PLATE I

Typical group of quartz crystals. Museum of the Geological Survey of Canada, Ottawa.
(Natural size.)

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN McLEISH, DIRECTOR

Silica in Canada

Its Occurrence, Exploitation, and Uses

Part I.—Eastern Canada

BY

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OTTAWA
GOVERNMENT PRINTING BUREAU
1923

No. 555

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INTRODUCTORY

Scope of the Report

The investigation of the sand, sandstone, and quartzite deposits of Canada was commenced in 1912[1]. Since then, considerable data relating to the above mentioned deposits have been collected.

The importance of gaining full knowledge of the country's resources along the line indicated is evident; and the number of enquiries received in the Mines Branch office concerning silica, shows the need of comprehensive reports on the subject.

A tentative division of sands, sandstones, and quartzites into classes according to their uses, is presented here:—

(1) Silica sands, sandstones, quartz, and quartzites.
(2) Moulding sands.
(3) Building sands.
(4) Sands for brickmaking.
(5) Sands for miscellaneous uses.

The following report deals with deposits which come under class (1). The area embraced deals with a part of Canada that is within easy transportation distance of the main centres of industry between the Atlantic seaboard and Fort William, Ontario. It is proposed, later, to extend the investigation to include the part of Canada west of Fort William.

It will be understood that in a comprehensive report of this character, covering as it does such a vast extent of country, only a brief description can be given of any individual deposit; and reference to many occurrences will, of necessity, have to be omitted. The results given, however, will indicate promising localities in which to prospect for high grade silica, and enable operators to locate deposits from which they can produce commercially.

The need for the production of silica in Canada is evident from the fact that probably two-thirds of the silica used in Canada is imported. The fact that Canada has been able to obtain extremely pure and uniform material from abroad has helped to discourage the vigorous investigation of our own resources; and the fact that silica, in all its forms, brings comparatively low prices, has also retarded the industry. Capital has naturally gravitated to the mining of metals with which the average layman is more or less familiar; hence the mining engineer is seldom called upon to report on silica deposits, or to undertake their development. The fault does not rest alone with the investor or operator, for the mining engineer is, generally, not sufficiently conversant with the mode of occurrence of these materials or the requirements of the several industries, to intelligently advise intending investors. Moreover, to work a deposit of

[1]Owing to press of other work the writer was unavoidably compelled to devote his energies to investigations which demanded immediate action, hence the investigation dealt with in this report had to be deferred until the present time.

low-priced material economically, a large tonnage has to be produced, and this must be prepared for the market and properly graded according to the use in which it is to be employed.

The silica deposits of Canada have not been exploited to any great extent in the past, and it is only within the last few years that any systematic investigation has been made of them, with a view to ascertaining their economic value. Recently, however, the attention of the Mines Branch has been concentrated on many of the more promising localities in which silica deposits are to be found, and considerable data have been collected. The field work in connection with this investigation was done in conjunction with some of the field work on sands in general; and in spare time between other investigations. Many of the deposits were determined in the field as unsuitable for any known commercial use; but wherever there was the slightest possible chance of a deposit being of commercial value samples were obtained for further examination in the Mines Branch laboratories. A number of these proved, on preliminary tests, to be worthless, and no further tests of them were made. Others gave promise of being capable of utilization in one or other of the forms in which silica is applied in manufacturing and other industries. Altogether, over 100 samples were obtained from representative deposits throughout eastern Canada, consisting of vein quartz, quartzites, sandstones, natural sands, flint, and diatomaceous earth.

Maps

The maps accompanying this report are mainly intended for the purpose of indicating the localities in which the prospect of locating silica deposits is the most promising. On account of the small scale on which they are printed, the limits of these areas are, necessarily, only approximate.

Acknowledgments

The sections on Silica Brick and Silica in the Pottery Industry have been kindly prepared by Mr. J. Keele, ceramic engineer, Mines Branch, Department of Mines.

The thanks of the writer are extended to many of the owners of the properties examined for courtesies shown, also to the superintendents of the silica mills visited for data relating to their plants, and to the numerous gentlemen in the different silica using industries for their readiness to furnish information relating to the requirements of their special industries. Without such cordial co-operation this report could not have been prepared.

CHAPTER I

GENERAL DESCRIPTION OF THE VARIOUS FORMS OF OCCURRENCE OF NATURAL SILICA

Oxide of silicon, either combined with other elements, or as free silica, constitutes, according to Clarke,[1] 59·77 per cent of the lithosphere. It is represented by the formula SiO_2 and its composition is oxygen 53·3 per cent, silicon, 46·7 per cent. The forms of silica dealt with in this report are those occurring in the free state, such as vein quartz, flint, quartzite, sandstone, silica sand, diatomaceous earth, and tripoli. These differ in many of their essential properties, but are all similar in chemical composition, since they consist almost wholly of silica.

Quartz

Quartz is not only the most common, but is also one of the most interesting and useful of minerals. Clarke estimates that it forms about 12 per cent of the entire lithosphere. Chemically it is pure silica. It has a molecular weight of 60·4, a specific gravity of 2·65, and a hardness of 7. When pure it is colourless, but is often tinted violet, yellow, red, green, blue, brown, or black, from the presence of slight impurities. Quartz possesses no cleavage or a cleavage so imperfect that for all practical purposes it may be considered as not having any. It has, however, a marked conchoidal fracture, and this serves to readily distinguish it from other minerals with which it might possibly be confused. It has a lustre varying from glassy to oily or greasy. The common acids, with the exception of hydrofluoric acid (HF), do not attack quartz, and this property, together with its hardness and high refractoriness is its most important property in relation to commercial value.

According to Kanolt[2] pure silica fuses at about 1710° + 10° C.

Before this temperature is reached, however, the quartz changes first to tridymite and then to cristobalite. The stability relations of the different crystal modifications of SiO_2 as determined by the Geophysical Laboratory of the Carnegie Institution may be briefly summarized as follows:—

Inversion	Temperature	Remarks
Quartz-tridymite...............	870° C. ± 10° C.	Very slow—reversible.
Tridymite-cristobalite.......	1,470° C. ± 10° C.	" "

The occurrence of tridymite in nature is rare. It is found as a mineral in cavities associated with quartz, opal and feldspar, also in certain volcanic lavas, and is not a commercial form of silica. It differs from quartz in its crystal form, refractive index, and specific gravity (2·28-2·33).

[1]Data of Geochemistry, Fourth Ed. p. 33, Bull. No. 695, U.S.G.S.
[2]Technologic Paper No. 10, Bureau of Standards, Washington, p. 14, Melting Points of Fire Brick.

Cristobalite, like tridymite, has the same composition as quartz, and likewise differs in its crystal form, refractive index, and specific gravity (2·27-2·34).

Quartz occurs as an essential constituent of many rocks, including granites, gneisses, mica schists, quartz porphyries, granite pegmatites, and many others. In such sedimentary rocks as sandstone, conglomerates, etc., it is usually the chief constituent present. Quartzites are composed mainly of quartz, and in the unconsolidated materials such as sands and gravels, derived from the disintegration and breaking up of the harder rocks, the main constituent is generally quartz.

While quartz occurs in nature in many different forms, only the more important are dealt with in this report.

Quartz Crystals

Quartz crystallizes in the hexagonal system, the common form being a hexagonal prism terminated by a pyramid. The transparency of the glassy crystals and their regular geometric form aid in the ready determination of this mineral. (Plate I.) This common form of quartz crystal is to be found in vein structure or drusy cavities, and is well illustrated on a large scale in the crystal form of quartz seen in some pegmatite dikes. Some of the quartz crystals attain a large size, and have been known to measure a yard in length and diameter, and to weigh half a ton. Twin crystals of quartz are fairly common.

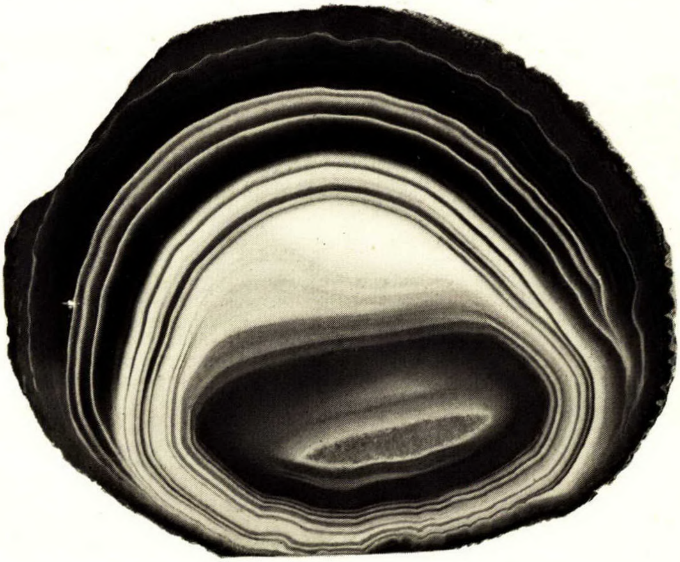
Amethyst is a variety of transparent crystalline quartz with a purple or bluish-violet tint. The colour, which changes to yellow or else disappears on heating, is attributed to the presence of small amounts of manganese. It is classed as one of the semi-precious or ornamental stones.

Smoky quartz is the term used for crystals that have a smoky tint. The colour varies from a light yellowish through a brown to a black so dark as to be nearly opaque, except in the finest splinters. The smoky colour is probably due to the presence of some compound of carbon. The brown and yellow varieties are generally known as cairngorm, so named from the locality in Banffshire, Scotland, where some of the finest examples have been found.

Chalcedony

Chalcedony is a variety of silica in which a part at least of the silica is in the amorphous form. It may be either transparent or translucent, with a glistening and somewhat waxy lustre, and presents a variety of colours, though usually white, grey, yellow, or brown. It is not found in crystals and is usually massive and frequently in concretionary, mamillated or stalactitic forms, breaking with a fine splintery fracture. It appears to have been deposited from aqueous solution, hence it is frequently found filling or lining cavities in decomposed igneous rocks or in geodes and veins. *Agate* is a variegated form of chalcedony in which bands of different colours are arranged parallel to one another. These bands may be straight, but are usually circular or curved. (Plate II.) *Onyx* is a variety of chalcedony similar to agate, where the colours are in flat horizontal layers. The colours are usually alternating bands of light transparent brown and opaque white. *Jasper* is a mixture of quartz with red or yellow

PLATE II



Agate. Museum of the Geological Survey of Canada, Ottawa.
(Natural size.)

hydrates of iron or some argillaceous material, the whole so densely disseminated as to make the quartz quite opaque and creamy. It is found closely associated with iron ores, especially in the states of Minnesota and Michigan, but also in northwestern Ontario. Its colours range from dull opaque red to yellow or brownish, and occasionally green. The deep red varieties are used as ornamental stones.

Opal

Opal is composed of silica, with a small, varying percentage of water. Its chemical formula might be written as $SiO_2 + nH_2O$, (1% to 20% H_2O). It is a hydrated silica with a hardness of 6 and a specific gravity of 2·1. It shows no trace of crystallization and is amorphous. Its lustre is greasy, vitreous, or resinous, and its colour is generally white. *Hyalite* is a transparent, colourless, glassy opal, usually found as an incrustation in botryoidal or mamillary form. *Precious opal* is the name applied to varieties of opal which exhibit a beautiful play of colours and which are opaque or translucent. They yield by reflected light a brilliant variety of colours and are considered to be precious gems.

Massive Quartz

Quartz usually occurs in massive form, without crystal faces. It varies in texture from coarse to fine-grained, and sometimes even cryptocrystalline. It is generally white and opaque to semi-translucent. Some of the vein quartz, such as that found associated with feldspar in pegmatite dikes, may for commercial purposes be considered as massive quartz, although many of the blocks are single crystals.

Flint

Flint is a dark grey or dark brown cryptocrystalline variety of silica, which has an almost vitreous lustre and no visible structure.[1] It is generally opaque or faintly translucent when seen in thin plates or splinters. Its colouring is due to inclusions of organic compounds. When heated these are driven off and leave the material, if pure, a dead white. It breaks with a conchoidal fracture and is very brittle. When crushed and pulverized it yields a white powder. Flint occurs as nodules or concretions in chalk formations in England, France and elsewhere. Some limestone formations contain flinty bands, but generally the flint in these cases is impure and is called chert.

Quartzite

Quartzite is a firm, compact rock, made up, chiefly, of grains of quartz sand united by a siliceous cement. It is in general, a metamorphosed sandstone. While no hard and fast rule can be laid down to say exactly where the dividing line between sandstone and quartzite lies, seeing that all stages of transition from one to the other can be found it is generally safe to say that a quartzite is much harder than a sandstone. In some quartzites the original shape of the sand grain has nearly, if not entirely disappeared,

[1] Under the microscope, thin sections show that flint is very finely crystalline and is composed of quartz or halcedonic silica.

so that the cementing material and the original quartz grains form a nearly homogenous substance. When fractured the break takes place through the grains and cement alike. The colour of quartzite is generally white, light grey or brownish, but these shades may be modified by the inclusion of minute grains of other minerals. Where the rock is employed in commercial use for its silica content, such inclusions of other minerals are considered as impurities.

There are numerous modifications of the normal, white quartzite, but for the purpose of this report only quartzites in which the silica content is high need be taken into consideration. One variety may be mentioned. Buhrstone is the name applied to a variety of quartzite, supposed to have been derived from the metamorphism of a highly fossiliferous limestone by the action of solutions containing silica. It is a rock full of elongated cavities or pores, the cavities representing the leached out fossils. The silica present consists mostly of chalcedony, and its hardness and toughness, together with its sharp cutting power, due to the numerous cavities, has made it an admirable stone for use as a millstone.

Sandstone

Sandstone is a rock composed essentially of grains of quartz, bonded together by some substance acting as a cementing material. The cementing material varies in different types of sandstone—thus in some it may be silica from solution, in others a calcareous cement, commonly calcite. Argillaceous material or clay is also a common cement, and occasionally thin films of iron oxide can be seen between each grain holding them together. The sand may be made up entirely of quartz grains, or it may contain grains of other minerals, such as feldspar, hornblende, magnetite, etc., in varying proportions. The proportion of the cementing material to the sand grains also varies in different sandstones. Usually the amount of cementing material is small as compared with the sand grains, but varying proportions up to 50 per cent of cementing material are encountered. For example, a sample of rock collected in the course of this investigation, consisted of well-rounded grains of quartz sand, bonded together with a dolomitic cement, the cementing material composing 32·5 per cent of the rock.

Sandstones range in colour from pure white to grey, light buff to dark yellow, brick red to reddish brown, also varying shades of green, some varieties even showing a dark purple, and in one locality a deposit of sandstone was encountered in which the uniform colour of the whole deposit was a brilliant salmon pink. In many cases these colours are not uniform throughout the whole mass of sandstone in any one outcrop, but may be confined to definite beds, so that in one deposit it may be possible to obtain sandstone of widely varying colours.

When the silica content of a sandstone is the prime essential for its employment in industry, only sandstones which show great purity need be considered.

Many types of sandstones are known by names derived from the character of the bonding material cementing the grains. Thus, such names as calcareous sandstones, argillaceous sandstones, and ferruginous sandstones, are frequently encountered in geological and mineralogical literature.

Sands[1]

Since silica forms such a large proportion of the lithospere, it follows that when rocks are subjected to mechanical disintegration and chemical decomposition, the predominant mineral usually found in the materials of disintegration is quartz. The complete disintegration of a rock is generally followed by the removal of the broken down fragments from the original site, by one of the many transporting agencies. The transporting of the residual material tends to further break up the rock particles, the softer ones being crushed finer and consequently transported farther. The hardness of quartz enables it to better resist attrition than most other minerals, hence it is generally found in the form of sand. It can readily be seen that the more a sand is subjected to sorting, the more nearly its composition will approximate pure silica, and localities are known where sands running over 99 per cent SiO_2 are to be found. For example, a beach sand from Pensacola, Fla., analysed by G. Steiger in the laboratory of the Geological Survey of the United States, contained 99·65 per cent of SiO_2.[2]

Sand grains vary greatly in shape according to the amount of erosion to which they have been subjected. Thus in some sands the grains are sharp and angular, while in others they are almost perfect spheres. All variations between these two extremes are to be found.

The texture of sand is also extremely variable, and grains differing greatly in size are often to be found in the same sand.

Diatomaceous Earth

Diatomaceous earth is the name given to a siliceous, earthy material composed of the siliceous frustules or shells of diatoms, which, when the plant has died, sink to the bottom of the water in which it lived. Such a process, if continuous for any length of time, forms deposits of this material, which eventually become compacted into definite beds. The material ranges in colour from white to grey, and sometimes greyish brown. Its composition is a hydrous silica with varying proportions of water. The silica content before calcination will range from 70 per cent to 88 per cent, according to purity, the rest being water and small percentages of other minerals. Diatomaceous earth is known under a variety of names, such as kieselguhr, tripolite, fossil flour, diatomite, and randanite. It is also known under the name of infusorial earth.

Tripolite (Tripoli)

Tripolite, or tripoli as it is sometimes called, is a very compact, laminated variety of diatomaceous earth, so named from Tripoli, Africa, where it has been found in extensive deposits.

According to American usage Tripoli is employed to designate a porous siliceous rock found in Missouri, U.S.A. It is regarded as having originated from the leaching out of the lime carbonate from a highly siliceous limestone. To the unaided eye it has all the appearance of diatomaceous earth; but, under the microscope, the typical structure of the minute diatoms is absent.

[1]For the purpose of this report, all material passing through a 3-mesh screen (6·680 mm. opening) and retained on a 150 mesh screen (·104 mm. opening), will be considered sand. Material coarser than this will be called lump silica, and that which is finer, powdered silica.

[2]Data of Geochemistry, 3rd Edition, Bull. No. 616. U.S.G.S., p. 504.

CHAPTER II

STRUCTURAL AND GEOLOGICAL FEATURES OF THE VARIOUS TYPES OF DEPOSITS IN EASTERN CANADA IN WHICH COMMERCIAL FORMS OF SILICA OCCUR

Silica, in one or other of the forms described above occurs in many of the formations represented in eastern Canada, from the Precambrian quartzites to the recent beach sands and deposits of diatomaceous earth. It is not the object of this report to describe all the formations in which silica is found. Only the more important will be briefly described. The following table shows the age of the different formations in eastern Canada and the class of silica to be found in each:—

FORMATION	LITHOLOGY
Grenville	Quartzites
Laurentian	Quartz.
Lorrain	Quartzites
Keweenawan	Sandstones
Cambrian	Quartzites
Potsdam	Sandstones
Beekmantown	Sandstones (calcareous)
Kamouraska	Quartzites
Oriskany (L. Devonian)	Sandstone
Sylvania (L. Devonian)	Sandstone
Springvale (Onondaga, M. Devonian)	Sandstone
Lower Cretaceous	Sands
Recent	Beach Sands Diatomaceous Earth

Grenville Series

The Grenville series consists of white crystalline limestones, quartzites, gneisses, and schists. The quartzites of this series are of possible economic value, since, in places, they occur in large masses of sufficient purity to be utilized as a source of silica. They are well developed in the Precambrian belt of rocks which runs north from the St. Lawrence river between Kingston and Gananoque to the Ottawa river, and eastward north of the Ottawa river in the province of Quebec.

This quartzite is generally a greenish to white rock and very hard. It is closely folded in places, with the beds standing at all angles, so that ridges composed of steeply tilted beds of quartzite frequently stand out as distinct topographical features. A deposit of this kind is favourable for quarrying the material from higher to lower levels. Minute inclusions of feldspar, as well as other minerals besides quartz, are to be found in some localities, but in other deposits these impurities are absent and the rock runs very high in silica.

Laurentian Quartz

Quartz, often in considerable quantities, is found associated with the feldspar deposits of eastern Canada of Precambrian age.

In referring to these deposits, Spence[1] divides them into three types, namely, aplites, mica-pegmatites or giant-granites, and irregular stringers of purple-brown microcline-quartz-sphene rock. The first class is generally comparatively free from quartz, so that it is to the latter two classes that we may look for any considerable quantities of high grade silica. The quartz associated with the feldspar occurs either in lenses or irregular stringers throughout the dikes.

Such quartz when obtained free from feldspar is in some cases remarkably pure, samples being obtained which run well over 99 per cent silica. The quartz is glassy and semi-translucent to opaque.

As feldspar is the primary mineral sought for, the quartz bodies encountered in quarrying have been either left standing, or disposed of as waste rock. Of late years, however, some of the feldspar quarries were able to sell a portion of their quartz rock to the smelters.

Lorrain Formation[2]

The Lorrain formation, which is widely distributed throughout northern Ontario, has a thickness of about 6,000 feet. There are three members in this formation, each having about the same thickness. The lowest one consists of impure feldspathic quartzite of a pale sea green to a dirty red colour. It graduates upwards into the middle member, which is conglomeratic, consisting of pebbles of quartz in a matrix of fairly clean quartzite. The pebbles are mainly white or green in colour, but in the neighbourhood of Sault Ste. Marie a great many red pebbles are to be seen, hence the name red jasper conglomerate is given to this member. This conglomerate member grades upwards into a pure white quartzite about 2,000 feet thick. There is a general increase of purity in the quartzite of the Lorrain formation from the bottom member to the top, and throughout the greater part of northeastern Ontario the uppermost 1,000 feet will run 97 per cent or more of silica. The impurities in the upper member consist of occasional grains of feldspar, partly altered to sericite or paragonite, with occasional small grains of zircon. In places also there are paper thin layers of magnetite along bedding planes.

The Lorrain formation[3] is found outcropping at intervals in a belt of country about 60 miles wide from Sault Ste. Marie to lake Timiskaming. At the lake Timiskaming end it is fairly flat-lying, with a dip seldom exceeding 30°. Towards Sudbury, and between Sudbury and Sault Ste. Marie, it is much more closely folded, and dips ranging from 45° to 90° are common. Very large areas of Lorrain quartzite are found between Ekoba and Thessalon, generally at distances of from 2 to 6 miles north of the Canadian Pacific Railway Soo line. Another great belt of the quartzite borders the coast of lake Huron from lake La Cloche eastward to Killarney, crossing the Algoma Eastern railway in the neighbourhood of mileage 65. Numerous large areas of this formation are also to

[1]Mines Branch, Dept. of Mines, Feldspar in Canada, No. 401, H.S. Spence, pp. 7 and 8, 1916.
[2]The notes from which this section was written were kindly furnished in a personal communciation to the writer by Dr. W. H. Collins, Director of the Geological Survey, Canada.
[3]An excellent map, prepared by Dr. Collins, showing the distribution of the Lorrain formation in northern Ontario is in press and will shortly be published by the Geological Survey of Canada.

be found in the country between lake Wahnapitae and lake Timiskaming. An exceptionally pure phase of this quartzite occurs in the neighbourhood of Helen falls on Lady Evelyn river.

The pure, upper part of the Lorrain quartzite was originally a clean, well worn sand. It is now entirely re-cemented to a hard quartzite, owing to the growth of secondary quartz around the original sand grains. Its extensive distribution and high purity make it a most promising source of silica.

Keweenawan Formation

Around the north shore of lake Superior there is a sandstone which is probably of Keweenawan age. This sandstone consists of medium to fine-grained quartz grains, generally loosely cemented with a calcareous bond. It is readily friable and ranges in colour from greyish-white to brown or sometimes pink. Quarries on Simpson island, lake Superior, have furnished a considerable amount of building stone.

Cambrian Quartzites

In the vicinity of Whiterock, Hants county, N.S., numerous quartzite bands occur associated with the slates of the Upper Gold Bearing Series. These quartzites are greyish white, very compact, and in some localities are probably of sufficient purity to be a source of silica. According to Faribault[1] they are probably of Precambrian age.

Potsdam Formation

The Potsdam sandstone, which constitutes part of the Cambrian, appears to be the most promising formation as a source for high grade silica sand. Extensive areas underlain by this formation are to be found in both Ontario and Quebec, the more important being the Kingston, Westport, Perth-Smith Falls and Nepean area, all in the province of Ontario, and the southwestern Quebec area, comprising parts of the counties of Beauharnois, Soulanges, and Two Mountains.

The erosional action of streams and of the Cambrian sea on the crystalline and metamorphic rocks of Precambrian age formed vast quantities of sand, and since these early rocks were rich in quartz, the sands produced from them were high in silica. The continual washing to which these sands were subjected also tended to further increase the silica content by removing the more friable material and leaving only the quartz grains. These sand deposits in time became consolidated and cemented into sandstone by both chemical action and the pressure of later formations on top. Uplift of the land and erosion in later times has laid bare these beds in many places, and they have been given the name of Potsdam formation, after the town of Potsdam, N.Y., where sandstones of this type were first examined in detail.

This formation fills inequalities in the underlying Archæan rocks, the lowest bed in some cases being a coarse conglomerate with quartz pebbles up to 8 inches in diameter. The greater part of the formation, however, is comprised of rounded grains of quartz sand rarely larger than would pass through a 3-mesh (6·68 mm. opening) screen.

[1]Summary Report, Geol. Surv. Can., 1908, pp. 150-151.

Photo. E. A. Whittaker.

Potsdam sandstone cliffs, 150 feet high, at the "Gulf," Covey Hill, Que.

The beds of Potsdam sandstone are generally flat-lying, and in some localities are of considerable thickness. Probably the thickest exposure of this formation is to be found in the vicinity of Covey Hill, Que., one mile from the international border. At Covey Hill corners sandstone is exposed at an elevation of approximately 525 feet above sea level. Going west from the corners the sandstone is exposed practically continuously in flat-lying beds to the top of the hill at an elevation of 1,113 feet. A mile east of the summit a gorge like depression cut in the sandstone shows a continuous section of the Potsdam formation 150 feet in thickness. (Plate III.)

The sandstone beds vary greatly in different districts both in texture and composition. This is to be expected, since the original sands were exposed to different erosional forces and were derived from varying kinds of bed-rock. Thus in some places where the sand is whitish in colour it may contain numerous grains of some of the softer materials from the earlier rocks, while elsewhere more vigorous erosion may have entirely removed the softer rock fragments. The chemical composition and physical characteristics are also found to vary from place to place. Some beds are so highly stained and impregnated with ferruginous material as to be dark reddish-brown, and even chocolate colour, while other beds are pure white. The rock may be very friable, and easily crushed in the hand, and all degrees of hardness may be found, including sandstone so hard as to be almost a quartzite.

The cementing material is generally siliceous, but is ferruginous, calcareous, or arenaceous in places.

Beekmantown Formation

Directly overlying the Potsdam sandstone formation, beds are to be found, in some localities, composed mostly of grains of quartz cemented by a calcareous bond, and placed in the Theresa formation of Beekmantown age. The beds are considered to be composed of material derived from the Potsdam formation, and in some cases are hard to differentiate from beds of true Potsdam age. It is not probable that such beds will furnish any large supply of high grade silica, but they are mentioned here on account of their close association with the older Potsdam sandstones. They grade gradually into true limestones and dolomites, which form the greater part of the Beekmantown formation.

Kamouraska Formation

The Kamouraska formation, according to Dresser[1], belongs to the middle or lower Cambrian. The rocks of this formation consist of quartzites and conglomerates, the quartzites in places being sufficiently high in silica to be used as a source of that material.

In describing these quartzites Dresser[2] says:—

> The quartzite is fine, even-grained, light coloured, and weathers to an almost pure white. Quartz is usually the only mineral that can be distinguished in the hand specimen, but in places the quartzite contains nodules of dolomitic sandstone. These nodules are occasionally found as large as 2 feet in diameter. They are ellipsoidal or cylindrical in shape, suggesting concretionary origin. They disintegrate more readily than quartzite under the action of the atmosphere, and give a pitted surface in exposed places.

[1]Geol. Surv. Can., Memoir No. 35, John A. Dresser, 1912.
[2]Geol. Surv. Can., Memoir No. 35, J. A. Dresser, p. 14, 1912.

In the thin section the quartzite is seen to be composed of rounded grains of quartz cemented by secondary silica. The original grains being uniformly small, the secondary enlargement, though observed, is not very distinct. The rock closely resembles the Potsdam sandstone of Lachute, Que., or other well known localities along the margin of the Precambrian.

These quartzite rocks are exposed in the district of Kamouraska, on the south shore of the St. Lawrence, below Quebec city. When examined by the writer, for a source of silica, they were found to be free from impurities in the eastern exposures, becoming higher in lime in the more western outcrops. In some places the rocks appear to be sandstone rather than quartzites.

Oriskany Formation

The Oriskany sandstone formation has apparently only a comparatively small development in eastern Canada. It is found in isolated and patchy outcrops in the part of Ontario lying between the western end of lake Ontario and the eastern end of lake Erie. It is found in a narrow belt running approximately east and west from Nelles Corners on the west to Fort Erie on the east. (Map No. 557.) In referring to this formation Stauffer[1] says:—

The Oriskany sandstone, the lowest certain Devonian formation in Ontario, was named by James Hall in 1839 from Oriskany Falls, Oneida county, New York, where it is typically developed. The Oriskany of Ontario does not differ essentially from the same deposit as it extends eastward into New York state. It is usually a massive, coarse-grained, friable, white to yellowish sandstone in which the individual grains sometimes attain an eighth of an inch in diameter. This sandstone lies unconformably on the Silurian dolomites and the lowest layer is often made up in part of dolomite pebbles embedded in a matrix of sand. It is usually rich in the characteristic, large, coarsely marked fossils, although small forms are also found in some abundance.

This formation varies greatly in thickness, lying unconformably as it does on the Silurian dolomites underneath. In places it is only a few inches thick, while in other areas it is 20 feet thick. It is best exposed in the vicinity of Nelles Corners, approximately 2½ miles west of Cayuga. Here it is practically one continuous outcrop (the overburden being very thin) over an area of approximately two square miles. It is in this area that all the quarries of any extent have been opened.

As might be expected, from its association with dolomites and limestones, the bonding material cementing the sand grains together is calcareous, sometimes running as high as 10 per cent of the crude sample. In places the sandstone is noticeably impregnated with bituminous material, which appears to burn off when the sand is subjected to heat.

The Sylvania Sandstone

In the southeastern part of the state of Michigan beds of sandstone of Sylvania age are being quarried to produce high grade silica sand for use in the manufacture of glass.

Grabau and Sherzer[2] describe the rock found in this formation as follows:—

Typically, the sand rock is a remarkably pure, sparking, snow white aggregation of incoherent quartz grains. By drillers it is often compared with snow, flour, salt and granulated sugar. Lumps of it may be crumbled in the hands, and when placed

[1]Geological Survey Can., Memoir No. 34, Geol. Series No. 63, p. 5. The Devonian of Southwestern Ontario, Clinton R. Stauffer, 1915.
[2]Mich. Geol. and Biological Survey, Part 2, Geol. Series 1, 1909, pp. 71 and 72.

in water simply falls to pieces like some varieties of clay. At the Rockwood pit the rock is being disintegrated by means of a small stream of water from a hose, and with the grains in suspension pumped to the washing vats of an adjacent building. The small amount of binding material present consists of a dolomitic cement, apparently introduced into the bed by percolating water, subsequent to the deposition of the sand. Immediately beneath the drift the rock is often discoloured by iron oxide to a depth varying from a few inches to several feet. Before marketing the sand for glass manufacture the dolomitic cement is removed by washing, when the per cent of silica is over 99 per cent. Grains of minerals other than quartz are relatively very infrequent. The following analysis of the sand rock, before being subjected to the washing process, is furnished by the National Silica Co., Toll's pits, Monroe county, Michigan.

	per cent
Silica	96·50
Calcium carbonate	1·50
Magnesium carbonate	1·04
Iron oxide	0·00
Sulphuric acid loss and undetermined	0·76
Loss on ignition	0·20
Total	100·00

While outcrops of this formation are unknown in southwestern Ontario, a number of well records show sandstone horizons which can probably be classed as of Sylvania age. The following table, compiled from numerous Canadian and United States government reports, briefly summarizes the data relating to the sandstone of this age as encountered in Ontario:—

Data Regarding Sandstone (Sylvania?) in Southwestern Ontario

Locality	Depth to top of sandstone	Approx. elevation of top of sandstone	Total thickness sandstone (feet)
Kincardine	297	311	29
Courtwright	1,062	−474	32
Petrolia	1,076	−429	16-26-47 (3 beds)
Pt. Lambton	1,200	−600	50-40 (2 beds)
Wallaceburg	1,000	....	100
Windsor C.P.R. well, No. 11	535	75	55
Windsor C.P.R. well, No. 11	550	60	65
Anderton tp., Essex co. (Sucker Creek)	410	199	30
Malden tp., Essex co., lot 4, con. II (Parke well)	258	....	84
Malden tp., Essex co., lot 2, con. I (Colwell grove)	260	....	60
Pt. Rowan	554	....	15
Near Comber, Essex co	360	240	10
Orford tp., Kent co. (Ravey well)	555	185	75 and 85 (2beds)
Orford tp., Kent co., lot 23, con. XIV (Grant well)	410	....	90 (several)
Camden tp., Kent co., lot 2, con. V (Camden well)	413	....	46
Camden tp., Kent co., lot 2, con. V (2nd Camden well)	559	....	10
Lot 12, con. VI, Maidstone, Essex co	275	....	25
Lot 64, con. I, Colchester S., Essex co	177	471	10
Lot 7, con. V, Tilbury W., Essex co	283	321	20, 10, 35 (3beds)
Sandwich, Essex co	525	....	100
Lot 7, con. III, Tilbury W., Essex co	283	....	20
Lot 7, con. III, Tilbury W., Essex co	250	353	50
Rochester, lot 28, con. II	228	392	40
Lot 3, con. II, Camden, Kent co	431	....	46
Dresden, Kent co	482	....	44
Glencoe, Middlesex co	962	....	38

From this table it can be seen that there are few .places where the Sylvania sandstones are close enough to the surface to permit of being mined profitably for the production of a glass sand. The most promising locality is that in the neighbourhood of Amherstburg, in either Anderdon or Malden township, Essex county. Dr. M. Y. Williams, late of the Geological Survey of Canada, has kindly furnished me with the following log of a well drilled by the Solvay Process Company—just to the north of this district:—

WELL BY SOLVAY PROCESS CO.,
LUCIFER FARM, LOT 10, SANDWICH W., ESSEX COUNTY.
BELOW MIDDLE FIGHTING ISLAND., WEST OF ELECTRIC RAILWAY.

	59 – 70	Fine grey sandstone, very calcareous.
	70 – 75	Fine light buff limestone, slightly arenaceous.
	75 – 80	Fine limy sandstone.
35	80 – 85	Coarser limy sandstone.
	85 – 90	Coarse lime sandstone quartz moderately rounded.
	90 – 94	Coarse limy sandstone quartz moderately rounded. $\frac{2}{3}$ limestone, $\frac{1}{3}$ sand (quartz).
	94 – 99	Light grey limestone; some grit.
	99 – 103½	Light grey limestone; some grit. Coarser.
	103½–108	Limestone; some fine sand.
	108–116	Light creamy limestone.
	116–117	Light buff limestone.
	117–122	Light buff limestone; some grit.
	122–127	Light buff with chert, strontianite, etc.
	127–132	Light buff limestone (dolomite).
	132–152	Core lost.
	152–157	Light buff limestone with grey streaks; hard.
	157–162	Light buff limestone; hard.
	162–167	Light buff limestone; dark buff.
	167–177	Light buff limestone; dark buff.
	177–187	Buff: some bitumen.
	187–200	Buff dolomite; white substance.
	200–212	Buff dolomite; some chert.
	212–232	Dark buff dolomite.
	232–245	Light buff dolomite; hard.
	245–250	Light buff; round quartz.
	250–285	Nearly pure beautifully rounded quartz sand, diameter about $\frac{1}{5}$ mm.
72	285–295	Nearly pure beautifully rounded quartz sand, diameter about $\frac{1}{5}$ mm.
	295–310	Nearly pure beautifully rounded quartz sand, diameter about $\frac{1}{5}$ mm.
	310–317	Nearly pure beautifully rounded quartz sand, diameter about $\frac{1}{5}$ mm.

The age of the Sylvania sandstone has been in dispute for a number of years, but lately the concensus of opinion seems to place it in the Monroe series, of Devonian age.

As the rocks of the Devonian period are only known to occur in a comparatively small portion of southwestern Ontario, it would be useless to look for sands of the Sylvania elsewhere in the province.

Springvale Sandstone

A sandstone formation, placed by Stauffer[1] at the base of the Onondaga, is to be seen in the area west of Hagersville, Ont. In describing this formation, and giving his reasons for differentiating it from the Oriskany, he says:—

> The Onondaga limestone usually rests on an eroded Silurian surface, but occasionally it lies unconformably on the Oriskany sandstone. Where the latter is the case, the unconformity is marked chiefly by the change in fossils, but at some places there

[1]Geol. Surv. Canada, Int. Geol. Congress Guide Book No. 4, p. 84.

may be found a well-developed conglomerate in which fossiliferous pebbles of Oriskany sandstone are mingled with the remains of Onondaga corals and fishes.

Where the Oriskany is absent the conglomerate persists, but at such places the pebbles are of Silurian dolomites. The lower portion of the Onondaga limestone, in this region, is usually arenaceous and very cherty. Sometimes the sand is so abundant that the deposit becomes an arenaceous chert, and again a true sandstone. This latter is the case at Springvale, where the lower portion of the Onondaga takes on such a marked resemblance to the true Oriskany that it has often been confused with it. The fauna, however, is Onondaga in every characteristic and cannot be confused.

But, because of the decided lithological difference from the ordinary appearance of the formation to which they belong, the beds are here referred to as the Springvale sandstone. This sandstone has a thickness of about 8 feet and the material of which it is composed was doubtless derived from the Oriskany sandstone, portions of which were re-worked by the advancing Onondaga sea.

The sandstone is friable and the grains are well rounded; they are white to yellowish white in colour, and in some cases the stone mottled with light brownish patches. As one would expect from a re-washed sandstone the Springvale has rounder grains, and is finer in texture and freer from impurities than the Oriskany sandstone from which it is supposed to have been derived, the average fineness of the former being 53·5 while the latter runs 45·75 average fineness.

Cretaceous

Deposits of unconsolidated, fairly pure quartz sands of Lower Cretaceous age occur on some of the streams flowing into Hudson bay in northern Ontario. The most important known deposits of these sands occur on the Missinaibi river, about 40 miles north of the National Transcontinental railway, but they are also found in an isolated deposit on the Mettagami river. These sands are associated with beds of high grade clays and generally the individual sand grains of the deposits are coated with white clay. A heavy cover of glacial drift overlies the clays and sands for the most part, which would render it difficult to obtain any large supplies of the sand.

In addition to the white sands, and occurring in more extensive exposures on the banks of the Abitibi and Mettagami rivers, are bodies of yellow and orange sands. These sands are not associated with clay beds and contain no disseminated clay. The sand grains, which are mostly of quartz, are stained with iron oxide which imparts a deep red or yellow colour to the deposit. It is possible that a good deal of the iron could be washed from the sands and a fairly high silica product obtained. The age of the yellow and orange sands is doubtful; they are certainly pre-glacial, but they may not be as old as the Lower Cretaceous white sands in the same region.

A more detailed account of these sands is given in Chapter IV of this report.

Sands are also known to occur associated with clays that are probably of Lower Cretaceous age in the Musquodoboit valley and at Shubenacadie in Nova Scotia. These clays are used in the manufacture of pottery and firebrick, but none of the sands so far uncovered in excavation have been found pure enough to be considered a source of silica.

Recent Formations

Silica deposits of recent origin have been found in several localities of eastern Canada. These deposits consist of beach sands and diatomaceous earth.

Beach Sands.

Beach sands which run high in silica are found in several places in eastern Canada, having been subjected to constant washing, which has rounded the quartz grains and removed most of the more readily abraded minerals. Notable examples of such deposits are those at Barrington bay, N.S., and near Souris, P.E.I.

Diatomaceous Earth.

Deposits of diatomaceous earth occur in the beds of numerous lakes and streams in both Nova Scotia and New Brunswick. This material is rarely found compacted and can readily be excavated by manual labour. It occurs in different degrees of purity, and is generally white or cream coloured, and sometimes mixed with carbonaceous and arenaceous material in its more impure state. When impure its colour may be yellowish or brownish.

CHAPTER III

INDUSTRIAL USES OF SILICA

Silica has been utilized for many years in a number of manufacturing industries. It is widely distributed in nature and is found in all degrees of purity. Many uses have been found for it, and its comparative cheapness tends to encourage further use. The accompanying diagram (Fig. 1) shows a few of the more important uses of this material. The diagram does not, by any means, set forth all the uses to which silica is applied, but all the industries which use it in large quantities are indicated.

Silica, as used in the industries, is required in many different forms and grades, and each industry demands that the material comply with definite specifications. Silica in a form suitable for one industry may be entirely unsuitable for another. The reasons, however, why a certain form of silica is suitable or unsuitable for a special purpose have been systematically studied in only a few instances. The consumer in most industries knows the form of silica best suited to his particular process, basing his knowledge upon long experience, and on long use of the special form found to be advantageous. He naturally obtains his material from the best available source from which he can procure a constantly uniform product adapted to his requirements. Therefore, the producer of silica is required to know not only what industries can use his product, but also the exact grade needed by each industry, in order that he may prepare his material properly.

