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SILICA IN ONTARIO

By

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BY

D. F. Hewitt[1]

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INTRODUCTION

Silica, or silicon dioxide, SiO_2, is the most common oxide found in the earth's crust and forms more than 59 percent of the "average rock" of the earth's crust. Most of the common rock-forming minerals are silicates. Silica itself is found widely as the mineral quartz.

Silica commonly occurs as pegmatite or vein quartz, unconsolidated silica sand, sandstone, and quartzite. Deposits of all these types have been worked from time to time in Ontario. Silica finds wide use as a basic raw material in many industries. Specifications regarding the form of silica, chemical purity, and physical characteristics, vary greatly according to consumers' requirements.

In terms of tonnage, one of the largest markets for silica in Ontario is for metallurgical flux. In 1942, International Nickel Company of Canada Limited opened the Lawson quarry, near Whitefish Falls, District of Sudbury, to supply quartzite flux, and this single operation currently produces over half a million tons of flux each year. Quartzite is quarried intermittently near Killarney and Sheguiandah for the production of ferrosilicon. Silica brick has been manufactured by Algoma Steel Corporation Limited from quartzite quarried in Deroche township, District of Algoma, 20 miles north of Sault Ste. Marie.

Silica sand and fused silica are used in plastic refractories and mortars. Furnace bottoms and linings for certain metallurgical processes are made of rammed silica sand or silica grits. Silica sand is an important raw material for production of silicon carbide and other abrasives. In the ceramic industry, the manufacture of glass requires large tonnages of high-purity silica sand. It is also used in other ceramic bodies and in enamels. Silica is a constituent of the batch for fiberglass and some types of rock wool. When ground finely, it forms an inert filler for paint, rubber goods, scouring powders, and cleansers. Silica sand is used in foundries for casting metals and for sand-blasting. Sandstone is one of the most widely used building stones.

In 1961, production of silica in Ontario amounted to 1,540,016 tons valued at $827,061. During the same year, imports of silica sand into Canada from United States for glass, carborundum manufacture, steel foundry use, sand-blasting, and filtration plants, amounted to 691,928 tons valued at $2,470,753. Imports of silica firebrick into Canada in 1961 were valued at $1,214,388 (Dominion Bureau of Statistics).

In answer to inquiries for information of a general nature on silica, this report gives a brief summary of the uses for silica and the occurrence and characteristics of the major Ontario deposits. Much of the information summarized here has been drawn from Keith (1949) and Cole (1923). Initial investigations of Ontario silica deposits were carried out by the writer in 1949. Specific deposits have been visited since that time, and a resurvey of silica deposits was conducted in 1962.

Silica constitutes an important non-metallic mineral resource in Ontario that should be developed more fully in the future. Considerable interest has been shown in the Potsdam or Nepean sandstones of southeastern Ontario in the past decade, and much exploration work has been carried out.

[1]Senior Geologist, Ontario Department of Mines.

TYPES OF SILICA DEPOSITS

Deposits of silica found in Ontario are of five types:

1. Unconsolidated Silica Sand.
2. Sandstone.
3. Quartzite.
4. Pegmatitic Quartz.
5. Vein Quartz.

1. Unconsolidated Silica Sand

Mineralogically, sand deposits found in Ontario consist predominantly of grains of silica and feldspar, with varying proportions of carbonate, rock fragments, ferromagnesian minerals (such as hornblende, pyroxene, biotite, and olivine), and accessory minerals (such as zircon, garnet, tourmaline, apatite, epidote, pyrite, magnetite, and rutile). In examining a sand deposit with a view to its commercial utilization as a source of silica sand, specifications may require that the following features be investigated:

1) Mineralogy of the sand; what proportion of silica grains; what accessory minerals.
2) Chemical purity, including analysis of silica, alumina, iron, lime, magnesia, and alkalis.
3) Grain size: sizing, fineness number, and sorting of the grains (checked by sieve analyses).
4) Roundness or angularity of the grains.
5) Toughness of the grains.
6) Cleanliness, and proportion of fines present.

Most of the sand deposits in Ontario are of glacial origin or are recent deposits derived from the reworking of glacial material. For this reason, high-purity silica sands are scarce. The sands derived from glacial debris usually consist of extremely heterogeneous material. Glacial and recent fluvial and lacustrine deposits are the source of large tonnages of sand suitable for silica flux, foundry sand, and other uses not requiring a high degree of purity.

2. Sandstone

Sandstones, consisting of aggregates of sand grains bonded by a mineral cement, usually silica or calcareous material, are the most widely used sources of silica sand. Sandstones, such as the St. Peter sandstone quarried in U.S.A. at Ottawa, Illinois, may be of high chemical purity and break down easily into sands with very little fracturing of the individual grains. The same specifications for chemical purity, grain size, angularity, and toughness of grains apply to silica sand originating from a sandstone as apply to silica sand from unconsolidated deposits.

Well-cemented sandstones may be suitable for making ferrosilicon. For building stone, the sandstone must be strongly cemented.

In Ontario, the most important sandstone formations are the Potsdam or Nepean sandstones of eastern Ontario, the Medina Sandstone of the Niagara escarpment, the Oriskany Sandstone of the Niagara peninsula, and the Sylvania Sandstone of the Windsor area.

3. Quartzite

When the quartz grains of a sandstone are recrystallized by metamorphism, the rock becomes a quartzite and loses the granular texture of the original sandstone. On crushing, the quartzite fractures across the original sand grains, and sands produced by grinding quartzite are characteristically sharp and angular. Quartzite is rarely crushed and ground to produce a silica sand because owing to its hardness, compactness, and coherence, the cost of crushing and grinding adds greatly to the processing costs.

Most of the silica sandstones of Precambrian age in Ontario are now metamorphosed to quartzite. The Lorrain Quartzite, a member of the Cobalt Group, which is exposed in outcrops in a wide area from Sault Ste. Marie to Cobalt, is one of our most important reserves of high-grade silica. Other quartzites occur in the Huronian and Grenville series of Precambrian sedimentary rocks.

4. Pegmatitic Quartz

During the course of operation of many granite pegmatites for feldspar, considerable tonnages of quartz have also been mined. This massive pegmatitic quartz is sometimes sold as lump silica for use as flux or ground to produce pottery flint. The quantity produced is relatively small and many of the feldspar operations are situated so far from markets that it is not economical to ship such a low-priced commodity as quartz to the consumers. Recently, interest has been shown in this type of quartz for aggregate for precast concrete facings used in building construction. Opaque and translucent quartz for this purpose is quarried and crushed by Industrial Garnet Company Limited near River Valley, and Rideau Aggregate Company in Verona.

5. Vein Quartz

No deposits of vein quartz are being mined for silica in Ontario, but large veins of opaque or translucent quartz situated near markets in southern Ontario would be of interest for aggregate for precast concrete facings.

SPECIFICATIONS AND USES

Silica Flux

Massive quartz, sandstone, quartzite, and silica sand are used for flux in smelting base metal ores where iron and basic oxides in the ore are slagged as silicates. Because free silica is the active slagging ingredient, the free silica content of the flux should be as high as possible. Impurities of iron, alumina, and bases, are not objectionable except for the reason that they reduce the proportion of available silica. Therefore, if a cheap local source of lower-grade silica is available, it may be used in preference to higher-cost high-purity silica that must be hauled from a distant source.

The largest users of silica flux in Ontario are the copper-nickel smelters of the Sudbury area; International Nickel Company uses more than 1,000,000 tons annually. In the roasting plant of the nickel circuit at Copper Cliff, silica flux consisting of ⅞ sand and ⅛ fine quartzite is mixed with the nickel concentrates, in the proportion of approximately 1 ton of flux to 5 tons of concentrates, for feed to the Nichols-Herreschoff roaster. The sand is obtained from Pleistocene deposits in nearby Garson township, and the quartzite is quarried at the Lawson quarry near Whitefish Falls.

Quartzite that is crushed to minus-¾-inch size is used as flux in the Pierce-Smith converters. The quartzite, running about 96 percent SiO_2, is fed into the converter by the Garr silica gun. In the copper circuit, sand flux is used in the reverberatory furnaces and flux for the converters consists of a 1 to 1 mixture of low-grade ore and quartzite.

Sands containing as little as 80 percent silica are used for rammed furnace bottoms in some open hearth furnaces in the steel industry.

Ferrosilicon

The manufacture of ferrosilicon uses lump silica, ¾ inch to 5 inches in diameter, derived by crushing quartzite or compact well-cemented sandstone. Chemically this material must be of high purity, within the following limits: silica, over 97.5 percent (quartzite now being mined in Ontario averages 98 to 99 percent); alumina, not over 1.0 percent; iron should be uniform, and total iron plus alumina not over 1.5 percent (iron in the Killarney quartzite runs from 0.2 to 0.4 percent); MgO and CaO each less than 0.2 percent; phosphorus and arsenic are particularly objectionable and should be absent.

Silicon Carbide

Silica sand used in the manufacture of silicon carbide should have the following specifications: silica content, 99.25 percent minimum; lime, magnesia, and phosphorus are objectionable; iron and alumina should each be below 0.10 percent. Canadian manufacturers use a sand with AFA[1] fineness No. 35. A coarse sand is preferred.

Silica Brick

Quartzite of medium to fine grain-size, ranging in composition from 96 to 98 percent silica, has proven to be the best raw material for silica brick. Much of the Lorrain Quartzite of the Sault Ste. Marie–Sudbury area is suitable for the manufacture of silica brick, comparing favourably with Pennsylvania and Wisconsin quartzites.

Silica, which melts at 1,728°C., has the ability to sustain loads even when temperatures approach the melting point; therefore, it is an extremely useful refractory material in the metallurgical industry. Silica brick is widely used in steel furnaces where operating temperatures may be in the range of 1,680°C.

Examination of the phase relations of silica–iron oxide and silica–lime, indicate that considerable amounts of iron and lime can be tolerated with little effect on the melting point of silica because these oxides are immiscible with silica at high temperatures in the high-silica range. However, alumina and alkalis present in the SiO_2–FeO–CaO system act as fluxes and materially reduce the refractoriness of the silica brick. Therefore, it has been found that the best range of chemical composition for raw material is as follows:

Silica	96 to 98 percent, or greater
Alumina	less than 1.0 percent
Iron oxides	less than 1.0 percent; (combined iron and alumina under 1.5 percent)

Alkalis, magnesia, and lime should be low

Quartz is the stable form of silica under normal conditions of temperature and pressure. However, on heating, quartz inverts at 870°C. to tridymite, which in turn inverts at 1,470°C. to cristobalite, both of which are the forms of silica stable in these high-temperature ranges. This inversion of quartz is accompanied by expansion and resultant decrease in specific gravity.

Silica bricks are manufactured by grinding the quartzite to a suitable mesh-size (usually about 55 percent between 4- and 28-mesh, 20 percent between 28- and 65-mesh, and 25 percent under 65-mesh); bonding with 1–2 percent lime; molding into bricks; drying and firing in a kiln. On firing, the quartz converts to tridymite and cristobalite with resultant expansion. The extent of the conversion has an important bearing on the behaviour of the brick in service.

[1]American Foundrymen's Association.

Texturally, the most suitable quartzites are those with a fine-grained closely interlocking texture, or those with both fine and medium grain-size. This is due to the fact that the inversion from quartz to the higher-temperature forms will occur more rapidly and be more complete in the finer-grained material.

To determine the suitability of a quartzite as a raw material for silica brick, tests should be carried out on brick made up from samples of several hundred pounds of quartzite.

Glass Sand

For the manufacture of glass, silica sand of high purity is needed. Specifications for glass sand, approved by the glass division of the American Ceramic Society and the U.S. Bureau of Standards, are shown in (I).

Moisture in delivered sand should not exceed 2.5 percent. Uniformity of grain-size is important. A glass sand should all pass 20-mesh, and not more than 3 percent should pass 80-mesh. Angular grains are preferred by some manufacturers owing to the larger surface area and more rapid reaction in the melt, but this feature does not appear to be a requisite of good glass sand.

Minor amounts of certain elements that are powerful colourants are objectionable in glass sand; chromium should not exceed 6 parts per million, and cobalt should not exceed 2 parts per million.

An analysis of a typical glass sand is given below:

	Percent
SiO_2	99.85
Al_2O_3	0.02
Fe_2O_3	0.022
TiO_2	0.01
CaO	0.02
MgO	0.01
CO_2	0.07
Cr	0.0002

Enamels

For enamel frits, a good grade of fine glass sand is used. Iron content should be less than 0.2 percent; alumina, less than 0.5 percent; and silica, more than 97.5 percent.

Pottery Flint

Finely ground silica is used for pottery flint in ceramic bodies. The chief requirement for purity is that the iron content should be low where a high degree of whiteness is desired.

Sodium Silicate

In the manufacture of sodium silicate, a high-grade glass sand is used. It must contain at least 99 percent silica, not more than 0.05 percent iron as Fe_2O_3, not more than 0.05 percent titania, not more than 0.50 percent alumina, and not more than 0.10 percent combined magnesia and lime. Grain-size should be minus-20 plus-100-mesh.

Paint Filler

Finely ground pottery flint is used in the paint industry as a filler. For this use, white colour, fineness, and freedom from impurities are the main requirements.

Foundry Sand

For foundry sand, a highly refractory tough silica sand, having rounded grains with rough surfaces, is preferred. Depending on the size and type of casting, various size-grades of sand are used, graded according to the American Foundrymen's Association specifications. The silica sands are bonded with clay, and rough grain surfaces improve the bonding power. Rounded grains are preferable to angular grains owing to the increase in permeability of the sand, which allows the escape of gases during casting. Both naturally bonded and artificially bonded sands are used.

Portland Cement

Silica sand may be added to the raw material slurry fed to the portland cement kiln to attain the required percentage of silica in the slurry. For special varieties of cement, appreciable tonnages of silica sand are required.

(I) SPECIFICATIONS FOR GLASS SAND

Quality	Minimum SiO_2	Maximum Al_2O_3	Maximum Fe_2O_3	Maximum $CaO + MgO$
First quality, optical glass	99.8	0.1	0.02	0.1
Second quality, flint glass containers and tableware	98.5	0.5	0.035	0.2
Third quality, flint glass	95.0	4.0	0.035	0.5
Fourth quality, sheet glass rolled, polished plate and window glass	98.5	0.5	0.06	0.5
Fifth quality, sheet glass rolled, polished plate and window glass	95.0	4.0	0.06	0.5
Sixth quality, green glass containers	98.0	0.5	0.3	0.5
Seventh quality, green glass	95.0	4.0	0.3	0.5
Eighth quality, amber glass containers	98.0	0.5	1.0	0.5
Ninth quality, amber glass	95.0	4.0	1.0	0.5

Autoclaved Concrete Blocks

In the manufacture of autoclaved concrete blocks, silica fines are added in the ratio of approximately 44 pounds of silica flour for each 100 pounds of portland cement used. This silica reacts to form crystalline hydrated monocalcium silicate.

Sand-Lime Brick

A light-coloured sand that is at least 55 percent quartz is desirable for sand-lime brick. The free silica in the sand reacts with the lime to produce lime silicates, and a high quartz content is desirable. Sand currently used for sand-lime brick in the Toronto area runs 60–70 percent quartz. The grading of a typical sieve analysis is shown in (II).

Feldspar is not desirable because it may break down in autoclaving and liberate soluble alkalis.

