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STONE RESOURCES
OF THE
NIAGARA ESCARPMENT

By

M.A. VOS

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STONE RESOURCES OF THE NIAGARA ESCARPMENT

By

M.A. Vos[1]

INTRODUCTION

A survey of stone resources along the Niagara Escarpment was made with a view to outlining potential areas of quarry development. The survey was undertaken on request of the Quarry Operators Section of the Ontario Mining Association.

There is a rising and justifiable concern amongst quarry operators for the future of quarrying in areas of urban development. Such areas, inversely, rely heavily on the products of quarrying for sustenance of expanding building construction. The trend in municipal legislation is towards confinement of existing pit and quarry operations and prohibition of new ones.

The area included in this study stretches along the Niagara Escarpment from Niagara Falls to Manitoulin Island. It covers ground between the Escarpment and the Welland River, Grand River and Highway 10 to Owen Sound. Also included is the Bruce Peninsula.

The Niagara Escarpment has been given priority in the study of stone resources for two widely varying reasons. It is primarily the area to which the Toronto metropolis is looking for its supply of construction mineral raw materials. Secondly the area is endowed with exceptional qualities of beauty and recreational potential. For these latter assets an equally great demand exists in the Toronto market. They must therefore be protected. In order to integrate both these uses with the historically developed land use of the

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Escarpment it will be necessary to plan for the future, taking into account demands which are likely to be made on its natural resources. It is hoped that the survey will serve as a basis for future planning of land development in the area and that municipalities will be guided by the findings in zoning for land uses in the townships concerned. Legislation and operation of pits and quarries must be based on a mutual understanding of the problems involved between officials and operators, and planning must take into account the eventual depletion of all available resources.

CONSTRUCTION MINERAL RAW MATERIAL REQUIREMENTS

Mineral raw materials are an integral part of building construction. They provide the builder with concrete aggregates, brick, structural tile, building stone and cement.

Pits and quarries are historically associated with construction projects. In most environments they form only a temporary landmark. Land values usually provide sufficient incentive to reclaim the area for other purposes after depletion of the mineral commodity. In areas of low land value on the other hand, many pits and quarries retain a lease on life, frequently operating on demand only.

An example of an active quarry with a long life-history is the Queenston building stone quarry at St. Davids. It was opened in 1837 and has produced building stone as well as crushed stone, rock wool and cement. The site is presently quarried by one company only, Queenston Quarries Limited. Products include building stone, crushed stone and asphalt sand. The Queenston quarry is Canada's largest building stone quarry. The stone is derived from the Gasport Member of the Lockport Formation. It has been used in many public buildings including the Whitney, Frost, Hepburn and Ferguson Blocks of the Ontario Parliament Buildings.

Present requirements of mineral raw materials are won from a relatively few large operations on the Escarpment. In 1966 thirteen quarries were actively producing from the Lockport-Amabel Dolomite which underlies the area. In contrast well over fifty quarries have been active at one time or another, but they were of smaller size compared with present

operations.

Present quarries provide the Toronto-Hamilton market with a large share of the necessary aggregate for concrete and road building, with fluxstone for the Hamilton steel industries, and with building stone.

Future demands of construction raw materials must be predicted on the basis of developments over the last two decades. Production figures of construction mineral raw material for 1966 for the Toronto-Hamilton area are given in (1). Comparative figures for 1950 appear in (2). The Toronto-Hamilton area is arbitrarily defined as a circle with a 60-mile radius centred in Toronto.

(1) PRODUCTION 1966, TORONTO-HAMILTON AREA

Commodity	Number of Producers	Quantity (Tons)	Value (Dollars)
Sand and gravel	86	34,251,694	25,252,199
Clay and shale products	21	-	20,363,086
Crushed stone	23	13,974,567	15,322,128
Portland cement	2	848,800	14,369,500
Lime	3	317,800	4,457,700
Gypsum	2	565,185	1,581,010
Building stone	10	131,375	866,292
Total			$82,211,915

(2) PRODUCTION 1950, TORONTO-HAMILTON AREA

Commodity	Number of Producers	Quantity (Tons)	Value (Dollars)
Sand and gravel	30	4,289,954	3,585,966
Clay and shale products	18	-	7,430,416
Crushed stone	15	2,792,834	2,841,217
Portland cement	1	197,000	2,399,825
Lime	3	103,977	1,511,459
Gypsum	2	199,314	875,217
Building stone	17	65,489	629,885
Total			$19,273,985

The tables show that our main concern is with trends in consumption of aggregate for roads and concrete. Annual production of sand, gravel and crushed stone is expressed in millions of tons. Sand and gravel, when in short supply, are replaced by crushed rock.

Clay and shale are the next most important construction mineral commodity, used in the manufacture of brick, tile, lightweight aggregate and sewer pipe. Consumption of clay and shale products has not kept pace with the increase in consumption of sand, gravel and crushed rock however. In building construction preference has been given to the use of concrete, a trend which places increasingly heavier demands on limestone resources for the supply of aggregate and cement.

Production of crushed stone in the Toronto-Hamilton area has risen from 2,792,834 tons in 1950 to 13,974,567 tons in 1966. This is a 5-fold increase over a period of sixteen years. The population increase in this area over the same period amounts to about 85%, from 2,004,000 in 1950 to 3,700,000 in 1966. The per capita use of sand, gravel and crushed stone rose from 3.5 tons in 1950 to 13 tons in 1966.

Based on the above trends of development in the building industry it may be assumed that by 1980, when the population will have increased to an estimated 5,000,000 the annual production of total aggregate will be roughly 90,000,000 tons with crushed stone making up about 35,000,000 tons of the total.

In 1966 production from the Lockport-Amabel Dolomites in the Toronto-Hamilton area amounted to 9,459,126 tons of rock. This tonnage equals a strip of land about 1 mile long, 360 feet wide and 60 feet deep.

Five quarries with a total production in 1966 of 4,986,090 tons have opened since 1954 in a location favourable for supplying the Metropolitan Toronto market. They are:

Nelson Crushed Stone,
Milton Quarries,
Dufferin Quarries,
Halton Crushed Stone,
Acton Limestone Quarries.

These quarries draw from Amabel Dolomite in the Escarpment area between Waterdown and Acton.

Amabel Dolomite frequently outcrops to the west of the Escarpment, up to 10 miles away in Beverly and Eramosa townships. In many locations however this source rock is covered by drift. The quality of the stone is also variable over small distances. Assuming that of the available acreage between Waterdown and Acton roughly about 30% is accessible to quarrying and suitable for the production of crushed rock, and that by 1980 about two thirds of the annually required tonnage of crushed stone or 23,000,000 tons will be produced from this area, a strip of land of ½ mile by 1/3 mile by 60 feet deep or over 0.2% of the total available resources, will soon be quarried annually.

It is obvious that the growing demand on stone resources may force operators to undertake quarrying in areas of increasingly heavier overburden or alternatively to mine limestone in underground operations, in which case excess overburden could be tapped for back filling.

LOCATING A QUARRY SITE

The success of a quarry operation is determined basically by three factors. They are geographic location, quality of the stone and freedom of operation. The choice of an area represents a compromise between those. Several instances can be given of operations which have failed before depletion due to the unfavourable disposition of one or more of these factors.

Geographic Location

The importance of geographic location of a quarry is twofold. It determines the elevation of a quarry relevant to the surrounding area which in turn affects the ease of drainage. Elevation difference may influence the layout of a flow sheet for production. A slight elevation of the quarry floor over its surroundings is desirable.

The other and more important aspect of geographic location is economic. It is essential for a quarry to be located close to a market for its products. The cost of transport of low-cost, bulk commodities like aggregate is

critical in determining the competitive position of a producer.

An average figure for the cost of transport in the industry is 5 cents per ton per mile. A producer who markets 1 million tons of aggregate per year loses $50,000 for every mile he is farther away from the market, or 1% profit on a $5,000,000 investment, in an enterprise in which profits are marginal to begin with.

In other words to the producer the value of a property of about 1 mile square, quarried to a depth of 60 feet, will increase by 69 million dollars, at present rates of transportation, for every ten miles it occurs closer to the market.

For crushed stone from the Milton area haulage cost to a job site on Yonge Street amounts to $1.65 per ton. Added to a cost price of $1.20 at the quarry the price of the product delivered is $2.85 per ton, consisting of about 60% transportation cost and 40% cost of stone at the quarry.

The Toronto market is being supplied with aggregate from sources as far as 110 miles away. This is made possible through rail transport. Rail freight is not computed on the same basis as trucking cost. It favours large shipments over long distances.

Many examples can be found of pits and quarries which were only temporarily active due to their geographic location. Construction of roads, railways, bridges and canals, remote from centres of urban development, draws on local resources of mineral raw material as a matter of course. After completion of the job the excavations become obsolete, being too far away from other markets. The site is abandoned and frequently constitutes a scar in the landscape.

Quality of the Stone

Limestone and dolomite have a long history of providing mankind with the basic necessities of shelter and industry, from cave dwellings to a variety of present day uses. Man's long lasting association with limestone has resulted in the development of several applications. Crushed stone is used for concrete aggregate, road metal, railroad ballast, and

sewage filter beds and in finer form, for poultry grit, stucco, manufactured sand, coal-mine dust, filler and whiting. Further uses of limestone and dolomite are as a fluxing agent in the smelting and refining of iron and other metals, as a soil conditioner, as a source of lime, which has a long list of industrial applications, as a chemical raw material in glass making, acid neutralization and other processes, and as building stone. Limestone is a basic raw material in the manufacture of portland cement. Dolomite, when calcined at high temperatures, produces a partially sintered mixture of lime and magnesia called dead-burned dolomite. It is used as a refractory material in lining metallurgical furnaces.

Production and uses of limestone and dolomite in Ontario, together with tests determining the suitability of different stones for these uses, are described by Hewitt (1960, p.2-16). The tests described concern grading, petrographic examination (for presence of deleterious materials, unfavourable structures or textures, etc.), soundness, abrasion, absorption and porosity, reactivity, incompatibility (thermal coefficient of expansion), loss on washing (percentage of fines), density, strength, stripping (surface tension of aggregate), and chemical analysis.

In the following tables some requirements for coarse aggregates as specified by the Ontario Department of Transportation and Communication are reproduced:

(3) PHYSICAL SPECIFICATIONS FOR COARSE AGGREGATE FOR ROAD METAL

	Surface Course Type A	Surface Course Type B	Granular Base Course "A"
Los Angeles Abrasion			
30 percent crushed percent loss maximum	-	22.4)	
40 percent crushed percent loss maximum	19.2	-)	60
50 percent crushed percent loss maximum	24	28)	
Absorption by weight..... percent maximum	2	2.5	
Petrographic number..... maximum	175	185	200
Crushed material..... percent minimum	40	30	50
Loss on washing..... percent maximum	1.5	2	
Plasticity Index.....			0

(4) PHYSICAL SPECIFICATIONS FOR AGGREGATE FOR ASPHALT CONSTRUCTION

	HL 1	HL 3	HL 4	HL 5,6	HL 8
Los Angeles Abrasion Grades B,C,D.. percent loss maximum	15	35	35	35	35
$MgSO_4$ soundness (5 cycles).... percent loss maximum	5	12	12	12	12
Absorption by weight.... percent maximum	1	1.75	2	1.75	1.75
Petrographic number..... maximum	100	135	160	140	160
Loss on washing - passing No.200 seive - for gravel..... percent maximum	1	1.3	1.3	1.3	1.3
for crushed rock... percent maximum	1	2	2	2	2
Thin and elongate particles..... percent maximum	15	15	15	15	15
Crushed material..... percent minimum	100	60	60	60	60

(5) PHYSICAL REQUIREMENTS FOR COARSE AGGREGATES FOR CONCRETE STRUCTURES

Los Angeles Abrasion..... percent loss maximum	35
$MgSO_4$ soundness (5 cycles)..... percent loss maximum	12
Absorption by weight..... percent maximum	2
Petrographic number..... maximum	140
Loss on washing - passing No. 200 seive - for gravel..... percent loss maximum	1
for crushed rock.... percent loss maximum	2
Thin and elongate particles..... percent maximum	20
Clay lumps..... percent maximum	0.25

A number of tests made on recently quarried stone of the area between Waterdown and Acton were found to range between the following values (6):

(6) RANGE OF RESULTS OF RECENT TESTS ON AMABEL DOLOMITE

H.L. Petrographic No.	$MgSO_4$ - Soundness	Absorption	L.A. - Abrasion
100.0 - 156	0.1 - 9.8	0.87 - 3.43	21 - 39.6

These figures show that the Amabel Dolomite is suitable for production of aggregate for roads, concrete, and asphalt. Discrimination is necessary however and testing of the rock before opening a quarry is essential. Disappointing quality of rock has caused some quarries to close down prematurely. Canada Crushed and Cut Stone Limited at one time operated a quarry on lot 4, concession V, Saltfleet Township. When fire destroyed the crushing plant in 1930 operations were suspended. In 1955 the following test results were obtained on rocks in the area (7):

(7) RESULTS OF TESTS ON DOLOMITE OF SALTFLEET TOWNSHIP

L.A. - abrasion	$MgSO_4$ - soundness	Absorption
15.6 - 18.6	10.2 - 53.7	0.87 - 2.29

Chemical analyses locally contain up to 4.18% Al_2O_3 with 2.32% Fe_2O_3 and 14.52% SiO_2. These values derive from a shaly facies of Eramosa Dolomite referred to as the Vinemount Shale Unit. It is particularly due to soundness losses in these shales that the material cannot be used as aggregate for asphalt and concrete. Selective quarrying is required to produce Granular Base course Class "A" and 5/8" crushed rock.

Freedom of Operation

Under the heading "freedom of operation" are to be considered the amount of overburden which covers the quarriable rock, as well as the number of rules, regulations and restrictions which burden the operation locally.

A factor frequently contributing to the competitive position of operators at greater distance from the market is the freedom of operation. Land uses in the area surrounding a quarry determine the size of the charge permissible in blasting. Freedom to choose the time of blasting is essential for efficient operation. Ease of access to and exit from the quarry over existing roads and the liberty to operate heavy equipment in or near the site are equally vital for a satisfactory performance.

The opportunity to expand operations when the market grows must be attractive to producers. In areas of urban development conditions to the contrary usually prevail. As demand grows the increased urban sprawl tends to curtail the freedom of existing quarries. The difficulties met with by quarry operators in this context are illustrated by the history of a quarry opened by Peel Construction in the Hamilton area. Residents in the area of the quarry site agitated against the use of heavy equipment on residential roads and against blasting of rock. Eventually, concerted efforts and road blocks erected by women in the surrounding area succeeded in getting the operations suspended.

In municipal legislation the trend is to confine the operation of pits and quarries and to prohibit the opening of new ones. A quarry serving the needs of a neighbouring area

or urban centre, rather than those of the donor township, risks being victimized by local legislation. The company may be forced to operate farther away from a market, raising expenses and, ultimately, the cost of building material.

Given proper safeguards against noise and air pollution however, a quarry or pit can be operated in a built-up area. It seems possible for instance for city redevelopment projects to make use of available gravel deposits which previously had been built over. Land values would guarantee the intensive exploitation of such deposits and the inconvenience to local residents would be of short duration only.

Planning of land use and land development should prevent situations in the future in which resources become a total loss to society. It must take into account the eventual depletion of all available resources.

At present the choice of a quarry site is limited economically to areas with less than 25 feet of overburden. Existing quarries are known to circumvent areas of heavy overburden in their own domain. The operation by Canadian Gypsum Company Limited in Guelph is leaving behind ground covered by a drumlin.

Areas of potential quarry development are outlined on maps accompanying this report. They are restricted to areas of 25 feet or less overburden. On the maps these are indicated by shading. In areas with less than 10 feet of overburden frequent outcrops of bedrock may be expected.

Drift deposits as a rule are not utilized by quarry operators. Exceptions occur however. The large property of St. Marys Cement Company Limited at St. Marys for instance is partly covered by till deposits with up to 65% stone. The stone, predominantly boulders of limestone and dolomite, is excavated and crushed in a pit operated by Yundt and McCann, gravel pit operators, and the aggregate used in Ready Mix-concrete.

