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NOVEMBER and DECEMBER 1917

The University of the State of New York New York State Museum

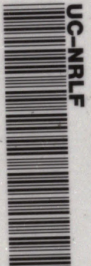
JOHN M. CLARKE, Director

HIGH-GRADE SILICA MATERIALS FOR GLASS, REFRACTORIES AND ABRASIVES

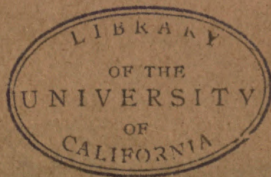
BY

R. J. COLONY.

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	PAGE		PAGE
Introduction.....	5	The Oriskany sandstone (Lower Devonian).....	14
Part I: The Poughquag quartzite (Lower Cambrian) in Westchester county.....	7	The Potsdam sandstone (Cambrian).....	15
Poughquag quartzite in Dutchess county.....	9	The Oneida glass sand (Pleistocene) Part 2: Economic value of the material described.....	23
The Shawangunk conglomerate (Silurian).....	11	Conclusions.....	29
		Index.....	31

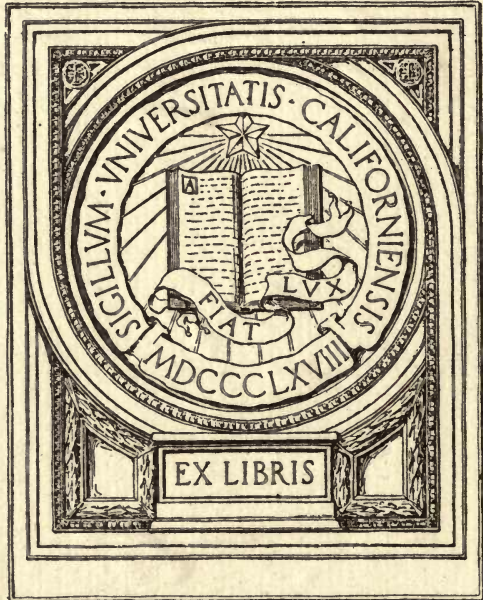


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EXCHANGE



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The University of the State of New York

Science Department, November 30, 1918

Colonel John H. Finley

President of the University

MY DEAR SIR: I beg to transmit to you herewith and to recommend for immediate printing, as a Bulletin of the State Museum, a manuscript entitled "*High-grade Silica Materials for Glass, Refractories and Abrasives*," which has been prepared, at my request, by Mr R. J. Colony.

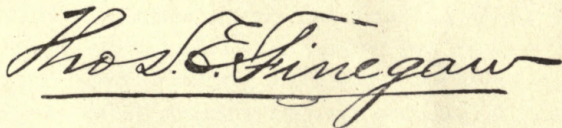
It is believed that this report meets a widespread demand for information as to the New York supplies of these materials.

Very respectfully yours

JOHN M. CLARKE

Director

Approved for publication this 8th day of January, 1919



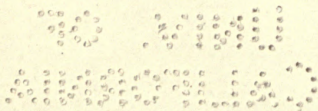
Acting President of the University

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JOHN M. CLARKE, Director

HIGH-GRADE SILICA MATERIALS

FOR GLASS, REFRACTORIES AND ABRASIVES

BY

R. J. COLONY

INTRODUCTION

Owing to conditions brought about by the war, the importation of certain kinds of both raw materials and manufactured products was either wholly prevented or seriously curtailed; this resulted in the revival of decadent industries, in the stimulation of others, and in the establishment of industries new to this country.

The demand for high-grade silica rock has recently been largely augmented because of its increasing use in the manufacture of ferro-silicon, in the making of glass, especially glass of optical quality, in the manufacture of silica refractories and in the production of grinding pebbles and tube-mill liners.

According to statistics compiled under the direction of G. F. Loughlin, of the United States Geological Survey, the increase in the demand for ganister, used in making silica brick, resulted in an augmentation of 49 per cent in quantity and 171 per cent in value in 1917, as compared with 1916. More than 50 per cent of the demand for pebbles and liners for tube-mills was supplied by domestic materials in 1917; previous to 1914 practically all grinding pebbles (flints) used in this country were imported from France, Denmark and Belgium. Pennsylvania appears to have furnished the bulk of the output of raw material of this character, notwithstanding the fact that within the borders of New York State there is an abundance of high-silica rock of excellent quality, conveniently located with respect to transportation, and easily quarried.

The formations in this State which may be expected to yield rock of good quality and which have been studied with that particular purpose in view, are:

a The Poughquag quartzite, fringing the northeastern border of Fishkill mountains, in Dutchess county; another smaller outcrop lies about three-fourths of a mile northwest of Peekskill, along Peekskill creek, in Westchester county.

b The Shawangunk conglomerate, which forms a prominent range of mountains running southwesterly through Ulster and Sullivan counties, and into Pennsylvania.

c The Oriskany sandstone, at Oriskany Falls, Oneida county, the type locality in the State of New York.

d The Potsdam sandstone, which in general forms part of the Paleozoic fringe around the Adirondacks; and outliers of the same formation in the Mohawk valley.

e The Oneida glass sands, at the east end and on the north side of Lake Oneida in Oneida and Oswego counties; these sands at one time were the source of supply for flourishing local glass industries in the vicinity of the lake. There are other formations in this State which might possibly furnish material of fairly good quality; these are:

f The Whirlpool sandstone, at Lewiston, Niagara Falls, Niagara county.

g The Oswego sandstone, at the falls of the Salmon river, in Oswego county.

h The Oneida conglomerate, at Washington Mills, Oneida county.

i A sandstone which lies at the base of the Lowville limestone, scantily exposed at Little Falls, and which may possibly be seen at Lowville.

These formations were not studied in the field, however, partly because of the time limit involved, and partly because either their lithologic character is such, or the probable quantity of high-grade material so questionable, as not to warrant investigation at this time.

The discussion will be limited to the first five formations named and will be divided in two parts:

1 A general description of the rock and its structural habit; the lithologic character, chemical analyses, and locality for each formation individually, with suggestions as to operating facilities and transportation.

2 The various specific industries in which rock from the different formations might be used, and whatever physical tests have been made during the course of the investigation.

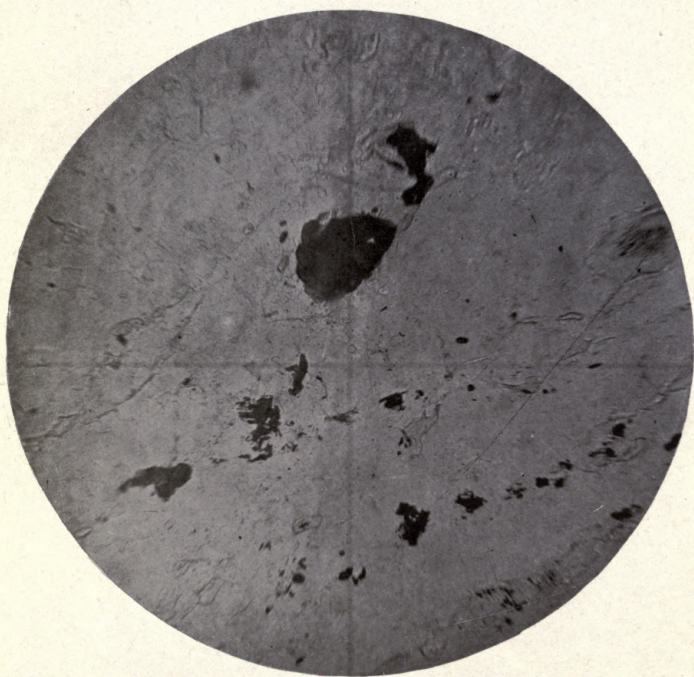


Fig. 1 Photomicrograph of Poughquag quartzite, Peekskill area; taken in ordinary light, magnification 65 diameters. This shows the distribution and quantity of minerals other than quartz; the larger triangular-shaped dark mineral is an almost-basal section of tourmaline; leucoxenized ilmenite and rutile make up the rest of the dark spots.

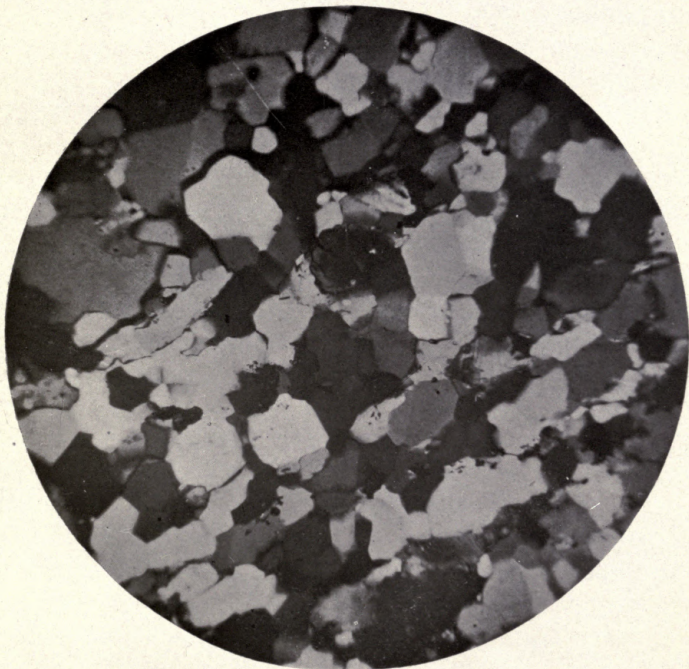


Fig. 2 Exactly the same field of view and the same magnification as figure 1; in this case, however, the photomicrograph was taken with crossed nicols ("polarized" light), which emphasizes the individual grains of quartz and shows their interlocking habit.



Part I

THE POUGHQUAG QUARTZITE (LOWER CAMBRIAN) IN
WESTCHESTER COUNTY

General description. The quartzite in this area lies about three-fourths of a mile northwest of the center of the city of Peekskill, along the southwest margin of Peekskill creek; it extends from a point near the tracks of the New York Central Railroad at the mouth of the creek, in a northeasterly direction to within approximately 500 feet of the state road running north from Peekskill and crossing Peekskill creek. A flat-topped ledge with almost vertical walls 10 to 12 feet in height in places, may be traced for 1200 or 1500 feet. The beds appear to be slightly overturned to the northwest; the overlying Wappinger limestone has been partially stripped by erosion, so that the ground falls away in a steep descent to the creek. On the other hand, a more or less fractured and crushed zone occurs between the quartzite and the gneiss, and weathering has operated along this line of weakness as well, thus imposing upon the much more resistant and steeply dipping quartzite the dikelike form mentioned.