Miscellaneous Uses

Silica is also an ingredient in some fiber glass and rock wool batches; it is used also in cleansing and scouring powders, matches, fertilizer filler, and roofing paper.

ORIGIN AND OCCURRENCE OF HIGH-GRADE SILICA DEPOSITS

All high-grade silica deposits of detrital origin, including silica sand, sandstone, and quartzite, are composed essentially of the mineral quartz, which was originally derived through the weathering of a quartz-bearing igneous rock such as granite. When a granite breaks down into a sand under normal weathering conditions, the sand will be composed of the constituent minerals of the granite, probably quartz, feldspar, mica, and hornblende; accessories, such as zircon, tourmaline, garnet, magnetite, and pyrite, possibly will be present. The result is an impure low-silica sand. Quartz is a very stable mineral and does not break down easily either chemically or physically during the weathering cycle. Most of the pure silica sand deposits, such as the well-known St. Peter Sandstone of Ottawa, Illinois, and the Oriskany Sandstone of Pennsylvania, have resulted from the cumulative concentration of grains of quartz that persisted as a very stable mineral through several cycles of weathering and lengthy transportation, while other less stable minerals were destroyed. These particular sandstones are usually derived from the weathering of a sandstone; with each cycle, the resulting product becomes purer.

The evidence that many of these deposits are the product of several cycles of weathering is found in the well-rounded worn character of the quartz grains and the paucity of associated accessory minerals. Probably the purest silica sand deposits recently formed in Ontario are those silica sands in the Sault Ste. Marie area, derived from the weathering of the Lake Superior Sandstone of that district. Ancient silica sands, such as the Potsdam Sandstone of eastern Ontario, and the Sylvania Sandstone of southwestern Ontario, probably represent fossil beach deposits of a transgressive epicontinental sea.

SILICA DEPOSITS IN ONTARIO

The chief silica resources in Ontario are the Lorrain Quartzite of Precambrian age, the Potsdam Sandstone of Cambrian age, the Medina Sandstone of Silurian age, the Sylvania Sandstone of Devonian age, and the unconsolidated sands of Quaternary and Recent age. The silica deposits are discussed in the following order:

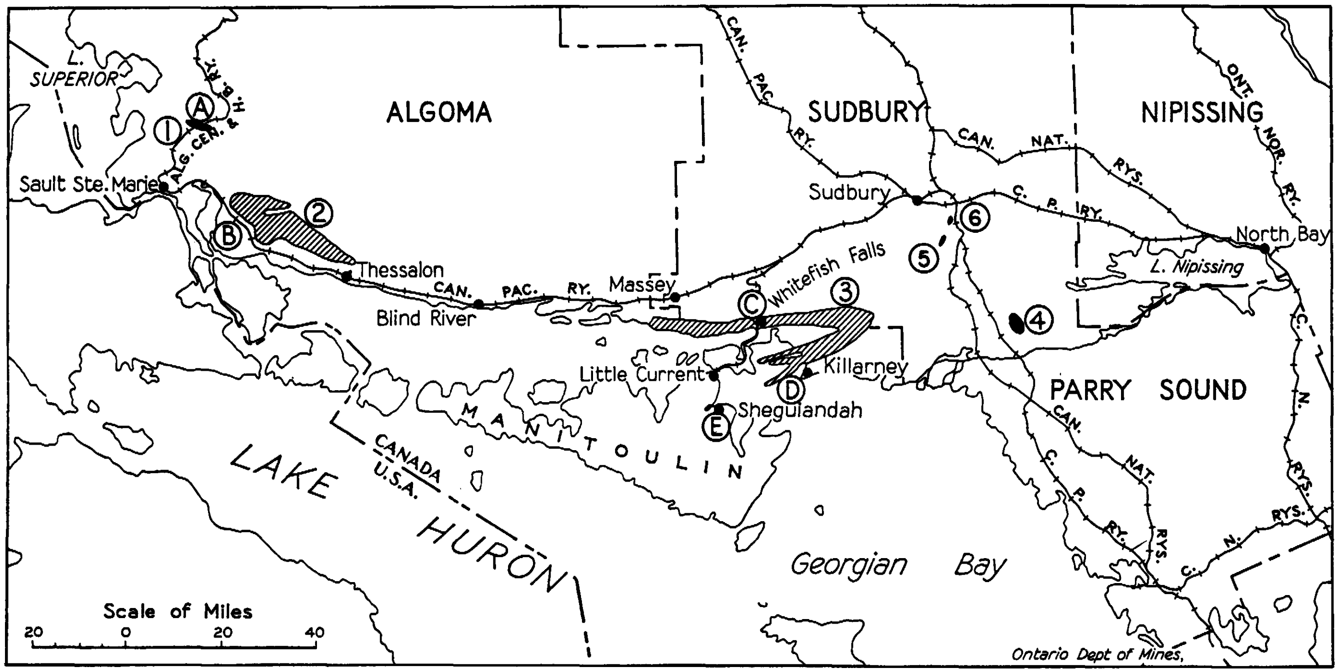
- Precambrian quartzites:
  - Lorrain Quartzite
  - Grenville Quartzite
- Paleozoic sandstones:
  - Potsdam or Nepean Sandstone
  - Medina Sandstone
  - Oriskany Sandstone
  - Sylvania Sandstone
- Unconsolidated sands:
  - Sault Ste. Marie area
  - Southern Ontario
- Pegmatitic and vein quartz.

Lorrain Quartzite

The Cobalt Group of Middle Huronian age is made up of a lower formation, the Gowganda, consisting predominantly of conglomerate, arkose, and greywacke, and an upper formation, the Lorrain Quartzite. The upper formation has a thickness ranging from 5,500 feet to 6,500 feet, of which the upper one-third is silica of high purity, being composed almost entirely of quartz. Chemical analyses of these high-purity deposits indicate a silica content ranging from 95 to over 99 percent.

(II) GRADING OF TYPICAL SIEVE ANALYSIS

Mesh	+4	−4 +8	−8 +14	−14 +28	−28 +48	−48 +100	−100 +200	−200
Weight percent	0.25	5.60	14.55	13.75	14.15	42.20	7.50	2.0



① Bellevue area, Deroche township
Ⓐ *Bellevue quarry*

② Bar River, Thessalon area
Ⓑ *Bar River quarry*

③ Whitefish Falls - Killarney - Sheguiandah area
Ⓒ *Lawson quarry*
Ⓓ *Killarney quarry*
Ⓔ *Sheguiandah quarry*

④ Cosby - Delamere area

⑤ Secord township

⑥ Dill township

Figure 1 — Distribution of Lorrain Quartzite.

DISTRIBUTION

The Lorrain Quartzite is exposed in outcrops in many places along the north shore of Lake Huron, from Sault Ste. Marie on the west to Killarney on Georgian Bay on the east. Figure 1 shows the distribution of the Lorrain Quartzite Formation.

Four belts of high-purity quartzite are readily accessible by rail, road, or water transportation and are, therefore, of particular commercial interest. The most westerly of these is near Bellevue in Deroche township on the Algoma Central and Hudson Bay railway, 20 miles north of Sault Ste. Marie; a quarry operated by Wright and Company formerly supplied silica to Algoma Steel Corporation for the manufacture of silica brick.

The second belt of quartzite, exposed in outcrops near Echo Bay in Macdonald township, District of Algoma, extends southeastward for a distance of about 30 miles to Thessalon, and has a maximum width of 10 miles.

The third and largest belt of quartzite is exposed on the mainland across from the eastern end of Manitoulin Island. It is horseshoe-shaped, and has a length of 70 miles and a width of 2–3 miles. The northern limb is exposed along the shore of the North Channel south of the town of Massey and extends eastward for a distance of 45 miles through Whitefish Falls to Goschen township in the interior. In Goschen township, the belt reverses its direction abruptly, and the southern arm extends southwest from Goschen township to Lake Huron just north of Killarney village. The quartzite ridges form three long points jutting out toward Manitoulin Island. These two arms of the horseshoe form the La Cloche Mountains standing up in bold relief as snow-white ridges above the surrounding country. On Manitoulin Island, the southern range of quartzite is exposed at Sheguiandah Hill in a monadnock completely surrounded by flat-lying Paleozoic rocks.

There are three quarry operations in this third and largest belt: at Whitefish Falls, International Nickel Company operates the Lawson quarry for silica flux; on Badgeley Point near the village of Killarney, Union Carbide Canada Limited operates the Killarney quarry, producing lump silica for ferrosilicon; at Sheguiandah on Manitoulin Island, silica for ferrosilicon is produced by Canadian Silica Corporation.

Although this quartzite belt has for many years been correlated as Lorrain in age, there is now some question as to whether this formation does not belong to a pre-Huronian series. This problem is discussed by Thomson (1962, pp. 76–89).

The fourth deposit of quartzite is much smaller, having an area of about 5 square miles. It is in Delamere and Cosby townships, District of Sudbury, on the north channel of the French River. Rutter Station, on the C.P.R. line from Sudbury to Toronto, is 5 miles west of the deposit.

LITHOLOGY

The Lorrain Quartzite Formation is described as follows by W. H. Collins (1925):

> . . . there is an imperceptibily easy graduation in the lowermost one-third to one-fourth of the Lorrain formation from an impure reddish or pale green quartzite into a purer white variety which continues to the top, and about the middle of the formation there is a zone of indefinite thickness which is distinguished by the presence of numerous thin beds of quartz conglomerate, locally rich in pebbles of red jasper.

The upper high-purity section of the Lorrain Quartzite Formation is the only part with which this report deals.

The quartzite is commonly white or grey, but may be green, pink, or red, depending upon impurities. It is completely recrystallized and is composed of interlocking grains of quartz. This recrystallization has rendered the rock extremely hard and coherent, and, on crushing, the rock often breaks with a conchoidal fracture. Texturally, the rock varies from a coarse-grained glassy quartzite to a fine-grained cherty milky-white quartzite.

The thickness of beds ranges between a few inches and 10 feet. The upper part of the formation is extremely uniform, consisting almost entirely of quartz. There are no impure interbeds of arkose or greywacke, and there are thick sections of pure quartzite available for quarrying.

Chemical analyses of 30 samples, collected from various deposits by the author, indicate: silica content ranging from 97.5 to 99.3 percent; alumina, 0.2 to 2 percent; iron oxides, 0.04 to 1.1 percent; lime, magnesia, and alkalis, less than 1 percent. Impurities noted on petrographic examination include feldspar, kaolin, sericite, talc, chlorite, and iron oxides.

STRUCTURE AND INTRUSIONS

The Lorrain Quartzite, together with the rest of the Cobalt Group, was highly folded during the post-Huronian Killarney orogeny. In most of the area herein described, the Lorrain Quartzite dips steeply. In the Whitefish Falls–Killarney belt, the quartzite of the La Cloche Mountains has a synclinal structure. The Gowganda Formation of lower Cobalt age flanks the quartzite ridges on both sides (Collins 1925).

The quartzite ridges are cut by faults. The shearing is often coincident with bedding planes and, along these zones of intense shearing, talc, chlorite, and sericite are developed. These talc-sericite slips account for a considerable amount of the alumina and alkalis present in the rock, and if a high degree of purity is required, this material should be wasted by selective mining or sorting.

The Lorrain Quartzite is cut by numerous narrow diabase dikes that are tentatively correlated as Keweenawan in age. In the Killarney area, there are two main sets of dikes; one set strikes approximately east-west, and the other set strikes northwest-southeast and(or) northeast-southwest. Careful preliminary examination is necessary in choosing a quarry site in order that the occurrence of the diabase dikes will not interfere with quarry development.

Occurrences of Lorrain Quartzite

The occurrences of Lorrain Quartzite are in eight localities, as shown on Figure 1. In the descriptions that follow, the bracketted number in the heading corresponds to the number of the property location on Figure 1.

BELLEVUE AREA

Hard white quartzite, which is correlated by McConnell (1927) as Lorrain in age, forms several ridges in the Sault Ste. Marie area. The most important of these is the Bellevue ridge, a narrow 6-mile-long closely-folded syncline of Lorrain Quartzite, extending in an east-west direction across the southern part of Deroche township and westward for a mile into Vankoughnet township.

The quartzite is intruded by granite and diabase and is completely recrystallized.

Bellevue Quarry, Deroche Township (1A)

Wright and Company operated a small quarry in the Lorrain Formation of the Bellevue ridge at mileage 19.8 on the Algoma Central and Hudson Bay Railway line. This quarry supplied crude mine-run quartzite to Algoma Steel Corporation for the manufacture of silica brick.

At the quarry, the quartzite strikes northeast and dips 50° to the northwest. The rock is grey or pink and contains scattered patches of specularite. Ripple marks and crossbedding can be seen on the ridge above the face of the opening. Quartzite breccias and quartz conglomerates were also noted. At the east side of the quarry, sericite soapstone is developed along a sheared zone striking N.10°W., and dipping 50° west. This quarry has been taken over by Algoma Steel Corporation.

The results of analyses of composite chip sample of quartzite from the Bellevue quarry are given in (III).

BAR RIVER QUARRY, LAIRD TOWNSHIP (2B)

The belt of Lorrain Quartzite previously mentioned running from Echo Bay to Thessalon, District of Algoma, has been quarried near Bar River station on lots 2 and 3, concession VI, in Laird township. The quarry, which was operated from 1941 to 1943, is 1 mile east of Bar River station. The rock is a greyish white fine-grained sugary quartzite occurring in massive beds from 8 inches to 4 feet in thickness. The formation strikes N.55°–75°E., and dips 20° north. The quarry face has a height of approximately 40 feet and was opened on the north face of a ridge rising more than 100 feet above the present quarry floor. The crest of the quartzite ridge lies about 800 feet south of the present quarry face.

Some iron staining, specularite, and soapstone were noted in the rock, but no diabase dikes are present. Microscopic examination shows that the rock is composed of interlocking grains of quartz averaging about 0.8 mm. in size, but showing a considerable variation in grain-size from 0.1 to 2.0 mm. Dusty inclusions outline the original rounded quartz grains. The quartz shows little or no evidence of strain.

An analysis of a chip sample taken across the 40-foot section exposed in the south face of the quarry gives the following results:

ANALYSIS OF LORRAIN QUARTZITE, LAIRD TOWNSHIP

SiO_2	98.89
Al_2O_3	0.59
Fe_2O_3	0.08
CaO	0.02
MgO	0.01
TiO_2	0.05
Na_2O	0.06
K_2O	<0.50

WHITEFISH FALLS AREA

The northern limb of the La Cloche Mountains runs east-west through Mongowin and Curtin townships, District of Sudbury, just north of the village of Whitefish Falls on the Espanola–Little Current highway. High-purity Lorrain Quartzite, forming the crest of this range of hills, underlies an area of about 20 square miles in the southern parts of Mongowin and Curtin townships. The highest point in this area is the hill just east of highway No. 68 at Willisville, about a mile north of Whitefish Falls. The elevation at the base of the firetower on the top of the hill is 1,114 feet, giving a relief of 533 feet above the level of Lake Huron (elevation 581 feet).

The Whitefish Falls area is easily accessible by road and rail, being served by highway No. 68 and the Espanola–Little Current branch of the Canadian Pacific Railway.

The Lorrain Quartzite of the Whitefish Falls area is a fine- to medium-grained, hard, flinty, white quartzite occurring in beds from 6 inches to 2 feet or more in thickness. On the Willisville Hill, the bedding strikes N.75°–80°E. and dips steeply to the south. Faint crossbedding is still discernible in places in the recrystallized quartzite. The rock has strong blocky jointing with fractures at right angles.