GEOLOGY

The Niagara Escarpment is a topographic feature extending from east-central New York State through southern Ontario and

Manitoulin Island into northern Michigan. It is the expression of outstanding erosion resistance of certain dolomite beds in the sequence of Silurian sediments underlying the Michigan and Appalachian basins (Figure 1).

Rocks underlying the Escarpment are referred to as the Niagaran Series in the literature. The formations in Ontario generally dip in a southwesterly direction towards the centre of the depositional basin. Local deviations occur due to unevenness in the basin floor and to pronounced reef structures in the carbonate rocks.

The character of Silurian sediments in Ontario has been influenced by a structural feature referred to as the "Cataract Axis" or "Algonquin Arch". In Figure 1 this axis runs through the southwestern extension of the province towards the "Chatham Sag" beyond which it continues as the "Cincinnati Arch". The expression of this structure in Middle Silurian sediments of the Escarpment area is characterized by Bolton (1957, p.6) as due to the existence of a broad, shallow platform extending from north of Hamilton to Owen Sound and intervening between two major basins of deposition.

Changes in the character of sediments occur north of Waterdown. Here the Rochester Shale Formation vanishes, a last remnant of it being preserved at the Clappisons Corners road cut. Irondequoit Limestone is less easily distinguished from overlying dolomites. The latter form a sequence of light grey, massive to medium bedded, fine to medium crystalline, porous and frequently reefy dolomite which is more uniform than the Lockport Formation on the Niagara Peninsula. To the north rocks equivalent in time to the Lockport Formation are referred to as Amabel Dolomite.

It follows from above that the thickness and character of the formations underlying the Escarpment is variable. Therefore the Escarpment is not everywhere equally pronounced. In Ontario its magnitude ranges from gradual inclines of about 100 feet per mile south of Georgetown to slopes rising 900 feet within one mile near Collingwood. Sheer cliffs occur in several locations. In a section east of Orangeville the Escarpment is buried by glacial deposits of the Oak Ridges moraine.

Details of the classification of Silurian sediments in Ontario have been subject to modification. In this report the classification in Table 8 by Bolton (1957) will be followed (see page 13).

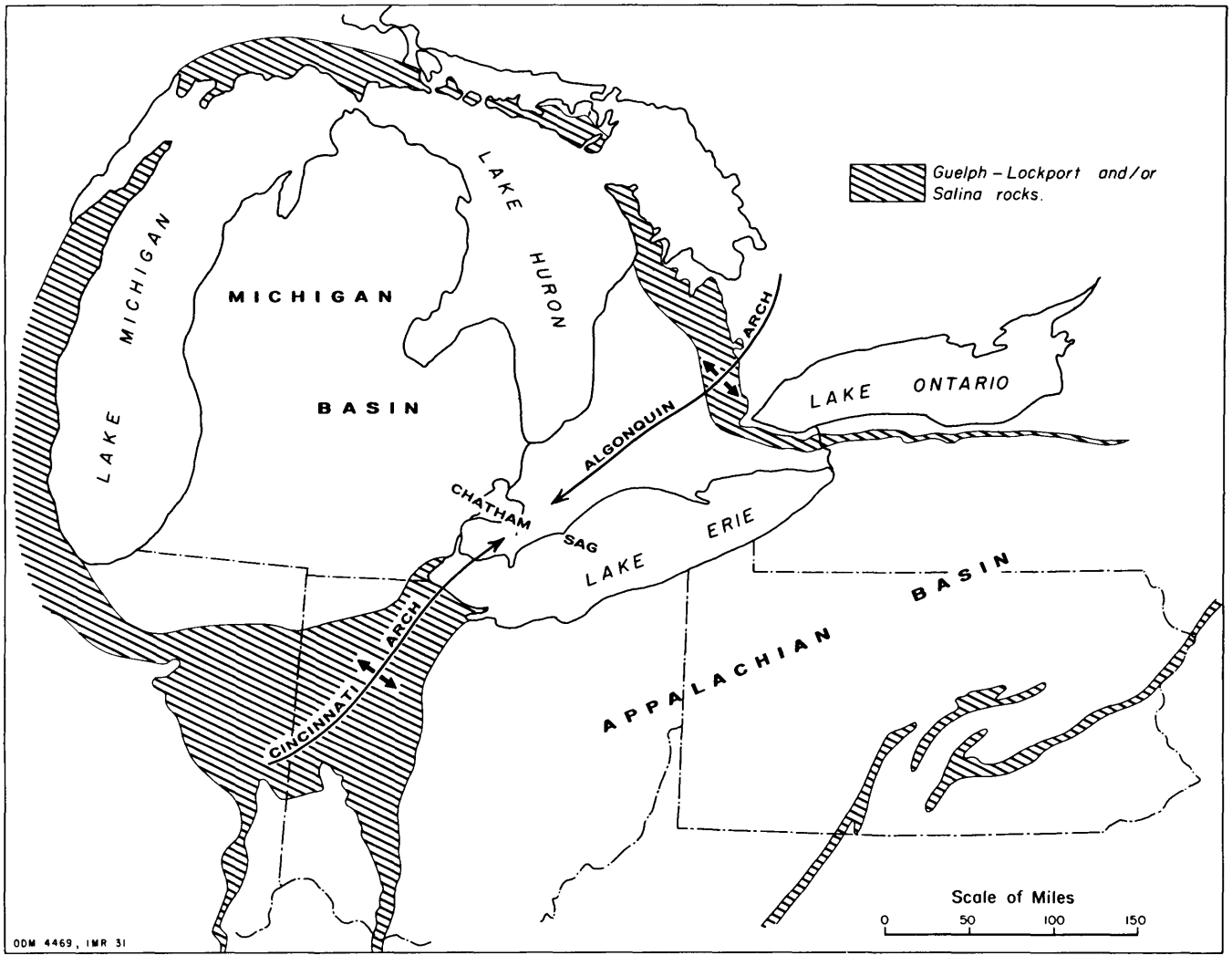

Figure 1 — Silurian depositional basins showing distribution of Guelph–Lockport Dolomite (modified after Guillet, 1964).

Table 8. PARTIAL CLASSIFICATION OF ORDOVICIAN AND SILURIAN

	Niagara Peninsula (Niagara Falls-Hamilton)			Hamilton-Tobermory, and Manitoulin Island		
		Formation	Member		Formation	Member
Niagaran Series (Middle Silurian)	Albemarle Group	Guelph		Albemarle Group	Guelph	
		Lockport	Eramosa Goat Island Gasport		Amabel	Eramosa Wiarton Colpoy Bay Lions Head
					?	?
	Clinton Group, Upper	DeCew Rochester Irondequoit		Clinton Group		
	Clinton Group, Mid.					
	Clinton Group, Lower	Reynales Neahga Thorold			Fossil Hill St. Edmund Wingfield Dyer Bay	
Alexandrian Series (Lower Silurian)	Cataract Group	Grimsby Power Glen Whirlpool		Cataract Group	Cabot Head Manitoulin Whirlpool	
(Upper Ordovician)		Queenston			Queenston	

Table 8 subdivides the Lockport Formation into the Gasport, Goat Island and Eramosa Members. These terms are frequently used in the following pages. They are more readily applicable than subdivisions in the Amabel counterpart north of Waterdown. Bolton (1957, p.51) sees in the dolomites between Waterdown and Georgetown a gradational transition from Lockport to Amabel lithology. According to him differentiation into members is impossible in this area.

A distinct lithological change similar in both Lockport and Amabel Formations is the appearance of thin bedded dolomites near the top. They are often bituminous and classified as the Eramosa Member. The bituminous quality is not a condition in Boltons' classification however. He notes that although these beds represent a constant and thick deposit in the south, where conditions of sedimentation seem to have been less varied, the Eramosa in the northern part of the Ontario peninsula is a particular facies directly associated with the development of bioherms in the Wiarton Member (Bolton 1957, p.55). It supposedly represents the deposits of late Wiarton and early Guelph time in areas less favourable to a continuous accumulation of organic material in bioherms.

The geology and economic importance of formations in Table 8 will briefly be discussed in the following paragraphs.

Queenston Shale

Outcropping at the base of the Niagara Escarpment throughout its length is the Queenston Shale, a red shale formation which forms the uppermost Ordovician strata in the area. The width of the outcrop band of Queenston shale varies from 2 to 12 miles extending north or east from the Niagara Escarpment as shown on ODM Map 2117. The Queenston Shale has a thickness of 850 feet at Niagara Falls, 600 feet at Hamilton and less than 200 feet at the tip of Bruce Peninsula (Sanford 1961, p.15).

Queenston shale is used for the manufacture of brick and tile. There are several brick and tile plants located along the base of the Escarpment. These include the following:

Brunstein Brick Ltd., St. Catharines;
Grimsby Tile Limited, Grimsby;
Canadian Pressed Brick Co. Ltd., Hamilton;
Hamilton Brick Limited, Hamilton;
Natco Building Products Limited, Aldershot;
National Sewer Pipe Limited, Hamilton;
Diamond Clay Products Limited, Tansley;
Milton Brick Co. Ltd., Milton.

In 1967 the production from these companies amounted to $7,803,000. In the Niagara Peninsula those plants using Queenston Shale for the manufacture of brick and tile will, of necessity, be close to the Escarpment. North of Aldershot the Queenston Shale has an outcrop width of up to 12 miles and several of the brick plants using this formation are somewhat withdrawn from the Escarpment being in the vicinity of Brampton and Streetsville.

Whirlpool Sandstone

Whirlpool Sandstone outcrops along the base of the Escarpment from Queenston to Collingwood. It is a quartzose sandstone or orthoquartzite resting everywhere with a sharp contact on the red Queenston Shale of Upper Ordovician age. Ranging in thickness from 6 to 28 feet it is typically white to light grey and massive to thick bedded.

Whirlpool Sandstone is quarried near Limehouse, Glen Williams, Terra Cotta and Inglewood. Known as the "Credit Valley Sandstone" it ranges in colour from light grey to deep brownish red. Its architectural value as building stone is displayed in prominent buildings in Ontario including the Royal Ontario Museum, the Main Block of the Ontario Parliament Buildings and the old Toronto City Hall.

In 1966 production of Whirlpool Sandstone from nine quarries in the area from Milton to Inglewood amounted to 28,016 tons valued at $447,954. The quarriable reserves of this stone should be carefully preserved for future use. They occur in places where the sandstone forms a secondary scarp at the base of the main Escarpment, or occurs as the principal scarp in areas detached from the main portion of the Escarpment by erosion as in the Glen Williams outlier.

Power Glen Formation

Grey shales of the Power Glen Formation rest conformably on Whirlpool Sandstone in the Niagara to Grimsby area. Alternating layers of shale and sandstone give the position of the contact an arbitrary character. Calcareous sandstones are interbedded with the shales at various levels. The formation ranges in thickness from 34 to 48 feet. The fauna has been correlated by Bolton (1957) with faunas of Manitoulin and Cabot Head Formations to the north.

The Power Glen Formation has little commercial value.

Manitoulin Formation

Manitoulin Dolomite, equivalent in time to Power Glen, extends from Stoney Creek northwards across Manitoulin Island into northern Michigan. The dolomite rests conformably on Whirlpool Sandstone as far north as Duntroon and on Queenston Shale in the Bruce Peninsula. Ranging in thickness from 4 feet at Stoney Creek to 26 feet or more north of the Nottawasaga river, the dolomite also gradually changes character in this direction. From buff to bluish grey, even-bedded, dolomitic limestone near Stoney Creek it grades into thick to thin bedded, grey, argillaceous dolomitic limestone with shale partings and lenses of white chert. In the Owen Sound area chert is particularly abundant near the top of the formation which is exposed in an abandoned quarry. Chert occurs in thin-bedded, medium brownish grey, fossiliferous dolomite. A thickness of Manitoulin Dolomite of more than 50 feet in a local biohermal development on Manitoulin Island is reported by Bolton (1957, p.15).

There are no quarries presently producing from the Manitoulin Formation.

Cabot Head Formation

The Cabot Head is predominantly a grey shale interbedded with grey dense calcareous sandstone and limestone. Defined as a lithological unit in Bolton's classification the Cabot Head Shale includes near the top, in almost every section between Hamilton and the Bruce Peninsula, a thin red facies of predominantly red calcareous sandstone and arenaceous limestone, overlain by green shales of variable thickness.

In the Stoney Creek-Hamilton area these red beds are sufficiently developed to deserve status as a formation, the Grimsby. Northward they are included with the Cabot Head.

At Owen Sound the Cabot Head Formation is approximately 120 feet thick, while 50 feet of Cabot Head Shale underlie the Grimsby at Stoney Creek. The contact with underlying Manitoulin Dolomite is gradational and arbitrarily drawn where alternating grey shales and limestone predominate over massive dolomitic limestone. The upper contact is sharp by definition, formed successively with overlying Grimsby Sandstone in the Hamilton region, with Reynales Dolomite at Limehouse, with Fossil Hill Dolomite from the Nottawasaga River to Owen Sound and with Dyer Bay Dolomite on the Bruce Peninsula and Manitoulin Island.

Although it is generally suitable for the production of brick, tile, and expanded aggregate there is no production from Cabot Head Shale, largely because exposures suitable for quarrying are scarce.

Grimsby Formation

As mentioned previously the Grimsby Formation, a sequence of red shales and sandstone with green and yellow-mottled, crossbedded red sandstone and occasional shales near the top, is considered by Bolton to be the southern counterpart of minor red beds in the Cabot Head Shale. Its thickness diminishes from 45 feet at Niagara Falls to 12 feet at Clappisons Corners. The rocks are not being quarried.

Clinton Group

The formations overlying the Grimsby and underlying the Lockport Dolomite are mainly restricted to the area south of Waterdown. The rocks belong to the Clinton Group. Only the Reynales Dolomite can be traced northward as far as Georgetown where it is overlain by Amabel Dolomite.

The Thorold Sandstone is considered by Bolton to be the first deposit of the transgressing Clinton sea. It is a white to light grey, quartzose sandstone with crossbedding on a small scale. From Stoney Creek north inclusions of grey and green shale gain importance. The thickness of Thorold Sandstone ranges from 4.6 to 13.5 feet in sections along the

Escarpment. No production is reported from these beds.

Neahga Shale conformably overlying the Thorold Sandstone, is blackish grey to green. It can be traced from the Niagara Gorge, where it is 5 to 6 feet thick as far west as Grimsby Beach, where it is measured in inches. These shales preceded the deposition of Reynales Dolomite.

Reynales Dolomite forms a persistent bed ranging from 8 to 14.5 feet between Limehouse and DeCew Falls. It is a light grey, aphanitic dolomite with grey shale partings throughout. A sandstone band occurs on the contact with overlying Irondequoit Limestone at DeCew Falls.

Irondequoit Limestone overlies the Reynales Dolomite unconformably. The contact is an undulating, irregular surface above which pebbles of Reynales have reportedly been found in several locations. The Irondequoit is typically a white to light grey, medium crystalline, porous, crinoidal limestone.

In Ontario the thickness of Irondequoit is fairly constant, ranging from 4 to 10 feet, a variation which is partly attributable to the presence of reef-like masses. A regular westward thinning occurs. North of Waterdown the formation can no longer be distinguished as a separate unit from Amabel Dolomite with which it comes into contact after the disappearance of Rochester Shale.

Together with Reynales Dolomite the Irondequoit Limestone has in the past been quarried for building stone near St. Catharines.

The Rochester Formation, overlying the Irondequoit Limestone, consists predominantly of black to grey, calcareous shale with numerous thin, grey, undulating limestone beds. West of Grimsby the formation becomes more compact until it is reduced to a dark grey limestone with shale partings at Clappisons road cut and north of Waterdown (Bolton 1957, p.30).

In Ontario the thickness of this formation ranges from 58 feet at Niagara Falls to 2.4 feet at Clappisons Corners road cut. It has been quarried in the past for the manufacture of rock wool.

The DeCew Dolomite, overlying the Rochester Formation, is referred to by Goudge (1938, p.20) as the DeCew Waterlime. It

is a massive to medium bedded, dark grey, aphanitic and impure dolomite. Thicknesses range from 3 to 12.5 feet. Variations in thickness and occasional absence are due to erosion at the end of Clinton time.

West of Stoney Creek the DeCew Dolomite becomes thinner bedded due to increased shaly parting. It is hardly distinguishable in this area from argillaceous dolomites occurring near the top of the Rochester Shale.