The best rock is contained in this ledge; in other places in the immediate vicinity the rock is much less pure, and occasionally so strongly schistose as to be essentially a quartz schist (figure 4).

The rock in the dikelike ledge is a massive, strongly jointed, fine textured, highly indurated, grayish white to grayish pink, hard, tough quartzite, inclined to be somewhat streaked, and weathering on exposed faces and along joints to splotchy, yellowish brown tones very erratically distributed.

Lithologic character. Thin sections of various samples of the rock taken at intervals along the strike, exhibit the following features:

Angular, jagged and elongate grains, ranging from 0.10 mm to 2 mm in diameter, and averaging 0.30-0.40 mm; well, and in some cases even intricately interlocked, with no traces left of original grain outlines. The dominant component is, of course, quartz; according to the chemical analysis (table 1), the percentage of silica in mixed samples of this rock is 95.51 per cent. Not all the silica is present as quartz, however, as numerous feldspar grains form the next most abundant mineral present.

The quartz grains are fairly clean and free from the innumerable dusty inclusions which characterize some sandstones and quartzites, containing only rutile needles sparingly distributed, a few liquid and gas inclusions, and an occasional minute zircon. The feldspar grains are perfectly fresh and are made up almost wholly of microcline, micropertthite, cryptopertthite, and an unstriated feldspar resembling orthoclase.

Quartz and feldspar make up practically over 98 per cent of the rock; tourmaline is next in order of abundance, with sericite and biotite in minute crystals closely following. Special interest is attached to the tourmaline because of the relatively large amount of it in a rock of this type, and because of its rather perfect form; the tourmaline in this rock does not represent former original worn, rounded, clastic grains. It occurs in interpenetrating relations, in fairly well-defined prismatic forms, and in ragged patches, the mode of occurrence suggesting replacement effects and actual introduction of material during or subsequent to the reorganization of the rock.

Titanium-bearing minerals are unusually abundant; rutile, in shapeless grains, in aggregates of grains, and in minute, well-defined crystals; ilmenite, both fresh, and partly, and sometimes wholly leucoxenized; and what was judged to be titanite, are widely disseminated. The presence of these minerals accounts for the 0.39 per cent TiO_2 found during the course of the chemical analysis (table 1). In addition to the occasional minute zircon crystals included in the quartz grains, there are also larger and more or less rounded zircons sparingly distributed throughout the rock.

These features are illustrated in figures 1 to 4 inclusive; figure 1 shows the distribution of minerals other than quartz, and figure 2 shows the same field taken with nicols crossed. This serves to emphasize strongly the individual grains and to illustrate their structural habit, already described. Figure 3 shows the variability in grain size common to these rocks, and a zircon crystal of unusual size. Figure 4 shows the strongly schistose phase of the Poughquag in this area; this material is of too poor quality to be of use.

The chemical analysis of the rock is given in table 1; the silica is too low (95.51 per cent) and the alumina too high (2.35 per cent) for its use in the manufacture of glass, ferro-silicon, or silica refractories. In addition to the constituents determined, the rock carries manganese, zirconia, alkalis, magnesia etc. in very small amounts. The structure of the rock is good, affording possibility of its use



Fig. 3 Poughquag quartzite, Peekskill area; taken in polarized light (nicols crossed), magnification 65 diameters. The quartz grains are fairly free from included matter, and are firmly interlocked; the large crystal near the center of the field is a zircon of unusual size. No trace of the original rounded grains remains because of the complete reorganization of the rock.

for grinding pebbles and liners in tube mills. This will be discussed in part 2.

Operating facilities and transportation. The situation appears to be very favorable for both quarrying and transportation; the best rock is exposed as an outcrop for over a quarter of a mile, and hence but little stripping would be necessary. It is massive, well jointed, and should break out easily into readily handled blocks.

Peekskill creek lies only a few hundred feet away, the Hudson river is less than a mile distant and the main line of the New York Central and Hudson River Railroad runs close by, with yard and freight facilities at Peekskill; transportation, therefore, offers no problem whatever. Provided this material has any economic value, it seems certain that it can be quarried and placed ready for shipment at a minimum cost.

POUGHQUAG QUARTZITE IN DUTCHESS COUNTY

General description. The quartzite in this section¹ is most extensively developed about 10 miles east of the city of Beacon, 4 miles east of Fishkill, and in the immediate vicinity of the villages of Wicopée (formerly Johnsville) and Shenandoah.

Two northeasterly-extending spurs of the Fishkill mountains form the "hooks" of a roughly crescentic area, convex southwest-erly. The quartzite fringes the inner slopes of the mountains, lying on the eastern and western margins respectively of the two spurs or "hooks," and on the northern (or inner) slope of that part which forms the bow of the crescent.

An outcrop of conglomeratic quartzite is exposed for a short distance on the eastern flank of Honness mountain (the western hook), about one-third of a mile south of Wicopée; but most of the quartzite in this vicinity is covered by drift. The best rock occurs 2 miles south of Wicopée on the farms of Ward Ladue and Garrett Smith; here it forms large prominent ledges extending southerly for about one-fourth of a mile.

This rock is a massive, well-jointed, grayish pink, vitreous quartzite, so highly indurated that surfaces polished by glaciation have an appearance as though varnished; it is extremely tough and hard.

Lithologic character. In thin section it is seen to be a beautiful, typical, most intricately interlocked, highly indurated, very pure

¹ An excellent description of the occurrence of the quartzite and its relation to the gneisses of the Highlands is contained in New York State Museum Bulletin 148, entitled "Geology of the Poughkeepsie Quadrangle," by C. E. Gordon.

quartzite. The original rounded grains are outlined by thin films of iron oxide; the secondary quartz, in parallel orientation, has most complicated crenulated margins which dovetail together in an extreme of interlocking. The grains average from 0.50 mm to 0.60 mm in diameter, and are composed practically wholly of quartz, fairly free from inclusions; a little scattered rutile, zircon and tourmaline are sparingly distributed. The purity of this quartzite is likewise shown by the chemical analysis (table 1); silica 99.51 per cent, iron oxide 0.21 per cent.

The rock shows a little more complicated history than one of simple induration, since all grains exhibit strong undulatory extinction and some show crushing; but subsequent silification has healed all crush effects, and has produced a remarkably tough, hard rock.

Figures 5 and 6 illustrate these features. In figure 5, a photomicrograph taken in ordinary light, magnification 65 diameters, the original rounded grains are shown outlined by iron oxide, and the notable absence of minerals other than quartz is evident; figure 6 represents the same field, viewed with nicols crossed, thus emphasizing the individual grains of quartz. Note the crenulated margins and the highly interlocking habit.

The rock in other places in this area appears to be less desirable; samples taken from a ledge resting unconformably on the gneiss, about three-fourths of a mile west of Ladue's farm, contain less quartz and such a considerable amount of ilmenite, leucoxene, rutile, zircon, tourmaline, carbonate, sericitized feldspars, iron oxide, magnetite etc. as to render it unfit for use. Figure 7 illustrates this type, which is inferior both in composition and structural habit to the rock shown in figures 5 and 6.

Operating facilities and transportation. The best rock in this area, so far as was determined by this investigation, is, as stated, that which outcrops in conspicuous ledges on Ladue's farm, 2 miles south of Wiccopee, extending southerly one-fourth of a mile or more.

The road from this outcrop to Wiccopee, level and in fairly good condition, merges into a state road at Wiccopee; the line of the Central New England Railroad (Newburg, Dutchess and Connecticut Railroad) crosses the state road at Brinckerhoff, about 1½ miles west of Wiccopee. This line connects with the Hopewell branch of the New York, New Haven and Hartford Railroad at Hopewell Junction, 5 or 6 miles north of Brinckerhoff, and with the main line of the New York Central and Hudson River Railroad at Dutchess

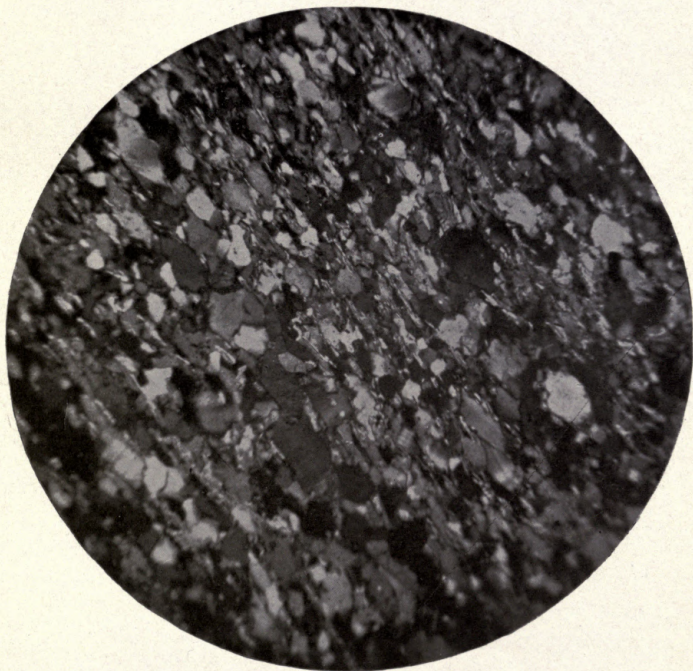


Fig. 4 The schistose phase of the Poughquag quartzite in the Peekskill area. Nicols crossed, magnification 65 diameters. The rock carries considerable pyrite, carbonate and sericite in addition to the quartz and feldspar. Note the small dimensions and elongate character of the grains.

Junction, south of Beacon; the only difficulty in transportation is a haulage by wagon or motor, for a distance of approximately $3\frac{1}{2}$ or 4 miles, over a road fairly good for half the distance and excellent the remainder of the way. No grades of any consequence are involved.

A normal fault of small throw, extending southwesterly and beginning in the neighborhood of Mr Ladue's house, is the cause of some difference in the quality of apparently adjacent beds; the rocks on the eastern or downthrow side are slightly younger than those on the western or upthrow side of the fault, and because of this contain occasional thinner-bedded, impure fossiliferous layers. With this fact in mind there should be no great difficulty in confining quarrying operations to the proper beds. The dip is gentle, and the structure in general massive; the ledges outcrop in a conspicuous manner, so that there is very little overburden to be disposed of, presenting, so far as could be judged, favorable opportunity for quarrying.

The special uses for which this rock is suited will be mentioned in part 2.

THE SHAWANGUNK CONGLOMERATE (SILURIAN)

General description. A comprehensive study of this formation is a problem in itself; no attempt was made to prospect extensively, search being confined to a few localities where quarries are now being operated, or where they have been operated in the past.