In some places, the quartzite is cut by narrow zones of faulting along which the sheared rock is in many places altered to a sericite-serpentine schist. These fractures may be occupied by diabase dikes up to 20 feet in width. The dikes strike in two predominant directions, east-west conformable with the bedding, and northwest-southeast.

Microscopic examination of the fine-grained cherty white quartzite from the Lawson quarry discloses that it is composed of a fine mosaic of interlocking quartz grains of rather uniform size. Average grain-size is 0.15 mm., with a range of 0.05–0.2 mm. The grains have sutured interlocking boundaries.

A sample of the medium-grained white quartzite from the Willisville Hill shows strong cataclastic structure. The quartz grains, averaging 0.5 mm. in diameter and reaching a maximum size of 2 mm., show evidence of strain and are elongated in one direction. Along intergrain boundaries are aggregates of mylonitic quartz. Sericite and pyroxene are developed in the quartzite in scattered radiating fibrous aggregates.

Lawson Quarry, Curtin Township (3C)

In 1942 the International Nickel Company of Canada Limited opened a quarry for silica flux in Lorrain Quartzite on lot 13, Township of Curtin (formerly Timber Berth 11) just north of the village of Whitefish Falls. The quarry is on the Canadian Pacific Railway line from Espanola to Little Current; the rail haul to Sudbury, via Espanola, is approximately 65 miles. The quartzite ridge now being quarried has a length of 2,700 feet between highway No. 68 and the railway line on the west shore of Frood Lake, and a width of 900 feet. It formerly rose to a height of 200 feet above the yard-level. The first bench has now been completed, and its floor is 120 feet above the yard-level. A second bench with a height of 60 feet is now being worked.

The quartzite is a white fine-grained hard, almost cherty, rock. A sheared diabase dike, about 20 feet wide, cuts the west face of the second bench. This rock is used for road stone.

For primary breaking, vertical 9-inch-diameter holes are drilled by 2 churn-drill rigs. Holes are drilled on 26-foot centres with approximately 32-foot burden. The quartzite is loaded into trucks by a 3-cubic-yard electric shovel. Three 30-ton Mack trucks are used for the short haul to the chute, which feeds the crusher plant on the side of the hill.

The quartzite is fed from the dump chute by an 8-foot-diameter 64-inch roll feeder, to a 60- by 42-inch jaw crusher that is set to crush to 3 inches. A 30-inch belt conveyor carries the crushed product to a 5- by 10-foot double-deck screen. The size of the openings in the upper or scalping screen is 1¼ by 5 inches. The oversize is crushed to 1¾ inches in a 4¼-foot standard Symons cone crusher; this product, along with the screen undersize, falls on a 30-inch belt conveyor to a 4- by 8-foot double-deck screen above the loading bins having ⅞- by 6-inch openings in the scalping screen and ⅜- by 5-inch openings in the lower screen. The oversize is discharged into a bin for shipment to the converter plants at Copper Cliff and Coniston; the undersize falls into a separate bin and is shipped to the reverberatory plant at Copper Cliff.

Production amounts to about 2,100 tons per 8-hour shift. The crushing plant is equipped with an efficient cyclone dust collection system.

Results of analyses of composite chip samples of quartzite from the Whitefish Falls area are shown in (IV). All the analyses quoted in this report were by spectrographic method, and were carried out by the Laboratory Branch of the Ontario Department of Mines. Silica was calcu-

(III) ANALYSES OF QUARTZITE, BELLEVUE QUARRY

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	TiO_2	Na_2O	K_2O
70-1	97.87	1.36	0.22	0.02	0.03	0.14	0.06	<0.50
70-4	98.69	0.63	0.20	0.05	0.03	0.05	0.05	<0.50
706-1	97.69	1.32	0.46	0.10	0.03	0.05	0.05	<0.50
706-2	98.43	0.51	0.60	0.04	0.02	0.05	0.05	<0.50

Sample 70-1 is a chip sample taken over a width of 300 feet across-structure on the quartzite ridge overlooking the quarry.
Sample 70-4 is a chip sample across the top of the quarry face.
Samples 706-1 and 706-2 are composite grab samples from the muckpile in the quarry.

Courtesy Royal Canadian Air Force

Lawson quarry, Willisville.

lated by difference, and K_2O was arbitrarily taken as 0.30 where it is shown as less than 0.50 in the analyses for this calculation.

It is difficult to get a sample adequate to represent an average analysis of the quartzite over a mineable width, but these analyses give an indication of the probable content of impurities in the rock.

KILLARNEY AREA

The southern limb of the La Cloche Mountains forms a series of high ridges running from Goschen township, District of Sudbury, in a southwesterly direction through Killarney township (formerly known as Timber Berth 10), District of Manitoulin, to Georgian Bay, where the quartzite ridges form three long fingers reaching out toward Manitoulin Island. These are McGregor Point, Fraser Point, and Badgeley Point. South and west of Badgeley Point, the quartzite formation is exposed on Haywood, Partridge, Centre, and Badgeley islands. Most of these islands are flanked by Ordovician limestones.

The highest point in the south range of the La Cloche hills is in Carlyle township, District of Manitoulin, where the quartzite ridge has a maximum elevation of 1,785 feet, standing 1,204 feet above the level of Lake Huron.

Killarney Quarry, Killarney Township (3D)

The Killarney quarry of Union Carbide Canada Limited is on the south shore of Badgeley Point, Killarney township, across from the northeast end of Badgeley Island, 4 miles west of the village of Killarney. Access is by boat from either Killarney or Little Current; the quarry and crushing plant are situated on the shore of Killarney Bay.

Badgeley Point is composed of white Lorrain Quartzite ridges standing up from 500 to 1,000 feet above the level of Lake Huron. The fine-grained, completely recrystallized quartzite occurs in steeply dipping beds striking northeast-southwest. At the quarry, the strike varies from N.40°E. to N.55°E. On the quartzite ridge immediately west of the quarry, strikes average N.55°E. and dips range from vertical to 70° south. Crossbedding indicates poor tops facing south. The quartzite is cut by diabase dikes up to 25 feet in width. One set of diabase dikes appears to run in a northeast-southwest direction conformable with the strike of the quartzite. A second set occupies valleys trending approximately east-west. These diabase dikes have dips ranging from 60° to vertical and appear to occupy sets of joints or faults having a regular structural pattern. Being softer and more easily weathered than the quartzite, these dikes form valleys that are readily visible on aerial photographs of the area.

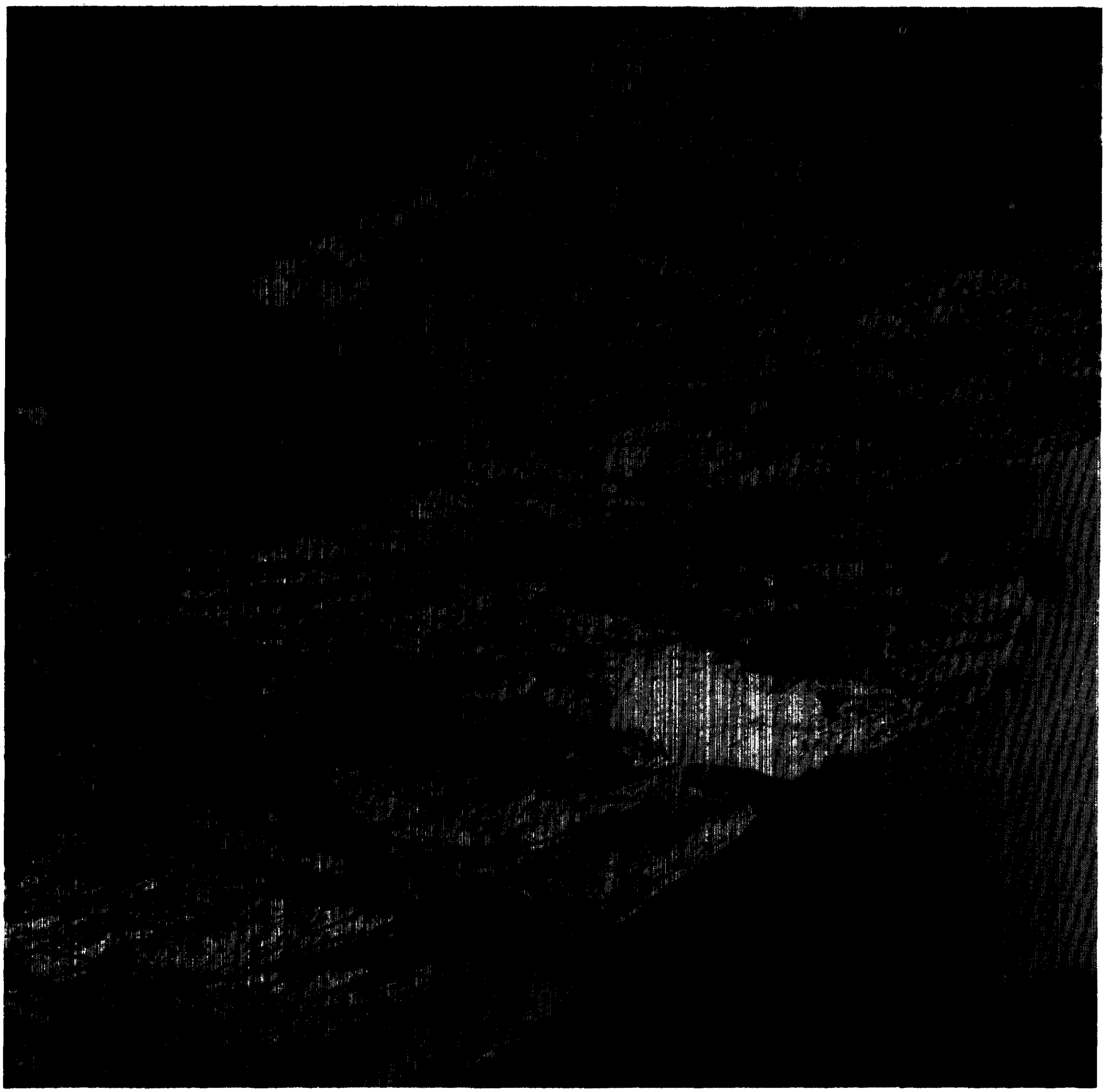
Fine-grained iron oxide gives the quartzite a reddish colour in some places. Microscopic examination of sections of quartzite from the Killarney quarry discloses that the rock is medium- to fine-grained, and average grain-size is 0.2 mm. It is made up of an aggregate of equant quartz grains with smooth boundaries. The degree of metamorphism appears to be less intense here than at the Lawson quarry. There is little or no alignment of quartz grains and no evidence of cataclastic structure in the specimens examined.

(IV) ANALYSES OF LORRAIN QUARTZITE, WHITEFISH FALLS AREA

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	TiO_2	Na_2O	K_2O
59-4	98.86	0.51	0.08	0.02	0.03	0.04	0.16	<0.50
59-5	98.78	0.64	0.10	0.02	0.02	0.04	0.10	<0.50
59-7	98.35	1.04	0.09	0.03	0.02	0.05	0.12	<0.50
76-2A	97.67	1.77	0.05	0.01	0.02	0.08	0.10	<0.50
76-2B	98.13	1.34	0.05	0.01	0.02	0.07	0.08	<0.50
76-6	97.74	1.73	0.05	0.01	0.02	0.06	0.09	<0.50
76-7	97.67	1.81	0.06	0.02	0.02	0.05	0.07	<0.50

Sample 59-4 is a composite chip sample taken as representative of the material at the east end of the first bench at the Lawson quarry.
Sample 59-5 is a composite chip sample representing the quartzite in the muckpile at the west end of the first bench, Lawson quarry.
Sample 59-7 is a composite chip sample taken on the second bench near the chute, Lawson quarry.
Sample 76-2A is a composite chip sample of quartzite taken in a north-south direction across-strike over a length of 100 feet on the east end of the firetower hill at Willisville, Curtin township.
Sample 76-2B is a second analysis of Sample 76-2A, indicating the magnitude of sampling error in this case.
Sample 76-6 is a composite chip sample of quartzite taken across-strike over a length of 3,000 feet at the west end of the firetower hill at Willisville, Curtin township.
Sample 76-7 is a composite chip sample of quartzite taken across-strike over a length of 300 feet on the quartzite ridge in Block A, Concession II, Mongowin township, ¼ mile west of highway No. 68.

Courtesy Royal Canadian Air Force



Killarney quarry, Badgeley Point.

The Killarney quarry has produced more or less continuously since it was opened by Willmott and Company in 1911. The quarry is now operated by Union Carbide Canada Limited on a seasonal basis from May to November almost every year. The lump silica is shipped by boat to Welland, Ontario, and to Ashtabula, Ohio, for manufacture of ferrosilicon and other silicon-bearing alloys.

The present quarry floor has an elevation of 625 feet, 45 feet above lake-level. The current face averages about 100 feet in height and has a length of about 800 feet in an east-west direction.

A churn-drill is used to drill 9-inch holes in the 90-foot rock face for primary breaking. Secondary breaking is done by sand-blasting. The quartzite is loaded into two 15-ton trucks by a 2½-yard diesel-driven shovel for the haul to the crusher plant.

The rock is discharged to a hopper feeding a 42- by 40-inch jaw-crusher set to 5 inches. The product is conveyed to a one-deck screen, oversize scalped off and recirculated, thence to a secondary crusher set to 3 inches, and another two-deck screen to produce a (nominal) 4-inch by ¾-inch product. The minus ¾-inch is washed through a classifier and stored for sale as by-product. From the mill, the 4-inch by ¾-inch product is conveyed about ¾ mile by belt conveyor to a rock-excavated storage bin with capacity of 18,000 tons. Lake freighters are loaded at the wharf by an outboard conveyor.

Analyses of composite chip samples of quartzite from the Killarney quarry area are given in (V).

SHEGUIANDAH AREA

The hills of Lorrain Quartzite exposed as monadnocks surrounded by flat-lying younger Paleozoic rocks in Howland and Sheguiandah townships, Manitoulin Island, 6 miles south of Little Current, are a continuation of the south range of the La Cloche Mountains. There are five areas of outcrop in the southern part of Howland and the northern part of Sheguiandah townships. The area is easily accessible by road and water.

Sheguiandah Quarry, Howland Township (3E)

The Sheguiandah or Trotter quarry, operated by the Canadian Silica Corporation, is on lot 2, concession XII, Howland township, on the shore of Sheguiandah Bay about 1 mile north of Sheguiandah village. The quartzite ridge trends N.80°E. and rises to a maximum height of 180 feet above the level of Lake Huron. The quartzite formation strikes east-west and has a dip ranging from 75° to 80° to the north. The very fine-grained, almost cherty, white quartzite is very similar to the material from the Lawson quarry. There is strongly developed blocky jointing at right angles to the bedding. Strong zones of shearing strike N.70°E. and dip steeply to the north. Along these shear zones, sericite and soapstone are developed in bands 4–6 inches wide.