DeCew Dolomite has in the past been quarried between St. Davids and Thorold as a source of natural cement.

Formations of the Clinton Group north of the "Algonquin Arch" include the Dyer Bay, Wingfield, St. Edmund and Fossil Hill. This sequence is fully developed only on Manitoulin Island, according to Bolton. Near Owen Sound the Dyer Bay is overlain by Fossil Hill and further south the dark brown, medium crystalline Fossil Hill Dolomite directly overlies Cabot Head Shales. Bolton correlates Fossil Hill Dolomite with Reynales Dolomite of the southern area via sections between Acton and Caledon.

A medium to dark bluish grey to brownish grey, fine crystalline Dyer Bay Dolomite is exposed in several sections north of Owen Sound. Numerous shale partings and occasional coarse crystalline lenses and intraformational conglomerates occur. Thickness of Dyer Bay is reported by Bolton (1957) to range from 10 to 25 feet where exposed, but complete sections are rare.

There is no production from the Dyer Bay Formation.

The Wingfield Formation is characterised by green to greenish grey shales and interbedded green to brown, aphanitic, argillaceous dolomite. A maximum thickness of 36 to 37 feet is reported by Bolton. The deposits have no economic importance.

St. Edmund Dolomite is 8 feet thick at its type locality 3 miles west of Cabot Head on the Bruce Peninsula. Thin bedded, brown, aphanitic, white weathering dolomite characterizes the formation which has a gradational contact with the overlying Fossil Hill Dolomite. Bolton has measured a maximum thickness of 90 feet for St. Edmund Dolomite on Manitoulin Island. No production is reported from these beds.

Fossil Hill Dolomite directly overlies the St. Edmund Formation around Fossil Hill, west of Manitowaning, Manitoulin Island. It is typically a uniform, thin and unevenly bedded, brown, fine to medium grained dolomite deposited in continuity with the St. Edmund Formation.

Bolton (1957, p.39) recognizes the Fossil Hill Dolomite as a mappable lithological unit which gradually thickens northward from about 8 feet south of Owen Sound to 22 feet in the Hope Bay region. On Manitoulin Island the Fossil Hill is reported by Liberty (1968) to obtain thicknesses of up to 115 feet in biohermal developments. Correlating Fossil Hill Dolomite with Reynales Dolomite to the south Bolton (1957, p.42) remarks that the formation may well contain the equivalent of later Clinton deposits in its northern extension.

There is no production from Fossil Hill Dolomite but Reynales Dolomite is included in quarry sections from Clappisons Corners northward.

Albemarle Group

The crest of the Escarpment is formed by a thick sequence of erosion resistant dolomites of the Albemarle Group. From Queenston to Waterdown they belong to the Lockport Formation. North of Waterdown these grade into the Amabel Dolomite which represents a more uniform reefy facies. In recently published sections of Palaeozoic stratigraphy (Beards, 1967) the Escarpment area from Waterdown to Manitoulin Island is characterized as the location of a barrier reef at the time of deposition of Amabel and overlying Guelph Dolomite. Thicknesses of these combined formations range up to 400 feet. In the Niagara Peninsula the equivalent sequence measures 210 feet in Crowland Township. Near Dundas the thickness of Lockport Dolomite alone is about 135 feet, according to Caley (1940, p.57).

Lockport Formation

The Lockport Dolomite has an outcrop width of up to 6 miles between Queenston and Waterdown and dips gently to the south. The formation is divided into three members: Gasport, Goat Island and Eramosa. The Gasport, lowest member of the

Lockport Formation, is a medium crystalline, crinoidal dolomitic limestone or dolomite, generally massive to thick-bedded, bluish grey to light buff in colour. It varies in thickness from 4.4 feet at Stoney Creek to 33 feet at Queenston Quarries. Massive basal beds of this member are quarried for building stone at Queenston. Aggregate is produced from the Gasport member in quarries at Thorold, St. Catharines and Vineland. Recently the quarry of Armstrong Brothers Company Limited at Vinemount reportedly has been deepened to intersect the Gasport.

The Goat Island Member, conformably overlying the Gasport with a gradational contact, is an aphanitic to fine crystalline, light buff to light brownish grey, massive to thick bedded dolomite. In places bluish-grey and white chert are abundant. The chert-bearing facies has been distinguished as the "Ancaster Chert Beds". The chert beds generally occur at the base of the Goat Island Member and are most common in the Ancaster-Stoney Creek area.

Thickness of the Goat Island Member is variable due to the development of an inter-reef Eramosa facies. This facies developed in some areas to the exclusion of the Goat Island facies according to Bolton (1957, p.50). A thickness of 46.5 feet of Goat Island Dolomite is exposed in the Vinemount quarry (Hewitt 1960, p.101).

Being part of most quarry sections along the Escarpment east of Stoney Creek the Goat Island is quarried primarily for the production of aggregate for road construction. The presence of chert frequently rules out other uses.

The upper limit of the Goat Island Dolomite is arbitrarily drawn at the first appearance of dark brown to black bituminous material characteristic of the Eramosa Member.

The Eramosa Member is a dark brown to medium brownish grey, aphanitic to sugary, medium to thin-bedded, dark grey streaked dolomite with bituminous or shaly partings. It is exposed in the Ancaster Highway road cut and in quarries set back from the brow of the Escarpment at Vinemount and Stoney Creek.

The largest section of Eramosa Dolomite is exposed in the quarry of Canada Crushed and Cut Stone Limited at Dundas. Here 44 feet of medium dark to light brown, aphanitic, medium to thick bedded dolomite is exposed in the quarry face.

Together with 15 feet of a thinner bedded and more shaly facies of Eramosa underlying this section, exposed in a separate lift below the main quarry floor, and 6 feet of Guelph Dolomite overlying the Eramosa at the top of the quarry face, these rocks provide one of the largest quarries in Ontario with a production of over 1,000,000 tons annually (Hewitt 1960, p.106-110). Products are concrete aggregate, road stone and railway ballast, agricultural limestone, stone for lining open-hearth furnaces, flux stone for the steel industry and stone for the production of dead-burned dolomite.

Lateral lithological variations with local development of a shaly facies make it necessary to thoroughly test dolomites of the Eramosa member before production is decided upon.

Eramosa Dolomite is absent from quarry sections on the brow of the Escarpment north of Waterdown. Known to form part of the Amabel Dolomite as far north as Cabot Head on the Bruce Peninsula it is encountered west of the Escarpment. Drilling in Puslinch Township established the presence of between 42 and 90 feet of Eramosa Dolomite (Hewitt 1960, p.125). A small quarry in lot 6, concession IV, West Flamborough Township probably produces in part from Eramosa Dolomite (Hewitt 1960, p.111). The contact with overlying dolomite of the Guelph Formation is here gradational and can only be established arbitrarily.

Amabel Formation

The northern equivalent of Lockport Dolomite, for which the name Amabel Formation was proposed by Bolton (1957, p.51), forms the crest of the Escarpment from Waterdown north to the Bruce Peninsula. The dolomite dips gently westward and outcrops over a width of up to 12 miles west of the Escarpment. From Waterdown to Georgetown the Amabel Dolomite is a light grey to buff, buff weathering, medium crystalline, porous, irregularly bedded, fossiliferous and reefy dolomite. The maximum thickness exposed is 84 feet at the old Milton quarry of Domtar Chemicals Limited.

In the Bruce Peninsula, Bolton (1957, p.51-57) divides the Amabel Formation into four members: Lions Head Dolomite, Colpoy Bay Dolomite, Wiarton Dolomite and Eramosa Dolomite. These members can be distinguished as lithological units in several sections north of Georgetown, notably at the Wiarton

road cut.

The Lions Head Member is described as a blocky, hard, conchoidal fracturing, white weathered, dark brown dolomite by Bolton (1957, p.52). It is recognized east of Caledon, in the Owen Sound region and on the Bruce Peninsula. A maximum thickness of 45 feet was measured at Dyer Bay. Lions Head Dolomite is not recognized in any of the quarries operating in the Amabel Formation.

The Colpoy Bay Member, in distribution the most consistent unit of Amabel stratigraphy, is typically a massive, porous, aphanitic, white to light grey to blue grey dolomite. Biohermal structures and thin bedded flank deposits are common. The maximum exposed thickness is 58 feet at Wiarton.

Overlying the Colpoy Bay strata and in gradational contact with them is the Wiarton Dolomite. It is typically a massive bedded, fine to coarse crystalline, porous, very light grey, blue-grey mottled, crinoidal dolomite. Bioherms are common.

Outcrops of Wiarton Dolomite are widespread along the Escarpment as well as at the surface in the Bruce Peninsula and in quarries from Rockwood to Hope Bay.

Crushed rock is produced from Wiarton Dolomite in a quarry recently opened by E.C. King about 3 miles east of Owen Sound. The white to light buff, medium to coarse crystalline, fossiliferous Amabel Dolomite quarried two miles west of Duntroon probably belongs to the Wiarton Member. Massive, aphanitic, very light grey and blue mottled Wiarton dolomite outcrops about two miles south of Hope Bay and is quarried by Angelstone Limited for the production of building stone.

At the close of Amabel deposition the Eramosa Dolomite was laid down. It is typically a thin bedded, brown, aphanitic dolomite in the area north of Owen Sound. The beds are frequently domed over, or flanking, bioherms in the Wiarton Dolomite.

Eramosa Dolomite is not recognized everywhere between Wiarton and Guelph deposits which are in gradational contact with each other in some areas (Bolton 1957, p.55). On Manitoulin Island non-bedded masses of creamy weathering, pink, lithographic to sub-lithographic dolostone are believed

to be the reefal equivalent of the typical Eramosa of the Bruce Peninsula (Liberty 1968, p.37).

Eramosa Dolomite is being quarried in the Bruce Peninsula for the production of building stone in several small operations near Owen Sound and Wiarton.

The upper part of the Albemarle Group, the Guelph Formation, underlies a belt of country to the south and west of the Niagara Escarpment from Niagara Falls to the tip of Bruce Peninsula. Guelph Dolomite generally consists of creamy buff to medium light grey, aphanitic to fine crystalline, thin to thick bedded, porous dolomite. The lower contact with the Eramosa is marked by a change to medium to dark brown, bituminous dolomite with dark grey, shaly streaks. Thickness ranges from 100 to 200 feet in the outcrop area.

The Guelph Dolomite is also characterized by reefy facies. Reefs consist of medium to coarsely crystalline, irregularly bedded or massive areas of highly fossiliferous, porous dolomite standing out as mounds or bioherms within the surrounding bedded dolomite.

The contact of Guelph Dolomite with the underlying Eramosa Dolomite is seen at Canada Crushed and Cut Stone quarry at Dundas and in the Guelph quarry of Canadian Gypsum Company.

Guelph Dolomite is an important source of high purity dolomite for the manufacture of dolomitic lime for the construction industry. It is quarried at Glen Christie by Domtar Chemicals Limited and at Guelph by Canadian Gypsum Company for the production of lime.

A substantial acreage of Guelph Dolomite is held in Puslinch Township by Canada Crushed and Cut Stone Limited for reserves of high purity dolomite suitable for blast furnace flux.

About 100,000 tons of stone for use as aggregate was produced in 1966 by the Guelph and Glen Christie quarries. The Guelph Dolomite is generally considered to be somewhat soft to produce a good quality of commercial aggregate, although this varies from area to area. The stone is particularly distinguished by its high chemical purity, and for this reason it is commercially desirable.

DISCUSSION OF AREAS OF POTENTIAL QUARRY DEVELOPMENT

Areas of potential quarry development will be reviewed in geographical order from the Escarpment southward and progressively westward, beginning at Niagara Falls, and continuing west of the Escarpment north of Hamilton.

Niagara Falls

The brow of the Escarpment near Niagara Falls supports the largest building stone quarry in Canada (see Map P.537). Thirty eight feet of Lockport Dolomite are exposed in the quarry face at an elevation of approximately 600 feet. The quarry operation and the geological section are described by Hewitt (1960, p.91-94; 1964, p.43).

Mill blocks for building stone are produced from the bottom of the quarry, from 14.5 feet of massive bedded, crinoidal, calcitic dolomite of the Gasport Member. Gasport (10.5 feet) and Goat Island (5 feet) Dolomite above these beds are quarried for crushed stone. The floor of the quarry is formed by DeCew Dolomite underlain by approximately 40 feet of Rochester Shale. Six feet of DeCew Dolomite, dark grey, aphanitic and buff-weathering, are exposed locally.

Along the Escarpment, between the above quarry at St. Davids and Walker Brothers' quarry just east of Thorold, there is an area of about 2 miles long and up to ½ mile wide in which water wells indicate less than 25 feet of overburden. The area comprises most of lots 7, 8, 9, 12, 13 and 14, Niagara Falls Township. Elevations in this area range from 500 to 600 feet and it may be supposed that quarriable rock occurs above an elevation of 540 feet, consistent with the depths of quarrying on either side of this area. The Escarpment is not pronounced and erosion has probably left an irregular bedrock surface behind. The area appears as an area of bedrock outcrops on other maps (Chapman and Putnam 1951).

As the terrain reaches a higher elevation to the south, the drift thickness increases to over 35 feet. A till moraine made up of stony clay, sand and gravel underlies this part.

Drift thicknesses below 25 feet are reported from the lower area to the south drained by Ten Mile Creek. It includes lot 47, 48, 51, 65, 66, 67 and 68, Niagara Falls Township.

About 60 feet of quarriable rock may be expected here from 575 feet down. Drift consists of clay with occasional fine sand or cemented gravel.

Further south, covering lots 119, 120 and parts of lots 135 and 136, Niagara Falls Township, an area of low overburden is drained by a tributary of Beaver Dams Creek. Consistent with an apparent southward dip of the beds of 35 feet per mile in this area the top of the Rochester Shale may be expected to reach an elevation of 425 feet. A section of rock of about 150 feet is available to be quarried. Much of this section is in Eramosa Dolomite which is rich in shale at times. The potential for quarry development depends on the result of rock tests. Drift consists of clay and occasional fine sand or stones.

Thorold

A small area south of Thorold in lots 93 and 94, Thorold Township is outlined (see Map P.537). Some water wells have indicated less than 25 feet of overburden here. Further determination of drift thickness and quality of the stone is needed to evaluate this location.

Quarries have been opened on the brow of the Escarpment, just west of Thorold. Present production by St. Catharines Crushed Stone Limited on lots16 and 17, concession X, Grantham Township is from Gasport and Goat Island Dolomite. A section and description are given by Hewitt (1960, p.97 and 98; 1964, p.43). Less than 7 feet of Gasport Dolomite, medium bedded at the base, rests directly on shaly dolomite of the Rochester Formation of the Clinton Group. Together with 30.5 feet of medium bedded to massive, aphanitic Goat Island Dolomite these beds here provide aggregate for road construction and concrete.

The present 39-foot quarry section occurs above an elevation of 535 feet. At lower elevation the Irondequoit Limestone was once quarried for building stone, according to Goudge (1938, p.280). Neither this quarry nor a building stone quarry in Gasport Dolomite, previously operated by Peninsula Limestone Limited and located on the brow of the Escarpment, 1 mile east of Thorold, are active at present.

The area south of the quarry of St. Catharines Crushed Stone Limited is favourable for further quarry development.

Four feet of overburden are reported south of the St. Davids Road in lot 22, Thorold Township. The overburden in this area consists mainly of clay and stones. Lots 20-24 and lots 33-39 are concerned. At an elevation of 575 feet approximately 50 feet of quarriable rock may be expected.

Rockway, Louth Township

The area between Rockway and Effingham features a low overburden of clay deposits and a steep slope towards Twelve Mile Creek which occupies the valley of a deeply incised re-entrant into the Escarpment (see Map P.537).

The area of possible interest is about 1 mile square southeast of Rockway. It is underlain by brown, fine crystalline Lockport Dolomite ranging from thin bedded dolomite with 1-inch shaly intercalations to heavily bedded, pure dolomite. It is estimated that a section of up to 50 feet of quarriable rock is available in this area, based on the assumption that all rocks overlying the Rochester Shale are suitable. Increased thicknesses to the south are due to a general southward dip of the beds of approximately 37 feet per mile. Chert nodules observed in outcrops just south of this area, near Effingham, may lower the value of the dolomite. Testing is necessary before quarry development.