An endeavour is made in this chapter to give a brief outline of the manner in which silica is utilized in the various industries, and to specify the requirements which must be complied with by the producer.

The classification of the uses under the headings lump silica, silica sand, etc., is only a matter of convenience, for it will readily be seen that no definite line of demarkation can be drawn in commercial practice, since one industry may possibly use material from any one of these classes.

USES OF QUARTZ CRYSTALS AND GEM VARIETIES

Quartz crystals, known sometimes to the trade as rock crystal, have been used to a considerable extent in the manufacture of optical instruments. Quartz is highly transparent to ultra violet rays as well as to ordinary light, and prisms cut from clear crystals are utilized in spectrum analysis. When the crystals are found clear and colourless, they have been employed in the construction of spectacle lenses, and as lenses in optical instruments, but the use of quartz has been discontinued to a great extent, through the substitution of optical glass. Rock crystal has been used in the arts and industries from a very early period, and although its use is gradually diminishing, owing to the employment of cheaper substitutes, it is still employed in the manufacture of cheap gem stones, paper weights, spheres for crystal gazing, and quartz plates for the circular

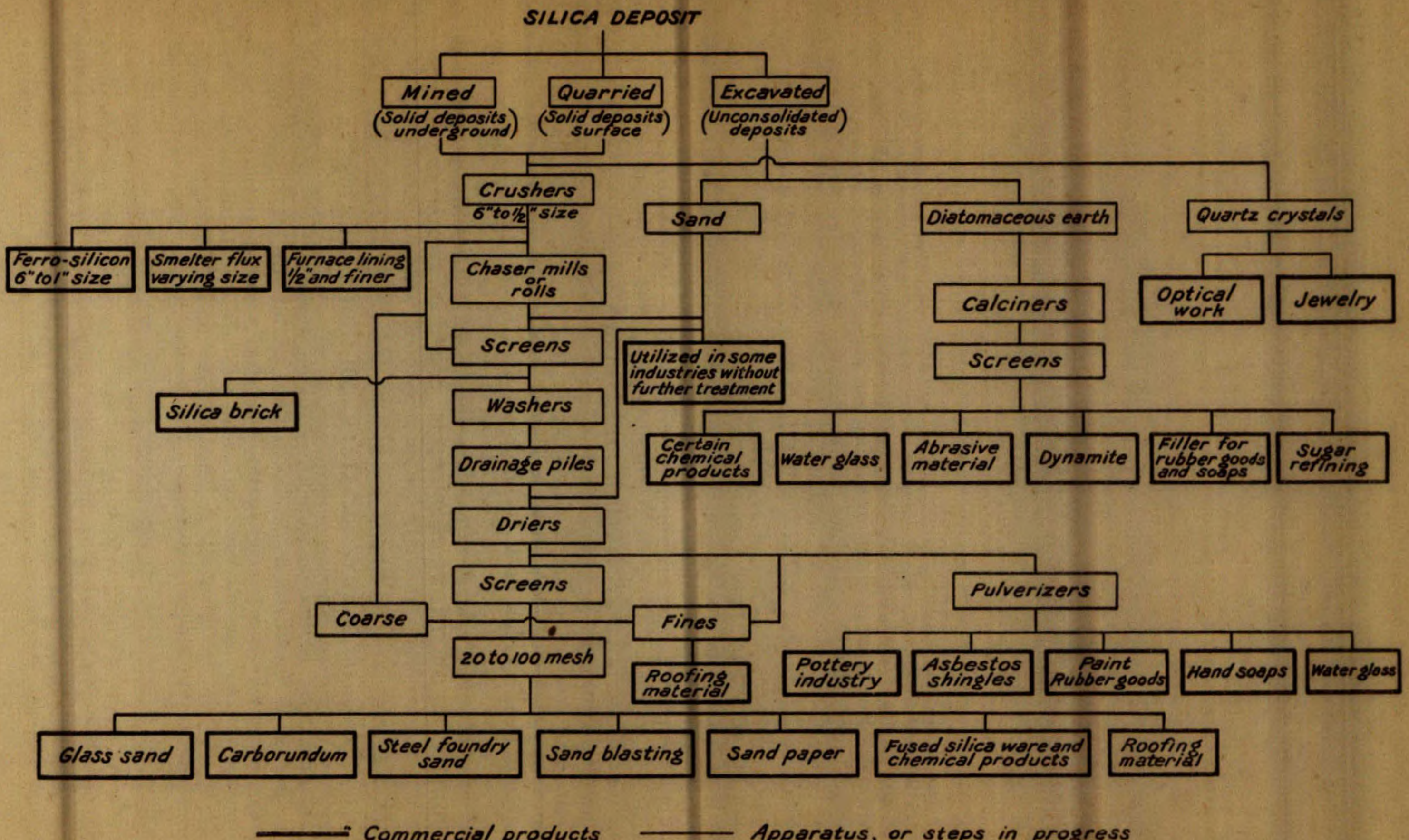


Fig. 1. Silica flow sheet from deposit to consumer.

polarization of light in connection with the microscope. Where clear, transparent, fused silica is required, rock crystal is preferred to high grade silica sand.

The varieties of silica which are classed as gem stones are, in many cases, highly prized. For use as gems, the size, purity, and beauty of the specimens naturally govern the value, some varieties bringing very high prices when properly cut and polished.

USES OF LUMP SILICA[1]

Lump silica, obtained from deposits of quartz, quartzite, or sandstone, has a number of uses. Some industries use the material just as it comes from the quarry, while others require a preliminary coarse crushing and screening to obtain material of a certain size. When employed in this form its commercial value is very small, and it is only when there is a large demand that it pays to operate a quarry for lump silica alone.

USE IN THE MANUFACTURE OF FERRO-SILICON

Ferro-silicon is the most extensively used of the ferro-alloys produced in the electric furnace. It is made in two ways: (1) by the reduction of silica and iron ore with carbon, (2) by the reduction of silica with carbon, the iron content being obtained by the addition of iron turnings.

The silica required for the manufacture of this alloy is obtained either from a pure grade of quartzite, or by using a highly siliceous, but otherwise pure iron ore. Chemical analysis gives a good indication of the suitability of a silica for this use. Material of the composition indicated below would be suitable:—

Silica	97·00% to 98·25%
Iron oxide and alumina	1·00% to 1·75%
Calcium oxide	not to exceed ·20%
Magnesia	" " ·20%
Phosphorus and arsenic	nil

The iron oxide (Fe_2O_3) content does not greatly matter, except that it should be uniform. The objectionable impurities are calcium, phosphorus, and arsenic, as these are reduced in the electric furnace to calcium phosphide (Ca_2P_2), and to calcium arsenide in the presence of carbon. These impurities remain in the ferro-silicon, and on coming in contact with water or moist air, give off phosphoretted hydrogen (PH_3), or arseniuretted hydrogen (AsH_3), both gases being very poisonous. Apart from the danger from these gases, the ferro-silicon in which they occur shows a decided tendency to spontaneous disintegration, and on being stored for a few weeks crumbles and falls to powder, thus rendering the material useless.

The physical characteristics, also, have an important bearing on the suitability of a silica material for use in the manufacture of ferro-silicon. Many firms specify quartzite, and assert that sandstone is unsuitable, but some firms have made use of a compact sandstone when quartzite was not available. There may be a reason for this in the fact that the sandstone might possibly disintegrate into sand in the furnace, due to a weak bonding material, and thus choke the furnace, but sufficient data on this point are

[1]See footnote in Chapter I, p. 7, for definition of lump silica, silica sand and powdered silica.

not available to determine the exact reasons why ferro-silicon manufacturers are prejudiced against sandstone.

It is manifest, therefore, that the present requirements of this industry, in the matter of silica, are, (1) a quartzite having approximately the above chemical composition, and (2) a compact and dense variety, broken to a size from 1 inch to 6 inches, according to practice.

USE AS A FLUX

Silica is used as a flux in metallurgical operations, principally in the metallurgy of copper, where the original ore is basic. Whenever possible, the smelting companies endeavour to obtain a supply of ore which has a siliceous (free silica) gangue, to mix with the basic ore being smelted, otherwise it is necessary to use barren quartz, quartzite, or sandstone.

In the converting of the copper-nickel matte, in the Sudbury district, quartzite or copper-bearing quartz is employed in fluxing the matte in the converters. In a personal communication Mr. J. F. Robertson, of the Mond Nickel Co., Ltd., Coniston, Ont., has furnished the following information relative to the use of silica in their operations:—

> Our average ore is siliceous, not basic, so we use no silica flux in our blast furnaces. In fluxing the converters we use siliceous ore from Bruce Mines, owned and operated by this company. It is chalcopyrite in white quartz and carries about two and one half per cent of copper. A typical analysis shows:—

	per cent
SiO_2	80·2
Al_2O_3	3·0
Fe_2O_3	5·0
S	2·8
CaO	1·0
MgO	1·5

> We crush it to about two inch size and feed it into the converters through the Garr silica gun. The quartz flux thus used amounts to roughly twelve per cent on the ores smelted in the furnaces.
>
> The hills at the Coniston smelter site are quartzite. We, therefore, have a huge reserve available for the cost of quarrying only, but carrying no copper or nickel. A typical analysis shows:—

	per cent
SiO_2	86·0
Al_2O_3	7·3
Fe_2O_3	1·6
CaO	0·3
MgO	0·7

> Both Bruce ore and quartzite make a satisfactory flux. Minimum grade for fluxing purposes would be perhaps 70 per cent silica.

In true pyrite smelting, silica is used as a flux to remove the iron oxide formed, and produce a siliceous slag. The silica used for this purpose should not be in the form of a silicate, but should be free silica, such as quartz, quartzite, or sandstone, so that a strong acid is at once available to combine readily with the FeO as it forms. For this purpose the silica should be in lumps not less than one-half inch in diameter.

MINOR USES

Silica is also used as a flux in the manufacture of phosphorus. For this purpose quartz obtained from the pegmatite dikes associated with feldspar is crushed to pass a $1\frac{1}{4}$-inch screen with as little fines as possible. A silica content of 99 per cent, or more, is required.

Blocks of massive quartz and quartzite are used in the chemical industry as a filler for acid towers, and in some cases as linings for digesters in the pulp and paper industry.

Flint or quartzite pebbles, well rounded, are used in ball or tube mills for fine grinding, the linings for the mills being composed of dressed blocks of quartzite[1], or else pebbles which are wedged in between steel ribs run longitudinally on the inside of the mill.

USES OF SILICA SAND[2]

Silica, in the form of sand, is an essential raw material in many industries. Its more important uses, and the requirements of each industry are briefly given.

USE IN THE MANUFACTURE OF SILICA BRICK

Silica brick is now used extensively as a refractory material in the metallurgical industries.

By far the largest part of the silica brick is manufactured from quartzites, since loose grained rocks—such as sandstones—are of little value for this purpose.

One of the most striking differences between silica and clay firebricks is that the former expand when heated, while the latter contract. Hence, silica firebricks are chiefly used where great heat resistance combined with an absence of shrinkage is essential. On account of these properties they are used for the arches, crowns, and higher parts of furnaces and kilns, for the upper parts of glass furnaces, and all parts above the floor level in by-product coke ovens.

The materials used in the manufacture of silica brick are quartzite, crushed to pass through an 8 mesh screen, and a bonding material to mix with it so that it can be moulded into shape.

Some silica rocks, known as gannisters, contain sufficient bond, in the form of highly refractory clay, to render any addition unnecessary. The bond generally used is lime, about two per cent being added to the crushed quartzite in the form of milk of lime. The quartzite and lime are milled thoroughly in wet pans, until a slightly cohesive mass is produced. The wet mass is moulded by hand, then partially dried, and afterwards re-pressed by machinery. When thoroughly dried, the pressed bricks are set in kilns which are fired to a finishing temperature of 1,500 degrees Centigrade.

Searle[3] gives a list of various other bonds used, as well as details regarding preparation, moulding, and burning, as carried out in Great Britain and France.

The chemical requirements of a siliceous material suitable for a refractory brick vary; but the silica content should be as high as possible. A reliable chemical analysis is of very great importance therefore, since the refractoriness of the finished brick will depend on the silica content, and on the presence of such impurities as lime, alkalies, and iron, which tend

[1]In some instances the lining is composed of a fine-graded siliceous rock obtained from Belgium.
[2]See footnote in Chapter I, p. 7, for definition of sand.
[3]Refractory Materials, their Manufacture and Use. Alfred B. Searle, Charles Griffin & Company, Ltd. London.

to act as fluxes, and lower the melting point of the bricks. For example, the material used in Pennsylvania is a quartzite from the loose boulders and fragmentary pieces that have been torn from the parent ledges and scattered over the surrounding country. An analysis of these pieces is, approximately, as follows:—

SiO_2	98·0%
Al_2O_3	0·6%
Fe_2O_3	0·7%
CaO	0·2%
MgO	0·1%
Alkalies	0·4%

The physical properties of the silica are of as much importance as the chemical composition. It has been found in testing a number of silica samples in the laboratories of the Mines Branch, that quartzites are preferable to sandstones or vein quartz, and that loose sand or gravel is altogether unsuitable, even though the chemical analysis is satisfactory. Consequently, the brick manufacturers are restricted in the selection of their raw material. It is only by actual test of a sample that it can be determined if a material is suitable for the manufacture of a silica refractory.

A quartzite, suitable for this industry, when ground, should have grains that are splintery, sharp, heterogeneous as to form and size, and slightly translucent. It should analyse approximately 97·5 per cent SiO_2, 1 to $1\frac{1}{2}$ per cent Al_2O_3, and 0·75 per cent other impurities; and when moulded into brick and fired, should expand and swell without perceptible cracking. The total fluxing materials in a silica brick should not exceed 3 per cent. In a gannister brick the clay content may run as high as 10 per cent. The only example approaching a gannister rock at present known in Canada occurs in an extensive deposit forming the wall rock containing the kaolin in the Canadian China Clay Company's mine at St. Remi d'Amherst, Quebec. This rock contains enough disseminated kaolin to form a bond for the quartzite when crushed and wet. Tests made with this material show it to be a desirable refractory for certain uses.[1]

The only place in Canada where silica brick is made is at Sault Ste. Marie, Ont., where the Algoma Steel Corporation have a plant turning out products chiefly for use in their own metallurgical processes. The quartzite used is obtained at Bellevue station on the Algoma Central railway, 20 miles north of Sault Ste. Marie. Deposits of quartzite of a similar character occur at Killarney, on Georgian bay, and at mile 65 west of Sudbury, Ontario, on the Algoma Eastern railway.

Another quartzite deposit which has attracted considerable attention, and which has been mentioned as a probable site for the manufacture of silica brick, is Skye mountain, near Whycocomagh, in Cape Breton county, N.S.

GLASS SAND

The chief raw constituent of commercial glass is silica, and this material may form from 50 per cent to 75 per cent of the original batch or charge. The other ingredients consist of various alkalies, alkali earths, and metals.

[1]Summary Report, Mines Branch, Ottawa, 1916, page 107.

To these raw materials there is generally added a certain percentage of cullet or ground up glass, comprising the breakage in the factory and the culls from articles produced. The materials, when properly mixed, are charged into the melting furnace, and after fusion has taken place the molten glass is made into different commercial glass products.

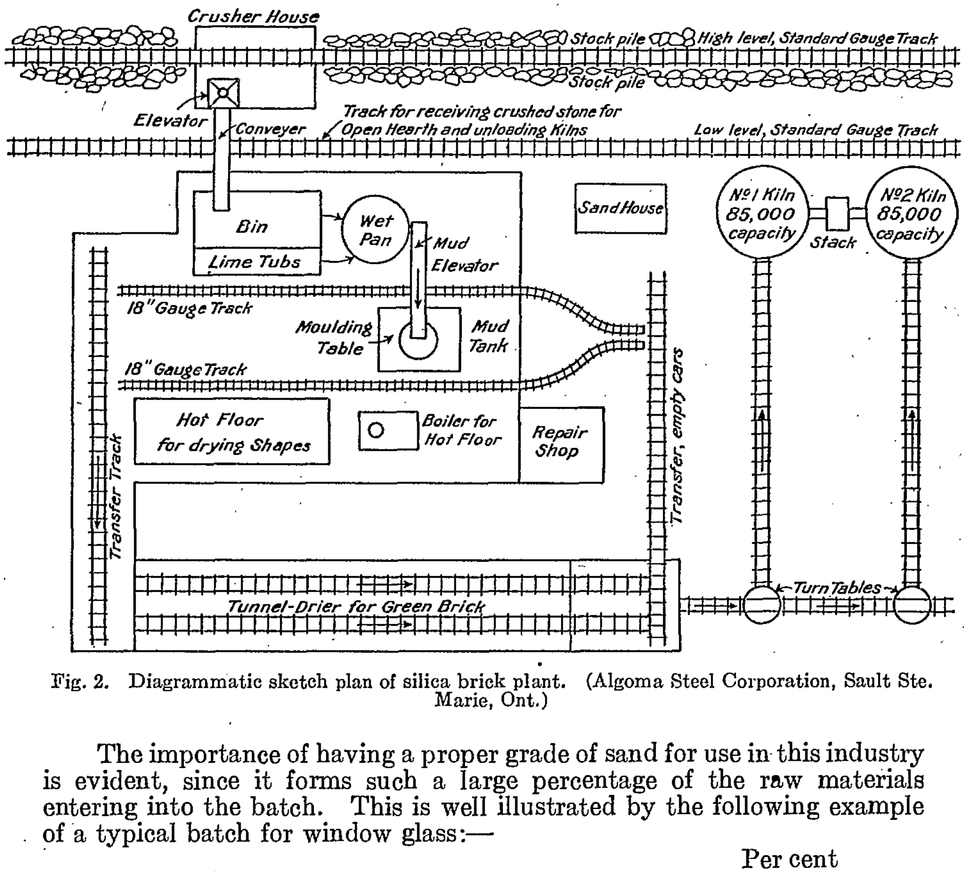


Fig. 2. Diagrammatic sketch plan of silica brick plant. (Algoma Steel Corporation, Sault Ste. Marie, Ont.)

The importance of having a proper grade of sand for use in this industry is evident, since it forms such a large percentage of the raw materials entering into the batch. This is well illustrated by the following example of a typical batch for window glass:—

	Wts.	Per cent of batch
Sand (silica)........................	100 lbs.	52·63
Salt cake........................	40 "	21·05
Soda ash........................	4 "	2·10
Limestone........................	38 "	20·00
Carbon........................	8 "	4·22

The silica used in the glass industry is generally in the form of sand. The greater part of the material used is obtained from natural sand deposits, or by crushing a friable or loosely bonded sandstone. It rarely pays to crush vein quartz or quartzite for glass manufacture, since the hardness of such materials greatly increases the cost of crushing, and there is also the danger of contaminating the sand with iron particles from the crushers.

Sand, either in the form of natural sand or as crushed sandstone, varies greatly both in chemical composition and physical properties. From long experience, the glass manufacturers have recognized certain properties which a sand should have to permit of its being classed as suitable for the manufacture of glass. These requirements vary to a small extent in different plants, and also according to the class of glass being produced, therefore, definite specifications cannot be laid down to suit all glass sands, since each sand will have to be chosen for the work for which it is required. Broad limits, however, can be given. It should be borne in mind, when attempting to place limits on sands for glass making, that although it is true that the sand generally forms over one-half the batch, the other materials which enter into the mixture may also carry impurities, or be of improper texture; therefore, they also should be governed by tests and specifications, as well as the sand.

CHEMICAL COMPOSITION

The sand should run as high in silica (SiO_2) as possible. Objectionable impurities are metallic iron and compounds of iron, alumina, magnesia, lime, and alkalies.

Iron oxide is the worst of the impurities found in glass sand, on account of its strong colouring power. The smallest percentage present in the sand tends to impart to the glass a green, yellow, or red colour, the intensity of which depends on the amount of iron oxide present. The following percentages seem to be the average limits allowable in common practice:—

For optical glass, best grades:—

	Per cent Fe_2O_3
Flint glass and soda lime glass	0·02 to 0·05
Plate glass	0·10 to 0·20
Bottles and window glass	0·20 to 0·35
Dark bottles	0·50 to 0·65 and higher.

When the iron oxide content is not above 0·20 per cent the green colour can be neutralized by some decolorizer, such as manganese, selenium, cobalt, or nickel. Above 0·20 per cent of iron oxide, the green colour is too intense to be entirely destroyed.

The presence of alumina in a sand, while it may be desirable for some purposes, tends, unfortunately, to decrease the transparency of the glass, and also makes the batch harder to melt. For the best grades of flint glass, therefore, the alumina should not run over 0·10 per cent, while for plate glass or window glass it should not exceed 0·60 per cent, except in special cases. The form in which the alumina is present in the sand is of great importance, since if it is present as clay—a silicate of alumina with probably iron and magnesia—it is not readily soluble, while if it is in the form of feldspar it is soluble and not so harmful.

Sands containing lime are to be avoided, for, although lime is an important ingredient in many commercial glasses, the calcareous material in the sand is generally sporadic in its distribution, and unless daily analyses of the sand employed are made the lime content in the batch cannot be depended upon. It is preferable therefore to use a lime-free sand, and add raw limestone to the batch as required.

Magnesia is generally present in glass sands in such small quantities that little trouble is caused by its presence. An excessive amount of magnesia (1 per cent or higher) tends to raise the fusion point of the batch, and this is objectionable on account of the extra fuel required.

Some sands contain appreciable percentages of decayed vegetable matter, but this is generally removed when the sand is well washed, so that it rarely causes trouble. If, however, the sand is improperly washed, and some of the organic matter remains, there is a danger of colouring the glass a dark amber.

Occasionally other impurities, such as titanium oxide and alkalies, are found in glass sands, but they are generally in such small quantities that they are not harmful.

MOISTURE

Sand is capable of carrying considerable moisture, and all sand should be thoroughly dried either before shipment or at the glass factory. The presence of moisture in a sand lessens the available amount of silica for a given weight. It should not exceed 2·5 per cent.

The following analyses are of typical glass sands:—

——	1	2	3	4	5
	%	%	%	%	%
Silica (SiO_2)	99·12	99·20	99·58	99·25	99·80
Iron oxide (Fe_2O_3)	0·07	0·17	0·02	0·04	0·006
Alumina (Al_2O_3)	·43	·53	·12	·59	·13
Lime (CaO)	·34	trace	·13	·11	trace
Magnesia (MgO)	·11	"	trace	·02	....
Alkalies	....	·10	....	....	....
Loss on ignition	·22	....	·17	·25	·18

1. Belgian sand (Dominion Glass Co., Montreal).
2. St. Paul, Minn., U.S.A. (Bulletin on British Sand Resources, by Boswell).
3. Wedron Silica Co., Ottawa, Ill. (Bulletin on British Sand Resources, by Boswell).
4. Lynn Sand, England. (Sands Suitable for Glass Making, by Boswell).
5. Fontainebleau sand, France. (Sands suitable for Glass Making, by Boswell).

TEXTURE

While considerable latitude may be allowed in the size of grains in good glass sand, uniformity is desirable. If the grains are larger than will pass through a 14-mesh screen (1·168 mm. opening) they are harder to melt than the rest of the batch, and combine with the fluxing ingredients too slowly, causing strings in the glass. The fact that the coarse sand is harder to fuse tends to decrease the daily throughput of each furnace, hence the cost of production is increased. If, on the other hand, much material finer than the 100 mesh (1·147 mm. opening) is present in the sand, there is liable to be considerable loss in charging, and the fine sand will also carry an excess of air into the molten batch in the furnace, which will require excessive heat to eliminate.

An important point in choosing a sand produced from crushed sandstone is, to see that the original size of the grains in the sandstone is not too fine, since when the stone is crushed to pass the 14-mesh some of the larger grains may consist of aggregates of a number of smaller grains cemented together, and although these will generally break down readily in the furnace, the cementing material may prove to be an objectionable impurity.

Opinions differ as to whether rounded grains or angular grains are best adapted for the manufacture of glass, and as both are used successfully in many glass factories on this continent, it does not appear that the shape of the grain has much influence on the product.

A general specification for the texture of a glass sand might be that all material should pass a 14-mesh screen, and 90 per cent be retained on the 100-mesh, with 65 per cent between the 20-mesh and the 65-mesh. The following granulometric analyses of sands used successfully in Canada and the United States, are typical:—

Cumulative Percentages

Retained on mesh	1	2	3	4	5
	%	%	%	%	%
10	....	....	....	....	....
14	....	....	....	....	·42
20	·16	....	·15	·07	1·20
28	1·10	....	·30	1·66	3·38
35	44·54	·15	51·24	14·77	10·66
48	83·91	59·84	79·53	76·48	41·41
65	94·53	79·07	89·53	97·01	79·09
100	99·22	96·88	97·34	99·80	99·02
150	99·85	99·69	99·53	99·96	99·87
200	100·00	99·84	99·84	99·99	99·97

1. Belgian sand.
2. American sand (Rockwood brand).
3. American sand (National brand).
4. American sand, Pittsburg Plate Glass Co., Kennerdell, Pennsylvania. (Trans. Am. Cer. Soc., Vol. XIX, p. 181).
5. American sand. American Window Glass Co., Derry, Pennsylvania. (Trans. Am. Cer. Soc., Vol. XIX, p. 181).

It will be seen, therefore, that a sand for glass manufacture should be one of uniform grain and of medium fineness, running as high in silica as possible; it should be practically free from iron and other impurities and should be washed to remove organic matter, etc., and then dried.

USE IN THE MANUFACTURE OF CARBORUNDUM

The discovery, in 1885, of the abrasive, carbide of silicon (SiC), a product of the electric furnace, opened up a large market for high grade silica. Carborundum—by which name this material is known—is produced by heating a mixture of coke, siliceous sand, sawdust, and salt, in an electric furnace. The charge is made up in approximately the following proportions:—

Coke	34 per cent	Sawdust	10 per cent
Sand	54 per cent	Salt	2 per cent

From this it will be seen that silica sand comprises over one-half the charge.

The silica must be a sand of fairly uniform texture, and graded between the 20 and 100 mesh screens. Chemical analysis gives a good indication of the suitability of a sand for the manufacture of carborundum, since the silica content is of vital importance. The sand should run 99·5 per cent SiO_2, and must not be lower than 99·25 per cent. While it is stated that alumina in small quantities is not injurious, lime, phosphorus, and magnesia should be entirely absent.

STEEL FOUNDRY SAND

Silica finds one of its largest markets in steel foundries. In this industry it is used in the form of sand for making moulds for steel castings. Some sands are found in nature suitable for this purpose, but the greater number of castings are made in moulds consisting largely of a high silica sand, to which some artificial bonding material has been added. This bonding material consists of highly plastic fireclay, flour, molasses or other suitable material.

A sand suitable for use in steel casting must have three essential properties, namely, good bonding power, high permeability, and great refractoriness.

BONDING POWER

The ability of a sand to retain the shape of the pattern when the latter is removed from it, and its power to resist the strain when the molten metal is poured into the mould, are prime requisites of a good moulding sand. A sharp, angular sand will obviously form a high bond due to the interlocking of the angular grains, but in doing so the permeability of the sand is greatly decreased, on account of the filling of the pore spaces. It is therefore better to use a sand with some rounded grains, and to depend on the bonding material added for the bonding power. It is apparent, therefore, that great care should be taken in selecting and testing the bonding material as well as in choosing the proper grade of sand. It would be the greatest folly to secure a high grade silica sand suitable in all respects, and not pay attention to the grade of the bonding material, since in using a clay with a poor bond, more of it would be required, and this would tend to close up the pore spaces in the sand, and to decrease permeability. This is the reason why many poor castings are produced, the blame being placed on the sand, which might have proved eminently satisfactory had a proper bonding material been employed.

PERMEABILITY

One of the properties of a sand, which is essential to a good silica sand for steel foundry use, is that of allowing the ready escape of gas through it. The molten metal, when poured into the mould, generates gases which exert a pressure on the face of the mould, and unless the channels between the grains are sufficient to enable the gases generated to escape freely, there will be serious danger of creating scabs, and causing the castings to blow. It is a well known fact that a sand in which the grains are well rounded and of uniform size has more pore space and better permeability than one in which the grains are of different sizes. The permeability of a sand is also dependent on the size of grain; since a fine sand, although the pore space may be as great as in a coarser sand, tends to compact more, and block up the connected passages between the spaces, thus preventing the ready escape of the gases. In a coarse, uniform sand, the channels between the sand grains are larger and the sand is harder to compact, hence the permeability of a coarse sand is relatively greater than that of one in which the grains, although of uniform size, are smaller. Obviously, then, a heavy casting, which generates greater quantities of gas at a higher rate and pressure than a small casting, will require a more open sand of a coarser uniform grain. Consequently, when choosing a sand for steel foundry purposes, it is necessary to consider the average size of the casting to be made, and to select the sand accordingly.

REFRACTORINESS

The property of effectively resisting the destructive action of the heat of the molten metal is of great importance in a sand for steel foundry purposes. The high temperature of the molten steel necessitates the employment of a highly refractory sand, hence sands which run well over 95 per cent silica are generally employed. These sands should be as free as possible from fluxing impurities, such as alkalies, since they increase the liability of failure of the mould, and cause the formation of scabs on the casting.

An ideal sand for steel foundry purposes would be one composed entirely of grains of silica, in which all the grains were well rounded and of a uniform size, varying according to the class of casting to be made. In commercial practice, the cost of such an ideal sand would be practically prohibitive, but the nearer a sand approaches the ideal requirements the better the results obtained by its use. For example, the following screen analyses show the composition of four commercial steel foundry sands being used successfully on this continent:—

Cumulative Percentages

—	1	2	3	4
Retained on 20 mesh	10·71	8·25	10·00	19·20
28 "	28·00	51·30	35·00	42·00
35 "	41·00	81·30	52·50	66·20
48 "	64·00	94·00	68·50	88·40
65 "	88·50	96·80	85·00	94·80
100 "	91·50	98·50	97·50	97·50
Average fineness[1]	38·9	26·6	34·8	29·1

A tentative specification for a steel foundry sand for average castings might call for one in which the silica content was 97 per cent or more, consisting of well rounded grains, graded between the 20 and the 100 mesh, having an average fineness of from 35 to 48.

SILICA SAND FOR FURNACE LININGS

Silica is employed for lining certain types of metallurgical furnaces, notably Bessemer converters, matte smelting reverberatory furnaces, and electric furnaces for the melting of scrap iron.

In Bessemer converters the lining is usually composed of a highly refractory siliceous material, such as a crushed quartzite or silica sand. Silica, containing small proportions of a plastic refractory clay, either present naturally in the rock or added to the crushed material in the form of a plastic fireclay, is best suited for this purpose. The bottoms are made by ramming in this crushed silica, slightly dampened, together with a small amount of coke breeze.

[1]For method of calculating average fineness see page 70.

For making the hearth of matte smelting reverberatory furnaces silica sand is employed. The following description by Thomson[1] of an actual installation of a hearth at Clarkdale, Arizona, is of interest in this connection:—

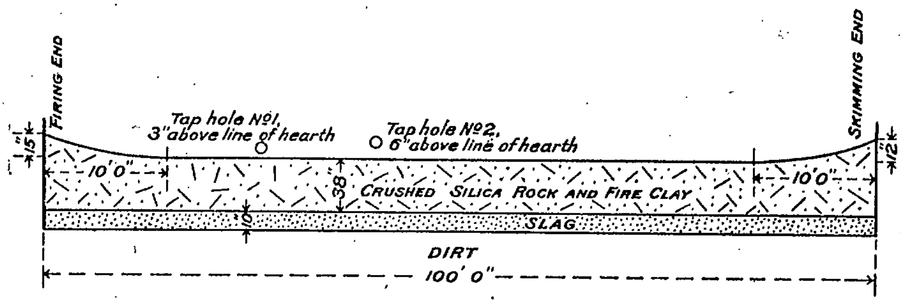


Fig. 3. Sketch showing construction of hearth reverberatory No. 2, Clarkdale, Arizona. (After Thomson.)

> The silica rock used came from Seligman, Arizona, in large slabs and had the following composition: SiO_2 96·0 per cent, FeO 1·0 per cent, Al_2O_3 2·0 per cent, CaO 0·7 per cent. It was put through two sizes of jaw crushers 30 x 18 inches and 20 x 10 inches, and then through 54 x 24 in. rolls set at one-half inch. This crushing was repeated, as there was too large a proportion of coarse pieces after a single run. The product from this second crushing consisted of a mixture of pieces up to $\frac{3}{8}$ inches. with powder of all degrees of fineness. On account of the high silica percentage it was feared that difficulty might be experienced in getting a thorough glaze without long and severe firing, which might seriously injure the furnace roof. The material for the top 12 inches of hearth was therefore prepared by mixing silica screenings (through an 8-mesh screen) with fireclay (65 per cent SiO_2) to reduce the silica percentage to about 93·5. The furnace was 19 x 100 feet (Anaconda type) and equipped with seven oil burners (Steptoe type). Only five of these were used after the furnace was in regular operation. The foundation consisted of 10 inches of slag put in while molten and allowed to cool for several days. 38 inches of material was tamped on this, 26 inches analyzing 96 per cent, and 12 inches 93 per cent SiO_2 as stated. In addition to this, a silica-clay mixture was banked for 10 feet from both skimming and firing ends, giving 12 and 15 inches additional bottom at these points. (See sketch Fig. 3), 285 tons of silica and four tons of fireclay were used in all.

Material required for this purpose, therefore, should run over 95 per cent SiO_2, and should be of even grade. The size of grain in general use should be from 0·1 to 0·35 mm.

Silica is used in some plants for lining electric furnaces in which scrap iron is being melted. In one plant visited, a mixture is employed for lining these furnaces, composed of crushed silica brick, crushed quartzite, and a silica sand, with a glucose bonding material. The quartzite and silica brick particles were about a 3-mesh size, and the sand was of similar texture to that used in glass manufacture or in steel foundries.

FUSED SILICA

The production of apparatus made of pure silica, for use in chemical laboratories and manufacturing industries, has been made commercially possible by the adaptation of the electric furnace.

[1]Making the Hearth of a Matte Smelting Reverberatory Furnace, Canadian Mining Institute Bulletin, May, 1920, pp. 387-8.

The process consists of using an electric resistance furnace in which is placed, between the terminals, a perforated carbon tube, surrounded by silica sand, similar in quality to sand used for glass making. The current passing through the carbon tube fuses the sand, after which compressed air is forced through the tube, and this causes the quartz cylinder, which has formed around the tube, to expand and take the shape of the mould. When the fused mass has solidified and is drawn from the mould, it is cut to the desired dimensions and polished. Fused ware prepared by this process is not transparent, on account of the numerous air bubbles disseminated through it, since the fused mass does not become fluid, but only reaches a plastic consistency.

Small apparatus for use in chemical laboratories is generally subjected to a further process, in order to impart to it a highly glazed surface.

Tubes 12 inches in diameter, and 30 inches long, dishes 20 inches in diameter and retorts of 75 litres capacity, have been produced by this process.

Silica for use in this industry is required in the form of sand having similar texture and composition to the sand used in glass manufacture.[1]

SILICA SAND FOR SAND BLASTING

In foundry work, the present practice for cleaning large and small castings is to use a sand blast. The sand used for this work varies greatly in different foundries. One operator prefers a sharp grained sand, another a round, smooth sand. The size of grain employed also varies. Gates[2] in discussing this question says:—

> Of the various sands offered, silica and ocean sands only have the sharpness and hardness to make a satisfactory sand blast abrasive. At the same, or even an advanced cost, undoubtedly the silica sands would have a general preference. Owing to the restricted areas of production, however, freight rates operate against their use at any considerable distance from the source of supply. It is only by a trial of each, that an intelligent selection of available sands can be made, and some initial expense in comparative tests of all the various sands and metal abrasives will undoubtedly be fully returned in satisfactory results and economy of sand blast operation. Highest blasting efficiency from any abrasive, however, may only be anticipated when it is evenly graded, dry and free from loam and dust.

MINOR USES OF SILICA SAND

Other minor uses of silica sand are numerous. Quartz, crushed and graded to various sizes, is used to a small extent in making sandpaper and sand belts. For this purpose, quartz or massive quartzite is preferable to sandstone, since the grains resulting from the crushing of the sandstone have less angularity and do not cut as well as the sharper quartz fragments. Silica sand is also used in stone and plate glass grinding, as an abrasive with stone cutting saws, for frosting glass with the sand blast apparatus, and for many other industrial purposes.

USES OF POWDERED SILICA

Powdered silica is used in a number of industries. Silica in this form may be prepared from flint, quartz, quartzite, or sandstone. The material

[1]For further details relating to fused silica the reader is referred to Chemical and Metallurgical Engineering, Vol. IX No. 4 pp. 226-228 and Vol. X, No. 4, pp. 248-249.

[2]Paper entitled, "Selecting Sand Blast Equipment for the Foundry," read before Annual Meeting American Foundrymen's Association, 1918. H. D. Gates, Hagerstown, Md.

used depends on the requirement of the industry in which it is employed, and, to a large extent, on its availability. The more important industries using silica in the powdered form are briefly described.

USE IN THE POTTERY INDUSTRY

The mining and preparation of siliceous rocks for use in potteries is one of the principal branches of the silica industry.

The various kinds of pottery in which silica is used are table ware, sanitary ware, electrical porcelain, chemical porcelain, and white floor and wall tiles.

About 35 per cent of finely ground quartz is used in the composition of the bodies from which these wares are made, the remainder of the body being clay and feldspar.

The source of the silica used in English potteries is the flint nodules which occur in the chalk in the southeastern portion of that country. These flint nodules are assembled and shipped to the pottery centres, where they are calcined in special kilns and afterwards crushed and pulverized, principally by a wet grinding process. The American potteries use, for the most part, finely ground white quartz sandstone, but they call it flint in their body formula, a practice inherited from the English potters who used only true flint.

The function of flint in the pottery body is to reduce the shrinkage in drying, and to give it a certain rigidity during firing, preventing deformation from softening.

The greater part of the white pottery ware is covered with glaze, and fired a second time, in order to fuse the glaze to the body. Silica, in the form of flint or pulverized quartz or sandstone, is always one of the ingredients of the glaze.

Flint or pulverized quartz is nearly always used in the manufacture of art pottery. A good deal of this ware is made from a plastic clay, which may or may not burn to a white colour. As most of these clays have a high shrinkage, a certain amount of flint is added to correct it. Furthermore, the addition of flint to a clay is often necessary in order to produce a body which will take a better glaze.

A considerable quantity of pure white sand is used in the manufacture of vitrified floor tiles. The sand is used to keep the tiles apart when packed in the saggars for firing.

For this industry, therefore, it is necessary to have a silica that will burn to a dead white. Hence a high grade material, free from iron, if possible, is desirable. The iron content should not exceed 0·32 per cent. The material should all pass through the 120 mesh, and 90 per cent, preferably, through the 150 mesh.

In the metal enamelling industry, silica is used as a partial substitute for feldspar in some of the cheaper grades of enamel. For this use it has been found, from practical observation, that the silica employed is better when not too finely divided. The material used should contain over 97 per cent SiO_2, and less than 0·35 per cent iron oxide.

USE IN THE MANUFACTURE OF PAINT

The introduction of silica into paint manufacture dates back many years, and the modern floated silica is now classed as a standard pigment.

Pure silica, in the form of an impalpable powder, is one of the most stable pigments known, being highly refractory, and practically insoluble in water and in all acids except hydrofluoric. It is, however, never used as a base paint, but may be added to some pigments—with the exception of siliceous ochres—up to 25 per cent, also to others, such as lamp black, the better grades of iron oxide pigments, and pure chrome green, up to as high as 50 per cent, without detracting materially from their value as a body paint.

Paints containing silica are the best for use on green lumber or material containing moisture, as the silica is said to allow the moisture to pass through the pores of the paint film, and at the same time is impervious to external dampness. It is also said to increase the durability of a paint.

For paint purposes, silica with a tooth is preferred, and, as a rule, clear, glassy quartz will yield a sharper grain than opaque massive varieties, no matter how fine the silica may be ground. The material should be well over 95 per cent SiO_2, and free from iron or other colouring impurities. The essential quality for its employment in the paint industry is its colour, which should be perfectly white. The finer the material is ground the better suited it is for paint manufacture, and as employed, it is generally in the form of water, or air floated silica, or else bolted.

The following analyses—after Scott—will serve to show the composition of silica from several sources, as used in paint manufacture:—

—	1	2	3
	%	%	%
Silica, SiO_2	99·38	98·00	96·86
Alumina, Al_2O_3	0·22	0·95	0·22
Ferric oxide, Fe_2O_3	....	·05	....
Lime, CaO	....	trace	1·30
Magnesia, MgO	·08	·15	....
Carbon dioxide, CO_2	....	....	·69
Sulphur trioxide, SO_3	....	....	·56
Water, H_2O	·30	·85	·29

(1) Floated silica made from rock quartz.
(2) " " milky quartz.
(3) " " quartzite.