The present quarry face has a length of 1,600 feet and a height ranging from 30 to 50 feet. The face trends N.80°E., and dips 75°N. parallel to the strongly-developed bedding shears. The face is being advanced southward across the structure. Primary breaking is done by drilling four sets of flatly-dipping holes into the face by means of wagon-drills operating on the quarry floor. Secondary breaking is done mostly by a 4,300-pound gasoline-driven drop ball. Haulage from the quarry to the primary crusher is by trucks loaded by a 2-cubic yard diesel shovel. Primary crushing is done by a gyratory crusher. The product is

(V) ANALYSES OF LORRAIN QUARTZITE, KILLARNEY QUARRY

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	TiO_2	Na_2O	K_2O
64-1	99.05	0.49	0.04	0.01	0.03	0.04	0.04	<0.50
64-2	98.66	0.86	0.04	0.01	0.03	0.04	0.06	<0.50
67-2A	97.72	0.98	0.76	0.07	0.04	0.06	0.07	<0.50
67-2B	98.28	1.01	0.22	0.07	0.02	0.05	0.05	<0.50
67-3	98.19	0.94	0.36	0.06	0.03	0.05	0.07	<0.50
69	98.67	0.80	0.08	0.03	0.03	0.04	0.05	<0.50

Samples 64-1 and 64-2 are composite chip samples taken across a high quartzite ridge immediately west of the Killarney quarry. Sample 64-1 was taken across a length of 700 feet in an east-west direction eastward from the west boundary of claim S.38001 at a point 600 feet south of No. 4 post. Sample 64-2 was taken across-strike in a north-south direction for a width of 1,100 feet along the west boundary of claim S.38001.

Samples 67-2A, 67-2B, and 67-3, are representative composite sample from the stockpile of minus-¾-inch fines at the Killarney quarry. Sample 67-2B is from the same 20-pound sample as 67-2A; 2B was screened and the plus-¼-inch fraction washed and analyzed. There appears to be no significant difference among these three samples. The high iron content is thought to be due mostly to iron introduced during the crushing operations.

Sample 69 is a composite grab sample from the muckpile in the quarry.

conveyed to a set of triple-deck screens having openings of 5 inches, 1½ inches, and ¼ inch. The minus-5-inch plus-1½-inch material is stockpiled over a tunnel conveyor fed by nine chutes. Soapstone is picked out on the conveyor belt and discarded in order to lower the alumina content of the commercial product. Freighters are loaded by boom-conveyor feeding from the stockpile. This lump silica is used for ferrosilicon. The minus-1½-inch plus-¼-inch, and the minus-¼-inch materials, are stockpiled separately. The operation is seasonal, and production depends mostly on market conditions. Quarrying operations began in 1945.

Analyses of composite chip samples from the Sheguiandah quarry are given in (VI).

COSBY AND DELAMERE TOWNSHIPS (4)

Hills of white quartzite, standing 100–300 feet in relief above the surrounding country, occupy an area of approximately 5 square miles in western Cosby and eastern Delamere townships, District of Sudbury. The quartzite is exposed on the road from Noelville to the French River station. Rutter station, on the Canadian Pacific Railway line to Sudbury, lies 5 miles west.

The quartzite in this area, tentatively correlated as Lorrain in age by T. T. Quirke, has a very coarse texture, and so differs from the other Lorrain quartzites examined. The rock is a glassy, coarse-grained, recrystallized, white to pink, quartzite with grains up to 5 mm. in diameter. Secondary sericite and specularite are to be found in many places throughout the formation. The bedding is nearly vertical in most of the places that were examined.

A small quarry was opened ½ mile north of the Noelville road on the east side of the quartzite range, but only test shipments were made.

Three analyses of quartzite from Cosby township are given in (VII).

SECORD TOWNSHIP (5)

A quartzite deposit on lot 7, concession IV, Secord township, District of Sudbury, has been

(VI) ANALYSES OF QUARTZITE, SHEGUIANDAH QUARRY

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	TiO_2	Na_2O	K_2O
60-1	99.09	0.37	0.07	0.02	0.02	0.08	0.05	<0.50
60-3	98.05	0.97	0.32	0.12	0.09	0.10	0.05	<0.50
61-1	99.17	0.37	0.05	0.02	0.02	0.03	0.04	<0.50
61-2	98.46	0.92	0.10	0.08	0.04	0.06	0.04	<0.50
61-3	99.27	0.26	0.05	0.02	0.02	0.04	0.04	<0.50
61-4	99.20	0.33	0.05	0.02	0.02	0.04	0.04	<0.50

Sample 60-1 is a composite sample of the minus-1-inch plus-¼-inch material in the stockpile at the water's edge.
Sample 60-3 is a composite sample of the minus-¼-inch material from the stockpile.
Sample 61-1 is a composite grab sample from an inactive quarry 500 feet west of the present operation.
Sample 61-2 is a composite chip sample taken across a 70-foot width in a north-south direction at the west end of the present quarry. This composite sample includes some of the soapstone from a sheared zone exposed in the west wall.
Sample 61-3 is a composite chip sample across a 125-foot width in a north-south direction at the east end of the present quarry operation.
Sample 61-4 is a composite chip sample taken over a length of 1,000 feet along the hilltop behind the quarry face being worked at present.

(VII) ANALYSES OF QUARTZITE, COSBY TOWNSHIP

Sample	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	TiO_2	Na_2O	K_2O
42	98.07	1.00	0.40	0.05	0.06	0.06	0.06	<0.50
44	96.98	1.76	0.75	0.05	0.03	0.09	0.04	<0.50
45	98.09	0.37	1.09	0.01	0.02	0.08	0.04	<0.50

Sample 42 is a composite chip sample taken over a 350-foot width across the strike of the quartzite just north of the Noelville road in the southern part of Cosby township.
Sample 44 is a composite chip sample taken over a 700-foot width across-structure on a quartzite, immediately north of the schoolhouse in Cosby township on the Noelville road.
Sample 45 is a composite grab sample from the small quartzite quarry, ½ mile north of the main road, Cosby township.

staked by Isaac Burns, of Lively, Ontario. The deposit is 15 miles south of Sudbury and is reached by a one-mile trail that runs northeast from the Horseshoe Lake road.

The band of quartzite is approximately 300 feet wide and has been traced for a length of about 1,600 feet along a northeasterly strike. It dips 45° southeast in conformity with the local hornblende gneiss country rocks. The quartzite is somewhat similar to the Cosby township quartzite: medium to coarse-grained in texture, white in colour, glassy in lustre, with minor secondary sericite and hematite.

Two chip samples across the 300-foot exposed width of the band, 80 feet apart, were taken by Mr. Burns and analyzed by the Laboratory Branch, Ontario Department of Mines, with the following results:

	Sample No. 1	Sample No. 2
SiO_2	98.28	98.16
Al_2O_3	0.55	0.74
Fe_2O_3	0.06	0.06
MgO	0.03	0.03
CaO	0.17	0.08
Na_2O	0.01	nil
K_2O	0.14	0.18
TiO_2	0.03	0.04
L.O.I	0.03	0.28
Total	99.40	99.57

This quartzite should be suitable for silica flux.

DILL TOWNSHIP (6)

Canadian Copper Company operated a quartzite quarry for silica flux on the east side of the Canadian National Railways line on lot 1, concession I, Dill township, from 1909 to 1923.

The quartzite strikes north-south and dips 60° east. A face, 60 feet in height, was worked. The quarry location is shown on map No. 2017 of the Ontario Department of Mines, on which the quartzite is shown as belonging to the Sudbury Group.

Grenville Quartzite

The Grenville Series of southeastern Ontario contains a number of quartzite members. Very little quantitative data is available on these quartzites but, in general, they are too impure to be used as a source of high-grade silica. Quartzite from the Actinolite–Cloyne area is reported by Miller and Knight (1914, p. 44) to "... be made up of interlocking grains of quartz, together with subordinate sericite, iron oxides, and a little iron pyrites." A chemical analysis of this rock indicates: silica, 87.05 percent; iron oxides, 3.28; alumina, 5.52; lime, 0.10; magnesia, 0.34; soda, 0.83; potash, 1.50; sulphur, 0.10; and water, 1.55 percent.

In a report on the geology of Leeds county, M. B. Baker (1923, p. 5) describes the Grenville quartzites and gives an analysis of the quartzite as follows:

SiO_2	98.14
CaO	0.35
Al_2O_3	0.88
Fe_2O_3	0.41
	99.78

He remarks that this quartzite would be suitable for the manufacture of silica refractories.

GANANOQUE-BROCKVILLE QUARTZITE DEPOSITS

Extensive ridges of white Precambrian quartzite are exposed in a belt, 6–8 miles wide, along the St. Lawrence River from Kingston to Brockville. Samples of typical outcrops of this Precambrian quartzite were taken by the writer in three separate locations.

Sample 60-47 was taken on lot 31, concession IV, Pittsburgh township, on a white quartzite ridge ¾ mile south of Findley station, which is 5 miles west of Gananoque. The white quartzite ridge is exposed for ¼ mile in width and 2–3 miles in length; it strikes northeast-by-east and dips vertically. The quartzite is white to glassy, medium- to coarse-grained, and completely recrystallized. There is minor intrusion of granite, and some limited granitization of the quartzite is observed. The ridge has a relief of 50–60 feet. The chip sample, taken across a width of 200 feet, gave the following analysis:

	Percent
SiO_2	95.56
Al_2O_3	1.44
Fe_2O_3	1.18
MgO	0.30
CaO	0.40
Na_2O	nil
K_2O	0.61
TiO_2	0.16
	99.65

Samples 60-48 and 60-49 were taken from a prominent ridge of white quartzite at Lyn, near Brockville; south of the village of Lyn, this quartzite ridge, about ½ mile in width, extends for 5–6 miles in a southwesterly direction. Sample 60-48 is a chip sample taken across 100 feet of the ridge just south of the Lyn sand pit south of Lyn village. Sample 60-49 is a chip sample taken across 150 feet of the quartzite ridge 1¼ miles northeast of sample 60-48. These two analyses are as follows:

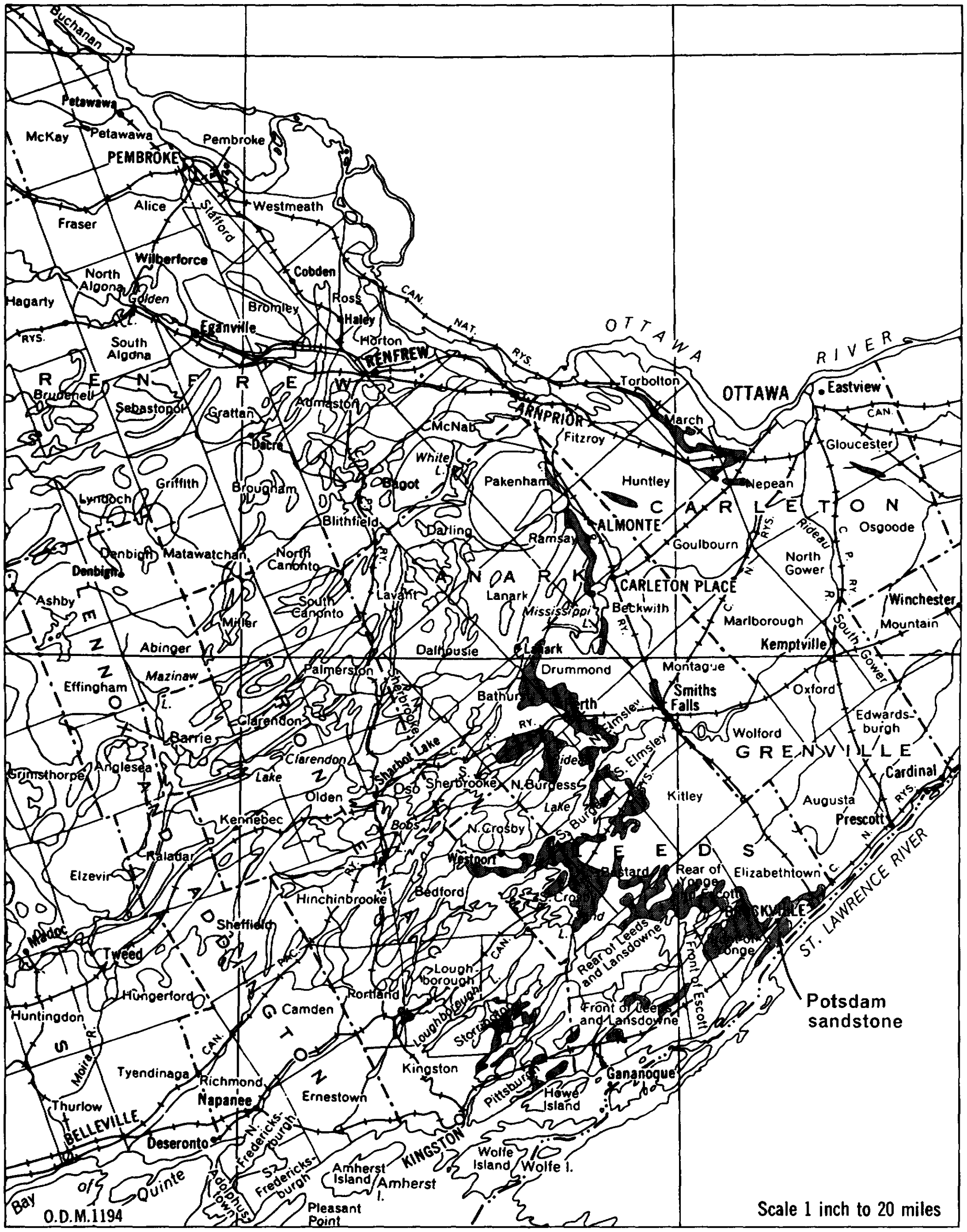


Figure 2—Distribution of Potsdam Sandstone in eastern Ontario.

	Sample 60-48	Sample 60-49
SiO_2	96.36	95.58
Al_2O_3	0.90	1.13
Fe_2O_3	1.03	1.36
MgO	0.31	0.27
CaO	0.07	0.19
Na_2O	0.42	0.49
K_2O	0.18	0.40
TiO_2	0.17	0.17
Total	99.45	99.59

Paleozoic Sandstones

POTSDAM SANDSTONE

Figure 2 shows the distribution of Potsdam Sandstone in southern Ontario.

The Potsdam Sandstone has been described by M. L. Keith (1949) in a report entitled "Sandstone as a source of silica sand in southeastern Ontario", and most of the following information on the Potsdam Sandstone is taken from Keith's report, to which the reader is referred for further details.

The Potsdam Sandstone is the lowermost Paleozoic rock in southeastern Ontario, and rests with unconformity on the eroded surface of the underlying Precambrian. It is exposed in numerous places in the Kingston-Perth area as shown on Ontario Dept. Mines map No. 1946-9 (Keith 1949), and in the Ottawa area as shown on Geological Survey of Canada map No. 588A (Wilson 1940). In the Ottawa area, A. E. Wilson of the Geological Survey of Canada uses the term "Nepean" for this formation.

In this report the term "Potsdam" is used to refer to all these sandstones following the nomenclature of M. L. Keith.

The Potsdam Formation is a buff to white, sugary-textured flat-bedded sandstone of high purity. Texturally, it consists of an aggregate of subrounded to angular individual grains of quartz that are poorly cemented together by silica cement. Owing to its lack of coherence in most occurrences, it is easily broken down on milling into a silica sand with very little crushing of the individual grains. Some of the Potsdam Sandstone is hard, compact, and quartzitic, and is unsuitable for the production of silica sand.

In some areas, the sand has a bond that is calcareous or argillaceous rather than siliceous. In other places the sandstone contains black carbonaceous material.

Chemically, the sandstone is from 98 to over 99 percent silica; analyses of the Potsdam Sandstone, taken from Keith's report, are listed in (VIII).

