GLASS-MAKING MATERIALS.

GLASS-SAND INDUSTRY OF INDIANA, KENTUCKY, AND OHIO.

By Ernest F. Burchard.

LOCAL GLASS-MAKING INDUSTRY.

Of the States manufacturing glass, Indiana and Ohio at present occupy, respectively, second and third rank. The total value of their glass products amounted in 1905 to $23,733,137, which is nearly one-third of the total value of the glass made in the United States. As the glass industry is largely dependent for its raw materials on the mineral deposits sand and limestone, the investigation of these materials for glass making, begun in 1905 in the Mississippi Valley, was resumed in December, 1906, in the Ohio Valley. It is of interest to note the sources of these materials, to compare their costs with that of other materials and with that of the finished product, and to consider whether any economies can be effected in their production. The following table shows the principal materials used in the manufacture of glass, their quantity and cost, and the character and value of the products in Indiana and Ohio for 1905.[a]

Glass-making materials used by kind, quantity, and cost, and products, by kind and value, Indiana and Ohio, 1905.

	Indiana.		Ohio.	
	Quantity.	Cost.	Quantity.	Cost.
Materials used, total cost		$5,558,839		$2,836,521
Glass sand, tons	193,600	316,265	81,541	179,152
Limestone, tons	27,120	54,055	11,704	21,562
Lime, cwt.	170,433	50,492	104,321	21,281
Soda ash (carbonate of soda), tons	55,249	1,039,241	19,683	372,630
Salt cake (sulphate of soda), tons	9,963	157,341	5,547	87,946
Nitrate of soda, tons	2,156	98,861	1,376	59,146
Litharge (red lead), lbs.	790,509	41,106	2,441,307	140,837
Potash or pearlash, lbs.	435,100	19,181	1,331,355	57,826
Pots, not made at factory, No.	1,589	67,263	1,070	71,980
Lumber, casks, barrels, boxes, and nails		1,231,220		623,406
Caps, metal trimmings, and rubber supplies		712,312		110,475
Fuel and rent of power and heat		1,069,075		621,497
All other supplies and materials		702,427		454,404
Products, total value		14,706,929		9,026,208
Building glass		3,790,618		1,625,126
Pressed and blown glass		2,859,087		3,954,660
Bottles and jars		7,213,456		2,961,727
All other products		843,768		484,695

[a] Census of Manufactures, clay and glass products, 1905: Bulletin U. S. Bureau of the Census No. 64, 1906.

In Indiana 71 glass works are in business, this number including 16 temporarily not in operation. Of these 71 plants, 39 make general flintware, 17 window glass, 3 plate glass, and 3 cast and rolled glass, including cathedral, colored, and opalescent glass; 9 confine their product to green and amber bottles, and some green and amber ware is also made by the flint factories.[a]

The glass works are situated mainly in the gas belt and coal fields of the State. With the gradual lessening of the natural-gas supplies during the last five years, the growth of the industry in Indiana has received a check. Many factories have been moved to Kansas and others have been moved from the gas fields to points within the State where cheap coal can be obtained. The introduction of glass-blowing machinery has, to some extent, offset the increased cost of fuel by reducing the number of employees and enlarging the output of the works, but the net result has been a slight loss in the total value of products since 1900.

In Ohio there are 50 glass works, one of which is temporarily inactive. Of these, 25 make general flintware; 16 window glass, 1 plate glass, and 2 cast and rolled glass.[a]

The glass-making industry in Ohio is in a prosperous condition. From 1900 to 1905 the value of products increased 98.5 per cent, and the amount paid in wages increased 118.2 per cent.

PRODUCTION OF GLASS SAND.

The following table shows the relation of production and value of glass sands produced in Indiana and Ohio to the total consumption of the material in these States.

Glass sand produced and consumed in Indiana and Ohio in 1905.[b]

State.	Production.			Consumption.			Production proportioned to consumption.
	Quantity.	Value.		Quantity.	Cost.		
	Short tons.	Total.	Average per ton.	Short tons.	Total.	Average per ton.	Per cent.
Indiana	1,640	$2,169	$1.32	193,600	$316,265	$1.63	0.84
Ohio	76,460	79,999	1.05	81,541	179,157	2.20	93.76

From these figures it is apparent that Indiana is producing less than 1 per cent of the glass sand used within the State; also that the sand produced can be sold for about 81 per cent of the average price paid for imported sand. This is a perfectly natural condition, since the local sand has the advantage of a differential in freight rates of 50

[a] Courtesy of The Commoner Publishing Company, Pittsburg, Pa., January, 1907.

[b] Statistics of production by A. T. Coons: Production of glass sand in 1905; Mineral Resources U. S. for 1905, U. S. Geol. Survey, 1906.

cents per ton over the sand brought from the Fox River (Illinois) district and the Klondike (Missouri) district. All the sand that can be produced, of sufficient purity even for green and amber bottles, finds a ready and waiting market at good prices. These conditions are encouraging to producers and manufacturers alike, and there is a tendency now on the part of certain manufacturers to secure for themselves reserves of undeveloped sandstone. At the same time it must be remembered that no large quantities of sandstone are known in Indiana which have the purity of the St. Peter sandstone, so abundant farther west. Consequently, for certain grades of glass, there will always be a demand for sand from beyond the State. As to the quantities of crushed limestone and burned lime produced within the State, there are at present no definite statistics, but the procuring of these materials does not seem to offer any serious difficulties, first, because much smaller quantities of them are used than of sand; second, because certain quarries in Illinois and Ohio have a well-established trade, and third, because Indiana herself has, in the Mitchell and Bedford limestones, inexhaustible supplies of satisfactory material.