Balls Falls, Louth Township

Between Sixteen Mile Creek and Twenty Mile Creek a triangular area with a base of about 1½ mile at the Escarpment and pointing 1 mile south has less than 25 feet of overburden. The area occurs directly east of Balls Falls. Goudge (1938, p.249-250) mentions several small quarries along the Escarpment, between Rockway and Balls Falls. In lots 19 and 20, concession V, Clinton Township, at an elevation of approximately 475 feet, Reynales Dolomite (15 feet) and Irondequoit Limestone (4 feet) were once quarried. Road metal has been produced from dark brown, fine grained, cherty dolomite (24 feet) in lot 2, concession VIII, Clinton Township. Downstream along Twenty Mile Creek, near Balls Falls, Gasport Dolomite was won for the production of lime. To the east, in lot 12, concession VII, Louth Township a small quarry was opened in brown, finely granular Lockport Dolomite.

The maximum thickness of rocks in the area suitable for

aggregate production is about 45 feet. The presence of some 40 feet of Rochester Shale between rocks of the upper and lower quarries, prevents extensive quarry development. The shale is not economically useful now although it was previously employed in the manufacture of rock wool. In an area of drift thicknesses of between 25 and 50 feet, west of Balls Falls, the Vineland quarry produces crushed stone from Lockport Dolomite. A section and description are given by Hewitt (1960, p.98, 99). Locally the overburden is apparently much lighter (from 1 to 3 feet) than would be expected from water well information in the surrounding area. Goat Island beds are free from chert in the quarry but contain irregular plates and nodules at a geologically higher level to the south.

Chemical analyses of Gasport and Goat Island Dolomites in the area are given in (9a) and (9b):

(9a) CHEMICAL ANALYSES - VINELAND QUARRIES AND CRUSHED STONE LIMITED*

(Analyses by the Provincial Assay Office, Ont. Dept. Mines, 1959)

Sample No.	Height Above Floor	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	CO_2	S	Total
	feet	percent	percent	percent	percent	percent	percent	percent	percent
1	0-15	2.66	2.45	0.85	30.01	19.70	43.45	0.84	99.96
2	15-35	3.38	1.06	0.70	29.90	20.48	45.10	0.08	100.70

* Reproduced from Hewitt 1960, p.99.

(9b) ANALYSES OF LINCOLN COUNTY LIMESTONES**

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
321	.70	0.59	0.80	0.07	52.62	41.73	99.51
323	0.86	0.64	0.47	.20	53.21	43.92	99.30

321. Jordan. Lockport dolomite exclusive of chert nodules in quarry worked for road metal in valley of Twentymile creek on lot 2, concession VIII, Clinton Township.

323. Jordan. Lockport dolomite on top of the Niagara escarpment in the valley of Sixteenmile creek, lot 15, concession VII, Lough Township.

** Reproduced from Goudge 1938, p.255.

Beamsville, Clinton Township

A large area of potential quarry development stretches across Clinton Township, from 1 mile south of the brow of the Escarpment at Beamsville to about 3 miles south (see Map P.537). It is separated from old building stone quarries on the brow by a till moraine of up to 90 feet thick at higher elevation.

Low drift thicknesses pertain east of this moraine, continuing through Campden to connect bedrock outcrops on the brow of the escarpment with the area of low overburden south of the moraine. The latter area is drained by Spring Creek to the south and by a smaller tributary of Twenty Mile Creek near the centre. It is generally underlain by clay deposits and bedrock outcrops. Elevations range from 600 feet in creek beds to a little more than 650 feet in the highest points. Information from drill core in the centre of this area indicates the presence of more than 87 feet of Lockport Dolomite. The contact between Goat Island and Gasport Dolomites occurs at a depth of 62 feet. The rocks are generally suitable for quarrying although the presence of chert in a fifteen-foot section of Goat Island Dolomite may detract from its potential value.

Two small areas south and southeast of Tintern, in the bed of Sixteen Mile Creek, have little drift cover. Since they occur in the riverbed they cannot be considered favourable for quarrying however.

Grimsby

The area directly south and southeast of Grimsby is a continuation of the quarriable Clinton Township domain (see Map P.536). Low drift thicknesses are recorded in most lots up to lot 8 of concessions III to VI, North Grimsby Township and VII and A, South Grimsby Township. West of lot 8 and south of concession A overburden thicknesses increase to over 30 feet in several instances. To the north a continuous till moraine deposit, about one half mile wide and frequently more than 25 feet thick, follows the Escarpment adjacent to the brow. The deposits are predominantly clay with stones, similar to those south of the moraine. Sand or gravel rarely occur.

Dolomites exposed on the brow, between Thirty Mountain

Church and Grimsby, belong to either the Gasport Member of the Lockport Formation or the DeCew Formation. An apparent dip of 29 feet per mile south of Grimsby leads one to expect a section of 100 feet of quarriable rock near Grimsby Centre where the bedrock surface is not much below an elevation of 640 feet. Information available at the time of writing indicates that in this area there are 34 feet of fine crystalline to aphanitic, and towards the bottom shaly, Eramosa Dolomite overlying fine to medium crystalline dolomite of the Goat Island Member. The latter is generally hard. A minor amount of chert was encountered near the top of the Goat Island Member and gypsum inclusions appear at a depth of 23 feet below the contact with Eramosa.

The area surrounding Smithville, with an elevation of approximately 620 feet, has supported small quarries for production of road metal and building stone for local use. Eramosa Dolomite of brownish grey colour, aphanitic to fine crystalline and medium bedded, with occasional uneven bedded coralline reefs, is found in the creekbed southeast of Smithville.

Downstream from St. Anns the riverbed is surrounded by clay deposits of more than 25 feet depth. Northwest and east of Smithville the drift cover consists of clay with occasional deposits of gravel or clay and stone near the bedrock surface.

Vinemount, Saltfleet Township

Till moraine deposits between Vinemount and Grimsby crowd the brow of the Escarpment (see Map P.536). They are about one half mile wide and over 40 feet thick extending west of Vinemount to where Stoney Creek approaches the Escarpment. The area just south of this moraine is drained by Stoney Creek and Forty Mile Creek. Parallel to the creek beds and extending from north of the creeks to as much as two miles south of the creek near Tweedside, a strip of land is underlain by shallow overburden. Central to this area is the Vinemount Quarry operated by Armstrong Brothers Company Limited in lot 5, concession V, Saltfleet Township. A section and description are given by Hewitt (1960, p.100-103). The quarry has recently been deepened. According to the log of an oil well drilled on lot 21, concession IV, North Grimsby Township, the top of Rochester Shale occurs at an elevation of 603 feet in this area. From the information of this well and other oil wells to the south, a dip of the beds

of 30 feet per mile in a southerly direction can be deduced. The depth of quarriable rock near Tweedside is expected to be about 80 feet therefore. At the lower elevation of creekbeds north of the Vinemount Quarry the quarriable depth will be reduced to 25 feet or less.

The quarry section by Hewitt (1960, p.101) indicates the shaly character of Eramosa Dolomite. Soundness loss of this material makes it unsuitable for use as aggregate for asphalt and concrete. Granular base course Class "A" and 5/8" crushed gravel can be produced from the better quality stone underneath, although here limitations are imposed by the presence of 8 feet of Ancaster Chert Beds.

A neighbouring quarry on lot 4, concession V, Saltfleet Township was previously operated by a subsidiary of Canada Crushed Stone Corporation Limited. Goudge (1938, p.307-308) remarks that operations ceased in 1930 when the crushing plant was destroyed by fire. The quarry bottomed on the shaly facies of Eramosa Dolomite. Small quarries in the neighbourhood of Tapleytown have been worked in dolomite of the Goat Island Member. An analysis is given in (10), sample 311.

Thick drift deposits are found between the parallel courses of Forty Mile Creek to the north and Twenty Mile Creek to the south. Thicknesses up to 50 feet are reported between Grimsby Centre and Grassie. The bedrock surface in this area occurs at an elevation of about 600 feet, which is the elevation of Twenty Mile Creek near Smithville. Surface drainage may at one time have created a valley below this elevation. Information at hand does not allow its course to be guessed. It seems likely however that a buried valley would have been discovered anywhere but in areas of high overburden to the southeast.

Former drainage of the bedrock surface west of the above area does not present a similar problem. Here, thick overburden deposits find expression in topographic elevation. The overburden deposits are referred to as the Vinemount Moraine. They are characterized in water well logs as clay. Stones and gravel occur at depth near the bedrock surface.

The area drained by Twenty Mile Creek south of the Vinemount Moraine has shallow drift deposits for about one mile on either side of the creekbed. Provided that deep quarrying is not prohibited by excess flooding it should be

possible to quarry to a depth of approximately 150 feet on high ground.

Little is known about the quality of the rock however and thorough testing will be necessary before a site for quarrying is decided upon. Near Kimbo 126 feet of Lockport Dolomite have been intersected in an oil well. The rock is fine crystalline to aphanitic, with calcite vugs in the aphanitic section. Medium crystalline dolomite of very light grey to medium grey colour occurs for 28 feet before the Rochester Shale is reached. The reported thickness of Rochester Shale is 50 feet.

Mount Albion, Saltfleet Township

The escarpment area between Mount Albion and the bed of Stoney Creek is only partly covered by overburden (see Map P.536). Bedrock outcrops are frequent west of Highway 20 and to the south until higher ground is reached near Elfrida. The thicker overburden deposits here are part of the Vinemount Moraine which is less heavy in surrounding areas. A small moraine deposit stretches northeast from Hannon, one half mile south of Mount Albion.

Rocks on top of the Escarpment are being quarried by A. Cope and Sons Limited. A section and description are given by Hewitt (1960, p.103-105; 1964, p.44). The quarry extends over lots 25-28, concession VI, Saltfleet Township. The shaly facies of Eramosa (Vinemount Shale) is very much in evidence in some parts of the quarry but less so to the east, near Highway 20, where the dolomite is medium bedded.

Underneath the Vinemount Shale Unit there is another 24 feet of dolomite before the Ancaster Chert Beds are reached. At the Highway 20 road cut the Gasport is thin (4.4 feet) and 32 feet of shaly dolomite and shales separate these quarriable rocks from the Irondequoit Limestone and Reynales Dolomite, together 14 feet thick. Quarrying is primarily of interest therefore in areas of higher elevation to the south, provided that the quality of the Eramosa and Guelph Dolomite to be found there is adequate.

Eramosa Dolomite has been quarried extensively south of Hamilton. Goudge (1938, p.304-308) reports several locations from which at one time road metal, lime and building stone were produced. Chemical analyses of samples and their locations are reproduced in (10):

(10) ANALYSES OF WENTWORTH COUNTY LIMESTONES*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
297	0.66	0.32	0.36	0.02	55.66	42.04	99.06
304	0.36	0.38	0.18	Tr.	55.23	43.21	99.36
305	0.54	0.25	0.23	0.02	55.13	43.58	99.75
305A	0.34	0.27	0.15	0.02	55.43	43.23	99.44
306	0.32	0.26	0.10	Tr.	56.79	42.56	100.03
307	0.26	0.23	0.09	Tr.	55.66	43.92	100.16
310	0.86	0.40	0.46	0.04	55.66	42.64	100.06
311	2.40	0.61	1.37	0.13	53.14	42.64	100.29
314	0.98	0.28	0.36	0.04	56.07	42.87	100.60

297. Rockton. Guelph dolomite in quarry on lot 18, concession IV, Beverly Township.
304. Hamilton. Lockport dolomite in quarry of Gallagher Lime and Stone Company.
305. Hamilton. Top 6 feet of Lockport dolomite on property of Hamilton Lime and Cement Works.
305A. Hamilton. Next 12 feet of Lockport dolomite on same property.
306. Rymal station. Lockport dolomite in idle quarry on lot 5, concession VIII, Barton Township.
307. Rymal station. Lockport dolomite one-half mile south of where Sample 306 was taken.
310. Tyneside. Guelph dolomite in bed of brook on lot 17, concession VII, Binbrook T ownship.
311. Tapleytown. Lockport dolomite in old quarry on lot 17, concession V, Saltfleet Township.
314. Woodburn. Lockport dolomite in bed of Twentymile Creek at boundary between Wentworth and Lincoln Counties.

* Reproduced from Goudge 1938, p.308-309.

Of particular interest are remarks on a quarry near Woodburn, on lot 1, concession I, Binbrook Township, in an area of less than 25 feet of overburden. The dolomite is described as dark brown, finely granular, variably thin to thick bedded, with patches of black shale, and smelling of petroleum when freshly broken. This dolomite is also exposed in the bed of Twenty Mile Creek east of Woodburn ((10), sample 314). It has been quarried for road metal and building stone. The feasibility of opening a large quarry in this area depends on the results of rock tests and solution of drainage problems. Near Woodburn the expected quarriable depth, consistent with a southward dip of the beds of 28 feet per mile, is 125 feet to possibly 190 feet, depending on the magnitude of the Vinemount Shale Unit and the composition of the Ancaster Chert Beds. Rochester Shale occurs at an elevation of approximately 460 feet and is 40 feet thick according to information from an oil well near Binbrook.

Rocks belonging to the Guelph Formation are as a rule less desirable for aggregate production. They are softer than Eramosa Dolomite. Goudge (1938, p.307) mentions outcrops near Tyneside in the bed of the Welland River. Old quarries in the Escarpment area south of Hamilton were all located in rocks of the Lockport Formation or on the contact of Lockport and Guelph Formations, as shown by Caley (1940, Map 584A).

Dundas

A prominent feature in the Escarpment topography is the re-entrant valley at Dundas (see Map P.535). It occurs at a point where the general direction of the Escarpment changes from east-west to north-south. To the east the Dundas valley finds a natural extension in Lake Ontario. Water well information establishes its continuation westward as a deeply eroded channel in the bedrock surface presently filled with drift deposits. Drift thicknesses range up to 200 feet along the boundary of Ancaster and Beverly Townships as far west as Lynden. A maximum thickness of 571 feet is reported just east of Copetown. Part of the valley east of here is referred to as the Dundas gorge by Hurst (1962, p.20). Based on dip measurements on both sides of the valley Hurst postulates a minor anticlinal fold with its axis running through the center of the valley. The manner of development of the Dundas valley and other re-entrants in the Escarpment is debated in the literature. Recently the importance of erosion by glaciers over that of pre-glacial or interglacial erosion by drainage water has been stressed by Straw (1968).

The drift deposits near Copetown are primarily red and blue clay and silt; sand and fine gravel are prominent only from a depth of 80 to 147 feet.

Dolomite is exposed on the brow of the Escarpment at Dundas where a quarry was previously operated by Canada Crushed and Cut Stone Limited. Dolomites of the Guelph Formation and the Eramosa Member of Lockport Dolomite were quarried to a depth of about 60 feet. Below this depth the Eramosa Dolomite is increasingly more shaly. When expansion in 1935 required removal of over 30 feet of overburden the company opened a new quarry to the northwest, in lots 10 and 11, concession II, West Flamborough Township.

The latter quarry and geological section are described by Hewitt (1960, p.106-110; 1964, p.44). Six feet of light

grey, medium bedded, aphanitic dolomite of the Guelph Formation overlie Eramosa Dolomite of which 44 feet is exposed in the face of the quarry and another 15 feet in a separate lift below the main quarry floor. The Eramosa Dolomite is medium dark brown to light brown, medium to thick bedded and aphanitic. The lower 15 feet are more shaly and thin bedded.

Following the brow of the Escarpment northeastward a second quarry is encountered at Clappisons Corners. It is described by Hewitt (1960, p.112-113; 1964, p.45). In a 35-foot face a complete section of the Reynales, Irondequoit and Rochester Formations is exposed, overlain by the Gasport and part of the Goat Island Member of Lockport Dolomite. The floor of the quarry exposes sandstone and grey-green shale of the Thorold Formation.

Northeast of here and about two miles east of Waterdown the old Nelson Quarry is located on the brow of the Escarpment. A 44-foot quarry section is described by Hewitt (1960, p.113). Thirty feet of light grey to buff, medium crystalline, porous, fossiliferous and occasionally reefy Amabel Dolomite overlie 13 feet of the Clinton Group sediments. Irondequoit Limestone and Rochester Shale have their most northern outcrop at this location. These formations seem to pinch out against Amabel Dolomite which rests directly on Reynales Dolomite north of here.

