative and qualitative measures of the materials. A discussion of these tests is provided in the following section.

Throughout the project there were discussions with industry people, the Nova Scotia Department of Transportation and Communications, the Nova Scotia Department of the Environment and local residents. These contacts were instrumental in the identification of new aggregate potential and obtaining a better understanding of the aggregate industry in the region.

Sampling and Laboratory Analysis

Aggregate materials vary widely in terms of their quality and characteristics and, depending on the end use of materials, this quality may or may not be important. For example, the aggregate used for fill may simply require an adequate size gradation to ensure good drainage, but the aggregate in exposed structural concrete, in which product integrity is critical, may require tests for grain size distribution, deleterious substances, resistance to abrasion, resistance to freeze-thaw cycles, alkali reactivity and petrographic analysis.

Because building and highway construction are the primary uses of aggregate, the sampling program was designed with construction materials in mind. Furthermore, the emphasis was placed on aggregate with potential for asphalt mixes and Portland cement concrete. The entire region was sampled and tested with analytical detail being applied to the best deposits.

It should be noted that, although sampling was carefully conducted in a manner to obtain representative samples, the test results should only be used as a rough guide to assessing a deposit. The problem lies in the general lack of homogeneity in composition of many aggregate deposits due to structure, sedimentology and weathering. Sampling a pit reflects the exposure at the time. Samples obtained at small exposures of bedrock or gravel may be entirely unrepresentative of the deposit. Practical considerations precluded the taking of large bulk samples which would be more representative. To properly assess the deposits identified in the study more information is required and the results described here should only be considered an initial step in the process.

The laboratory analyses were provided by the Technical University of Nova Scotia, Halifax, and Warnoek Hersey Professional Services, Burnside, Nova Scotia. The tests comprise sieve analysis, Los Angeles Abrasion Test, sodium sulphate soundness test, Petrographic Number and organic content. A description of the tests is provided below.

Grading

Grading in aggregate may be defined as the grain size distribution of the rock particles in either a naturally occurring state (e.g. gravel) or as a crushed product (e.g. quarried bedrock). It is one of the most common properties to be considered in the assessment of an aggregate's potential for two reasons: (1) to determine the potential uses of the materials, and (2) to identify technical problems associated with processing which could affect the profitability or production efficiency of a deposit (e.g. too many fines require additional separation equipment and expense, too much oversize rock requires removal or size reduction prior to crushing).

The size gradation determination was conducted by the Technical University of Nova Scotia. The total sand/gravel samples were dried at 100°C and sized from 4" to No. 4 screens using Gilson sieves. The minus No. 4 materials were split using a Riffle Splitter and approximately 1000 g were wet sieved with a No. 200 screen. The remainder of the sample was dried and sized from No. 8 to No. 200 screens using a Ro-tap sieve shaker. Combined sieve fractions were then calculated to determine the percentage of gravel (plus No. 4), sand (minus No. 4 to plus No. 200), and silt/clay (minus No. 200).

The bedrock samples were crushed (jaw crusher) to Department of Transportation and Communications Type B aggregate. The size gradation of the materials were then determined using the above screening method.

The specifications for grain size distribution in Portland cement concrete aggregate, asphalt aggregate and road gravel are provided in Appendix 1, Tables A1-1A, A1-2A and A1-2B.

Los Angeles Abrasion Test

The Los Angeles Abrasion Test (ASTM Standard 131-81) conducted by Warnock Hersey Professional Services Limited, is a method for determining the relative competence and durability of the materials in an aggregate source as compared to other sources. It represents a measure of the degradation of the particles in an aggregate sample which has been subjected to a combination of actions including abrasion, grinding and impaction.

The test is conducted using a steel drum containing a specified number and size of steel balls. The aggregate sample (crushed to Department of Transportation and Communications specifications for Type B aggregate) is weighed, put into the drum and rotated 500 times. The aggregate is then removed from the drum and reweighed to determine the weight loss, which is expressed as a per cent. This number can then be compared to acceptable maximum limits for different grades of aggregate. The test is important where the aggregate product is subjected to static and dynamic stresses, impact and wearing action. It is significant in the Province for determining the resistance to wear of aggregate used in highway applications. Appendix 1 provides tables indicating acceptable maximum abrasion loss for different products.

Sodium Sulphate Soundness Test

Nova Scotia's maritime climate produces severe weathering conditions which can have a serious effect on exposed aggregate materials. Depending on where the aggregate is being used, the weathering can result from a variety of conditions, including temperature-related freeze-thaw cycles, combined temperature and road salt freeze-thaw cycles, marine tidal exposure, and wetting and drying due to high precipitation rates. These conditions produce significant volume change in some types of aggregate at or near the surface of products such as asphalt and Portland cement concrete. The resulting stress causes breakage, spalling or disintegration of the aggregate particles. This, in turn, can result in unsightly surfaces, structural weakness or reduction in wear life of the product.

The sodium sulphate soundness test (ASTM Standard C88), conducted by Warnock Hersey Professional Services Limited, is a measure of the effects that severe weathering has on aggregate. It is conducted by obtaining a carefully graded and weighed aggregate sample (Nova Scotia Department of Transportation and Communications Type B aggregate), immersing it in a solution of sodium sulphate and oven drying it. The procedure is repeated on the sample for a total of five cycles. (Note: The oven drying causes dehydration of the salt which is retained in the pores and fractures of the aggregate particle. With subsequent immersions, the salts are rehydrated, causing expansion and simulating the action of freezing water. Like freeze-thaw conditions, the salt expansion causes the breakdown of aggregate particles.) After the final drying, the sample is washed of salts and dried. The weight-loss of each sieve fraction is determined and expressed as a percentage of the initial weight of the test fraction. A weighted percentage loss is then determined by multiplying the percentage weight loss by the weight percentage for that sieve size in the original sample (before test fractions were extracted). The total weighted percentage loss is then calculated. This number can then be compared to maximum limits or standards required for the different aggregate products. Appendix

1, Tables A1-1C and A1-2B indicate acceptable maximum soundness loss for different products.

Petrographic Analysis

The quality of an aggregate sample can be determined by a petrographic analysis of the coarse aggregate particles. There are two primary methods used by the industry for conducting this examination: (1) the American Society for Testing and Materials Standard C295 (American Society for Testing and Materials, 1988), and (2) the Canadian Standards Association (CSA) Test Method A23.2, Appendix B (Canadian Standards Association, 1977). Both methods involve the visual inspection of the aggregate particles using a series of simple tests. The particles can then be grouped according to rock types and characteristics. Numerical values are assigned to the groups, permitting a quantitative comparison of aggregate samples with standards established for specific application or products.

The test used in this study is the Petrographic Number method, the standard test used by the aggregate industry in Nova Scotia when a petrographic analysis is required. It was developed by the Ontario Ministry of Transportation and Communications (OMTC) for asphalt aggregates and is a modified version of CSA Method A23.2, Appendix B (Canadian Standards Association, 1977) for concrete. A description of the test procedures is provided in the OMTC Laboratory Testing Manual.

The procedure, conducted by Warnock Hersey Professional Services Limited, begins with crushing, sizing and drying of a sample to produce Department of Transportation and Communications Type B aggregate. Approximately 1800 g of the sample falling within four size ranges are examined to determine particle rock type and characteristics which would prove deleterious in an aggregate (e.g. coatings and high porosity). This includes index tests such as strength, scratch hardness and acid reactivity. The particles are then grouped into rock types described in CSA Test Method A23.2, Appendix B (Canadian Standards Association, 1977) with each group being weighed and expressed as a percentage of the total weight. The percentage is then multiplied by a factor assigned according to the following qualitative descriptions: good = 1, fair = 3, poor = 6, and deleterious = 10. The Petrographic Number is determined as a sum of the above products for each rock type. An example is provided in Appendix 1, Table A1-3. Theoretically, the Petrographic Number can vary between 100 and 1000 with the lowest numbers indicating the best quality. In Nova Scotia the Petrographic Number is used almost exclusively for evaluating highway materials. Maximum acceptable limits for this test vary and are stated in the highway contracts. One exception to this is the 100 series highways which require that the aggregate in the surface coarse of the asphalt concrete have a Petrographic Number no greater than 135.

Organic Content

Organic impurities in aggregate are considered deleterious substances primarily because they can decrease durability and wear resistance, produce popouts and cause staining. The physical properties responsible for these problems are softness, absorption and colour.

Many of the sand and gravel deposits in the study area contain visible coaly material. This usually occurs as thin layers of particles in the sands, however fragments as large as 2 cm are present in some deposits. This applies primarily to the granular materials found on the northern side of the Cobequid Highlands in the Cumberland Basin. Many of the sedimentary rocks in this Carboniferous basin are coal bearing rocks which were subsequently scoured by glaciation, with the coal being redeposited in melt water streams as thin, wispy layers. Because the coaly materials are so common in the deposits, it was felt that it was important to determine some measure of their concentration.

The samples for organics in this study were extracted from sand and gravel deposits showing the highest concentrations of coaly matter. They were taken several metres below the deposit surface to ensure that recent organics would not contaminate the materials. The samples were submitted to the Technical University of Nova Scotia for Loss on Ignition (LOI) analysis. The samples were dried, weighed, heated to 500°C and then reweighed to determine the percentage weight loss. During the procedure the volatiles (carbon, hydrogen, nitrogen) are driven off. Because the coaly materials appear to be the only organic matter in the samples, the weight loss should be indicative of the coal content. The limits for coal and lignite in aggregate for concrete are 0.5% where surface appearance of the concrete is important and 1.0% for all other concrete (American Society for Testing and Materials, 1988).

AGGREGATE POTENTIAL

The aggregates in northern Nova Scotia can be divided into three major types: granular aggregate, bedrock aggregate and slag (Fig. 3). All of the materials are currently being used. Appendix 2 illustrates the different types of deposits within each group and summarizes the important characteristics of each.

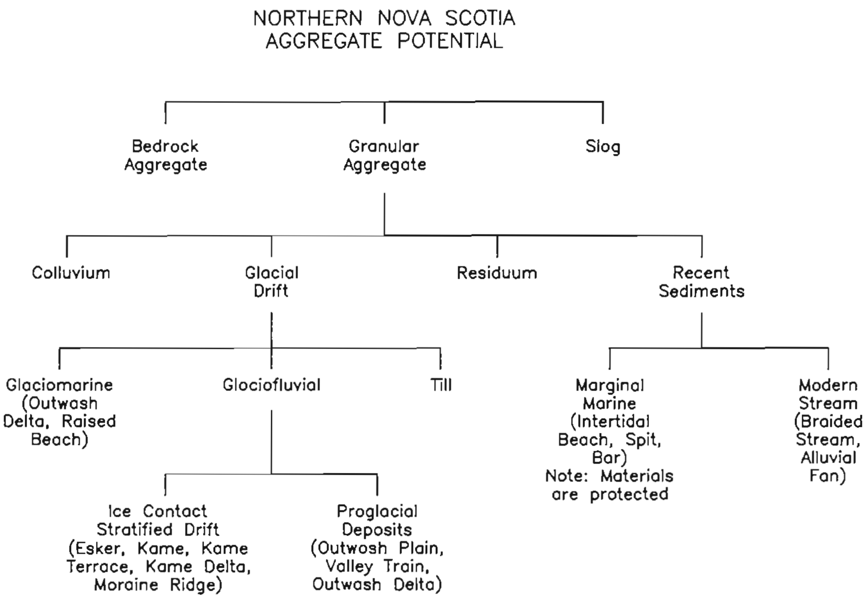

Figure 3. Types of aggregate in Cumberland and Colchester Counties.