Alumina ranges between 0.3 and 1.0 percent, total iron between zero and 0.4 percent; lime is low, and alkalis are generally absent. The iron is usually present as hematite or limonite coating the quartz grains or in the intergranular cement, and much of it can be removed during disaggregation and washing of the sand.

On disaggregation, most of the grains (80–98 percent) are between 28- and 100-mesh, with an average AFA fineness number of 56.

As formerly quarried at the Kingston Silica property at Joyceville, the sand was too high in iron content for the glass trade. However, beneficiation tests conducted by the Industrial Minerals Division of the Mines Branch at Ottawa have indicated that the iron content could probably be reduced from 0.32 to 0.06 percent by a process of dry milling.

Kingston Silica Mines Limited

Kingston Silica Mines Limited formerly operated a sandstone quarry and plant on lots 13 and 14, concession V, Pittsburg township, Frontenac county, near the village of Joyceville on the Rideau Canal, 12 miles northeast of Kingston.

The Potsdam Sandstone quarry had a 15-foot face. Eighteen-foot holes were drilled vertically by wagon-drill. The rock was loaded by a 1-cubic yard gasoline shovel into trucks and hauled to a 30- by 30-inch impact crusher in closed circuit with a 1-inch screen. This crusher produced minus-1-inch material that was stockpiled at the mill.

(VIII) ANALYSES OF POTSDAM SANDSTONE, EASTERN ONTARIO

	SiO_2	Al_2O_3	Fe_2O_3	FeO	CaO	MgO	S	L.O.I.
Average of 12	98.61	0.47	0.15	0.10	0.13	0.05	0.02	0.35
Kingston Silica	98.03	1.00	0.26	0.06	0.12	0.06	0.01	0.36
Hart Road	99.40	0.30	0.13	0.13	0.00	0.00	0.01	0.07
Charleston Lake	99.07	0.32	0.10	0.07	0.12	0.07	0.03	0.24
Newboro (1)	99.19	0.33	0.04	0.08	0.04	0.05	0.03	0.22
Newboro (2)	99.00	0.29	0.13	0.08	0.06	0.05	0.02	0.16
Newboro (3)	98.41	0.54	0.19	0.06	0.39	0.07	0.03	0.53
Battersea	98.21	0.50	0.14	0.07	0.11	0.02	0.05	0.46
Opinicon Lake	99.04	0.65	0.03	0.04	0.07	0.03	trace	0.22

Owing to the poor coherence of this sandstone, much of the material was reduced to a sand in this initial crushing stage.

The flow-sheet for the mill is given in Keith's report, (1949, p. 28). This scheme was later somewhat modified, the impact crusher replacing the jaw-crusher, and a rod-mill replacing the rolls. After screening, the sand was classified in two hydraulic classifiers. The sand was dewatered in a Rotascoop dewatering cone, drained, and stored in bins.

The plant closed in 1953, and the property was later expropriated by the Canada Department of Justice to form part of the Joyceville penitentiary.

During the summer of 1950, Kingston Silica Mines Limited opened a new quarry 10 miles east of Kingston on highway No. 2 on the north shore of the St. Lawrence River, lots 29 and 30, concession III, Pittsburg township, Frontenac county. This sandstone contains more carbonaceous material, but the grains appear to be better rounded and less pitted than the Joyceville material.

This property was later taken over by St. Lawrence Industrial Silica Limited.

St. Lawrence Industrial Silica Limited

St. Lawrence Industrial Silica Limited was incorporated in 1956 to develop a Potsdam Sandstone deposit on the St. Lawrence River, 4 miles west of Gananoque on lots 29 to 32, concessions II and III, Pittsburgh township, Frontenac county.

A small quarry, opened by Kingston Silica Corporation, is on the 760-acre property near the river front on the farm of R. Paddle. The quarry exposed a 10- to 12-foot section of grey mottled Potsdam Sandstone. Overburden is shallow. The 10½-foot section exposed in the north quarry face is illustrated in Figure 3.

Chip samples were taken of the lower 4.5 feet and the upper 6 feet by the author. Chemical analyses of these chip samples are as follows:

	Lower 4.5 Feet	Upper 6 Feet
SiO_2	96.11	94.71
Al_2O_3	1.55	1.59
Fe_2O_3	0.26	1.02
MgO	0.26	0.30
CaO	0.67	0.17
Na_2O	nil	0.46
K_2O	0.41	0.31
TiO_2	0.09	0.13
Total	99.35	98.69

A program of diamond-drilling was carried out by the company on lots 29 and 30, south of highway No. 2. Twenty-two holes, averaging 40–50 feet in depth, were drilled. Average thickness of overburden was 9 feet; average thickness of sandstone cut was over 35 feet, and the average silica content of the sandstone was 90 percent.

Diamond-drillholes, spaced on 500-foot centres, were drilled. Company estimates of tonnage were as follows:

SiO_2 Average	Depth	Estimated Quantity
percent	feet	tons
96.0	4.3	1,714,600
92.6	19.8	7,855,300
83.0	11.5	4,585,600

The company reported total reserves of approximately 20,000,000 tons. Grain-size distribution was said to be in the minus-20 plus-200-mesh range. Limonite and carbonaceous material are present, and beneficiation of the sand was planned. The sand is of a granularity suitable for foundry sand.

The company plans indicated a nominal plant capacity of about 500,000 tons per year of sand, of which about 50 percent was foundry sand, and 50 percent beneficiated sand for the glass and abrasive industries.

The mill flow-sheet planned would have involved crushing and grinding, washing, desliming, sizing, and stockpiling. Foundry sands would be reclaimed as required from the stockpiles, run through a dryer, and sized by air separation.

Washed foundry sands from the sand preparation section would be too high in Al_2O_3 for artificial abrasives. Attrition scrubbing in an acid solution at high solids-density was planned to reduce the alumina from 0.5 percent to 0.1 percent and to reduce the iron to 0.04 percent.

Glass sand can be produced by first heating the sand to 1,200°F. to remove organic impurities and then leaching with concentrated sulphuric acid to remove the iron. Washing then removes the residue of iron and alumina. The product is then dried and sized.

The company's affairs were wound up in 1961; it surrendered its charter after failure to obtain financing for a mill. Difficulty was encountered in reducing the chromium content to acceptable levels for glass sand.

Rochester and Pittsburgh Coal Company (Canada) Limited

Elgin Silica Sand Property

In 1958, Rochester and Pittsburgh Coal Company (Canada) Limited acquired a 2,700-acre silica sand property near Elgin, Ontario, comprising all or parts of lots 8 to 13, in concession I, South

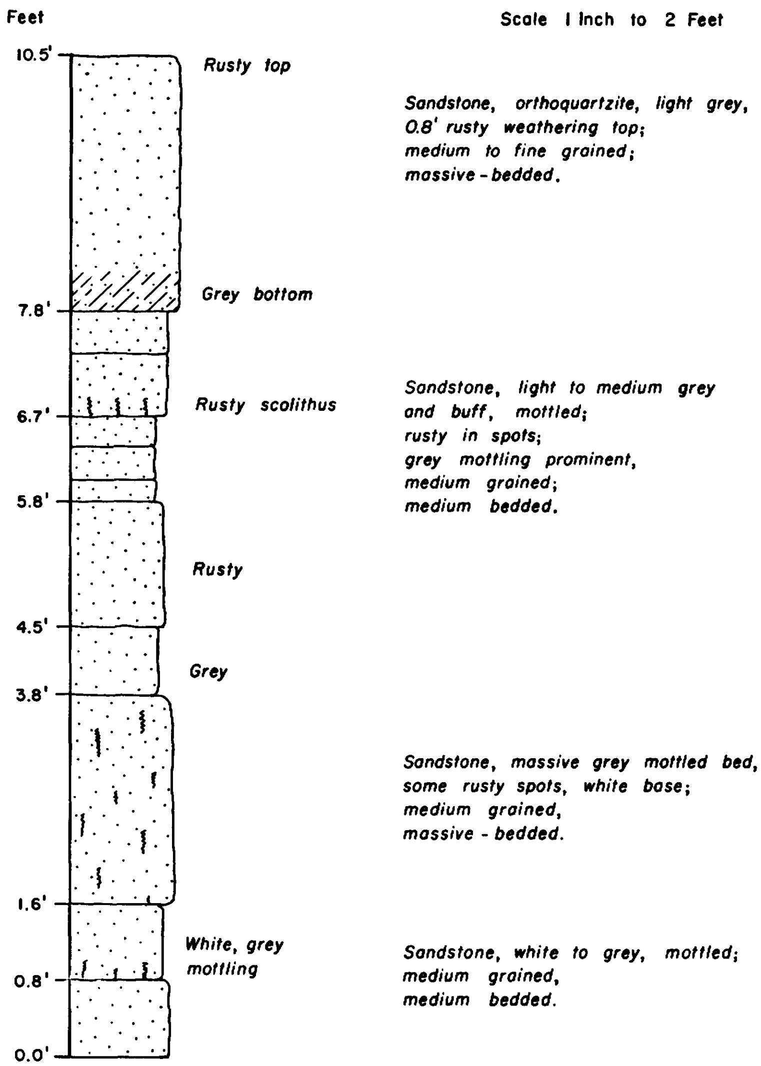


Figure 3—Potsdam Sandstone section at the Paddle quarry, Pittsburgh township.

Crosby township, and all or parts of lots 25 to 29, in concessions VI to VIII, Bastard township, Leeds county. The Wedron Silica Company of Wedron, Illinois, was associated with Rochester and Pittsburgh Coal Company in the examination of the property and the testing of the silica sand.

The area, as indicated on Ontario Department of Mines map No. 1946-9, is underlain by grey and white to brownish Potsdam Sandstone that has a thickness of 20–147 feet. The Potsdam Formation is composed of fine- to medium-grained sandstone, commonly white to buff on fresh surfaces and grey on weathered surfaces. The sandstone is friable enough to be easily broken down, on crushing, into individual sand grains or aggregates. The grains are subangular to well-rounded. There is some iron staining, but the main iron-bearing impurity is pyrite that occurs in minute grains intergrown with the quartz. Some beds have a calcareous cement and effervesce with hydrochloric acid.

In June, July, and August, 1958, 17 AXT diamond-drillholes, totalling 1,573 feet, were drilled on 2,500-foot (approx.) centres through the Potsdam Sandstone to the Precambrian basement.

The depths of holes ranged between 57 and 147 feet, and averaged 93 feet.

In the drill-core, the lower 20–30 feet of sandstone in each hole appeared to be purer than the beds above; composite samples of these footages were crushed, washed in a laboratory scrubber, dried, and sieved to give a screen analysis of the material. Spectroscopic analyses were run for iron, alumina, magnesia, and titania. A sample of the material was placed in a laboratory crock and ground for 1½ hours. The proportion of the ground material then retained on a 200-mesh screen was measured to give an assessment of the hardness of the material. The ground material was also checked on a colorimeter for colour.

Typical results of these tests are shown in (IX).

The sieve tests indicated that a satisfactory range of silica sand products could be produced. The colorimetric tests indicated that difficulty would be encountered in making a product sufficiently white for the cleanser trade. Analysis for iron content indicated that beneficiation would have to be carried out to produce a glass sand.

Iron analyses in various holes were as follows:

Diamond-drillhole	Footage Analyzed	Fe_2O_3
		percent
No. 1	4–22	0.14
No. 2	36–66 3–68	0.092 0.22
No. 3	45–63 5–63	0.23 0.22
No. 4	32–53 4–54	0.22 0.21
No. 5	41–65 5–66	0.17 0.20
No. 6	59–83 12–83	0.16 0.24
No. 7	52–74 5–75	0.21 0.28
No. 8	48–83 5–90	0.18 0.45
No. 9	45–66 0–77	0.29 0.28
No. 10	94–114 0–114	0.21 0.29
No. 11	80–93 7–93	0.58 0.21
No. 12	102–130 2–130	0.43 0.21
No. 13	100–131 4–131	0.29 0.42
No. 14	129–147 4–147	0.41 0.20
No. 15	98–118 7–118	0.15 0.45
No. 16	41–65 18–70	0.38 0.47
No. 17	52–73 16–73	0.28 0.49

A further detailed program of diamond-drilling at 400-foot centres was carried out in October 1958, on a 100-acre property on the south half of lot 28, concession VII, Bastard township, between diamond-drillholes No. 1 and No. 2, which were slightly lower in iron content than the other holes. Fourteen holes were drilled through the Potsdam Sandstone for a total of 594 feet.

Sieve analyses on these core samples were again satisfactory. Analyses of iron content were as follows:

Diamond-drillhole	Footage Analyzed	Fe_2O_3
		percent
No. 18	18–37	0.24
No. 19	26–45	0.23
No. 20	42–59	0.24
No. 21	30–47	0.098
No. 22	20–60	0.10
No. 23	9–31	0.10
No. 24	7–25	0.092
No. 25	2–25	0.12
No. 26	13–50	0.13
No. 27	2–23	0.10
No. 28	7–25	0.040
No. 29	5–15	0.13
No. 30	7–35	0.17
No. 31	9–26	0.11

A bulk composite sample of the above footage (holes 18–30) of core was subjected to flotation and acid leaching. The plus-100-mesh product from the leached silica product analyzed 0.065 percent Fe_2O_3, and 0.14 percent Al_2O_3. The minus-100-mesh fraction analyzed 0.058 percent Fe_2O_3, and 0.47 percent Al_2O_3.

(IX) TYPICAL RESULTS OF LABORATORY TESTS

Diamond-drillhole	No. 1	No. 2	No. 3	No. 4	No. 5	No. 11
Footage tested	4–22	36–66	45–63	32–63	41–65	80–93
Sieve analysis	percent	percent	percent	percent	percent	percent
plus- 40-mesh	13.6	15.0	12.2	14.4	13.4	9.4
plus- 50-mesh	29.0	30.2	33.8	23.8	22.6	24.2
plus- 70-mesh	24.0	21.2	22.6	25.0	26.0	26.6
plus-100-mesh	20.2	19.6	18.4	21.2	21.8	23.4
plus-140-mesh	8.6	9.2	8.6	11.6	11.2	11.0
plus-200-mesh	3.4	3.8	3.4	3.0	4.0	4.2
plus-270-mesh	1.0	0.8	0.8	0.8	0.8	1.0
plus-325-mesh	0.2	0.2	0.2	0.2	0.2	0.2
Plus-200-mesh after grinding	percent 7.2	percent 8.0	percent 8.6	percent 8.4	percent 7.8	percent 8.0
Colorimeter test, comparison	percent 53	percent 56	percent 51	percent 50	percent 49	percent 38
Spectroscopic analysis	percent	percent	percent	percent	percent	percent
Fe_2O_3	0.14	0.092	0.23	0.22	0.17	0.58
Al_2O_3	—	—	—	—	—	0.5
MgO	—	—	—	—	—	0.02
TiO_2	—	—	—	—	—	0.04

Further test work carried out by the Mines Branch, Department of Mines and Technical Surveys, Ottawa, indicated that the iron content could be reduced to 0.04–0.05 percent Fe_2O_3 by attrition scrubbing and washing, followed by roasting and leaching. The alumina content was reduced to less than 0.16 percent. Attrition scrubbing and washing, followed by roasting at 1,000°F. and magnetic separation, reduced the iron to 0.03–0.05 percent Fe_2O_3. Since a glass-grade material running not more than 0.02 percent Fe_2O_3 was desired, the test work was judged unsatisfactory and the property was dropped.