USE IN THE MANUFACTURE OF SODIUM SILICATE

Commercial sodium silicate, also called soluble glass or water glass, approximates the composition $Na_2O \cdot 4(SiO_2)$ and contains about 79 per cent silica. There is about $120,000 worth of silicate of soda consumed in Canada each year, and not a pound is being manufactured in the Dominion. It is prepared, commercially, in two ways, namely, the dry and the wet methods. In the dry method, a mixture of powdered quartz or silica, and either sodium carbonate or sodium sulphate, is fused in a regenerative furnace, at a temperature of 1100°C, for eight hours. A small quantity of coal is added, to aid in the reduction of the carbonate. The product is drawn off, when in the fused condition, into a receptacle, and allowed to cool. It is crushed, and then subjected under pressure to long boiling with water. The resulting solution is allowed to stand, and then evaporated to the required consistency.

In many cases the wet method is preferred, on account of the greater uniformity of the product, and the fact that it is obtained at once in the form of a solution. This method consists of digesting silica under pressure with a solution of caustic soda having a specific gravity not above 1·24. The liquid is heated by blowing in steam, and is constantly stirred by machinery. The clarified liquid is drawn off and concentrated to the required strength.

For the manufacture of this material the silica is preferred in the form of a pure diatomaceous earth, or as a finely powdered flint, quartz, etc., and should be as pure as possible.

SILICA FOR USE IN ASBESTOS SHINGLES

Finely ground silica is used in the manufacture of asbestos shingles. As high as 40 per cent silica is sometimes employed. In this industry it is ground to pass through the 200-mesh screen, and one of the essential requirements is that it shall be colourless.

MINOR USES FOR POWDERED SILICA

Numerous uses of silica in the powdered form are found in many industrial processes. It is used extensively as a filler and scouring substance in hand soaps, for dusting moulds in foundries, in roofing papers to keep the rolled sheets of tar paper from sticking, in dental work as a detergent, in numerous chemical operations, and as a filler in paper and rubber goods. It also enters into the composition of match heads, and is used as an abrasive for polishing pearl and bone buttons, and for the making of metal polishes.

USES OF DIATOMACEOUS EARTH

The nature and mode of occurrence of diatomaceous earth has already been described. This material, when properly prepared, finds a use in a number of industries. Its value in the several industries depends on its silica content and the shape of the individual skeletons.

Its three largest uses are probably (1) as an abrasive material, (2) as a heat insulator, and (3) for filtration.

As an abrasive material it has found considerable favour on account of the extreme hardness and minuteness of the grains, as well as their sharp cutting power. In this connection it is used extensively in metal polishing, and in soaps for scouring.

The great porosity of diatomaceous earth makes it a non-conductor of heat, and this property, together with its extreme lightness, has caused it to be employed extensively as an insulating material, for covering high pressure steam pipes, for linings of furnaces, and in many places where a high grade fire-resisting insulating material is required. For this use it is employed either in loose form, with some bonding material, or in the form of bricks, either manufactured or cut to size from the compact varieties of the material. It is also used as an insulator for steel safes, refrigerators, etc.

As a filtrant it may be used directly as the filter body or added to the filtering medium to keep it porous. It has also been found to have considerable decolourizing power, and has been employed to a small extent like fullers earth, in the filtering and decolourizing of vegetable or mineral oils.

Owing probably to the fact that a considerable portion of the silica present in diatomaceous earth is present in a form soluble in alkali, the purer varieties are used in the manufacture of silicate of soda (water glass) in preference to the less easily soluble powder ed quartz. For this purpose however, only the purest grades, free from iron, are suitable.

To a small extent, it is employed in the manufacture of dynamite as an absorbent of nitroglycerine.

It enters as a filler into the composition of rubber, sealing wax, phonograph records, fertilizers, and wherever a light and inert filling agent is required.

The material, as excavated, is allowed to stand for some time exposed to the air to dry, after which it is either calcined or treated directly in the pulverizers before being graded into the several sizes required by screens or air separation.

CHAPTER IV

OCCURRENCES OF SILICA IN EASTERN CANADA

Silica occurs in eastern Canada in the form of quartz, quartzites, sandstones, sands, and diatomaceous earth. The more important localities were visited and representative samples obtained. The areas visited will be briefly described, and references made to the localities from which samples were taken. It should be remembered when reading this chapter, that the individual deposit described is not necessarily the best to be found in a district. In covering such an extensive territory as eastern Canada; in which there is such broad distribution of these deposits, it was only possible to select certain typical samples as representative of the material which might reasonably be expected from each of the districts examined, hence a general description is given of each area, before referring to the individual localities from which the samples were taken.

ONTARIO

The more important occurrences of silica in the province of Ontario are in the form of sandstones, quartzites, and vein quartz. Their geological and structural features have already been mentioned in Chapter II. The occurrences have been divided into districts or areas for descriptive purposes.

PORT ARTHUR AREA

The district in the vicinity of Port Arthur and the northwestern shore of lake Superior contains numerous beds of sandstone of Keweenawan age, which are more or less friable, and range in colour from dark brown to creamy white. Many of these sandstones are altogether unsuitable as a source of silica, and only those that are creamy white or white in colour are of possible commercial importance. As a general rule, the sandstone in this district carries considerable calcareous bonding material, and the rock being friable, breaks down readily, resulting in considerable fine material, which, if used for glass manufacture, would entail a large loss in the washing process.

Only a few exposures could be visited in the time available and, consequently, although the samples were taken from the creamy white variety, it is possible that other localities will yield a rock freer from impurities than the samples analysed.

Four samples were obtained from this district, Nos. 1835, 1837, and 1842 being sandstones, and No. 1868 an altered sandstone or quartzite.

Sample No. 1835 was taken from sandstone beds occurring on the east bank of the Wolf river, 7 miles north of Dorion station, on the Canadian Pacific railway, about 50 miles east of Port Arthur. The beds are mostly drift covered, but a small amount of material has been quarried, and a face of 15 feet of sandstone above the bed of the river has been opened. No idea of the extent could be obtained. The rock is fine-grained, and creamy white in colour, with sometimes a slightly pinkish cast. The unwashed sample ran high in lime and alumina, but these impurities were considerably reduced by washing. The washing test, however, removed nearly one-fourth of the material. Under the microscope the rock shows well-rounded grains of quartz, with numerous cavities, some of which are filled with a calcareous cement.

As the writer was unable to visit the sandstone deposits of Simpson island, lake Superior, a sample (No. 1837) was obtained from a stone-cutting yard at Port Arthur. This sample was accepted as representing the stone quarried on Simpson island, on the word of Mr. Thomas Marks of Port Arthur, who was present when the sample was taken.

Under the microscope, the stone shows a similar texture to sample No. 1835, with the exception that there are fewer cavities, and the rock is more compact and homogeneous. Occasional grains of hornblende and iron-stained quartz are to be seen. An analysis of this rock, unwashed, shows that it carries a high percentage of iron and lime, which, however, was partially removed on washing. It loses about one-fifth of its weight when washed, due to the great amount of fines produced in crushing.

Sample No. 1842 was collected, at the request of the writer, by Mr. H. D. Parizeau, of the Hydrographic Survey, Department of Naval Service. He gives the location of this sample as an abandoned quarry near the entrance to Black bay, approximately longitude 86° 31′ 05″ and latitude 48° 33′ 10″. This sample differs materially from the two foregoing samples. It contains considerable argillaceous material, and is very fine in texture. It loses over 50 per cent in fines in the process of washing. The individual grains are not so rounded as in the other two samples, and there is an appreciable amount of grains other than quartz present in the rock. Numerous elongated cavities are to be seen when examined under the microscope.

Sample No. 1868 was furnished by Mr. J. G. Cross, Port Arthur, Ont., at the request of the writer. Mr. Cross in a personal communication referring to this sample says:—

> I found it impossible to get a sample of the quartzite that was free from stain. This quartzite is of great horizontal extent, but never appears to form cliffs where I could get a sample free from stains. Even by breaking large boulders of the material, the stain seemed to persist to the centres. The only specimens I saw free from stain were round pebbles on the beach, these had been apparently leached till the stain was largely removed, however as I did not know the exact locality from where these boulders came, I did not think that they would be of interest to you.
>
> This quartzite belongs to the base of the Keweenawan sediments and are the same series as the sandstones that outcrop along the east shore of Thunder bay, except that they are much more metamorphosed. These areas of extreme metamorphism seem to gradually fade into the less metamorphosed material, and in some cases into normal sandstone. The areas of quartzite like the sample sent you have considerable lateral extent. The depth, however, I do not think would exceed ten feet at the most. The sample was taken from Woods Location, Sibley township, one mile east of Silver Islet Landing.
>
> I might say that this is the best grade of quartzite I have ever observed in this section of the country.

This sample was more compact than the others examined from the Port Arthur district, but chemically was very similar. The individual grains of quartz are indistinct, and the bond is partly argillaceous.

GEORGIAN BAY-TIMISKAMING AREA

In the territory lying to the north of Georgian bay, and extending from Sault Ste. Marie on the west to lake Timiskaming on the east, there are extensive deposits of massive quartzites, which run high in silica, and are probably suitable for the manufacture of silica brick, ferro-silicon, and other ferro-alloys, or as a flux in copper-nickel converters. Already the quartzite from Killarney is being quarried for ferro-silicon manufacture, and the quartzite occurring in the vicinity of Bellevue station on the Algoma Central railway, north of Sault Ste. Marie, is being utilized by the Algoma Steel Corporation for the manufacture of silica brick. Quartzite from the vicinity of the nickel deposits of the Sudbury region is being used as a flux in the copper-nickel converters. The extent and character of this Lorrain quartzite has already been indicated in Chapter II. Two samples of this quartzite, Nos. 1839 and 1840, were taken in this district, as representative of the material available.

Sample No. 1839 was collected from quartzite exposed in the cut at mileage 65 from Sudbury on the Algoma Eastern railway, running to Little Current, Manitoulin island. This quartzite ridge has a face exposed in the railway cut of over 50 feet, and is of great extent. The rock is massive and compact, greyish white in colour, and crushes into splintery fragments. It has a somewhat glassy or vitreous lustre, and in some places is semi-translucent. The deposit appeared very uniform wherever examined, and it could be quarried easily. (See Plate IV.)

Sample No. 1840 was taken from the stock pile in the yard of the Algoma Steel Corporation at Sault Ste. Marie, Ont. This material was obtained for the manufacture of silica brick, from the company's quarry near Bellevue, a station on the Algoma Central railway, 20 miles north of Sault Ste. Marie. The rock is manufactured into silica brick at the company's brick plant.

For this purpose it is crushed to pass an 8-mesh screen, after which it is thoroughly mixed, in a wet pan, with a certain percentage of lime in the form of milk of lime. From the wet pan it goes to a moulding bin, from which it is drawn as required, and moulded by hand into bricks, and any special shapes desired. These shapes on the moulding boards are placed on a hot floor, and afterwards in a tunnel dryer, for drying before being set in the kilns. There are two kilns, each of 85,000 brick capacity, in which the bricks are burned for 14 to 16 days, the temperature reaching 1,500° C. during the burn. This plant is of special interest, since it is the only plant where silica brick are being manufactured at the present time in Canada. (See sketch Fig. 2.) The bricks and special shapes are used by the company in their steel plant.

At Killarney, on the north shore of Georgian bay, quartzite has been quarried for a number of years for the Electro Metals Co., of Welland, Ont., who use it in the manufacture of ferro-silicon. The material obtained at Killarney is very white, and similar in texture and composition to that obtained at Bellevue, Ont., by the Algoma Steel Corporation.

A sample of calcareous sandstone was also obtained from the Quebec shore of lake Timiskaming, directly opposite Haileybury, Ont. (Sample No. 1841.) The rock is exposed along the shore at Pt. Piche for a few hundred yards, and is of no great thickness. It is highly calcareous, and the weathered surface shows numerous cavities due to the leaching out of portions of the lime. The quartz grains are well rounded.

ORISKANY SANDSTONE AREA

The Oriskany sandstone, already described in Chapter II, occurs in isolated and patchy outcrops in a narrow area running from Fort Erie westward to the vicinity of Hagersville. The most important development of this formation is found in the vicinity of Nelles Corners, where it outcrops over several square miles in the townships of North Cayuga and Oneida in Haldimand county. (See Map No. 557.) In this area the beds vary in thickness from 1 foot to 20 feet, and rest on dolomite. There is usually very little stripping to be done to expose the beds, which are horizontal. The rock is massive and coarse-grained, easily friable, and ranges in colour from a creamy white to yellowish. The friability, and comparatively low iron content of the rock from this district, have led to its exploitation as a silica sand, and one company, the Oneida Lime Co., has had a plant in operation on lot 49, con. I, Oneida township, for a number of years.

The sandstone of this formation carries a considerable amount of lime as a bonding material, and as can be seen from the analyses, the material from different parts of the area varies considerably in composition. However, the ease with which the material can be crushed to a sand, and the possibility of removing much of the impurities by washing, thus increasing the silica content, makes the material suitable for some of the silica using industries.

The main exposures of this formation were examined, and samples Nos. 1738, 1739, 1740, 1741, 1742, 1826, and 1827 were taken and tested as representative of the district. The main sandstone areas are controlled by three companies as follows:—

Oneida Lime Co., Ltd., head office, Buffalo, N.Y., SE. ½ lot 49, con. 1 Onedia township, 50 acres; S. ½ lot 48, con. I, Oneida township, 100 acres.

Pilkington Bros., Thorold, Ont., N. ¼ lot 48, con. I N., N. Cayuga township, 30 acres; Centre of lot 46, con. I N., N. Cayuga township, 50 acres.

Consolidated Plate Glass Co. of Canada, Toronto, Ont., N. ½ lot 47, con. I N., N. Cayuga township, 100 acres; NW. ½ of N. ½ of lot 46, con. I N., N. Cayuga township, 50 acres; S. ¼ lot 47, con. I, Oneida township, 38 acres; SW. ½ lot 49, con. I, Oneida township; S. ½ lot 50, con. I, Oneida township, 150 acres.

Samples Nos. 1738-1742, were obtained from the property owned by the Oneida Lime Co., Ltd., which has its head office in Buffalo, N.Y. When the property was visited in 1918, it was being operated under lease by Messrs. Doolittle and Wilcox, of Dundas, Ont.

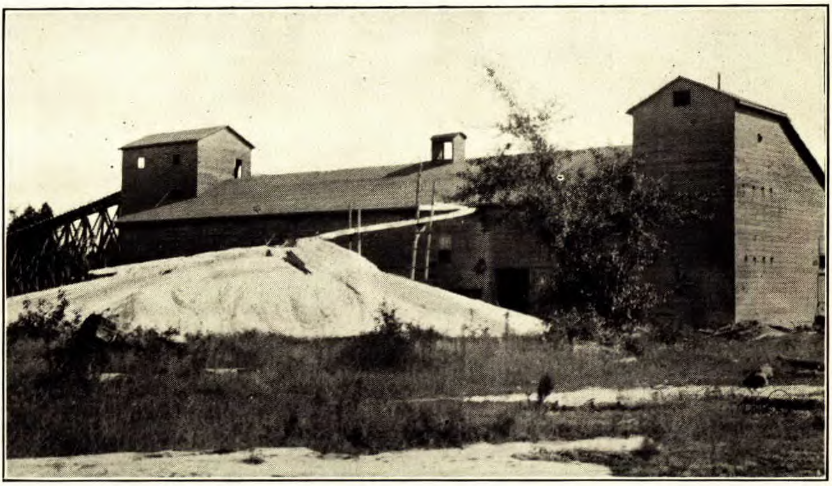
The Oneida Lime Co. has a sand crushing and washing plant on its property. The mill is served by a standard gauge spur 6,300 feet long, connecting to the south of the deposit with the Buffalo and St. Thomas division of the Grand Trunk railway. Hagersville, 5 miles to the west of the plant, is a junction point of the Grand Trunk and Michigan Central railways.

The present plant and quarry are about 10 years old, but numerous old pits indicate that rock was excavated for local use as building material previous to that time.

PLATE IV

Lorrain quartzite ridge cut by the Algoma Eastern railway at mileage 65 from Sudbury, Ont.

PLATE V



Plant of the Oneida Lime Co., on SE. $\frac{1}{2}$ lot 49, con. 1, township of Oneida, Haldimand county, Ont.

The sandstone which is up to 18 feet in thickness, is flat-lying and has very little overburden, is won by open quarry methods. The rock is broken at the face to one man size, and loaded in narrow gauge cars of 2 to 3 tons capacity, which are hauled by horses to the foot of the incline, thence by cable to the top of the mill and dumped into a 25 ton bin. From this bin the rock passes by gravity to a 26″ × 18″ Blake jaw crusher. Water is played on the rock entering the crusher to wash down all the fine material, which has been broken off in handling.

The wet process of grinding is employed in the mill. The material, after passing through the crusher which reduces it to 1½ inch and finer, passes to a 9 foot wet grinding pan, which reduces it to 12 mesh and finer.

From the grinding pan the crushed rock passes to two revolving screens, set one on each side of the pan. The screens used are of 12 mesh, the oversize being returned to the pan for further grinding. The material passing through the screens is washed in two batteries of standard type log-washers, the washed sand being removed by a belt conveyer, while the slimes are carried out of the mill and allowed to accumulate on a waste pile. The washed sand travelling up an incline on the belt conveyer loses some of its surplus water. At intervals along this belt, scrapers are provided for taking off the sand, which then flows by gravity directly into the cars. The sand reaches the car in a very wet condition; and if it is not required for immediate use, is allowed to run to the end of the belt, and to stand in drainage piles, to remove as much of the surplus water as possible. There is a dryer capable of handling a small part of the output, but it is seldom used.

The crushing and washing plant is driven by a 90 H. P. two cylinder gas engine, operated by natural gas from the company's well on the property. This engine also operates two small air compressors supplying air for the rock drills used in the quarry. The output of the mill is from 100 to 125 tons per day of 10 hours. The sand is shipped to glass plants and steel foundries.

Samples Nos. 1738 and 1742 were taken as representative samples from the quarry on the S. ½ of lot 48, con. I, Oneida township. The rock in this quarry contains a high percentage of lime. Another quarry was opened on the S.E. ½ of lot 49, con. I, Oneida township, from which sample No. 1740 was obtained.

The crushed and washed sandstone as shipped from the mill was sampled and tested (sample No. 1739), as was also the material which is discarded on the waste pile (sample No. 1741). It was thought that some possible use for this material might be found.

The water used in the mill is brought from a distance of nearly two miles.

The properties owned in this district by the other two companies are not being operated. About 6,000 tons of crude rock was excavated during one year on the property owned by Pilkington Bros., and shipped to their plant at Thorold, where it was crushed. The Consolidated Plate Glass Co. did considerable prospecting by test pits on their holdings during the summer of 1918. On their property, lying to the west of that owned by the Oneida Lime Co., the limestone, in places, overlies the sandstone, and would have to be removed before the sandstone could be quarried. Two samples, Nos. 1826 and 1827, were taken on the property of the Consolidated Plate Glass Co. as representative of the rock. No. 1826 was from the north end of the S.W. $\frac{1}{4}$ of lot 49, con. I, Oneida township, Haldimand county. Washing improved this sample considerably. Sample No. 1827 was an average sample taken from the S. $\frac{1}{4}$ of lot 47, con. I, Oneida township; and the N.W. $\frac{1}{8}$ of lot 46, con. I N., N. Cayuga township, Haldimand county.

These seven samples give a good idea of the grade of material available from this formation.

SPRINGVALE AREA

To the west of Hagersville, Ont., there are sandstone beds exposed on the farm of S. W. Winger, on lot 6, con. XIV, Walpole township, county of Haldimand. These beds are very similar in appearance and structure to the Oriskany sandstone, but on examination with the microscope the sand shows rounder grains, freer from lime and other impurities. As already stated, these beds have been classified by Stauffer as belonging to the Onondaga series, and he has given them the name Springvale sandstone.

The beds, in places, are 8 feet thick, and are exposed in a ridge running north from Winger's farm, and extending in a northwesterly direction towards the village of Springvale. A general sample, No. 1828, was taken from the face of the ridge in a field just north of Winger's barns. The washing test showed that the sand loses only a small amount in fines.

To the east of Port Colborne, Ont., on lot 13, Lake Erie front, Bertie township, there is a limestone quarry owned by the Standard Crushed Stone Company. Resting on top of the limestone in this quarry is a $2\frac{1}{2}$-foot bed of siliceous material which is practically a flint. A sample, No. 1829, was taken of this material for testing. The material is too high in fluxing impurities to be suitable for use in the pottery industry, but is of interest, because this bed occurs at other localities in this area, and it is possible that other outcrops may be found where the material is purer.

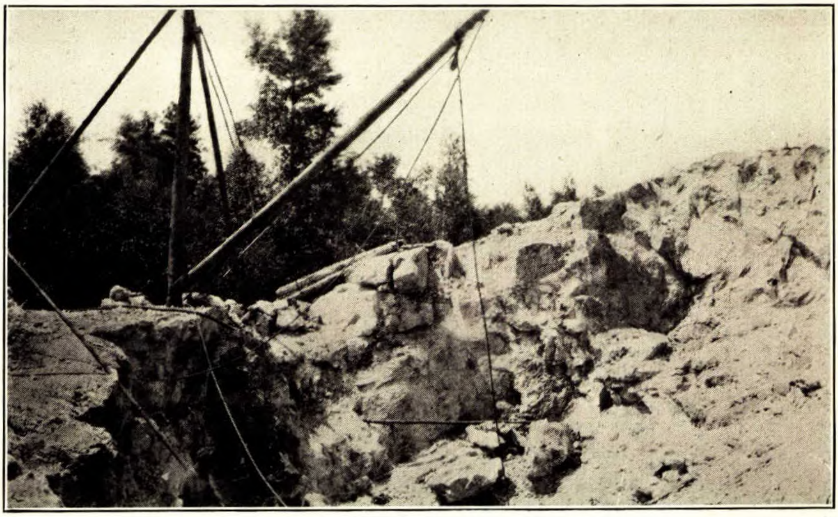
MILTON AREA

There is a band of whitish grey sandstone in the Medina formation in the vicinity of Milton, Ont., running north to Forks of Credit, which has an average thickness of about 12 feet. This material is well exposed in the quarry of D. Robertson and Company, on lot 3, con. VII, Nassagaweya township. The sandstone is very fine-grained, rests on shales, and is capped by a considerable thickness of limestone. The material, in places, is hard and compact, and very irregular in composition. In crushing, much of the rock breaks down to a fine powder, so that over 25 per cent would be lost in washing. An average sample, No. 1833, was taken in the Robertson quarry, as representative of the material in the district.

QUARTZ AND QUARTZITE DEPOSITS OF CENTRAL ONTARIO

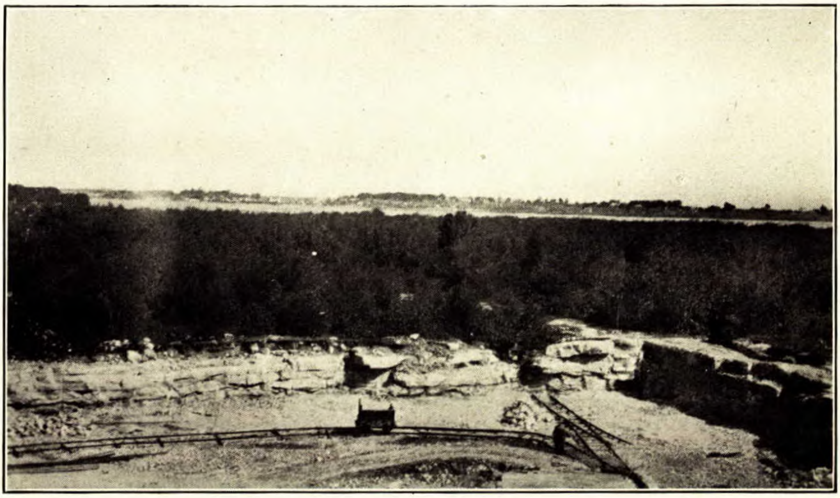
The area in lower Ontario, in which the ancient crystalline rocks are found, lies to the north and east of a line from Kingston to the south end of Georgian bay, and west of a line running from a point on the St. Lawrence river, west of Brockville, in an irregular way to the Ottawa river near Arnprior. Throughout these crystalline rocks many deposits of quartz are found associated with feldspar.

PLATE VI



Quartz-feldspar quarry on lot 12, con. V, township of South Sherbrooke, Lanark county, Ont.

PLATE VII



Potsdam sandstone quarry at Cascades Point, Vaudreuil county, Que.

Heretofore, deposits of this nature have been worked primarily for feldspar, and the quartz encountered in quarrying has either been left standing, or disposed of as waste rock. Of late years, however, some of the feldspar operators have been able to sell a portion of their quartz rock to the smelters, and to manufacturers of ferro-silicon.

The quartz in these deposits occurs as an intimate intergrowth of quartz and feldspar, such as is found in graphic granite, or as masses of quartz separating large crystals of spar. The commoner type of deposit in this district consists of massive microcline feldspar, in which occur lenses or bosses of more or less pure quartz. It is deposits of this nature that are of interest to the consumers of quartz, since it is from them only that any considerable tonnage of clean quartz may be expected. Occasionally, these quartz masses are highly ferruginous, sometimes carrying appreciable amounts of iron pyrites, which prevents their use in most of the silica industries. Quartz, of great purity, however, is frequently encountered. The quartz is similar in practically all these deposits, being very compact, glassy, and semi-translucent to opaque. A number of typical localities were examined, and samples obtained from deposits in which considerable quantities of clean quartz were being encountered.

Sample No. 1818 was obtained from the Morrow property, owned and operated by Messrs. Orser and Kraft, of Perth, Ont. The deposit is situated on lots 12 and 13, con. V, S. Sherbrooke township, Lanark county, and produces a small amount of clean quartz of a high degree of purity. There is a haul of one and three-fourths of a mile to the siding at Feldspar, a station on the Canadian Pacific railway. On the west side of the road opposite this quarry numerous quartz outcrops are to be seen, but so far no quarrying has been done to prove their character or extent.

Sample No. 1819, from the property of Rinaldo McConnell, Perth, Ont., situated on lot 6, con. VI, S. Sherbrooke township, Lanark county, was of great purity. Large masses of quartz, associated with feldspar, are to be seen on this property, which is situated on the face of a hill sloping to the west, and there would be a haul of approximately two miles to Feldspar station.

Sample No. 1820, taken from a quartz outcrop approximately 200 feet long by 40 feet wide, also showed a high degree of purity. This property is situated on the S. ½ of lot 9, con. IV, S. Sherbrooke township, Lanark county, and is distant from one-half to three-fourths of a mile from Feldspar station.

Sample No. 1821 was obtained from the stock pile of the feldspar property known as the Card mine, situated on the E. ½ of lot 16, con. XI, Portland township, Frontenac county. There was from 600 to 1,000 tons of clean quartz, piled separately from the feldspar on this property, when visited in 1918. In the bottom of the pit at one end (the other end was filled with water), a mass of quartz 20 feet wide is exposed. This quarry lies 2½ miles west of Verona, on the Kingston and Pembroke division of the Canadian Pacific railway.

Sample No. 1822 is from the feldspar property on the W. ½ of lot 16 con. X, Portland township, Frontenac county. The property, in 1918, was being operated for feldspar, but considerable quartz was being encountered. The pit was from 40 to 50 feet deep. The distance from Verona is 2½ miles.

Sample No. 1824 from the E. ½ of lot 5, con. X, Madoc township, Hastings county, contained over 99 per cent of silica. A small amount of stripping has been done on this property, which shows the quartz to be 30 feet wide at one place, and numerous test pits have exposed quartz for a distance of 150 feet. Neither the lateral extent of this quartz mass nor its relationship to the rocks of the district, could be determined from the amount of stripping done, so that the exact character of the deposit is not known. The material is vitreous and semi-translucent, and has all the characteristics of pegmatitic quartz, found associated with feldspar, although no feldspar was to be seen in any of the test pits. The deposit occurs in a belt of rocks classed by Miller and Knight as belonging to the Hastings series.

Quartzite deposits are numerous in this area. They belong to the Grenville series. These rocks are sometimes vitreous in appearance, so that they are difficult to distinguish from the true quartz masses, found associated with the feldspar and as vein quartz. In some cases it is only by the mode of their occurrence and their association with the other rocks of the series that they can be properly identified in the field. This point is of considerable importance to the silica operator, since deposits of quartzite are generally of greater extent than the deposits of quartz found in the district. A number of typical localities were examined, and samples taken to determine the nature of this material.

Sample No. 1726 was obtained from the S. ½ of lot 22, con. II, Elizabethtown township, Leeds county. This quartzite stands out as a series of ridges on the north side of the tracks of the Grand Trunk railway, three miles west of Brockville. It carries a considerable amount of undecomposed grains of feldspathic material closely disseminated through it. The iron content is also higher than usual.

An important quartzite ridge running in a north-westerly direction is to be found on lots 14-18, con. I, Pittsburgh township, Frontenac county. This ridge, which is one of the topographic features of the district, rises in places to a height of 125 feet above the level of the St. Lawrence river and its lateral extent varies to upwards of a hundred yards towards the centre. The rock is vitreous, in places, and has frequently a pinkish cast. Feldspathic minerals are to be seen disseminated through the quartzites in part of the ridge, but these inclusions seem to be confined to irregular zones throughout the mass. Large areas of quartzite are found in which these impurities are absent, or present only in small amounts. Mr. G. M. Thomson, the owner of this deposit, furnished the following analysis of a general sample from this ridge:—

	per cent
SiO_2	97·56
Fe_2O_3	0·65
Al_2O_3	0·97
MgO	0·33
CaO	none
Loss on ignition	0·35
Total	99·86[1]

[1]This sample was analysed by A. G. Larsson, laboratory St. Marys Cement, Ltd., St. Marys, Ont., April 21, 1919.

According to Mr. Thomson, tests of this material for the manufacture of silica brick have been made by the Algoma Steel Corporation, Sault Ste. Marie, Ont., and have proved satisfactory.

On lots 22 and 23, cons. V and VI, Lavant township, Lanark county, there are two prominent quartzite ridges, which run in a northeasterly direction. The rock in these ridges looks very white and seems to be free from the feldspathic inclusions noted in other deposits of a similar nature. A sample, No. 1810, taken from the easterly ridge, showed the presence of considerable lime; in fact, when the rock in the field was tested with hydrochloric acid, effervescence was noticed. The material from the western ridge, sample No. 1811, did not exhibit any effervescence when treated with acid in the field. There is a haul of a mile and a half from this deposit, over a winter road, to a point on the Kingston and Pembroke branch of the Canadian Pacific railway, two miles north of Clyde Forks station.

Sample No. 1825 was taken from a small vein 10 feet wide in places, interbanded with a rusty schist and badly foliated. The best exposure of this occurrence is on lot 3, con. IV, Elzevir township, Hastings county, on the east bank of the Moira river, just north of the village of Actinolite. Hand specimens have all the appearance of vein quartz, but from their association with the rusty schists they have been tentatively classed as quartzites. There would be a haul of one-fourth of a mile to Actinolite, a station on the Canadian Northern railway.

Sample No. 1859 was submitted by Mr. T. D. Ledyard, Toronto, Ont., as an average sample of material from a quartz or quartzite deposit, situated on lot 22, con. II, Dungannon township, Hastings county. The sample was taken from a deposit situated about 350 feet west of the track of the Central Ontario branch of the Canadian National railway, a short distance south of Turriff, a station 75 miles north of Trenton. According to Mr. Ledyard, he has stripped this deposit for over 120 feet, and it has a width of 4 feet on the surface.

THE POTSDAM SANDSTONE AREAS OF ONTARIO

Along the eastern flank of the Precambrian rocks of southeastern Ontario, numerous beds of sandstone of Potsdam age are to be found. These beds show great diversity in character, and irregularity in bedding. They are seen as scattered and isolated outcrops (see Map No. 558) from the vicinity of Brockville to Westport, and throughout the district north of Kingston; also along the Rideau lakes to Smiths Falls and Perth, and northward to Carleton Place and Almonte. An isolated occurrence of some extent is also found in Nepean township (see Map No. 559). These deposits of sandstone, for purposes of description, are grouped under the following headings:—

Kingston area	Perth-Smiths Falls area
Westport-Brockville area	Nepean area

Kingston Area

In the district lying between Kingston and Gananoque, on the St. Lawrence river, and northwestward to Sydenham, there are numerous outcrops of Potsdam sandstone, that, in a number of cases, were found to be fairly white, and uniformly free from iron stains. In several of the outcrops sampled the white beds were of considerable thickness, and could be readily quarried without an excessive amount of waste material.

Sample No. 1728 was taken from lot 19, con. X, Loughborough township, Frontenac county. The rock is a dark reddish brown, and a specimen was collected to see what relationship the colour bore to the chemical composition. Washing improves the sample slightly, but the dark colour still remains even after fine grinding. The pulverized material, when fired to 1,000° C., turns lighter in colour, but still has a strong buff tint, although the material remains powdery. The outcrop extends over several acres, and is situated one mile from Perth Road, a station on the Canadian National railway line between Ottawa and Trenton.

Outcrops of sandstone are to be seen on the property owned by the General Electric Company, adjacent to their well-known mica mine, on lots 9 and 10, con. VII, Loughborough township, Frontenac county. These outcrops extend over several acres, and rise from 10 to 12 feet above the surrounding fields. The rock varies from dark red to light pink, and appears fairly uniform in texture. A sample, No. 1731, was taken of the lighter coloured material. To the south of the mica mine, and on the same property, a small deposit of uncemented silica sand occurs under about 12 inches of black loam. This sand (Sample No. 1732) is pure white to light grey; the grains are well rounded and comparatively free from material finer than 100 mesh. It extends over two acres, and averages 12 inches in depth. These deposits are distant $1\frac{1}{2}$ miles from the Canadian National railway. (Ottawa to Trenton line.)

On the N. $\frac{1}{2}$ of lot 16, con. VII, Pittsburgh township, Frontenac county, there is an extensive deposit of massive sandstone. The beds in this deposit are of considerable thickness, and rise to a height of 30 feet above the level of Dog lake. In places the rock is of good white quality, with only occasional iron stains. The grain appears uniform, and the rock is fairly soft. Sample No. 1735 was taken from this white rock, which outcrops over about 30 acres. About 500 yards to the north and east of the white outcrops the rock is pink and salmon-coloured, and beds of considerable thickness can be obtained. Sample No. 1747 was taken as representative of the salmon-pink variety. The deposits are situated on the shores of Dog lake, connected with the Rideau canal system, and transportation by barges is possible if desired. The nearest point on a railway is about 7 miles.

Sample No. 2002 was taken from a sandstone outcrop on the S. $\frac{1}{2}$ of lot 19, con. I, Pittsburgh township, Frontenac county, on the property of John Gates, about five miles west of Gananoque. The ground gradually rises from the river, and if a quarry should be opened on this property, a working face of 20 feet could soon be obtained, and the excavation would be free from water. The rock is white, easily crushed, and comparatively free from iron stains. There would be very little stripping required to uncover about 20 acres of rock. A portion of this sample, after washing, was ground to pass 150 mesh, and burned to 1,000° C., to test its suitability for the pottery industry. It burned to a dead white, free from specks, and as fully equal to a standard sample of potter's flint burned under similar onditions. The unburned, washed, and pulverized material, as well as the burned sample, was analysed in the Public Works Department laboratory for testing materials. Mr. E. Viens, director of this laboratory, furnished the writer with a copy of the analyses of these two samples:—

—	Washed only	Washed and burned
Silica (SiO_2)	99·31%	99·42%
Ferric oxide (Fe_2O_3)	0·09%	0·09%
Alumina (Al_2O_3)	0·26%	0·27%
Calcium oxide (CaO)	0·17%	0·18%
Magnesia (MgO)	0·09%	0·10%
Loss on ignition	0·12%	0·00%
Total	100·04[1]	100·06[1]

Sample No. 2003 was taken from the property adjoining the Gates property, on lot 20, con. I, Pittsburgh township, Frontenac county. There is a face of an old quarry, 12 to 14 feet high, on the shore of the St. Lawrence river, from which, in past years, considerable material has been taken. The rock is white to yellowish in colour, with only a slight cementing bond in the rock exposed. Material from this quarry was employed about 20 years ago for glass making in Montreal, but the quarry was abandoned when glass sand from the United States and Belgium could be imported cheaper than this rock could be quarried and crushed. The imported sand was also a washed product, while the material produced in this quarry was only crushed.

Both these deposits are situated on the banks of the St. Lawrence river, convenient to deep water, so that water transportation would be possible. The nearest point on the Grand Trunk railway is 2½ miles.

Westport-Brockville Area.

In the district around Westport and Newboro, in the townships of North and South Crosby, and extending in isolated outcrops in a southeasterly direction to Brockville, there are extensive exposures of fine-grained sandstone. In many places the sandstone is badly stained with iron oxide, but a number of outcrops were noted in which certain beds appeared comparatively free from impurities. The material crushes readily to the natural grain of the sand, which is between 16 and 100 mesh.

Sample No. 1719 was taken from the centre of lot 8, con. VII, North Crosby township, Leeds county. When this property was visited in 1917, large blocks of sandstone were being excavated for repairing the locks on the Rideau canal. The beds exposed are creamy white, and 5 feet of face was exposed. The material in this 5 feet was fairly soft, and crushed readily, but the rock rests on 12 inches of cherty sandstone, which is very hard and brittle. There is a haul of 2 to 3 miles to the station or wharf at Westport.

Sample No. 1720 was collected from the property owned by R. J. Mustard, on lot 15, con. I, South Crosby township, Leeds county. It is stated that this is the property from which the material for the first locks of the Rideau canal was quarried. The beds are of considerable thickness

[1]A. K. Light, chemist, Laboratory for Testing Materials, Department of Public Works, Ottawa.

and large blocks 2 feet thick can be obtained. The rock is very friable when first quarried. No idea as to the depth of the deposit was obtainable. The rock is highly iron-stained, in places, and much hand-sorting would have to be done at the quarry to obtain the white material. The shortest haul to the railway is one mile to Phillipsville, a station on the Brockville and Westport branch of the Canadian National railway.

Sample No. 1727 was taken from sandstone beds exposed on the shore of the St. Lawrence river, on the S. ½ of lot 36, con. I, Elizabethtown township, Leeds county. These beds are exposed in a thickness of 25 feet from the water's edge up, but are covered by a capping of thin-bedded limestone, at least 25 to 30 feet thick. This overburden of limestone would probably prevent the sandstone being recovered economically, but there are some good white beds mixed with the yellow beds in this exposure. The beds vary in thickness from a few inches up to 18 inches, and are fairly soft, and very fine in texture.

Sample No. 2006 was obtained from lot 3, con. X, Lansdowne township, Leeds county. This outcrop of sandstone rises abruptly on the east side of the road just north of Lyndhurst village. The rock is exposed over 10 or 12 acres, and is white, and fairly uniform throughout. Only occasional iron stains were seen. The nearest shipping point is 1½ mile distant, at Lyndhurst station on the Brockville-Westport branch of the Canadian National railway.

The Westport-Brockville sandstone areas are of considerable extent, but only in a few places were beds seen of any degree of whiteness, free from discoloured patches. The beds are of fair thickness, and blocks of large dimensions could be obtained, but much of the rock is spotted with iron stains.

Perth-Smiths Falls Area

In the neighbourhood of Perth, and between Perth and Smiths Falls, another sandstone area is to be seen. The iron-stained beds noted in the Westport-Brockville area are also to be found in this area. White beds are present, although they are not so numerous nor so thick.

Sample No. 1724 was taken on the S. ½ of lot 11, con. VIII, North Burgess township, Lanark county. No work has been done on this property, but the rock outcrops over several acres on both sides of the road. In places the rock in this outcrop is badly shattered and broken, and there are occasional white patches or beds, but the rock exposed on the surface is mostly iron stained and pitted. It is soft and readily crushed. The beds exposed average from 6 inches to 8 inches thick. The nearest shipping point by rail is 8 miles distant, at Glentay station on the Canadian Pacific railway, or by water 4 miles to the Rideau lakes on the Rideau canal system.

Sample No. 1725 represents an average sample of the beds, 4 feet thick, on lot 26, con. X, North Elmsley township, Lanark county. This deposit has been worked for building stone. The beds are fairly white for the top 4 feet, below which they are a rich golden yellow. This deposit extends over several lots, and sample No. 2011 was taken on the northern half of the deposit. The beds are flat-lying, and range from 6 to 18 inches thick. There would be a haul of one mile to the station at Perth.