Granular Aggregate

Granular aggregate is defined here as any unconsolidated sediment or mechanically or chemically broken near surface bedrock which is used for aggregate purposes. The materials may be sorted or unsorted and range widely in quality. There are four types of granular deposits: (1) glacial drift; (2) recent sediments; (3) colluvium; and (4) residuum.

Glacial Drift

Glacial drift, according to Bloom's (1978) definition, is a general term to describe glacially derived sediments. In this report it includes all materials transported by the Pleistocene glaciers, their river systems, and associated marine environments. Raised beach deposits are also placed in this group although their relationship with the ice mass is indirect. Glacially derived sediments are currently the primary source of aggregate materials in the Province.

Ice Contact Stratified Drift

Ice contact deposits are mounds of sand and gravel produced by sediment laden meltwaters in contact with the ice mass. The deposits are a product of high energy stream flow and are commonly quite coarse in composition. With ice wastage, the deposits are dumped onto the landscape, often resulting in subsequent modification of both sediments and landforms. The five types identified in the study area are eskers, kames, kame terraces, kame deltas and moraine ridges. They are commonly found substantial distances from the aggregate markets, however their wide-spread presence makes them valuable throughout the region as sources of construction materials.

Eskers (Fig. 4) are long sinuous ridges of sand and gravel deposited by meltwaters in the tunnels or crevasses of stationary or retreating glaciers. They may occur as a single continuous ridge or as a series of ridges or hills showing a linear development. Occasionally there are offsets or small ridges paralleling the main one. Eskers in the region vary in length from hundreds of metres to several kilometres, with a maximum thickness of 15 m. Commonly they occur in or near the major stream valleys, paralleling their courses. Their identification on air photos or in the field is virtually unmistakable. The Boars Back, an esker paralleling the western side of the Herbert River, Cumberland County, is one of the best known eskers in the Province.

The eskers in the study area are generally well-stratified, poorly-sorted and consist predominantly of cut-and-fill channel deposits which are discontinuous laterally (Fig. 5). Due to fluctuations in stream energy,

Figure 4. Esker at Greenfield, Colchester County.

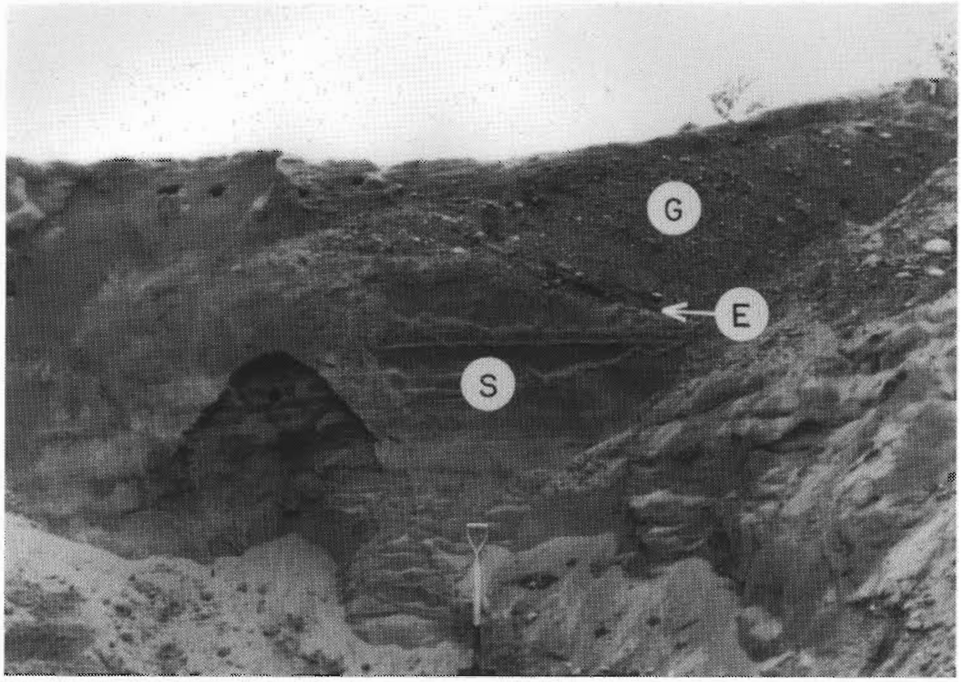

Figure 5. Cut-and-fill channel deposits typical of eskers and kames. Photo shows a sand channel deposit (S) overlain by a gravel deposit (G). Contact between the two is erosional (E).

the channel deposits may vary in composition from entirely sand to cobble-boulder gravel. Large boulders are common. The quality of the materials varies from poor to excellent depending on the source of the materials and the hydrodynamics of the stream flow. Some deposits contain abundant coaly material and silt which strongly limits their potential use as aggregate. One important consideration in the development of these deposits is the lack of consistency of the materials along their length, making an accurate assessment of their quality and composition difficult.

Kames are individual mounds or hummocky terrain composed of sand and gravel which was produced in meltwater channels occurring in depressions in the ice mass. They are commonly found associated with hilly, terminal moraine belts or within major stream valleys. An excellent example of a kame field is observed at Lakelands, Cumberland County (Fig. 6).

Figure 6. Hummocky terrain in a kame complex at Lakelands, Cumberland County.

Kame deposits in northern Nova Scotia consist predominantly of gravels with lesser amounts of sand. They vary from a few metres to several tens of metres in thickness and can cover several tens of square kilometres in area. Within a deposit the thickness is generally variable, from thin veneer in one area to a thick blanket in another area. The materials consist of channel deposits (Fig. 7) which vary from well-stratified to extremely poorly-stratified, from well-sorted to very poorly-sorted and often contain a significant proportion of large boulders (Fig. 8). Glacial till is rarely found in the deposits. The strata may be strongly deformed with folds, faults and severely contorted bedding. Silt, clay and coaly material are abundant in some deposits.

The materials vary in quality from excellent to very poor and often lack consistency within deposits. Kame deposits are the most common granular deposits in the region and are extensively exploited for all types of aggregate use. Some of the best materials for aggregate occur in the Cobequid Highlands such as the large operation owned by Permanent Lafarge at Folly Lake, on the county line between Cumberland and Colchester Counties.

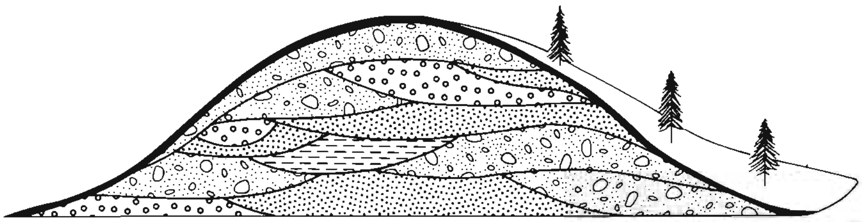

Figure 7. Typical stratification of a kame deposit composed almost entirely of cut-and-fill meltwater channel gravels.

Figure 8. Kame deposit at Springhill, Cumberland County, contains a high proportion of boulder sized clasts. Note that the friable nature of these sandstone clasts makes the deposit poorly suited as an aggregate source. Hammer (arrow) for scale.

Kame terraces are planar-surfaced, glaciofluvial deposits located along valley walls. Consisting predominantly of sand and gravel, the deposits formed in meltwaters occurring between a wasting ice lobe and valley wall. The terrace was produced when the supporting ice was removed. The surface of the deposits may be either horizontal or gently sloping. The hydrodynamic conditions which produced the deposits varied from standing water to high-energy streams paralleling the direction of ice flow.

Kame terrace deposits are present in the study area at Lakelands near Parrsboro, Cumberland County, and Windham Hill, near Rodney, Cumberland County. The deposit at Windham Hill consists predominantly of coarse, poorly-sorted, poorly-stratified gravel containing an abundance of large boulders. The characteristics of the kame terraces observed indicate that stream flow conditions were chaotic.

The aggregate potential of kame terraces is largely dependent on the source of the materials and grain size distribution. These deposits represent a minor component of the aggregate resources in the region.

Kame deltas are mound-shaped deltaic sand and gravel deposits found on the sides of glaciated valleys where they formed in pooled-water between the ice margin and valley walls. The deposits form a minor component of glacial deposits in the study area. They were first identified in the Parrsboro gap area by Wightman (1980). Other kame deltas identified in this study are small deposits near Southampton, Cumberland County, and Earltown, Colchester County.

Kame delta deposits are well-stratified and dominated by foreset and topset gravels typical of coarse deltaic deposits (Figs. 9 and 10). The topset beds consist of horizontal channel sand and gravel produced in shallow meltwater streams. Where the streams encountered pooled water, an abrupt decrease in energy resulted in the development of moderate to steeply dipping planar crossbeds. The topset and foreset beds are typically separated by an irregular erosional surface.

The topset gravels generally form a minor component of the deposits. The foreset units predominate, consisting of beds of well-sorted sand or gravel or both (Fig. 11). The gravel beds commonly consist of open-work gravels (i.e. unfilled voids). The deposits are generally red brown and consist of pebble/cobble grain size. The thickness of the deposits varies from 5-15 m. The overlying till or soil cover is approximately 1 m in thickness.

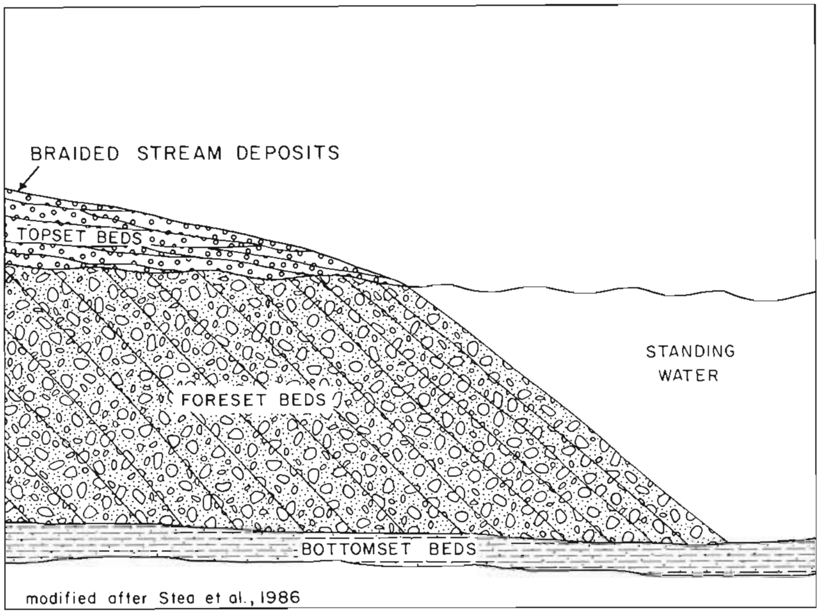

Figure 9. Gilbert type or coarse delta illustrating topset, foreset, and bottomset units. Deposits form where a meltwater river enters a standing water body such as a lake or ocean.

The potential of kame deltas in the study is limited because they are not common. The quality of the materials depends primarily on the source of the detritus. The deposits in the study area consist predominantly of soft, sedimentary rock clasts. The materials are being used as aggregate, however the quality is low and the applications limited.