The Shawangunk at Accord. In the vicinity of Accord, Ulster county, the Lawrence brothers operate quarries in a small way, converting the stone taken out into mill wheels of various sizes as the demand arises; Accord is the center of the quarry industry in this locality.

The quarries operated by the Lawrence brothers are situated about $1\frac{1}{2}$ miles southeast of the village at an elevation of about 500 feet; the rock here is in general a typical, fairly coarse conglomerate dipping very gently in a northwesterly direction, variable in structure, texture and composition.

The rock is not very heavily bedded, so that coarse conglomerate, fine conglomerate, strongly laminated, highly colored, red and yellow cross-bedded sandstone, pink conglomerate carrying numerous clay galls, and conglomeratic quartzites of various colors, succeed one another in short distances in exposed faces in the quarries, and in crossing the beds.

Going up the dip (that is, lower down in the formation) the rock improves somewhat in quality. These beds are slightly pinkish to brownish gray conglomeratic quartzites. They are variable, even in the same bed, frequently contain streaks and patches of clay, and are often cross-bedded. Samples selected from these beds present the following characteristics:

Lithologic character. Practically all the grains are quartz; most of them are clouded with inclusions, both heterogeneously distributed, and in trains which often terminate abruptly at the margins of the grains and also pass indiscriminately from grain to grain regardless of boundaries. The trains are composed of liquid and gas inclusions; the rest of the included matter consists of rutile needles, minute zircon crystals, magnetite, and many minute specks and crystals of indeterminate nature. Occasional larger patches of sericite, chlorite, granular aggregates of rutile, rounded grains of hornblende, tourmaline, zircon, leucoxene, magnetite, iron oxide, are very sparingly disseminated; both iron oxide and sericite occur between the grains to some extent.

The rock has been subjected to considerable crushing and granulation. A photomicrograph of rock from one of the quarries operated by the Lawrence brothers is shown in figure 8, which exhibits some of the features enumerated; more especially granulation.

Chemical analyses (table 1) of samples selected from different beds yield 98.46 per cent and 98.68 per cent SiO_2 respectively. The best rock will probably average not over 98.50 per cent SiO_2 .

The Shawangunk at Ellenville. In the vicinity of Ellenville, rock was at one time quarried for use in a local glass factory, not now in operation. The Shawangunk in this locality dips steeply toward the valley (47° northwesterly); a strong thrust from the southeast up-turned the conglomerate and at the same time overthrust the underlying Hudson River formation on it. In climbing the Shawangunk slope the Hudson River slates will be encountered at an approximate elevation of 1500-1800 feet.

The coarse conglomerate possesses the same general characteristics as that described as occurring at Accord; certain beds, however, are grayish white quartzite, and it was from these beds the rock used in the glass factory at Ellenville was taken. Rock of this description may be seen about 2 miles south of Ellenville, along the road to Mount Meenahga, at an elevation of about 800 feet, rising for at least 100 feet or more at an approximate angle of 47° , and almost free from overburden.

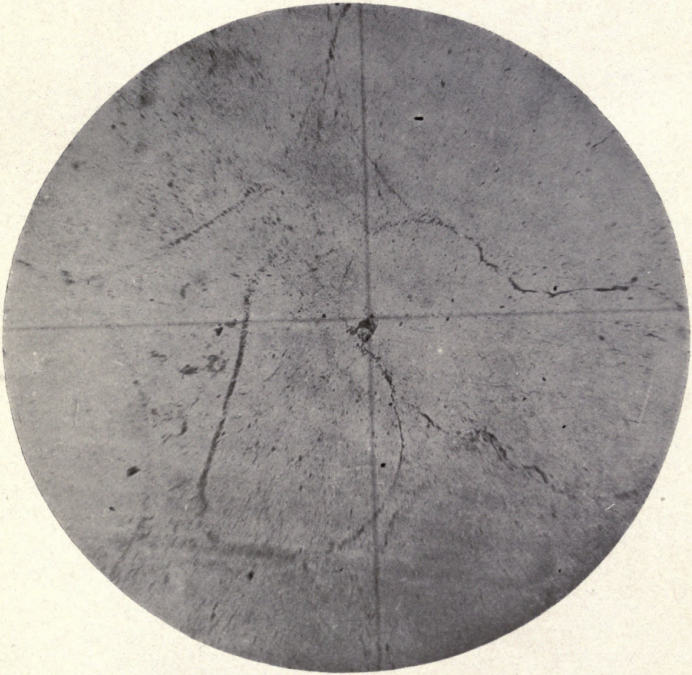


Fig. 5 Photomicrograph of Poughquag quartzite, taken in ordinary light, magnification 65 diameters. Sample from ledge on the farm of Ward Ladue, two miles south of Wicopee. Showing the original rounded grains, outlined by iron oxide, and notable absence of minerals other than quartz.

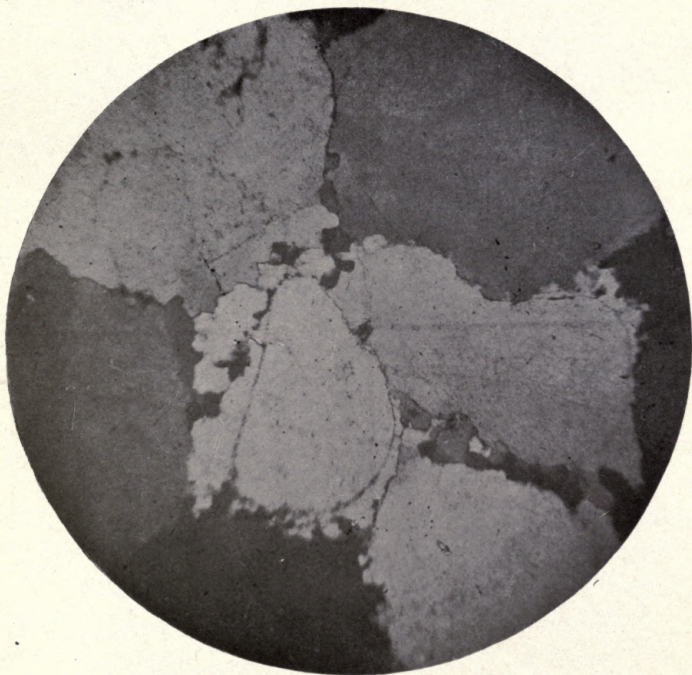


Fig. 6 Showing the same field as illustrated in figure 5, taken with crossed nicols. The original grains, the secondary growth in parallel orientation, the crenulated margin and striking interlocking are plainly shown.



Lithologic character. The gray-white quartzite has the same general habit and composition as the rock at Accord; the grains are smaller, however, and in many cases traces of the original rounded grains still exist. The same included matter is prominent, and about the same quantity and distribution of minerals other than quartz may be seen; crushing and granulation are also just as much in evidence. The appearance of the rock in thin section is shown in figure 9; by comparing with figure 8 it will be seen that the chief difference between the rock at Accord and at Ellenville is in grain size and not in quality. This difference is no doubt due to different beds having been sampled. All the quartz grains show secondary growth; the rock from both localities has a fairly good interlocking structure, and is fairly tough and hard.

The Ellenville grayish white quartzite bed carries 98.32 per cent SiO_2 (table 1); the alumina (1.23 per cent) is confined to sericite, and to kaolinitic and claylike patches, and the iron (0.20 per cent Fe_2O_3) is present chiefly as oxide, distributed between grains; the same holds true for the Accord rock. Washing the crushed rock would undoubtedly improve its quality.

Operating facilities and transportation. Both Accord and Ellenville are on the Kingston branch of the New York, Ontario and Western Railroad; the quarries now in operation, or which have been operated in the past, are situated not more than 3 or 4 miles from the railroad. The mountain roads leading into the quarries near Accord are poor; those in the vicinity of Ellenville are better. The only problem connected with transportation is confined to the mountain roads, especially at Accord; the haul is down grade, steep in some places; in the valley the roads are good, and as the valley is very narrow, any quarries which might be subsequently opened would not be far from the railroad, but at a greater or less distance, of course, from a freight station.

There is not, as a rule, a very heavy cover or overburden on the Shawangunk, especially where the dip is steep, as at Ellenville; the rock is variable, however, and considerable care would be necessary in stripping undesirable beds in order to reach and quarry the better layers, an operation which would cause much wastage.

The rock seems to be better adapted for the manufacture of silica refractories or ferro-silicon than for any other purpose; this feature will be referred to in part 2.

THE ORISKANY SANDSTONE (LOWER DEVONIAN)

General description. The Oriskany formation in this State in many places is a dark, siliceous, highly fossiliferous limestone; as a sandstone it is best exposed in the type locality, at Oriskany Falls, Oneida county, where it consists of 20 feet¹ of nearly pure, white fossiliferous quartz sandrock.

Less than one-fourth of a mile north of the town, along a road leading out of it in a northeasterly direction, 60–80 feet higher than the road and 500–600 feet west, is exposed a ledge of rather coarsely granular, apparently quite pure quartz sandstone, very friable on weathered surfaces, and with an estimated thickness of 12 or 15 feet at the point where the rock was sampled; the dip is very gentle, probably not over 45 or 50 feet to the mile.

The Oriskany sandstone rests on the Helderbergian limestone, which is locally quarried, the rock being used for road metal and other purposes; the Onondaga limestone overlies the sandstone, but the limestone capping is not very thick at this point.

The rock is massive, heavy bedded, and well exposed as a fairly prominent, weathered ledge, for one-fourth of a mile or more.

Lithologic character. The grains are composed almost wholly of quartz; secondary enlargement has affected most of them, but silicification has not been carried so far as to make the rock a quartzite.

The texture is decidedly coarser than any of the other rocks described in this report, the grains averaging about 0.6 mm in diameter, with a maximum of about 2 mm. The original rounded grains are plainly outlined, and frequently crowded with inclusions in trains, which terminate at the original grain margins, the added secondary quartz being clear and clean. The inclusions are chiefly liquid and gas; bubbles of the latter may be seen in constant and rapid motion.

There is no very firm interlocking of grains so characteristic in most quartzites, which probably accounts for the ready disaggregation of the rock where it is exposed to the action of the weather.

According to the chemical analysis (table 1) the percentage of silica is 99.71; the rock crushes readily into granular "sand," the purity of which is slightly improved by washing (table 2).

Figure 10 represents a photomicrograph taken with nicols crossed, magnification 65 diameters. The outlines of the original rounded

¹Grabau, A. W., Guide to the Geology and Paleontology of the Schoharie Valley in Eastern New York. New York State Museum Bulletin 92. 1906.