Rio Tinto Canadian Exploration Limited
Crosby and Elgin Silica Deposits

In 1960 and 1961, Rio Tinto Canadian Exploration Limited carried out an exploration program to investigate the Potsdam Sandstone in the vicinity of Crosby and Elgin, Leeds county, as a potential source of silica sand. Reconnaissance roadside drilling was carried out from January to March 1960 in the Newboro-Crosby-Elgin area, mainly in northeastern South Crosby township. Twenty-seven short vertical holes, totalling 1,384 feet, were drilled to Precambrian basement.

Subsequent test-work on the cores by Riocanex resulted in the optioning of two areas near Crosby and Elgin for further exploration. Area B consisted of 567 acres near Crosby in lot 1, concession I, North Crosby township, and lots 25 and 26, concession I, South Crosby township. Area D consisted of 572 acres near Elgin, forming parts of lots 16, 17, and 18, concession I, South Crosby township, and parts of lot 29, concessions IV and V, Bastard township.

In August 1960, further drilling was carried out; fifteen NX holes were drilled in Area B, and 7 NX holes in Area D, totalling 1,004 feet. The drilling indicated that a layer of friable soft sandstone existed in the Potsdam Sandstone section that could be easily crushed, and it was more amenable to beneficiation. This favourable zone was overlain by up to 12 feet of hard quartzitic Potsdam Sandstone.

As a result of this drilling, Area B was chosen as being most favourable and, in 1961, 23 further holes totalling 744 feet were drilled in that area. The cores were examined, and note was taken of the friability, content of pyrite and carbonate, colour, iron staining, and roundness of grains. A milling test consisting of crushing, grinding, desliming, and sieving, was carried out to delineate sections of the core that might be amenable to beneficiation to a glass-grade sand of suitable grain-size. Analyses were made of the beneficiated products.

The drilling program outlined two zones of relatively white friable sandstone amenable to milling in Area B. One zone contained 5,000,000 tons of sandstone averaging 13.5 feet in thickness, with average cover of 3.9 feet of quartzitic sandstone and 2.6 feet of soil. The second zone contained 2,100,000 tons of sandstone averaging 17.7 feet in thickness, with average cover of 17.7 feet of sandstone and 5.4 feet of soil. Bench-scale test-work indicated that this sandstone could possibly be beneficiated to produce a glass-grade sand, and

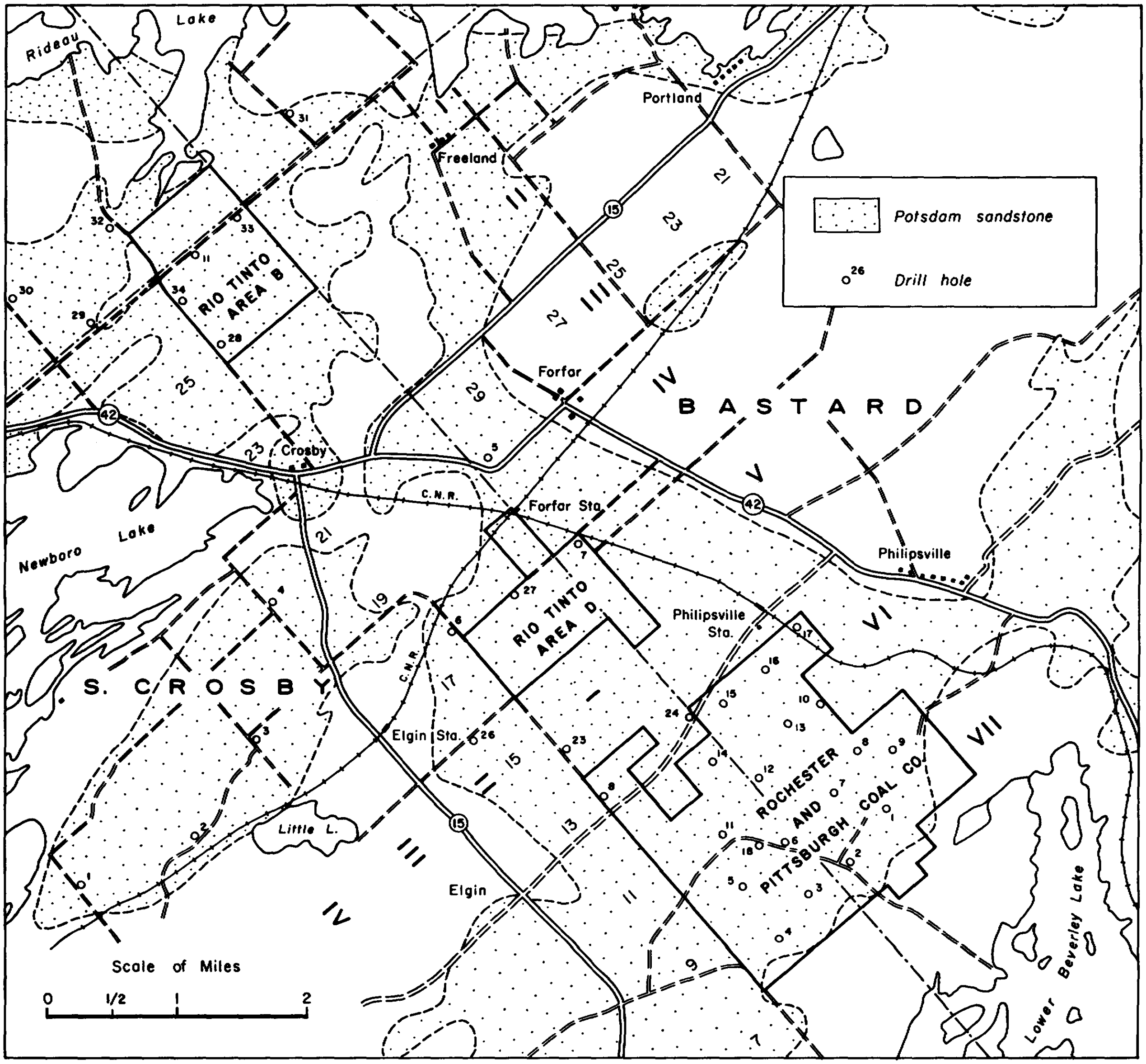


Figure 4—Potsdam Sandstone in the Crosby and Elgin areas where recent exploration has taken place.

that appropriate blends of screen fractions might also be acceptable as foundry sands.

Within the favourable zone, the friable sandstone forms a lens thinning to 10 feet at the edges and thickening to 20 feet at the centre. The friable bed passes laterally into harder quartzitic sandstone. The zone is limited to the north and west by the irregular Precambrian basement. Southward, the friable sandstone passes into quartzitic sandstone unsuitable for beneficiation.

Owing to market conditions in the Canadian silica industry, the company dropped its options on these properties in 1962.

Smiths Falls

In 1962, a small quarry was opened by Ontario Building Materials Limited on lot 29, concession V, Montague township, Lanark county, for the production of silica sand for sand-lime brick. The quarry is east of the highway on the northern outskirts of Smiths Falls.

The Potsdam Sandstone quarry face consists of 10 feet of grey to white, medium-grained, medium-bedded sandstone, in part mottled. Beds are 3–12 inches thick. Overburden is meagre, ranging from 12–18 inches. The face is drilled by wagon-drills; 1⅞-inch holes are at 3½-foot spacing. The sandstone is loaded by power shovel and crushed in a portable plant consisting of jaw crusher and rolls. The product is a sand minus-$\frac{3}{16}$-inch in size.

A mineralogical analysis of the sand indicates the following mineral content: quartz, 69 percent; dolomite, 2.7; calcite, 18.4; feldspar, 7.1 percent.

A chemical analysis of the sand product gives the following results:

	Percent
SiO_2	72.75
Fe_2O_3	1.28
Al_2O_3	1.86
MgO	0.95
CaO	11.17
K_2O	1.49
Na_2O	0.08
CO_2	9.8
	99.5

A sieve analysis of the sand product is given in (X).

Late in 1962, beds of dolomite were encountered in the sandstone section at this quarry, and the operation was moved to Carleton Place.

Carleton Place

The Potsdam Sandstone is exposed in Ramsay township, north of Carleton Place. In 1962, Ontario Building Materials Limited opened a small sandstone quarry on the James farm, lot 5, concession VII, Ramsay township, a mile north of Carleton Place.

An 8- to 10-foot face of medium- to thin-bedded, medium- to fine-grained, grey to white Potsdam Sandstone is exposed. A sand product is produced by a portable crushing plant similar to that used at the Smiths Falls quarry. The sand is used for sand-lime brick.

A chemical analysis of the sandstone by the Laboratory Branch, Ontario Department of Mines, gives the following results:

	Percent
SiO_2	97.06
Al_2O_3	1.36
Fe_2O_3	0.08
MgO	0.08
CaO	0.11
K_2O	0.52
CO_2 (Not Included in Total)	0.10
TiO_2	0.08
Loss on Ignition	0.48
	99.93

Nepean Township

The author is indebted to R. K. Collings, of the Canada Department of Mines and Technical Surveys, Ottawa, who provided the information on the occurrence in Nepean township.

The Nepean Sandstone that is exposed near Bells Corners in Nepean township, Carleton county, has long been worked as a building stone. Campbell Sandstone Quarries operates a quarry on lot 3, concession II, Nepean township, for the production of building stone and silica rock for portland cement manufacture.

In 1949 and 1950, a program of exploration work was carried out in the Bells Corners area under the direction of F. W. Huggins of Ottawa with a view to developing a deposit of Nepean sandstone as a source of glass sand. The average of chemical analyses of twenty-four core samples obtained in a diamond-drill program, is given as follows:

	Percent
SiO_2	97.5
Al_2O_3	0.76
Fe_2O_3	0.116
L. O. I.	0.54

(X) SIEVE ANALYSIS OF SAND PRODUCT

Mesh	+4	−4 +8	−8 +14	−14 +28	−28 +48	−48 +100	−100 +200	−200
Weight percent	0.76	7.51	10.19	8.80	26.94	25.92	10.86	9.02

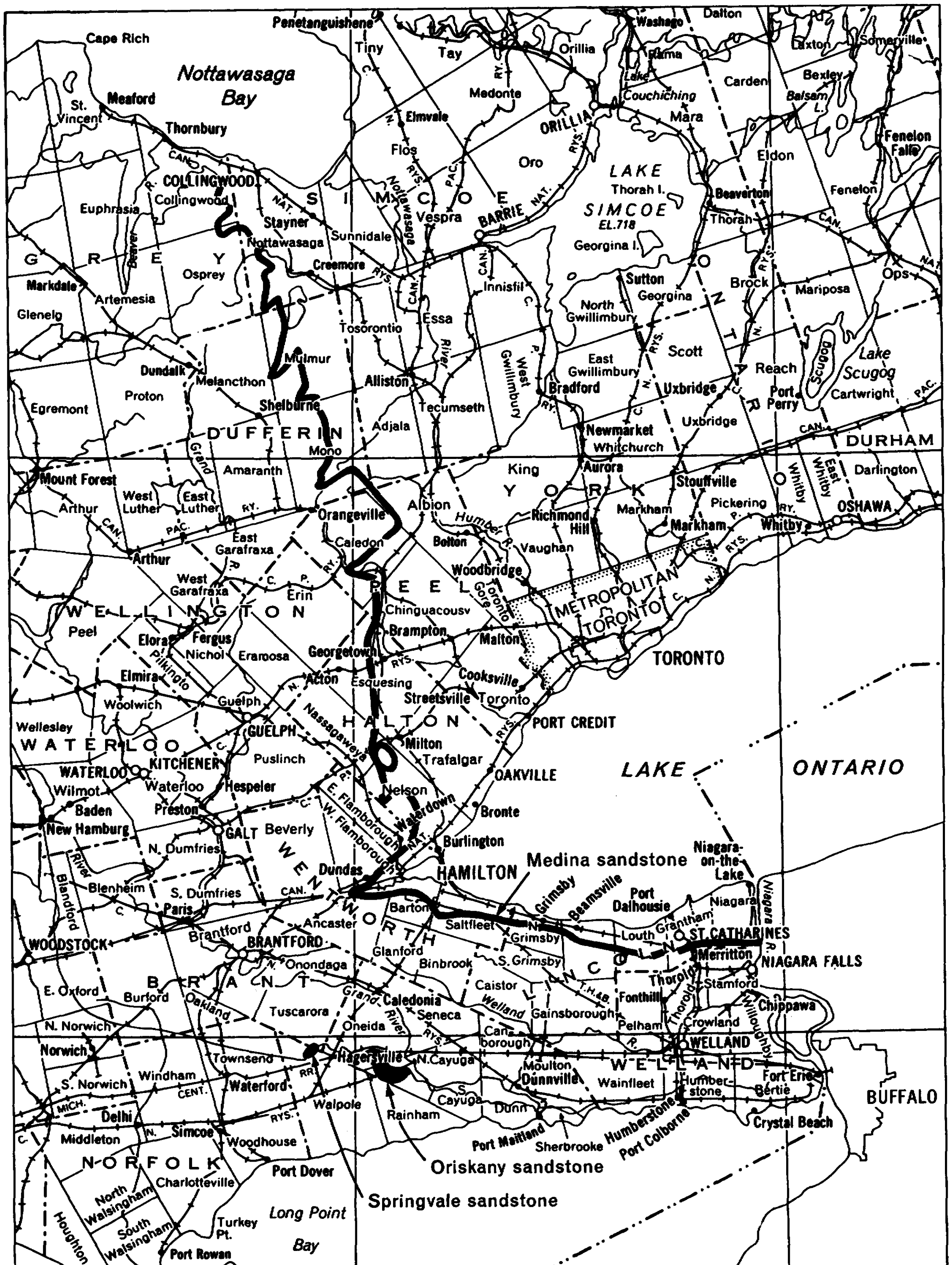


Figure 5—Distribution of Medina, Oriskany, and Springvale sandstones in southern Ontario.

The drilling program is reported to have outlined some 7,000,000 tons of sandstone of the above composition in a 10-foot bed at a depth of 110 feet.

In December 1950, a test shaft 5 by 8 feet was sunk to a depth of 120 feet on lot 5, concession II, Nepean township, to test the pure sandstone beds near the base of the Nepean Formation. A bulk sample of 100 tons taken at the shaft area had the following analysis:

	Percent
SiO_2	97.65
Al_2O_3	0.74
Fe_2O_3	0.195
L. O. I	0.53

A 250-ton sample of sandstone, obtained from a 30-foot room 170 feet from the shaft, was shipped to Ottawa where it was reduced to sand in an Aerofall mill and, after removal of the fines, treated in an Exolon magnetic separator. Mr. Huggins' report indicates that 70–80 percent of the sample was recovered as glass sand of satisfactory physical requirements for the glass industry.

It was considered that the added costs of underground mining would make the project uneconomic.