According to statistics, Ohio produced 93.7 per cent as much glass sand as is used in the State. A large part of this product, however, passes from the eastern part of the State to glass factories in western Pennsylvania, and a corresponding amount is brought in from other States—notably from West Virginia and Illinois—at relatively higher prices. Glass works are established within an area extending north and south across the State from Toledo to Cincinnati and as far east as Steubenville. Each plant is usually well situated with regard to fuel, either natural gas or coal, but many have to pay excessive freight charges on their sand. The opening of new deposits and the readjustment of markets would simplify this situation.

Kentucky has only recently begun to manufacture glass. Factories are in operation at Frankfort and Owensboro, and glass sand is produced at Tip Top.

PREPARATION OF GLASS SAND.

The method of treatment of glass sand depends on the character of the deposit and on its position. The materials used for glass sand in central United States are mainly bedded sandstones, and a complete process of preparation includes quarrying, breaking, crushing, and grinding into component grains, screening, washing, draining, drying, and final screening to various sizes. Some beds of sandstones are so loose and friable that they can be reduced by a strong hydraulic jet; some producers dispense with the operation of washing their sand, others do not dry it. It has been shown that washing improves the quality of sand of the highest grade.[a] It is mistaken economy to neglect this important

[a] Burchard, E. F., Glass sand of middle Mississippi basin: Bull. U. S. Geol. Survey No. 285, 1906, p. 461.

phase of treatment on account of the expense of installing washers, for the price of sand, and often its use or rejection, is affected by the small percentage of impurity that may be washed away. Two methods of washing are followed. One method involves several sets of bins, into which sand and water are elevated or pumped so that the sand settles quickly while the finer impurities are washed away; the other employs a crude, open-top pug mill, in which rotating "augers" or screws move the sand up inclined troughs, rolling it over and over so that by attrition it is freed from a large portion of its impurities and stain, and the impurities are then readily removed by a stream of water playing down the troughs.

Drying is effected by three general types of apparatus: (1) Rotary cylinders, through which the sand passes against a draft of flame and hot gas; (2) a stationary roaster, and (3) coils of steam pipes. The first method involves the greatest initial cost, but is by far the most rapid and efficient. Fuller description of methods of obtaining and preparing sand will be found under the heading "Detailed descriptions of sand properties," pp. 367–375.

Sand that passes a 60-mesh sieve or one of smaller mesh is regarded as fine grained; that which passes 30- and 40-mesh sieves is regarded as medium grained, and that which is retained by 30- or 20-mesh sieves or sieves of coarser mesh is considered coarse grained. These divisions have been made the basis for classifying, according to their grain, the various sands mentioned in the following notes.

ROCKS UTILIZED.

INDIANA AND KENTUCKY.

In Indiana sandstones of Silurian, Devonian, Carboniferous, and Tertiary age have been utilized for glass making, but at present the Carboniferous sandstone furnishes the greater part of the glass-sand output.

Silurian.—Rocks of Niagara age extend from the Illinois line, in Newton County, eastward nearly across Indiana and cover the upper Wabash Valley. For the most part they are buried under a great thickness of drift. These Niagara rocks consist principally of magnesian limestone of varying composition and texture, but in some localities they occur as thin lenses of sandstone. One of these lenses, near Kenneth, Cass County, 3 miles west of Logansport, is 5½ feet thick and is composed of pure white quartz sand, containing only traces of calcium carbonate and iron. Just west of the Hamilton-Madison county line, at a point 1½ miles southwest of Fishersburg, a 5-foot bed of very pure white sandstone has been quarried for glass making. At this point the rock is massive, fine grained, and friable, and is overlain by less than 1 foot of buff magnesian limestone, over

which lie 18 to 24 inches of surface clay. Owing to the scarcity of outcrops and the thinness of the beds the sandstone of the Niagara formation can hardly be regarded at present as a very valuable source of glass sand in this region.

Devonian.—Rocks of Devonian age, like those of Silurian age, are covered by thick drift where they occur in the northern part of Indiana, but farther south are more favorably situated. In the vicinity of Pendleton, 28 miles northeast of Indianapolis, there is a massive, soft, white sandstone, varying in thickness from 7 to 15 feet. This sandstone is sufficiently pure for use as a glass sand and has been quarried as such at Pendleton, but in general has not proved thick enough for successful exploitation.

Carboniferous.—Sandstone and shale of Pennsylvanian age constitute the country rock of the southwest part of Indiana from Ohio River northward to Benton County, for a distance of 200 miles, in which they outcrop to a width varying from 2 to 3 miles at the north and reaching 75 miles at the south. These rocks dip westward, or a little south of west, so gently that locally they are nearly horizontal. Active quarries at Wolcott, White County; Loogootee, Martin County, and Coxville, Parke County, are in Pennsylvanian rocks, the first two being in the Mansfield sandstone.