Sample No. 1809 was obtained from the north bank of the Tay canal, $1\frac{1}{2}$ miles southeast of Perth. This deposit is flat-lying, and there is only a small amount of material above the normal level of the water in the canal. Iron stained rock is abundant, and there is considerable material showing the purple stains characteristic of certain sandstone deposits in the neighbourhood of Perth.

On lot 24, con. IX, Montague township, there is a flat-lying area containing considerable quantities of white sandstone. There are patches with iron stains, but these could possibly be hand cobbed. Sample No. 2001 was taken from this deposit. The property lies in a low ridge to the east of the road and about one-fourth of a mile distant from where the Canadian Pacific railway, Smiths Falls-Carleton Place line, crosses the road. The nearest station, Welsh's, is about two miles to the south.

Nepean Area

About 9 or 10 miles to the west of Ottawa, a number of sandstone quarries have been operated for a considerable time, producing building stone and paving blocks. The waste material from these quarries averages 95 per cent or more silica; and in certain beds a white rock can be obtained which will analyse considerably higher. The rock crushes readily into sizes between 20 and 100 mesh.

The sandstones of this area occur chiefly in the southwest corner of Nepean township and the south part of March. The principal quarries are in the township of Nepean, on the following lots:—

				Owner.
Lot 6,	con.	I,	Ottawa Front,	C. Keefer, Rockcliffe Park, Ont.
" 5,	"	I,	"	Howard Rock, Bells Corners, Ont.
" 4,	"	I,	"	Mrs. John Beattie, Bells Corners, Ont.
" 6,	"	II,	"	T. W. Tillson, Bells Corners, Ont.
" 4,	"	II,	"	J. Davis, Bells Corners, Ont.
" 3,	"	II,	"	R. Morrison, Bells Corners, Ont.

The beds in these quarries are exposed in a low escarpment rising some 40 feet above the surrounding farm land. There is a dip to the north at a low angle.

The Nepean Sandstone Quarries, Ltd., for several years operated Rock's quarry and produced stone for use in the new parliament building at Ottawa. Several of the other quarries furnished stone for the same purpose.

On the Rock property there are fully 20 acres of sandstone exposed, with practically no overburden, except a large tonnage of broken rock which has been discarded in the preparation of paving blocks and building stone. Considerable quarrying has been done on this property, and a face, varying from 3 feet to 15 feet deep, is exposed. As this quarry is on the top of the hill close to the north edge of the escarpment, a face of 35 feet could readily be obtained, with only a slight amount of work. Only the beds in the upper part of the escarpment have been exposed so far. The sequence of beds in different parts of the quarry varies so greatly that no general description can be given, which would hold good throughout the whole quarry. A typical opening, however, showed the following series in descending order:—

3 feet	white, thin-bedded stone, fairly hard.	
1 foot	brownish and yellowish banded stone.	
18 inches	" " "	
9 "	" " "	
16 "	white, friable stone.	
4 "	brownish and yellowish banded stone.	

In another part of the quarry, at a lower level than the above opening, the beds have been worked to a depth of 6 feet in a white stone which occurs in layers about 18 inches thick. These bands do not seem to be continuous throughout the quarry, but may gradually grade into the yellow variety.

Three types of stone can be recognized, a white, friable variety, a hard, white, consolidated kind, and a brown and yellow variety. The beds are very irregular in their distribution, and considerable hand cobbing would have to be resorted to in order to obtain any commercial tonnage of white material.

Sample No. 1753 was obtained from the white, soft beds on the Rock property.

About 3½ miles to the northwest of South March station there are extensive outcrops of white sandstone, which is easily crushed, and fairly free from iron stains. There is very little overburden over an area of ten to twelve acres, and a quarry face could readily be developed. No quarrying has been done in this locality. Sample No. 2013 was collected from the west side of the road on lot 19, con. III, March township. (Map No. 559.)

In the vicinity of Fitzroy Harbour, and between that place and Galetta, there are numerous outcrops of quartzite and occasional areas of sandstone, which might furnish a small tonnage of silica for local consumption.

One of these localities, where quartzite occurs, is situated on lot 24, con. VIII, Fitzroy township, about three-fourths of a mile southeast of the west bridge of the Canadian National railway, crossing the Mississippi river.

Sample No. 2010 was taken from this deposit, as representative of the area.

SANDS OF NORTHERN ONTARIO

Silica sands occur in northern Ontario associated with deposits of fireclay along both the Mattagami and Missinaibi rivers, north of the Transcontinental railway. These sands, although at present too far from the railway to be of any commercial use, are of interest for possible future development.

The sands on Mattagami river were examined by Keele[1] in the summer of 1919, and were described by him as follows:—

> The white sands which underlie the clay beds are composed almost entirely of sub-angular and rounded quartz grains, with which is intermingled a small quantity of white clay.
>
> A washing test made of an average sample of 10 feet in depth of this sand showed that it contained 15 per cent of white clay.
>
> The sand when freed from the clay was found to be of the proper texture for glass making, and the chemical analysis of 99·8 per cent silica shows it to be of exceptional purity.

[1] Ontario Bureau of Mines Report, Vol. XXIX, Pt. II, pp. 45 and 54-55.

The white clay washed from the sand is very plastic and highly refractory, while it burns to a whiter colour than any clay in the overlying beds.

The sand contains enough plastic fireclay in its natural state to act as a bond when moistened and pressed into brick shapes. A brick of this description is known as gannister brick, its use being principally confined to lining steel furnaces. The test brick were subjected to frequent burnings up to a temperature of 3,000 degrees F., but they remained soft and friable, as the materials appeared to be too refractory to produce a fused bond. The addition of a little iron and lime oxide would be required in order to produce the necessary bond in firing.

One of the most striking objects on the Mattagami river is the deposit of oxidized sands which occupy about a quarter of a mile of the east bank between the mouth of Pike creek and the iron ore deposit at the head of Grand rapids.

These sands extend below water level and vary in height from 10 to 25 feet. They are overlain only by a foot or two of stratified silts from which they are separated by a thin layer of rusty pebbles. The sands are composed entirely of coarse quartz grains often with a cross bedded arrangement, interbanded occasionally with streaks of pea-sized gravel composed mostly of quartz, although pebbles of the harder parts of Pre-Cambrian rocks are also present. Occasionally pockets and streaks of micaceous clay are included, as well as rusty and disintegrated cobble stones.

The materials become coarser at the northern end of the deposit, finally passing into yellow gravels of cobble stone size ending abruptly against boulder clay.

The sands are compact enough to retain a fairly vertical face, but there are no cemented beds.

The colour of the beds varies from yellow to orange and reddish brown, and appears to be mainly due to the coating on the quartz grains and not to any fine material intermixed with the sands.

A similar deposit occurs on the west bank of the river opposite the above occurrence, and was evidently a portion of the latter before the river cut through it.

A smaller deposit of the same type of sands occurs a short distance below the foot of Long portage on the Mattagami river in the bank overlying the fireclay beds. The deposit is limited in width, being enclosed in boulder clay, but it is about forty feet thick. The sands are arranged in beds sloping down stream and contain a band of grey and yellow clay about a foot thick. Above the clay bed the materials are yellow gravels and cobble stones. The orange sand and gravels are overlaid by grey fluvioglacial gravels with included lenses of boulder clay. A solid mass of hard grey gritty till carrying unusually large boulders caps the bank.

The largest deposit of orange sands in the region occurs on the east bank of the Abitibi river between Sextant portage and the head of Long rapid.

The sands here are about thirty feet thick and extend for a mile along the banks, under a capping of boulder clay. The sands are composed almost exclusively of coarse angular to round quartz grains sometimes running as coarse as fine gravel. Angular fragments of disintegrated Pre-Cambrian schist are mixed with the sand toward its base. The bottom of the sand deposit was not seen as it reaches down below water level.

The question arises concerning the place in the geological sequence to which these sands should be assigned. It is difficult to place them as pre-Glacial in view of the accepted theories regarding the scouring action of a continental glacier, such as passed over this region. Friable unconsolidated deposits like these sands would seem to have small chance of surviving glaciation. On the other hand, we are confronted with the strongly oxidized and residual character of the materials in the deposits, and their freedom from glacial dirt of any kind. If it is urged that the lack of cementing material would indicate a recent origin, it may be pointed out that there are sands of Silurian age on the Abitibi river with no more cementing material present.

Turning to the economic aspect of these sands, it would appear that their comparative freedom from materials other than quartz would suggest their use as a source of silica. It is probable that they contain too high a percentage of iron to be used as a glass sand, although washing would no doubt reduce this. As the texture of the sands is about right for glass making purposes, a few washing trials and chemical analyses would settle the question. There are no sands so pure as these in the Glacial series.

During the summer of 1920 Keele[1] examined the sands on Missinaibi river, took several samples, and reported on them:—

A large portion of the deposit on the Missinaibi river consists of coarse-grained quartz sand. The sand grains are coated with white and in some places pink and yellowish clay. A sample of sand collected from this deposit was washed and yielded only 4 per cent of the fine white clay, but some portions of the sand contain a larger quantity of clay. The texture of the washed sand is shown by the following screen analysis:—

			per cent
Retained on	10	mesh screen	8·27
	20	"	19·47
	35	"	38·04
	100	"	32·44
	200	"	1·33
Through	200	"	0·10

The chemical composition of the washed sand is as follows:—

	per cent
Silica (SiO_2)	97·72
Alumina (Al_2O_3)	0·42
Iron (Fe_2O_3)	0·32
Lime (CaO)	0·28
Magnesia (MgO)	0·21
Loss on ignition	0·12

The grain size or texture of the washed sand is suitable for glass making purposes, but the iron content is a trifle too high for white glass, but would answer for coarse glass products such as bottles where a water white colour was not essential.

A small portion of the clay and sand along the immediate bank of the river could be obtained without removing much overburden, but farther away from the bank the capping of glacial dirt increases in thickness, and consequently becomes more difficult to remove.

Another deposit of this description occurs in the bank of the Wabiskagami river about 2 miles west of the Missinaibi deposit. The white sands and clays are exposed for a height of 10 feet above low water level and are overlain by a great thickness of glacial debris. These two occurrences may be a continuous deposit underneath the glacial drift, but it was difficult to prove it by boring with an auger owing to the presence of numerous stones in the overburden.

QUEBEC

Silica is found in the province of Quebec in the form of sandstone, vein quartz, and quartzite. The principal deposits are to be found in the following areas.

POTSDAM SANDSTONE AREA IN SOUTHWESTERN QUEBEC

The Potsdam sandstone which is so well developed directly north of the international boundary, between Huntingdon and Hemmingford, as well as along the St. Lawrence and Ottawa rivers, is, in many places, fairly free from iron oxide. The grains of the rock are small, and, in most cases, the material crushes readily. The best exposures, having regard to transportation facilities, are to be found in the vicinity of Beauharnois, Melocheville, Cascades Point, and in the area lying between the St. Lawrence river and the Lake of Two Mountains. North of the Ottawa river, a number of outcrops are conveniently situated relative to the several railways, notably those at St. Canute and St. Scholastique. Material from these deposits has been used in Montreal and elsewhere for the manufacture of bottle glass, for steel foundry work, and for furnace linings.

[1]Summary Report, Mines Branch, 1920.

Many of the outcrops in the southern part of this area are too distant from present lines of transportation to make them of economic value at present, but a few samples were taken from representative localities, in order to obtain a general idea of the whole area.

Sample No. 1704 was taken from an outcrop on the farm of J. Louden, 200 yards west of Covey Hill corners, and half a mile south of the east and west road. The sandstone on this property lies horizontally in thin beds, the thickest exposed being not more than 12 inches. The rock is very brittle and fairly hard to crush. It is also close-grained and fine in texture, but, in places, numerous large pebbles are embedded among the finer grains. The outcrop from which this sample was taken is typical of the material underlying the whole of Covey Hill.

On the main road between Hemmingford and Vicars, about one mile east of the latter place, an outcrop of sandstone extends for a considerable distance on each side of the road, and outcrops also on the Covey Hill-Frontier road, about two miles west of Frontier. Sample No. 1705 was taken from the outcrop where it crosses the road, one mile east of Vicars. The beds are very thin, but appear to be fairly uniform in composition, and the rock is fine-grained and close in texture.

Another outcrop, on the farm of Joseph Foyer (Maritana P.O., Que.) on the south side of the east and west road, one mile west of Maritana P.O., was sampled—No. 1706. This outcrop shows in thin beds over about an acre. The rock in the outcrop is very variable in both texture and composition. There are numerous iron stained patches, and the natural grains vary from the size of peas down to very fine, compact. On weathered surfaces the cementing material and some of the smaller grains have been washed out, leaving only the larger grains standing up in strong relief.

Sample No. 1707 was obtained at Franklin Centre, from the bottom of the east branch of Outard creek on the north side of the stone bridge. The sandstone is exposed in the creek bottom on both sides of the road as far as can be seen. This outcrop is one of the best exposures to be seen in the southern part of the area outside of the "Gulf" and "Lake" at Covey Hill. Fifteen feet of beds are exposed and can readily be seen. They are for the most part very thin, the thickest being probably only 6 inches. The texture is fine towards the bottom, and the rock is fairly hard, but is coarser in grain and softer towards the top. The rock appears fairly uniform in composition throughout the whole fifteen feet exposed. This exposure is 9 miles from the railway at Ormstown.

On the north and south road, 4½ miles south of Ormstown, there are extensive blueberry flats, in which the sandstone is either exposed as outcrops or lies under a very thin layer of soil. Sample No. 1708 was taken at this place. The rock is comparatively soft and easy to crush, is uniform in texture, and does not show any large grains. The extent of the outcrop along the road is about 1½ mile. The east and west extension is about five miles, and similar rock shows to the east on the next north and south road running through Brysonville, Tullogoram, Cairnmore, etc.

Sample No. 1710 was obtained from a low escarpment of sandstone exposed on both sides of the east and west road 2½ miles west of the road from Hemmingford to Barrington. The rock outcrops over an area of 20 to 30 acres, and is very hard and compact.

Sample No. 1712 was a fine white sand, occurring on the farm of G. H. Brooks, No. 6 in range III of Franklin township. This sand was covered by 6 inches of black loam, in a depression. This is probably only a pocket which has caught some of the eroded sand from the surrounding sandstone.

Sample No. 1713 was taken from a deposit similar to No. 1712, on the farm of Benjamin Roberts, 2½ miles west of Russelltown, on the road to Stockwell. This sand is very fine in texture, but the deposit is of only very limited extent, covering about 2 acres. The thickness of the sand varies from 6 inches to 1 foot, and the whole area is covered with 6 inches of black muck.

An interesting occurrence of calcareous sandstone is to be found to the east of the Potsdam sandstone area, east of St. Armand station, on the road to Mitchells Corners. In this rock the grains of sandstone are of about 20 mesh and well rounded, and the bonding material is calcareous. The sand and bonding material are present in about equal

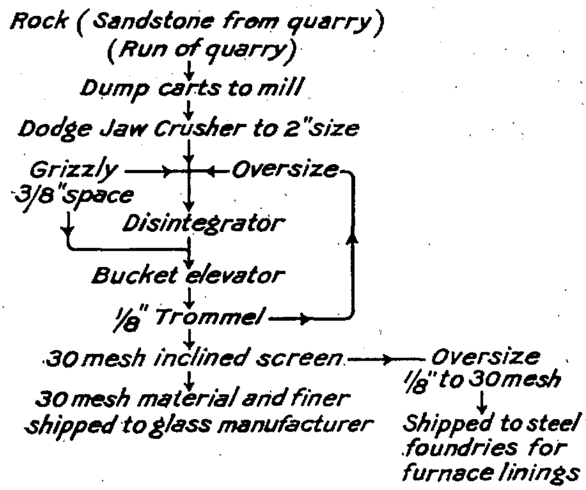


Fig. 4. Flow sheet of the plant of the Consolidated Sand and Supply Co., Melocheville, Que.

quantities. By calcining this rock and slaking in water a considerable percentage of the lime can be removed. Sample No. 1711 was taken from this outcrop.

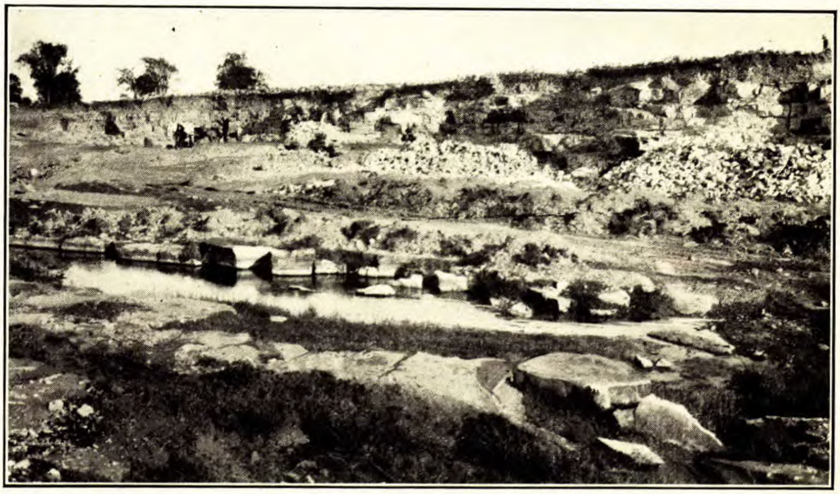
The most important outcrops of sandstone in this area are to be found along the river front in Beauharnois county, between Melocheville and Beauharnois, and a number of quarries have been opened there. Outcrops of similar material are also found at Cascades point, and at a number of places on Isle Perrot, Vaudreuil county.

Along the south shore of the St. Lawrence, between the village of Melocheville and Beauharnois, the rock is exposed almost continuously. Several quarries have been opened on this outcrop, in the vicinity of Melocheville, the principal one being at the eastern limits of the village. (See Plate No. IX), where a quarry is in operation at the present time, and the material is crushed in a mill on the bank of the old Beauharnois canal. This quarry has a 10-foot face, of fairly white, clean sandstone, in beds approximately 18 inches thick. The quarry and mill are owned and operated by the Consolidated Sand and Supply Co., Ltd., of Montreal. The

PLATE VIII

Potsdam sandstone quarry in bed of St. Louis river, Beauharnois, Que.

PLATE IX



General view of Potsdam sandstone quarries, Melocheville, Que.

plant is producing silica sand of two grades, and sells them in Montreal to glass manufacturers and steel foundries.

The sandstone, after quarrying, is teamed to the mill on the south bank at the east end of the Beauharnois canal. (Plate No. X.) At the mill it is crushed, ground, screened, and shipped in barges to the Montreal market. The flow sheet of the mill is shown in Figure 4.

The average throughput of this mill is 100 tons of crude rock per day, and the plant operates during the summer months only. The power is supplied by a steam boiler, operating a 70 h.p. engine.

No. 1714 is an average sample taken from the quarry. No. 2031 was taken from one of the barges loaded at the plant ready for shipment.

In the bed of St. Louis river, on the western outskirts of the town of Beauharnois, a quarry is being operated by Wm. Robert. (See Plate No. VIII). The beds in this quarry have a thickness of over 4 feet, and the rock is easily crushed, creamy white in colour, and of very even texture. Samples Nos. 1750 and 2012 were obtained from this quarry.

On the north side of the St. Lawrence river, at Cascades Point, there is an abandoned quarry, from which considerable material has been excavated, for building purposes, for the manufacture of glass and for steel foundry sand. The rock is harder than similar material on the south shore of the river, and the iron oxide content is higher. The beds average about one foot thick. (Plate No. VII.)

A few years ago, a 75-ton plant was operated at this quarry by the Cascades Silica Products Co., Ltd., of Montreal; but, owing to the hardness of the rock, it was deemed advisable to dispose of the quarry for use as building stone. The whole plant was therefore dismantled in 1919, and the machinery removed to the company's newly acquired property at St. Canute.

Sample No. 1816 was obtained from the mill at Cascades Point, when in operation. The sample was collected by taking 200 pounds of the rock after it has passed through the crusher, and quartering this down to 15 pounds. Sample No. 1817 is a representative sample of the washed sand produced at this mill.

There are a number of places on Isle Perrot where outcrops of sandstone are found, and in several places fairly white beds were noticed. The rock in these beds is fairly soft, and a general sample No. 2041 was taken from a series of piles of recently broken material. The rock is well exposed on both sides of the road on lot 167, cadastral, at the northeast point of the island at Pointe du Domaine. Water transportation is available.

The best exposures of Potsdam sandstone in the northern part of the Quebec area north of the Ottawa river, are to be found in the neighbourhood of St. Canute. The sandstone in this district occurs as a dome-like mass rising to a height of 40 feet above the surrounding country. The outcrop is situated on parts of lots 125, 126, 127, 129, and 130, parish of St. Canute. (See Fig. 5.)

A siding from the Canadian government railway has been built to serve this deposit, and the Cascades Silica Products Co., Ltd., Montreal, owns the central part of the deposit, and operates a mill on the property.

The rock is very white, fine-grained and easily crushed. No. 1815 is a general sample from this property. The company has a quarry face opened up for a length of nearly 300 feet, and a height of 30 feet. From the quarry the rock is hauled up an incline in small cars, and dumped into a

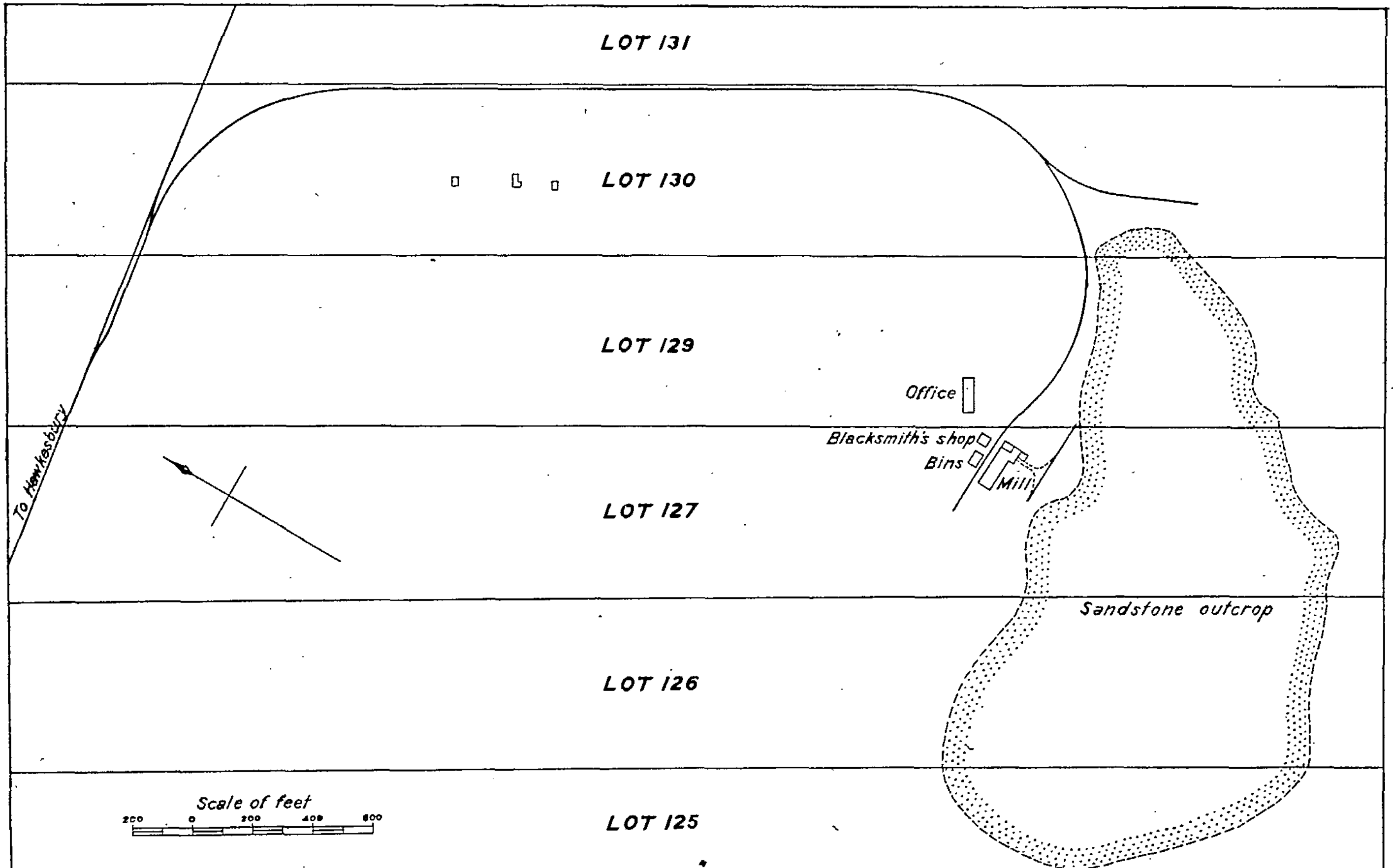


Fig. 5. Plan of sandstone deposit, St. Canute, Que., showing property and plant of Cascades Silica Products Company, Ltd.

receiving bin over the crusher. From the crusher the material passes to an 8-foot wet pan, provided with two revolving screens, 12 mesh. The material passing through the screens is fed into a battery of 8 log washers, the oversize from the screens being returned to the wet pan for further grinding.

The washers discharge the washed sand on a belt conveyer running the full length of the building. From the belt conveyer it is either deposited on the floor of the building in drainage piles or dumped into a steam dryer. From the drier or drainage piles it is conveyed to storage bins for shipment. The capacity of the mill is about 100 tons of sand per day of 10 hours.

BUCKINGHAM AREA

In this area are included outcrops of Potsdam sandstone occurring in the vicinity of East Templeton; quartz associated with feldspar from the Lievre River district; and quartzite associated with the kaolin from the property of the Canadian China Clay Co., at St. Remi d'Amherst, Que.

The sandstone occurs as a prominent ridge near the Canadian Pacific railway line from Ottawa to Montreal. It is iron stained in many places, but is readily crushed, and it is possible that it can be washed to a fairly clean and pure product, since thin sections of the rock show that the iron is present almost entirely in the cementing material between the quartz grains.

The best outcrops on this ridge are one mile west of East Templeton, on the properties owned by E. Scarf, Sam Bilsky, and McFadden.

On the Bilsky property, which is typical of the district, the escarpment rises to a height of 50 feet above the level of the Canadian Pacific railway track, from which a siding is run to serve the property. An extensive quarry face could quickly be obtained, and a small lake on the property would supply sufficient water for all milling purposes.

Two samples were obtained from this property. No. 1861 is a general surface sample taken over a considerable area, and No. 2201 is a general sample from the broken material piled at the foot of the escarpment at the southeast end of the small lake. This broken material had recently been quarried from the face of the cliff, and is typical of a considerable tonnage of material.

The quartz of this area is found associated with feldspar in numerous small outcrops on many of the farms in the Lievre district. It is quarried in the winter by the farmers, and sold to the Electric Reduction Company at Buckingham, Que., by whom it is utilized as a flux in the preparation of phosphorus. As a rule these quartz deposits are very pockety, and it is hard to obtain one from which a constant output can be assured. In order to obtain a representative sample of material from this class of deposits, No. 1812 was taken from the stock pile at the plant of the Electric Reduction Company. The rock is a massive pegmatitic quartz, generally fairly pure.

On the property of the Canadian China Clay Company, on lots 5 and 6, range VI S, Amherst township, Labelle county, the foot wall rock of the main kaolin deposit consists of a highly shattered white quartzite, carrying from 5 to 12 per cent kaolin in the fractures. This material is capable of being crushed and washed to a sand containing over 99 per cent silica.

The western slope of the ridge on which the deposits of quartzite occur, consists almost wholly of practically vertical beds of Grenville quartzites[1] and garnet gneiss. A portion of this quartzite is badly shattered, and the fractures filled with white and sometimes discoloured kaolin. The kaolin also occurs in lenses and large massive bodies; the main one so far opened reaches 65 feet or more in width. The shattered quartzite is well exposed in the west wall of the largest pit opened for kaolin. (Plate XI.) A white quartzite carrying disseminated kaolin is found over a considerable width.

Recently, a shaft has been sunk on this property, and a cross-cut put in to reach the kaolin. The cross-cut penetrated 167 feet of white kaolinized quartzite. (See sketch Fig. 6.)

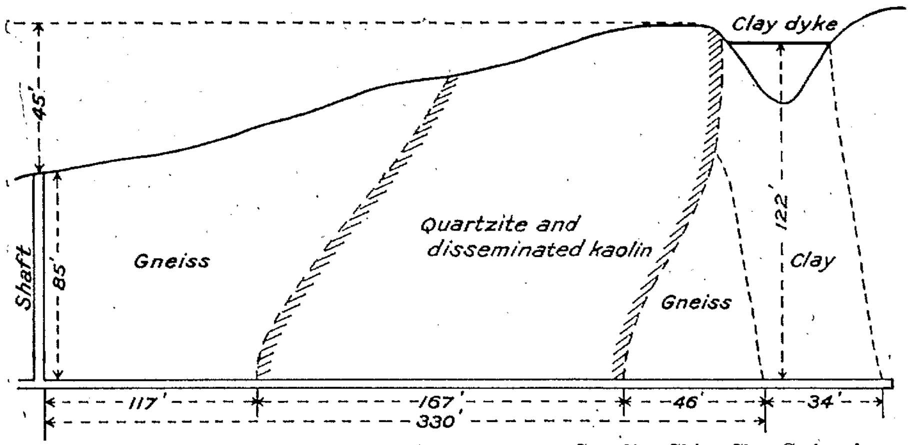


Fig. 6. Sketch showing section through shaft and cross-cut, Canadian China Clay Co.'s mine, lots 5 and 6, range VI S., Amherst township, Labelle county, Que.

Until further prospecting is done, however, and more definite information is available relating to the lateral extent of the quartzite, it is useless to make any estimate of tonnage.

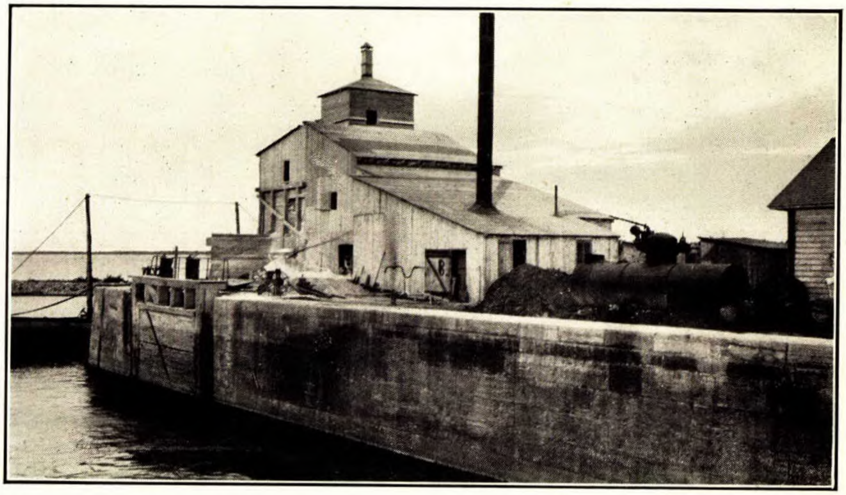
The quartzite is readily crushed to a sand yielding angular, sharp, and very brittle silica grains mixed with kaolin. The greater part of this kaolin can be removed by washing. An average sample, No. 1754, of the crude white quartzite was taken. It was crushed and washed, and yielded a silica sand containing 99·25 per cent silica. Disseminated through the quartzite there are occasional grains of feldspar and some black iron-bearing minerals, which, generally, are not removed in the washing process. Experimental washing was carried on at the company's plant in 1918, and sample No. 1814 was taken of the washed sand produced in the washing plant.

In order to determine the suitability of this quartzite for the manufacture of silica (gannister) brick, a test was made by Mr. Joseph Keele in the Mines Branch laboratory, who furnished the following report[2]:—

[1]For a detailed discussion of the mode of occurrence of these deposits, and a description of the geology of the district, the reader is referred to Memoir No. 113 of the Geol. Survey of Canada, "Geology and Mineral Deposits of a Part of Amherst township, Quebec," by M. E. Wilson.

[2]See Memoir No. 113, Geol. Surv. Can., p. 35, 1919.

PLATE X



Plant of the Consolidated Sand and Supply Co. for crushing sandstone, Melocheville, Que.

PLATE XI

Quartzite wallrock in open pit of Canadian China Clay Co.'s mine on lots 5 and 6, range VI S., Amherst township, Labelle county, Que.

as Middle or Lower (?) Cambrian. These quartzites, which are best developed in the counties of Kamouraska and L'Islet, are found in an area approximately 40 miles in length and 4 miles in width, bordering the shore.

The quartzites are fine, even-grained, and weather to almost a pure white. They appear, in places, to be partially altered sandstones, rather than true quartzites. In the southeastern part of the district, the quartzites contain nodules of dolomitic limestone, sometimes two feet in diameter. The higher grade silica rock was found in the northeastern part of the area. On this account the examination of these quartzites, to determine their utility for manufacturing purposes, was confined to the northeastern area, in the vicinity of St. Pascal and St. Andre.

From St. Pascal, as a centre, a large number of quartzite ridges were examined, and five different localities were sampled as fairly representative of all the deposits. As the question of transportation with relation to these deposits is of extreme importance, they will be dealt with in the order of their accessibility.

The Pilgrim Islands

In the St. Lawrence river, about $2\frac{1}{2}$ miles off the south shore, opposite the village of St. Andre, there is a group of five islands, known as the Pilgrim islands. These are a continuation of the quartzite ridges found on the mainland, and are composed entirely of quartzite. From an examination in the field, the quality of the material appeared to be the same on all five islands, so it was decided to confine the detailed examination to the two largest.

The area of each island, with the name of the owner, is as follows:—

—	Approx. area in acres	Name of owner
Little Pilgrim island	97	A. G. E. Rankin, Montreal, Que.
Long Pilgrim island	344*	
Middle Pilgrim island (1)	103	Fraser estate, Riviere du Loup, Que.
Middle Pilgrim island (2)	183	
Great Pilgrim island	133	

*This is the total area of the Island. The Federal Government owns 9·6 acres, as shown on the sketch map No. 563.

LONG PILGRIM ISLAND

Long Pilgrim, the main island in the group, is approximately $2\frac{1}{2}$ miles long, with an average width of 1,200 feet. The main axis of the island runs northeast and southwest. A ridge, extending the full length of the island, rises 100 to 125 feet above high water level. On the northwest side, the shore is abrupt, and at high tide the cliffs rise in most places from 40 to 50 feet, directly out of the water. The southeast slope is more gradual, and in several places there is sufficient ground, fairly level, at an elevation about 10 feet above high tide, on which to erect buildings. Over

The material was crushed to pass a 10-mesh screen and milled with a little water until it became somewhat cohesive. At this stage it could be moulded into brick shapes by hand, and re-pressed by machinery when partly dry. The bricklets were burned in a gas kiln to 1,300 degrees C. and afterwards in an electric resistance furnace to 1,530 degrees C., a small portion of one of the bricklets finally raised to 1,650 degrees C. The bricklets burned to 1,530 degrees were hard and dense, and showed that a fused bond between the kaolin and quartz grains was effected.

Raising the temperature to 1,650 degrees changed the character of the material only slightly, there being no indication of failure through softening, and it would probably stand a temperature of 1,700 degrees just as effectively.

These results seem promising for such uses as puddling, malleable, cupola, and crucible furnaces, or for converter linings, glass-making furnaces, or brick for use in by-product coke ovens.

With large quantities of quartzite available, this deposit should be capable of supplying several grades of silica for use in the industries.

NOTRE DAME DES ANGES AREA

Bancroft[1] in his report to the Quebec Department of Mines, in 1915, on the geology of the Notre Dame des Anges district, mentions the occurrence of several areas of Grenville quartzites which might be suitable for use where a high grade silica rock is required.

Two exposures in this locality were examined. (See Map No. 561).

Lots 5 and 6, Con. I, S.W., Chavigny township, Notre Dame des Anges, Que.—Sample No. 1807 was taken on this property, from a massive bed of quartzite which outcrops at the base of the hill on the north side of the Batiscan river. It is covered with sandy drift at the top of the hill. The rock is massive, very compact, and fairly uniform throughout. Bands of biotite-schist run through the deposit, in places, but these are clearly defined, and only of limited width. A working face of 25 feet could easily be developed in this deposit. (See Plate No. XII).

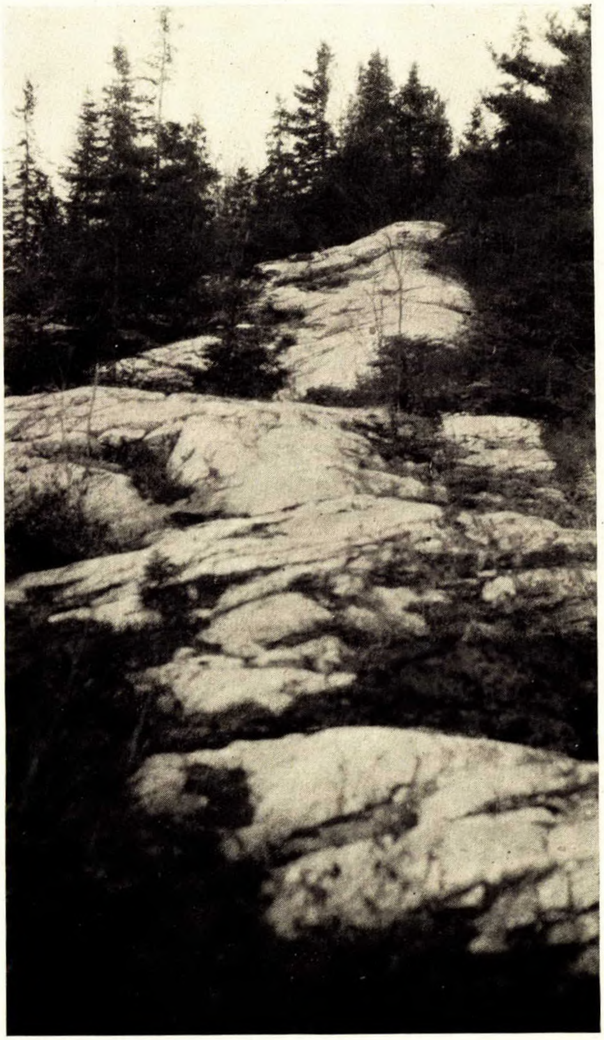
Lot 1, con. V, S.W., Montauban township, and lot 1, con. V, N.E., Montauban township, Notre Dame des Anges, Que.—Sample No. 1808 was taken from the above property, which is shown on the map. The quartzite on these lots extends over a larger area than that on the other locality examined, but the ridge does not rise so high. It runs along the south shore of the river just east of the bridge, the top of the ridge being possibly 40 feet above the level of the river. The rock is similar, with the exception of having occasional patches of pure translucent quartz.

The results of the analyses of these two samples show that, chemically, this material is suitable for the manufacture of ferro-silicon. The probable difficulty of obtaining this material, free from the included bands of biotite schist, might increase the expense of preparing a marketable product.

KAMOURASKA DISTRICT

In the province of Quebec, between the counties of Levis and Temiscouata, and situated along the south shore of the St. Lawrence river, there is a well developed series of quartzite hills rising as abrupt dome-like masses above the St. Lawrence lowland, between the river and the escarpment which parallels it for a distance of nearly 70 miles. According to J. A. Dresser[2] these quartzites belong to the Kamouraska formation, classified

[1]See Report on Mining Operations in the Province of Quebec, 1915, p. 103.
[2]See Memoir No. 35. Reconnaissance along the National Transcontinental Railway in Southern Quebec, by J. A. Dresser, Dept. of Mines, Geological Survey, 1912.



Quartzite deposit on lot 5, range I, SW., township of Chavigny, Notre Dame des Anges, Que.

most of the island the rock is bare, and the vegetation consists of scattered patches of stunted evergreens. The rock is covered with lichens and moss. These features of the island are well shown in Plate XIII.

The surface of the rock, in most cases, is weathered nearly white, but on breaking a fresh face the rock appears considerably darker. It is fine-grained, and consists of rounded grains of quartz of very even texture cemented by a siliceous cementing material. It is very compact, and hard to break with a hammer, but is very brittle, and when crushed produces considerable fines.

Two large samples, Nos. 1801 and 1802, were taken on this island, each representative of a considerable area. The exact localities where these were taken are shown on sketch map No. 563. A smaller sample, No. 1802A, was also taken on the northeastern half of the island, and given to Mr. Theo. Denis, Superintendent of Mines, province of Quebec, who had it analysed, and furnished the analysis given in Table IIB.

THE GREAT PILGRIM ISLAND

This island is the most northerly of the group. It is approximately 4,200 feet long, by 1,700 feet wide, and contains roughly 133 acres. There are two prominent hills, rising over 200 feet above high water level, one at each end of the island, with a deep depression between, and very little level ground. There is fairly deep water around the island, which in all other respects, is similar to the Long Pilgrim.