MEDINA SANDSTONE

The old term "Medina sandstone" has been used to refer to three sandstone formations of Lower Silurian age outcropping near the base of the Niagara Escarpment from Niagara Falls through Grimsby, Hamilton, Waterdown, Milton, Georgetown, Credit Forks, and Orangeville, to Duntroon. These formations are the Whirlpool Sandstone, the Grimsby Sandstone, and the Thorold Sandstone. The former two formations are now placed in the Cataract Group, and the Thorold Sandstone is placed in the Clinton Group as shown in the following table, (*after* Bolton 1957):

Clinton Group	Thorold Sandstone
Cataract Group	Grimsby Formation: red shale and red sandstone Cabot Head Shale } Power Glen Shale Manitoulin Limestone } Power Glen Shale Whirlpool Sandstone
	Queenston Shale

The Whirlpool Sandstone, known to drillers as the "White Medina", is a massive to thick-bedded, white to grey, fine-grained, crossbedded sandstone. Red mottled zones are found near Niagara Falls and Inglewood, and deep chocolate-red sandstone is found in the formation near Terra Cotta and Credit Forks. The Whirlpool Sandstone rests on the Queenston Shale and is overlain either by the Power Glen Shale in the Niagara–Stoney Creek area or the Manitoulin Limestone from Stoney Creek northward. The Whirlpool Sandstone ranges in thickness from 18 to 28 feet at Niagara Falls, 12 feet at DeCew Falls and Hamilton, 15 feet at Belfountain and Cataract, to 6 feet at Duntroon (Bolton 1957, p. 10).

The Whirlpool Sandstone is quarried as a building stone at Limehouse, Glen Williams, Terra Cotta, and Inglewood. The sandstone is fine-grained and is not of sufficient purity to constitute an important source of high-grade silica sand.

Milton

William R. Barnes Company Quarry

William R. Barnes Company operates a quarry in the Whirlpool Sandstone on lot 6, concession VI, Nassagaweya township, Halton county, for the manufacture of silica grit and ganister for iron foundries and steel plants in the Hamilton area. A 6–10 foot section of fine-grained medium-bedded grey Whirlpool Sandstone is exposed in the quarry. It is overlain by Manitoulin Limestone and Cabot Head Shale to a depth of up to 10 feet.

An analysis of the silica sand produced by crushing this Whirlpool Sandstone was carried out by the Laboratory Branch, Ontario Department of Mines, with the following results:

	Percent
SiO_2	93.80
Al_2O_3	1.21
Fe_2O_3	0.09
MgO	0.11
CaO	1.90
Na_2O	nil
K_2O	0.08
TiO_2	0.04
L. O. I	1.78
	99.01

The analysis of a sample of Whirlpool Sandstone from a quarry formerly operated by D. Robertson and Company on lot 3, concession VII, Nassagaweya township, is given by L. H. Cole (1923, p. 96) as follows:

	Percent
SiO_2	91.9
Fe_2O_3	0.45
Al_2O_3	3.65
CaO	1.70
MgO	0.22
L. O. I.	0.90

The Grimsby Formation consists of mottled red and green sandstone and red shale. The formation thins from 45 feet at Niagara Falls, to 29 feet at Hamilton, 12 feet at Clappisons Corners, and 5 feet at Limehouse (Bolton 1957, p. 19). The

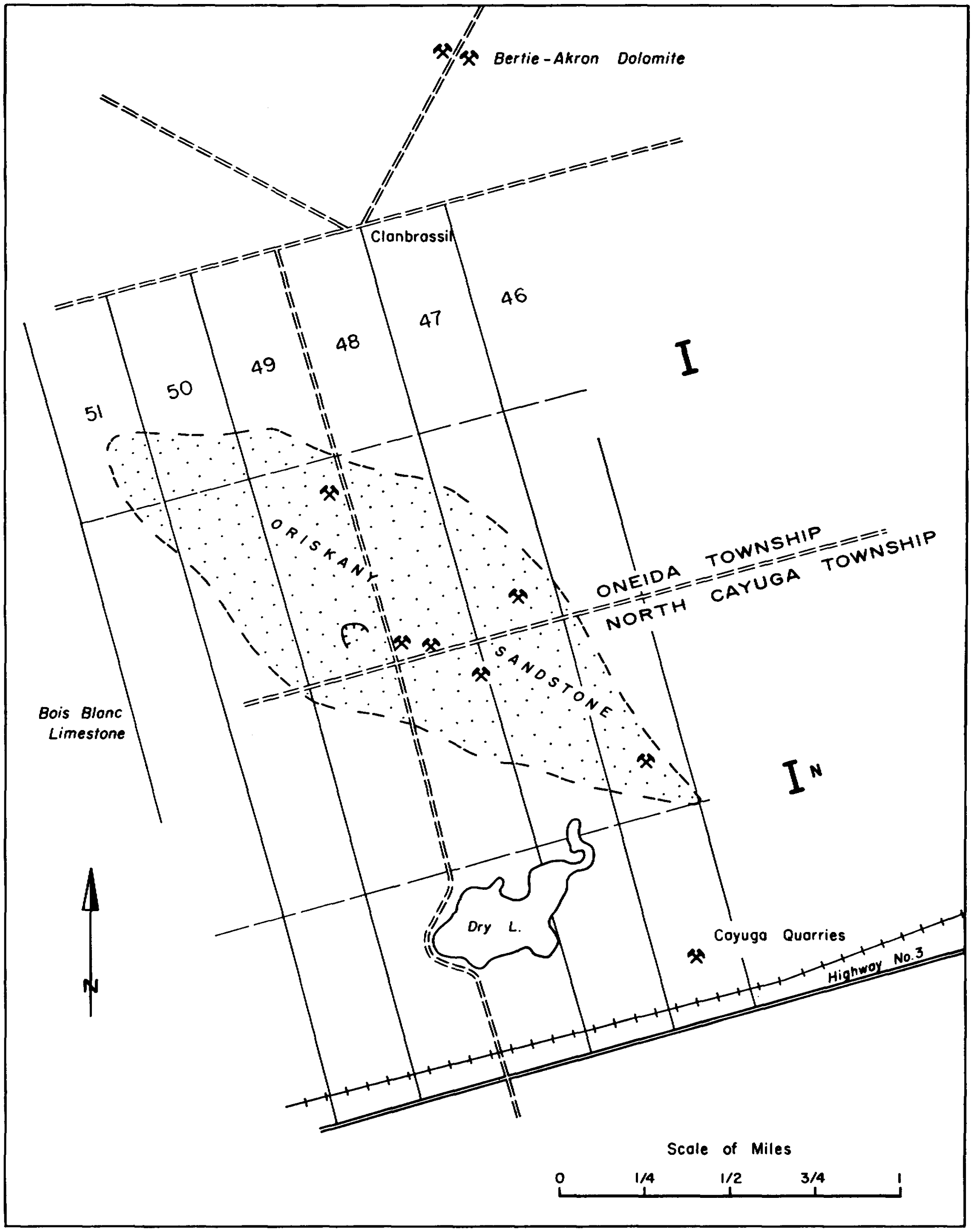


Figure 6—Oriskany Sandstone area, in Oneida and North Cayuga townships.

red sandstone layers are interbedded with red shale, and thin beds of red shale appear in the main mottled red sandstone member. This sandstone, the "Red Medina" of the drillers, has been quarried from time to time as a building stone but is not now worked.

The Thorold Sandstone lies above the Grimsby Formation and consists of 5–14 feet of massive, white to light grey, fine-grained dense compact quartzose sandstone (Bolton 1957, p. 23). It is overlain by the Neagha Shale or Reynales Dolomite. The Thorold Sandstone is not quarried for commercial use.

ORISKANY SANDSTONE

The only deposit of Oriskany Sandstone in Ontario is in Oneida and North Cayuga townships, Haldimand county, 4 miles west of the town of Cayuga. Oriskany Sandstone underlies an area of less than a square mile, as indicated in Figure 6. The sandstone has a maximum thickness of 20 feet, and pinches out to zero along-strike southeast and northwest. The sandstone is underlain by brown Bertie-Akron Dolomite and is overlain by grey cherty Bois Blanc Limestone. The formations dip gently southwest. At Cayuga Quarries, ½ mile south, the cherty Bois Blanc Limestone rests directly on the Bertie-Akron Dolomite with no Oriskany Sandstone present.

The formation exposed in several small quarries is medium light grey to white, medium-grained, irregularly thick-bedded sandstone. In places, brown iron staining is present. The sand grains are well-rounded and frosted; the sandstone is frequently quite friable, especially where leached of lime cement. The formation is fossiliferous, and a study of the fauna has been made by Best (1953). Overburden is generally shallow.

Seven small quarries, whose locations are shown in Figure 6, were examined in the Oriskany Sandstone. Two quarries were operated intermittently in 1962 by William R. Barnes Company, and by Cayuga Quarries Limited. There was considerable activity in the area in the period from 1912–18 when Oneida Lime Company, Pilkington Brothers, and Consolidated Plate Glass Company held properties in the area. Oneida Lime Company operated a quarry on lot 49, concession I, Oneida township, from 1912–18, producing glass and foundry sand. There was a small production from Pilkington Brothers quarry on lot 48, concession I, Oneida township.

(XI) ANALYSES OF ORISKANY SANDSTONE (*after* COLE 1923)

SIEVE ANALYSES (weight percent)

Mesh	Sample No. 1738	Sample No. 1739	Sample No. 1742	Sample No. 1826	Sample No. 1827
+ 14	0.40			1.75	4.90
− 14 + 20	2.20	1.75	2.15	1.55	3.85
− 20 + 28	13.25	14.00	9.35	6.60	13.85
− 28 + 35	16.75	20.98	19.35	16.30	23.65
− 35 + 48	24.40	31.45	34.42	32.55	19.55
− 48 + 65	22.08	21.84	21.28	23.18	17.05
− 65 +100	14.20	7.94	8.22	9.75	6.75
−100 +150	2.65	0.79	1.37	1.70	2.60
−150 +200	2.40	0.69	2.09	2.85	2.35
−200	1.67	0.56	1.77	3.77	5.45

CHEMICAL ANALYSES (weight percent)

	Sample No. 1738	Sample No. 1739	Sample No. 1742	Sample No. 1826	Sample No. 1827
SiO_2	87.94	98.78	92.59	93.65	89.45
Fe_2O_3	0.15	0.17	0.18	0.28	0.24
Al_2O_3	0.54	0.09	0.08	0.22	0.06
CaO	($CaCO_3$, 5.87)	0.04	($CaCO_3$, 3.59)	2.10	4.20
MgO	($MgCO_3$, 0.44)	0.10	($MgCO_3$, 0.51)	0.22	0.29
L.O.I.	(105°C., 0.29)	0.42	(105°C., 0.27)	1.70	4.20
Total	95.23	99.60	97.22	98.17	98.44

Sample 1738: from quarry, S½ lot 48, concession I, Oneida township.
Sample 1739: crushed and washed sand from Oneida mill.
Sample 1742: from quarry, S½ lot 48, concession I, Oneida township.
Sample 1826: north end of SW¼ lot 49, concession I, Oneida township.
Sample 1827: S¼ lot 47, concession I, Oneida township.

Sieve analyses and chemical analyses of five samples of Oriskany Sandstone from this area are given by Cole (1923) in (XI).

Oneida Township, Concession I, Lot 49, North Half

A small quarry has been opened, and was operated in 1962 by William R. Barnes Company Limited, on the north half of lot 49, concession I, Oneida township. Overburden is very shallow, rarely exceeding 1 foot. Thirteen to fourteen feet of sandstone is exposed in the quarry face. The sandstone is grey to brown, iron-stained in part, medium-grained, and has mainly thick irregular bedding. It is usually friable but some quartzitic patches were noted. There are some oval quartzitic concretions. The beds are 1–5 feet thick. The lower 7 feet shows less iron staining.

A chemical analysis of the sand produced from this pit was carried out by the Laboratory Branch, Ontario Department of Mines, with the following results:

	Percent
SiO_2	97.04
Al_2O_3	0.30
Fe_2O_3	0.08
MgO	0.12
CaO	0.59
Na_2O	0.04
K_2O	0.10
TiO_2	0.04
L. O. I.	1.02
	99.33

The company reports that further development of the quarry indicates a silica content varying between 88 and 92 percent, and an increase in lime cement.

Oneida Township, Concession I, Lot 49, South Half

On the south half of lot 49, concession I, Oneida township, a quarry was opened by the Oneida Lime Company. A 14-foot face of sandstone is now exposed. The Bertie-Akron Dolomite is exposed in places in the quarry floor. The sandstone is medium to light grey, with minor brown iron staining, medium-grained, friable, with thick irregular bedding. There are some thin-bedded weathered sections in parts of the quarry.

A chip sample taken down the face gave the following analysis (Laboratory Branch, Ontario Department of Mines):

	Percent
SiO_2	91.28
Al_2O_3	1.37
Fe_2O_3	0.06
MgO	0.09
CaO	2.85
Na_2O	0.05
K_2O	0.07
TiO_2	0.04
L. O. I.	2.94
	98.75

Oneida Township, Concession I, Lot 48, South Half

A small quarry was examined just east of the road on the south half of lot 48, concession I, Oneida township. Here, a 5-foot face of sandstone is exposed. It is medium-grained, and white with some brown iron staining, thick-bedded, massive, and fossiliferous. It was apparently used to some extent for building stone. The stone weathers white.

North Cayuga Township, Concession I N., Lot 46, South Half

In 1962, a small quarry was opened on the south half of lot 46, concession I N., North Cayuga township, by Cayuga Quarries Limited. Six feet of Oriskany Sandstone is exposed. The sandstone is grey to brown, medium- to fine-grained, and thick-bedded.

SPRINGVALE SANDSTONE

The Springvale Sandstone is regarded by Best (1953) as a lower member of the Bois Blanc Formation. The sandstone is exposed on the farm of Clarence Winger, lot 6, concession XIV, Walpole township, Haldimand county. A small abandoned quarry with a 5-foot face, 200 feet long, exposes grey, medium-grained, highly fossiliferous, medium-bedded sandstone in beds from 12 inches to 2 feet thick. The weathered surface has a porous appearance. The stone was formerly quarried as a building stone (Parks 1912, p. 167–69).

A chip sample taken down the face gave the following chemical analysis (Laboratory Branch, Ontario Department of Mines):

	Percent
SiO_2	80.90
Al_2O_3	1.32
Fe_2O_3	0.27
MgO	0.47
CaO	8.43
Na_2O	0.01
K_2O	0.12
TiO_2	0.06
L. O. I.	7.62
	99.20

SYLVANIA SANDSTONE

The Sylvania Sandstone of lower Middle Devonian age is underlain by the Bois Blanc Limestone and overlain by the Detroit River Limestone. The formation is exposed in Munroe county, Michigan, south of Detroit, where it is quarried for glass sand at Rockwood, Michigan. It is exposed also in the Detroit River south of Amherstburg. The formation is present in the subsurface in Essex county, Ontario, but is not exposed. Approximately 75 feet of Sylvania Sandstone was encountered in the shaft of the

Ojibway salt mine, just south of Windsor, at a depth of 360–435 feet below the surface. The maximum thickness of Sylvania Sandstone in Essex county is almost 125 feet (Sanford and Brady, 1955, p. 6).

The occurrence of Sylvania Sandstone on the Patton farm, lot 5, concession I, Malden township, 1 mile south of Amherstburg, has been described by Dyer (1930, pp. 41–46). The Sylvania Sandstone was encountered in drilling a well on the Patton farm in 1926 at a depth of 42½ feet, and 30 feet of sandstone was cut before the well was stopped in the sandstone. Dyer (1930) quotes an analysis of the sandstone from this well as follows:

	Percent
SiO_2	98.07
Fe_2O_3	0.05
Al_2O_3	0.28
CaO	0.68
MgO	0.16
L. O. I.	0.62

G. P. Cole of Dominion Glass Company investigated the deposit in 1927 and had a shaft sunk at the water's edge, encountering sandstone at a depth of 29 feet. The shaft was continued in sandstone to 31 feet, and an anlysis of the sandstone is reported by Dyer as follows:

	Percent
SiO_2	93.46
Fe_2O_3	0.46
Al_2O_3	1.09
CaO	1.84
MgO	0.67
L. O. I.	2.36

Later in 1927, the Pennsylvania Drilling Company of Pittsburgh drilled 3 holes on the property, encountering 47 and 40 feet of sandstone respectively at depths of 52 and 54 feet without reaching the bottom of the formation. A sample from the 93-foot depth in the first hole drilled, analyzed only 46.18 percent silica, with 16.28 percent CaO and 11.54 percent MgO.