To the northwest, away from the brow of the Escarpment, there is little room for quarry development in this area. Heavy overburden is found at a distance of about one half to one mile. The deposits belong to the Waterdown Moraine. Several crests of this moraine can be distinguished in the topography. Attendant drift thicknesses are up to 90 feet at Mill Grove. The moraine deposits are continuous from Bullocks Corners near Dundas to the bed of Bronte Creek at Cedar Springs. They do not occupy the area east of Lake Medad however.

Mount Nemo, Burlington Township

East of Lake Medad less than 25 feet of overburden is found over an area of 5 miles by 2 to 2½ miles. The quarry potential of this area is confirmed by the presence of the Mount Nemo Quarry, one of the largest limestone quarries in Ontario (see Map P.535). Nelson Crushed Stone Limited, a division of King Paving and Materials Limited of Oakville,

produces here over 1,000,000 tons of crushed stone per year, largely for road construction and concrete aggregate. The quarry is located on lots 1 and 2, concessionsII and III, Burlington Township. The operation and geological section are described by Hewitt (1960, p.113-118; 1964, p.45).

In the quarry face some 50 to 70 feet of Amabel Dolomite are exposed overlying the Reynales Formation. The upper 30 to 50 feet is massive and reefy dolomite showing reef mounds of 100 to 300 feet wide and 20 to 50 feet high. The dolomite is porous, hard and fossiliferous. Below this reefy dolomite another 14.5 feet of medium bedded Amabel Dolomite is present.

The Amabel Dolomite is medium crystalline in contrast to the underlying aphanitic Reynales Dolomite of which 3½ feet are included in the quarry section.

Outcrops of light grey, medium crystalline dolomite are common in the area. Uneven amounts of sand, clay and boulder till fill in the holes between massive reefmounds which were left after erosion of the bedrock surface. Stripping is difficult and the upper few feet of weathered rock may be quarried separately as was done in the Lowville Quarries two miles southeast of Lowville.

The Lowville Quarries are not operating at present. Hewitt (1960, p.118) reports 70 feet of Amabel Dolomite exposed in the quarry face. The upper 50 feet of this dolomite is reefy. The stone was mainly used for road construction and as concrete aggregate.

The quality of stone in the Mount Nemo area is high. Products are suitable as aggregate for asphalt and concrete. Chemical analyses representing the complete section of the Mount Nemo Quarry of Nelson Crushed Stone Limited are given in (11):

(11) CHEMICAL ANALYSES - NELSON CRUSHED STONE LIMITED*

(Analyses by the Provincial Assay Office, Ont. Dept. Mines, 1959)

Sample No.	Height Above Floor	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	CO_2	P_2O_5	S	Total
	feet	percent	percent	percent	percent	percent	percent	percent	percent	percent
1	0-18	0.88	0.21	0.82	21.15	30.30	46.33	0.10	0.42	100.21
2	18-38	1.58	0.25	0.47	21.13	29.30	45.30	0.13	0.20	98.36
3	38-50	1.74	0.20	0.37	21.11	30.00	45.83	0.09	0.05	99.39

* Reproduced from Hewitt 1960, p.115.

West Flamborough Township

West of the Waterdown Moraine, in West Flamborough Township, bedrock outcrops and loose boulders and slabs of dolomite indicate the shallowness or lack of overburden (see Map P.535). Surface rocks range from medium dark brownish grey, aphanitic dolomite east of Hayesland on the Brock road to light grey, buff weathering, porous and aphanitic dolomite west of this place. South of Hayesland the dolomite is light brownish grey, aphanitic and porous.

The presence of a gradational contact between Eramosa and Guelph dolomite has been mentioned in connection with a quarry on lot 6, concession IV, West Flamborough Township (p.22). This contact crosses the Brock road north of Hayesland, in the vicinity of the crossing of a tributary of Spencer Creek.

Goudge (1938, p.298) mentions the production of lime from Guelph Dolomite in lots 5 and 6, concession V, West Flamborough Township. Other quarries are reported by Goudge (1938, p.298) near Freelton and west of Valens in Beverly Township. Both quarries produced road metal, supposedly from Guelph Dolomite.

In a 25-foot face in the quarry near Freelton lower beds of coarse-grained, yellowish grey, coralline dolomite of possible Lockport age underlie fine-grained, bluish grey dolomites which Goudge thinks may belong to the Guelph Formation.

Drilling near Hayesland for Canada Crushed and Cut Stone

Limited, on lots 7 or 8, concession VI, West Flamborough Township, indicated 60 feet of high-purity dolomite.

A thickness of 175 to 200 feet of Guelph-Amabel Dolomite is encountered in oil wells in West Flamborough Township near the boundary with Beverly Township. In lot 2, concession VI, 174 feet of Guelph-Amabel Dolomite plus 8 feet of the Reynales Formation were intersected before the Cabot Head Shale was reached. The dolomite is brownish grey to dark grey and predominantly fine crystalline to aphanitic in the upper 80 feet. At lower depth the dolomite is light grey and medium crystalline. In lot 1, concession III, a thickness of 212 feet of dolomite is reportedly overlying the Cabot Head Formation. The rock is yellowish grey to light brownish grey and fine crystalline to a depth of 80 feet. Another 60 feet is medium grey and aphanitic, underlain by creamy white to light grey, fine crystalline to aphanitic dolomite.

North of the previously mentioned tributary of Spencer Creek the bedrock is partly overlain by drumlins. A drumlin field with drumlins predominantly in east-west direction stretches west across West Flamborough and Beverly Townships, to meet the Galt Moraine west of Sheffield. The most southern drumlins occur between Westover and Sheffield. Drift thicknesses up to 122 feet have been reported in these drumlins. The material encountered is variously characterized as sand, gravel and stony clay. Other glacial deposits are shown on ODM Map 2029, Pleistocene Geology of the Galt Area (Karrow 1963). Some peat and muck is present in swampy areas.

Beverly Township

Large parts of Beverly Township are underlain by bedrock. Outcrops of Guelph Dolomite are common everywhere north of Highways 5 and 8 as far west as Sheffield. Only the northwest corner of the township is taken up by thick overburden deposits of the Galt Moraine. Scattered overburden deposits in the northern part of the township are made up of drumlins and moraine material alternating with peat in swampy areas. Much of the shallow overburden between Sheffield and Troy, and from Troy east to Peters Corners, consists of clay, silt and some sand deposited in glacial lakes.

Troy, Beverly Township

Small areas of bedrock outcrop occur in the bed of Fairchild Creek near Troy. A section of about 8 feet, east of Troy, shows light grey, medium to thick bedded, aphanitic to fine crystalline dolomite. The dolomite is porous and vuggy. Minor reefs are present. An oil well on lot 1, concession III, Beverly Township intersected 16 feet of Rochester Shale at a depth of about 300 feet. Buff, dark grey and white dolomite are overlying the shales. A bore hole in lot 14, concession IV, Beverly Township intersected close to 300 feet of dolomite. The upper 100 feet is very light to medium light grey and fine crystalline; the lower beds are predominantly medium crystalline and range in colour from light to medium grey. Some road metal and lime have been produced in the Troy area.

Sheffield, Beverly Township

Bedrock in outcrops surrounding Sheffield is thick to thin bedded, vuggy, fine crystalline to aphanitic and light- to medium-light-grey. It is generally fossiliferous and porous. A regular bedrock surface underlain by even bedded dolomite is evident from exposures in a creek bed on lot D, concession IV, Beverly Township. Road metal has been produced from a quarry on lot 5, concession VII, Beverly Township, according to Goudge (1938, p.297).

Rockton, Beverly Township

Thin bedded, medium light grey dolomite is exposed 2 miles north of Rockton along Highway 52. Near Rockton outcrops of light grey, medium bedded dolomite are found. The latter dolomite is porous and fine crystalline but not as fine grained as the thinner beds to the north.

At the intersection of Highways 5 and 8 there is an abandoned quarry. The face of the quarry shows a 12-foot section of very fine crystalline to aphanitic Guelph Dolomite. The dolomite is light grey and predominantly thin bedded near the top and light to medium light grey and medium bedded in the lower 8 feet. A two-inch bed with prominent shaly parting and nodular surface separates these two sections. Minor fossil cavities and worm borings filled with calcite are prevalent in the lower beds. Shaly parting with occasional development of stylolites is common. Goudge (1938, p.298)

informs us that this quarry has produced road metal. An analysis of the rock exclusive of the shaly component is shown in (10), sample 297.

Little is known about the history of this quarry. Suspension of operations at an early date may reflect the quality of the stone but no details are available.

Beverly Swamp

In the northern part of Beverly Township, between deposits of the Moffat Moraine near Valens and drumlins to the southeast, a large area of flat land with shallow overburden is known as the Beverly Swamp. Peat and some marl cover the bedrock. The organic soil is from 3 to 7 feet deep. Peat from this area is sold to gardeners. Lack of drainage will no doubt impede quarry development here.

Valens, Beverly Township

Along Highway 97, 2 miles east of Valens, 5½ feet of medium bedded, aphanitic, porous and vuggy dolomite is exposed, ranging in colour from light brownish grey near the top to medium dark brown in the lower two feet. In the area an oil well, drilled on lot 35, concession VI, Beverly Township, intersected over 200 feet of dolomite before the Cabot Head Shale was reached. Light brown, fine crystalline dolomite is underlain by medium grey, aphanitic dolomite below a depth of 55 feet. At 95 feet depth a change to medium crystalline, light grey to creamy white dolomite takes place. This dolomite is over 100 feet thick.

Although production of road metal has taken place in several areas of Beverly Township careful testing must be carried out before the choice of a quarry site is made. Guelph Dolomite is frequently found too soft for use as aggregate. It is better known for its high purity which will be discussed in connection with production of lime in the Guelph area.

Milton

The Milton area combines a readily available supply of stone with proximity to a market. Three large quarries, the

Milton, Dufferin and Halton Crushed Stone Quarries, have opened here since 1958 and cater to the Toronto market (see Map P.534).

Milton Quarries Limited produces crushed stone and some armour stone from the northern tip of the Milton outlier, 1 mile west of Milton. The quarry is located in lot 1, concession VII, Nassagaweya Township. The outlier is an area of high elevation rising over 300 feet above its surroundings and capped by typical scarp-forming Amabel Dolomite. A narrow valley separates the outlier from the main Escarpment.

The caprock of the outlier is exposed in sheer cliffs of up to 100 feet high. It covers an area of 3 miles by about 1½ miles and is quarried to a depth of 75 feet in the Milton Quarry. In other quarries to the west near Christie the same rocks have been quarried to a depth of 90 feet. Operations and geological sections are described by Hewitt (1960, p.119-120; 1964, p.47).

The Amabel Dolomite is light grey to buff, massive to medium bedded, medium to coarsely crystalline and crinoidal. It is in part reefy and vuggy. Medium grey to bluish grey, mottled, aphanitic dolomite of the Reynales Formation underlies the Amabel Dolomite and forms the floor in both quarries. Colour changes in the lower 6 to 8 feet of Amabel Dolomite suggest possible correlation with subdivisions in the lithology of the Niagara Peninsula.

Chemical analyses representing respectively the 80-foot quarry face near Christie (12a) and a sample of 2-inch stone from the stockpile in the Milton Quarry (12b) are given in (12).

(12) CHEMICAL ANALYSES OF DOLOMITE OF THE MILTON OUTLIER

(a)*

Sample No.	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
	percent	percent	percent	percent	percent	percent	percent
289	0.38	0.48	trace	0.04	55.11	43.25	99.26

(b)**

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	S	P	LOI	Total
1.84	0.59	0.67	32.26	17.67	0.14	0.001	46.60	99.77

Note: LOI = Loss on ignition.

* Reproduced from Goudge 1938, p.242.

** Reproduced from Hewitt 1964, p.47

Bedrock in the Milton outlier is generally covered with less than 25 feet of overburden although elevations in the area range from 1,000 to 1,075 feet. Up to 20 feet of overburden has to be removed at the Milton Quarry as the face progresses westward. In areas of higher elevation towards the centre of the outlier a larger section of quarriable rock may be expected. One waterwell near Rattlesnake Point bottomed out in grey limestone at a depth of 106 feet.

The quarry of Halton Crushed Stone and the Dufferin Quarry of Associated Quarries and Construction Limited are described by Hewitt (1960, p.120-121; 1964, p.48-52). They are located on the brow of the Escarpment north of Highway 401, respectively in lot 8, concession VI, Nassagaweya Township and lots 9 and 10, concession I, Esquesing Township.

The Amabel Dolomite is here light grey to buff, medium to coarsely crystalline, medium bedded to massive and highly fossiliferous. It is in part irregularly bedded and reefy and in part porous. The lower 6 to 10 feet of Amabel are distinguished by a change in colour to grey and buff banded or medium grey dolomite which is medium to thick bedded.

The Reynales Dolomite underlying the Amabel Formation is fully exposed in the Halton Crushed Stone Quarry and only

partly in the Dufferin Quarry. It is a medium bedded, aphanitic dolomite which is grey to buff, mottled or grey green in colour and from 6 to 8 feet thick in the area.

The dolomite quarries produce mainly crushed stone and some armour stone. The stone is of high quality, suitable for use in asphalt and concrete. Three chemical analyses are given in (13):

(13) CHEMICAL ANALYSES - HALTON CRUSHED STONE AND DUFFERIN QUARRY*

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	S	CO_2	Total
a)	0.59	0.04	0.46	31.08	20.59	0.04	46.88	99.68
b)	0.16	0.69	0.33	30.28	21.02	-	47.22	99.70

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI	SO_3	Total
c)	1.30	1.54	0.30	29.52	20.94	47.44	0.12	101.16

a) Supplied by Halton Crushed Stone Ltd.
b) Sample of 3/4 inch stone from stockpile, Halton Crushed Stone Ltd.
c) Sample of 1-inch stone from stockpile, Dufferin Quarry.

* Reproduced from Hewitt 1964, p.49 and 51.

A sandstone quarry is operated by W.R. Barnes on lot 6, concession VI, Nassagaweya Township. It produces from Whirlpool Sandstone at a lower level in the Escarpment section.

An area of potential quarry development about 5 miles wide runs parallel to the brow of the Escarpment west of Milton. It is limited to the west by scattered deposits of Moffat Moraine and drumlins and beyond by the more continuous deposits of Galt Moraine. Scattered deposits of overburden are also found to the south in the eastern part of Puslinch Township and the northern part of East Flamborough Township. The overburden consists mainly of clay and stones or gravel. Gravel deposits are excavated south of Rattlesnake Point at the mouth of the valley between the Milton outlier and the main Escarpment. Commercial gravel deposits are also found near Campbellville, just north of Highway 401.

Puslinch

Potentially favourable ground with little overburden is found south of a line through Puslinch and Mountsberg (see Map P.535). In Puslinch Township this area, occupying both sides of the Canadian Pacific railway line and extending westward to lot 25, Puslinch Gore supports several old quarries. Goudge (1938, p.295) mentions a quarry on lot 29, Gore of Puslinch Township, from which Guelph Dolomite was won for the production of white lime. Another quarry on lot 34, Puslinch Gore produced crushed dolomite. Chemical analyses of rocks in both quarries are given in (14), samples 285 and 286.

(14) ANALYSES OF WELLINGTON COUNTY LIMESTONES*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_3$	$CaCO_3$	$MgCO_3$	Total
281	0.41	0.42	0.37	0.04	55.63	42.91	99.78
281A	7.96	0.68	1.19	n.d.	51.00	39.13	99.96
283	0.28	0.17	0.07	Tr.	56.07	43.10	99.69
283A	0.26	0.23	0.19	Tr.	55.57	43.31	99.56
285	0.20	0.34	Tr.	Tr.	55.14	43.19	98.87
286	0.34	0.27	0.33	Tr.	54.77	43.94	99.65
286A	0.16	0.11	0.19	Tr.	55.05	45.13	100.64
286B	0.12	0.24	0.13	0.02	55.12	44.94	100.57

281. Rockwood Lockport dolomite in quarry formerly worked by E. Harvey, Ltd.
281A. Rockwood Impure reefs in Lockport formation in the same quarry.
283. Guelph Quarry of Canadian Gypsum Company, top buff dolomite (Guelph formation).
283A. Guelph Same quarry; bottom 7 feet of dark brown dolomite.
285. Puslinch Guelph dolomite in abandoned quarry formerly worked to supply a lime plant.
286. Puslinch Puslinch Quarry Company, Ltd.; top 15 feet of Guelph dolomite.
286A. Puslinch Same quarry; next 11 feet of Guelph dolomite.
286B. Puslinch Same quarry; bottom 6 feet of Guelph dolomite.