On viewing the island from a distance, one gains the impression that the rock is whiter on the weathered surface than that on Long Pilgrim, but this is probably due to the fact that there is more bare rock and less vegetation. A freshly fractured surface is considerably darker than the material from any of the other localities visited. Sample No. 1806 was taken as representative of the material on this island.

ST. PASCAL DISTRICT

In the vicinity of St. Pascal station there are a number of quartzite ridges, all of which were examined. The material in these ridges seems to be very similar throughout. Topographically, the ridges are similar to those on Pilgrim islands, having the same general strike, and with steep bluffs on the northwesterly side. Three samples were taken from different ridges, in order to ascertain the purity of the rock. These samples were numbered 1803, 1804, and 1805.

Property of Joseph Lebris, Kamouraska P.O., Que.—Sample No. 1803 was taken from a ridge on this property, $3\frac{3}{4}$ miles from St. Pascal station, on the Canadian National railway. The ridge rises about 10 feet above the level of the wagon road on the southeast side, and drops abruptly on the northwest, so that a working face of about 30 feet could be obtained. The ridge examined covers an area of about 4 acres. The rock is similar in appearance to that found on Pilgrim islands.

Property of Arsine Drapeau, Kamouraska P.O., Que.—Sample No. 1804 was obtained from a ridge on the property of Arsine Drapeau, three miles southeast from the wharf at Kamouraska. This ridge is lightly wooded, and rises about 20 feet above the level of the surrounding plain. The general trend of the ridge is parallel to the river. The rock outcrop covers an area of about 6 acres on this property.

Property of Louis Migneault, St. Pascal P.O., Que.—Sample No. 1805 was taken from the property of Louis Migneault, three miles southwest of the station at St. Pascal. Here there is a rocky ridge rising abruptly about 30 feet above the level of the surrounding fields, and running parallel to the Canadian National railway, from which it is about half a mile distant. The ridge is lightly wooded, and extends over a number of farms adjacent to the property examined. The average width is 100 yards. The rock, in the field, appeared to be similar to that from other localities examined in the district.

The results of the chemical analyses of the seven samples taken from this district are given in Table No. IIB. A study of these results will show that the material from Pilgrim islands has a high silica content, and it appears to be sufficiently dense to be suitable for use in the manufacture of ferro-silicon.

As regards transportation facilities, these islands are admirably situated with relation to the principal markets in the province of Quebec and the Maritime Provinces. (Fig. 7.) From Long Pilgrim, for example, the crushed rock could be loaded directly into barges at low tide at the end of a small wharf, and there would be sufficient water at high tide to enable them to be taken out to the main channel.

Samples 1803, 1804 and 1805 run considerably higher in lime and iron, but lower in silica. The transportation question for these properties is also serious, due to the lack of cheap water routes, and the long rail hauls would greatly increase the cost to the consumer.

MARITIME PROVINCES

PRINCE EDWARD ISLAND

The recent beach sands which are found at numerous places along the coast of Prince Edward Island are a possible source of silica sand for some industries. It is doubtful if any deposits will be found of sufficient purity to be employed as high grade glass sand, but sands which could possibly be used for the cheaper grades of bottle glass are known to occur. One typical locality was visited, and samples taken.

BEACH SAND, EAST OF SOURIS, P.E.I.

About six miles east of Souris, towards the eastern end of Prince Edward Island, a beach sand was examined which ran well over 95 per cent silica, was very low in iron, and had only small quantities of undecomposed feldspar. The beach from which this sand was taken is roughly 1¼ mile long, and at its widest part probably three-fourths of a mile, tapering at both ends. The sand, in places, has been blown into hills or dunes, which rise from 15 to 20 feet above the surrounding beach. There is a fairly large quantity of sand in this deposit. Sample No. 1755 was an average sample taken from this deposit. The sand has well-rounded grains, each

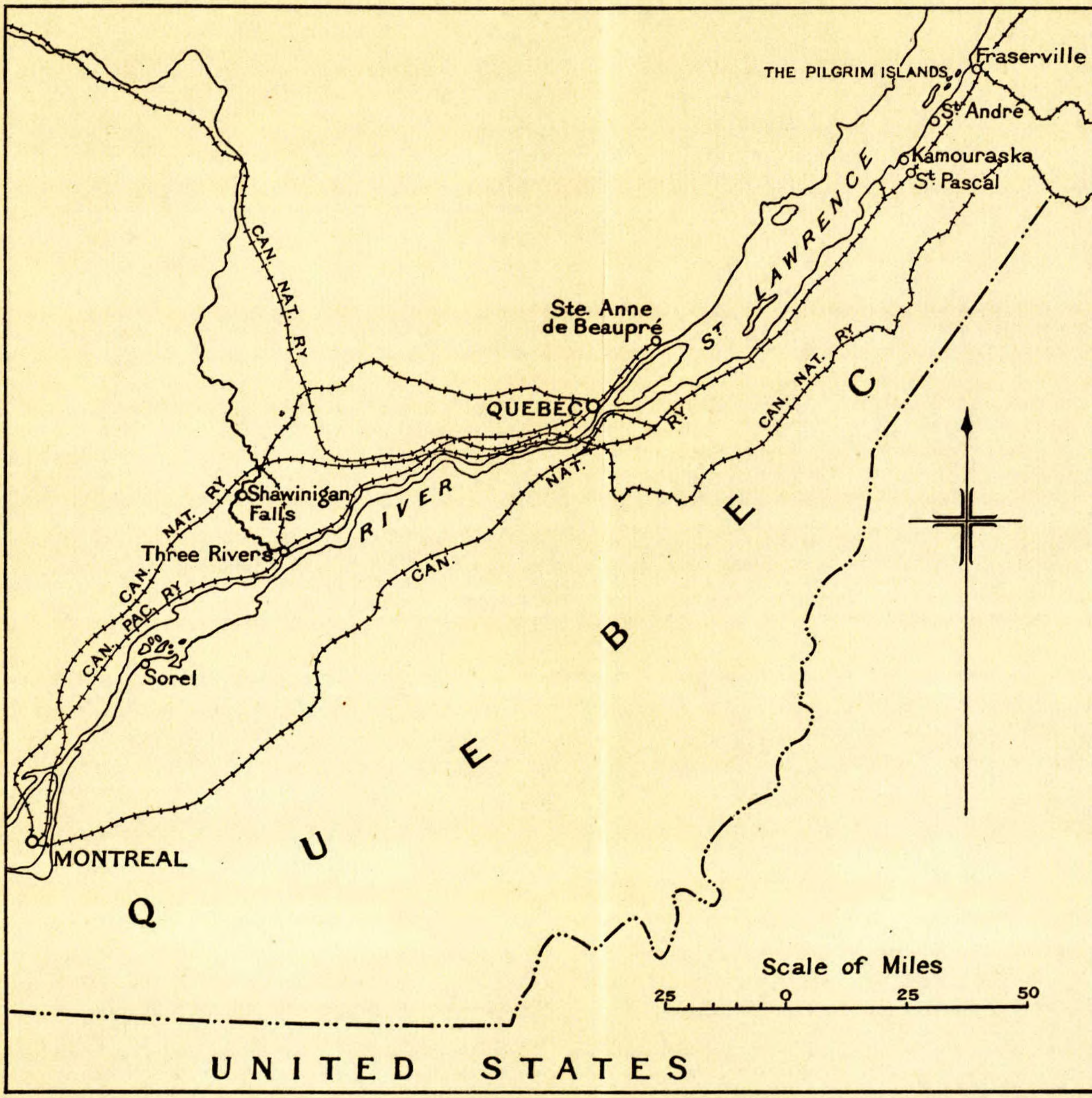


Fig. 7. Sketch map showing relation of Pilgrim island quartzite deposits to Quebec markets.

To face p. 60

Looking northeast from top of ridge on southwest end of Long Pilgrim island, Kamouraska county, Que. Middle Pilgrim island in distance.

grain being clean, and of a high lustre, due to the constant washing to which it has been subjected. The sand is clean, and fairly uniform in grade, having very little material finer than 65 mesh, and all passing through the 20-mesh screen. It might be possible to use this material as a steel foundry sand.

NOVA SCOTIA AND NEW BRUNSWICK

The most important deposits of silica found in Nova Scotia and New Brunswick are in the form of quartz, quartzites, sandstones, sands, and diatomaceous earth. A few typical deposits were visited, and samples taken.

QUARTZ, QUARTZITE, AND SANDSTONE DEPOSITS

There are numerous deposits of quartzite at different localities in Nova Scotia, which are of possible economic importance.

In the eastern part of Cape Breton island there are extensive areas of quartzites, the material from some of which is suitable for the manufacture of silica brick.

The Dominion Iron and Steel Company have been experimenting for a number of years with a view to producing silica brick from the quartzites which occur on the east shore of Cape Breton island. This material, a sample of which (No. 1856) was obtained from the stock pile of the company, at Sydney, is a fine-grained, compact quartzite, of uniform texture, greyish-white in appearance, and very brittle. It crushes readily, however, and a number of brick, made in a small experimental plant, have given good service under actual working conditions, when placed in the front walls of open hearth furnaces.

Another sample of quartzite (No. 1749) was submitted by Dr. A. O. Hayes, late of the Geological Survey. This sample was collected from a series of trenches made up the side of Skye mountain, Whycocomagh district, Inverness county, N.S.

Quartz is found associated with many of the gold deposits which are found in certain parts of the province, and it is possible that a small tonnage of clean material might be obtained from such occurrences. The quartz is generally, so intimately mixed with other rocks, however, that the possibility of obtaining a large tonnage of pure silica from this source is extremely doubtful.

In the southwestern part of the province, notably in Shelburne, Yarmouth, Digby, Annapolis, and Kings counties, numerous well-defined belts of quartzites occur, which have been extensively studied and mapped by E. R. Faribault of the Geological Survey.[1] In referring to one of these belts of quartzites occurring in Yarmouth county, Faribault says:—

> From Fort Cove to Chegoggin point the rocks are much metamorphosed into crystalline schists and knotted slates of different varieties, and white quartzites.
>
> The belt of white quartzite outcrops prominently on the seashore between high and low tides for a length of about 800 feet. Its thickness is 350 feet and it consists of thick, massive beds of white, pinkish-white, and yellowish-white, semi-transparent and vitreous quartz rock. Some beds consist apparently of pure silica rock, others

[1]For detail descriptions of some of these areas and for the source of the following abstracts, see Summary Repor Geol. Surv. Can., 1919, Part F, pp. 3 and 18. Summary Report, Geol. Surv. Can., 1920, Part E, p. 14.

are slightly coloured with iron oxide, or have a banded structure, with developments of sericite and silvery white mica along the bedding plane. Under the microscope, grains of quartz sand are visible. The deposit is a highly metamorphosed quartzose sandstone of sedimentary origin conformably interstratified with the schists.

Another belt of quartzites of similar nature occurs in the vicinity of Whiterock, Kings county, 12 miles southwest of Wolfville, N.S. The rock is well exposed in high cliffs on the east side of the road, at Whiterock, half a mile north of the junction of Black and Gaspereau rivers. The rock is massive and vitreous, and has a pinkish-white colour. Flakes of white mica and sericite are scattered through the rock, but only in small amounts. Sample No. 1866 was taken as representative of this deposit.

In the province of New Brunswick there are several localities where sandstones high in silica occur, which may possibly be suitable for commercial exploitation.

An outcrop of sandstone occurs at tide level, on the shore of Kennebecasis bay, to the west of Hastings cove, and north of Berryburn station on the Canadian National railway line from St. John to Moncton. This outcrop rises to a height of about 20 feet, at a distance of 50 yards from the shore. The rock is exposed about 300 feet along the shore, and dips, approximately, 35° to the southwest. No quarrying has been done on this outcrop.

The rock varies in character in different parts of the exposures, from a badly shattered stone, spotted with iron stains, through a medium-grained, gritty stone, fairly clean and uniform, to a compact, close-grained, and very brittle rock, which is practically a quartzite. The outcrop extends about 200 yards back from the shore. Similar rock outcrops about one-fourth to one-third of a mile inland. The sample for testing, No. 1860, was taken from the medium-grained, gritty stone, at the shore.

A sample of creamy white sandstone (No. 1865) was submitted for testing by Dr. W. J. Wright, late of the Geological Survey. This material was obtained from the vicinity of Hillsboro, Albert county, N.B., and it is probable that it may occur in considerable quantities. The rock is very even-grained, friable, and crushes readily.

SANDS IN NOVA SCOTIA

On the southwest shore of Nova Scotia there are several beaches of white sand. These sands have been mentioned in a number of Geological Survey reports[1] as being suitable possibly for the manufacture of glass. These beaches were examined in the fall of 1918, and samples obtained.

The beach to the northeast of this point (Summerville Beach), is cut by the railway, and extends over a considerable area. In places dunes, several feet in height, have been formed by the wind. Sample No. 1849 was taken from this deposit.

About two miles southwest of this beach a more extensive deposit occurs on the shore (Plate XIV) where the sand has been piled up in a series of dunes, which run back from the shore for several hundred yards. Each year they are extending farther inland. Sample No. 1850 is representative of this deposit.

[1]See Report by L. W. Bailey, Vol. IX (new series) Geol. Surv., 1896, Part M.

PLATE XIV

Sand hills on the beach southwest of Port Mouton, Nova Scotia.

PLATE XV

Sand dunes on the beach on the northeast shore of Barrington bay, Nova Scotia.

Victoria county:—Another locality at which diatomaceous earth has been worked in recent years is near Munro Point, St. Ann's, Cape Breton. The Premier Tripolite Company, of New York, were the lessees of this deposit, which was formerly worked by the Victoria Company. No extraction work has been carried out however, for a number of years, though small shipments of crude material have been made from time to time from stock. A small mill for treating the earth was erected on the property, but has not been in operation for a number of years. The company has recently been dissolved and the lease allowed to lapse. The deposit is from 3 to 4 feet thick and extends over about 12 acres. Only a relatively small portion of the available material has been taken out.

New Brunswick—

Kings county:—Pollet River lake, Mechanic settlement. This deposit covers the bed of the lake and has an average thickness of four feet. A sample of the material was the subject of experiments conducted in the laboratory of the Geological Survey, the results of which are published in Vol. XV, (N.S.) Geological Survey of Canada, 1902-3, pp. 21S-25S.

St. John county:—An important deposit of diatomaceous earth exists at Fitzgerald lake, about 8 miles east of St. John. At this lake about 50 acres of earth have been rendered accessible by draining operations, the average thickness of the beds being 10 feet. The deposit has been known for many years, but no attempt at development was made until 1909, when the Boston and St. John Tripolite Company was formed to exploit it. This company leased the property from the owner, Wm. Murdock, of St. John, and in the above year extracted a small quantity of earth, which was air-dried and experimentally treated in a small mill. The operations were soon discontinued, however, and the plant is now in a dilapitated condition. Practically no work has been done since. The material appears to be of good grade, and the deposit contains a large amount of earth, which could be conveniently extracted, and hauled by a good road to St. John for shipment.

Albert county:—A sample of clean, cream-white earth was submitted to the writer by Albert E. Milton, who stated that it was obtained from the bed of Standards lake near Caledonia. Mr. Milton states that there is a considerable deposit of this material in the lake.

The following tabulation gives a brief record of all reported occurrences of diatomaceous earth in the Maritime Provinces.

Diatomaceous Earth Occurrences in Maritime Provinces

County	Location	Owner or operator	Description
	NOVA SCOTIA		
Antigonish	Lochaber L.[3]		
Cape Breton	Ainsley L.[3]		
Colchester	Silica L.[3, 10] (formerly Bass River L.) 12 m. from Thompson, I.C.R.	Oxford Tripoli Co., Oxford, N.S.	Area, 12 acres. Earth removed from whole area. Mill on property.
	Folly L.[3] (I.C.R.)		Area, 135 acres. Worked to small extent prior to 1903.
	Mackintosh L.[3]		
	Earltown L.[3]		
	Gully L.[3]		
Cumberland	Fountain L.[3] 8 m. from I.C.R.		Worked to slight extent prior to 1903.
	Cobequid Mts. area[3]		Small deposits in many lakes.
Digby	Meteghan River[2]		
Halifax	Dartmouth L.[12] (near Halifax.)		Beds reported 8 ft. thick.
	Grand L.[12] (near Halifax.)		Beds reported 8 ft. thick.
	Paint L.[8] (near head of Chezzetcook).		
Inverness	River Denys[3] on I.C.R.		Small amount work done
Kings	3 miles south of [13] Nicholsville, on west branch of S. Annapolis river, ¼ mile below Beach Hill dam.	Lloyd Johnson, Aylesford, N.S.	Two holes (3 feet) did not reach bottom. Section shows 2 ft. pure white material covered with 1 ft. decomposed vegetable matter. Deposit occurs in a marsh and is undeveloped.
	Horseshoe meadow[13] east branch South Annapolis river, 1 mile above Shingle mill fall	Chas. Tupper	Said to be 10 feet deep. Undeveloped.
	3 miles east of [13], Lake George road, on south brook of Four mile lake.	Daniel Francis, Millville, N.S.	Undeveloped.
	North Mountain,[13] one-quarter mile east of Morden road.	James McGarvie	Area unknown. Said to be 20 feet in depth.
Lunenburg	Sabody Pond,[4] on Middle River near Chester.	Capt. Lordley, Chester, N.S.	
	NOVA SCOTIA		
Pictou	Upper Barney river[3]	Alex. Sutherland	Extent not known. Thickness 2 ft.
	Mackay L.[3]		
	Black Brook lake[3]		
	Garden of Eden L.[3]		
	Grant L.[3]		
	McLean L.[3]		
	Calder L.[3]		
	Forbes L.[3]		
	Ben L.[3]		
	Toney L.[3]		
Queens	Loon L. falls,[6] on Liverpool river, 8½ mi. from Caledonia, N.S.		Undeveloped. Chances of tonnage fair.

Diatomaceous Earth Occurrences in Maritime Provinces—*con.*

County	Location	Owner or operator	Description
Victoria...............	St. Ann's P.O. Munro pt.,[3,10] 25 m. from North Sydney.	Premier Tripolite Co. (lessee), 159 Maiden Lane, New York.	Area, 12 acres. Only partially worked over. Not operated in recent years.
	Englishtown,[3] 22 m. from North Sydney.	F. Torrence............	....
	NEW BRUNSWICK		
Kings.................	Pollet River L.,[3,7] Mechanic's Settlement, P.O. 11 m. from I.C.R.	....	Thickness 4 ft. Lake drained and preparation made for working.
	Pleasant L.[3] 1 m. SW. of Pollet L.	....	....
	Westfield[7] — across St. John river from.	....	No information. Occurrence noted on mineral map of New Brunswick. Map No. 969 Geol. Sur. Can.
St. John..............	Fitzgerald L.[3,5,7,10] 7 m. from St. John.	Wm. Murdock, St. John (owner). Boston & St. John Tripolite Company. (lessees).	Area, 50 acres. Thickness 10 ft. Shipments for experimental purposes *only* to date.
Albert................	Standards lake[11] near Caledonia.	A. E. Milton, Cape de Moiselle Creek P.O., Albert co., N.B.	Undeveloped. No detailed information.

KEY TO REFERENCES

1 Geol. Sur. Can. Report 1875-76, p. 256.
2 " " Ann. Report Vol. IX, Sec. A, p. 93.
3 " " " " XV, Sec. S, pp. 25-28.
4 " " " " XVI, Sec. A, p. 346.
5 " " Sum. Report, 1913, p. 242.
6 " " " " 1915, pp. 189-192.
7 " " Geology and Mineral Resources of New Brunswick, Ells, Publication No. 983.
8 " " Memoir No. 20-E, p. 300.
9 " " " " 36, p. 137.
10 Mines Branch Sum. Report 1914.
11 " " Files.
12 Mines and Minerals of Nova Scotia, Gilpin, 1880, p. 115.
13 Geol. Sur. Can., Summ. Report 1920, Part E, p. 15.

The following table gives statistics of the Canadian production from 1896 to date, all of which has been exported.

Annual Shipments of Diatomaceous Earth

Calendar Year	Tons	Value	Calendar Year	Tons	Value
		$			$
1896..........................	644	9,960	1909....................	nil	nil
1897..........................	15	150	1910....................	22	134
1898..........................	1,017	16,660	1911....................	20	122
1899..........................	1,000	15,000	1912....................	38	230
1900..........................	336	1,950	1913....................	620	12,138
1901..........................	850	15,300	1914....................	650	13,000
1902..........................	1,052	16,470	1915....................	317	12,119
1903..........................	835	16,700	1916....................	620	12,130
1904..........................	320	6,400	1917....................	600	18,000
1905..........................	300	3,600	1918....................	500	12,500
1906..........................	nil	nil	1919....................	565	11,300
1907..........................	30	225	1920....................	260	8,600
1908..........................	30	195	1921....................	341	11,268

A record of analyses of diatomaceous earth from Canadian deposits is given below, together with a table of analyses of samples from various other localities for purposes of comparison.

Analyses of Canadian Samples (Diatomaceous Earth)

Locality	1	2	3	4
Sample from	H.S. Spenc	H.S. Spenc	R. W. Ellis	H.S. Spence
Silica	72·10	81·30	80·487	74·98
Alumina	....	....	3·146	3·81
Ferric oxide	....	....	·951	·72
Ferrous oxide	·51	·38	....	·64
Lime	....	....	·342	·54
Magnesia	....	....	·283	·36
Soda	....	....	....	·65
Potash	....	....	....	·25
Water - below 110°C	6·10	5·16	13·321	5·74
Water - above 110°C	10·70	9·34		9·56
Organic matter	6·30	·82	....	2·72
	nil	nil	·011	nil
Total	....	....	....	99·97

Analyses by laboratory, Mines Branch, Ottawa. Key to localities:—
1. St. Ann's, Victoria co., N.S.
2. Silica lake, Colchester co., N.S.
3. Pollet River lake, Mechanic's Settlement, Kings co., N.B.
4. Fitzgerald lake, St. John co., N.B.

Analyses epresentative of Foreign Samples (Diatomaceous Earth)

Locality	1	2	3	4	5	6
Silica	80·53	80·66	81·53	86·92	84·15	87·2
Alumina	5·89	3·84	3·43	4·27	1·40	2·0
Ferric oxide	1·03	....	3·34	....	·70	....
Lime	0·35	0·58	2·61	1·60	1·75	....
Magnesia	....	....	....	trace	1·10	....
Potash	....	....	1·16	2·48	....	....
Soda	....	....	1·43	....	....	....
Water	12·03*	14·01*	6·04*	5·13	10·40	10·0

*Water and organic matter.
1. Lake Umbagog, New Hampshire, U.S.A.
2. Morris county, New Jersey, U.S.A.
3. Pope's creek, Maryland, U.S.A.
These three analyses from Non-Metallic Minerals, G. P. Merrill, 2nd Edition, 1910, p. 72.
4. Porcelain diatomaceous earth, Pt. Sal., Santa Barbara co., California, U.S.A. Bull. Dept. Geol. Surv., Univ. Calif., Vol. II, 1896, p. 12, Sp. Gr. 2·12.
5. Hanover, Germany, Bull. California State Min. Bur. No. 38, 1906, p. 28.
6. Auvergne, France, Mines Branch, Min. Prod. 1914, p. 174.

CHAPTER V

LABORATORY TESTS ON CANADIAN SILICAS

The samples collected during the field work in connection with this investigation of Canadian silicas were subjected to a series of tests in the laboratories of the Mines Branch, Department of Mines, to determine their suitability for use in the various industries.

The quartz, quartzite, and sandstone were crushed in a Blake type crusher, until the whole of each sample passed through an 8 mesh screen. The samples of natural sands were submitted to the tests without crushing since in all cases they were finer than 8 mesh.

Each sample was then thoroughly mixed and quartered in a Jones sampler, to about 500 grams, after which a granulometric analysis was made on 100 grams. The remainder was ground in a porcelain lined pebble mill, to pass through a 150-mesh screen. A portion of this pulverized material was submitted to the chemists for chemical analysis, and another portion used in the pottery test.

The sands and crushed sandstones were subjected to a washing test, and the washed material to granulometric analysis. It was then pulverized in the pebble mill to 150 mesh, and analysed, and in some cases, a pottery test was also made.

The quartz and quartzite samples were, in some cases, tested to determine their suitability for use in the manufacture of silica brick.

The method employed in the several tests, and the results obtained were as follows:—

GRANULOMETRIC ANALYSIS

One of the most important features of a sand is its grain size, or, as it is termed, its texture. The texture is determined by granulometric analysis. A 100-gram sample is passed through a series of Tyler standard screens, and subjected, for a definite length of time, to agitation on a mechanical shaker, the material retained on each screen being collected, weighed, and noted. Since the sample in the first place weighs 100 grams, the weight recorded as retained on each screen is the percentage retained on that screen, and the cumulative percentage of all material that would be retained on any given screen, if that screen alone were employed, can readily be determined. The screen sizes used for this test are shown in the following form used for tabulating the results:—

Indicate the screen crushed through and also first retaining screen	Screen scale ratio 1·414				Weights		
	Openings		Mesh	Diameter wire inches	Sample weights	Per cent	Per cent cumulative weights
	Inches	Millimeters					
....	1·050	26·67	....	·149	....	....	....
....	0·742	18·85	....	·135	....	....	....
....	·525	13·33	....	·105	....	....	....
....	·371	9·423	....	·092	....	....	....
....	·263	6·680	3	·070	....	....	....
....	·185	4·699	4	·065	....	....	....
....	·131	3·327	6	·036	....	....	....
....	·093	2·362	8	·032	....	....	....
....	·065	1·651	10	·035	....	....	....
....	·046	1·168	14	·025	....	....	....
....	·0328	·833	20	·0172	....	....	....
....	·0232	·589	28	·0125	....	....	....
....	·0164	·417	35	·0122	....	....	....
....	·0116	·295	48	·0092	....	....	....
....	·0082	·208	65	·0072	....	....	....
....	·0058	·147	100	·0042	....	....	....
....	·0041	·104	150	·0026	....	....	....
....	·0029	·074	200	·0021	....	....	....
Pass..................	·0029	·074	200	·0021	....	....	....
				Totals...	....	....	....

In order to gain some idea of the relative fineness of texture, and to be able to express this in one figure, the average fineness of the sample is calculated. It is determined as follows. The percentage of material passing through each screen, and retained on the next smaller, is multiplied by the mesh of the screen passed through. The results obtained are totalled and divided by 100, the resultant being the average fineness. In other words, if all the grains of the sample were brought to an average size, they would just pass through a screen whose mesh was equal to the average fineness of the sample. To illustrate this, the granulometric analysis of a sample being:—

—	Mesh	%	The calculation for average fineness will be	
Retained on..........	8	....	8 x 0·20	1·60
	10	·20	10 x 0·60	6·00
	14	·60	14 x 1.45	20·30
	20	1·45	20 x 8·00	160·00
	28	8·00	28 x 15·15	424·20
	35	15·15	35 x 32·10	1,123·50
	48	32·10	48 x 28·75	1,380·00
	65	28·75	65 x 8·55	555·75
	100	8·55	100 x ·90	90·00
	150	·90	150 x 1·90	285·00
	200	1·90	200 x 2·40	480·00
Through..........	200	2·40		
				4,526·35

$$\text{Thus } \frac{4,526\cdot 35}{100} = 45\cdot 26$$

Therefore the average fineness of the sample is 45·26.

Tables IA and IB give the results of the granulometric analyses.

TABLE IA.

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1704				1705				1706				1707			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
20	6·65	6·65	6·06	6·06	2·37	2·37	1·85	1·85	4·60	4·60	2·31	2·31	6·94	6·94	11·25	11·25
28	18·50	25·15	21·40	27·46	12·58	14·95	9·80	11·65	21·28	25·88	19·76	22·07	19·67	26·61	28·30	39·55
35	10·25	35·40	16·55	44·01	11·85	26·80	12·95	24·60	17·85	43·73	23·51	45·58	18·46	45·07	23·40	62·95
48	11·56	46·96	13·89	57·90	18·52	45·32	27·66	52·26	17·74	61·47	24·21	69·79	18·53	63·60	20·90	83·85
65	10·86	57·82	14·98	72·88	17·08	62·40	23·67	75·93	12·65	74·12	17·24	87·03	10·78	74·38	8·39	92·24
100	15·85	73·67	20·40	93·28	20·73	83·13	23·26	99·19	10·56	84·68	11·91	98·94	9·27	83·65	6·50	98·74
150	4·68	78·35	4·86	98·14	2·96	86·09	·70	99·89	2·48	87·16	·89	99·83	3·07	86·72	·85	99·59
200	10·76	89·11	1·80	99·94	7·07	93·16	·06	99·95	5·76	92·92	·15	99·98	6·19	92·91	·05	99·64
Through 200	10·89	......	·06	......	6·84	......	·05	......	7·08	......	·02	......	7·09	......	·36	......
Average fineness	69·33	......	42·75	......	61·83	......	42·97	......	54·32	......	36·50	......	54·39	......	30·99	......

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1708				1710				1712				1713			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14	......	......	......	......	......	......	......	......	6·85	6·85	......	......	2·70	2·70	......	......
20	3·20	3·20	1·96	1·96	1·67	1·67	0·85	0·85	5·95	12·80	......	......	4·55	7·25	......	......
28	15·38	18·58	10·61	12·57	7·95	9·62	2·12	2·97	12·24	25·04	......	......	16·50	23·75	......	......
35	13·87	32·45	18·15	30·72	12·45	22·07	12·35	15·32	18·74	43·78	......	......	14·68	38·43	......	......
48	17·58	50·03	21·40	52·12	24·47	46·54	31·22	46·54	35·15	78·93	......	......	23·56	61·92	......	......
65	14·63	64·66	17·54	69·66	22·62	69·16	27·75	74·29	14·12	93·05	......	......	20·94	82·87	......	......
100	19·27	83·93	25·06	94·72	19·50	88·66	24·36	98·65	2·70	95·75	......	......	9·75	92·62	......	......
150	5·12	89·05	4·71	99·43	3·32	91·98	1·31	99·96	·57	96·32	......	......	1·36	93·98	......	......
200	5·87	94·92	·51	99·94	4·25	96·23	·01	99·97	1·39	97·71	......	......	2·61	96·59	......	......
Through 200	5·08	......	·06	......	3·77	......	·03	......	2·29	......	......	......	3·41	......	......	......
Average fineness	57·19	......	45·00	......	54·64	......	45·60	......	37·46	......	......	......	48·02	......	......	......

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1714				1719				1720				1724			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14	......	......	0·25	0·25	......	......	......	......	......	......	......	......	......	......	......	......
20	2·93	2·93	3·80	4·05	·85	·85	·80	·80	2·25	2·25	·91	·91	3·10	3·10	2·31	2·31
28	10·68	13·61	12·70	16·75	6·32	7·17	2·05	2·85	5·64	7·89	3·57	4·48	12·98	61·08	10·27	12·58
35	14·35	27·96	18·10	34·85	9·00	16·17	8·75	11·60	7·40	15·29	9·21	13·69	22·87	38·95	26·31	38·89
48	29·44	57·40	33·85	68·70	28·50	44·67	33·41	45·01	25·42	40·71	26·75	40·44	29·49	68·44	34·76	73·65
65	22·74	80·14	21·80	90·50	32·30	76·97	37·90	82·91	27·47	68·18	33·24	73·68	14·48	82·92	16·99	90·64
100	11·48	91·62	8·40	98·90	15·55	92·52	16·95	99·86	22·80	90·98	25·83	99·51	8·80	91·72	9·05	99·69
150	1·96	93·58	·75	99·65	1·40	93·92	·11	99·97	2·25	93·23	·46	99·97	1·97	93·69	·25	99·94
200	3·49	97·07	·30	99·95	2·98	96·90	·02	99·99	3·40	96·63	·02	99·99	3·64	97·33	·04	99·98
Through 200	2·93	......	·05	......	3·10	......	·01	......	3·37	......	·01	......	2·67	......	·02	......
Average fineness	48·30	......	37·24	......	50·56	......	45·07	......	54·51	......	45·58	......	45·91	......	36·30	......

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1725				1727				1728				1731			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....
14	......	....	......	....	......	....	......	....	......	....	......	....	......	....	......	....
20	1·38	1·38	0·82	0·82	2·63	2·63	......	....	3·37	3·37	2·74	2·74	2·62	2·62	1·65	1·65
28	8·32	9·70	4·80	5·62	8·82	11·45	......	....	13·65	17·02	9·75	12·49	19·23	21·85	12·55	14·20
35	15·50	25·20	16·15	21·77	11·62	23·07	......	....	17·85	34·87	21·75	34·24	24·08	45·93	24·53	38·73
48	28·10	53·30	32·70	54·47	28·01	51·08	......	....	31·43	66·30	35·06	69·30	29·57	75·50	40·31	79·04
65	21·55	74·85	26·11	80·58	21·27	72·35	......	....	18·58	84·88	19·76	89·06	14·47	89·97	16·98	96·02
100	14·28	89·13	16·81	97·39	14·62	86·97	......	....	8·27	93·15	8·51	97·57	5·64	95·61	3·52	99·54
150	3·48	92·61	2·20	99·59	2·50	89·47	......	....	1·47	94·62	2·03	99·60	·97	96·58	·46	100·00
200	4·33	96·94	·05	99·64	5·02	94·49	......	....	2·70	97·32	·36	99·96	1·79	98·37	·00	....
Through 200	3·06	....	·36	....	5·51	....	......	....	2·68	....	·04	....	1·63	....	·00	....
Average fineness	51·75	......	43·69	....	55·95	....	......	....	44·37	....	38·20	....	39·83	....	37·48	....

TABLE Iᴀ.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1732				1735				1738				1739			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	......	......	......	......	......	......	......	......	......	Sample No. 1740 is washed sand from this property.		......	......	Sample No. 1740 is washed sand from this property.	
14	0·30	0·30	......	......	......	......	......	......	0·40	0·40			......	......		
20	2·15	2·45	·89	·89	2·22	2·22	1·03	1·03	2·20	2·60			1·75	1·75		
28	9·90	12·35	4·30	5·19	17·22	19·44	12·52	13·55	13·25	15·85			14·00	15·75		
35	24·17	36·52	23·70	28·89	30·59	50·03	39·10	52·65	16·75	32·60			20·98	36·73		
48	42·25	78·77	48·90	77·79	26·27	76·30	33·50	86·15	24·40	57·00			31·45	68·18		
65	17·09	95·86	19·36	97·15	9·91	86·21	9·63	95·78	22·08	79·08			21·84	90·02		
100	3·42	99·28	2·80	99·95	5·43	91·64	4·15	99·93	14·20	93·28			7·94	97·96		
150	·32	99·60	·04	99·99	1·37	93·01	·04	99·99	2·65	95·93			·79	98·75		
200	·15	99·75	·00	99·99	3·32	96·33	·02	99·99	2·40	98·33			·69	99·44		
Through 200	·25	......	·01	......	3·67	......	·01	......	1·67	......			·56	......		
Average fineness	35·34	......	35·91	......	43·48	......	32·73	......	45·64	......	....		35·50	......	......	......

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1740				1741				1742				1747			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10......	See Sample No. 1738 for unwashed sample.		......	......	......	......	......	......	......	......	......	......	......	......	......	......
14......			2·85	2·85	0·10	0·10	......	......	......	......	......	......	......	......	......	......
20......			1·55	4·40	·35	·45	......	......	2·15	2·15	......	......	2·50	2·50	1·39	1·39
28......			7·05	11·45	·75	1·20	......	......	9·35	11·50	......	......	18·61	21·11	12·10	13·49
35......			13·63	25·08	·82	2·02	......	......	19·35	30·85	......	......	29·25	50·36	25·85	39·34
48......			25·48	50·56	2·47	4·49	......	......	34·42	65·27	......	......	29·05	79·41	36·95	76·29
65......			28·58	79·14	11·17	15·56	......	......	21·28	86·55	......	......	10·34	89·75	12·65	88·94
100......			16·65	95·79	31·67	47·33	......	......	8·22	94·77	......	......	4·85	94·60	8·00	96·94
150......			2·23	98·02	10·50	57·83	......	......	1·37	96·14	......	......	1·07	95·67	1·95	98·89
200......			1·68	99·70	23·30	81·13	......	......	2·09	98·23	......	......	2·17	97·84	1·05	99·94
Through 200......			·30	......	18·87	......	......	......	1·77	......	......	......	2·16	......	·06	......
Average fineness......	......	......	44·54	......	110·54	......	......	......	42·55	......	......	......	39·20	......	37·70	......

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1750				1753				1754				1755			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10							0·70	0·70	18·50	18·50	See No. 1814 for washed sample.					
14					·10	·10	0·40	1·10	15·30	33·80						
20	2·07	2·07	1·34	1·34	1·12	1·22	3·30	4·40	13·40	47·20						
28	11·92	13·99	5·60	6·94	4·98	6·20	6·15	10·55	13·20	60·40			1·40	1·40		
35	15·39	29·38	16·50	23·44	14·27	20·47	19·10	29·65	8·40	68·80			7·60	9·00		
48	23·90	53·28	28·06	51·50	35·37	55·84	39·60	69·25	7·30	76·10			58·45	67·45		
65	18·28	71·56	22·35	73·85	16·61	72·45	14·10	83·35	6·43	82·53			31·62	99·07		
100	14·22	85·78	19·76	93·61	18·20	90·65	12·80	96·15	5·25	87·78			·70	99·77		
150	2·92	88·70	3·69	97·30	4·87	95·52	2·80	98·95	1·70	89·48			·10	99·87		
200	4·65	93·35	2·65	99·95	3·76	99·28	·95	99·90	3·82	93·30			·08	99·95		
Through 200	6·65		·05		·72		·10		6·70				·05			
Average fineness	56·60		47·18		49·28		40·50		39·76				38·97			

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1809				1814				1815				1816			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10.......	5·75	5·75	8·20	8·20	See No. 1754 for unwashed sample.		......	....	2·37	2·37	......	....	10·32	10·32	See No. 1817 for washed sample.	
14.......	5·45	11·20	4·60	12·80			......	....	3·37	5·74	......	....	8·30	18·62		
20.......	3·10	14·30	3·30	16·10			......	....	2·52	8·26	0·90	0·90	6·50	25·12		
28.......	4·45	18·75	3·20	19·30			3·72	3·72	6·10	14·36	3·00	3·90	8·72	33·84		
35.......	7·00	25·75	9·25	28·55			3·57	7·29	12·62	26·98	14·90	18·80	11·35	45·19		
48.......	16·10	41·85	27·95	56·50			12·70	19·99	25·15	52·13	36·80	55·60	11·92	57·11		
65.......	23·05	64·90	24·80	81·30			24·93	44·92	23·52	75·65	27·97	83·57	15·00	72·11		
100.......	15·35	80·25	15·70	97·00			33·07	77·99	10·95	86·60	15·22	98·79	7·47	79·58		
150.......	4·25	84·50	1·75	98·75			8·22	86·21	2·35	88·95	1·15	99·94	2·20	81·78		
200.......	5·85	90·35	·95	99·70			12·07	98·28	1·45	90·40	·05	99·99	7·32	89·10		
Through 200.......	9·65	....	·30	....			1·72	....	9·60	....	·01	....	10·90	....		
Average fineness.......	63·28	....	40·47	....	....	....	69·41	....	56·57	....	42·39	....	57·27	....	....	....

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1817				1826				1827				1828			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	See No. 1816 for unwashed sample.		......	....	0·35	0·35	......	....	1·55	1·55	......	....	0·20	0·20	......	....
14			......	....	1·40	1·75	......	....	3·35	4·90	......	....	·60	·80	......	....
20			1·15	1·15	1·55	3·30	·70	·70	3·85	8·75	2·80	2·80	1·45	2·25	·71	·71
28			2·30	3·45	6·60	9·90	3·66	4·36	13·85	22·60	11·05	13·85	8·00	10·25	2·76	3·47
35			7·80	11·25	16·30	26·20	23·11	27·47	23·65	46·25	27·20	41·05	15·15	25·40	16·55	20·02
48			14·70	25·95	32·55	58·75	40·10	67·57	19·55	65·80	39·56	80·61	32·10	57·50	41·95	61·97
65			28·50	54·45	23·18	81·93	24·86	92·43	17·05	82·85	15·57	96·18	28·75	86·25	30·12	92·09
100			21·50	75·95	9·75	91·68	7·50	99·93	6·75	89·60	3·71	99·89	8·55	94·80	7·67	99·76
150			6·30	82·25	1·70	93·38	·04	99·97	2·60	92·20	·06	99·95	·90	95·70	·24	100·00
200			13·35	95·60	2·85	96·23	·01	99·98	2·35	94·55	·03	99·98	1·90	97·60	·00	....
Through 200			4·40	....	3·77	....	·02	....	5·45	....	·02	....	2·40	....	·00	....
Average fineness	....		65·02	....	48·64	....	38·23	....	46·83	....	34·09	....	45·26	....	41·81	....