The Mansfield sandstone, or "Millstone grit," the basal conglomeratic sandstone of the Pennsylvanian series, doubtless is more important to the glass-sand industry than any other formation in the State. It varies greatly in texture, color, and thickness. Locally it is a coarse conglomerate, which grades into a coarse sandstone, and in places it consists of alternating sandy and pebbly strata. The sandstone may be massive or thin bedded, and at many places it shows cross-bedding. The rock is mostly rather friable, but along bedding planes, in places where it is cemented by ferric oxide, it becomes very hard. It comprises hollow nodular masses and thin streaks of limonite and thin streaks of carbonaceous matter in all stages of alteration, from decomposed woody matter to bituminous coal, and these are accompanied by seams of fire clay. The color of the rock, where freshly broken, ranges from white and light gray, through buff, yellow, and brown, to red. The outcrop area of the formation is about 12 miles wide from west to east in Martin County, where the rock is well exposed by the drainage system of East Fork of White River. The beds strike in general N. 12° W., and a strip running 15 miles wide extends in Indiana from Ohio River at Canneltown, Perry County, for about 180 miles north-northwest into Benton County, where it becomes hidden by consolidated gravels, clays, and soils of Quaternary age. The Mansfield sandstone occurs in Benton, Jasper, Owen, Monroe, Greene, Lawrence, Martin, Daviess, Orange, Dubois, Crawford, Perry, and Spencer counties. Owing to

its superior durability, it has expressed itself strongly on the topography, forming vertical cliffs and capping many limestone and shale hills. Its observed thickness ranges from a few feet to more than 100 feet, although 40 to 60 feet are the usual limits. In consequence of its position above ground-water level it is at most places well situated for quarrying and is also well situated as regards transportation facilities, since no less than 16 railroad lines cross its area of outcrop in Indiana.

A Pennsylvanian sandstone of later age than the Mansfield is worked extensively for glass sand at Coxville, Parke County. The geologists of the Indiana survey regard this rock as the filling of a valley or channel carved in the "Upper Coal Measures." It appears to be younger than coal "VI" and older than coal "VII," and may correspond to the Merom sandstone of Sullivan County. Other evidences of filled channels have been observed in Parke and Fountain counties, and in Vermilion County, Ill., and these channels have been tentatively referred to the drainage system of the "Coxville Carboniferous River."[a]

Tertiary (?).—Deposits of sand, gravel, and, in places, conglomerate occur on the high points of the upland bordering the Ohio River flood plain in Indiana and Kentucky. G. H. Ashley[b] mentions their occurrence in Spencer, Perry, Harrison, Washington, Floyd, and Clark counties, Ind., and the writer has observed deposits of a similar nature in Hardin County, Ky. As these fragmentary deposits are associated with an old peneplain and are evidently younger than Carboniferous and older than Quaternary, they are regarded by Ashley as of Tertiary age. These beds, known as the Ohio River formation, consist of white, yellow, red, and brown sand and soft sandstone, which farther south attain a thickness in places of more than 50 feet. The grain of the material grows coarser from south to north, and the thickness of the deposits decreases notably toward the north. Beds of various-colored clays are found at or near the bottom of the deposits. Sands of the Ohio River formation have been dug for glass material at De Pauw and New Albany, Ind., and are now being exploited at Tip Top, Ky.

Maps and publications.—The United States Geological Survey has not yet issued topographic or geologic maps of these areas, but the Indiana Geological Survey has thoroughly covered the ground in that State, and much information may be obtained concerning the sandstones from the twentieth, twenty-first, twenty-third, and twenty-eighth annual reports of the Indiana survey, the latter containing a State geological map.

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[a] Ashley, G. H., The coal deposits of Indiana: Twenty-third Ann. Rept. Dept. Geology and Natural Resources Indiana, Indianapolis, 1898, pp. 80, 300, 345, 378, 385, 386, and 406.

[b] Ashley, G. H., and Kindle, E. M., The geology of the Lower Carboniferous area of southern Indiana: Twenty-seventh Ann. Rept. Dept. Geology and Natural Resources Indiana, Indianapolis, 1903, pp. 68–70.

OHIO.

Sandstones of Silurian and Carboniferous age are at present being exploited for glass sand in Ohio.

Silurian.—Interbedded with the "Lower Helderberg" ("Waterlime") limestones are a few beds of extremely pure silica sandstone that have long been known to outcrop in northwest Ohio, in Lucas and Wood counties, and in Monroe County, Mich. These beds have been grouped together as the Monroe formation by the Michigan Geological Survey.[a]

The quarries at Sylvania and Holland, Ohio, are in this sandstone. Silurian limestones occupy fully one-third of the area of the State and contain lenses of sandstone at some places, as in Champaign and Logan counties.

Carboniferous.—Sandstones covering a wider range in geological position than those available in the Silurian occur in the Carboniferous system in Ohio. The lowest beds utilized are formations of the Waverly group of the Mississippian series, locally termed the Black Hand formation, which is worked at Black Hand on Muskingum River, below Newark. Other localities in which Mississippian sandstones are worked are at Rockbridge, Hocking County, and at Akron.

Rocks of early Pennsylvanian age, belonging to the "Conglomerate" group, or Pottsville formation, are widespread and are worked for glass sand at Chalfants and Niles. Sandstone still higher in the system, or in the "Lower Coal Measures," is another source of glass sand. Such is the Massillon sandstone, quarried at the city of that name. Topographic maps of the Akron, Massillon, and Toledo quadrangles are issued by the United States Geological Survey, and the Ohio Geological Survey has issued a number of geologic maps showing, in a general way, the distribution of the rock formations in this State. Among the most useful of these are the atlases accompanying Volumes V, VI, and VII, as well as a small-scale map in Volume VIII and the large atlas sheets issued in 1879.