* Reproduced from Goudge 1938, p.296.

Diamond drilling on lots 27 and 28, Puslinch Gore, mentioned by Hewitt (1960, p.125), intersected 42 feet of Guelph Dolomite and bottomed in Eramosa Dolomite at a depth of 90 feet. Chemical analyses of these intersections are given in (15):

(15) CHEMICAL ANALYSES - PUSLINCH DRILLING*

(Analyses by the Warnock Hersey Company Limited, by permission of J.D. Campbell)

Depth	SiO_2	Fe_2O_3 + Al_2O_3	$CaCO_3$	$MgCO_3$	S	Organic Matter
feet	percent	percent	percent	percent	percent	percent
5-10	0.42	0.23	54.05	44.85	0.03	0.01
10-20	0.58	0.41	55.55	43.26	0.03	0.03
20-30	0.48	0.37	54.55	44.33	0.02	0.08
30-40	0.11	0.19	54.38	44.82	0.02	0.07
40-50	0.42	0.33	54.19	44.56	0.04	0.25
50-60	0.76	0.39	54.21	44.07	0.09	0.31
60-70	3.64	0.55	51.15	41.72	0.27	1.51
70-80	8.39	1.16	48.58	39.08	0.31	1.16
80-90	5.79	0.90	51.75	39.64	0.27	0.50

* Reproduced from Hewitt 1960, p.126.

The dolomite is of high purity and suitable for use as chemical and flux stone to a depth of about 60 feet.

In an oil well near Morriston, in lot 30, concession VII, Puslinch Township, a section of 200 feet of dolomite was found to overlie the Cabot Head Shale.

Kilbride, Town of Burlington

From Puslinch east to Kilbride on the brow of the Escarpment, there is a gradual drop in elevation. Combined with an inverse inclination of the bedding planes this loss of elevation of the surface significantly reduces the quarry potential of the area. An oil well on lot 2, concession X, East Flamborough Township, collared at an elevation of 869 feet, intersects only 34 feet of dolomite before reaching the Cabot Head Shale.

On higher ground to the northeast, one quarter mile southwest of Crawford Lake, in lot 15, concession III, Burlington Township, dolomite extends to a depth of at least 48 feet.

Guelph Junction, Nassagaweya Township

One mile southwest of Guelph Junction, at an elevation of about 975 feet, more than 89 feet of dolomite is found. Distinct colour changes occur at 46 and 58 feet, from grey to brown and from brown to white respectively. Approximately 2 miles east of here, south of Campbellville, red shale of the Cabot Head Formation is intersected at an elevation of about 885 feet, limiting the expected section of quarriable rock around Guelph Junction to about 100 feet. A larger intersection was encountered near the Mohawk Raceway on lot 9, concession 3, Nassagaweya Township. Drilled at an elevation of approximately 1,020 feet the well intersected white limestone to a depth of 9 feet, brown limestone to 59 feet and grey limestone to 135 feet, followed by blue shale at an elevation of approximately 885 feet.

Moffat, Nassagaweya Township

Near Moffat, on lot 15, concession I, Nassagaweya Township a well collared at about 1,020 feet elevation intersects black dolomite to a depth of 57 feet and below that brown, blue and grey dolomite respectively to the bottom of the well at a depth of 114 feet. The black rock is part of the Eramosa Dolomite which is also found in outcrops in this area. It is difficult to assign the 10 to 12 feet of brown dolomite underlying the Eramosa Dolomite. Outcrops of the contact of Eramosa Dolomite with underlying dolomite of the Amabel Formation are lacking.

Acton

The Acton area is geographically favourable for future quarry development (see Map P.534). Highways 7 and 25 together with the Canadian National railway from Toronto to Guelph provide the area with multiple access routes.

Abundant land with shallow overburden and bedrock outcrops is found alongside Highway 25, from Speyside north to Acton. Quarriable rock may be expected to bottom out at elevations of about 1,025 feet near Speyside to about 1,050 feet west of Acton. In lot 23, concession III, Nassagaweya Township, 5 miles southwest of Highway 25, near Darbyville, an oil boring intersected Cabot Head Shale at an elevation of 915 feet. This compares with an elevation of 850 feet for shales near

Guelph and 915 feet for Cabot Head Shale 3 miles east of Fergus in lot 32, concession II, Eramosa Township. Based on these figures a southwesterly dip of the Cabot Head Shale surface of roughly 20 feet per mile may be assumed.

Two large quarries in the area, the Georgetown Quarry of Armstrong Brothers Company Limited, 3 miles west of Georgetown, and the operation of Acton Limestone Quarries Limited near Acton, at the site of the old Dolly Varden property in lots 23 and 24, concession IV, Esquesing Township, both excavate to a depth of about 50 feet. In the former quarry, located close to the brow of the Escarpment, the face includes about 5 feet of Reynales Dolomite. A descripton is given by Hewitt (1960, p.121).

Amabel Dolomite in the upper part of the quarry face is light grey to light buff, medium crystalline to aphanitic, medium to thick bedded and crinoidal. In the Acton quarry only Amabel Dolomite is exposed. The Reynales Formation can be seen in a roadcut a few feet beneath the quarry floor. It is 8 feet thick here.

The Acton quarry opened in 1963. The geology and operation are described by Hewitt (1964, p.51-52). The quarry has the benefit of being located next to the Canadian National railway and a siding has been built to serve the quarry. It is approximately 34 miles by rail to the Union Station in Toronto. Up until 1930 the quarry was worked for the production of dolomitic lime by the Toronto Lime Company. At present it is one of the largest producers of crushed rock.

Amabel Dolomite in the Acton Quarry is light buff to light grey, medium to coarsely crystalline, medium to thick and irregularly bedded, crinoidal and in part porous.

Reefy Amabel Dolomite is found in several outcrops south of Acton and west of Crewsons Corners (see Map P.534). It is generally medium crystalline, fossiliferous and porous. A light to very light grey, thick bedded to massive dolomite is exposed along Highway 7, just southwest of Crewsons Corners. On higher ground, 1 mile west of Crewsons Corners and north of the railway, medium brownish grey, fine crystalline, fossiliferous, reefy and porous dolomite is found. Due south of there, in the bed of Blue Springs Creek, outcrops of medium light grey, medium crystalline, fossiliferous, massive and reefy dolomite occur at elevations of approximately 1,090 and 1,120 feet. In general the area directly north, west and

southwest of Crewsons Corners is favourable for quarry development.

South of Acton, at a distance of 1¼ miles, medium light grey to medium grey, medium crystalline, reefy dolomite is exposed at an elevation of 1,190 feet. West of this outcrop and north of Knatchbull deposits of the Galt Moraine reach thicknesses of more than 60 feet.

Heavy overburden is found all along the southern shores of Blue Springs Creek and Eramosa River, from south of Crewsons Corners to Guelph. Deposits of the Galt and Paris moraines cover most of the area to the south and effectively bar quarry development there. Overburden thicknesses of 125 feet or more are common. The moraine material consists primarily of clay with stones; sand and gravel are less frequently encountered.

The area north of Acton is only partly favourable for quarry development. A strip of land between Acton and Ballinafad, approximately 1 mile wide and underlain by bedrock and shallow overburden, is separated from quarry land along the brow of the Escarpment by an almost 2-mile wide zone of hummocky terrain with kame deposits of a thickness of more than 25 feet. Between these kame deposits and the brow there is less than one mile of quarriable ground left. The maximum quarriable depth to be expected in this area does not exceed that of the Georgetown Quarry which is 50 feet deep. Both loss of elevation and inclination of the beds combine to diminish the amount of quarriable rock to the north. The presently inactive quarry of Limehouse Crushed Stone and Gravel Limited on lot 27, concession VIII, Esquesing Township, operated on a 15-foot quarry face.

Rockwood, Eramosa Township

The Eramosa River flows along bedrock for a large part of its course from Everton to Guelph (see Map P.534). The riverbed is particularly narrow at Rockwood where a more than 100-foot deep gorge is cut in Amabel Dolomite. The dolomite is reefy, fossiliferous and vuggy and alternatingly massive and medium bedded. The beds are sloping against reef formations. The colour of the dolomite varies from medium dark grey to light grey. Near the top of the section, at an elevation of about 1,140 feet, thin bedded, light grey, crinoidal dolomite with irregular bedding surfaces is observed

locally. It is overlain by Eramosa Dolomite which is exposed along the road, 1 mile southwest of Rockwood. Here thin bedded, dark grey, fine crystalline to aphanitic dolomite is interbedded with dark grey shale. Small vugs filled with calcite are prevalent.

There is no production in the Rockwood area at present. Formerly lime was produced from a few small quarries. These are described by Hewitt (1960, p.122) and Goudge (1938, p.291). The dolomite in these quarries is irregularly bedded and reefy. Impure, shaly sections occur. The stratified, inter-reefal beds were preferred in lime production for their purity. They are represented by sample 281 in (14). Sample 281A represents the impure, bluish grey, reef-like rock.

Abandoned quarries are also found along the railway in lot 6, concession VI, Eramosa Township. Thin to medium bedded, medium dark brownish grey, fine crystalline dolomite is exposed in a 12-foot face. In an outcrop north of the railway these rocks are underlain by a few feet of dark brownish grey, reefy, fossiliferous and vuggy dolomite. Although locally water well information is scarce it appears that an area west of Rockwood, about 3 miles wide, narrowing down towards Eden Mills but including a 1-mile wide section east of the Eramosa River between Rockwood and Eden Mills, is suitable for quarry development. Where Highway 7 and the railway are near they may offset the disadvantage of remoteness from the Toronto market.

West of Eden Mills there is a partial cover of till deposits of prohibitive thickness but close to the highway some ground continues to be favourable for quarry development as far west as Guelph. An outcrop in lot 6, concession III, Guelph Township shows yellowish grey to buff, aphanitic, porous and vuggy dolomite. The vugs are filled with gypsum. South of here, on the bank of the Eramosa River, the Guelph Reformatory operates a quarry. Production is not necessarily on a competitive basis however.

North of Rockwood quarriable ground is mainly confined to narrow zones in creek beds. These are outlined by contours of less than 25 feet of overburden. Unfavourable drainage conditions will probably rule out development of many of these locations. A small area directly northwest of Everton, straddling Highway 24 and covering parts of lots 13, 14 and 15, concession VI and VII, Eramosa Township, may form an exception. The underlying dolomites are outcropping in

Everton where they are irregularly bedded, reefy, fossiliferous and porous. In a 20-foot section, between elevations of about 1,225 to 1,245 feet, medium light grey, medium bedded to massive, fine to medium crystalline dolomite is exposed. The colour varies from medium grey to light brownish grey. Elsewhere, at an elevation of about 1,190 feet massive, very light and occasionally medium grey, medium crystalline, fossiliferous and porous dolomite is found, apparently in continuity with these dolomites. A water well drilled on lot 15, concession VII, just northeast of the area of low overburden, intersected 30 feet of clay and boulders and below that, to the bottom of the well at a depth of about 1,185 feet, 110 feet of light brown to brown limestone.

Guelph

The area surrounding Guelph is underlain by Wentworth till and drumlins (see Map P.534). Outwash gravels and sand are prevalent in stream beds. Bedrock outcrops are only found in small sections of some stream beds and on the banks of the Speed River, south of Guelph. Major quarries occur in the latter location.

The Canadian Gypsum Company Limited operates a quarry for the production of lime and crushed stone on the east bank of the Speed River on the outskirts of the city, just east of Highway 24. The operation and geological section are described by Hewitt (1960, p.124; 1964, p.55-57). The dolomite overlying Eramosa beds in the bottom of the quarry is white, aphanitic and medium to irregularly bedded. Light creamy-buff, massive to medium-bedded, fine crystalline dolomite forms the upper part of the 40-foot quarry face. The surface at the time of visiting in May 1968 was rolling and relatively easy to strip. Although an area of heavy overburden has been avoided there is still about 12 feet of overburden to contend with ahead of the quarry face. Dark to brownish grey, aphanitic Eramosa Dolomite forms the floor of the quarry which is fairly regular although occasionally slightly domed over reefs. Goudge (1938, p.293) describes Eramosa Dolomite of the Reforamtory Quarry as hard, fine-grained, dark brownish grey dolomite with bituminous shale partings. Besides chemical analyses in (14), sample No's 283 and 283A, a recent analysis of Guelph dolomite appears in (16).

(16) CHEMICAL ANALYSIS - CANADIAN GYPSUM COMPANY*

SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3
0.05	0.13	0.054	30.3	22.3	0.003

* Reproduced from Hewitt 1964, p.57.

The second major operation referred to above is the Glen Christie Quarry and Lime Plant of Domtar Chemicals Limited, located in lots 1-4, concession IV, Puslinch Township (see Map P.535). The geological section and quarry operation are described by Hewitt (1960, p.123-124; 1964, p.57). Excavations on both sides of the Canadian National railway expose well over 78 feet of dolomite which in the lower 52 feet is typical of the Guelph reef facies, with reef flank beds sloping against the reef formations. The dolomite is irregularly bedded, light-creamy-buff, aphanitic to fine crystalline, vuggy, in parts rusty, porous and fossiliferous. It is overlain by thick and even bedded, vuggy dolomite of the same colour and crystallinity, changing to light buff and even finer grained dolomite in the higher part of the section west of the railway.

A series of chemical analyses of rock to a depth of 100 feet is given in (17):

(17) CHEMICAL ANALYSES - DRILLHOLE 19 - DOMTAR CHEMICALS LTD.*

Footage	CaO	MgO	Insoluble	Fe_2O_3	R_2O_3	LOI
0-31	(overburden)					
31-40	31.00	21.62	0.07	0.12	0.13	47.52
40-50	30.95	21.52	0.08	0.10	0.12	47.60
50-64	30.95	21.60	0.06	0.09	0.10	47.58
64-70	31.10	21.55	0.05	0.075	0.09	47.71
70-80	31.05	21.52	0.03	0.07	0.11	47.64
80-90	30.90	21.72	trace	0.08	0.10	47.52
90-100	31.00	21.65	0.01	0.06	0.08	47.70

* Reproduced from Hewitt 1964, p.57.

From water well data it is obvious that heavy overburden impedes quarry development at a greater distance from the river. About 1 mile north and 1 mile south of the quarry site areas

of shallow overburden are indicated along the river course. Including the stream itself these areas are about 1 mile wide and may constitute a possible alternative to the present quarry location.

Minor areas of shallow overburden occur along the Speed River and its tributaries north of Guelph, e.g. at Armstrong Mills and Birge Mills. Northwest of Marden on Highway 6 a larger area of interest is outlined. It covers lots 19-21, concession IV, lots 17-21, concession III, lots 17-23, concession II and concession I, Division D, Guelph Township in part or total, as well as lots 1-5, concession X and concession XI, Division C, Guelph Township in part. The dolomite formations are known to be at least 200 feet thick here.

Other areas of shallow overburden along Highway 6 northwest of Guelph are likely to have a drainage problem associated with quarrying.

Fergus and Elora

Activity in quarries along the banks of the Grand River near Elora and Fergus, mentioned by Goudge (1938, p.288-290), has since been suspended. Production included stone for the manufacture of dolomitic lime, crushed stone, some building stone and rubble. The area of shallow overburden is confined to the river bed and is not favourable for quarry development.

Terra Cotta, Chinguacousy Township

Quarry activity in the Terra Cotta region is concentrated on the Glen Williams outlier, southwest of Terra Cotta (see Map P.534). The Whirlpool Sandstone is here exposed to advantage as the principal scarp former. In 1966 building stone was produced in three different operations. The sandstone is from 6 to 12 feet thick in the area.