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1833				1835				1837				1841			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	5·20	5·20	......	....	6·30	6·30	......	....	3·65	3·65	......	....	2·80	2·80	......	....
14	6·70	11·90	22·81	22·81	7·60	13·90	......	....	5·37	9·02	......	....	4·70	7·50	......	....
20	5·37	17·27	9·04	31·85	5·80	19·70	6·80	6·80	3·35	12·37	2·61	2·61	5·25	12·75	......	....
28	4·47	21·74	6·25	38·10	9·05	28·75	12·15	18·95	7·45	19·82	7·21	9·82	9·70	22·45	......	....
35	2·75	24·49	5·91	44·01	10·75	39·50	22·75	41·70	12·55	32·37	18·80	28·62	10·25	32·70	......	....
48	2·90	27·39	6·66	50·67	15·35	54·85	26·25	67·95	17·90	50·27	30·70	59·32	11·35	44·05	......	....
65	5·36	32·75	7·89	58·56	10·50	65·35	16·17	84·12	18·51	68·78	24·52	83·84	10·46	54·51	......	....
100	15·40	48·15	24·71	83·27	10·43	75·78	14·15	98·27	10·35	79·13	14·00	97·84	11·12	65·63	......	....
150	11·65	59·80	10·76	94·03	3·45	79·23	1·41	99·68	2·90	82·03	1·65	99·49	4·17	69·80	......	....
200	25·05	84·85	1·56	95·59	7·97	87·20	·20	99·88	7·47	89·50	·26	99·75	5·55	75·35	......	....
Through 200	15·15	....	4·41	....	12·80	....	·12	....	10·50	....	·25	....	24·65	....	......	....
Average fineness	96·62	....	50·55	....	65·09	....	37·85	....	63·28	....	41·22	....	84·25	....	......	....

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1842				1849				1850				1851			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	6·15	6·15														
14	7·65	13·80											0·10	0·10		
20	5·40	19·20	50·70	50·70										·10		
28	5·90	25·10	10·22	60·92	·10	·10							·28	·28		
35	3·75	28·85	13·18	74·10	·10	·20			2·05	2·05			1·75	2·13		
48	2·77	31·62	12·10	86·20	·30	·50			9·30	11·35			19·25	21·38		
65	5·13	36·75	6·80	93·00	3·40	3·90			44·05	55·40			44·15	65·53		
100	4·55	41·30	4·30	97·30	64·30	68·20			40·90	96·30			31·70	97·23		
150	3·00	44·30	·60	97·90	20·00	88·20			2·95	99·25			2·00	99·23		
200	5·45	49·75	·90	98·80	11·60	99·80			·15	99·40			·62	99·85		
Through 200	50·25		1·20		·20				·60				·15			
Average fineness	129·11		27·48		81·38				55·93				52·32			

TABLE IA.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1860				1861				1865				2001			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	1·55	1·55	......	....	2·07	2·07	......	....	8·90	8·90	......	....	......	....	......	....
14	2·50	4·05	......	....	2·62	4·69	......	....	9·25	18·15	24·60	24·60	......	....	......	....
20	2·85	6·90	1·35	1·35	2·57	7·26	2·21	2·21	6·50	24·65	9·77	34·37	3·70	3·70	2·96	2·96
28	8·70	15·60	3·20	4·55	7·75	15·01	4·75	6·96	7·47	32·12	8·11	42·48	12·90	16·60	11·45	14·41
35	19·35	34·95	27·51	32·06	15·30	30·31	24·21	31·17	5·50	37·62	9·95	52·43	31·00	47·60	30·90	45·31
48	27·50	62·45	40·54	72·60	27·30	57·61	40·30	71·47	5·00	42·62	12·62	65·05	26·65	74·25	28·81	74·12
65	13·66	76·11	17·54	90·14	13·99	71·60	16·84	88·31	11·61	54·23	13·50	78·55	10·75	85·00	12·98	87·10
100	7·70	83·81	9·01	99·15	10·30	81·90	10·95	99·26	12·32	66·55	17·35	95·90	9·21	94·21	11·35	98·45
150	2·67	86·48	·60	99·75	2·60	84·50	·65	99·91	5·15	71·70	3·40	99·30	1·48	95·69	1·47	99·92
200	4·60	91·08	·20	99·95	5·10	89·60	·04	99·95	9·85	81·55	·50	99·80	1·76	97·45	·06	99·98
Through 200	8·92	....	·05	....	10·40	....	·05	....	18·45	....	·20	....	2·55	....	·02	....
Average fineness	56·53	....	37·99	....	60·68	....	38·10	....	77·75	....	34·95	....	41·47	....	36·65	....

TABLE 1A.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	2002				2003				2006				2011			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	0·15	0·15
14	......	......	......	......	......	......	......	......	......	......	......	......	2·41	2·41	3·65	3·80
20	4·41	4·41	2·31	2·31	2·40	2·40	2·36	2·36	4·56	4·56	5·15	5·15	4·15	6·56	5·90	9·70
28	4·70	9·11	2·96	5·27	2·65	5·05	3·66	6·02	4·60	9·16	6·24	11·39	3·90	10·46	4·25	13·95
35	22·41	31·52	18·02	23·29	12·97	18·02	17·67	23·69	12·56	21·72	16·13	27·52	7·06	17·52	9·15	23·10
48	26·96	58·48	36·76	60·05	25·85	43·87	34·45	58·14	16·81	38·53	24·02	51·54	10·58	28·10	17·60	40·70
65	12·47	70·95	17·25	77·30	17·63	61·50	21·89	80·03	11·06	49·59	15·85	67·39	26·56	54·66	28·50	69·20
100	13·15	84·10	16·05	93·35	17·15	78·65	17·60	97·63	14·85	64·44	19·37	86·76	20·60	75·26	23·25	92·45
150	3·10	87·20	3·80	97·15	4·35	83·00	2·11	99·74	6·60	71·04	8·10	94·86	4·49	79·75	4·55	97·00
200	·20	87·40	2·40	99·55	·55	83·55	·11	99·85	11·60	82·64	2·32	97·18	8·60	88·35	2·75	99·75
Through 200	12·60	......	·45	......	16·45	......	·15	......	17·36	......	2·82	......	11·65	......	·25	......
Average fineness	39·30	......	45·84	......	71·60	......	42·59	......	84·64	......	52·31	......	74·11	......	48·74	......

TABLE 1A.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	2012				2013				2031				2041			
Mesh	Unwashed		Washed		Unwashed		Washed		Unwashed		Washed		Unwashed		Washed	
	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	......	......	0·30	0·30	......	......	0·15	0·15	See No. 1714 for unwashed sample.		......	......	......	......	0·20	0·20
14	2·15	2·15	3·35	3·65	·75	·75	1·25	1·40			......	......	2·55	2·55	4·65	4·85
20	4·61	6·76	6·65	10·30	1·60	2·35	2·85	4·25			......	......	5·63	8·18	10·65	15·50
28	4·75	11·51	4·70	15·00	1·15	3·50	4·80	9·05			·18	·18	7·00	15·18	12·70	28·20
35	9·95	21·46	13·35	28·35	9·82	13·32	10·75	19·80			8·35	8·53	14·50	29·68	17·90	46·10
48	19·05	40·51	27·05	55·40	22·50	35·82	28·65	48·45			36·10	44·63	21·35	51·03	20·70	66·80
65	17·27	57·78	22·95	78·35	23·62	59·44	25·10	73·55			30·43	75·06	17·65	68·68	16·90	83·70
100	18·50	76·28	19·25	97·60	22·50	81·94	21·20	94·75			13·95	89·01	12·90	81·58	10·70	94·40
150	4·30	80·58	1·60	99·20	4·25	86·19	3·50	98·25			2·55	91·56	2·95	84·53	2·40	96·80
200	7·35	87·93	·65	99·85	5·76	91·95	1·60	99·85			3·94	95·50	6·50	91·03	2·70	99·50
Through 200	12·07	......	·15	......	8·05	......	·15	......			4·50	......	8·97	......	·50	......
Average fineness	71·04	......	41·84	......	66·10	......	46·56	......	......	......	56·47	......	61·47	......	39·29	......

TABLE 1A.—*continued*

Granulometric Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	2201			
Mesh	Unwashed		Washed	
	%	Cumulative %	%	Cumulative %
Retained on 10	2·25	2·25	4·75	4·75
14	2·72	4·97	3·35	8·10
20	3·53	8·50	4·90	13·00
28	11·30	19·80	8·60	21·61
35	26·01	45·81	24·45	46·05
48	31·95	77·76	38·50	84·55
65	11·22	88·98	10·40	94·95
100	6·30	95·28	4·35	99·30
150	1·23	96·51	·45	99·75
200	1·73	98·24	·20	99·95
Through 200	1·76	....	·05	....
Average fineness	38·50		32·11	

TABLE Iʙ.

Granulometric Analyses

Vein Quartz and Quartzites—Eastern Canada

Sample No.	1726		1749		1801		1802		1803		1804		1805		1806	
Mesh	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	.....	.....	.....	.....	10·45	10·45	7·26	7·26	10·55	10·55	10·02	10·02	4·80	4·80	8·40	8·40
14	.....	.....	·13	·13	12·37	22·82	8·05	15·31	11·20	21·77	11·05	21·07	7·65	12·45	8·38	16·78
20	·45	·45	·97	1·10	8·60	31·42	7·25	22·56	6·70	28·45	7·37	28·44	7·00	19·45	5·77	22·55
28	6·47	6·92	13·77	14·87	7·75	39·17	8·20	30·76	6·40	34·85	6·95	35·39	7·30	26·75	5·55	28·10
35	13·38	20·30	19·52	34·39	6·65	45·82	6·35	37·11	6·50	41·35	8·12	43·51	5·30	32·05	5·50	33·60
48	11·94	32·24	17·40	51·79	7·35	53·17	8·80	45·91	10·65	52·00	10·30	53·81	8·32	40·37	9·70	43·30
65	22·94	55·18	10·69	62·48	10·78	63·95	13·14	59·05	11·80	63·80	11·09	64·90	10·38	50·75	11·31	54·61
100	13·52	68·70	9·78	72·29	11·80	75·75	12·75	71·80	13·55	77·35	12·90	77·80	14·80	65·55	15·00	69·61
150	3·78	72·48	3·81	76·07	4·00	79·75	5·25	77·05	5·00	82·35	4·10	81·90	5·25	70·80	6·00	75·61
200	11·77	84·25	8·75	84·82	7·75	87·50	8·30	85·35	4·95	87·30	7·35	89·25	4·75	75·55	9·02	84·63
Through 200	15·75	.....	15·18	.....	12·50	.....	14·65	.....	12·70	.....	10·75	.....	24·45	.....	15·37	.....
Average fineness	81·92	.....	73·34	.....	62·73	.....	70·49	.....	62·02	.....	60·53	.....	83·95	.....	73·81	.....

TABLE IB.—*continued*

Granulometric Analyses

Vein Quartz and Quartzites—Eastern Canada

Sample No.	1807		1808		1810		1811		1812		1818		1819		1820	
Mesh	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	5·10	5·10	8·35	8·35	12·75	12·75	16·50	16·50	13·70	13·70	12·95	12·95	13·35	13·35	8·77	8·77
14	8·37	13·47	11·75	20·10	12·50	25·25	11·35	27·85	13·30	27·00	14·47	24·42	14·00	27·35	12·87	21·64
20	9·17	22·64	9·90	30·00	10·65	35·90	11·00	38·85	12·55	39·55	12·67	41·09	6·40	33·75	12·20	33·84
28	14·00	36·64	12·00	42·00	11·20	42·10	8·55	47·40	13·25	52·80	14·37	54·46	13·30	47·05	13·70	47·54
35	12·87	49·51	10·85	52·85	11·70	58·80	9·90	57·30	8·75	61·55	8·95	63·41	9·05	56·10	9·27	56·81
48	14·70	64·21	10·65	63·50	7·60	66·40	9·20	66·50	8·35	69·90	8·97	72·38	8·45	64·55	9·05	65·86
65	11·89	76·10	12·61	76·11	7·58	73·98	6·40	72·90	7·45	77·35	7·97	80·35	9·73	74·28	9·26	75·12
100	9·10	85·20	8·50	84·61	6·80	80·78	6·80	79·70	6·20	83·55	6·40	86·75	6·40	80·68	7·35	82·47
150	2·40	87·60	2·25	86·86	2·22	83·00	3·10	82·80	2·93	86·48	1·65	88·40	6·22	86·90	2·20	84·67
200	5·85	93·45	5·77	92·63	·55	83·55	6·15	88·95	5·22	91·70	3·65	92·05	4·35	91·25	4·80	89·47
Through 200	6·55	......	7·37	......	16·45	......	11·05	......	8·30	......	7·95	......	8·75	......	10·53	......
Average fineness	49·97	......	......	......	63·36	......	53·60	......	47·17	......	43·77	......	50·59	......	51·87	......

TABLE IB.—*continued*

Granulometric Analyses

Vein Quartz and Quartzites—Eastern Canada

Sample No.	1821		1822		1824		1825		1829		1839		1840		1856	
Mesh	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	11·00	11·00	17·30	17·30	10·40	10·40	12·75	12·75	12·67	12·67	10·30	10·30	10·15	10·15	10·40	10·40
14	13·75	24·75	14·80	32·10	11·72	22·12	14·50	27·25	14·35	27·02	9·55	19·85	12·45	22·60	12·55	22·95
20	13·20	37·95	13·65	45·75	12·20	34·32	11·70	38·95	14·37	41·39	15·85	35·70	11·65	34·25	11·85	34·80
28	13·95	51·90	13·40	59·15	13·25	47·57	13·50	52·45	13·60	54·99	14·75	50·45	11·75	46·00	12·60	47·40
35	9·00	60·90	8·42	67·57	7·55	55·12	8·87	61·32	8·75	63·74	7·25	57·70	7·80	53·80	8·70	56·10
48	8·60	69·50	4·65	72·22	10·92	66·04	8·35	69·67	8·42	72·16	8·95	66·65	4·60	58·40	8·80	64·90
65	7·31	76·81	10·83	83·05	8·02	74·06	7·43	77·10	8·08	80·24	7·18	73·83	11·93	70·33	8·95	73·85
100	6·42	83·23	5·30	88·35	7·20	81·26	6·60	83·70	5·75	85·99	5·97	79·80	7·95	78·28	7·75	81·60
150	2·26	85·49	1·55	89·90	3·22	84·48	1·80	85·50	1·77	87·76	2·00	81·80	2·60	80·88	2·40	84·00
200	4·85	90·34	4·25	94·15	5·97	90·45	4·25	89·75	·62	88·38	4·80	86·60	6·50	87·38	4·45	88·45
Through 200	9·66	......	5·85	......	9·55	......	10·25	......	11·62	......	13·40	......	12·62	......	11·55	......
Average fineness	48·96	......	39·71	......	52·10	......	48·75	......	46·07	......	55·53	......	58·32	......	53·90	......

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TABLE IB.—*continued*

Granulometric Analyses

Vein Quartz and Quartzites—Eastern Canada

Sample No.	1866		1868		2010	
Mesh	%	Cumulative %	%	Cumulative %	%	Cumulative %
Retained on 10	.....	.....	.....	.....	.....	.....
14	9·45	9·45	25·15	25·15	2·15	2·15
20	15·40	24·85	9·55	34·70	4·90	7·05
28	17·15	42·00	8·35	43·05	5·40	12·45
35	10·55	52·55	8·16	51·21	8·50	20·95
48	10·35	62·90	9·06	60·27	21·85	42·80
65	6·95	69·85	7·46	67·73	17·86	60·66
100	7·20	77·05	7·35	75·08	17·67	78·33
150	2·70	79·75	3·35	78·43	5·07	83·40
200	6·25	86·00	6·56	84·99	6·75	90·15
Through 200	14·00	.....	15·01	.....	9·85	.....
Average fineness	61·20	.....	62·55	.....	66·96	.....

WASHING TEST

Many of the industries require a silica sand, which has been washed in order to remove the excess of fine material produced by crushing, as well as to remove some of the impurities, such as iron, alumina, and lime.

The samples subjected to this test were the sands and sandstones.

A sketch of the apparatus employed is shown in Fig. 8. The valve A was opened, and the Mohr percolator half filled with water. Two hundred grams of the sample being tested were placed in the percolator and the valve A again opened. At the same time valve B was opened, and the discharge pipe filled with water by placing a finger over the end of pipe C. When the level of the water in the percolator reaches the top, valve B is closed, and the finger removed from pipe C, the discharge pipe thus acts as a syphon. Valve A is regulated to keep the level of the water in the percolator constant at the bottom of the pipe D. The water, entering the percolator through the small orifices in the copper tube, keeps the sand in constant agitation, and the fines are carried off through the discharge pipe. A 100-mesh screen was placed at the discharge end of the syphon, in order to catch any material coarser than 100 mesh which was washed from the percolator.

The washing was continued until the water over the sand was clear. Valve A was then closed, and the cork at the bottom of the percolator removed, and the washed sand flushed into a receptacle for drying and weighing. The material caught on the 100-mesh screen was also dried and weighed, the loss in fines being obtained by difference.

Results obtained by the washing test:—

[1] Sample No.	Washed sand, grams	Washings retained on 100 mesh, grams	Fines (by difference) grams	Fines per cent
1704	151·1	13·3	35·6	17·8
1705	158·9	16·5	24·6	12·3
1706	159·6	15·4	25·0	12·5
1707	172·5	6·8	20·7	10·3
1708	166·4	8·8	24·8	12·4
1710	169·7	11·6	18·7	9·3
1714	180·4	6·4	13·2	6·6
1719	175·7	12·3	12·0	6·0
1720	171·6	10·7	17·7	8·8
1724	175·4	9·4	15·2	7·6
1725	177·3	5·0	17·7	8·8
1728	187·9	1·2	10·9	5·4
1731	181·8	11·2	7·0	3·5
1732	189·0	7·4	3·6	1·8
1735	183·6	9·1	7·3	3·6
1747	183·9	1·5	14·6	7·3
1750	173·8	1·3	24·9	12·4
1753	186·9	5·6	7·5	3·7
1809	141·1	17·2	41·7	20·8
1815	172·1	5·8	22·1	11·0
1826	176·7	9·9	13·4	6·7
1827	156·2	25·7	18·1	9·0
1828	184·7	6·2	9·1	4·5
1833	158·9	16·5	24·6	12·3
1835	144·1	9·9	46·0	23·0
1837	155·5	5·7	38·8	19·4
1842	63·5	32·9	103·6	51·8

[1] 200 gram sample used.

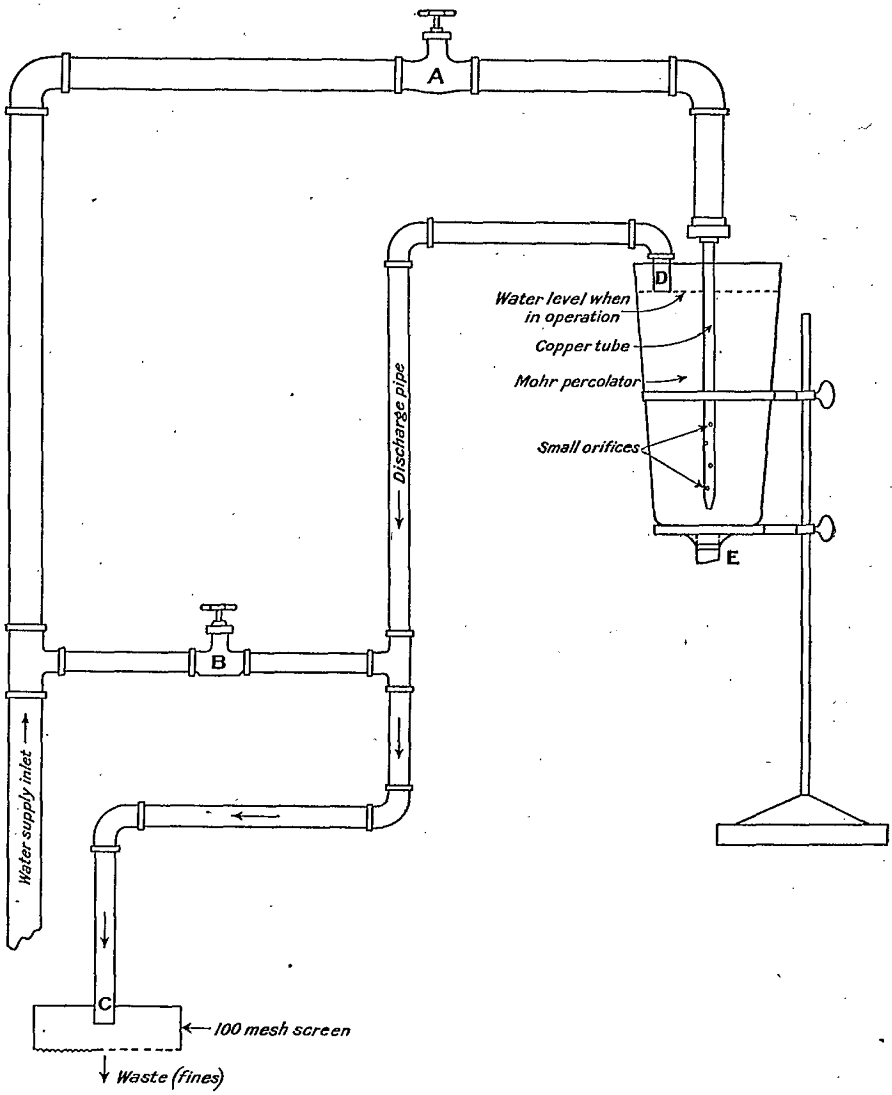

Fig. 8. Sketch of apparatus employed in the washing test referred to in Chapter V.

[1] Sample No.	Washed sand, grams	Washings retained on 100 mesh, grams	Fines (by difference) grams	Fines per cent
1860	159·7	11·2	29·1	14·5
1861	161·3	10·1	28·6	14·3
1865	130·6	16·0	53·4	26·7
2001	186·4	·8	12·8	6·4
2002	172·2	·7	27·1	13·5
2003	157·9	4·9	37·2	18·6
2006	143·9	·9	55·2	27·6
2011	150·5	15·8	33·7	16·8
2012	138·4	17·5	44·1	22·0
2013	171·8	6·7	21·5	10·7
2041	170·4	5·6	24·0	12·0
2201	191·2	2·9	5·9	2·9

[1] 200 gram sample used.

CHEMICAL ANALYSES

The chemical analyses shown in the following tables were made in the laboratories of the Mines Branch, Department of Mines, Ottawa, by Messrs. Baridon, Thompson, Sadler, and MacNiven. The following method was employed in making these analyses:—

The sample was fused with Na_2CO_3, after which it was digested with hot water and HCl, and evaporated to dryness on the water bath. The residue was moistened with a few drops of HCl, and hot water added and thoroughly stirred and boiled until all is in solution except the SiO_2, which is filtered off and washed with hot water. The filtrate is evaporated to dryness a second time, and treated in a similar manner. The second residue on the filter paper is added to the first, then dried, ignited, and weighed. The residue in the crucible was moistened with a few drops of H_2SO_4, and volatilized with HF, ignited, and weighed. The difference between this weight and the weight before obtained, represents the SiO_2 present in the sample.

The residue, after the HF treatment, was fused with Na_2CO_3 and then digested with hot water and HCl, and added to the original filtrates. From this combined filtrate the iron and alumina were precipitated with NH_4OH. This precipitate was filtered out, washed with hot water, dried, ignited, and weighed, and then fused with potassium bisulphate. The fusion was dissolved in a few c.c. of hot water and HCl, and the iron determined by titration with $KMnO_4$. The iron, calculated as Fe_2O_3, was subtracted from the total weight of the residue before fusion with potassium bisulphate, and the difference gives the amount of Al_2O_3 present.

The lime was precipitated from the iron and alumina filtrate with ammonium oxalate, then filtered, washed, dried, ignited, and weighed as CaO.

The magnesia was precipitated from the lime filtrate with microcosmic salt, and determined in the usual manner.

The loss on ignition was obtained by heating one gram of the sample until the weight was constant.

Tables IIA and IIB give the results of the chemical analyses

TABLE IIA

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada.

Sample No.	1704		1705		1706		1707		1708		1710	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	88·70	89·02	96·48	97·31	89·62	92·08	93·12	93·23	96·56	97·82	97·54	98·79
Fe_2O_3	0·94	0·36	0·66	0·16	0·85	0·44	0·81	0·26	0·29	0·10	0·24	0·08
Al_2O_3	4·42	4·09	0·32	1·14	3·73	3·30	2·57	2·71	0·90	1·00	0·28	0·26
CaO	0·25	0·09	0·25	0·18	0·26	0·25	0·22	0·19	0·10	0·10	0·10	0·06
MgO	0·24	0·23	0·20	0·06	0·15	0·11	0·20	0·13	0·12	0·04	0·10	0·06
Loss on ignition	0·13	0·29	0·20	0·39	0·69	0·58	0·35	0·40	0·19	0·28	0·14	0·20
Total	93·68	94·08	98·06	99·24	95·30	96·76	97·27	96·92	98·16	99·34	98·40	99·45

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1711		1712		1713		1714		1719		1720	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	65·90	....	94·80	....	89·70	....	97·08	....	97·01	97·92	97·40	98·19
Fe_2O_3	0·49	....	0·40	....	0·65	....	0·39	....	0·18	0·04	0·39	0·14
Al_2O_3	1·11	....	0·10	....	5·45	....	0·55	....	0·81	1·01	1·21	1·32
CaO	11·00	....	1·50	....	2·10	....	0·13	....	0·25	0·13	0·07	0·06
MgO	6·12	....	0·36	....	0·48	....	0·20	....	0·19	0·07	0·14	0·06
Loss on ignition	15·00	....	0·30	....	0·80	....	0·31	....	0·74	0·32	0·50	0·30
Total	99·62	....	97·46	....	99·18	....	98·66	....	99·18	99·49	99·71	100·08

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1724		1725		1727		1728		1731		1732	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2............	97·91	98·10	98·47	98·35	95·35	....	97·76	97·76	98·57	98·32	98·00	98·50
Fe_2O_3............	0·19	0·31	0·17	0·04	0·27	....	0·60	0·42	0·15	0·32	0·19	0·21
Al_2O_3............	0·80	0·39	0·25	1·25	1·11	....	0·54	0·98	0·38	0·61	0·16	0·79
CaO............	0·14	None	0·40	0·13	$CaCO_3$ 2·86	....	0·19	0·19	0·34	0·21	0·40	None
MgO............	0·12	Tr.	0·09	0·06	$MgCO_3$ 0·39	....	0·34	0·20	0·21	0·09	None	Tr.
Loss on ignition..	0·35	0·20	0·19	0·24	105°C. 0·24	....	0·56	0·38	0·49	0·38	1·10	0·10
Total........	99·51	99·00	99·57	100·07	100·22	....	99·99	99·93	100·14	99·93	99·85	99·60

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1735		1738		1739		1740		1741		1742	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2............	98·50	98·60	87·94	No. 1740 is washed sand from this property.	98·78	....	See No. 1738 for unwashed sample.	95·50	79·20	....	92·59	....
Fe_2O_3............	0·28	0·26	0·15		0·17	....		0·19	0·49	....	0·18	....
Al_2O_3............	0·34	0·34	0·54		0·09	....		1·21	0·61	....	0·08	....
CaO............	0·28	None	$CaCO_3$ 5·87		0·04	....		0·30	10·20	....	$CaCO_3$ 3·59	....
MgO............	0·11	0·31	$MgCO_3$ 0·44		0·10	....		0·57	1·26	....	$MgCO_3$ 0·51	....
Loss on ignition..	0·42	0·20	105°C. 0·29		0·42	....		0·30	8·00	....	105°C. 0·27	....
Total........	99·93	99·71	95·23	....	99·60	....	....	98·07	99·76	....	97·22	....

TABLE IIa.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1747		1750		1753		1754		1755		1809	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	98·77	98·90	98·07	98·30	98·80	....	96·30	See No. 1814 for washed sample.	95·72	....	96·54	....
Fe_2O_3	0·20	0·25	0·35	0·15	0·12	....	0·46		0·10	....	0·57	....
Al_2O_3	0·06	0·15	0·10	0·45	0·18	....	1·49		2·66	....	2·08	....
CaO	Tr.	....	0·03	....	....	....	0·20		Tr.	....	0·55	....
MgO	0·04	0·28	0·27	....	....	....	Tr.		0·10	....	....	....
Loss on ignition	0·19	0·10	0·32	0·40	0·40	....	1·10		0·24	....	0·10	....
Total	99·26	99·68	99·14	99·30	99·50	....	99·55	....	100·47	....	99·84	....

TABLE IIa.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1814		1815		1816		1817		1826		1827	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	See No. 1754 for unwashed sample.	99·09	99·20	98·30	92·40	See No. 1817 for washed sample.	See No. 1816 for unwashed sample.	94·40	93·65	96·40	89·45	93·10
Fe_2O_3		0·32	0·48	0·25	1·05			1·05	0·28	0·16	0·24	0·73
Al_2O_3		0·12	0·07	0·15	2·95			1·66	0·22	0·34	0·06	1·17
CaO		0·09	0·05	....	0·50			1·00	2·10	1·30	4·20	1·40
MgO		Tr.	....	0·04	0·29			0·18	0·22	0·21	0·29	0·21
Loss on ignition		0·20	0·20	0·40	0·70			0·40	1·70	1·00	4·20	1·70
Total	....	99·82	100·00	99·14	97·89	....	....	98·69	98·17	99·41	98·44	98·31

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1828		1833		1836		1837		1841		1842	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	98·30	98·30	91·90	93·40	91·30	96·30	92·40	94·90	41·15	....	81·00	82·20
Fe_2O_3	0·24	0·31	0·45	0·71	0·32	0·23	0·64	0·08	1·05	....	0·89	1·07
Al_2O_3	0·36	0·99	3·65	3·09	4·08	1·77	0·16	0·02	8·15	....	9·31	9·03
CaO	0·40	....	1·70	1·00	1·90	1·00	2·40	1·80	15·50	....	3·20	1·40
MgO	Tr.	Tr.	0·22	....	0·72	....	0·61	0·43	6·01	....	1·26	1·60
Loss on ignition	0·20	0·30	0·90	0·80	1·70	0·90	2·00	1·20	25·40	....	2·40	3·50
Total	99·50	100·10	98·82	99·00	100·02	100·20	98·21	98·43	97·26	....	98·06	98·80

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	1849		1850		1851		1860		1861		1865	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	85·30	....	80·20	....	80·20	....	95·95	96·80	98·75	98·10	98·15	98·40
Fe_2O_3	2·43	....	0·97	....	0·89	....	0·49	0·71	0·56	0·62	0·32	0·71
Al_2O_3	7·77	....	14·45	....	14·11	....	2·41	1·59	0·24	0·38	1·38	0·49
CaO	0·60	....	2·50	....	1·80	....	....	....	....	....	Tr.	....
MgO	0·56	....	0·32	....	0·25	....	....	....	0·15	....	Tr.	....
Loss on ignition	0·67	....	0·30	....	0·60	....	0·65	0·70	0·20	0·50	0·40	0·20
Total	97·33	....	98·74	....	97·85	....	99·50	99·80	99·90	99·60	100·25	99·80

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	2001		2002		2003		2006		2011		2012	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	....	97·90	....	98·50	....	98·40	....	97·60	96·76	....	97·48	....
Fe_2O_3	....	0·15	....	0·39	....	0·24	....	0·27	0·51	....	0·60	....
Al_2O_3	....	0·75	....	0·31	....	0·76	....	1·13	0·71	....	0·26	....
CaO	....	....	....	....	....	....	....	....	0·28	....	0·48	....
MgO	....	0·36	....	....	....	Tr.	....	0·36	0·27	....	0·41	....
Loss on ignition	....	0·30	....	0·50	....	0·30	....	0·20	0·30	....	0·44	....
Total	....	99·46	....	99·70	....	99·70	....	99·56	98·83	....	99·67	....

TABLE IIA.—*continued*

Chemical Analyses

Sandstones and Silica Sands—Eastern Canada

Sample No.	2013		2031		2041		2201	
	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed	Un-washed	Washed
SiO_2	99·00	....	....	98·24	95·08	....	97·76	....
Fe_2O_3	0·30	....	....	0·64	0·33	....	0·09	....
Al_2O_3	0·10	....	....	0·50	0·67	....	1·07	....
CaO	Tr.	....	....	Tr.	1·60	....	....	....
MgO	0·20	....	....	0·32	0·44	....	0·17	....
Loss on ignition	0·32	....	....	0·32	1·40	....	0·91	....
Total	99·92	....	....	100·02	99·52	....	100·00	....

TABLE IIb.

Chemical Analyses of Samples of Vein Quartz and Quartzites—Eastern Canada

Sample No.	1726	1749	1801	1802	1803	1804	1805	1806	1807	1808	1810	1811	1812	1818	1819
SiO_2..........	94·35	85·20	98·24	97·77	95·40	96·80	95·42	98·18	97·67	97·46	94·10	98·70	99·00	99·15	99·30
Fe_2O_3..........	1·74	1·58	0·24	0·19	0·35	0·32	0·42	0·24	0·22	0·18	0·45	0·32	0·41	0·24	0·14
Al_2O_3..........	2·56	6·87	1·52	1·27	1·65	1·13	0·68	1·34	1·93	1·09	0·70	0·33	0·14	0·01	0·01
CaO..........	0·20	2·10	0·10	0·10	0·86	0·60	0·80	0·14	0·13	0·08	2·10	0·40	0·15	0·50	0·10
MgO..........	0·14	0·58	0·16	0·17	0·75	0·43	0·62	0·25	0·13	0·14	0·94	....	....	....	Tr.
Loss on ignition	0·50	3·60	0·29	0·29	0·30	0·35	0·30	0·45	0·21	0·22	0·60	0·20	0·20	0·05	0·25
Total......	99·49	99·93	100·55	99·79	99·31	99·68	98·24	100·60	100·29	99·17	98·89	99·95	99·90	99·95	99·80

TABLE IIb.—*continued*

Chemical Analyses of Samples of Vein Quartz and Quartzites—Eastern Canada

Sample No.	1820	1821	1822	1824	1825	1829	1839	1840	1856	1859	1866	1868	2010	1802A
SiO_2....................	99·20	99·25	98·00	99·15	98·30	85·35	96·80	98·20	98·00	97·72	96·50	92·88	97·46	98·86
Fe_2O_3....................	·10	0·08	0·17	0·21	0·16	0·52	0·41	0·49	0·41	0·32	·60	0·84	0·24	0·26
Al_2O_3....................	0·03	0·02	0·18	0·29	0·04	0·68	1·60	0·61	0·29	1·08	1·90	1·84	0·54	n.d.
CaO....................	0·20	0·05	0·85	0·30	0·55	5·40	1·00	0·70	0·90	....	Tr.	0·54	0·24	n.d.
MgO....................	....	....	....	Tr.	....	0·46	0·36	0·29	0·21	0·32	0·14	1·68	0·62	n.d.
Loss on ignition........	0·22	0·20	0·40	0·15	0·40	5·30	0·30	0·20	0·10	0·38	0·76	1·40	0·58	n.d.
Total..............	99·75	99·60	99·60	100·10	99·45	97·71	100·47	100·49	99·91	99·82	99·90	99·18	99·68	99·12

Localities from which Samples were obtained

Sample No.	Material	Location
1704	Sandstone.......	Huntingdon co., Covey Hill, Que., on the farm of J. Louden, ½ mile to south of east and west road.
1705	Sandstone.......	Huntingdon co., on main road between Hemmingford, Que., and Vicars, Que., 7 miles west of Hemmingford.
1706	Sandstone.......	Huntingdon co., on east and west road, about one mile west of Maritana, Que., on farm of Joseph Foyer.
1707	Sandstone.......	Huntingdon co., Franklin Centre, Que., from bottom of each branch of Outarde creek, just north of bridge.
1708	Sandstone.......	Chateauguay co., on north and south road, 4½ miles south of Ormstown, Que.
1710	Sandstone.......	Huntingdon co., on east and west road, 2½ miles west of road from Hemmingford to Barrington, Que.
1711	Sandstone....... (calcareous)	Missisquoi co., St. Armand tp., on road to Mitchell's corners, one mile east of St. Armand sta., Que.
1712	Silica sand......	Huntingdon co., Franklin tp., lot 6, range III, on the farm of G. H. Brooks.
1713	Silica sand......	Huntingdon co., Havelock tp., from the farm of B. Roberts, 2½ miles west of Russeltown, Que., on the road to Stockwell, Que.
1714	Sandstone.......	Beauharnois co., general sample from the quarry of the Consolidated Sand and Supply Co., Melocheville, Que.
1719	Sandstone.......	Leeds co., centre of lot 8, con. VII, tp. of North Crosby, Ont.
1720	Sandstone.......	Leeds co., lot 15, con. I, tp. of South Crosby, and lot 29, con. V, tp. of Bastard, Ont.
1724	Sandstone.......	Lanark co., south half lot 11, con. VIII, tp. of North Burgess, Ont.
1725	Sandstone.......	Lanark co., south half lot 26, con. X, tp. of North Elmsley, Ont.
1726	Quartzite........	Leeds co., south half lot 22, con. II, tp. of Elizabethtown, Ont.
1727	Sandstone.......	Leeds co., from cliff on shore of St. Lawrence river, on south half lot 36, con. I, tp. of Elizabethtown, Ont.
1728	Sandstone.......	Frontenac co., lot 19, con. X, tp. of Loughborough, Ont.
1731	Sandstone.......	Frontenac co., lots 9 and 10, con. VII, tp. of Loughborough, Ont.
1732	Silica sand......	Frontenac co., lot 10, con. VII, tp. of Loughborough, Ont.
1735	Sandstone.......	Frontenac co., north half lot 16, con. VII, tp. of Pittsburgh, Ont.
1738	Sandstone.......	Haldimand co., lot 49, con. I, tp. of Oneida, Ont., run of pit, quarry Oneida Lime Co., Nelles Corners, Ont.
1739	Sandstone.......	Haldimand co., lot 49, con. I, tp. of Oneida, Ont., from outcrop just north of mill, Oneida Lime Co.
1740	Silica sand......	Haldimand co., lot 49, con. I, tp. of Oneida, Ont., crushed and washed sand as shipped from mill of Oneida Lime Co., Nelles Corners, Ont.
1741	Silica sand......	Haldimand co., lot 49, con. I, tp. of Oneida, Ont., material washed out of crushed sandstone and at present allowed to go to waste, Oneida Lime Co., Nelles Corners, Ont.
1742	Sandstone.......	Haldimand co., lot 49, con. I, tp. of Oneida, Ont., from north side of quarry east of mill, Oneida Lime Co., Nelles Corners, Ont.
1747	Sandstone.......	Frontenac co., north half lot 16, con. VII, tp. of Pittsburgh, Ont. This sample was taken about 300 yards north of sample No. 1735.
1749	Quartzite........	Inverness co., Skye mountain, Whycocomagh district, Cape Breton, N.S. Sample furnished by Dr. A. O. Hayes.
1750	Sandstone.......	Beauharnois co., from bed of St. Louis river, near grist mill of W. H. Robert, Beauharnois, Que.
1753	Sandstone.......	Carleton co., lot 5, con. I, Ottawa front, tp. of Nepean, Ont., quarry of Howard Rock, Bells Corners, Ont.
1754	Quartzite........	Labelle co., lots 5 and 6, range VI S., Amherst tp., Que., from the property of Canadian China Clay Co., St. Remi d'Amherst, Que.
1755	Silica sand......	Kings co., East tp., Prince Edward Island. Beach sand from beach 6 miles east of Souris, P.E.I.
1801	Quartzite........	Kamouraska co., Que. Long Pilgrim island. See map No. 563.
1802 } 1802A }	Quartzite........	Kamouraska co., Que. Long Pilgrim island. See map No. 563.
1803	Quartzite........	Kamouraska co., Que., from property of Joseph Lebris, Kamouraska, P.O., Que. See map No. 562.
1804	Quartzite........	Kamouraska co., Que., from property of Arsine Drapeau, Kamouraska P.O., Que. See map No. 562.
1805	Quartzite........	Kamouraska co., Que., from property of Louis Migneault, St. Pascal P.O., Que. See map No. 562.
1806	Quartzite........	Kamouraska co., Que. Great Pilgrim island. See map No. 563.