DETAILED DESCRIPTIONS OF SAND PROPERTIES.

INDIANA.

Coxville.—The works of the Acme Glass Sand Company are located at Coxville, about 2 miles northwest of Rosedale, a station on the Vandalia line; 16 miles northeast of Terre Haute. The sandstone quarried here is a deposit filling an erosion channel in the "Productive Coal Measures." The sandstone is exposed to a height of about 40 feet above the flood plain of Raccoon Creek. The base of the deposit is not exposed in the quarry, but overlies shale and coal "No. VI" at the margins of the channel, which are some 600 feet apart.

[a] Lane, A. C., Rept. State Board of Geol. Survey for 1891–92, Lansing, Mich., 1893, p. 66.

The beds are massive, lie nearly horizontal, and are covered by a few inches to nearly 10 feet of drift clay containing bowlders and gravel. This sand is rather soft, of medium-sized, angular grains, and the mass ranges from white to light brown in color. Close inspection shows that certain beds are speckled with iron-oxide spots the size of a pin head, so closely spaced that 30 or more spots appear in a square inch of surface. The sand is slightly micaceous and the bed contains occasional clay streaks. When crushed and dried the average sand has a light yellowish-brown color, due to impurities, a large proportion of which might be removed if the product were washed. The process of treatment is simple. After the customary drilling and shooting down, the broken rock and loose sand is loaded into the mill by a steel bucket on a cable conveyer and dumped directly into a Blake jaw crusher. The material then passes through one set each of corrugated rolls and smooth rolls and is thus separated into its individual grains. A belt conveyer, elevator, and chute, in the order given, carry the sand to a rotary drier burning coke. From the drier the sand may be delivered directly to cars or stored in bins. The capacity of this mill is about 250 tons a day. The quarry is fairly well situated with respect to transportation facilities, having direct connections with the Chicago and Eastern Illinois Railroad, and switching connections at Rosedale with the Vandalia line. The market for this sand consists chiefly of glass works in the State that make beer bottles. Some of these works are at Terre Haute. Without washing the sand is not satisfactory for flint and window glass. It is, however, in great demand for furnace use. Its analysis is shown on page 376.

Loogootee.—The Loogootee Glass Sand Company operates a quarry in Martin County, 1½ miles east of Loogootee, on the Baltimore and Ohio Southwestern Railroad. The Mansfield sandstone occurs in this vicinity in its typical development, forming the bluff of Boggs Creek, about 50 feet high, and it is reported to be nearly 100 feet thick, as determined by drill. A face of 25 feet above the railroad level is open in the quarry, disclosing masses of cross-bedded white to brown, rather coarse, soft sandstone containing a thin bed of fine quartz pebbles. Thin lenses of dark iron-cemented sandstone are common and in places iron oxide has been segregated to such an extent as to form lenses 1 foot thick. Streaks of carbonaceous matter further increase the percentage of impurity in the deposit, while joint planes enlarged to a width of 6 inches are filled with clay from the surface. All these objectionable substances, constituting about 5 per cent of the quarried material, are separated by hand..

The equipment of this plant is at present inadequate, but the addition of more complete washers, together with driers, is contemplated. From the quarry the material is wheeled in barrows into a small mill consisting of one set of rolls, a rotary screen having 10 meshes to the

inch, and 2 wash bins. A belt conveyer delivers the sand into cars on a siding. The present capacity of this plant is 150 to 200 tons weekly. The best grade of sand is used at Loogootee for common bottles and fruit jars. Other grades are used for molding, and some goes to the large lime quarries at Mitchell and Bedford for stone sawing. The quartz pebbles, separated by screening, are reserved for sale separately.

Wolcott.—The quarry at Wolcott, formerly operated by the American Window Glass Company, was not visited by the writer, but E. M. Kindle has made mention of it as follows:[a]

> Just west of Wolcott the Mansfield sandstone appears at the surface. It is extensively quarried for glass making in the southwest quarter of section 25. The section exposed in the quarry shows:
>
> | | Ft. | in. |
> |---|---|---|
> | Surface clay | 6 | 8 |
> | Light bluish gray, coarse sandstone with quartz pebbles scattered through it | 25 | |
>
> The sandstone is very friable and in part of the quarry is but little more than an unconsolidated sand.

KENTUCKY.

Tip Top.—The Kentucky Silica Company has opened recently a sandpit at Tip Top, Hardin County, 28 miles southwest of Louisville, on the Illinois Central Railroad. Post-Carboniferous sand, probably of Tertiary age, is obtained here from a deposit occupying the highest points of the upland surface and reaching elevations of 400 feet above the mean level of Ohio River. As stated on page 366, this sand is probably to be correlated with the Ohio River formation of the Indiana geologists. It here attains a thickness of more than 50 feet and covers 40 or more acres. The deposit consists of massive sandstone, so soft and so poorly cemented that it crumbles when touched. The sand is mainly white and yellow, the yellow sand constituting the upper three-fifths of the deposit. Along joints the yellow sand has been stained deep red by infiltration of a fine red silt from the surface. The lowest beds exposed in the quarry are of pure white, very fine-grained, clear quartz sand, and interstratified with them are a few lenses and bands, 2 to 6 inches thick, of yellow and white plastic clay. At the lowest point excavated in the quarry a reef of fossiliferous chert has been uncovered, but this was not visible at the time of the visit. Deep drill holes within one-half mile of the deposit do not encounter any such beds as are here exposed and thus tend to confirm the belief as to the fragmentary nature of the deposit. The acreage of sand available, however, has proved to be large enough to warrant the erection of an efficient plant for procuring and washing the product.