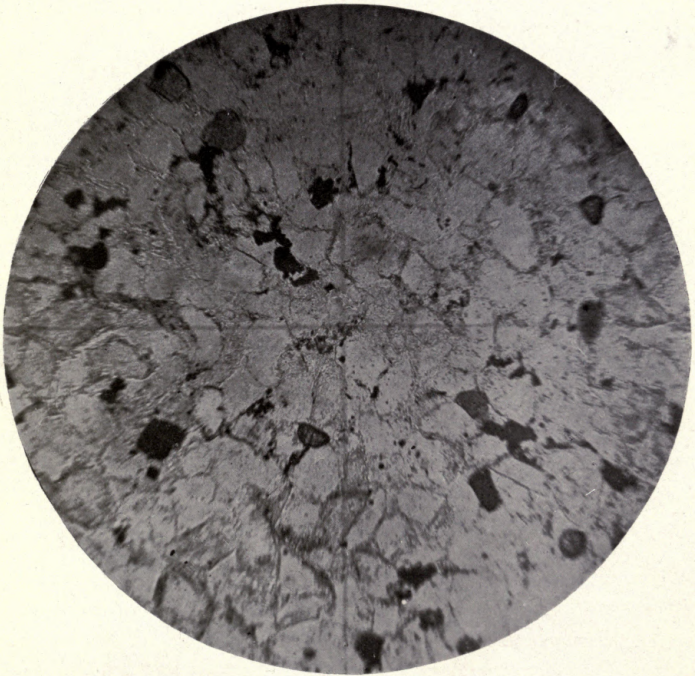


Fig. 7 Photomicrograph taken in ordinary light, magnification 65 diameters. Specimen of Poughquag quartzite from a ledge resting unconformably on the gneiss, about three-fourths of a mile west of Ladue's farm; the rock is inferior to that shown in figures 5 and 6. Note the distribution and quantity of minerals other than quartz.

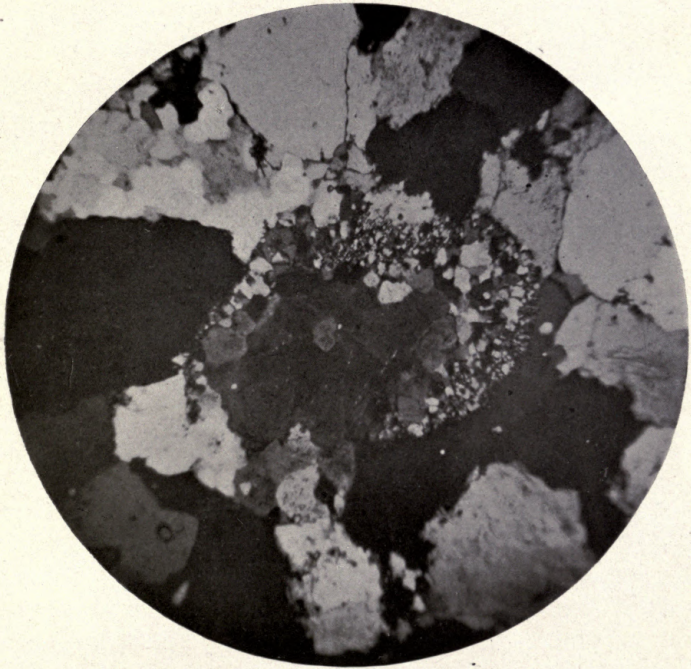


Fig. 8 Photomicrograph of conglomeratic quartzite (Shawangunk) from quarry near Accord; taken with nicols crossed, magnification 65 diameters. Crushing, granulation, and silicification have destroyed grain outlines; especially well shown by the grain in the center of the field. Mill wheels (buhr stones) are made from this rock. Average grain diameter about 0.45 mm, disregarding the very large pebbles which are two or three centimeters in diameter, and occasionally larger.

grains with trains of inclusions terminating at original grain margins, the clear secondary growth of quartz in parallel orientation, the size of the grains and the character of their interlocking, are all very well illustrated.

Operating facilities and transportation. The Utica division of the New York, Ontario and Western Railroad offers excellent transportation facilities; this line runs not more than one-fourth of a mile distant from the outcropping ledge. The station, at Oriskany Falls, is about 1 mile from the outcrop.

The roads are good, no serious grades are involved, and the motor or wagon haul is short; the ledge is not more than 500 or 600 feet from, and at a slightly greater elevation than, the highway. There seem to be no difficulties attached to the question of transportation.

The formation is essentially horizontal, not particularly heavily covered, although in places the drift is very thick, and not difficult to quarry.

The situation appears to be very favorable for successful operation. The rock crushes readily, breaking down into a granular "sand" which could be washed without difficulty and improved thereby in quality. It is probably the best glass rock of the series, but not so well adapted for other purposes as some of the quartzites described.

THE POTSDAM SANDSTONE (CAMBRIAN)

General description. This formation forms a part of the Paleozoic fringe around the Adirondack massif; occasional outliers occur in the Mohawk valley, and it may likewise be found in isolated fault blocks at the edge of the Adirondacks in various places. It is variable in quality and character, ranging from a compact, hard quartzite, to a thin and evenly bedded porous sandstone. In a number of localities the Potsdam is a distinctly white, saccharoidal, more or less friable, fairly pure, quartz sandrock, and it is this type that offers material which may possibly be of sufficiently high grade for use. This phase of the Potsdam occurs in the town of Mooers, Clinton county; in Franklin county, 4 or 5 miles southwest of Malone, and in the towns of Moira (almost on the township line between Moira and East Dickinson, well exposed in a brook running into the west branch of the Little Salmon river), Bangor, West Bangor village, and on the Thomas farm about 3 miles southeast of Bangor.

In these various localities the rock is a friable to fairly compact, granular, quartz sandrock, rather thin bedded, and dipping at a small angle (7 to 10 degrees) in a northerly to northwesterly direction.

The maximum thickness of individual beds is from 6 to 8 inches; many of them are more or less iron stained and apparently not sufficiently pure for use in the manufacture of glass, but some are white and quite pure. Analyses of the better beds (table 1; Potsdam, Moira-Bangor) gave 99.22 per cent SiO_2 and 98.99 per cent SiO_2 respectively; an analysis of one of the less pure beds gave 95.08 per cent SiO_2 (no. 3).

In the latter case (no. 3), sericite is the chief impurity, as shown by the high alumina content (3.27 per cent) and in the photomicrograph (figure 13). It should therefore be possible to improve the quality of material of this grade by washing; an analysis of the crushed and washed rock (table 2) shows an increase in silica, from 95.08 to 97.46 per cent, and a decrease in iron oxide from 0.24 to 0.15 per cent. Samples from beds of better quality (no. 1 and no. 2) show likewise an increase in silica, when crushed and washed; no. 1, from 99.22 per cent SiO_2 to 99.54 per cent, and no. 2 from 98.99 to 99.33 per cent. The better beds of this formation in the localities mentioned seem to offer, therefore, possibilities as sources of supply for glass-making rock, so far as indicated by these analyses.

Potsdam outliers in the Mohawk valley. Ten or 12 miles west of Johnstown, in Fulton county, an outlier of Potsdam sandstone occurs, which resembles in lithologic character the rock in the Moira-Bangor area; promising rock also lies near Yosts Station, on the New York Central and Hudson River Railroad, in Montgomery county, probably a part of the same outlier. The rock in Fulton county is more massively bedded than that on the northern edge of the Adirondacks in Franklin and Clinton counties, but it is similar in other respects. It is a massive, rather heavily bedded, moderately granular, friable to compact, fairly pure, quartz sandrock, generally white, but more or less variable in color and purity; some beds are flecked and streaked with iron oxide, but the chief impurities are sericitic and kaolinitic matters derived from altered feldspar grains.

The best material carries 98.84 per cent SiO_2 , the poorer beds 96.83 per cent (table 1); washing the crushed rock increased the silica contents to 99.05 and 97.46 per cent respectively (table 2).

Quartzite phase of the Potsdam. In some localities the Potsdam is a typical quartzite, which in general, and in most places,

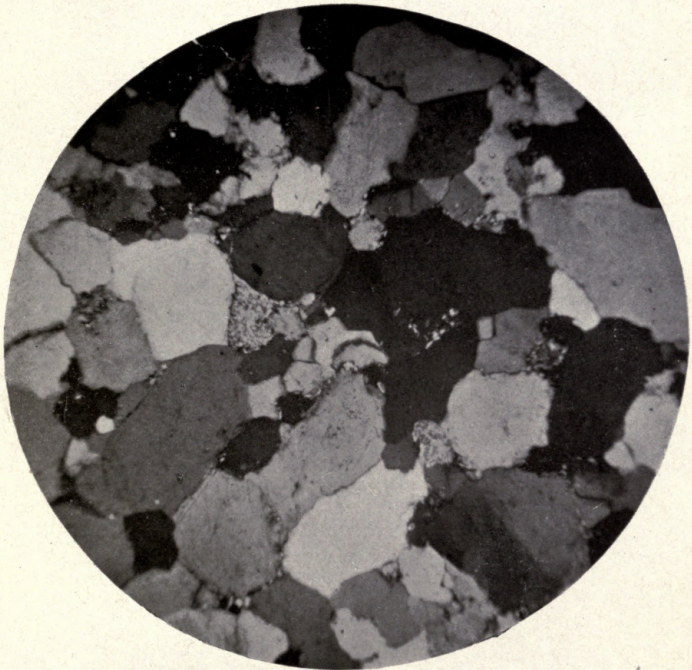


Fig 9 Shawangunk from Ellenville; photomicrograph taken with nicols crossed, magnification 65 diameters. Outlines of original rounded grains still remain; the grain size averages 0.25 mm in diameter, as contrasted with the rock from Accord (figure 8); patches and shreds of sericite are visible, but the rock is composed chiefly of quartz, with added secondary growth in parallel orientation, fairly well interlocked.