Localities from which Samples were obtained—Continued

Sample No.	Material	Location
1807	Quartzite........	Portneuf co., lots 5 and 6, con. I, SW., tp. of Chavigny, Notre Dame des Anges, Que.
1808	Quartzite........	Portneuf co., lot 1, con. V, SW., tp. of Montauban, lot 1, con. V, NE., tp. of Montauban, Notre Dame des Anges, Que.
1809	Sandstone.......	Lanark co., lot 5, con. X, tp. of North Elmsley, Ont., on the north bank of the Tay canal, 1½ mile SE. of Perth, Ont.
1810	Quartzite........	Lanark co., Ont., from the NE. ½ of property owned by T. B. Caldwell, situated 1½ mile NW. of Clyde Forks station, Ont.
1811	Quartzite........	Lanark co., from the SW. ½ of property owned by T. B. Caldwell, situated 1½ mile NW. of Clyde Forks station, Ont.
1812	Quartz...........	Labelle co., Buckingham tp., Que. General sample of quartz from Lievre river district, taken from stock pile in yard of Electric Reduction Co., Buckingham, Que.
1814	Silica sand.......	Labelle co., lots 5 and 6, range VI S., Amherst tp., Que. Sample of washed sand from experimental mill on the property. Canadian China Clay Co., St. Remi d'Amherst, Que. See sample No. 1754.
1815	Sandstone.......	Two Mountains co., parish of St. Canute, lot 130, Que., from property of Cascades Silica Products Co.
1816	Sandstone.......	Vaudreuil co., average sample of rock from old quarry of Cascades Silica Products Co., at Cascades Point, Que.
1817	Silica sand.......	Vaudreuil co., washed silica sand from old mill of Cascades Silica Products Co., at Cascades Point, Que.
1818	Quartz...........	Lanark co., lots 12 and 13, con. V, tp. of South Sherbrooke, Ont.
1819	Quartz...........	Lanark co., lot 6, con. VI, tp. of South Sherbrooke, Ont.
1820	Quartz...........	Lanark co., south half lot 9, con. IV, tp. of South Sherbrooke, Ont.
1821	Quartz...........	Frontenac co., lot 16, con. XI, tp. of Portland, Ont.
1822	Quartz...........	Frontenac co., west half lot 16, con. X, tp. of Portland, Ont.
1824	Quartz...........	Hastings co., east half lot 5, con. X, tp. of Madoc, Ont.
1825	Quartz...........	Hastings co., lot 3, con. IV, tp. of Elzevir, Ont.
1826	Sandstone.......	Haldimand co., north end of SW. ¼ lot 49, con. I, tp. of Oneida, Ont. Property of Consolidated Plate Glass Co.
1827	Sandstone.......	Haldimand co., average sample from south ½ lot 47, con. I, tp. of Oneida, Ont., and NW. ¼ lot 46, con. I N., tp. of North Cayuga, Ont.
1828	Sandstone.......	Haldimand co., lot 6, con. XIV, tp. of Walpole, Ont.
1829	Flint............	Welland co., lot 13, Lake Erie front, tp. of Bertie, Ont.
1833	Sandstone.......	Halton co., lot 3, con. VII, tp. of Nassagaweya, Ont., from the quarry of D. Robertson and Co., Milton, Ont.
1835	Sandstone.......	Thunder Bay dist., from outcrop on west bank of Wolfe river, 7 miles north of Dorion station, Ont., and about 50 miles east of Port Arthur, Ont.
1837	Sandstone.......	Thunder Bay dist., from quarry on Simpson island, Lake Superior, Ont., obtained from stone-cutting yard, Port Arthur, Ont.
1839	Quartzite........	Sudbury dist., from railway cut at mileage 65 from Sudbury, Ont., on the Algoma Eastern railway.
1840	Quartzite........	Algoma dist., from stock pile. Algoma Steel Corporation, Sault Ste. Marie, Ont. This rock is obtained from a quarry near Bellevue, a station on the Algoma Central railway, 20 miles north of Sault Ste. Marie, Ont.
1841	Sandstone.......	Pontiac co., tp. of Fabre, from Quebec shore of lake Timiskaming, directly opposite Haileybury, Ont.
1842	Sandstone.......	Old quarry near entrance of Black bay, lake Superior, Ont. Approximate location, 86° 31′ 05″ longitude, 48° 33′ 10″ latitude.
1849	Silica sand.......	Queens co., from Summerville beach, Port Mouton, N.S.
1850	Silica sand.......	Queens co., from the southwest beach, Port Mouton, N.S.
1851	Silica sand.......	Shelburne co., from the beach at Barrington bay, N.S.
1856	Quartzite........	Cape Breton co., from the stock pile in yard of Dominion Iron and Steel Co., Sydney, N.S. Material quarried on east coast of Cape Breton island.
1859	Quartz...........	Hastings co., lot 22, con. II, tp. of Dungannon, Ont., near Turriff station on Can. Govt. ry., 75 miles north of Trenton, Ont. Sample furnished by owner, T. D. Ledyard.
1860	Sandstone.......	St. John co., Lancaster tp., N.B., from outcrop on shore of Kennebecasis bay, to the west of Hastings cove, and north of Torryburn station on the Can. Govt. railway line from St. John to Moncton, N.B.

Localities from which Samples were obtained—Continued

Sample No.	Material	Location
1861	Sandstone.......	Labelle co., centre of lot 14, con. I, tp. of Templeton, Que. Surface sample over several acres.
1865	Sandstone.......	Albert co., N.B. Sample from vicinity of Hillsborough, submitted by Dr. W. J. Wright.
1866	Quartzite........	Kings co., N.S., from cliffs at east side of road at Whiterock, 12 miles southwest of Wolfville, N.S.
1868	Quartzite........	Thunder Bay dist., Ont. Sample taken by J. G. Cross, Port Arthur, Ont., from Woods location, Sibley township, one mile east of Silver Islet landing.
2001	Sandstone.......	Lanark co., lot 23, con. IX, tp. of Montague, Ont.
2002	Sandstone.......	Frontenac co., lot 19, con. I, tp. of Pittsburgh, Ont.
2003	Sandstone.......	Frontenac co., lot 20, con. I, tp. of Pittsburgh, Ont.
2006	Sandstone.......	Leeds co., lot 3, con. X, tp. of Lansdowne, Ont.
2010	Quartzite........	Carleton co., lot 23, con. VIII, tp. of Fitzroy, Ont.
2011	Sandstone.......	Lanark co., north half lot 26, con. X, tp. of North Elmsley, Ont.
2012	Sandstone.......	Beauharnois co., Que., from bed of St. Louis river, in quarry near grist mill of W. H. Robert, Beauharnois, Que.
2013	Sandstone.......	Carleton co., lot 19, con. III, tp. of March, Ont.
2031	Silica sand.......	Beauharnois co., sample of sand taken from loaded barge of material prepared at plant of Consolidated Sand and Supply Co., Melocheville, Que.
2041	Sandstone.......	Vaudreuil co., from lot 167 Cadastral, Isle Perrot, Que.
2201	Sandstone.......	Labelle co., north half lot 14, con. I, tp. of Templeton, Que.

TEST OF MATERIAL FOR SILICA BRICK

The results obtained from a number of tests of silicas in the Mines Branch laboratories, while yielding valuable information of a general character, tended to show that small laboratory tests of silica brick material do not give conclusive results, since samples so tested cannot be subjected to the prolonged heating at high temperature that the bricks receive in a commercial kiln. It is therefore advisable, in order to determine definitely the suitability of a material for the manufacture of silica brick, to submit a large sample for burning, to some commercial plant, and afterwards to place the bricks in a steel furnace crown, and notice their behaviour under actual working conditions.

The general results of the tests made show that not all forms of silica are suitable for the manufacture of refractory ware. Quartzite gives much better results than igneous quartz or sandstone. The sharp, splintery particles into which quartzite breaks on crushing form an interlocking bond which is essential to the strength of the finished brick. Bricks made from the rounded grains of sandstone or sand lack the proper strength for handling both before and after burning. Although vein quartz breaks down into splintery fragments on crushing, it is not desirable material to use, on account of its behaviour upon heating, since it generally shows considerable expansion, and destroys the bond produced in firing, making the bricks weak and crumbly. Some of the quartzites tested also showed a tendency to undue swelling under heat treatment.

For further information the reader is referred to the following reports:—

Mines Branch Summary Report 1916, pp. 114-116.
Mines Branch Summary Report 1917, p. 120.
Bull. No. 116, Bureau of Standards, Washington, D.C.

POTTERY TEST

Silica for use in white pottery bodies must be sufficiently free from iron-bearing and other impurities, so that there will be no discoloration in the finished ware. To test this quality, a small portion of each sample was ground to pass the 150-mesh screen, then placed in a fireclay scorifier, and levelled flush with the rim. A sample of high grade English potter's flint was prepared in the same way, as a standard for comparison. These samples were all burned together in a muffle kiln to cone 5 (1230°C.). After cooking, the colour and condition were noted, and samples were graded into three classes as follows:—

Class I.—Those placed in this class were fully as white as the standard, and in many cases whiter. They showed absolutely no black specks or discoloration and as regards colour, would, therefore, be entirely suitable for pottery use.

Class II.—The samples falling in this class were, in some cases, slightly off colour, and showed either a few spots of stain or a uniformly faint but decided tint. While not suited for use in the finest pottery bodies, it might be possible to employ them in the cheaper grades of pottery. It is also possible that a test of these samples, after washing, would show a sufficient improvement to warrant placing them in the first class.

Class III.—The samples placed in this class were all those which, for one reason or another, appeared hopeless for use as potter's flint. Many actually fused in the scorifier. In all cases they were so badly off colour that even washing would not be likely greatly to improve them.

Pottery Test

Class I	Class II	Class III	Remarks
	1,704		Faint greyish tint. Numerous minute black specks disseminated uniformly through the sample. Slightly cemented. Small shrinkage in volume.
	1,705		Slight cream tint. Occasional black specks. Powdery. No shrinkage.
		1,706	Light rose tint. Partially cemented. Slight shrinkage.
	1,707		Faint buff tint. Fused. Numerous minute black specks disseminated uniformly through the sample. Slightly cemented Small shrinkage.
1,708			Unwashed. White. Powdery. No shrinkage.
1,708			Washed. White Powdery. No shrinkage.
	1,710		Unwashed. Light cream colour. Powdery. No shrinkage.
1,710			Washed. White. Powdery. No shrinkage.
	1,712		Slight grey tint. Black specks disseminated through the whole sample. Slightly powdery. Small shrinkage.
		1,713	Light buff. Slightly powdery with only small shrinkage.
1,714			White. Slightly powdery. No shrinkage.
1,719			Unwashed. White. Powdery. No shrinkage.
1,719			Washed. White. Powdery. No shrinkage.
		1,720	Rose tint. Material powdery. No shrinkage.
1,724			White. Powdery. No shrinkage.
1,725			White. Slightly powdery. No shrinkage.
	1,726		Light grey tint. Black specks disseminated through whole sample. Slightly powdery. Small shrinkage.
	1,727		Slight cream tint. Slightly powdery. Small shrinkage.

Pottery Test—Continued

Class I	Class II	Class III	Remarks
		1,728	Cream yellow. Uniform colour. Powdery. No shrinkage.
		1,731	Light cream. Powdery. No shrinkage.
	1,732		Faint pink tint. Uniform colour. Powdery. No shrinkage.
1,735			White. Powdery. No shrinkage.
	1,738		Faint cream tint. Powdery. Small shrinkage.
		1,739	Light buff. Powdery. Small shrinkage.
1,740			White. Powdery. No shrinkage.
	1,741		Light cream tint. Iron stains developed to a small extent. Slightly powdery. No shrinkage.
1,742			White. Powdery. No shrinkage.
		1,747	Light rose tint. Uniform colour. Powdery. No shrinkage.
		1,749	Light buff, due to black specks developed uniformly throughout.
	1,750		Slight greyish tint. Few black specks disseminated through sample. Powdery. Small shrinkage.
1,753			White. Powdery. No shrinkage.
	1,754		Unwashed. Light cream colour. Powdery. No shrinkage.
1,754			Washed. White. Powdery. No shrinkage.
		1,755	Light buff colour. Black specks scattered throughout whole sample. Slightly powdery. Small shrinkage.
	1,801		Faint cream. Powdery. No shrinkage.
	1,802		Faint cream. Powdery. No shrinkage.
	1,803		Cream colour. Powdery. No shrinkage.
	1,804		Faint cream colour. Powdery. No shrinkage.
	1,805		Faint greyish tint. Powdery. No shrinkage.
	1,806		Faint cream colour. Powdery. No shrinkage.
1,807			White. Powdery. No shrinkage.
	1,808		Cream colour. Powdery. No shrinkage.
1,809			White. Powdery. No shrinkage.
1,811			White. Powdery. No shrinkage.
1,812			White. Powdery. No shrinkage.
1,814			White. Powdery. No shrinkage.
	1,815		Unwashed. Light cream colour. Powdery. No shrinkage.
	1,815		Washed. Slight greyish tint. Material powdery and no shrinkage.
		1,816	Light grey. Black specks disseminated through sample. Slightly cemented. Small shrinkage.
	1,817		Light cream. Powdery. No shrinkage.
1,818			White. Powdery. No shrinkage.
1,819			White. Powdery. No shrinkage.
1,820			White. Powdery. No shrinkage.
1,821			White. Powdery. No shrinkage.
1,822			White. Powdery. No shrinkage.
1,824			White. Powdery. No shrinkage.
1,825			White. Powdery. No shrinkage.
1,826			Unwashed. White. Powdery. No shrinkage.
1,826			Washed. White. Powdery. No shrinkage.
	1,827		Faint cream colour. Powdery. No shrinkage.
		1,828	Light rose tint. Powdery. No shrinkage.
	1,829		Light grey colour. Powdery. No shrinkage.
	1,833		Light buff. Black specks uniformly distributed throughout sample. Slightly cemented. Small shrinkage.
	1,835		Faint cream colour. Powdery. No shrinkage.
		1,837	Light buff tint. Slightly powdery. Black specks scattered throughout the whole sample. Small shrinkage.
1,839			White. Powdery. No shrinkage.
		1,840	Light rose tint. Powdery. No shrinkage.
		1,841	Light buff. Partially cemented. Small shrinkage.
		1,842	Cream grey in colour. Partially fused. High shrinkage.
		1,849	Grey in colour. Partially fused. Showed a small amount of shrinkage.
		1,850	Unwashed. Light grey colour. Partially fused. High shrinkage.
		1,850	Washed. Light grey colour. Partially fused. High shrinkage.
		1,851	Decided grey colour. Sample partially fused. Showed decided shrinkage.
	1,856		Light cream colour. Powdery. No shrinkage.

Pottery Test—Continued

Class I	Class II	Class III	Remarks
1,859	....	....	White. Powdery. No shrinkage.
....	1,860	....	Light cream tint. Slightly powdery. Small shrinkage.
....	....	1,861	Light rose tint. Powdery. No shrinkage.
....	....	1,865	Light buff. Powdery. No shrinkage.
....	2,001	....	Faint buff colour. Powdery. No shrinkage.
....	....	2,002	Light buff colour. Powdery. No shrinkage.
....	....	2,003	Light rose tint. Powdery. No shrinkage.
....	2,006	....	Faint cream colour. Powdery. No shrinkage.

CONCLUSIONS

Canada, at the present time, uses considerable quantities of silica, and, while much of the lower grades, such as that employed as a flux in metallurgical operations or for the manufacture of ferro-silicon, is obtained from domestic sources, a large part of the higher grades is imported from the United States, Great Britain and Belgium. Canadian consumers have always shown a willingness to use the domestic product when it can be obtained of a constantly uniform grade, and at a price as low as that of the imported material; but since only a few of the Canadian deposits have been operated, and these only on a small scale, the consumers have been forced to import silica, to insure constant supplies.

The chemical analyses are of first importance, in considering the results of the tests, and much information can be gained from them. In examining these results, however, to determine the suitability of a silica for a certain industry, the class of the material as well as the granulometric analysis should be taken into consideration.

The information gained from a study of the results of the tests shows that there are many deposits in eastern Canada which warrant further examination, and which, if properly operated, should yield silica fully equal to the material now imported.

CHAPTER VI

PROVING AND OPERATING SILICA DEPOSITS

INTRODUCTION

In making a search for a silica deposit, considerable preliminary work can be carried on advantageously in the office before investigation in the field is undertaken.

The various forms of silica, such as quartz, quartzite, and sandstone, occur under different conditions, and one should know beforehand the class of silica which is being sought. A district in which that form of silica is known to occur, or in which the rock formations are favourable to its occurrence, should be chosen for prospecting. A careful study of all available geological maps and literature of the area should be made in order to note the distribution of the form of silica suitable for the purpose required. Remoteness from rail or water transportation, as well as from markets, will eliminate many of these occurrences from the list of promising localities. When definite districts are finally decided on for examination, careful prospecting should be carried on over each area before deciding on detailed examination of any particular deposit. In this way, much valuable information, which could not otherwise be obtained, will be available when the detailed examination is commenced.

THE PROVING OF A DEPOSIT

Too great stress cannot be laid on the necessity for thoroughly proving a property before any large sum of money is expended for plant or equipment. It is far better to expend a few thousand dollars on testing a property, even though it should be eventually abandoned, than to find after a plant has been installed and the deposit opened up that the material is unsuitable, or that there is a smaller tonnage available than was originally estimated. Too many examples of such lack of foresight are to be seen. Therefore, before it is finally decided to develop a property, a careful examination of the deposit in the field should be made, as well as numerous tests carried out on the material in the laboratory or in a recognized testing plant, and a number of economic points taken into consideration.

EXAMINATION IN THE FIELD

An examination in the field should take into consideration at least the following points:—

Quality of the rock.
Uniformity of deposit.
Core drilling.
Stripping required.
Prospective operating conditions.

Quality of the Rock

The quality of the rock, such as its colour, hardness, etc., grain size, and uniformity of texture, will give an idea of the use to which it is best suited.

Uniformity of the Deposit

All outcrops should be thoroughly examined and variations in composition or texture carefully noted. Superficially, this can be done by noting character of the rock in each outcrop, and by trenching to remove the overburden between outcrops. A study of the surface of flat-lying beds of sandstone is of little value in determining the uniformity of a deposit. It is frequently the case in sandstone deposits that the character of the stone varies greatly in different beds—far more so than within any single bed as evidenced by different outcrops. If, therefore, an outcrop can be found exposing a number of beds, much valuable information can be obtained from a close examination. Such a section enables differences in beds to be carefully noted, which could not be done if the examination were confined to one bed.

Core Drilling to Determine Character of Rock at Depth

The information obtained from a surface examination should only be deemed sufficient in cases where operations are to be on a very small scale. Where any considerable tonnage is contemplated, the data gained from surface exposures should, if possible, be supplemented by systematic and extensive drilling. It is essential in prospecting with a drill, that one giving a core be employed, as it is necessary that samples of uncrushed rock be obtained in order to determine the depth of a deposit, and, where a sandstone is being tested, the thickness of the different beds; also to insure clean and representative specimens for examination and analysis.

Accurate records should be kept of every drill hole, and the location of each should be definitely shown on a map of the deposit. The elevation of the collar of each hole with respect to a fixed datum level, as well as its exact location from some permanent base, is necessary. If this information is not obtained at the time the hole is drilled, the value of the data may be useless at a later date, if the property is operated, by the hole becoming filled up and the original collar removed by quarrying.

The information obtained from the drill cores enables an estimate to be made of the quantity of rock available, as well as the quality of the material in the deposit. The number of holes required will depend on the size of the deposit and the amount of variation in quality of the rock in different holes, as well as the uniformity in the depth of the deposit.

Amount of Stripping Required

The composition and depth of the overburden should be determined, and note taken as to whether there is a suitable place available for the disposal of the stripping, so that it will not cover up any commercial rock, or have to be removed at a later date to enable expansion for buildings, etc.

Prospective Operating Conditions

The ease with which a deposit may be operated, and the possibility of obtaining a good working face in the quarry, are important factors to be noted in the field examination. It is also necessary to determine what areas are available for disposal of waste rock from the quarry, the location best suited for the erection of the mill or plant, and whether a sufficient water supply is available.

Another point to be determined is that of drainage, since if the quarry is so situated that it fills with water, necessitating pumping, the quarrying costs are increased. Other factors being equal, it is therefore better to select a deposit on a hill in preference to one which has to be quarried below the level of the surrounding country.

Economic Points to be Considered

In addition to the foregoing, there are several other matters of importance in the examination of a deposit.

Transportation facilities, either by rail or water, are essential, and the nearer a deposit is situated to either the better. If a siding can be constructed at small cost, or if a wharf is located on the property, from which the product can be loaded directly into boats, shipments can be made easily and cheaply. A wagon haul, however short, necessitates extra handling and increases the cost of operation.

The location of the deposit with respect to the larger markets is another important factor. This necessitates a study of the market requirements of the industries using material similar to that which it is proposed to produce from the deposit, as well as a thorough study of freight rates to all the market centres. A study of the requirements for the several industries enables an estimate to be made on which to base a calculation for the daily output required from the mill in order to meet all demands.

The power available for running the mill hoists and drills should be determined as cheap power is of great importance.

Another factor that sometimes influences the operation of a deposit is the labour market. In some of the rural districts it has been found that many of the neighbouring farmers are willing to work in the quarry part of their time, and although in that case the cost of labour may be a little lower, considerable time is lost, as the farmers will not work regularly, since they spend considerable time attending to their farms. Consequently, the availability of steady labour is an item that should be taken into account. Where such labour is obtainable, better work can be accomplished, and new and improved methods can be taught the quarrymen when they are working continuously instead of intermittently.

TESTS IN THE LABORATORY

In addition to the field examination, thorough laboratory testing of the samples collected should be made. The principal tests required are described in Chapter V.

When all available data have been collected an opinion can be formed as to the value of a deposit, and plans can be drawn up for the plant and equipment required; but, unless all the foregoing information is obtained and carefully studied, it would be an extremely hazardous speculation to proceed with the erection of a full-sized commercial plant.

THE EXPLOITATION OF A SILICA DEPOSIT

The methods employed in the exploitation of a silica deposit are generally of the simplest character. The operations consist of stripping, quarrying or mining, grading, and transportation to the mill for treatment. In cases where the rock is required as it comes from the quarry it may be loaded directly into railway cars for shipment.

STRIPPING

The amount of useless material, or overburden, resting on top of the deposit, has a great bearing on both the method of operating the quarry and its successful development. Where there is a rock covering over the silica rock, and also a deposit of drift material, stripping of the deposit is usually out of the question, and mining methods are employed, but where the overburden consists of unconsolidated material, it is more economical to remove this and to recover the silica by open quarrying. In most of the localities examined the overburden resting on the deposits was very light, many of the deposits being bare, so that the cost of stripping would be, generally, a small item in the cost of operation.

The methods of stripping in general practice come under the three following heads:—

Stripping by— (1) Hand.
(2) Horse scrapers.
(3) Steam shovel.

Hand Stripping

It is only in very small quarries, or where the material to be stripped is very light, that the work is done by hand. When the work is done in this way the overburden is shovelled into carts and hauled to the nearest dumping ground, or it is allowed to cave into the quarry and is then sorted from the silica and carted away. This practice is to be condemned, as the loose waste becomes mixed with the white rock and impairs its value.

Horse Scrapers

A method that has been employed successfully in a number of cases is to remove the overburden by horse scrapers, similar to those used in railway construction work. Where the overburden is unconsolidated and the top of the silica beds are flat-lying this method is very satisfactory.

Steam Shovel

In larger quarries, where the overburden is of considerable thickness, it is sometimes found more economical to employ a steam shovel for stripping. This method, however, can only be used economically where work is being carried out on a large scale. In very few of the deposits is the overburden of sufficient thickness to warrant the initial cost of a steam shovel equipment.

QUARRYING OR MINING

Consideration of the best means of exploitation of silica deposits is a matter which has not hitherto been given the attention it deserves. The cost of mining silica is generally excessive as compared with the selling price, and it is only in exceptional cases that mining operations are resorted to. The method usually employed, therefore, is to recover the rock by quarrying. This has a number of advantages over underground mining:—

(1) Low cost. The rock is recovered with the least expense.

(2) Easier supervision. A better idea can be obtained of the material that is being quarried.

(3) Better ventilation. The men are always working in the open air.

(4) Easier handling of the rock. Better chance for disposal of waste rock.

(5) No timbering is necessary. All the material can be extracted, since no pillars have to be left.

Its disadvantages are few, the principal one being the exposure of the workmen to all kinds of weather, thus hindering the work.

QUARRY METHODS

The operations by means of which silica is quarried are drilling, blasting, grading, and transportation. A consideration of these operations involves a study of the equipment needed to insure the rock being won with the greatest efficiency.

To obtain the maximum efficiency in the operation of a quarry, the general layout of the whole plant as well as of the quarry has to be taken into consideration. The location of the mill and other buildings having been settled, the best method of operation of the quarry to permit of the rock being delivered to the mill, or railway, with the least amount of handling can be decided.

Whenever possible, it is advisable to obtain a level floor in the quarry to facilitate the laying of narrow gauge tracks for the removal of the rock to the mill in small cars. The higher the face of the quarry the better, since the cost of stripping per cubic foot of rock recovered decreases with the height of the face. If, however, to obtain a high face, it is necessary to have the floor of the quarry much below the drainage level of the surrounding country, it may perhaps be advisable to remove the rock in a series of benches in order to avoid trouble from water and facilitate the handling of the material to the mill. Where the floor of the quarry is below the general level, hoisting by derricks or an inclined trestle has to be resorted to, thus increasing the cost of production.

Drilling

The best means of drilling the rock preparatory to blasting is by means of tripod drills and jackhammers, and these may be operated either by steam or air, whichever is the more economical. The former is a reciprocating drill mounted on a tripod such as is in common use in mining operations. The jackhammer is a non-reciprocating drill, used without a tripod and employing hollow steel bits through which the exhaust passes and blows the cuttings from the hole. It is held by the operator and is provided with an automatic rotating device. This type of drill can be operated dry, while the tripod drill requires water to be supplied to the drill hole to remove the cuttings.

In small quarries drilling may be done by hand, but this method is slow and expensive and is not to be recommended in large scale operations.

Blasting

The choice of explosives depends on the physical properties of the stone. Black blasting powder is generally employed where the rock is to be used in large blocks without further crushing, but where the rock has to be crushed, it is advisable to use a higher grade dynamite in order to shatter the rock as much as possible. In some quarries, where large masses are broken at a single blast, a charge consisting of both black powder and dynamite is found to give the best results. The large blocks are then further broken up by means of bulldozing.

Grading

In many deposits of silica it is necessary to carry on a crude sorting of the rock in the quarry in order to prevent any badly stained stone going to the crusher. This can be done by the men loading the cars for the mill. The waste material should be transported to the permanent dump where it will not interfere with any further expansion of the quarry, or piled in a convenient place if there is any possibility of using it at a later date.

Transportation

Many methods are employed for transporting the rock to the mill. Wherever possible, it is advisable to employ a system of radiating tracks laid on the floor of the quarry, which reach to all parts of the face. Small dump cars, holding from 1 to 2 tons each, can then be used, and these can be filled at the face and pushed by hand, or hauled by horses to the mill. If the quarry is on an extensive scale, small locomotives may be installed and several cars may be hauled at a trip. Horses and dump carts are occasionally used, but this method is slow, and is not economical where a large tonnage has to be handled.

When the crusher is above the level of the floor of the quarry it is necessary to have an inclined trestle up which the cars are hauled to dump them into the bin over the crusher. If the crusher mouth is on the same level as the floor of the quarry the incline can be dispensed with.

If the floor of the quarry is at any considerable depth below the surrounding country it is necessary to employ derricks or other means of hoisting, in order to place the rock either directly in the crusher, or in cars for transportation to the mill.

THE SILICA MILL AND PLANT

The preparation of silica in a form suitable for the industries necessitates, in most cases, a mill for the treatment of the rock as it comes from the quarry. The design of such a mill will be governed largely by the class of material which it is proposed to manufacture.

The ideal layout is one where gravity can be employed in moving the material from one operation to another, and in which all handling is done automatically. The nature of the ground available for the mill site will have an important bearing on the design, and this should be chosen in such a manner that additional mill units can be added when required, without interfering with the original installation. Most of the large machinery companies manufacturing silica milling machinery recommend the unit type of mill, and the most modern mills are built in this manner. The advantage of this is obvious, since one complete unit can be installed and put into operation when the deposit is first opened and additional units added when needed, without interfering with the operation of the first unit.

MILLING

Several of the industries employ silica crude, as obtained from the quarry or deposit, but by far the greater part of the silica used has to be put through a number of milling operations before it is in a form suitable for the market. These processes consist of coarse and fine crushing, screening, washing, drying, pulverizing, bolting, and air or water floating. Some of the industries require the milling to be carried through all these stages, but marketable products may be produced by employing any combination of these operations.

In milling two methods are in use, namely, the wet and dry methods, the one employed being dependent on the nature of the crude rock, and also on the nature of the product desired. The wet method is the one more commonly adopted.

Wet Method of Milling

Coarse Crushing

For nearly all uses, silica requires to be crushed to sizes finer than that produced in the quarry. The material as it comes from the quarry

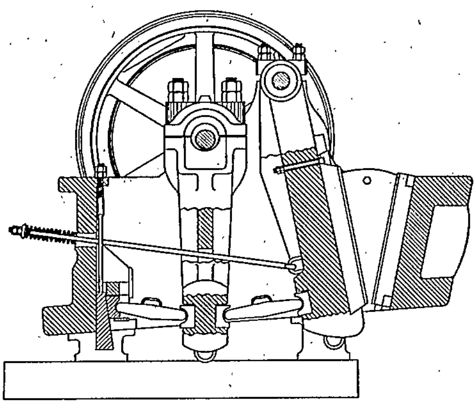

Fig. 9. Vertical section of rock crusher, Blake type. (Phillips and McLaren Company, Pittsburgh, Pa.)

is dumped upon a grizzly, consisting of a number of steel rails placed parallel to each other, two inches apart. These rails are inclined and the coarse material slides down them into a crusher, while the fines pass through the spaces directly into the fine crushing apparatus. A stream of water is played on the rock as it is dumped on the grizzly. For coarse crushing, either the jaw type or gyratory type of crusher is employed. The jaw crusher of the Blake type is most frequently used for smaller units. Figure 9 shows an elevation of a Blake rock crusher as built by the Phillips and McLaren Company, Pittsburgh, Pa. A 20×12 inch crusher of this type will handle from ten to forty tons of rock per hour according to the hardness of the rock, and will reduce it to about two inch diameter. Twenty-five horsepower is required to operate a crusher of this size, when running at full capacity.

Fine Crushing

The material passing through the primary crusher and that which was fine enough to go through the spaces in the grizzly is fed into the fine grinding apparatus. For fine grinding several types of machine are employed, the principal being rolls, disintegrators, and chaser mills.

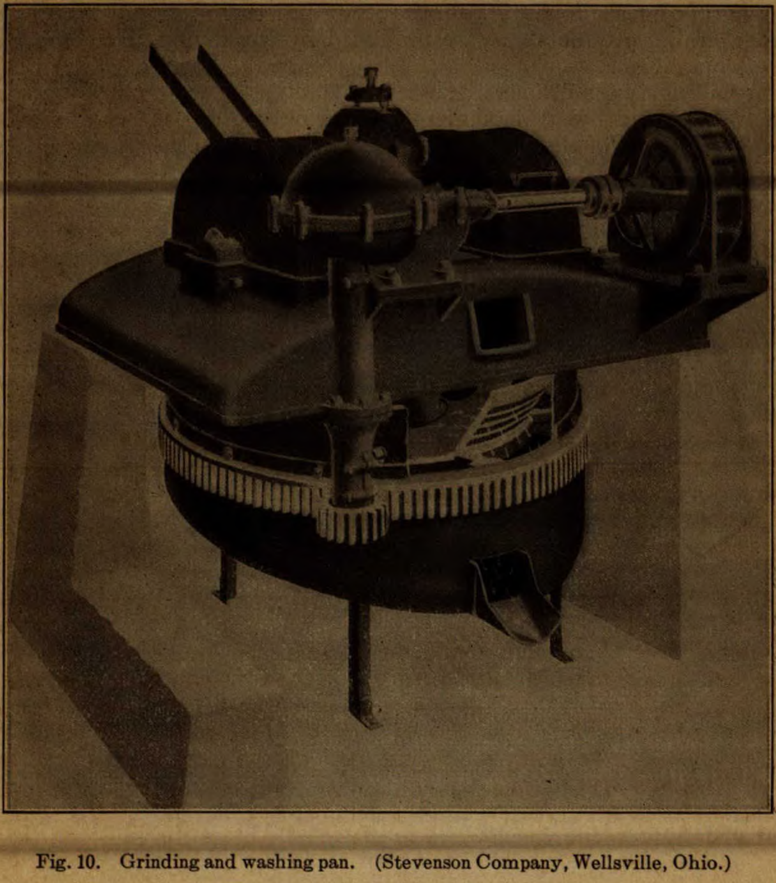

Fig. 10. Grinding and washing pan. (Stevenson Company, Wellsville, Ohio.)

The common type used is the chaser mill, or grinding pan. Figures 10 and 11 show two types of this machine. These mills consist of circular steel pans, varying in diameter from 6 to 9 feet, in which two heavy steel rolls revolve, the pan itself being stationary. Water is fed into the pan along with the material from the crusher, which is crushed between the

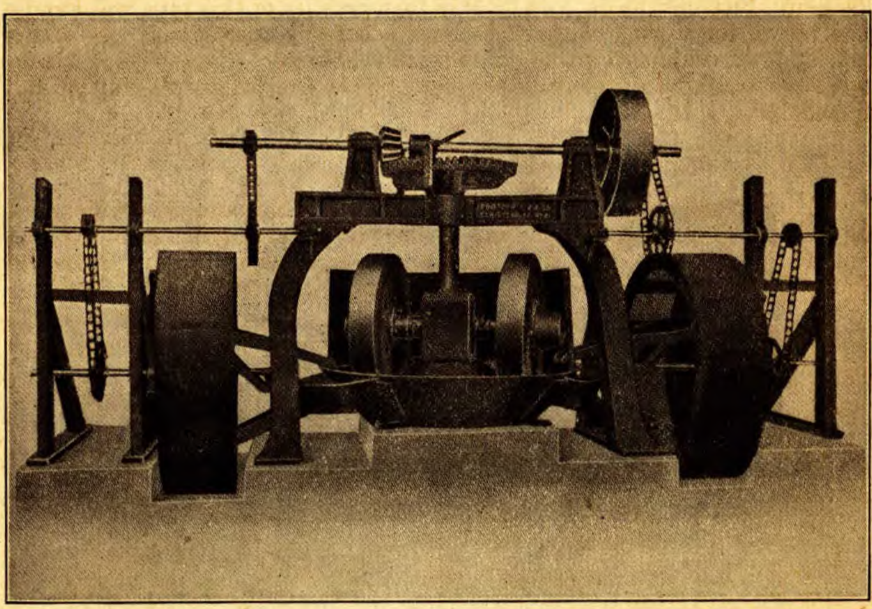

Fig. 11. Standard 8-foot chaser mill and screens. (Lewiston Foundry and Machine Company, Lewiston, Pa.)

rollers and the bottom of the pan. The side of the pan is provided with screens to allow the material when sufficiently reduced in size to pass through to the revolving screens.

The capacity of one of these mills varies according to the size of the pan, the hardness of the rock, and the fineness to which it is crushed. A pan 9 feet in diameter will handle from 100 to 275 tons of material per day of 10 hours, and requires 35 horse-power to operate. In a pan of this diameter the rolls have a 12-inch face and weigh about 6,000 pounds each.

Screening

On each side of the chaser mill, or in such position as is most convenient, revolving screens are placed into which the material from the grinding pan is fed. See Figure 11. These screens are 7 to 8 feet in diameter and have a face of from 2 to 3 feet. Brass wire screening of from 14 to 16 mesh is used for the screens. They are generally operated from the same shafting that operates the chaser mill.

The oversize from these screens is returned to the chaser mill for further grinding, while the undersize material passes through the screens to the log washers.

Washing

Two types of sand washers are shown in Figures 12 and 13. They consist of inclined boxes, or troughs from 10 to 12 feet in length, and from 18 to 22 inches inside diameter, in which a revolving screw elevator is placed. The material from the revolving screens is fed into the lower end of the trough, and water at the upper end. The screw conveyer carries the sand up the trough against the stream of water, which carries away with it the clay and finer material present in the sand. In the Lewiston type of

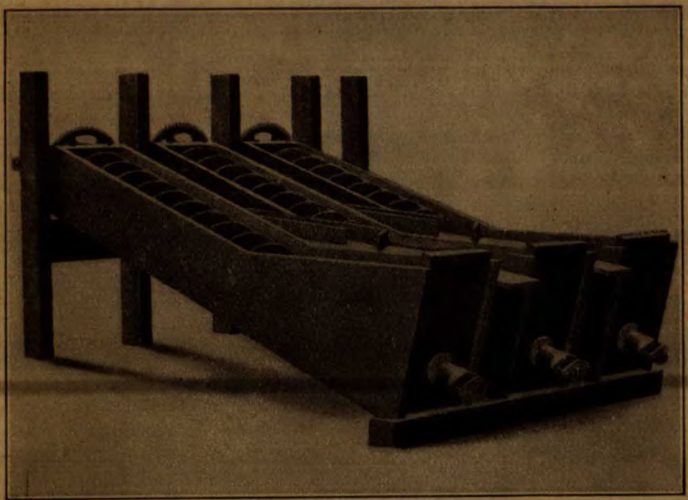

Fig. 12. 18 in. x 12 ft. log washers. Lewiston Foundry and Machine Co., Lewiston, Pa.

washer shown in Figure 12 the troughs are arranged in parallel alignment. The material in this type of washer is sluiced from the upper or discharge end of the first trough to the lower end of the second, and so on through the three troughs, the washed material being finally discharged from the upper end of the third. In some mills the washers are arranged in tandem in such a manner that the material is discharged directly from one washer into the lower end of the next.

The Stevenson type of duplex washer is a departure from the usual practice in that two washing screws are employed to each tank where one has been the regular practice. This saves one tank side to each set and is said to allow a better channel for the drainage of water down the centre. These machines can also be arranged parallel, or tandem, as required.

The amount of water required for the chaser mill, and for the log washers, is from 150 to 600 gallons per minute. It is therefore necessary to have an abundant water supply available for a mill of this type.

Drainage and Drying

If the sand is not to be dried, it is ready for shipment as it comes from the log washers. It is better practice, however, in this country to dry the sand, since, if shipped in the wet state, the mill and plant can only be operated during the summer months, since in the winter the wet sand would freeze solid in the cars during transit. When the sand is to be dried it is carried from the log washers on a belt conveyer to drainage piles and the

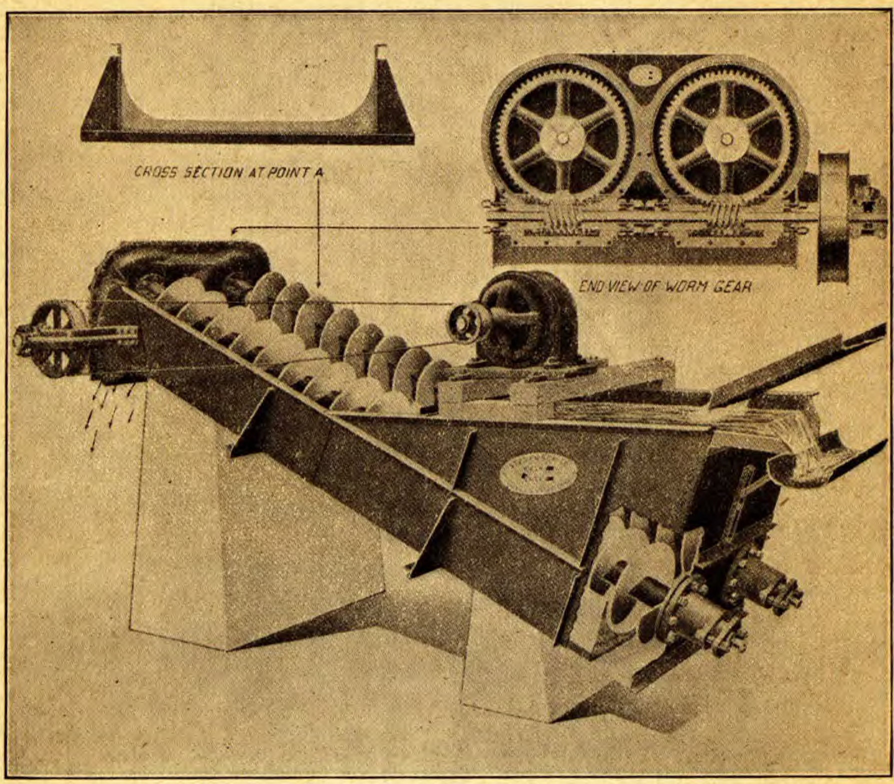

Fig. 13. Duplex log washer. (Stevenson Company, Wellsville, Ohio.)

excess water allowed to drain off. These piles build up in cone shape, and arrangements are such that the material may be discharged from the belt at a number of points, thus enabling several cones to be built up.

When the surplus water has drained away from the sand, which is usually left for 24 hours before being touched, the material is passed through some type of dryer. Figures 14, 15, and 16 show types of dryers in general use.