Moraine ridges are defined here as morphologically distinct moraine landforms having characteristics of both ice and water transport. They consist of mounds which are composed of till and stratified drift. The deposits are included as part of the ice contact deposits in this study because they show the stratification and sorting of glaciofluvial processes and are commonly found in close association with kame deposits. Where glaciofluvial influences are pronounced it is often difficult to distinguish between the moraine mounds and kame deposits, resulting in the term kame moraine being used to describe them (Sugden and John, 1979).

The moraine ridges in the study area which have aggregate potential are primarily end moraines such as observed at Lakelands, Cumberland County, north of Parrsboro, where they occur as part of a kame field complex. Exposure of the moraine sediments in the study area is extremely limited. The deposits (Fig. 12) are generally poorly-sorted, massive to poorly-stratified and commonly contain contorted bedding. Grain-size distribution is poor with the materials containing abundant fines and coarse boulders. The potential of these deposits as an aggregate source primarily depends on the source of the materials. They generally have characteristics similar to the kame deposits.

Proglacial Deposits

Proglacial deposits are flat-lying gravel deposits produced at the front of the glacier where meltwater streams come in contact with lowland areas. There are three types of deposit in this group consisting of outwash plains, valley trains and outwash deltas. The first two are discussed below and the deltaic deposits are described under glaciomarine deposits.

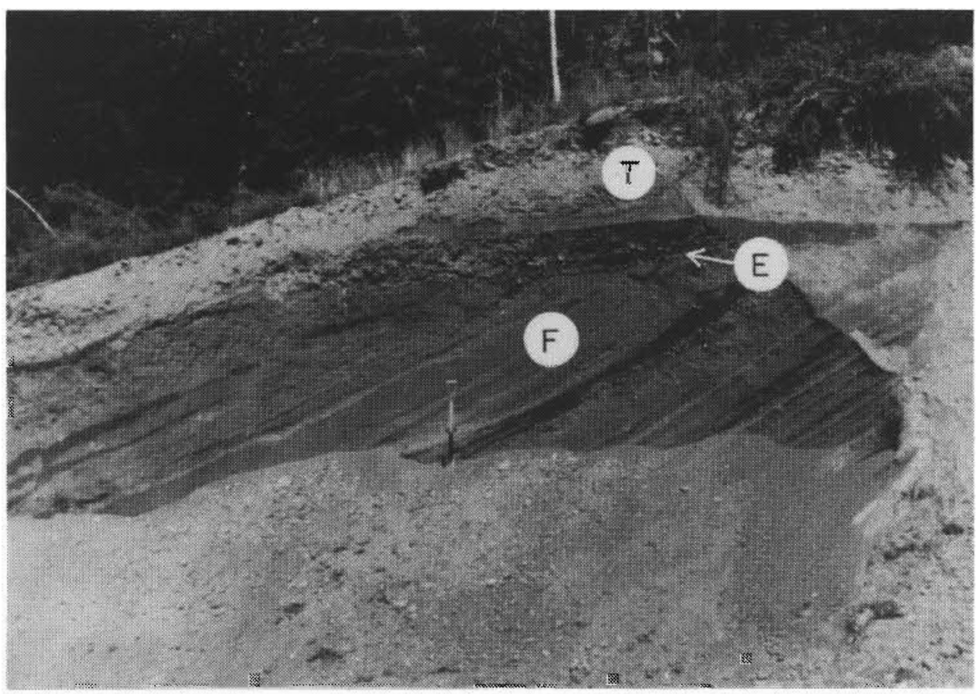

Figure 10. Coarse deltaic deposit (kame delta) near Southampton, Cumberland County. Borrow pit exposure shows topset (T) and foreset (F) beds separated by an erosional contact (E).

Figure 11. Pit exposure of well sorted, well stratified ice contact deposit (kame delta) at Halfway River Station, Cumberland County.

Outwash plain deposits are planar-surfaced gravel deposits (Fig. 13) occurring on lowland plains. They can often be recognized by the abandoned meltwater channels that break up the flatness of the landscape. The deposits developed at the front of the glacier as a series of shallow, migrating, braided river channels separated by bars and small islands (Fig. 14). The sediments are coarsest in proximity to the ice mass, consisting almost entirely of gravel. In more distal locations, sand and silt lenses become increasingly abundant. Most of the deposits along the northern shore of the Minas Basin are thick and terraced, reflecting post Pleistocene incision and erosion by modern rivers.

The deposits are well-stratified and composed of channel and bar gravels with only a minor sand component (Fig. 15). The colour of the materials ranges from grey to light brown. Cut-and-fill structures are produced when channel beds are eroded by subsequent channels which then become filled and the process is repeated. The materials are well-sorted and most often in the pebble/cobble size range. The deposits are usually thick (maximum of 50 m), laterally extensive and quite consistent in character.

The aggregate potential of outwash deposits in the study area varies from fair to excellent, depending largely on the composition of the sediments. Characteristics of the deposits which make aggregate production attractive include: (1) depth to groundwater which is at least several metres; (2) thin soil cover; (3) consistency in deposit thickness and composition; (4) accessibility; (5) grain size distribution which is easily and economically processed with little wastage, (i.e. minor fines and oversized boulders); and (6) locations which are near primary aggregate markets. The

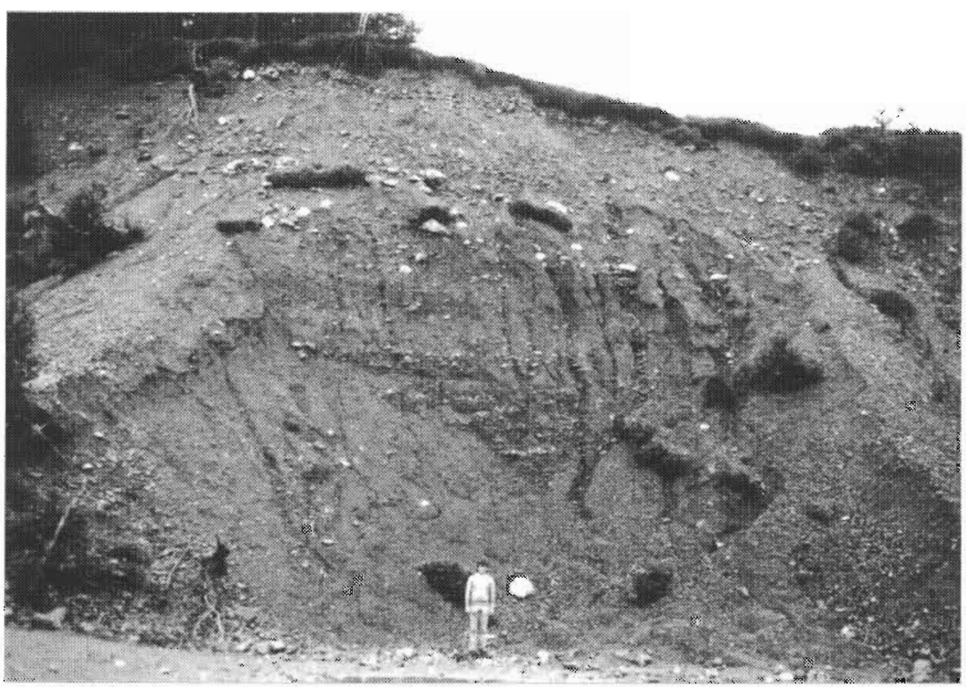

Figure 12. Ice contact deposit at Lakelands, Cumberland County, exhibiting very poor stratification and sorting. Deposit is classified here as a moraine ridge and is closely associated with a nearby kame complex.

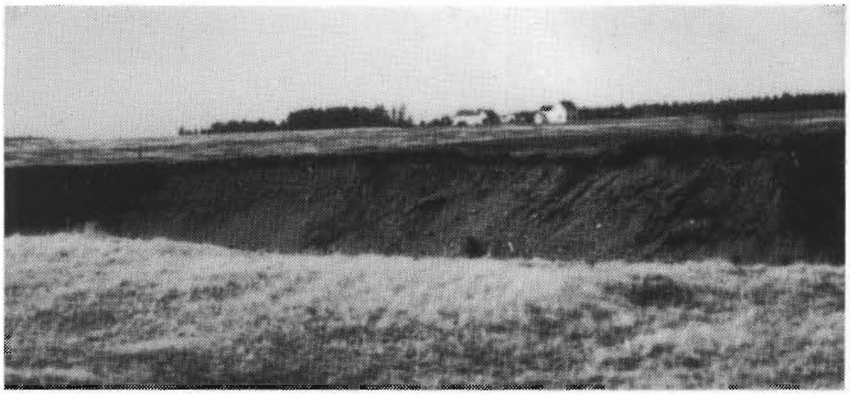

Figure 13. Gravel pit in outwash deposit at Diligent River, Cumberland County. Note planar surface of deposit.

location factor also has drawbacks in that the deposits generally underlie some of the better arable land or populated centres. This results in competition for the resource land, public opposition to aggregate operations and the loss of potential resource land due to sterilization (e.g. residential and commercial development). Glacial outwash deposits are the preferred materials of the aggregate industry, however the resource potential in these areas is rapidly diminishing.

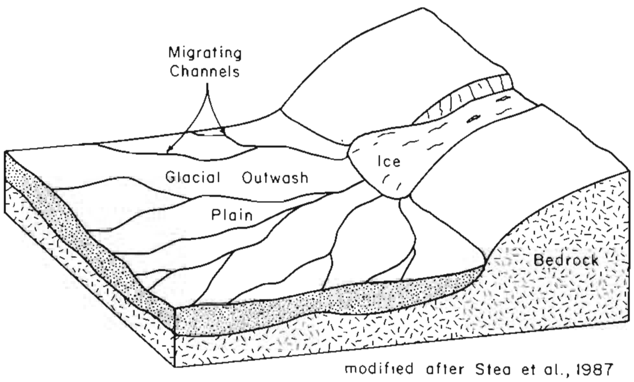

Figure 14. Schematic diagram of glacial outwash plain development.

The best outwash materials for aggregate purposes occur on the northern shore of the Minas Basin between Truro and Portapique, Colchester County. These deposits have a good composition of basement rock lithologies and are of substantial thickness.

Valley train deposits are primarily gravel deposits produced in valley floor meltwater channels at the front of a downwasting glacier. Similar to outwash plain deposits, the deposits are produced in heavily loaded, high-energy, braided streams which exhibited highly variable discharge. Valley train deposits differ from outwash plains in that they are more linear and confined than outwash plains. In the study area they consist of coarse gravels in proximal locations with a decrease in grain size and increase in sand fraction downstream. Due to the high energy of the meltwater system the strata are massive to poorly bedded in proximal locations. Sand lenses are generally present as a minor component. Poorly-sorted boulder beds are common and indicative of chaotic streamflow. In the lower reaches cut-and-fill channel sand and gravel similar to outwash plain deposits predominate. The deposits are commonly several metres deep. A good example of a valley train is the deposit along River Philip between Wyvern and Oxford, Cumberland County.

Figure 15. Pit exposure of outwash channel gravel. Face consists of channel deposits in the shape of lenses.

It should be noted that valley train deposits are often difficult to distinguish from modern stream deposits. There are two reasons for this: (1) both types of deposits have braided stream characteristics; and (2) modern stream deposits occupy all of the valleys; therefore, any proglacial valley deposits which did form will have modern streams cutting through them. Bloom (1978) discussed the problem of distinguishing relict proglacial alluvium from in transit modern stream alluvium. He suggested that if the modern stream does not have competence to move all grain sizes in the deposit, then the deposits are probably glacially derived and acting as a substrate for the modern stream.