Figure 7 shows depths to the top of the Sylvania Sandstone in Malden township, Essex county, and indicates two domical structures that bring the sandstone close to the surface. One of these two domes underlies the Patton farm a mile south of Amherstburg; the other rises where Big Creek crosses highway No. 18. At the Patton farm, the sandstone rises within 29 feet of surface. At Big Creek, the sandstone rises within 74 feet of surface.

Recent drilling on the Patton farm was carried out by Malden Development Corporation, and Reavely and Winder (1961) have described the results in a paper on the Sylvania Sandstone:

> As seen in core, the sandstone of the Sylvania varies in colour and texture from a gray or brownish gray fairly compact medium- to coarse-grained sandstone to a similarly compact pure white sandstone. In general the white sandstone has less than 5 percent of carbonate cement and the gray has up to forty percent . . . . The average maximum grain diameter is about 0.4 mm. and the sorting coefficient is 1.12 indicating an extremely well sorted sand . . . . The quartz grains have been well rounded and highly polished.

This exploration work indicated that the Sylvania Sandstone on the Patton property contained layers of high-purity sandstone interbedded with beds containing up to 30 percent carbonate. Ten composite silica samples indicated over 0.1 percent ferric oxide content, which is excessive for glass sand. Overburden was in excess of 40 feet, and the sandstone is below the level of the Detroit River, indicating a water problem in the porous aquifer.

In 1960 and 1961, American Nepheline Limited and Ventures Limited[1] carried out an exploration program on the Sylvania Sandstone in the Big Creek dome where the Malden gas field is located. Options were taken on the Gibb and Martin farms, and 4 holes that were drilled indicated over 10,000,000 tons of silica sandstone underlying an area having 80–100 feet of overburden. Several samples of the sandstone analyzed less than 0.03 percent Fe_2O_3, but a variable carbonate content up to 5 or 6 percent was present. The range of grain-size was 92 percent between 28- and 100-mesh, suitable for use as glass sand and foundry sand.

Drilling indicated 40–50 feet of overburden and 40–50 feet of dolomite overlying the sandstone. Logs of the holes follow:

Hole No. 1

Footage	Formation
0– 40	Clay and till
40– 82	Dolomite (Detroit River)
82–104	Sandstone (Sylvania)
104–109	Dolomite (Sylvania)
109–146	Sandstone (Sylvania)
146–156	Dolomite, sandy (Bois Blanc)

Hole No. 2

Footage	Formation
0– 46	Clay and till
46–106	Dolomite (Detroit River)
106–111	Sandstone

Hole No. 3

Footage	Formation
0– 46	Overburden
46–113	Dolomite (Detroit River)
113–161	Sandstone (Sylvania)

[1]Information supplied by Industrial Minerals of Canada Limited.

Courtesy of Industrial Minerals of Canada Limited

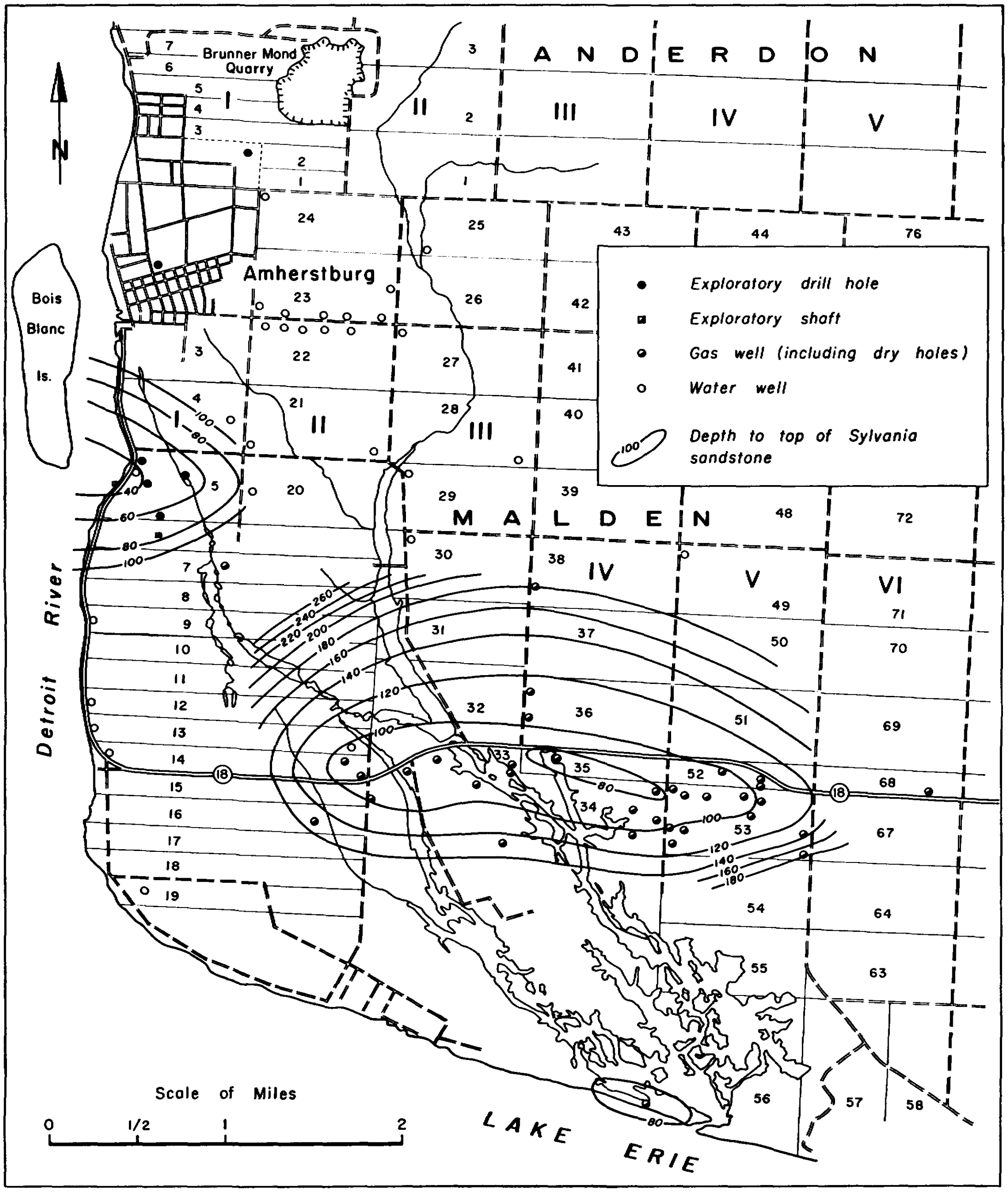


Figure 7—Contours of the top of the Sylvania Sandstone, Malden township.

Hole No. 4

Footage	Formation
0– 45......	Overburden
45– 90......	Dolomite (Detroit River)
90–117......	Sandstone (Sylvania)
117–121......	Dolomite (Sylvania)
121–156......	Sandstone (Sylvania)

The Sylvania Formation in this area consists of two sandstone beds, an upper one of 22–27 feet and a lower one of 25–35 feet separated by 4 or 5 feet of sandy dolomite. Contact with the underlying Bois Blanc was transitional.

A composite sample of core from Hole No. 1, between 82 and 103 feet, gave the following analysis:

	Percent
SiO_2	89.92
Fe_2O_3	0.035
CaO	2.21
MgO	1.39
Al_2O_3	1.63

A sieve analysis of the sand from the upper 28 feet of Hole No. 1 is shown in (XII):

These investigations indicated that the lime and magnesia content of the sandstone, the depth of overburden and rock to be stripped, and the probable water problem, would make it uneconomic to mine the sandstone, at this location under present conditions, to produce a glass-grade product.

Unconsolidated Sands

The unconsolidated sand deposits of Ontario are mainly of Pleistocene and Recent age and are usually not high in silica content. A recent mineralogical study of sand samples from southern Ontario by the Ontario Research Foundation indicating the content of quartz and other major minerals and rocks in several typical Ontario sands is given in (XIII).

As indicated in (XIII), the quartz (free silica) content in Ontario sands ranges between about 17 and 62 percent in the normal cases. Niagara bar sand, dredged near Niagara-on-the-Lake, has a free silica content of 60 percent. Sands in the Kingston–Gananoque area, where the Potsdam Sandstone supplies detrital material, generally range between 50 and 62 percent. The proportion of silica in sand in the Toronto area is lower, ranging between 17 and 40 percent. An unusually pure silica sand occurs on Campement d'Ours Island, near Sault Ste. Marie.

CAMPEMENT D'OURS ISLAND

A small deposit of high-purity silica sand exists on the southwest shore of Campement d'Ours Island and in the adjacent channel between

(XII) ANALYSES OF SAND FROM HOLE NO 1.

Mesh	+24	−24 +28	−28 +35	−35 +48	− 48 +100	−100 +200	−200
Weight percent	0.1	0.2	8.7	37.8	45.3	5.1	2.8

(XIII) MINERALOGICAL STUDY OF SAND SAMPLES

Locality	Quartz	Carbonate	Feldspar	Shale and Siltstone	Acid Igneous	Basic Igneous
	percent	percent	percent	percent	percent	percent
Niagara bar sand..........	60	15	22	—	—	—
Picton dune sand..........	50	18	29	—	—	—
Sydenham area, Kingston...	62	8	17	5	2	2
Dixon pit, Gananoque......	54	9	25	4	4	—
Kingston Sand and Gravel...	54	10	24	2	4	4
Fenelon Falls.............	19	38	24	14	3	—
General Aggregates, Oshawa.	36	35	22	—	5	—
Niagara Falls area.........	42	11	20	27	1	—
Bowmanville.............	26	49	20	1	1	1
Pickering township.........	33	35	20	5	4	2
Malton..................	34	33	15	8	7	2
Maple..................	43	25	22	3	5	1
Milton..................	17	31	13	28	10	1
Clarkson................	23	27	16	26	7	2
Picton esker..............	56	15	21	3	2	1
North Bay...............	26	—	42	—	18	11
Sudbury.................	29	—	17	—	21	34
Campement d'Ours Island...	99	—	—	—	—	—

St. Joseph's Island. The sand was derived by weathering of the Lake Superior Sandstone and overlies the sandstone in depths of 30 inches to 6 feet. Samples of the sand, taken by the author from two pits 3 feet deep on the shore, gave the following chemical analyses:

	Pit No. 1	Pit No. 2
SiO_2	99.26	99.09
Al_2O_3	0.24	0.34
Fe_2O_3	0.06	0.09
MgO	0.02	0.02
CaO	0.02	0.02
TiO_2	0.05	0.09
Na_2O	0.05	0.05
K_2O	< 0.5	< 0.5

The deposit was investigated in 1958 and 1959 by Rochester and Pittsburgh Coal Company. It was estimated that 800,000 to 2,000,000 tons of silica sand were available.

Sieve analyses of the sand from the 3 pits are as shown in (XIV).

Although the sand appears to be of good quality for most uses, the deposit was considered to be too small for economic development.

Unconsolidated beds of silica sand are associated with the Cretaceous fire clays in the James Bay lowland.

Pegmatitic and Vein Quartz

Most of the granite pegmatites mined for feldspar contain considerable tonnages of quartz that must be mined as waste. Owing to the low price for quartz, it was not normally feasible to market the quartz at a profit. However, in recent years there has been increased interest in sources of white opaque and translucent quartz for use in facing precast concrete slabs for construction use. This type of quartz is produced by Industrial Garnet Company, of River Valley, Ontario, and Rideau Aggregate Company, of Verona, Ontario. Favourably situated deposits of white pegmatitic and vein quartz are in demand for this use.

GRADE AND EVALUATION OF SILICA DEPOSITS

As pointed out in a previous section, the specifications for silica vary greatly and depend on the consumer's requirements. However, one of the most important factors in evaluation of a silica deposit is its location. Being a low-priced high-tonnage type of operation, the deposit must be located where cheap transportation to large markets is available.

The ease of mining, the type of mining to be employed (i.e. underground vs. open pit), the size of the deposit, and uniformity of the deposit and potential reserves, merit initial consideration. Other determining factors are the character of the rock, whether sandstone or quartzite, its texture, grain-size, grain-shape, grain-size distribution, toughness of grains, and coherence of grains.

Most consumers have very definite limits of tolerance for impurities. In the glass and ceramic industries, for example, the proportion of iron oxide is important. If this is too high, the iron content may be reduced to the permissible range possibly by processes of beneficiation such as air classification, washing, acid leach, etc. However, if beneficiation is necessary, a close examination of costs must be made to ensure that the price of the final product is still within a competitive range for the proposed market.

MARKETING SILICA

In 1962, the following companies produced silica in Ontario:

- Canadian Silica Corporation Limited, 100 Adelaide St. W., Toronto;
- International Nickel Company of Canada Limited (Lawson quarry), Willisville;
- Falconbridge Nickel Company Limited, Falconbridge;
- Union Carbide Canada Limited (Killarney quarry), Killarney;
- Wm. R. Barnes Co. Ltd., Waterdown;
- Industrial Garnet Company, River Valley;
- Rideau Aggregate Company, Verona.

Imports of silica sand into Canada in 1961 amounted to 693,210 tons valued at $2,490,688; exports of quartzite during the same year amounted to 26,774 tons valued at $116,109.

The Dominion Bureau of Statistics gives the

(XIV) SIEVE ANALYSES FROM 3 PITS, CAMPEMENT D'OURS ISLAND

Mesh		+20	+30	+40	+50	+70	+100	+140	+200
Weight percent	Pit No. 1	21.8	24.6	30.6	13.2	3.6	4.0	2.0	0.2
	Pit No. 2	3.2	9.6	23.4	37.4	17.0	8.0	1.2	0.2
	Pit No. 3	7.0	8.0	24.6	23.0	12.4	14.0	10.0	1.0

following figures for consumption of silica in Canada in 1960 by industry:

Industry	Short Tons
Smelter flux (including sand)	1,886,590
Glass manufacture	310,326
Foundry sand	150,463
Ferrosilicon	102,520
Artificial abrasives	140,285
Cement manufacture	25,921
Chemical industry	26,785
Soap and cleanser	798
Fertilizers; stock and poultry feed	29,389
Asbestos products	2,495
Ceramics	11,833
Other industries	22,264
	2,709,669

The value of silica products at the quarry or mill varies greatly, and depends on the type and grade of material. The cheapest grade of silica is smelter flux valued at approximately $1.00 to $2.50 per ton at the quarry. Glass sand selling for $2.30 per ton at quarries in Ottawa (Illinois, U.S.A.) can be landed in Toronto for $8.56–$9.00 per ton. Foundry sand imported into Ontario from United States is landed in Toronto for $9–$10 per ton. Pulverized silica sells in the Toronto market for $12–$18 per ton. Sand for silicon carbide manufacture is landed in Niagara Falls for $9–$10 per ton. Quartz chips for precast concrete facings sell for $20–$36 per ton at the quarry, depending on size and quality.

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