[a] Kindle, E. M., Stratigraphy and paleontology of the Niagara in northern Indiana: Twenty-eighth Ann. Report Dept. Geology and Natural Resources Indiana, Indianapolis, 1904, p. 417.

The hydraulic method, so successfully used in the Ottawa, Ill., glass-sand district, is employed here to remove the sand from the pit. The material is so slightly indurated that a jet of water from the nozzle of a large hose is sufficient to break it down, free it from the interbedded clay, and wash it into the sump of a Nye pump at the lowest point in the pit. The pump raises the sand about 12 feet to a screen having one-eighth inch meshes. The screened sand drops through the chute into a tank, from which it is carried by a gently inclined elevator out of the pit into the first set of wash bins. The washers consist of 2 sets of 2 bins each, the bins of the first set holding about 25 tons each, those of the second holding about 40 tons each. A second elevator carries the sand to the second set of bins, from which a second Nye pump moves the sand to the drain bins. The sand is not subjected to any further drying. The drain bins are used for storage purposes and are built alongside a railroad spur. They consist of 3 bins of 50 tons capacity each and 3 of 40 tons each, making convenient measures in loading cars. They are built of 2 by 6 inch lumber, laid flat, and have a basal compartment 8 feet deep, filled with cinders to insure rapid drying. Owing to the upland location of this quarry water is scarce, and the problem of maintaining a steady and adequate water supply has been solved satisfactorily by utilizing the waste waters from the washers after thorough settling, the loss from evaporation and seepage being replenished by piping a supply down from a pond about one-third of a mile distant. The dissected topography has favored the construction of storage and settling bins. The present capacity of this plant is about 200 tons a day, and it is planned to install steam driers in order to increase this capacity and to furnish the sand in better condition. The white and yellow sands are worked up together, and after washing make a light-colored, clean quartz sand, suitable for good grades of glass. When prepared by itself the white sand is of very high grade, while the deep red clay sand makes an excellent molding material. The glass sand is mostly used at present by the flint and bottle houses at Frankfort, Ky. Analyses of this sand are given on page 376.

OHIO.

Sylvania.—The plant of the Toledo Stone and Glass Sand Company is located about 4 miles southwest of Sylvania, a station on the Lake Shore and Michigan Southern Railway, 10 miles northwest of Toledo. Sandstone and dolomite are obtained in neighboring quarries from beds of the Monroe formation. In the latest Ohio Survey reports the sandstone phase is termed the Sylvania sand-

stone, and the limestone phase the Lucas limestone. The rocks are covered by only a thin veneer of drift, a few inches to 2 or 3 feet thick. The surface of the country is flat and the rocks are quarried from two large pits trending north-south, or with the strike of the rocks. The beds dip about 5° to the west, the sandstone underlying the dolomite and outcropping on the east of it. The sandstone quarry to the east is 15 to 25 feet deep and covers about 2½ acres. The dolomite quarry has been excavated to about the same depth and covers about twice the area of the sand quarry. Numerous springs emerge near the bases of the quarries and are drained by ditches into water holes, which are emptied by 6-inch pumps. Between the two pits stands the sand mill, with its necessary trackage, while west of the dolomite quarry stands a mill for crushing that stone. Both quarries are operated on the same plan. The sandstone is a grayish to white, firm rock, in thin beds, having a total thickness of 15 to 25 feet. At the base of the sandstone lies a conglomerate of dolomite pebbles in a sandstone matrix, below which is a bed of hard, fine-grained, dove-colored dolomite with an uneven surface. At the top the sandstone has in places received a slight yellowish stain. Its grains are rather fine and under a field lens appear to be clear quartz, for the most part worn smooth. On the whole, the sand is a very light-colored, clean material. Compressed-air drills are used, and the sand is blasted and loaded into trams that are moved by gravity over tracks that converge at a turntable. The cars are drawn up an incline by cable into the mill, where they dump into a Blake crusher. When crushed the sand passes through three sets of rolls is washed twice by the "auger" method, is screened, dried by steam coils, screened again, and stored. From the stock house the sand is delivered through pipes into cars. This company owns and operates its railroad into Toledo. The output of sand aggregates 80 tons a week and it is shipped for glass making mainly to Ohio, Indiana, and Pennsylvania. An analysis of the sandstone is given on page 376,

The dolomite is not burned, nor sold as building stone, but is all crushed and used as fluxing material.

Holland.—Near Holland and Monclova, about 10 miles west of Toledo, interbedded sandstone and dolomite of the Monroe formation lie near the surface, as at Sylvania. About 2½ miles southwest of Holland are the quarries of the Ohio Stone, Cement, and Construction Company and of the Lake Shore and Michigan Southern Railway Company. Both quarries produce only crushed dolomite at present, although about fourteen years ago glass sand was obtained here, crushed, screened, cleaned by fan draft, and about 1,000 cars of it were shipped to the glass factory at Maumee. The

beds have a low dip to the west and in a generalized section are stratified as follows:

Generalized section near Holland, Ohio.