As an aggregate source, the deposits in some areas have been exploited extensively. The potential of materials depends largely on the source of the detritus and the proximal-distal location in the meltwater system. Proximal areas commonly contain a large proportion of oversized boulders which cannot be processed in the secondary crushers. This translates into lost production and requires a disposal area or additional equipment to break down the blocks. A shallow water table, which is often present in these stream valleys, limits the extraction potential of these deposits unless there is additional capital outlay for special equipment. As with the outwash plain deposits, these materials occur on some of the more arable land and the future potential will become increasingly limited due to competition for the resource land and residential development.

Glaciomarine Deposits

Glaciomarine deposits consist of sand and gravel which was produced in a marine environment during or immediately following deglaciation. The two types of deposits found in the study area are deltas and raised beaches.

Deltaic deposits were produced where a glaciofluvial system came in contact with standing water such as a subglacial lake or marine basin. The deposits in northern Nova Scotia are, primarily, glaciomarine in origin and occur as an extension of the outwash plains. The deposits are Gilbert delta sequences composed of three zones (Fig. 9): (1) topset beds consisting of land-based, subhorizontal gravels that were deposited in outwash streams as channel and bar deposits; (2) foreset, gravel beds which were formed where the streams encountered standing water, resulting in steeply dipping strata deposited on a slope front; and (3) bottomset, laminated silt and clay which settled out of suspension at the front of the fluvial system in the standing water. The topset and foreset deposits are well-stratified, well-sorted and very thick. The bottomset beds are of no use as aggregate. The majority of the deposits in the area are poor to fair in terms of their petrographic composition, however they are clean.

Raised-beach deposits are sand and gravel deposits occurring above present sea level and containing evidence of marine deposition. They were produced during former elevated stands of sea level during or following deglaciation when beach fronts developed. The linear ridges produced by these seas represents the uppermost beach area, the backshore facies, which was deposited as a storm ridge (Wightman, 1980). Subsequent emergence left the deposits several metres above present day sea level.

The deposits in the study area are located along the northern shore of the Minas Basin west of Spencers Island (Stea et al., 1986) with the most prominent ones at Advocate Harbour, Cumberland County (Fig. 16). They appear to have been produced in part by the reworking of glacial outwash deposits in the near shore or littoral zone followed by subsequent emergence. In general, the deposits are light brown, well-stratified and consist of inclined beds which dip seaward. The materials are well-sorted and contain minimal fines or large

Figure 16. Raised beach deposit (arrows) at Advocate Harbour, Cumberland County.

boulders. They consist predominantly of pebble/cobble gravels and sand. The clasts are commonly tabular, an indication of their soft, sedimentary rock origins. These glaciomarine deposits make fair aggregate materials in the region primarily because of poor petrographic composition. Some of the materials have been used in asphalt mixes, however they usually do not meet the specifications for asphalt or concrete.

Till

Till is defined as unsorted, nonstratified, glacial drift. It is produced when soil and rock debris, transported in and beneath a glacial ice mass, are subsequently deposited without any sorting mechanism. Some of the materials were plastered to the glacier bed as basal or lodgment till, deposits characterized by their high degree of compaction. The remaining materials became incorporated into the ice mass, later being dumped onto the landscape with the downwasting of the glacial ice. These deposits are ablation tills and are less consolidated than the lodgment tills.

In general, the tills in the study area consist of poorly-sorted, massive sediments composed of subangular clasts. The deposits comprise a wide range of grain sizes, including abundant clay and large boulders. Stratified units are rarely found. The thickness of the deposits can be extremely variable, ranging from thin veneers to blankets tens of metres thick.

As an aggregate source, these deposits are used primarily for fill, with small borrow pits in till being found throughout the region. The main problem with the materials is their high percentage of silt and clay. A few of the deposits have a composition similar to poorly sorted gravel, however their thickness and location near better sources of aggregate suggest that it is unlikely that they will be processed as high quality gravel. One pit which was recently opened to process till for highway upgrading is located north of Earltown, Colchester County.

Recent Sediments

Recent sediments are defined here as those sediments which have been deposited in postglacial environments. The aggregate potential of these deposits is the sand and gravel found in marginal marine and modern stream depositional environments.

Marginal Marine Deposits

Marginal marine deposits consist primarily of intertidal to supratidal beach deposits, spits and bars. These materials are generally clean, well-sorted sands and gravels which vary in petrographic composition according to location. The deposits have been used extensively in the past, however they are now protected by the Beaches Preservation and Protection Act of 1975. **Unauthorized extraction of beach materials is prohibited by law.**

Modern Stream Deposits

These deposits consist of sand and gravel produced in postglacial streams on lowland plains or valley floors. The streams are found throughout the study area and comprise three distinct fluvial systems: (1) braided streams; (2) meandering streams; and (3) alluvial fans.

Braided and meandering streams generally occupy valley floors. The upper reaches of the valley or watershed consist of braided streams which are gradually transformed into more sinuous meandering streams in distal areas. The braided streams consist predominantly of gravels and the more distal floodplain areas consist of sands, silts and clays. Only the braided stream deposits are coarse enough to have potential as quality aggregate.

The alluvial fans are also a product of braided stream deposition. Furthermore the materials are coarse enough to offer potential as good aggregate.

Braided stream deposits are well-stratified, well-sorted and consist of channel deposits. The deposits are generally thin (maximum of a few metres) with a shallow groundwater surface. Sand lenses may or may not be present depending on the location in the system. The petrographic composition of the gravel varies according to the source rock. Streams exiting the highlands should have clasts consisting of competent rock types.

There has been local extraction of aggregate materials from braided stream deposits in the past, however future potential is limited. The reasons for this are: (1) environmental regulations; (2) the deposits are generally thin and of low volume; (3) the depth to the water table is shallow; and (4) they underlie some of the more arable land.

Alluvial fan deposits are small fan-shaped wedges of gravel which are commonly found along streams at junctions where they exit the highland areas and contact lowland plains or valley floors (Fig. 17). The deposits in the region were first documented in the Shubenacadie area by Hughes (1957). Subsequent work by Stea et al. (1986) included mapping of some of these fans as modern stream deposits, however no genetic distinction was made between these and other alluvial stream deposits. For a complete discussion of alluvial fans, refer to Bull (1977).

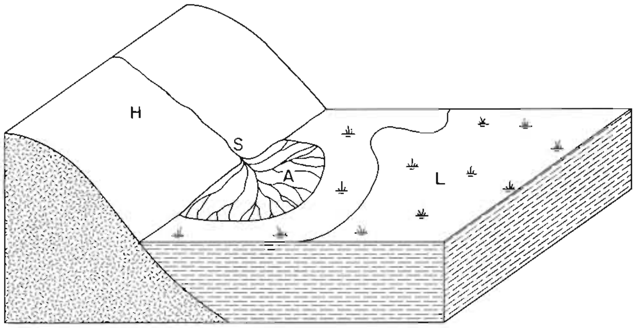

Figure 17. Schematic diagram of modern alluvial fan (A) developing where a mountain stream (S), exiting the highlands (H), empties onto a valley floor or lowland (L). Note that the lowland trunk stream typically bends away from alluvial fan area.

The alluvial fans in the Province were produced where small entrenched streams coursed down the steep inclines of the uplands to suddenly encounter flat-lying areas where stream movement was less confined. At this point a dramatic reduction in stream energy and carrying capacity caused the shallow braided stream to migrate unimpeded across the land surface. The repeated migration of the stream produced a fan-shaped deposit which consists primarily of gravel due to the settling out of the coarser fractions. It is speculated that the fans probably formed early in the postglacial period. Some of the fans may even represent late stage periglacial deposition. Hughes (1957) suggested that they were deposited immediately following glaciation and prior to the establishment of vegetation.

Two of the fans in New Prospect near Parrsboro, Cumberland County, (Fig. 18) were sampled using a backhoe. The excavated trenches were not entered so the deposit description only applies to the top 2-3 m. The sedimentology of the materials below this depth is a matter of speculation and extrapolation based on what the excavator removed at the lower levels and how it compared to the upper material.

The sampling indicates the deposits consist of pebble-cobble gravel which is clean and well-sorted (Fig. 19). Clast shape is subrounded to subangular. Stratification was not observed, suggesting that the deposits are either massive or contain poorly defined bedding. The small fan to the left in Figure 18 has a maximum width of 150 m and estimated thickness of 6 m. The large test fan has a maximum width of 500 m and estimated depth of 10 m. In the larger fan, clay-rich, poorly-sorted, boulder gravel was unearthed in a proximal location.

The clean gravel in the fans is interpreted as being deposited as channel and bar deposits typical of shallow braided streams. The coarse, clay-rich gravel observed in the large test fan is interpreted as a debris flow unit which was transported and deposited as a viscous, mud-rich gravel. The debris flow deposit, which is characteristic of the proximal areas of large alluvial fans observed in the sedimentary basins (Bull, 1977), is probably common in the small fans in the study area.

The aggregate potential of the alluvial fan deposit appears promising. The reasons for this are as follows: (1) the streams have their source in the upland igneous-metamorphic basement complex, thus the deposits generally consist of resistant rock types which produce high quality aggregate; (2) the grain size distribution, sorting and homogeneity of the deposits are characteristics which make the gravel favourable for processing;

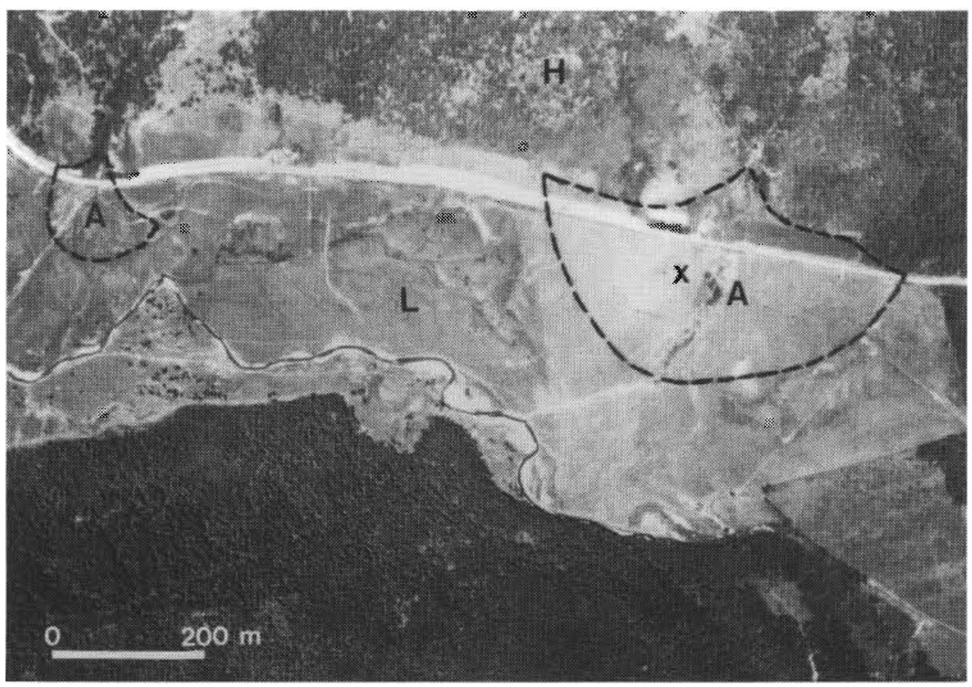

Figure 18. Airphoto of two small alluvial fans (A), at the base of highlands (H), New Prospect (near Parrsboro), Cumberland County. In stereoscopic view the fans appear as subtle mounds superimposed on a planar landscape (L). Location X is the sample site shown in Figure 19.