At higher elevation in the outlier Industrial Sand and Gravel Company Limited operated a quarry for crushed rock in Amabel Dolomite. The face of this quarry exposes 30 feet of white to light buff, medium crystalline, massive, crinoidal dolomite, occasionally porous, reefy and medium dark grey. Aphanitic, medium bedded, shaly and light grey to dark grey streaked Reynales dolomite underlies this section in the 35-

foot quarry face. A description of the operation is given by Hewitt (1960, p.122), including the chemical analysis in (18):

(18) CHEMICAL ANALYSIS - INDUSTRIAL SAND AND GRAVEL COMPANY LIMITED*

(Analysis by Provincial Assay Office, Ont. Dept. Mines, 1959)

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	CO_2	P_2O_5	S	Total
	percent	percent	percent	percent	percent	percent	percent	percent	percent
1	0,54	0.38	0.73	21.00	31.20	47.02	0.13	trace	101.00

* Reproduced from Hewitt 1960, p.122.

The area west of Terra Cotta and the Glen Williams outlier is favourable for quarry development over a width of about 2½ miles. Galt Moraine deposits are minor north of Ballinafad. The western limit of the area is determined by deposits of the Paris Moraine which are continuous to Credit Forks.

The contact of dolomite with underlying shale rises gradually from an elevation of about 1,050 feet east of Ballinafad to an elevation of 1,100 feet west of Terra Cotta. Further north elevations of 1,265 feet near Cataract and 1,330 feet near Caledon are recorded. There is more than 100 feet of dolomite available for quarrying on high ground west of Terra Cotta.

Inglewood, Caledon Township

North of Terra Cotta sandstone at the base of the Escarpment continues to be favourable for production of building stone (see Map P.533). Of eight quarries in Whirlpool Sandstone in the area west of Inglewood three were active in 1966. The quarries are located in lots 1 to 4, concession III W, Caledon Township. They are described by Hewitt (1964, p.32-38). Some excavations have progressed westward to the point where up to 30 feet of overlying limestone, shale and drift have to be removed. The section of rocks overlying Whirlpool Sandstone in this area is described by Bolton (1953, p.162-163). More than 15 feet of grey, thick to thin bedded, argillaceous, Manitoulin Dolomite

and more than 48 feet of Cabot Head Shale occur between the quarriable sandstones and the overlying Amabel Dolomite. Amabel Dolomite is massive, white and dense in the lower part of the 25-foot section and massive, buff grey to white, porous and crinoidal near the top. Between sandstone quarries at the base and heavy overburden deposits west of the brow of the Escarpment an area of one half to one mile wide is outlined as favourable quarry ground. The thickness and quality of Amabel Dolomite will have to be tested. The level of the ground is steadily rising to the west but at high elevations thick overburden deposits of the Paris Moraine are prevalent. These deposits also cover the area surrounding Belfountain as far north as Cataract. Bedrock is exposed only in the Credit River gorge.

Cataract, Caledon Township

Although some ground with shallow overburden occurs between Erin and Alton the most promising potential quarry ground of the West Credit River drainage area is found along Highway 24, northwest of Cataract (see Map P.533). Bedrock outcrops occur at several points west of the highway. The dolomite is light grey, massive to thick bedded, fine crystalline and porous. At Cataract the top of Cabot Head Shale reaches an elevation of about 1,265 feet while at Alton it is found at approximately 1,240 feet. These elevations indicate the presence of a section of at least 100 feet of Amabel Dolomite along Highway 24. To the west and at lower elevation outcrops in the riverbed at Erin show light grey to buff, thin to medium bedded, fine crystalline, crinoidal and porous dolomite.

The presence of a spur of the Canadian Pacific railway just east of Highway 24 connecting the Toronto area with points north and west of Cataract should be mentioned here in connection with the development potential of the area.

Between Cataract and Caledon elevations do not rise significantly above the contact of Amabel Dolomite with Cabot Head Shales at about 1,300 feet. Quarrying of dolomite between Highway 10 and the Credit River in the area south of Caledon is therefore virtually ruled out.

Caledon, Alton and Melville, Caledon Township

Highway 10 to Orangeville runs through Caledon (see Map P.533). The area between Caledon and Orangeville is characterized by comparatively shallow overburden. Drift deposits of 30 to 40 feet thick are common, in contrast to deposits of over 100 feet thick both to the east and west of this area. Locally at Caledon, Alton and Melville even less overburden is reported.

Abandoned quarries occur at Alton and north of Melville. They are described by Goudge (1938, p.266-267). At Alton a quarry section exposes 20 feet of buff, porous dolomite at the base, overlain by 12 feet of dense, bluish grey dolomite and capped by 15 feet of thick bedded, yellowish buff, fine grained and porous dolomite. The rocks at Melville Junction are bluish grey and buff, hard, fine grained and porous and contain many fossils and cavities. Chemical analyses of these rocks are given in (19):

(19) ANALYSES OF PEEL COUNTY LIMESTONES*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
263	0.72	0.50	0.54	0.02	55.16	42.85	99.79
264	0.48	0.39	0.51	0.02	54.84	43.06	99.30
264A	1.06	0.51	0.57	0.07	55.11	42.56	99.88
264B	1.18	0.48	0.95	0.07	54.29	42.14	99.11

263. Melville Junction. Lockport dolomite in quarry formerly worked by Contractors' Supply Company, on lot 27, concession I W, Caledon Township.

264. Alton. Top 15 feet of Lockport dolomite in a abandoned quarry at the village.

264A. Alton. Next 12 feet of Lockport dolomite in the same quarry.

264B. Alton. Bottom 20 feet of Lockport dolomite in the same quarry.

* Reproduced from Goudge, 1938, p.267.

Amabel Dolomite is known to underlie the drift deposits northeast of Caledon. From the small amount of well data available it appears that in a few locations the dolomite occurs within 25 feet of the surface. Little is known of the bedrock topography in this area. In lot 12, concession IV E, Caledon Township, hard limestone is reported over a depth from 12 to 25 feet. Cabot Head Shale reaches an elevation of

approximately 1,385 feet. Bolton (1957, p.96-97, section 62) describes 16 to 17 feet of dolomite overlying the Cabot Head Shale just northwest of here. The dolomite is divided into Fossil Hill, Lions Head and Colpoy Bay Formations, respectively a brown, fine crystalline and predominantly massive dolomite, a white to grey, dense and thin bedded dolomite and a whitish to grey, medium crystalline, thick bedded and porous dolomite. These formations reach thicknesses of respectively 7 feet, 1.3 to 3 feet and 7 feet in the section.

Mono Mills, Albion Township

Well data near Mono Mills, north of Caledon, indicate an elevation between 1,400 and 1,450 feet for the top of Cabot Head Shale. Up to 30 feet of dolomite has been intersected in some of these wells. The Escarpment area east of the till moraine deposits between Orangeville and Mono Mills will at best provide a section of 100 feet of quarriable dolomite in areas of high elevation. Lack of information in this area does not permit the demarcation of more than a few small areas of potential quarry development, one 3 miles east of Caledon, two areas respectively about one mile southeast and one mile southwest of Mono Mills and another area 2 miles east of Glen Cross. In the latter area a bedrock outcrop shows very light yellowish grey, massive, medium crystalline, porous and fossiliferous dolomite. A minor escarpment is formed by this dolomite between elevations of 1,425 and 1,475 feet.

Orangeville

A small abandoned quarry near Orangeville (see Map P.533) is mentioned by Goudge (1938, p.215). It is located 1½ miles east of Orangeville in lot 1, concession I E, Mono Township. Thick and irregularly bedded, bluish grey dolomite (12 feet) and, at lower elevation, thin bedded, buff dolomite are exposed in the area. A chemical analysis of each is given in (20), samples 262 and 262A:

(20) ANALYSES OF DUFFERIN COUNTY LIMESTONES*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
260	0.24	0.34	0.02	0.02	55.55	43.14	99.31
262	0.38	0.38	0.38	0.02	55.55	42.35	99.06
262A	0.90	0.37	0.55	0.04	55.02	41.66	98.54

260. Shelburne. Lockport dolomite in quarry formerly worked for building stone 1 1/2 miles east of Shelburne.

262. Orangeville. Bluish grey Lockport dolomite exposed in small quarry on top of ridge on lot 1, concession I E, Mono Township.

262A. Orangeville. Buff Lockport dolomite exposed lower down on the sides of the same ridge.

* Reproduced from Goudge 1938, p.216.

A water well in this area intersects 50 feet of limestone in contact with underlying shale at an elevation of approximately 1,380 feet.

Discussion of areas of potential quarry development along the Niagara Escarpment north of Orangeville and in the Bruce Peninsula is based on data of the Physiographic Map of Southern Ontario, Western Section (Chapman and Putnam 1951), expanded with information from water wells and observations in the field. Areas of shallow overburden have been added to the limestone plains of the Physiographic Map as potentially favourable for quarry development.

The elevation above which suitable dolomite occurs rises steadily northward. A water well on the brow of the Escarpment 2 miles north of Mono Centre intersects 160 feet of dolomite. The underlying blue shale occurs at an elevation of approximately 1,450 feet. Although shallow overburden is reported in some wells along the Escarpment a large number intersect substantial till deposits.

Shelburne

The Boyne and Pine Rivers occupy deep channels in the Escarpment area northeast of Shelburne (see Figure 2, back pocket). Whirlpool Sandstone forms the bed of the Boyne River just north of Primrose at an elevation of approximately 1,350 feet. At higher elevation to the north close to one hundred feet of brown and grey dolomite have been intersected in a well boring on lot 4, concession I W.H.S., Mulmur Township. Red and grey shale of the Cabot Head Formation

occur at an elevation of about 1,400 feet according to the log of this well. Near Hornings Mills the Pine river cuts approximately 60 feet of Cabot Head Shale. Bolton (1957, p.98, section 71) notes the presence of 8 feet of light grey, dense, thin bedded Fossil Hill Dolomite and 17 feet of whitish grey, crystalline, massive and porous Colpoy Bay Dolomite overlying the Cabot Head Shale in this area. An abandoned building stone quarry on lot 32, concession I, Amaranth Township is mentioned by Goudge (1938, p.214-215). Sixteen feet of pale buff, soft, vuggy, thick bedded dolomite is exposed in the quarry face. The beds are 1 to 3½ feet thick and frequently wedge-shaped. A chemical analysis of this dolomite is given in (20), sample 260.

Honeywood, Mulmur Township

Shallow overburden is reported in the neighbourhood of Honeywood, 10 miles north of Shelburne. In one well over 125 feet of dolomite have been encountered, of white, grey, brown and blue colour respectively. Three miles northeast of Honeywood a similar sequence of dolomite is underlain by brown shale reaching an elevation of approximately 1,450 feet. In lot 30, concession III E.M.S., Mulmur Township, on the brow of the Escarpment southeast of Dunedin, only 40 feet of light brown dolomite is found overlying red shales. About 2 miles west of Lavender an outcrop of dolomite was observed at an elevation of approximately 1,625 feet, showing 15 feet of light yellow, thick bedded to massive, fine crystalline and porous dolomite locally forming a minor escarpment.

Singhampton, Nottawasaga Township

Shallow overburden is encountered in the area of Singhampton (see Figure 2, back pocket). Outcrops along the road ascending the Escarpment south of the Mad River, in lot 15, concession IX, Nottawasaga Township show thick bedded, whitish to light grey, fine crystalline, porous and fossiliferous dolomite near the top at elevations of approximately 1,600 to 1,675 feet. At an elevation of 1,525 feet a secondary scarp is formed by thin bedded, medium light grey to light brownish grey, fine crystalline and fossiliferous dolomite. In Singhampton soft brown shale is encountered between scarp forming dolomites. The shale reaches an elevation of approximately 1,540 feet in this more western location.

North of Singhampton and along Highway 24 where it turns east to Duntroon bedrock is exposed in several places. A quarry 2 miles west of Duntroon, operated by Collingwood Sand and Gravel Limited, is described by Hewitt (1964, p.57-58). White to light buff, medium to coarse crystalline, porous, fossiliferous and massive to irregularly bedded Amabel Dolomite is exposed in the 40-foot quarry face. A chemical analysis of one-inch stone from the stockpile is given in (21):

(21) CHEMICAL ANALYSIS - McKEAN QUARRY, DUNTROON*

SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	SO_3	LOI	Total
0.24	0.50	0.10	21.16	30.28	0.09	47.50	99.87

* Reproduced from Hewitt 1964, p.58.

At lower elevation to the east a building stone quarry, previously operated by Angelstone Limited, exposes 2 to 6 feet of Whirlpool Sandstone and about 12 feet of Manitoulin Dolomite.

Besides a large area of outcrop of Amabel Dolomite indicated on the Physiographic Map and stretching along the brow of the Escarpment from Eugenia Lake northeast to Banks in lot 15, concession IV, Collingwood Township, there is an area of shallow overburden between the Beaver River and the Little Beaver River, west of and surrounding Maxwell and there are indications of shallow overburden around and to the northwest of Feversham. At an elevation of 1,565 feet 1½ miles northwest of Maxwell brown and white dolomite occur to a depth of at least 160 feet. Near the brow of the Escarpment east of Banks shale reaches an elevation of approximately 1,570 feet. In this area a careful check of the available amount of dolomite would have to be made before deciding on a quarry location.

Markdale

For a study of the area west of Beaver Valley, covering NTS Map 41 A/7, scale 1:50,000, Markdale East and West, use was made of a preliminary survey provided through courtesy of

Officers of the Ontario Water Resources Commission. The area is underlain primarily by till plains and till moraine according to the Physiographic Map (Chapman and Putnam 1951). Spillways and kame moraine are found near Markdale. Limestone plains occur along the brow of the Escarpment from Fairmount to Walters Falls and in an area to the south and southwest of Walters Falls. Scattered occurrences of shallow overburden have been recorded southwest of Rocklyn, in lot 18, concession IX and lot 18, concession XI, Euphrasia Township, near Wodehouse and Vandeleur on the brow of the Escarpment west of Beaver Valley; and in several river and creek beds. At the brow of the Escarpment 2 miles north of Fairmount shale is encountered at an elevation of approximately 1,340 feet, leaving 45 feet of dolomite to be quarried locally. Southwest of Walters Falls, at a distance of 1½ miles, shales are intersected at approximately 1,100 feet elevation. Accordingly the surface of the Cabot Head Shale dips about 27 feet per mile in this direction.

Owen Sound

Consistently low values of drift thickness are found along Highway 10 north of Chatsworth where an area of shallow overburden connects with limestone plains surrounding Owen Sound and extending east of this town (see Figure 2, back pocket). In the latter area, on lot 25, concession II S.C.R., Sydenham Township, a quarry for the production of crushed stone has been opened in Amabel Dolomite by E.C. King of Owen Sound. Thirty feet of massive, reefy and aphanitic dolomite are exposed in the quarry face. The very light grey, greenish to bluish grey mottled, porous dolomite is occasionally fossiliferous and vuggy. Vugs are partially filled with calcite crystals. Medium bedded, interreefal deposits are common.

The limestone plains east of Owen Sound are separated from those surrounding Walters Falls by a drumlinized till plain which occupies the topographic depression of the Bighead River drainage system. Several water wells in both limestone areas intersect the underlying Cabot Head Shale. To the north in Sydenham and St. Vincent Townships, 3 miles north of Woodford, the top of shales is found at approximately 1,140 feet elevation. Sections of rock exposed locally on the boundary of these townships are described by Bolton (1953, p.174; 1957, p.99). Thirty four feet of white, dense, massive and porous Colpoy Bay Dolomite underlie the Escarpment

and are mainly responsible for the cliff formation. This dolomite is underlain in succession by 10 feet of dense, thin bedded, brown to whitish brown Lions Head Dolomite, 8.5 feet of brown, thin bedded, medium crystalline Fossil Hill Dolomite and 2 feet of blue-to dark-grey Dyer Bay Dolomite with shale lenses and partings. The remaining Dyer Bay and Cabot Head Formations, not exposed in the section, Bolton considers to be 100 feet thick. Secondary scarps are formed at lower elevation to the northeast.