	Feet.
1. Glacial drift, clay, pebbles, and bowlders	0– 5
2. Dolomite, dense, fine-grained, in thin beds	10±
3. Sandstone, grayish-white, friable, of fine, rounded grains	15±
4. Dolomite, very hard, siliceous	2
5. Sandstone, similar to No. 3, bottom not visible, reported thickness	60

At the time of visit mills and quarries were closed for the winter and the old sandstone pit was filled with water. The sand appears to be of good grade, and as the quarries are connected with the Lake Shore and Michigan Southern main line by a well-constructed spur it is probable that the production of glass sand will at some time be resumed.

Toboso.—The E. H. Everett Company operates a large quarry one-half mile west of Toboso, a station on the Baltimore and Ohio Railroad, about 15 miles east of Newark. The quarry is in sandstone and conglomerate beds that outcrop in bluffs about 60 feet high on the right bank of Muskingum River. About 30 feet of sandstone are now worked after stripping the top 5 to 20 feet, which are of thin-bedded and shaly sandstone. The quarry can be worked probably to river level, about 15 feet lower, since the rock contains very little water to that depth. The fresh quarry face presents on the whole the appearance of a uniformly yellowish-brown sandstone. The rock is massive, cross-bedded, rather coarse-grained, and contains many layers of fine to coarse quartz pebbles. Some of these pebbles attain a diameter of three-fourths inch. A few streaks of white sandstone occur, composed of clear quartz and white, opaque quartz grains with a sprinkling of fine black specks, mainly of tourmaline and hornblende. Rarely there are seams, 2 to 4 inches thick, of siliceous iron ore and a few thin clay seams. The sand is drilled by steam, shot down, and loaded into skips, which travel on trucks to the middle of the quarry, where the skips are picked up by cable conveyer and carried to the mill. This cableway is about 900 feet long and well illustrates the efficiency of this method of handling sand. The sandstone is reduced first by a jaw crusher, next by a 16-hammer Williams mill, is next screened, and then ground in a wet grinder, or vat, in which two heavy iron rollers or "chasers" revolve at the ends of an axle. Washing is accomplished by two sets of "augers," each set consisting of two screws 10 feet in length, which carry the sand up inclined troughs against a flow of water. Water for washing is obtained from Muskingum River, which at times is very muddy, and it would seem preferable if clear water could be used. Possibly

this might be obtained from wells in the sandstone sunk below river level or to the first shale bed. When finished the sand is of a light brownish-yellow color, evidently containing a high percentage of ferric oxide as compared with most glass sands. The whole output, averaging 120 tons a day, is used by the American Bottle Company at Newark in the manufacture of green and amber bottles. The quartz pebbles, or gravel, separated in screening, constitute an important by-product of the sand and are sold for sand blasting.

Chalfants.—The Central Silica Company, with offices at Zanesville, operates quarries at Chalfants, Perry County, and at Rockbridge, Hocking County. The sandstone utilized at Chalfants lies high in the bluff, 125 feet above the Baltimore and Ohio Railroad track. The rock is a light grayish-yellow sandstone, massive at the base but becoming thin-bedded at the top, and about 35 feet thick. A few layers contain small, rounded quartz pebbles. The sandstone is underlain and overlain by clay, the upper clay, 3 to 10 feet thick, forming the surface of the hill. About 2 feet of sandstone is left at the base for a floor. The next 20 feet of beds are easily crushed and worked into glass sand, while the upper 10 to 12 feet, which is a very fine-grained material, indurated nearly to a quartzite, is crushed and mixed with the overlying clay to form ganister. The rock is lowered to a mill at the base of the hill by a cable incline, or tramway, crushed, screened, washed by "augers," and dried in a rotary drum. Of the finished product the glass sand goes to window and bottle plants in central Ohio, and the ganister and pebbles are mainly taken by steel mills in Detroit, Mich.

It is probable that a vast amount of good material is still available in the sandstone of Licking, Muskingum, and Perry counties.

Massillon.—The Everhard Company and the Sonnhalter Sand and Stone Company are deriving glass sand from the Massillon sandstone of the "Coal Measures." In the Everhard quarry about 40 feet of grayish and buff-colored sandstone are exposed. The rock of the lowest beds is coarse grained and at some places has been used for making grindstones. The middle beds are fine to medium grained, and the upper beds in places grade into shale. Shale underlies the sandstone and clay overlies it. The Everhard quarry is one of the oldest in the State, as it was opened nearly 70 years ago and at present the quarry face extends for more than one-fourth of a mile. The preparation of the sand is accomplished in a very compact and efficient mill. The process comprises crushing, rolling, screening, and drying. The drying is effected by two 16-foot double-draft rotaries, which burn natural gas. The sand is then elevated to cooling drums, where the fine dust is drawn out by fans. This method of removing the dust is supposed to obviate the necessity of washing the sand. The finished product is a light-yellow, fine

to medium-grained, partly angular sand. It is used mostly in Massillon by manufacturers of green and amber bottles. An analysis of the sand is given on page 376. The Everhard brick plant, consisting of a mill and 6 down-draft kilns has been built in the southern part of the quarry. Here fire clay mined 2½ miles from the plant is utilized in the manufacture of a fine, mottled, fire-faced brick.

The Sonnhalter quarry, adjoining the one just described, produces glass sand and an even-grained, pink building stone. At this quarry the sand is washed and is dried in a Ruggles-Cole rotary dryer. An analysis of the Sonnhalter sand is given on page 376.