Figure 19a. Sampling of one of the alluvial fans, New Prospect (near Parrsboro), Cumberland County.

(3) the groundwater appears to occur at considerable depth in these well-drained deposits; and (4) the deposits occur as subtle land forms which could be mined and reclaimed with minimal disruption to the landscape. Potential drawbacks to exploiting the deposits are: (1) they are quite small in size; and (2) streams entrenched on the deposits may result in environmental concerns if the materials were removed.

Exploration for the alluvial fan deposits is simple where vegetative ground cover is minimal, such as agricultural land. Air photos can be used to identify the deposits by closely examining those areas surrounding mountain streams at the point where they intersect the lowlands. Geological maps indicating the rock types in the highlands will allow a rough determination of the quality of the gravels in the deposit prior to field checking.

Where forest cover is thick, the deposits are more difficult to detect on the air photos, so that field investigation appears to be the only method of detection. Potential targets would be those streams with maximum stream gradient cutting through good basement complex, bedrock types and resulting in valley trunk stream/upland stream junctions causing the bending of the trunk stream to the far valley wall (Fig. 17).

Colluvium

Colluvial deposits (Figs. 20a and 20b) are unconsolidated materials produced from the downslope movement of rock debris and soils. The rock debris is a product of weathering and frost-shattering of the underlying bedrock. The soils generally consist of tills and other glacial sediments. The deposits occur on hillsides and valley walls where the angle of the slope exceeds the angle of repose of the sediments. This movement or

Figure 19b. A closer view of the gravel extracted from the deposit at New Prospect (near Parrsboro), Cumberland County.

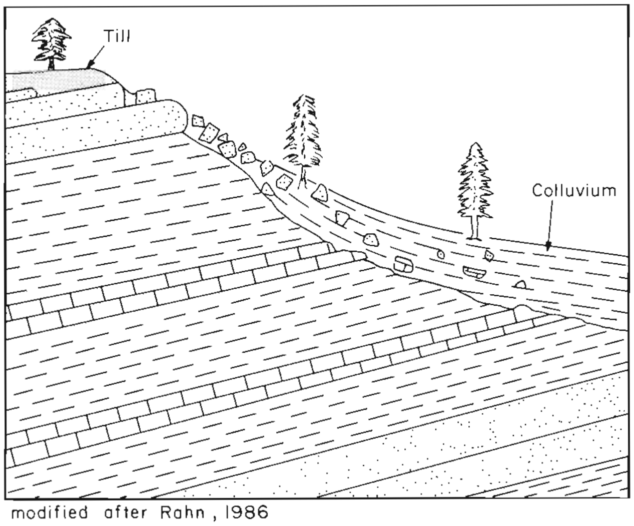

Figure 20a. Diagram illustrating the formation of colluvial deposits.

creep is caused by a combination of gravity and volumetric changes in the soils due to heating and cooling, freezing and thawing, and wetting and drying.

Colluvial deposits in northern Nova Scotia range from till to shattered bedrock to gravelly soil. They are massive and poorly sorted. Sand lenses and stratification are rarely present. The deposits vary in thickness from a thin veneer to up to 10 m.

As an aggregate source, the quality of the materials is poor and probably would only be suitable for fill and haulage road construction. In terms of exploration potential, maps produced by Stea et al. (1986) indicated that they are commonly found in the deeply-incised valleys of the Cobequid Highlands and along the Glooscap Fault scarp. Only those deposits observed in the field are located on the maps of the present study. For a more complete picture of the potential of these deposits, refer to the Quaternary maps of Stea et al. (1986).

By definition colluvium is an unstable material associated with sloped surfaces and gravitational movement. Any modification of these deposits through pit development or other excavation (e.g. access road construction) could make them more unstable and more susceptible to slope failure and landslides (Rahn, 1986). This is a safety concern and would have negative environmental consequences.

Residuum

Residuum (Figs. 21a and 21b) is a surficial deposit of rock materials produced from the in situ alteration and fragmentation of bedrock. This process occurs as the result of chemical and physical weathering which takes place primarily by water and frost action. Stea et al. (1986) suggested that lithology and cleavage development are important factors in the production of the deposits in northern Nova Scotia. They proposed that the timing of the fragmentation may be different for different rock types, however they generally ascribed a preglacial age to the production of the materials.

The two primary sources of residuum in the igneous-metamorphic belt of the Cobequid Highlands are slate and granite. The slate residuum (in the study area) is generally confined to the southern side of the Highlands near the Cobequid-Chedabucto Fault. The slate can be fragmented to a significant depth. The granite residuum is more widespread in the study area with deposits occurring all along the Cobequid Highlands. The maximum depth of the deposits is 6 m.

Figure 20b. Thick deposit of colluvium near Fraserville, Cumberland County, along the northern shore of the Minas Basin.

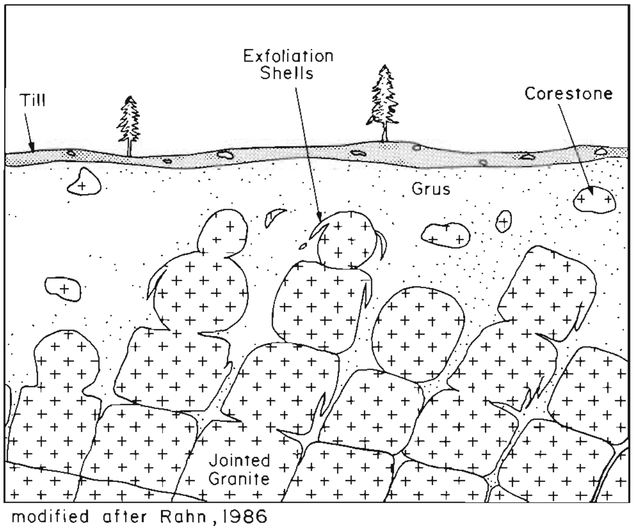

Figure 21a. Diagram illustrating the formation of granite residuum.

The granites appear to be more susceptible to disaggregation due to their mineralogy, specifically the reaction of mica and feldspar with water. Groundwater infusion into the bedrock fracture system probably caused the expansion of the micas and breakdown of the feldspars. Initially this produced exfoliation shells around the jointed rock, followed by the later formation of corestone and grus, a sand-like granular material (Rahn, 1986). The weathering is usually deeper in humid climates with grus up to 100 m in depth (Rahn, 1986). In this study the aggregate pits in grus are a maximum of 5-6 m deep, however the weathering may locally go much deeper.

The igneous-metamorphic residuum has limited use. The quality depends largely on the rock type, however their use as an aggregate would be primarily as fill and for local road construction purposes. The rotted nature of the materials generally reduces their durability, making them unsuitable for applications where high quality is required.

In addition to the igneous and metamorphic rocks identified as residuum by Stea et al. (1986), this study includes the weathered conglomerates (Fig. 22) which are found in much of the region. The conglomerates which are Devonian, Carboniferous and Triassic in age, occur as disaggregated materials near the surface and closely resemble true gravel deposits. Although the timing of the weathering is unknown, the apparent location of most of the deposits at or near the ground surface (i.e. where till cover is thin) may suggest that they have formed primarily post-glacially. Areas with a thicker till blanket may have protected the bedrock from deep weathering.

The fragmentation of the conglomerates appears to be produced primarily by groundwater migration. As the water percolates through the permeable conglomerates found near the surface, the rocks become susceptible to the dissolution of the matrix cements and frost action. This causes the break down of the bedrock matrix to produce a gravel-like material composed of the original conglomerate clasts, fragments of clasts and fragments of matrix. The materials are unconsolidated at the surface where the weathering has been more intense. With depth, the materials become progressively more cohesive to the point where the bedrock remains intact, usually at a maximum depth of 2-5 m. Till depth over the deposits is quite thin, in the range of 0-2 m thick.

These deposits are currently being exploited on a small scale as aggregate for fill, haulage road construction, highway subbase and road shoulder materials. Depending on their lithological composition, the

Figure 21b. Granite residuum deposit used for aggregate purposes (East Mapleton, Cumberland County).

Figure 22. Conglomerate residuum at Eatonville, Cumberland County. Materials are very similar to gravel near the surface. This pit was used to produce Class C gravel for highway upgrading.

conglomerates may offer potential as good aggregate in some areas where conventional sources are scarce. Drawbacks in using these materials include their thickness and large amounts of clay/silt matrix. Furthermore, regardless of their petrographic composition, it is unlikely that they could be used in the manufacture of Portland cement concrete because of the hematite coating of the clasts. This could compromise the bonding strength between paste and aggregate in the concrete as well as producing a detractive iron staining.

Only a small number of the weathered bedrock exposures observed in this study are located on the 1:50 000 aggregate maps of Cumberland and Colchester Counties (Prime, 1991). Potentially, most of the areas underlain by conglomerate bedrock contain varying thicknesses of weathered conglomerate materials. Stea et al. (1986) identified many areas which contain igneous and metamorphic residuum. The potential of the deposits is limited primarily by their limited thickness and petrographic composition, however in combination with the quarriable bedrock underlying the unconsolidated materials some of the deposits could be of economic significance. The importance of these deposits should not be underestimated in view of the fact that weathered conglomerates form an important component of Prince Edward Island's aggregate resource (Prince Edward Island Department of Energy and Forestry, 1989).

Bedrock Aggregate

Introduction

Bedrock aggregate is defined as aggregate produced from solid rock by means of quarrying. It consists primarily of materials which have been blasted and processed to produce crushed stone; however rocks which can be ripped with an excavator or bulldozer are also included. Crushed stone produced from bedrock is the primary alternative to gravel.

The major crushed stone quarry in the study area, at Folly Lake (Fig. 23), is active on demand. Owned by Permanent Lafarge, Division of Lafarge Canada Inc., the quarry rock is processed through its permanent gravel processing facilities. Other small quarries throughout the study area have been operated sporadically in the past for specific projects such as the production of armour stone for breakwater construction, dyke repair, erosion control and road metal in the construction of a highway. Most recently two quarries have been opened in the northwestern portion of the Cobequid Highlands to provide materials for all aspects of the twinning of Highway 104.

Although bedrock aggregate is not widely used in the region it does play a key role in the aggregate industry of the Province. Furthermore it is expected that demand for bedrock aggregate in northern Nova Scotia will increase substantially in the future because of (1) the lack of good granular aggregate in key areas of the region, and (2) the depletion of high quality granular reserves through use or deposit sterilization. As the population base and economic development for Cumberland and Colchester Counties increase so will the pressures on the remaining usable granular deposits. Aggregate quarries generally provide a more consistent product of a quality which meets the rigid specifications that are demanded today by industry. If a quarry operation is well designed it can provide a stable, long term supply of materials resulting in minimal disruption to the countryside.

An indepth examination of the bedrock potential in the region was not attempted due to time constraints.

Figure 23. The aggregate quarry at Folly Lake, Colchester County, is owned by Permanent Lafarge, Division of Lafarge Canada Inc. The operation is active on demand.