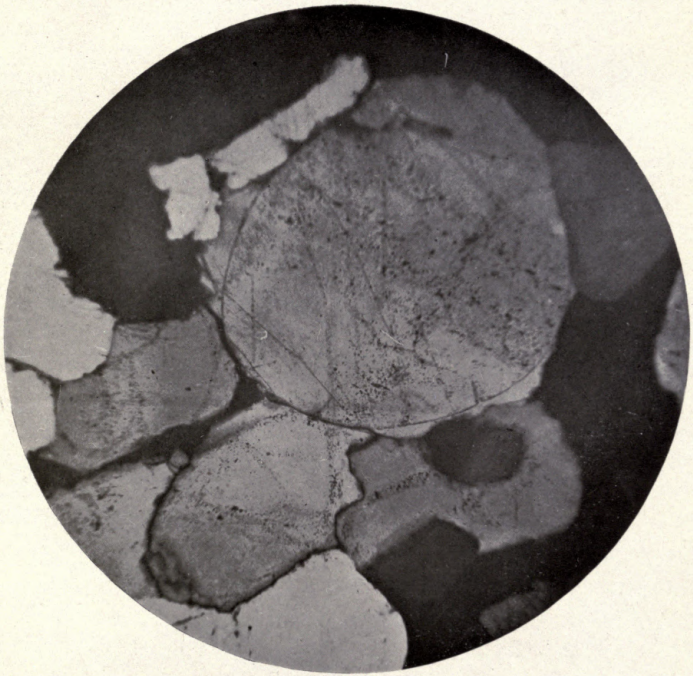


Fig. 10 Photomicrograph of thin section of Oriskany sandstone, taken with nicols crossed, magnification 65 diameters, showing

a Original rounded grains with trains of inclusions terminating at original grain margins

b Secondary growth of clear quartz in parallel orientation

c Size of grains and slight interlocking habit; this poorly interlocking habit makes the rock susceptible to ready disaggregation where exposed to weathering action.

is not of very great purity. Occasionally, however, a fairly pure and white variety occurs, such as that in the vicinity of Fort Ann, Washington county; here a thin-bedded, fine-textured, hard quartz-rock, dipping gently in an easterly direction lies on both sides of the canal, well exposed in many places and easily accessible.

Some beds are quite white; analyses gave 98.82 per cent SiO_2 in one case, and 95.45 per cent in another, the chief impurity being feldspar.

The rock is of no value for glass making, but might be used for tube mill liners and pebbles, and in the manufacture of refractories.

A small quarry, not now being operated, is situated about $1\frac{1}{2}$ miles north of Fort Ann, several hundred feet west of the tracks of the Delaware and Hudson Railroad, and convenient thereto; the sample giving the lower silica value was taken from this quarry.

Lithologic character. Photomicrographs of Potsdam rock from the several localities mentioned are shown in figures 11 to 15.

Moirra-Bangor district. The rock from the Moirra-Bangor district varies in grain size; samples from the vicinity of Moirra average about 0.50 mm in grain diameter, while samples taken near Bangor average about 0.30 mm. All grains are enlarged by secondary growth, but no complex interlocking has resulted from silicification; the rock breaks down readily, when crushed, into a granular sand, whose individual grains are more or less angular because of secondary enlargement, notwithstanding the original rounded character of the grains. The quartz grains are fairly free from included matter, containing only trains of liquid and gas inclusions, minute groups of tiny hematite specks, minute rutile needles, occasional small zircons, minute apatite crystals, and other very small specks and tiny crystals whose identity could not be established. The rock from both Clinton and Franklin counties is inclined to be sericitic; some of the samples giving lower silica values contained appreciable amounts of sericite; figure 13 illustrates this type. Associated with the sericite in some places, are many very small prismatic and tabular crystals with high relief and low birefringence, responding to the optical tests for barite, and judged to be that mineral (see table 1). Patches of leucoxene, iron oxide, kaolinitic and sericitic matter, small black metallics, altered feldspar, small shapeless grains of titanite, and occasional rounded tourmaline grains constitute the rest of the mineral matter other than quartz; all these are interstitial with respect to the quartz, and, as shown

in table 2, more or less readily removed from the crushed rock by washing.

Johnstown district. Samples taken from the Potsdam outlier in the Mohawk valley are somewhat similar to the rock from the Moira-Bangor area, but very much less sericitic and more feldspathic; the feldspar grains are all more or less altered, most of them having been kaolinized to a greater or less degree.

The feldspathic, rather than sericitic, nature of the impurities, and a slightly smaller average grain size, constitute the chief difference between the Potsdam in this locality and that in Franklin and Clinton counties. An unusual and interesting feature in connection with the feldspar is that in almost every instance each rounded and altered feldspar grain has, like the quartz, been enlarged by secondary growth; the later and added on feldspar has been altered to some extent also, but as a rule not to such a degree as the older original and rounded grains, so that the evidence of secondary enlargement is clear and unmistakable.

The quartz contains liquid and gas inclusions and much minute, indeterminate dusty matter, as well as small zircons, minute rounded grains of tourmaline, rutile in needles and stouter crystals as well, small groups of hematite specks, small needles of sillimanite and other very minute indeterminable crystals.

Larger grains of similar sorts occur interstitially to some extent, and in the less pure beds a little more iron oxide.

The sum total of all these impurities is not great, however, as may be seen by referring to the analysis, table 1.

Quartzite phase at Fort Ann. The rock in the vicinity of Fort Ann, Washington county, is in general too highly feldspathic to be of much value. Figure 15 illustrates the general character and habit of this rock; the grains are smaller than those of the saccharoidal sandstones just described, and the rock is thoroughly indurated. Silicification and recrystallization have not entirely obliterated all traces of former structure, however; in occasional grains the former rounded character is still plainly evident.

The grains are angular, fairly well interlocked, and reasonably free from much included matter. The chief objection to the rock is the presence of considerable feldspar.

In grain size, structure and lithologic character the rock resembles some phases of the Poughquag. Small rounded grains of tourmaline, minute zircon crystals, rutile needles, an occasional minute patch of leucoxene, small black metallics resembling magnetite, and

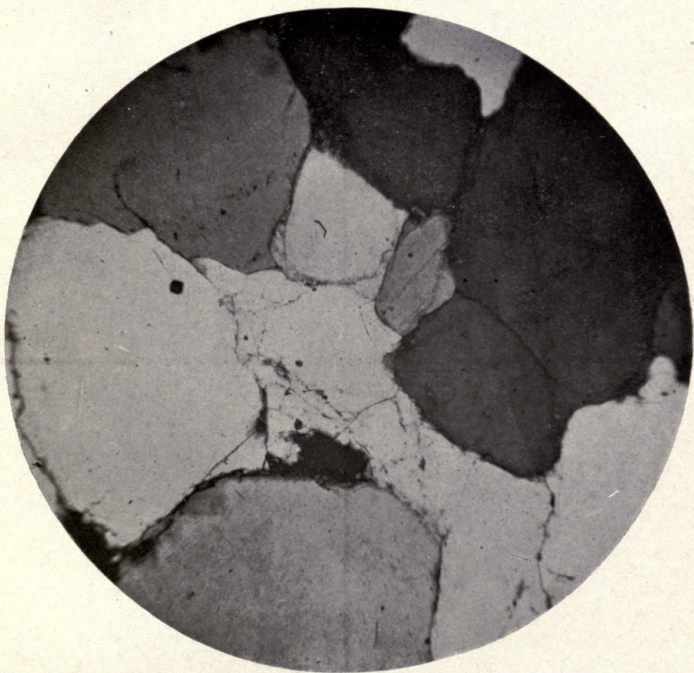


Fig. 11 Potsdam sandstone, East Dickinson — Moira, Franklin county. Taken with nicols crossed, magnification 65 diameters. Composed almost wholly of quartz; the original rounded grains have been enlarged by secondary growth and are fairly free from included matter. Most of the impurities (chiefly sericite and a little iron oxide) have an interstitial distribution, and may be in part removed by washing the crushed rock.

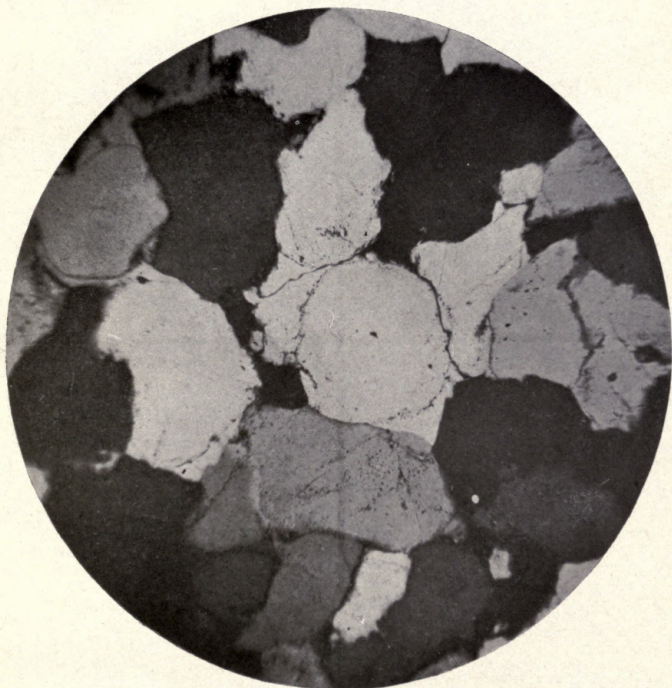


Fig. 12 Potsdam sandstone, Bangor, Franklin county. Taken with nicols crossed, magnification 65 diameters. The original rounded grains show enlargement, and are smaller than those of figure 11, but the quality of the rock is about the same. Both rocks are friable, crush easily, and may be improved by washing.

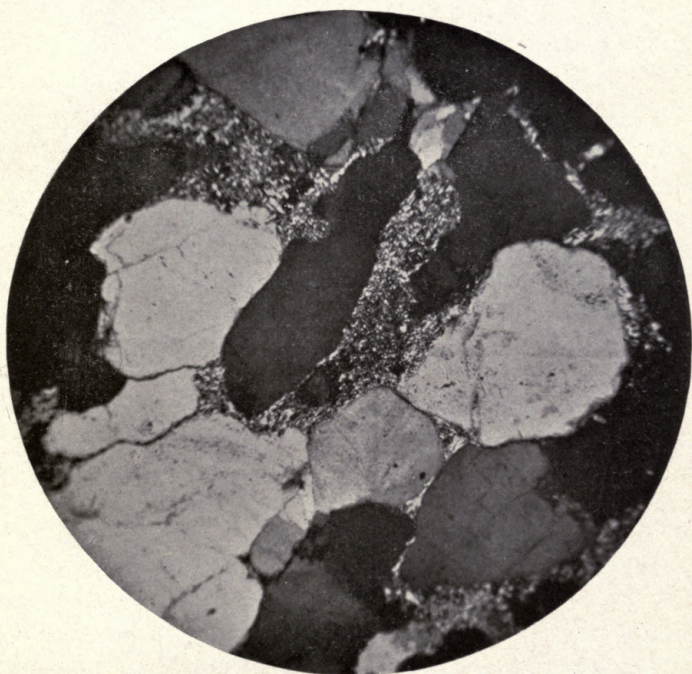


Fig. 13 Potsdam sandstone, Bangor. One of the poorer beds; taken with nicols crossed, magnification 65 diameters. Note the interstitial sericite. This rock carries only 95.08 per cent SiO_2 ; which was increased by washing to 97.46 per cent.

a little interstitial iron oxide are very sparingly distributed; feldspar is the chief impurity, and most of it has been more or less kaolinized. Certain beds, however, are much less feldspathic (see table 1, and figure 15).