The quarries of the Massillon Sand and Stone Company and of the Wetter Steel Sand Company are also in the Massillon sandstone at a distance of one-half mile from the Sonnhalter quarry. These firms are now producing mill sands rather than glass sand, for which they have suitable material.

Small quantities of glass sand and larger quantities of sand for metallurgical purposes are produced at Barrs Mills, Dundee, and Strasburg, Tuscarawas County; Twinsburg, Summit County; Warwick, Wayne County; Killbuck, Holmes County, and Layland, Coshocton County, all in east-central Ohio.

Akron.—The quarry of the Akron White Sand Company is about 3 miles northwest of the center of Akron, on the line of the Northern Ohio Railway, on the brow of a scarp overlooking the valley of Cuyahoga River. At this place 12 to 20 feet of fine-grained, sharp, gray to buff sandstone above and 16 feet of pebbly conglomerate below are utilized.

The sand is crushed, rolled, screened, and dried, and is at present all sold for steel making, while the coarse pebbles from the conglomerate are used for concrete work.

Niles.—The National Sand and Stone Company operates a large quarry and mill about 4 miles south-southwest of Niles, near Austintown, on the Erie Railroad. Sandstone of Pennsylvanian age is quarried here from a large, open cut 25 feet deep. The face shows 8 feet of yellow to reddish sandstone at the top, with 15 feet of gray to white sandstone below. The beds have a slight dip to the north and are composed of a moderately coarse, subangular quartz sand, showing cross-bedding and containing in places near the base of the quarry some carbonaceous material in streaks and bands, one of which reaches 6 inches in thickness. The sand is sorted in the quarry and four grades are produced. The three best grades are sent to glass factories in Pennsylvania, principally for window glass, and the fourth-grade sand is sold for furnace and mill purposes. A symmetrically arranged mill completes the preparation of the sand, which passes in turn through a high-speed jaw crusher, a wet grinder, a reel screen, three sets of "auger" washers, further screens, and

then is pumped through a delivery pipe to various places in the large drain room. The floor of this room is constructed of coarsely crushed rock covered by mineral wool. The sand is dried in a stationary roaster, the essential parts of which are (1) an uncovered oblong, iron box, roughly estimated at 7 feet wide, 25 feet long, and 2 feet deep, fitted with a bottom of grate bars; (2) a fire box directly below the grate, but separated from it by a slanting sheet or plate of iron.

The sand is dropped from the belt into the open box, the capacity of which is about 25 tons. While drying it sifts slowly through the grate at the rate of 3 tons an hour, falls on the hot, inclined plate above the fire, and slides out onto a screw conveyer which operates in front of and at the base of the drier. After one more screening the sand is stored ready for shipment.

Glass sand is reported to be produced at Leavittsburg, Trumbull County, about 10 miles northwest of the Austintown quarries.

Undeveloped sand.—Sandstones as yet undeveloped, but known to be suitable for glass making and for other purposes for which a high-grade sand is in demand, occur in Holmes, Jackson, Knox, Licking, and Muskingum counties, mainly in the "Coal Measures" or Sharon conglomerate area of the State.

CHEMICAL ANALYSES.

The analyses here tabulated represent for the most part the best product from each locality. The only criticism that might be offered is that analyses are usually made from small selected samples and do not represent average carload lots. Samples taken from the cars invariably show slightly greater percentages of impurities.

Analyses of glass sands from Indiana, Kentucky, and Ohio.

Location.	Operator.	Sample.	Constituents.							Authority.
			Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3)	Lime (CaO).	Magnesia (MgO).	Other items.	Total.	
INDIANA.										
Coxville	Acme Glass Sand Co., Terre Haute, Ind.		98.61	0.74	0.22	0.12	Tr.	Loss on ignition, 0.32.	100.01	W. A. Noyes, Rose Polytechnic Institute, Terre Haute, Ind.
Loogootee	Loogootee Glass Sand Co., Loogootee, Ind.	Selected	97.78	1.13	.10	.06			99.07	J. F. Elsom, New Albany, Ind.
Do	do	Crude	96.26	2.50	.92		0.16	Na_2O and K_2O, 0.13.	99.97	Operator; report of State Geologist.
KENTUCKY.										
Tip Top	Kentucky Silica Co., Louisville, Ky.	Selected, washed.	99.14	.23	.02	.21	.08	CO_2+H_2O, 0.52	100.20	R. B. Hulme, Louisville, Ky.
	do	Selected	98.87	.21	.08	.24	.12	0.48	100.00	Operators of quarry.
	do	Crude	98.404	.751		.043	.372	H_2O, 0.271	99.841	Do.
OHIO.										
Sylvania	Toledo Stone and Glass Sand Co.		98.53	.18	.007	.67			99.387	Operators of quarry.
Chalfants	National Sand Co. (in 1902)		98.506	.09			.014	H_2O, 0.60	99.210	Professor Horton, Columbus, Ohio.
Massillon	Everhard Co., Massillon	Prepared for glass	97.50	1.50	.50		.50		100.00	Operators of quarry.
Do	Massillon Sand and Stone Co., Massillon.	do	98.611	.123	.033	.130	Tr.		98.897	Otto Wuth, Pittsburg, Pa.
Do	Sonnhalter Sand and Stone Co., Massillon.	do	99.60		.02	.23		Clay (?) 0.15	100.00	Jno. McNamee, Anderson, Ind.
Dundee	F. W. Meyers, Massillon, Ohio		98.45	.77	.14				99.36	F. A. Emmerton, Cleveland, Ohio.
Layland	Layland Stone and Sand Co. (in 1903).		98.78	.73	Tr.	.12	.04	Organic, 0.33	100.00	F. S. Schwab, Chicago, Ill.
Niles	National Sand and Stone Co.	First grade, washed	99.915	.062	.0019	.021	Tr.		99.9999	Otto Wuth, Pittsburg, Pa.
		First grade, not washed.	98.09	.75	.03	None.	.16	Loss on ignition, 0.33.	99.36	Pittsburg Testing Laboratory, Pittsburg, Pa.
		Second grade, not washed.	97.10	2.35	.14	.10	Tr.	H_2O, 0.31	100.00	Do.