However, the geology was examined in enough detail to allow general discussion of the potential in the region and where it lies. Followup studies of the rocks in specific areas are planned for future programs. The following is an overview of the bedrock aggregate potential in the region.

Types of Bedrock Aggregate

The bedrock potential in the study area can be divided into two broad categories: (1) igneous and metamorphic rocks, and (2) unmetamorphosed sedimentary rocks. Figure 24 is a geology map showing a general classification of the rock types found in the study area.

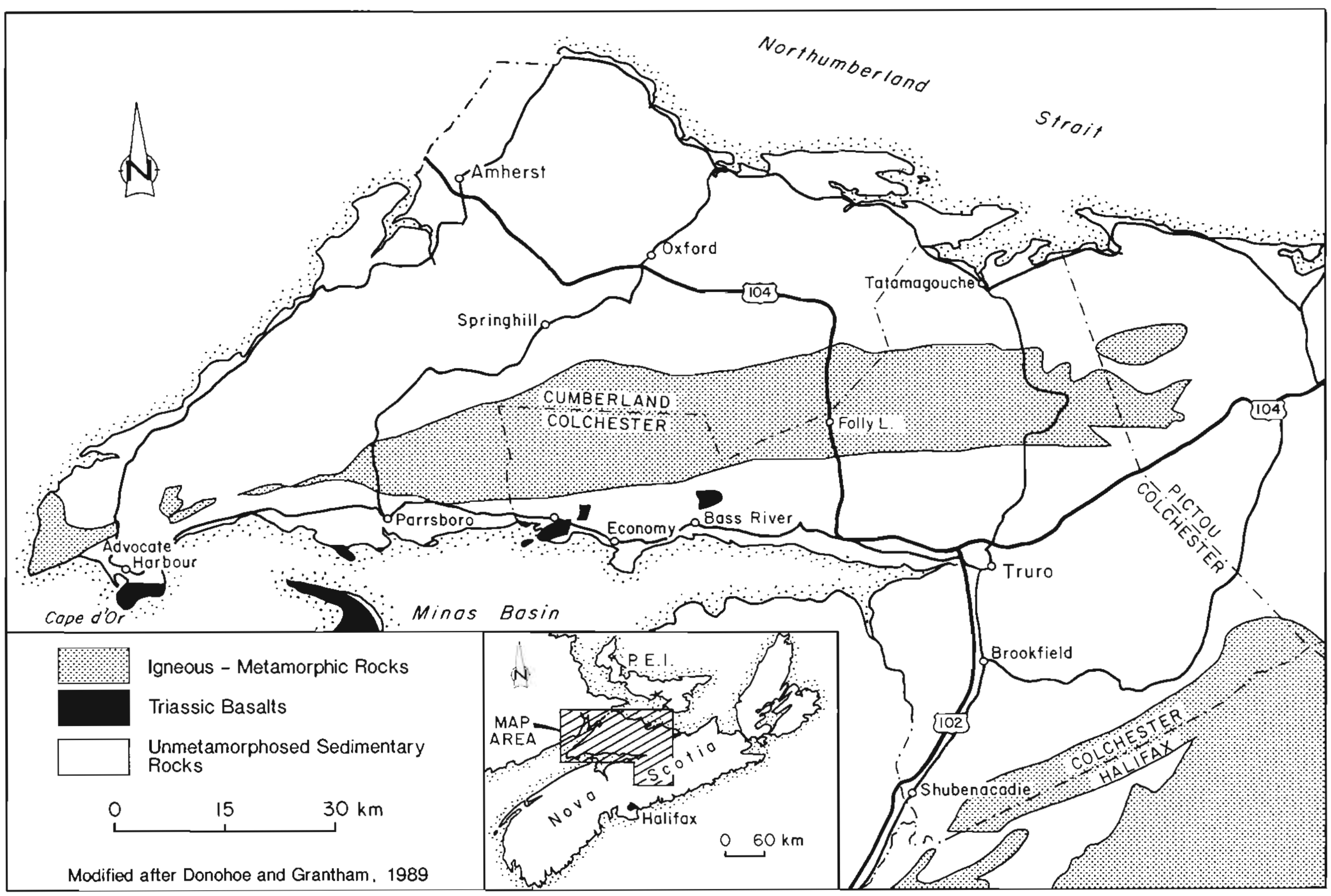

Figure 24. Geology map showing general bedrock geology of project area.

Igneous and Metamorphic Rocks

The igneous and metamorphic rocks are comprised of Hadrynian to Devonian rocks, Carboniferous granites and Triassic volcanics. Together, this complex corresponds to the Cobequid Highlands and the outliers of Triassic basalt shown on Figure 24. The very characteristics which produce these uplands (i.e. their resistance to erosion) also make the rocks suitable for high quality durable aggregate.

The Cobequid Highlands consist primarily of granitoids, volcanics, quartzites, slates and schists. Many of these rock types offer good potential as aggregate for two reasons: (1) the physical properties of the rocks, and (2) their location in an east-west line through the middle of the study area which makes the materials accessible to most of the region. The granitoids, volcanics and quartzites are very competent, having excellent potential as aggregate in the production of asphalt and concrete. The friable, less competent slates and schists generally can be excavated without blasting, producing low quality materials suitable for fill and haulage road construction. As previously noted, some of the Cobequid Highlands rocks contain an upper layer of residuum which may be as thick as 6 m (Stea et al., 1986). This material would probably have to be treated as overburden and removed in order to quarry the high quality rock. The surficial maps of Stea and Finck (1988) and Stea et al. (1986) indicated the areas in the Highlands where residuum should be encountered.

In addition to the physical properties of the rock, the Highlands make a good choice for quarrying for other reasons. Firstly, there is little opportunity for land use conflict because of sparse population, poor soil and predominant forest cover which make the uplands primarily suitable for wood harvesting, blueberry farming and recreation. Secondly, the surficial cover in the Highlands is minimal due to glacial scouring. This is an important factor when considering the expense of overburden removal at a quarry site.

Three areas in the Cobequid Highlands have been earmarked as being significant for their aggregate potential:

(1) The northern side of the Highlands between Halfway River and Collingwood Corner, Cumberland County, (Fig. 25) contains several igneous rock bodies which should make good aggregate. Included in this group are the Hanna Farm, Gibert Mountain and Wyvern Plutons (Donohoe and Wallace, 1982). The area represents the most proximal location of the Cobequid Highlands basement rock to the Amherst market and is considerably closer than present aggregate suppliers. Considering the high cost that transportation represents in the price of aggregate, this area could prove strategic in the future.

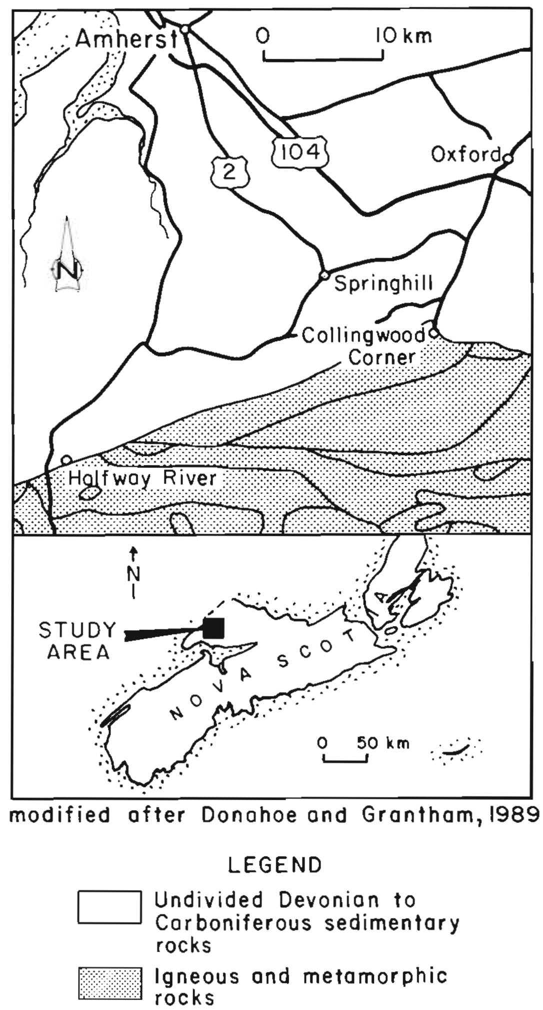

Figure 25. Map showing basement geology south of Amherst, Cumberland County.

(2) On the southern side of the Highlands between East Folly Mountain and Kemptown, Colchester County, (Fig. 26) is an area of interest to the Truro market. It contains several rock types, including the McCallum Settlement Pluton and the Salmon River Pluton, which may offer good potential as high quality aggregate. This is the closest area to Truro where the Cobequid Highlands basement rocks outcrop.

(3) In the extreme west of Cumberland County is Cape Chignecto (Fig. 27), an area of interest because of its tidewater aggregate potential. The shoreline area surrounding Cape Chignecto contains a variety of igneous rock types which may be suitable as high quality aggregate for the export market.

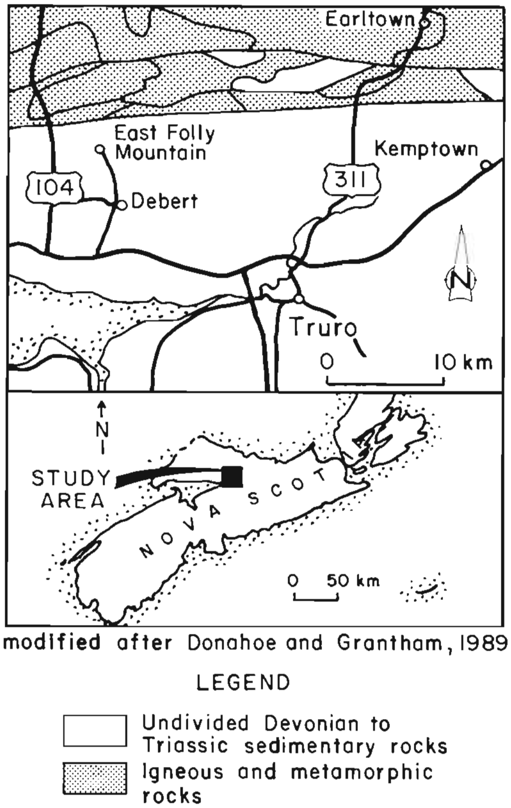

Figure 26. Map showing basement geology north of Truro, Colchester County.

The outliers of the Cobequid Highlands are the Triassic basalts shown on Figure 24. Known in the industry as trap rock, basalt is a green-black rock of volcanic origin. It is a very competent rock type which could produce high quality aggregate in areas along the northern side of the Minas Basin. The potential of this rock type is currently limited by the presence of gravel deposits which are less costly to extract and process. Furthermore, the limited demand in the area for high quality materials would not justify the expense of a quarry operation at this time.

Unmetamorphosed Sedimentary Rock

Unmetamorphosed sedimentary bedrock in the region is Devono-Carboniferous to Triassic in age and comprised of sandstone, shale, conglomerate and carbonate. The rocks are characterized by low levels of deformation and alteration, high porosity and permeability (sandstone and conglomerate), and are generally much softer than the igneous rocks. Thus, the materials have poor durability and low resistance to a variety of stresses.

Sandstone is a sedimentary rock produced from the lithification of ancient sand deposits. It is an abundant rock type in the region which generally produces a soft aggregate. It is used primarily as fill, for road metal and as armour stone for breakwaters and dikes. Most recently it has been used for Class E gravel in the twinning of Highway 104. The quarries are small, often being opened and operated for a specific project and subsequently abandoned. The potential of sandstone as an aggregate source is limited, due to problems with porosity, permeability and durability.