Operating facilities and transportation. Clinton and Franklin counties are served by the New York Central and Hudson River Railroad, the Delaware and Hudson Railroad, the Rutland Railroad, and to a less extent by the Grand Trunk Railroad; Moira, Malone, Mooers and Rouses Point are junction points. No quarries were seen in this area, although quarries are said to have been in operation in the past at Moira, Bangor, Mooers, and along the banks of the Chateaugay and Salmon rivers.¹

The samples selected were taken from exposures along streams and elsewhere, from 4 to 6 miles from the railroad. There are good state roads in the region, but the secondary roads are very sandy in places, owing to the character of the drift which covers the greater part of the Potsdam in this area. The location of the outcrops would necessitate a haulage of several miles over roads more or less sandy, but not uniformly bad; the distances involved are not great, and provided the material is of any value the question of transportation is not a serious one.

The chief objections to the rock in Clinton and Franklin counties are its thin-bedded character and the presence of much interbedded impure and unusable rock; considerable stripping and consequent wastage would be necessary to obtain the purer and usable material.

The outcrops in the Mohawk valley are situated 5 or 6 miles from Johnstown, requiring a motor or wagon haul for that distance; the Fonda, Johnstown and Gloversville Railroad passes through Johnstown, connecting with the main line of the New York Central and Hudson River Railroad at Fonda, which is situated on the Mohawk river and adjacent to the Barge canal.

Other outcrops of more or less promising material lie near Yosts Station, on the New York Central and Hudson River Railroad, and convenient likewise to the Mohawk river and Barge canal.

The Potsdam outliers in the Mohawk valley at the localities mentioned are much more heavily bedded than the Moira-Bangor rock, but are more inclined to be feldspathic; the rock is variable in quality, but so far as could be judged from an inspection of the outcrops, a large quantity of good rock is available, and should be readily quarried.

¹ Emmons, Ebenezer, Natural History of New York, Geology of the Second District, 1842.

The quartzite phase of the Potsdam at Fort Ann is very favorably situated so far as transportation is concerned, being in the immediate vicinity of both the Delaware and Hudson Railroad and the Champlain canal; nor is quarrying difficult, as the rock is thin bedded, slabby, gently dipping and but thinly covered with drift. It is doubtful, however, if a very large quantity of high-grade rock is obtainable; most of it is too highly feldspathic.

Judging from the chemical analyses of these rocks and their structural features, the granular white quartz sandrocks of the Potsdam formation are promising sources of supply for glass-making material, and as such merit further investigation; they may be used also in the manufacture of ferro-silicon.

THE ONEIDA GLASS SAND (PLEISTOCENE)

General description. Twenty-five or thirty years ago glass factories were in operation in the villages of Durhamville and Dunbarton; near the east end of Oneida lake, and glass sand was shipped from the area east and north of the lake to factories in Lockport, Lancaster, Ithaca and Clyde. The factories at Durhamville and Dunbarton have long been abandoned, and no glass has been made in the Oneida lake area for many years.

Mr C. A. Hartnagel, of the New York State Museum, while working in this locality during the summer of 1907 gathered the following data on the glass sand of this region, which have been kindly communicated to the writer:

“Glass sand (near Oneida lake) is found near the surface just below the vegetable mold. In the vicinity of Oneida lake the best quality of sand is found underlain by hardpan, in distinction from clay. Sometimes clay is found beneath the sand, but then the sand is regarded as of not so good a quality. The largest deposits are near the east end of the lake about three-fourths of a mile back and the area extends north and south, most of the area being on the east side of Black creek. The average thickness of the sand is from 3 to 6 inches. It is as much as 2 feet thick in the area east of the lake, but not often as thick as that. Around Oneida lake to the north, glass sand is found 4 and 5 feet thick in patches. No glass sand is found on the beaches of Oneida lake . . . (but) from the lake sand is obtained for forges, rolling mills, etc.”

Mr Williams, of Durhamville, a pioneer in the exploitation of these sands, who has extracted, washed and shipped thousands of tons of this material in the past, and to whom the writer is indebted

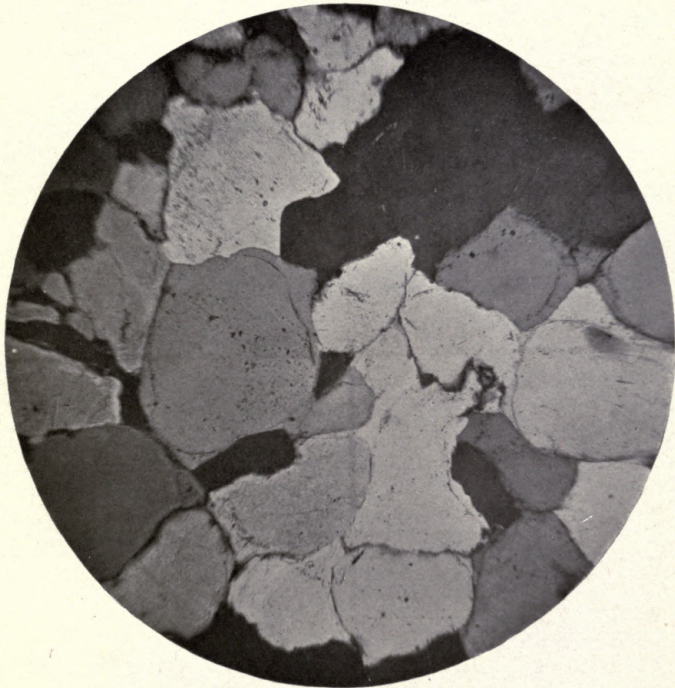
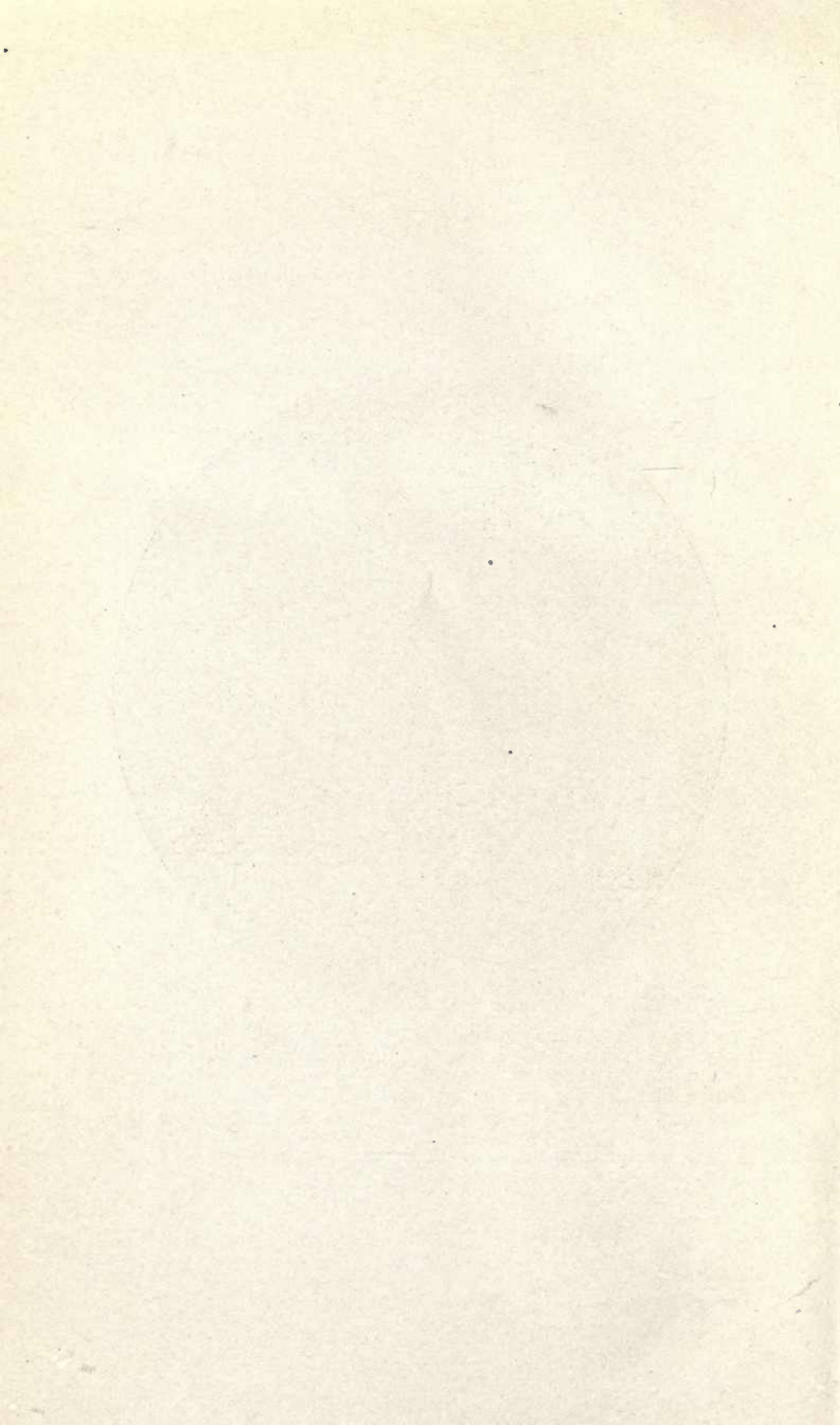


Fig. 14 Potsdam outlier in the Mohawk valley; sample from one of the better beds. Taken with nicols crossed; magnification 65 diameters. Similar in grain size, and lithologic character to the white friable sandstones in the Moira-Bangor area on the northern edge of the Adirondacks; the rounded original grains are enlarged by secondary growths of quartz in optical orientation, but interlocking is not a prominent feature, the rock being quite friable where exposed to the weather.