Dip of the shale surface in a southwesterly direction can be measured at several locations. Near Owen Sound, along Highway 6 to Rockford, the shale surface is down to an elevation of 800 to 820 feet. At Sheppard Lake, south of Highway 26, there is a gain of at least 100 feet. Near Hoath Head, 3 miles south of Sheppard Lake, an elevation of approximately 935 feet is reached. The difference between these points is consistent with data of other wells in the area, e.g. in lots 11 and 12, concession VIII, Sydenham Township, where shales reach an elevation of about 930 feet. The apparent dip in southwesterly direction based on these figures amounts to 28 feet per mile.

Quarries for production of rubble, crushed stone and foundation stone were previously worked at lower elevation in the cherty Manitoulin Dolomite on the eastern city limits of Owen Sound. Lime was produced from Amabel Dolomite of the upper part of the Escarpment west and south of the city. These operations have been discontinued.

The approximate or assumed boundary between Amabel and Guelph Dolomite is given by Liberty (1966, Map 23-1965). This boundary runs north from Flesherton at the head of Beaver Valley and after a few miles turns northwest to cross Highway 6 between Chatsworth and Rockford. An 8-foot section of Guelph Dolomite ¾ mile north of Chatsworth has been sampled by Goudge (1938, p.228). The rock is buff, very fine grained and contains many fossils and cavities. An analysis appears in (22), sample 254, together with analyses of other rocks in the area.

(22) ANALYSES OF GREY COUNTY LIMESTONES*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
249	0.76	0.31	0.23	0.02	54.30	43.79	99.41
249A	13.68	0.65	1.53	0.04	46.55	36.16	98.61
250	0.60	0.79	Nil	0.02	54.60	43.60	99.61
251	7.80	1.17	1.14	0.07	50.62	39.11	99.91
252	0.80	0.50	0.06	Tr.	54.73	43.54	99.63
253	0.58	0.22	0.21	0.02	55.04	44.40	100.47
254	0.18	0.29	0.05	Tr.	55.80	43.52	99.84

249. Owen Sound. Top 30 feet of Lockport dolomite in now idle quarry known as the Oliver Brown quarry at the west edge of the city.
249A. Owen Sound. Lower 10 feet of cherty Lockport dolomite in the same quarry.
250. Owen Sound. Lockport dolomite in quarry of Brown's Lime Works.
251. Owen Sound. Manitoulin dolomite in quarry worked by Law Construction Company, at east edge of the city.
252. Owen Sound. Lockport dolomite in cutting on the road to Meaford, 5 miles east of the city.
253. Owen Sound. Lockport dolomite in cutting on the Sydenham road, 2 1/2 miles south of the city.
254. Chatsworth. Guelph dolomite in cutting on the Sydenham road, three-fourths of a mile north of the village.

* Reproduced from Goudge 1938, p.229-230.

One building stone quarry is active in the Owen Sound area. In lot 17, concession IV, Keppel Township Owen Sound Ledgerock Limited produces random flagstone, coursing, wallflag, copings, sills and mantles from banded Eramosa Dolomite. The rocks are described by Hewitt (1964, p.58) as medium grey-brown, thin bedded and aphanitic and are exposed in a quarry face of 18 inches to 2 feet high.

In the quarry area a well boring intersected successively overburden (22 feet), brown dolomite (23 feet), light grey dolomite (20 feet), blue dolomite (91 feet) and, at the bottom of the well, 1 foot of blue shale. Accordingly the shale reaches an elevation of about 640 feet here. A boring near Gleason Lake to the north, in the Skinner Bluff area, intersects Cabot Head Shale at an elevation of approximately 745 feet. In between, but further east, just east of Wolseley, the shale contact is reached at an elevation of approximately 785 feet. Just west of Owen Sound, near

Springmount, shale occurs at an elevation of about 700 feet. It is difficult to derive more than a general idea of the dip of the shale surface in this area. A westerly direction is indicated. It is possible that present elevations represent different shale horizons or indicate an irregular shale surface rather than true dip.

Wiarton

The Wiarton roadcut, providing access for Highway 6 to the top of the Escarpment north of Wiarton, is a favourable location for studying a section of the underlying dolomites (see Figure 2, back pocket). Bolton (1957, p.102) describes a sequence from Fossil Hill to Guelph Dolomite. A section of 51 feet, part of which comprises Eramosa Dolomite, is not exposed. Below this interval the dolomites measure 96 feet between approximate elevations of 609 to 705 feet. Seventy four feet of this section, the Colpoy Bay and Wiarton Dolomites, are massive, white to blue-grey, medium crystalline, fossiliferous dolomites. The Colpoy Bay Dolomite is denser, brown and blocky towards the bottom where it is in transitional contact with Lions Head Dolomite. The Fossil Hill Formation is represented by 16 feet of thin bedded, brown, medium crystalline and fossiliferous dolomite which becomes fine grained, light buff and massive to thick bedded near the top. Six feet of Lions Head Dolomite, a brown, dense to sublithographic and blocky dolomite, occur between these formations. Twenty three feet of Guelph Dolomite is exposed along the highway at higher elevation. It is a brown, sugary to dense, thin bedded dolomite with rare bituminous streaks and a faint petroliferous odour. In the basal 9 feet it is more massive.

The Eramosa Dolomite, not exposed in this section, is well known from several small building stone quarries 2 miles west of here. Four of these quarries are described by Hewitt (1960, p.125-126; 1964, p.58-59). Two more have recently opened 3 miles northwest of Wiarton in lot 10, concession XXV, Amabel Township. The quarries produce wall coursing, flagstone, copings, sills, steps etc. from thin to medium bedded, light buff to brown, aphanitic Eramosa Dolomite. Dolomite in the newly opened quarries is light grey to brownish grey and fine crystalline to aphanitic.

The upper Cabot Head Shale contact has a gentle apparent dip in northwesterly direction. It is found at an elevation

of approximately 585 feet near Burford Lake and near an elevation of 500 feet 11 miles northwest of Wiarton.

Guelph Dolomite underlies part of the limestone plains northwest of Wiarton. It is not found directly south and southwest of Hope Bay however. Here at a distance of ¾ mile south of the village, in lot 4, concession VIII, Albemarle Township, a building stone quarry is operated in Amabel Dolomite by Angelstone Limited. The property has recently been acquired by this company. Mill blocks of 2½ x 2½ x 6 feet are being produced from massive, very light grey and blue mottled, aphanitic dolomite.

Lions Head, Eastnor Township

The Physiographic Map (Chapman and Putnam 1951) records the presence of clay plains and beach formations south and southwest of Lions Head (see Figure 2, back pocket). Information has been gathered from existing water well records in an attempt to outline drift thicknesses in the area. It was found that maximum drift thicknesses occur 1½ miles south of Ferndale. The overburden here consists of clay and sand with clay to a depth of 85 feet. The well extends 39 feet in brown dolomite which puts the surface of shales locally below an approximate elevation of 506 feet.

Along the shore of Georgian Bay shales are encountered at higher elevation. Bolton (1957, p.103-106) records the presence of 8 feet of Wingfield Dolomite at Jackson Cove. Near Lions Head this formation is rich in shaly interbeds and is recorded as a 10-foot section of alternating shales and dolomite, occurring below an elevation of approximately 590 feet. Below the Wingfield Formation about 14.5 feet of Dyer Bay Dolomite occur overlying the Cabot Head Shale. Shales have been reported in water wells north of Lions Head at elevations between 550 and 570 feet. At Barrow Bay an elevation of about 570 feet can be deduced for the top of the Cabot Head Shale. A water well log records the presence of 85 feet of blue, red and grey shale.

Chemical analyses of Bruce County limestones have been recorded by Goudge (1938, p.213-214). They are given in part in (23).

(23) ANALYSES OF BRUCE COUNTY LIMESTONES*

Sample	SiO_2	Fe_2O_3	Al_2O_3	$Ca_3(PO_4)_2$	$CaCO_3$	$MgCO_3$	Total
230	0.36	0.11	0.19	0.04	55.00	44.67	100.37
230A	0.08	0.10	0.08	Tr.	54.93	44.94	100.13
230B	0.18	0.11	0.14	0.02	54.64	43.86	99.95
231	6.94	0.34	0.70	0.04	51.71	39.59	99.32
231A	0.58	0.12	0.16	0.11	54.64	44.60	100.21
232	0.13	0.14	0.08	0.02	55.20	44.73	100.30
233	0.40	0.15	0.17	0.04	54.91	43.86	99.53
233A	2.68	0.49	0.38	0.02	54.04	42.56	100.17
234	0.82	0.26	0.40	0.06	55.50	42.77	99.81
235	0.38	0.11	0.21	0.02	55.32	44.42	100.46
235A	0.42	0.12	0.20	0.02	55.23	44.28	100.27
235B	0.44	0.16	0.20	0.02	55.21	43.71	99.74
236	1.00	0.35	0.27	0.07	55.38	42.45	99.52
236A	2.44	0.26	0.24	0.07	53.41	42.91	99.33

230 Tobermory. Highest strata of Guelph formation as exposed southeast of the village.
230A. Tobermory. Fifteen feet of Guelph dolomite immediately beneath beneath the above.
230B. Tobermory. Lowest strata of Guelph dolomite exposed along the shore.
231. Dyer bay. Lockport dolomite as exposed in the cliffs on the shore.
231A. Dyer bay. Highest strata of Lockport formation as exposed near the village.
232. Lionhead. Lockport dolomite on hilltop north of Lionhead village on the road to Tobermory.
233. Lionhead. Lockport dolomite in the upper 120 feet of cliff on the shore.
233A. Lionhead. Bottom 10 feet of Lockport dolomite on same cliff.
234. Wiarton. Quarry of J.S. Cook, 6 feet of Guelph dolomite.
235. Wiarton. Brown dolomite on hill north of deep cutting on the road to Tobermory.
235A. Wiarton. Upper 50 feet of Lockport dolomite in road cutting on road to Tobermory.
235B. Wiarton. Next 8 feet of dolomite in road cutting.
236. Wiarton. Lockport dolomite midway up cliff along the shore of Colpoy bay, just north of the town.
236A. Wiarton. Bottom 25 feet of Lockport dolomite exposed in this cliff.

* Reproduced from Goudge 1938, p.213.

Lindsay and St. Edmund Townships, Bruce Peninsula

The remaining area of the Bruce Peninsula northwest of Lions Head is characterized by lack of overburden. The area is underlain by Guelph and Amabel Dolomite, with generally

little topographic expression. Maximum elevations between 875 and 900 feet are encountered near Cabot Head where several bluffs rise from the waterlevel below 600 feet to an elevation of 800 feet or more. These bluffs are capped by Guelph Dolomite according to Liberty (1966). Dyer Bay Dolomite occurs at beach level in the Dyer Bay area (Bolton 1953, p.203).

Guelph Dolomite underlies most of the area surrounding Tobermory. It is a fine crystalline, yellowish grey to buff, sugary dolomite. Its accessibility for lake transport has attracted at least one company in recent years.

A large area east of Highway 6, covering lots 35 and 36, concession I; lots 34-43, concession II; lots 34-44, concession III; lots 33-43, concession IV and parts of lot 35 and lot 36, concession V, E.B.R., St. Edmunds Township, is being held by Pickands Mather and Company of Cleveland, Ohio for future production of flux stone. In this area rocks are suitable for excavation to below the waterlevel.

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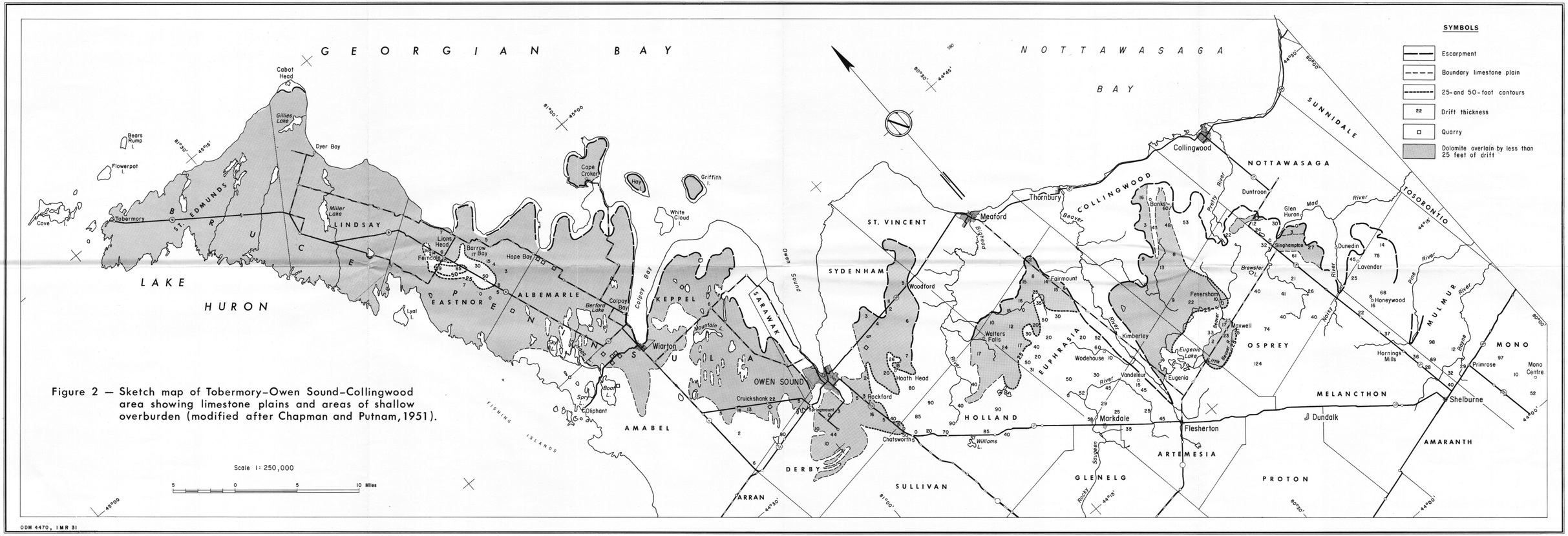

Figure 2 — Sketch map of Tobermory–Owen Sound–Collingwood area showing limestone plains and areas of shallow overburden (modified after Chapman and Putnam, 1951).

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FEET

AMABEL FORMATION

TRANSITION ZONE

GUELPH FORMATION

ERAMOSA DOLOMITE

55' covered interval

VINEMOUNT SHALY DOLOMITE BEDS (ERAMOSA MEMBER)

GOAT ISLAND DOLOMITE

LOCKPORT FORMATION

ANCASTER CHERT BEDS (GOAT ISLAND DOLOMITE)

GASPORT DOLOMITE

DECEW DOL.

ROCHESTER SHALE

IRONDEQUOIT DOLOMITE

REYNALES DOLOMITE

DECEW DOLOMITE

BASE OF LOCKPORT–AMABEL

GASPORT DOLOMITE

MAP SHOWING LOCATION OF QUARRIES OR REFERENCE SECTIONS

CHERT NODULES

SHALY BEDS

SANDSTONE

1. INDUSTRIAL SAND AND GRAVEL, GEORGETOWN
2. ARMSTRONG BROTHERS, GEORGETOWN
3. GYPSUM LIME AND ALABASTINE, MILTON
4. MILTON QUARRIES, MILTON
5. LOWVILLE QUARRIES, LOWVILLE
6. NELSON CRUSHED STONE, NELSON
7. OLD NELSON QUARRY, WATERDOWN
8. KING CITY SAND AND CRUSHED STONE, CLAPPISON CUT
9. SYDENHAM ROAD, REFERENCE SECTION (BOLTON)
10. CANADA CRUSHED AND CUT STONE, DUNDAS
11. ANCASTER REFERENCE SECTION (BOLTON)
12. WENTWORTH STREET REFERENCE SECTION, HAMILTON
13. STONY CREEK REFERENCE SECTION, NO. 20 HIGHWAY (BOLTON)
14. A. COPE AND SONS, STONY CREEK
15. ARMSTRONG BROTHERS, VINEMOUNT
16. VINELAND QUARRIES AND CRUSHED STONE, VINELAND
17. DECEW FALLS REFERENCE SECTION (BOLTON)
18. ST. CATHARINES CRUSHED STONE, ST. CATHARINES
19. WALKER BROTHERS, QUARRIES, THOROLD
20. QUEENSTON QUARRIES, QUEENSTON

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Geological Reference Sections and Quarry Sections, Lockport–Amabel Formations, Niagara Falls–Dundas–Georgetown Area