Shale is a sedimentary rock produced from the lithification of ancient mud deposits. It is a friable rock which is easily excavated, breaking apart along bedding planes to produce platy fragments. Although the rock is common in the region, use of the materials is restricted to a few borrow pits (technically called quarries). Shales have been used to build and surface low traffic haulage roads, the reasons being availability, ease of extraction, and the platy characteristics of the rock. The potential of shale as an aggregate is extremely limited.

Conglomerate is a sedimentary rock produced from the lithification of ancient gravel deposits. It is found throughout the region, ranging in age from Middle Devonian to Triassic (Fig. 28).

The Triassic conglomerates, which occur on the southern side of the Cobequids, are currently being

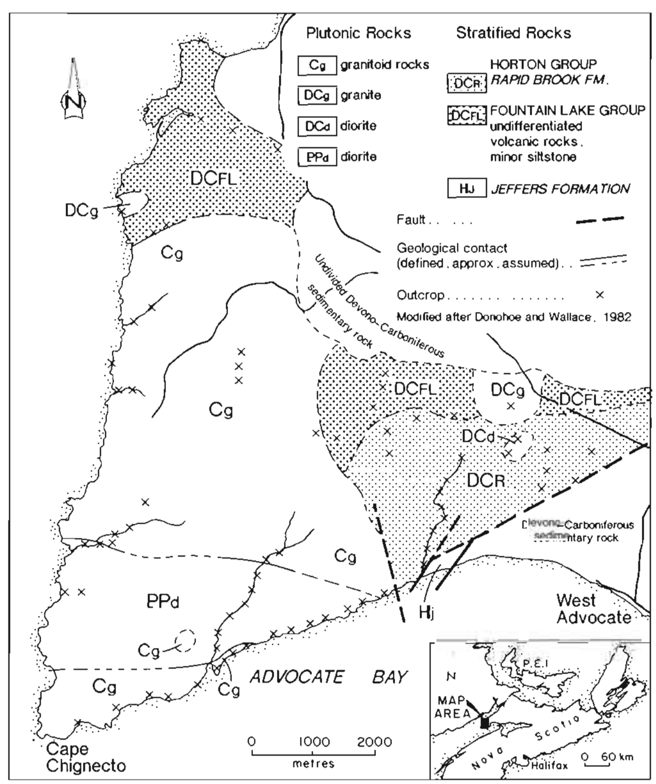

Figure 27. Geology map of Cape Chignecto area, Cumberland County.

Figure 28. Steeply inclined conglomerate strata of the Wolfville Formation near Spencers Island, Cumberland County. Exposure demonstrates the thickness of some of the conglomerate units in the study area. Note hammer (arrow) for scale.

exploited on a small scale for borrow materials where they have been weathered at the surface. In some locations, the composition of the conglomerates is primarily igneous-metamorphic clast types which could be processed to produce high quality materials. Because the area has an abundance of gravel and igneous-metamorphic bedrock potential, it is unlikely that the Triassic conglomerate bedrock will be used other than on a small, local scale.

The Upper Carboniferous conglomerates are more ubiquitous in the region; however the main area of interest and potential is north of the Cobequids in the Cumberland Basin (Fig. 29). The three formations containing polymictic conglomerate in the Cumberland Group which are of significance are the Claremont, Polly Brook, and Ragged Reef Formations. The petrographic composition of some of these conglomerates is predominantly igneous and metamorphic clast types (Fig. 30). Furthermore some of the conglomerate units are clean and clast-supported, which should make them suitable for processing as highway materials.

One problem associated with the use of the conglomerates is the presence of interbedded sandstone and shale, lithologies which are characterized by low durability and produce an inferior product. If these rock types are retained during the processing of the conglomerate, the overall quality of the product would be substantially reduced. Depending on the proportion of the inferior rocks in the conglomerate deposit their removal prior to or during processing could be prohibitively expensive and produce large volumes of waste rock. Interbedding of the conglomerates with shale and sandstone occurs in most parts of the region, so good potential conglomerates are rare. The conglomerate units are commonly 2-3 m thick, below which point waste material is encountered. Quarry development in thin conglomerate units would require excavation over a large area to obtain small volumes of aggregate, making these locations uneconomic and environmentally less acceptable.

The areas of conglomerate with the best potential are limited to those: (1) lacking traditional aggregate sources, (2) having conglomerates with clast-supported igneous-metamorphic rock types, (3) with minimal surficial cover or overburden, and (4) with deposits of economic size. Further work will be done on these deposits in the future.

Carbonates are chemically precipitated sedimentary rocks which consist of calcium or calcium-magnesium carbonate. They are found in the region as limestone and dolomite in the Carboniferous Windsor Group. There are minor amounts of marble or metamorphosed carbonates in the Cobequid Highlands. The rocks are generally quite soft and split along bedding planes; however some of the rocks can locally be competent or massive or both. They are currently being quarried for aggregate at one location, Green Oaks, Colchester County, primarily for road metal. Carbonate potential is limited due to a low abundance of the materials in the region and problems with durability.

One area with aggregate potential is Lime-kiln Brook, Cumberland County, near Amherst, where there is a small abandoned quarry in carbonates (Fig. 31). This rock, initially quarried for aglime, is of interest because: (1) it is more competent than the other Carboniferous rocks in the surrounding area, (2) it is found near Amherst, a large aggregate market where good aggregate must currently be transported long distances, (3) the rock unit is thick, and (4) the unit appears traceable beyond the quarry area. One drawback at the site of the quarry is its proximity to a large stream. However, there may be locations at a more appropriate distance from the stream where the unit

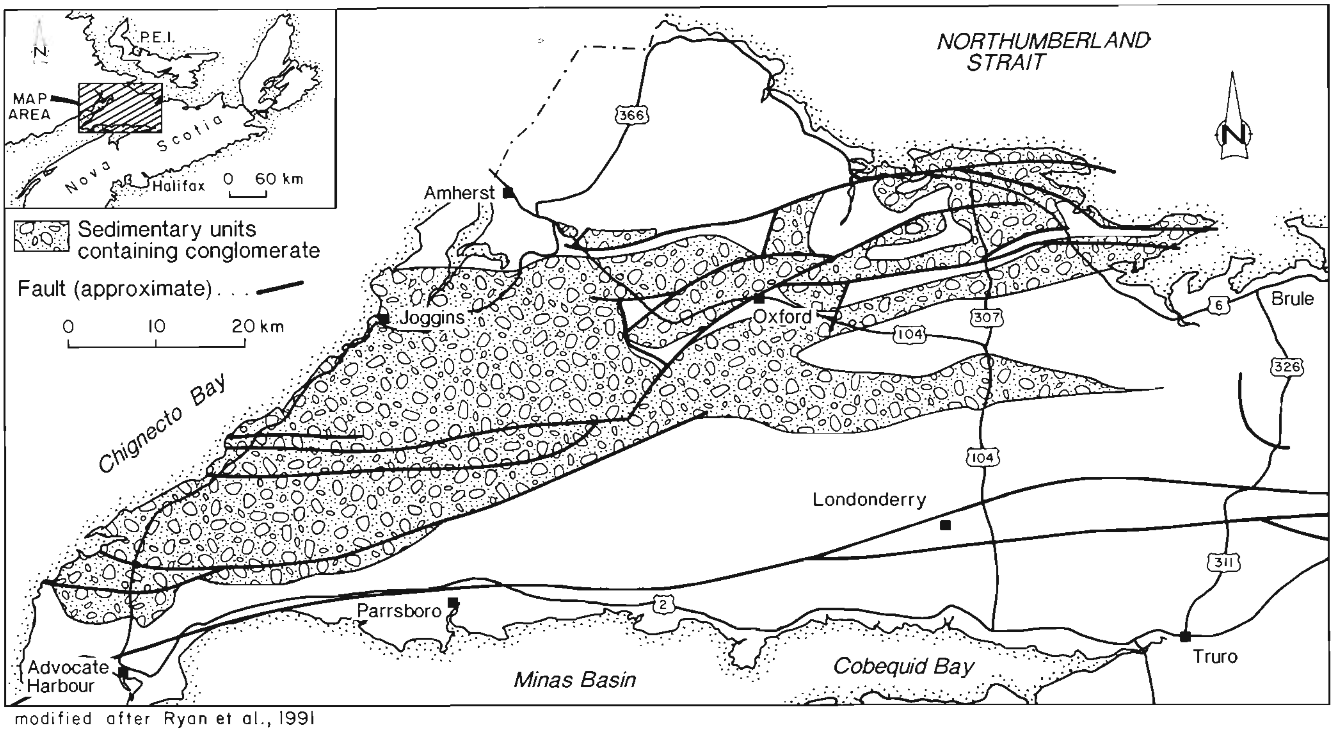

Figure 29. Conglomeratic units with aggregate potential in the Cumberland Basin, northern Nova Scotia.

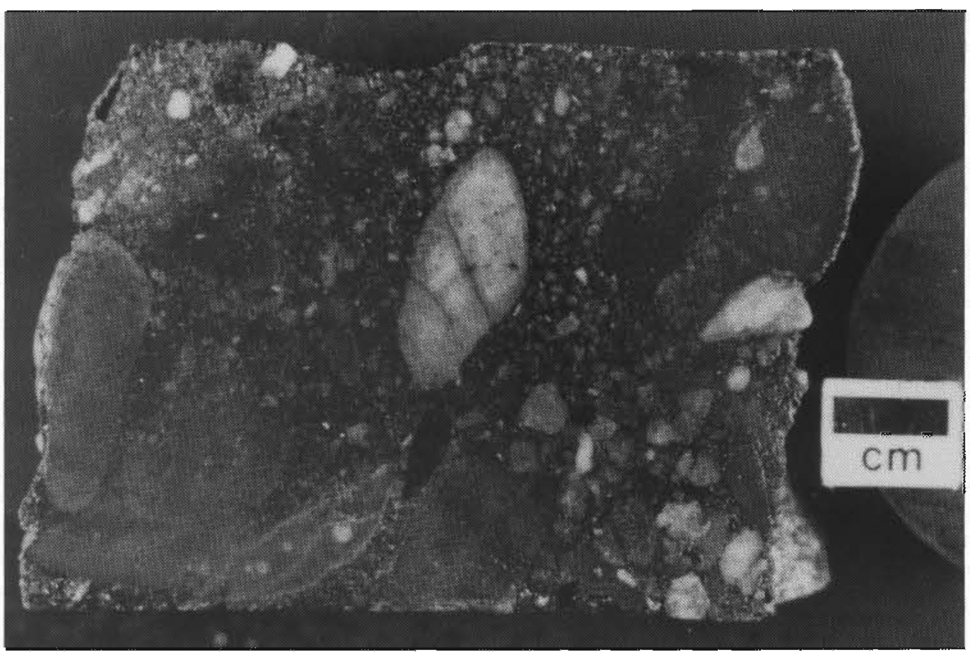

Figure 30. Sample of drill core of Ragged Reef Formation conglomerate near Oxford, Cumberland County, (diamond-drill hole BP-5) (Ryan et al., 1990b). Polymictic conglomerate consists of durable bedrock clasts and may be suitable as aggregate where there are minable thicknesses.

could be quarried. Further work is required to properly evaluate this area.