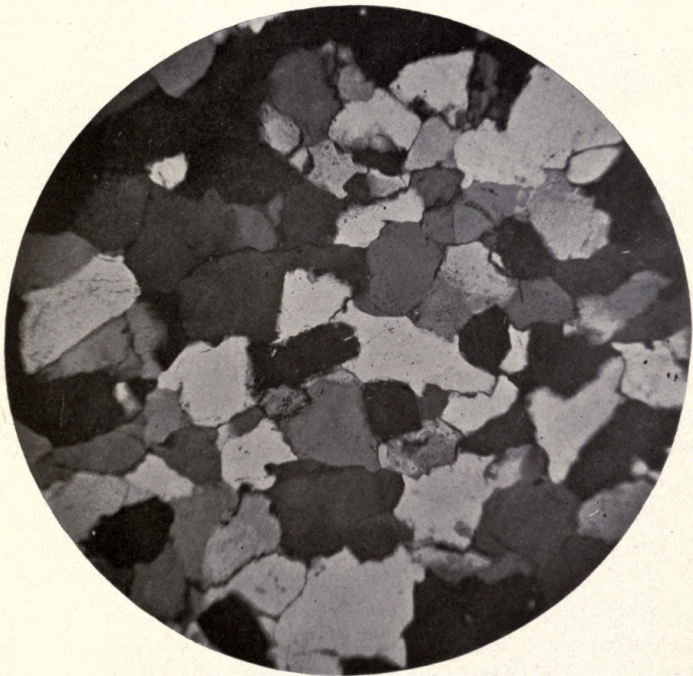


Fig. 15 Potsdam quartzite, Fort Ann, Washington county. Taken with nicols crossed, magnification 65 diameters. A fine-textured, highly indurated, somewhat feldspathic, hard white quartzite; this sample was selected from an especially white bed, and carries 98.82 per cent silica.

for the samples obtained (see table I- for analysis), stated that the sands at the east end of Oneida lake have been practically worked out; there may be possibly 1000 tons left in the area bounded by the east shore of the lake, the New York, Ontario and Western Railroad, Sylvan Beach and the highway to the south. On the north side of the lake, according to Mr Williams, there is a deposit extending from Cleveland to Constantia. This is several feet thick in places, and of about the same quality as the sand at the east end of the lake; there may be 100,000 tons or more available.

The sand was used in the manufacture of glass fruit jars, bottles, and occasionally lamp chimneys; the samples obtained by the writer from the east end of the lake contain 98.56 per cent SiO_2 , 0.68 per cent Al_2O_3 and 0.41 per cent Fe_2O_3 (table I); it is not of optical quality.

Lithologic character. The Oneida glass sand is composed of angular to subangular grains ranging from 0.10 mm to 0.50 mm in diameter; the minerals other than quartz are feldspar, both fresh and kaolinized, tourmaline, colored and colorless garnet, zircon, hornblende, rutile, magnetite, ilmenite, leucoxene, and rarely both corundum and monazite, and occasionally brookite.

The quartz grains are in many cases coated with iron oxide and contain minute included specks of iron oxide as well, so that it would probably be impossible to lower the iron content by additional washing.

While it is probable that small patches of greater purity may be encountered, the deposit as a whole will conform in quality and mineralogy to that here described.

Operating facilities and transportation. All the glass sand taken from the vicinity of Oneida lake was, so far as could be learned, extracted and washed by hand; the operation involved stripping the soil covering, never very thick, and conveying the crude sand in wagons to either the canal or lake, where it was washed several times in some sort of trough or cradle.

The irregular distribution of this material, the thinness of the deposits, its rather poor quality and the relatively small quantity available prohibit the erection of a plant capable of handling the sand more efficiently and at less cost than the slow and laborious methods used in the past.

There are no difficulties in the way of transportation, the region being particularly well served. The main line of the New York Central and Hudson River Railroad lies 6 or 7 miles south of the

lake; the Lehigh Valley and the New York, Ontario and Western Railroads traverse the area underlain by glass sand at the east end of the lake, and the latter railroad turns and runs along the north shore, directly adjacent to the sand-bearing area on the north side of the lake. The highways are excellent, and so far as the movement of material is concerned the situation is ideal.

Table 1

	Per cent SiO ₂	Per cent Fe ₂ O ₃	Per cent Al ₂ O ₃	Per cent CaO	Per cent BaO	Per cent TiO ₂
Potsdam-Johnstown (good bed).....	98.84	0.09	0.44	0.04	.....	.....
Potsdam-Johnstown (poorer bed).....	96.83	0.17	1.18	0.04	.....	.....
Potsdam-Moira-Bangor, no. 1.....	99.22	0.06	0.46	0.02	.....	.....
Potsdam-Moira-Bangor, no. 2.....	98.99	0.10	0.73	0.05	.....	.....
Potsdam-Moira-Bangor, no. 3.....	95.08	0.24	3.27	0.13	0.07	.....
Potsdam-Fort Ann, no. 1.....	98.82	0.17	0.52	0.04	.....	0.11
Potsdam-Fort Ann, no. 6.....	95.45	0.12	3.04	0.03	0.02	.....
Oriskany sandstone, New York.....	99.71	0.08	0.11	0.02	.....	.....
Oriskany sandstone, Pennsylvania.....	99.53	0.18	0.34	0.04	.....	.....
Shawangunk no. 1, Ellenville, N. Y.....	98.32	0.20	1.23	0.03	0.02	.....
Shawangunk no. 5, Accord, N. Y.....	98.46	0.26	0.77	0.01	.....	.....
Shawangunk no. 6, Accord, N. Y.....	98.68	0.27	0.72	0.06	.....	.....
Poughquag quartzite, Westchester co., New York.....	95.51	0.27	2.35	0.07	.....	0.39
Poughquag quartzite, Dutchess co., New York.....	99.51	0.21	0.15	0.05	.....	.....
Oneida glass sand, Durhamville, N. Y..	98.56	0.41	0.68	0.07	.....	0.07

Part 2

ECONOMIC VALUE OF THE MATERIAL DESCRIBED

High silica rock is used in the manufacture of glass, ferro-silicon, carborundum, abrasives, silica brick, and tube mill liners and pebbles; quartz sand is used chiefly in the manufacture of glass of various qualities.

The availability of the rock used by these industries is in large part dependent upon its composition and structure, and it is from this point of view that the formations described will be referred to the industries for which they seem best fitted.

Manufacture of glass. Material used in the manufacture of glass must be of uniform grain, of medium fineness (20 to 50 mesh), and must contain, in general, not less than 98 per cent silica, and not more than 0.25 per cent ferric oxide; sand of optical quality must be of much greater purity than this, however, and purer material is also required in the making of flint and plate glass.

Different writers are not in accord in their judgment of purity; thus, Peddle¹ suggests five qualities of glass sand: (1) for common work, not washed or sieved; Fe_2O_3 0.10 to 0.20 per cent; (2) for common work, sieved, but not washed; particles larger than 1 mm rejected, Fe_2O_3 0.10 to 0.20 per cent; (3) for ordinary colorless glassware, plate and sheet glass; washed and dried, but not graded; Fe_2O_3 about 0.05 per cent; (4) for best crystal glass; washed and sieved; Fe_2O_3 about 0.04 per cent; (5) for work of highest class; washed, dried and graded between 30 and 80 mesh; Fe_2O_3 about 0.03 per cent.

According to these requirements, glass sand may contain a maximum of 0.03 per cent Fe_2O_3 and still be fit for the most exacting work. Kümmel and Gage,² however, place the allowable limit of Fe_2O_3 at less than 0.01 per cent for ordinary glass, and from 0.01 to 0.02 per cent for common green bottle glass; the best flint glass sand contained, according to analyses given, as little as 0.0017 per cent Fe_2O_3 .

¹ Peddle, C. J., *British Glass-making Sands. I. Substitution of some British sands for foreign sands in the manufacture of high-grade glass. J. Soc. Glass Tech.*, 1, 27-61. 1917.

² Kümmel, Henry B., and Gage, R. B., *Glass Sand Industry of New Jersey; Report of State Geologist*, 1906.

Burchard¹ gives analyses of glass sands of different quality, listing a sand containing 99.99 per cent silica and a slight trace of ferric oxide, as fit for the manufacture of the highest grade of glass; sands containing from 0.006 to 0.011 per cent Fe_2O_3 are judged suitable for tableware, plate glass, lamp chimneys, etc., and material sufficiently pure for making window glass carries 0.021 per cent Fe_2O_3 . Numerous analyses of sands of possible value for glass making range in silica content from 96.45 to 98 per cent and in iron oxide from 0.33 to 0.84 per cent.

Table 2

	Before washing		After washing	
	Per cent SiO_2	Per cent Fe_2O_3	Per cent SiO_2	Per cent Fe_2O_3
Potsdam, Johnstown (good bed).....	98.84	0.09	99.05	0.06
Potsdam, Johnstown (poorer bed).....	96.83	0.17	97.46	0.20
Potsdam, Moira-Bangor, no. 1.....	99.22	0.06	99.54	0.01
Potsdam, Moira-Bangor, no. 2.....	98.99	0.10	99.33	0.12
Potsdam, Moira-Bangor, no. 3.....	95.08	0.24	97.46	0.15
Oriskany, New York.....	99.71	0.08	99.82	0.06

These rocks crush readily into granular "sand," which is improved as to the silica content by washing; in most cases the percentage of ferric oxide has likewise been lowered, but two of the determinations may be questionable. The results at least suggest that some of this material may prove to be of economic value for glass making.

Table 3
Sieve tests

Passes	20-mesh	30-mesh	60-mesh	100-mesh	200-mesh
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
Potsdam, Johnstown, no. 1.....	100	96.8	60.8	10	1.5
Potsdam, Moira, no. 1.....	100	70	22.5	5.3	0.5
Potsdam, Moira, no. 2.....	100	96	38.4	10.4	2.2
Potsdam, Moira, no. 3.....	100	91.3	14.7	2	0.5
Oriskany, New York.....	100	69.8	12.3	1.8	0.3
Oneida glass sand.....	100	100	96.2	25.7	0.7

The Potsdam and Oriskany samples were crushed in a mortar through a 20-mesh screen, washed and dried; the Oneida glass sand was washed and dried.

According to the judgment of Fettke,² sand used in the manufacture of the best grades of optical glass should not contain more

¹ Burchard, Ernest F., Requirements of Sand and Limestone for Glass Making; Geol. Survey Bul. 285, p. 452-58, 1906; idem; Glass Sand of the Middle Mississippi Basin; same publication, p. 459-72.

² Fettke, Charles R., The Glass Sands of Pennsylvania. Science, n. s., 48, 1230, 98-100; July 26, 1918.

than 0.002 per cent Fe_2O_3 ; for the better grades of lead flint, used in the manufacture of cut glassware, the percentage of iron oxide should not exceed 0.02 per cent.

Plate glass used for mirrors may be made from sand containing as much as 0.10 per cent Fe_2O_3 , while if the plate glass is to be used for windows the amount of iron oxide in the sand may run as high as 0.20 per cent; in the case of ordinary green and brown bottle glass, sands may be used containing from 0.50 to as high as 7 per cent ferric oxide.

Provided quartz rock is used instead of sand, the rock should break down readily into a fine granular sand of fairly uniform grain, when crushed; this will be the case provided induration has not proceeded far enough to have converted the rock into a hard compact quartzite with more or less intricately interlocking structure.