Direct heat dryers and steam dryers are the two types most frequently found in practice. An example of the direct heat dryer is the Cummer Salamander type, manufactured by F. D. Cummer and Co., Cleveland, Ohio. Figures 14 and 15 are longitudinal and end sectional elevations of a

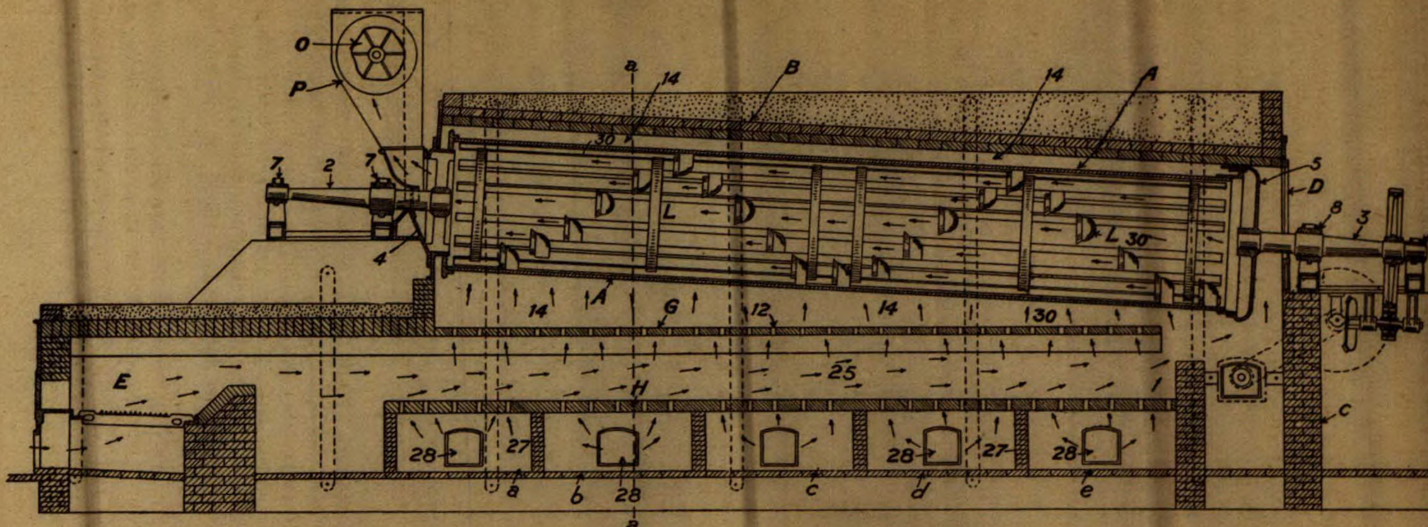

Fig. 14. Cummer dryer, side elevation.

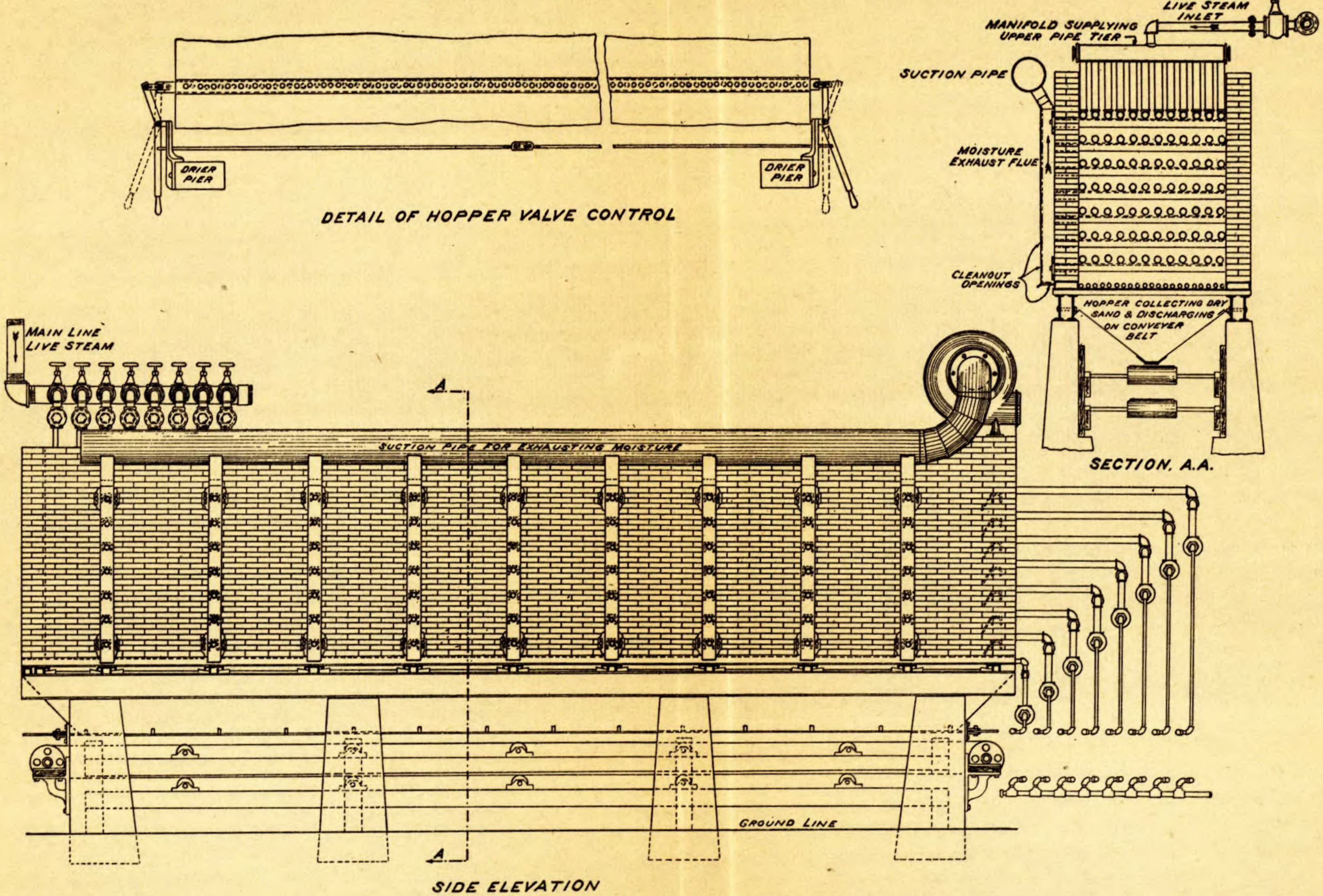

Fig. 16. 60-ft. steam dryer. (Lewiston Foundry and Machine Company, Lewiston, Pa.)

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complete dryer built by this company, consisting of a revolving steel cylinder enclosed in a brick chamber and supported at the ends by extended trunnions projecting from the spiders at the ends of the cylinder, or carried on steel tires, which run on steel rolls, at each end. Hooded cylinders are let into the wall of the cylinder to enable the heated gases to enter the interior. The cylinder also has lifting blades, placed longitudinally on the inside, for lifting and tossing the material. A fan in the exhaust flue creates a strong suction that quickly carries off the evaporated moisture.

In this type of dryer the wet material is fed continuously into one end, and while in the cylinder is tossed and tumbled about by the lifting blades as the cylinder revolves, gradually passing down the dryer until discharged in a dry condition at the opposite end. The heated gases of combustion

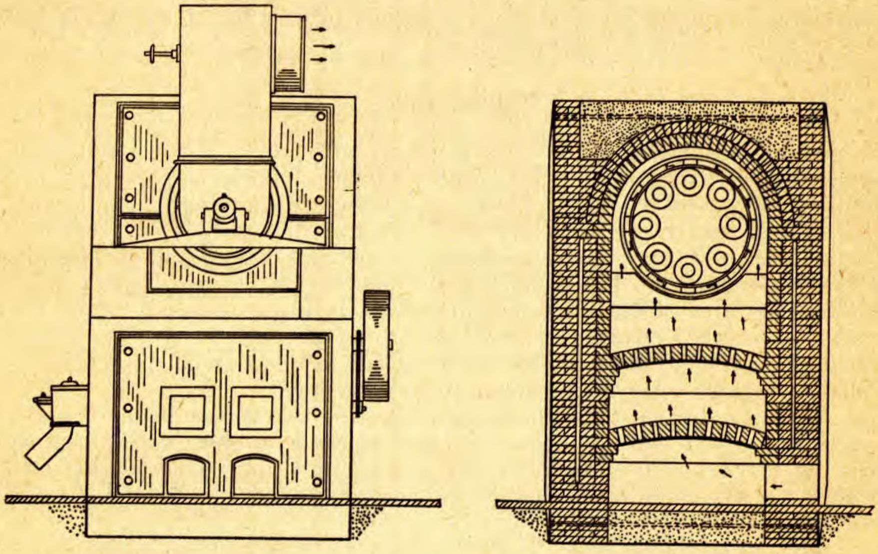

Fig. 15. Cummer dryer, section and end elevation.

from the furnace chamber are drawn through a perforated arch into the heating chamber surrounding the cylinder, and thence pass into the cylinder either through the hooded inlets or the rear end. These gases coming in contact with the wet sand soon remove the moisture present, and both the evaporated moisture and spent gases are drawn off rapidly by the exhaust fan.[1] About 10 h.p. is required to operate this dryer.

When such a dryer is employed on sand to be used in glass manufacture, coke should be used as fuel, since it has been found that when soft coal is employed, a coating of carbon is formed on the sand grains which is detrimental when the sand is used for high grade glass.

A steam dryer (see Figure 16) is of simpler construction and has the advantage of keeping the sand away from contaminating gases.

[1]For a fuller description of this type of dryer the reader is referred to Gypsum in Canada, by L. Heber Cole. Report No. 245. Mines Branch, Dept. of Mines, Ottawa, 1913, pp. 130-133.

The usual type of steam dryer consists of a concrete or brick bin with sloping bottom discharging onto a gutter belt elevator. In this bin, and running lengthwise, are placed a number of steam pipes, arranged in tiers one above the other and placed closer and closer together towards the bottom.

The moist sand is discharged onto the top tier of pipes from a belt conveyer, and it is held there by the moisture until the grains free themselves, and they then trickle down through the staggered arrangement of the pipes. When the sand reaches the bottom it is removed from the hopper-shaped bottom by means of a belt conveyer in a perfectly dry condition. The heat for evaporation of the moisture is supplied by passing steam through the pipes. An exhaust fan removes the evaporated moisture from the dryer.

The sand, after drying, is generally screened through screens ranging from 14 to 20 mesh, after which it is placed in bins for shipment, or fed to the pulverizers for fine grinding.

Pulverizing

Where material is required to be finely ground for potter's flint it is generally pulverized dry, in tube mills similar to those employed in the grinding of cement clinker. These tube mills are lined throughout with silica blocks and carry a charge of 10 tons of flint pebbles as grinders. The capacity of a mill varies according to the rate of feed and the degrees of fineness required. The usual charge, however, is about 5 tons of dried sand. The sand flows in a constant stream into the feed end, while the finished product is discharged at the lower end, through a perforated plate which prevents the discharge of the pebbles. The material discharged is tested at regular intervals to insure proper fineness.

A common method in practice is to employ two tube mills and to use one to reduce the sand to about 80 mesh and the second for the finished grinding to 120 mesh or finer. It has been found that by employing this method a greater quantity can be put through the two mills and a more uniform product obtained.

After pulverizing, the product should be screened to remove any particles of pebble or other foreign material, after which it may be shipped in bulk or bags.

Dry Method of Milling

In some plants the rock coming from the quarry, is crushed and milled in the dry state, but this system is rapidly being replaced by the wet method. It has been learned in many countries, at considerable expense, that the dry method is not adapted to the production of silica sand, since such a plant can only be operated under the most favourable weather conditions. Even when the weather is dry, the capacity is small, and if the rock is at all wet, the output is negligible. A plant of this nature can therefore be operated only in the summer months.

When a dry grinding plant is installed the operation is very similar to the wet method, with the exception of the log washers. The material from the screens after crushing in the dry pan or chaser mill is either shipped directly, or put through the ball mills and screened.

The conditions in Canada are such that the wet method of milling is preferable in order to insure a large output continuously the whole year.

Capacity and Cost of Plant

Very little information can be given as to the capacity of a mill producing silica sand, since this will vary with the hardness of the rock being crushed and the amount of loss due to fines. One unit, consisting of crusher, 9-foot chaser mill and screens, log washers consisting of four right hand and four left hand washers and steam dryer, will produce from 75 tons to 450 tons per day of ten hours. These figures are actual production figures obtained in mills on this continent, and the production will vary anywhere between these limits.

The cost of such a unit also varies greatly according to the type of machinery installed and the operating machinery employed.

In a letter from the Lewistown Foundry and Machine Co., Lewistown, Pa., the estimated cost of a unit plant, consisting of the machinery noted in the preceding paragraph is given as follows:—

> A complete plant of this kind with an improved method of handling the drained sand in the drainage building, what we term as a floor loader, and including steam dryer and boiler completely erected, which was covered by a most recent estimate made a few weeks ago, comes to $59,000. An addition to this plant of a pulverizing system, consisting of a pebble mill, would add an additional $18,000.

It should be understood that to these prices duty would have to be added on machinery imported into Canada.

The Phillips and McLaren Co., Pittsburgh, Pa., quote the approximate price of $5,500 f.o.b. cars Pittsburgh, Pa., for one unit consisting of 20 inch ×12 inch rock crusher, 8-foot wet grinding pan, two 7-foot diameter by 30-inch face revolving screens and 4 feet 18 inch diameter sand washing screws.

The Stevenson Company, Wellsville, Ohio, give approximate cost of a 100 ton per day unit as $6,025 f.o.b. cars Wellsville, Ohio. This unit consists of 20 inch×12 inch jaw crusher, 9-foot sand reduction and washing pan, 8 feet×3 feet revolving screen and one duplex screw washer.[1]

To erect a mill in Canada for the preparation of silica sand, and powdered silica, consisting of crusher, chaser mill, screens, log washers, dryer and pebble mill, together with the necessary conveyers, elevators, shafting and driving machinery, complete and ready to operate, would cost in the neighbourhood of $100,000.

[1]It should be understood that all these figures are as of the time given (May, 1922), and subject to constant changes in price of material and supplies.

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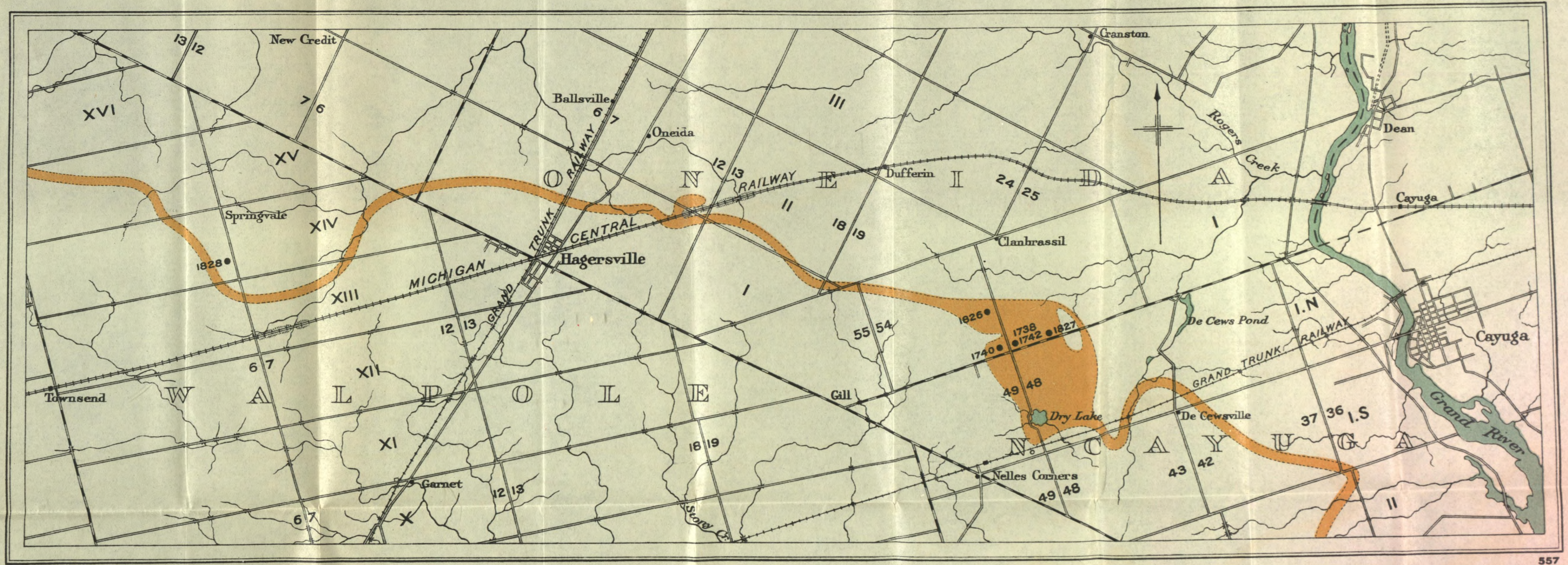
MINES BRANCH
JOHN MCLEISH, DIRECTOR.

1923



H. E. Baine, Chief Draughtsman.

DISTRIBUTION OF SANDSTONE
IN THE DISTRICT OF
NELLES CORNERS
HALDIMAND COUNTY, ONTARIO

Scale: 1 Mile - 1 Inch

Sandstone areas

●1826 *Location of samples referred to in report.*

Note:—Sandstone boundaries compiled from maps of Geological Survey, Canada, and field notes by L. H. Cole.

Base map, Dept. of Militia and Defence.

CANADA

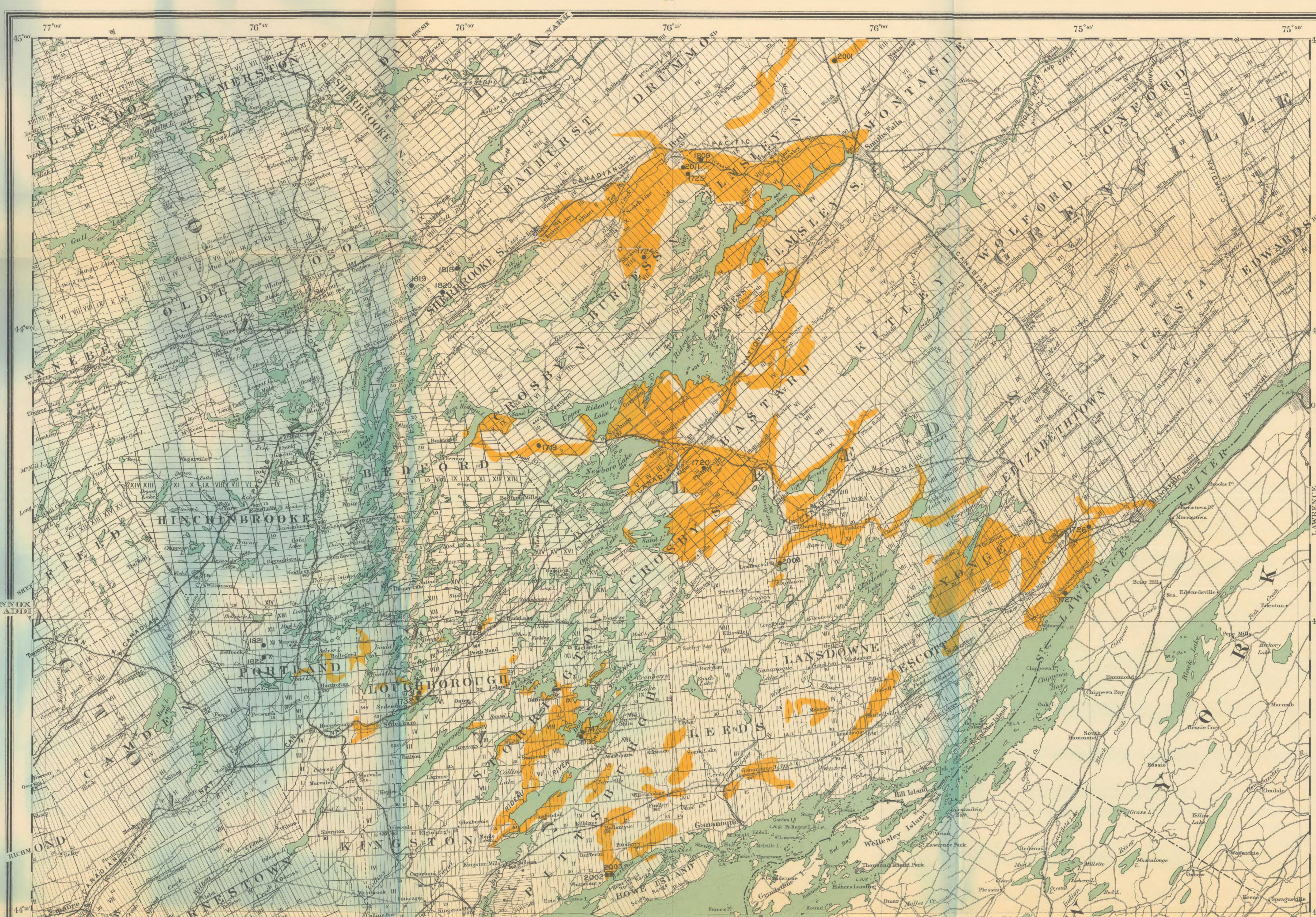
DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN MCLEISH, DIRECTOR.

1923



H. E. Baine, Chief Draughtsman.

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DISTRIBUTION OF SANDSTONE

NORTH OF THE ST LAWRENCE RIVER

BETWEEN

KINGSTON AND BROCKVILLE

ONTARIO

Scale: 3·95 Miles to 1 Inch

1 0 1 2 3 4 5 6 7 8 9 10 11 12

Sandstone areas

● 1747 *Location of samples referred to in report.*

Note:--Sandstone boundaries compiled from maps of Geological Survey, Canada, Department of Mines, Ontario, and field notes by L. H. Cole.

Base map from plate of the Department of the Interior.

CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

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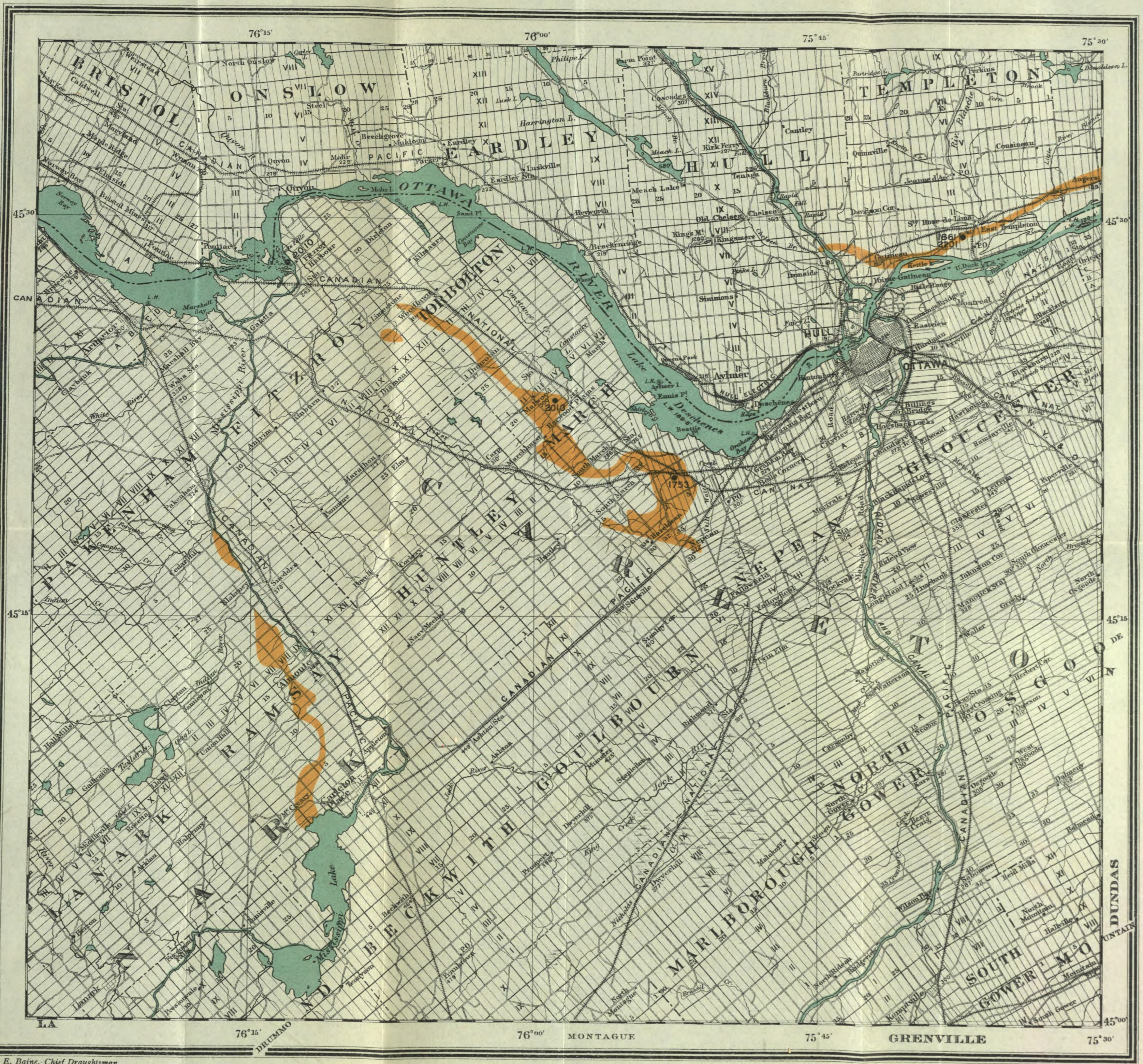
1923



H. E. Baine, Chief Draughtsman.

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DISTRIBUTION OF SANDSTONE

IN THE VICINITY OF

OTTAWA, ONTARIO

Scale: 3·95 Miles to 1 Inch

0 1 2 3 4 5 6 7 8 9 10

Sandstone areas

●1753 Location of samples referred to in report.

Note:—Sandstone boundaries compiled from maps of Geological Survey, Canada, and field notes by L. H. Cole. Base map from plate of the Department of the Interior.

CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER
MINES BRANCH
JOHN MCLEISH, DIRECTOR.
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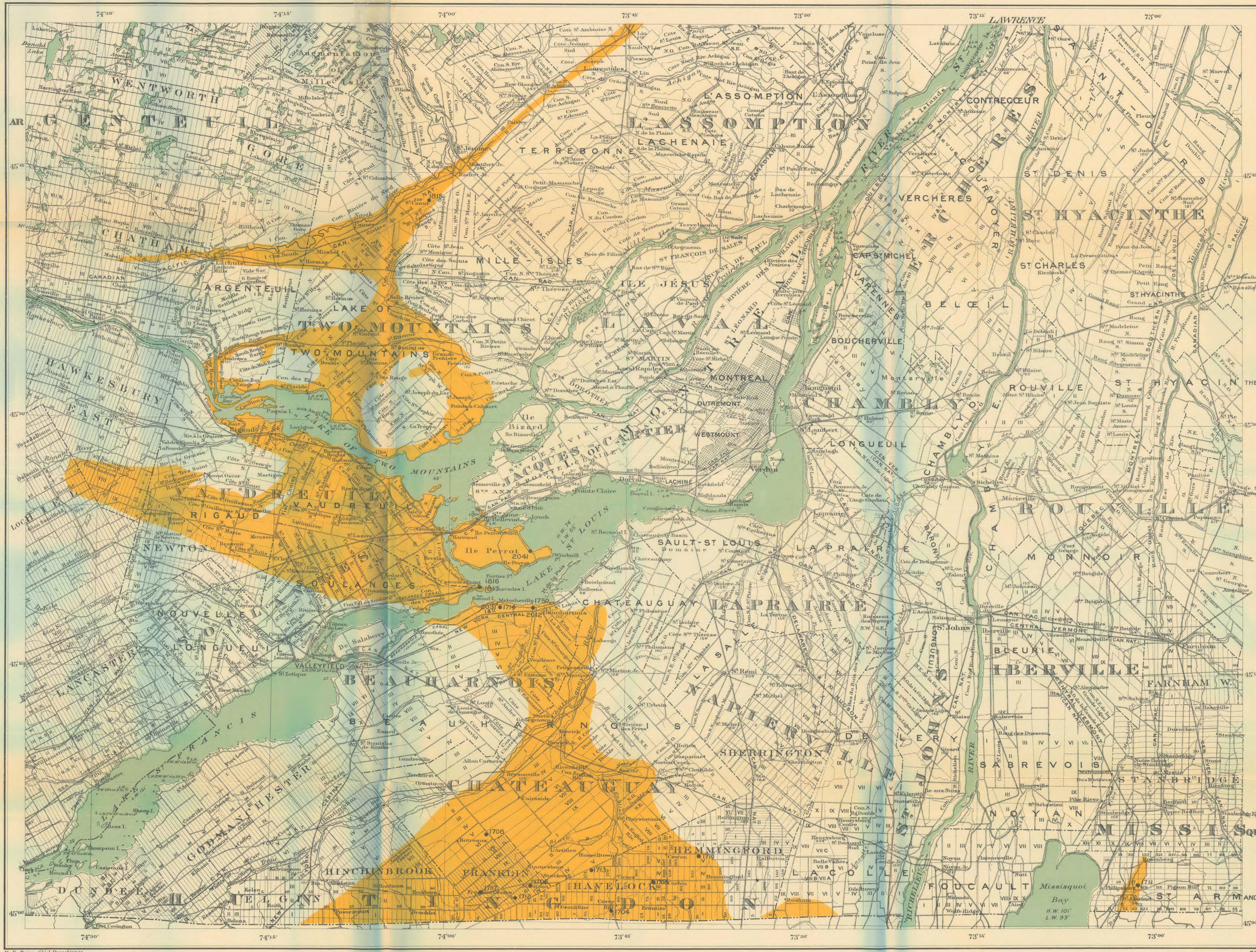

H. E. Baine, Chief Draughtsman.

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DISTRIBUTION OF SANDSTONE
IN THE VICINITY OF
MONTREAL, QUEBEC

Scale: 3·95 Miles to 1 Inch

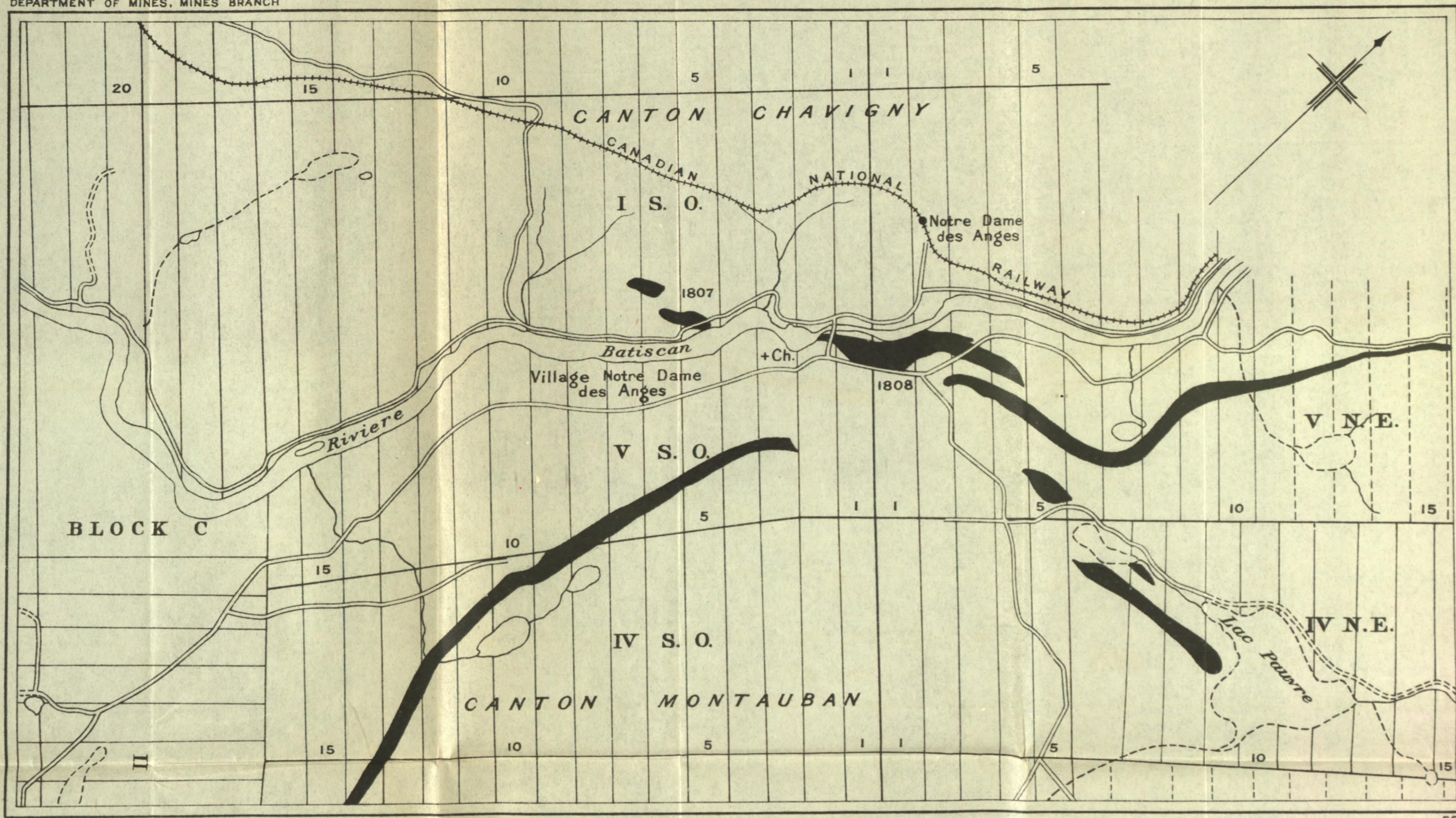
0 1 2 3 4 5 6 7 8 9 10 11 12

Sandstone areas

● 1710 Location of samples referred to in report.

Note:--Sandstone boundaries compiled from maps of Geological Survey, Canada, and field notes by L. H. Cole. Base map from plates of the Department of the Interior.

DEPARTMENT OF MINES, MINES BRANCH



QUARTZITE DEPOSITS

TOWNSIHPS OF CHAVIGNY AND MONTAUBAN

QUEBEC

Scale of Miles

½ ¼ 0 ½ 1 1½

Quartzite deposits

1808 *Location of samples referred to in report*

Note: Quartzite deposits compiled from Bureau of Mines, Quebec and field-notes by L.H. Cole.

CANADA

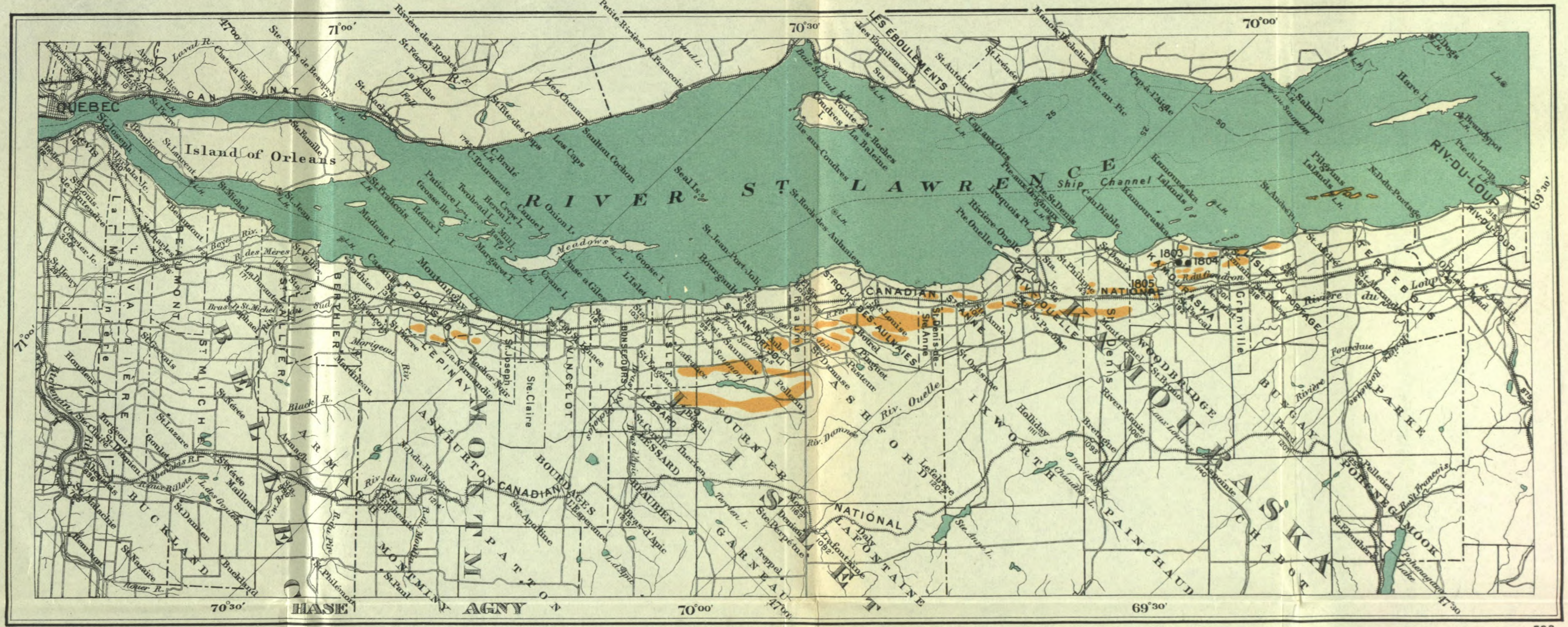
DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH

JOHN McLEISH, DIRECTOR.

1923



H. E. Baine, Chief Draughtsman.

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DISTRIBUTION OF QUARTZITE

IN THE

KAMOURASKA DISTRICT

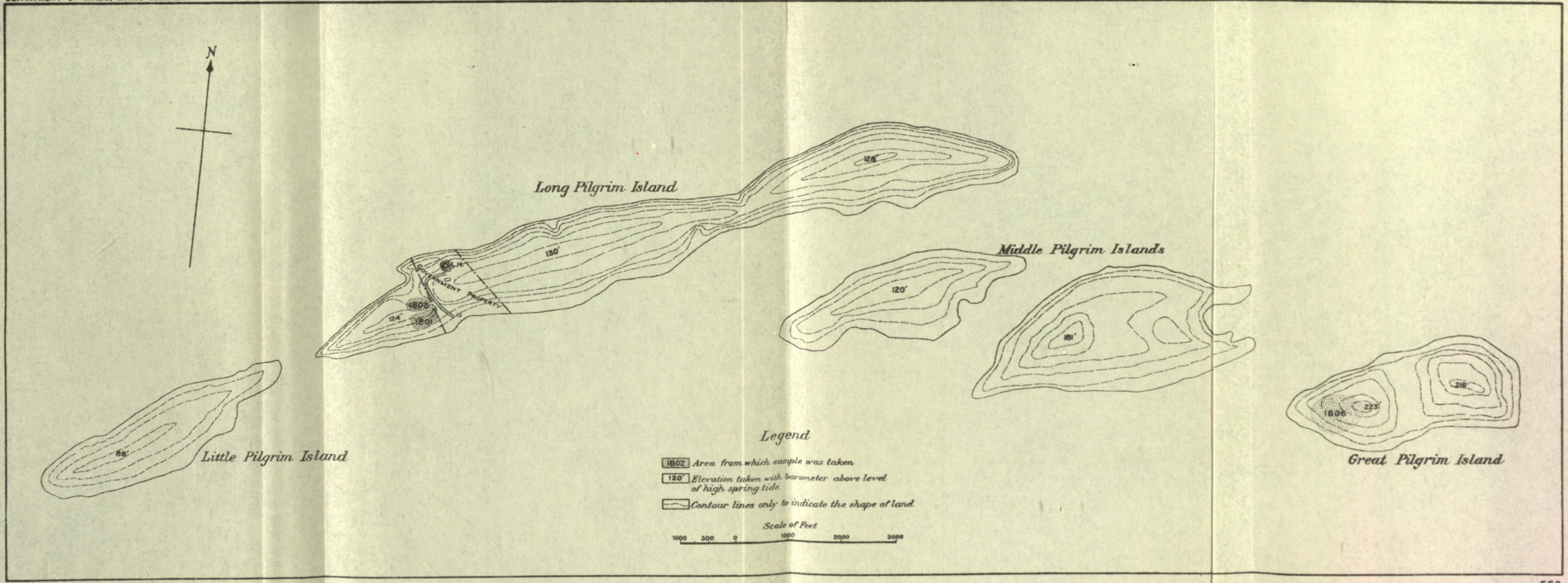
QUEBEC

Scale : 7·89 Miles to 1 Inch

Sandstone areas

●1803 *Location of samples referred to in report.*

Note:--Sandstone boundaries compiled from maps of Geological Survey, Canada, and field notes by L. H. Cole. Base map from plates of the Department of the Interior.



Sketch map of Pilgrim Islands, St. Lawrence River, near St. André, Kamouraska county, Quebec.

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