Slag

Blast furnace slag is defined by the American Society for Testing and Materials (1988) as a "nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace."

Air cooled slag is produced when the molten slag is allowed to solidify in a pit under prevailing atmospheric conditions (Lewis, 1982). With cooling, dissolved gases entrapped in the slag cause bubbles to form, producing a cellular or vesicular structure in the slag.

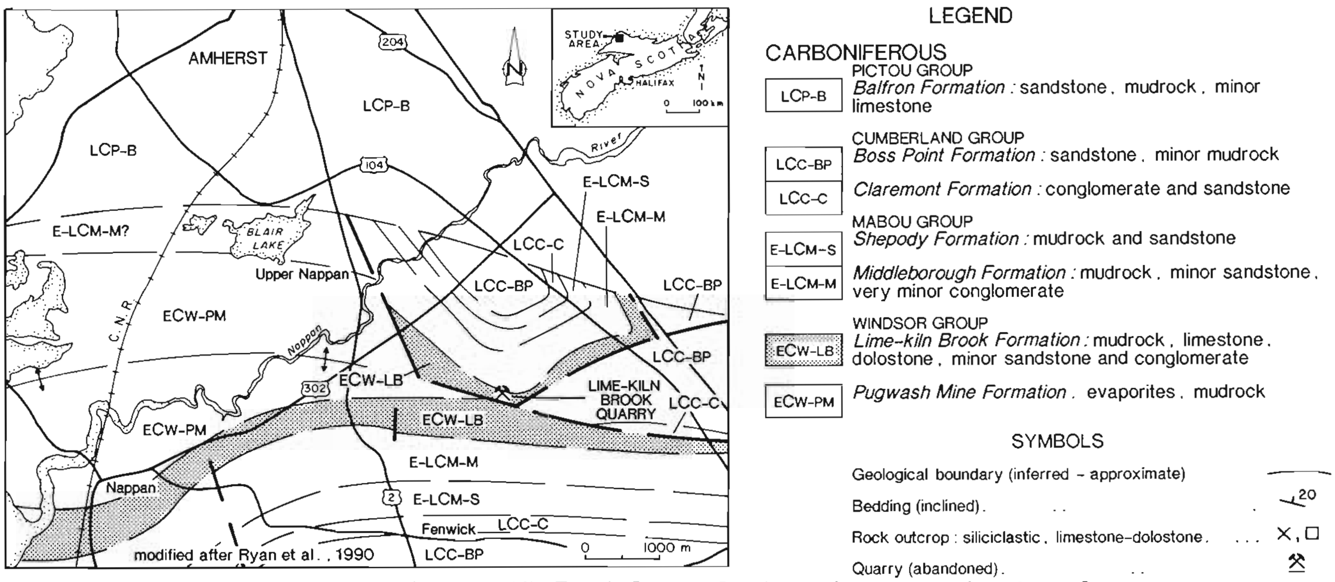

Figure 31. Map showing Lime-kiln Brook Quarry, Cumberland County, and geology of area.

Slag is present in an air cooled state at Londonderry, Colchester County, (Fig. 32) where iron and steel were produced from the mid-1800s to the early 1900s. Approximately 2 Mt of iron ore were processed over the life of the mine (Wright, 1975). A rough estimate of the volume of materials in the slag pile was calculated by Fowler (personal communication) to be 300 000 t.

The slag at Londonderry (Fig. 33) is predominantly pale grey, crystalline, vesicular and contains abundant iron. Determination of the composition of the slag by visual examination is difficult due to the heterogeneity of the deposit. For example iron is in abundance in some areas and rare in others. This heterogeneity is probably due, in part, to the conversion from the earlier iron works to later steel production.

A bulk sample of the Londonderry slag was crushed and tested for size gradation, abrasion loss, magnesium sulphate soundness loss, density, absorption, and whole rock analysis (Table 1).

The potential of the Londonderry slag as a mineral aggregate is probably quite limited, in spite of the fact that air cooled slag is being used at present as a source for most types of aggregates (Lewis, 1982). The analysis (Table 1) indicates that the materials are marginally suitable for most classes of highway gravel. The slag's characteristics of being coarsely vesicular and containing pockets of iron would adversely affect its durability and appearance in products such as Portland cement concrete, where the highest quality aggregates are required. Furthermore, the porosity of the slag would make it unsuitable for the production of asphalt due to the expense of the additional liquid asphalt which would be required in the mix.

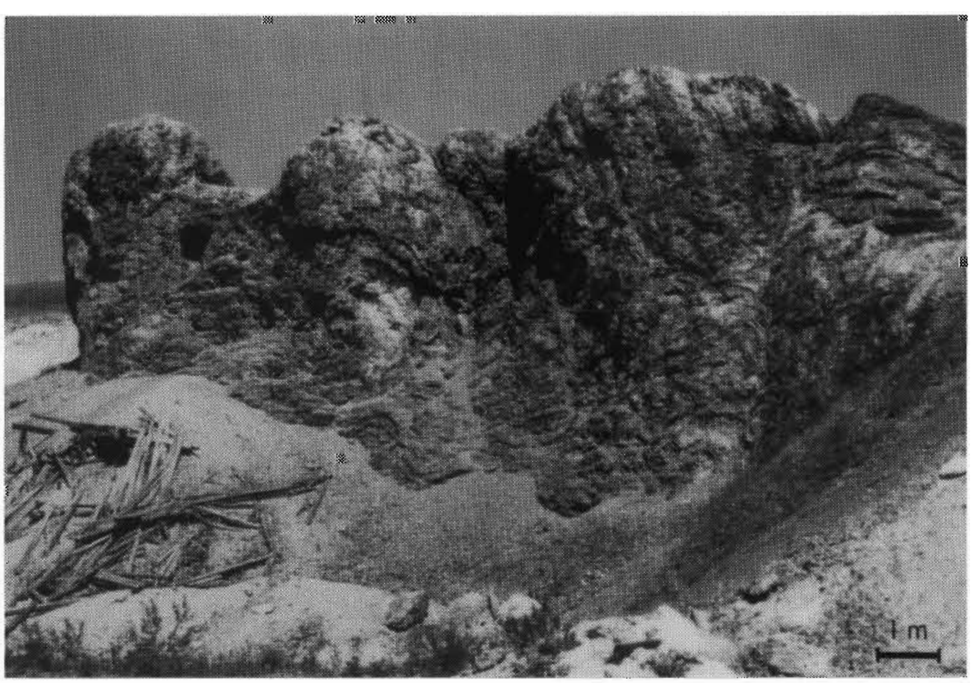

Figure 32. Air cooled, ferrous slag dump at Londonderry, Colchester County.

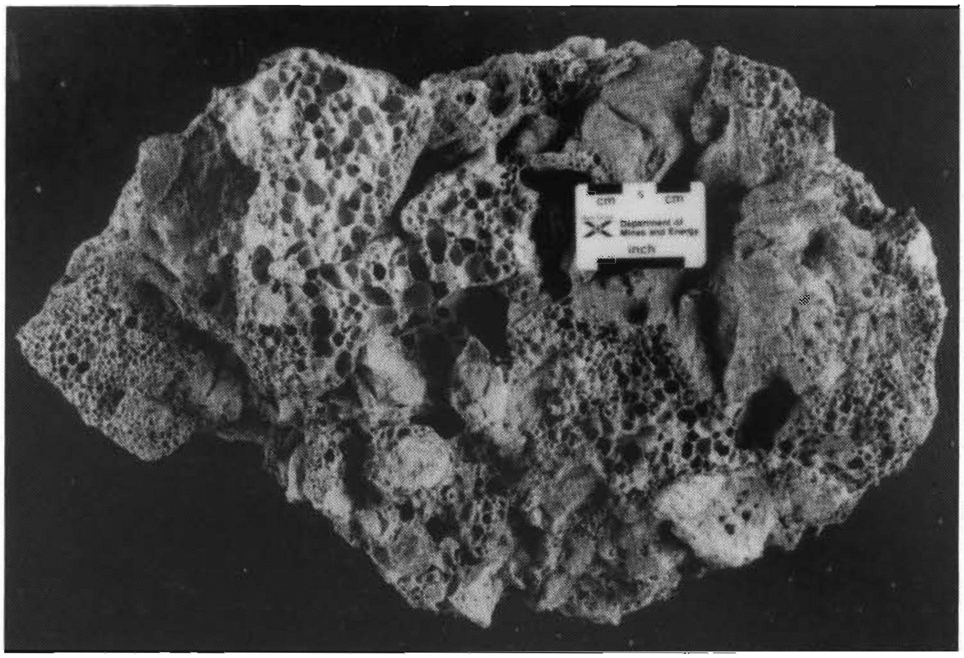

Figure 33. Sample of slag taken from Londonderry, Colchester County. Note honeycomb texture of the material.

Table 1. Bulk sample analysis for the Londonderry slag, Colchester County.*

Sample AGG-1

Los Angeles Abrasion Loss (%):	35.5
Magnesium Sulphate Soundness Loss (%):	17.8
Relative Mass Density (Oven Dried):	1.78
Absorption (% of Oven Dried Mass Density):	14.76

Whole Rock Analysis	**%**
CaO	37.44
MgO	9.94
SiO_2	31.28
Al_2O_3	7.16
Na_2O	0.12
K_2O	0.12
Fe_2O_3	0.17
MnO	0.60
TiO_2	0.23
LOI (1000°C)	10.74

Screen Analysis

Sieve No.	**%**
+2"	0.0
-2" + 1 1/2"	0.7
-1 1/2" + 1"	11.5
-1" + 3/4"	19.5
-3/4" + 1/2"	27.1
-1/2" + 1/4"	18.5
-1/4" + 4	10.7
-4 + 8	4.8
-8 + 16	3.0
-16 + 30	1.7
-30 + 50	1.1
-50 + 100	0.7
-100 + 200	0.4
-200	0.3

* Minerals Engineering Centre, Technical University of Nova Scotia, Halifax.

The Londonderry slag is, at present, infrequently being used locally to surface driveways and for fill applications, however the availability of larger, high quality aggregate deposits in the area limits its potential. On the positive side, there are properties in air cooled slag which should be considered favourable for its development. A good discussion of these characteristics is provided by Emery (1982). The properties include good drainage capability, frost resistance, absence of settling after compaction, ability to stabilize wet, soft soils, cubicity and low density. Thus slag should prove excellent in the construction of driveways, parking lots and as high quality fill. Finally it should be noted that concerns over resource conservation and environment make utilization of this accessible, nonreactive waste product a desirable goal.

PIT AND QUARRY REGULATIONS

Sand, gravel and crushed stone are not Crown Minerals under the current Mineral Resources Act. In order to establish or reactivate a sand and gravel pit or crushed rock quarry, two conditions must be satisfied: (1) the owner/operator of the potential production facility must hold the surface rights of the property or enter into an agreement with the landowner to develop the deposit, and (2) the owner/operator must obtain permission to establish an aggregate operation from the Nova Scotia Department of the Environment. Once the facility is in operation, health and safety practices are regulated by the Nova Scotia Department of Labour and environmental concerns, by the Nova Scotia Department of the Environment. In the case of developing a pit or quarry on Crown Land, permission must be obtained from the Nova Scotia Department of Natural Resources, Operations Branch. Permitting for pits and quarries used solely for highways applications is administered by the Nova Scotia Department of Transportation and Communications on behalf of the Nova Scotia Department of the Environment.