The formations which seem most nearly to meet the foregoing requirements are (a) the white saccharoidal variety of the Potsdam sandstone, near Johnstown, and in the Moira-Bangor-Mooers district; (b) the Oriskany sandstone at Oriskany Falls, and (c) the Oneida glass sand.

Structurally both the Potsdam and Oriskany meet the conditions, breaking down without much difficulty into grains not far removed in size from the rounded originals of which the rocks were made.

The results of sieve tests on the crushed, washed and dried rock, and on the Oneida glass sand, are given in table 3. The grains are, moreover, fairly angular, because even in the friable saccharoidal sandstones the grains have been more or less affected by secondary growth, which has been sufficient to give them angularity of form without at the same time having developed a very firmly interlocking structure.

Some of this material seems to meet the requirements with respect to composition also, judging from the results of the analyses; by referring to tables 1 and 2 it will be seen that the better beds of the Potsdam in both the Johnstown and Moira-Bangor sections contain very promising material for glass making, as does also the Oriskany sandstone.

Washing seems to improve the crushed rock to some degree, and it might even be possible to obtain from some of the beds rock which, after proper treatment, would closely approach optical quality. There has been included in table 1 an analysis of Oriskany sandstone from Pennsylvania, for the purpose of comparison; this sandstone, under favorable conditions of weathering, disaggregates

to a friable sandstone (as do the Potsdam and New York Oriskany) and in some places even to loose sand. The disaggregated and friable portions are used as glass sand. A comparison of the analyses shows that the two are similar in composition and there seems to be no reason why the Oriskany sandstone of New York should not be used for glass making.

It is possible that the rock at Oriskany Falls may be somewhat calcareous in places, since the maximum thickness is small and it is associated in the field with the Helderbergian and the Onondaga limestones; this seems to be the only argument against its use. The samples analyzed did not contain much lime, however.

The glass sands of the Oneida lake region seem to be suitable for the manufacture of the commoner grades of glass; it will probably be impossible to improve their quality by washing.

The quartzite phase of the Potsdam, the Poughquag quartzite and the quartzites and conglomeratic quartzites of the Shawangunk are not suitable for the manufacture of glass because of the difficulty and expense involved in crushing and sizing and because of their poorer quality.

Manufacture of ferro-silicon. Considerably greater variation in composition appears to be permissible in quartz rock used in the manufacture of ferro-silicon; the presence of ferric oxide is not objectionable, except in so far as it reduces the amount of silica in the rock. Lime and alumina appear to be undesirable constituents, but no very definite information could be obtained from the several manufacturers visited as to the limiting quantities of lime and alumina allowable; estimates were given ranging from 0.10 to 4 per cent Al_2O_3 , less than 0.10 per cent CaO , and a minimum silica content of 95 per cent.

The general consensus of opinion was that while it was possible to use a rock carrying as little silica as 95-96 per cent, much more satisfactory results were obtained by using as high-grade rock as could be obtained at reasonable cost. Loosely compacted and friable rock is undesirable; hard, compact sandstones or quartzite give better results.

Rock from all the formations described, with the exception of the glass sands of Oneida lake, meets these requirements.

Some of it seems especially suitable; such, for example, as the Poughquag quartzite from Dutchess county, which carries 99.51 per cent of SiO_2 , 0.21 per cent Fe_2O_3 , 0.15 per cent Al_2O_3 , and 0.05 per cent CaO , and certain beds of the Shawangunk, which are almost as pure; more especially numbers 5 and 6, table 1.

The quartzite phase of the Potsdam, at Fort Ann, contains beds of sufficient purity, also, but the beds are thin and too widely separated by less pure material.

The saccharoidal sandstones of the Potsdam and the Oriskany sandstone at Oriskany Falls are likewise ideal material so far as composition is concerned, and provided unweathered material is used some of these rocks are sufficiently firm and compact in structure likewise, although not so desirable in this respect as the quartzites.

Provided these rocks were used for the manufacture of glass, the waste, or strippings, of less pure beds would probably be of sufficiently good quality for the manufacture of ferro-silicon.

It is evident, therefore, that all these formations contain rock of sufficiently high grade for use in the manufacture of either ferro-silicon or carborundum.

The manufacture of silica refractories. In the manufacture of silica brick it has been found that quartzite with medium to strongly interlocking grains give the best results; the silica content should not fall below 97 per cent.

Mr P. H. Bates, of the Bureau of Standards, Pittsburg branch, has kindly furnished the writer an abstract article by Donald W. Ross, entitled "Silica Refractories," which will appear in the near future in the Journal of the American Ceramic Society; in this very interesting article are enumerated the requirements to which high silica rock should conform in order to be available for use in the manufacture of silica refractories.

Of the formations studied, only the Shawangunk conglomerate and the Poughquag quartzite contain material which meets the conditions.

There are certain conglomeratic-quartzite beds in the Shawangunk which have the requisite firmly interlocked structure (figures 8 and 9) and the necessary purity (table 1; Shawangunk, nos. 1, 5 and 6).

Particular attention is called, in this connection, to the Poughquag quartzite on Ladue's farm, in Dutchess county (figures 5 and 6); this rock is very highly indurated, has an intricately interlocking structure, and contains 99.51 per cent silica (table 1; Poughquag quartzite, Dutchess county).

It appears to be equal, if not superior, to the various quartzites mentioned in the article by Mr Ross, which are sources of supply for the manufacture of silica refractories, and seems to merit further investigation.

The Poughquag quartzite near Peekskill, in Westchester county, is not of sufficient average purity, although it possesses the proper structure.

The manufacture of tube mill liners and pebbles. Rock used in the manufacture of linings and grinding pebbles for tube mills should be very hard and tough; these characteristics are more essential than great purity.

Most quartzites possess the requisite hardness, but some are so brittle that their toughness is relatively low as compared with rocks having very high toughness, like diabase; in spite of this disadvantage, quartzites are being used very successfully for this purpose, and their use is increasing. The writer is indebted to the New York State Highway Commission, bureau of tests, for hardness and toughness tests, made on various samples taken from the different formations studied; the results of these tests appear in table 4. According to these tests the hardness is satisfactory in all cases, but the toughness is low. The actual behavior of these rocks when crushed in a mortar, does not accord very well with the results listed for toughness; for example, the white saccharoidal variety of the Potsdam sandstone from the vicinity of Johnstown, crushes readily to a granular sand, whereas the Poughquag quartzite, and the Shawangunk conglomeratic quartzites crush with much greater difficulty.

Table 4

Tests made in the testing laboratories of the bureau of tests, New York State Highway Commission.

	Hardness	Toughness
Potsdam sandstone, Johnstown.....	18.6	6.0
Shawangunk, Ellenville, no. 1.....	19.0	9.0
Shawangunk, Ellenville, no. 2.....	18.7	5.0
Shawangunk Accord, no. 9.....	18.0	6.0
Poughquag quartzite, Dutchess co., from Ladue's farm.....	19.3	11.0
Poughquag feldspathic variety.....	19.3	10.0
Poughquag near Peekskill.....	18.2	5.0

Notwithstanding this behavior, the toughness of the Potsdam sandstone, as determined by tests, is 6.0; that of the Shawangunk (Accord, no. 9) likewise 6.0, while a sample of the Poughquag quartzite from Peekskill is but 5.0; this is surprising in view of the firmly interlocking habit shown by the Poughquag quartzite (see figures 2 and 3), and, to a less extent, by the Shawangunk as well (see figures 8 and 9).

The writer is of the opinion that the results of the toughness test should not be too heavily weighted in considering the availability of this material for tube mill uses.

The best rock in the series for this purpose is the Poughquag quartzite from Ward Ladue's farm, Dutchess county; the structural habit of this rock (figure 6), and its relative purity (table 1; Poughquag, Dutchess co.) recommend it highly for trial in an actual test run.

CONCLUSIONS

From field, laboratory and microscopic studies of high-silica rock it is evident that within the borders of the State of New York there is rock of good quality, easy of access, capable of being readily quarried, and which may be used for:

1 *Glass making*

- a The Potsdam sandstone, Johnstown
- b The Potsdam sandstone, Moira-Bangor
- c The Oriskany sandstone, Oriskany Falls
- d The Oneida glass sands

2 *Ferro-silicon manufacture*

Rock from all the formations enumerated

3 *Silica refractories*

- a The Poughquag quartzite, especially that phase seen on Ward Ladue's farm, in Dutchess county
- b Certain beds of the Shawangunk

4 *Tube mill liners and pebbles*

- a More especially that phase of the Poughquag quartzite on Ladue's farm, which appears to be well suited to the purpose
- b Possibly the Poughquag in the vicinity of Peekskill
- c Possibly certain beds of the Shawangunk

INDEX

- Accord**, 11
- Bangor**, 15
Beacon, 9
Burchard, Ernest F., cited, 24
- Clinton county**, 15
- Dutchess county**, 6, 9, 29
- East Dickinson**, 15
Ellenville, 12
Emmons, Ebenezer, cited, 19
- Ferro-silicon**, manufacture of, 26, 29
Fettke, Charles R., cited, 24
Fishkill, 9
Fishkill mountains, 6
Fort Ann, 17, 18
Franklin county, 15
Fulton county, 16
- Glass**, manufacture of, 23, 29
Gordon, C. E., cited, 9
Grabau, A. W., cited, 14
- Hartnagel**, C. A., quoted, 20
- Johnstown district**, 18, 29
Johnsville, 9
- Kummel**, Henry B. and Gage, R. B., cited, 23
- Lewiston**, 6
Lowville limestone, 6
- Malone**, 15
Mohawk valley, 16
- Moira-Bangor district, 15, 17, 29
Mooers, 15
- Niagara county**, 6
- Oneida conglomerate**, 6
Oneida county, 6
Oneida glass sands, 6, 20, 25, 29
Oriskany sandstone, 6, 14, 25, 27, 29
Oswego county, 6
Oswego sandstone, 6
- Peddle**, C. J., cited, 23
Peekskill, 6, 7, 29
Potsdam sandstone, 6, 15, 25, 27, 28, 29
Poughquag quartzite, 6, 27; in Westchester county, 7, 28; in Dutchess county, 9, 26, 29
- Salmon river**, 6
Shawangunk conglomerate, 6, 11, 26, 27, 28, 29
Shenandoah, 9
Silica refractories, manufacture of, 27, 29
- Tube mill liners and pebbles**, manufacture of, 28, 29
- Washington county**, 17
Washington Mills, 6
West Bangor, 15
Westchester county, 6, 7, 28
Whirlpool sandstone, 6
Wiccopee, 9
Williams, Mr., quoted, 20
- Yosts Station**, 16

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