NOTES ON VARIOUS GLASS SANDS, MAINLY UNDEVELOPED.

By Ernest F. Burchard.

Information relative to glass sands is occasionally obtained in connection with geological surveying, and some data thus procured are presented here to show the wide range in the geologic age and geographic distribution of suitable material.

Alabama.—Near Gate City, on the east side of Red Mountain, the formation heretofore mapped as the "Oxmoor" by the Alabama Geological Survey, composed of sandstone and beds of shale, has an outcrop width of 1,000 feet on both sides of Red Gap. The formation is nearly 200 feet thick and includes one sandstone bed about 75 feet thick. The beds dip southeastward at an angle of about 10°. The "Oxmoor" sandstone is of Mississippian age. It is composed of relatively pure quartz sand having very fine, subangular grains, which appear nearly white in mass. The rock is very soft, breaking down and crushing easily. Quarries which are worked intermittently for mill sand have been opened on both sides of Red Gap. About twenty years ago a small bottle plant operated at Gate City demonstrated that this sand was suitable at least for common bottles and fruit jars. It has been used also by the Dixie Glass Works at Tallapoosa, Ga.

Gate City, just on the outskirts of Birmingham, is on the line of five railroads which enter Birmingham by way of Red Gap, and is therefore favorably situated with regard to material, fuel, transportation, and market. No glass factory can be operated as many months of the year at this latitude as can those in the North, but if window glass could be made from this sand there is little doubt that it would find a ready market.

About seven-eighths mile northeast of Trussville, a station on the Alabama Great Southern Railroad, 15 miles northeast of Birmingham, sand quarries utilize the "Oxmoor" sandstone, as well as a reddish loam that overlies it. This loam may be of Tertiary (Lafayette) age. The characteristics of the "Oxmoor" sandstone here are similar to those of the beds at Gate City. Analyses of samples of this sandstone taken at both localities are given on page 382. At present the silica

sand, with an admixture of the red loam, is shipped in large quantities to mills at Birmingham, Bessemer, Ensley, and New Decatur, Ala., where it is used for molding purposes.

At North Birmingham the Lookout sandstone, of early Pennsylvanian age, is quarried for sand-lime brick making. Certain beds of this sandstone might prove pure enough for glass. The rock is of coarser grain than the "Oxmoor," but is very firmly cemented and is consequently harder to crush. Its chemical composition is shown on page 382.

Arkansas.—Attention was called in an earlier paper [a] to deposits of glass sand of excellent grade on White River, in northern Arkansas. These are practically inexhaustible and of the same age (Ordovician, St. Peter formation) as the great Pacific, Missouri, and Fox River, Illinois, deposits. It is of interest to note that near Guyon, on the White River branch of the Missouri Pacific Railroad the exploitation of these deposits has recently been undertaken, and it is reported that the glass sand is to be used for flint, window, and bottle glass at Coffeyville, Kans. (See p. 382 for analyses.)

Georgia.—The rare use of a river sand for glass making is reported from Augusta, Ga. Sand obtained along Savannah River is shipped to Chattanooga, Tenn., where bottles are successfully made from it. The sand is composed of fine to coarse angular grains of quartz, both clear and milky varieties being present. In mass it has a light gray or dingy white color.

Florida.—The unusual cleanness and even grain of the Gulf beach sand at Pensacola, Fla., suggested to the writer its suitability for glass making, and analysis of this sand (see p. 382) shows that it possesses the requisite purity. The sand is slightly coarse, the greater part of it passing a 20-mesh sieve, but not 40-mesh. Although at present remote from any glass-making centers, the deposit is not far from lines of rail and water transportation.

Iowa.—The Potsdam sandstone (Cambrian) and the St. Peter sandstone (Ordovician) occurring along Mississippi River in northeastern Iowa have already been mentioned as available glass-making materials.[b] In addition, it is now possible to give certain information concerning the Dakota sandstone (Cretaceous) in the northwestern part of the State. This rock has been found in quantity and purity sufficient to make it a possible source of sand for making bottle glass. It outcrops in bluffs along Floyd River valley northeast of Sioux City and has been quarried for building and molding sand near the

[a] Burchard, E. F., Glass sands of the middle Mississippi basin: Bull. U. S. Geol. Survey No. 285, 1906, p. 470.

[b] Burchard, E. F., ibid., p. 471.

Springdale station of the Sioux City-Leeds trolley line. Between 35 and 40 feet of massive, cross-bedded, soft sandstone with thin clay partings are exposed. The top is overlain by 10 to 80 feet of loess. The sand is a fine to medium grained quartz, rather angular, and carries a small proportion of mica flakes. Its color ranges from pure white through gray to yellow and dark brown. The average is light yellow. Where iron stained the objectionable material is usually hard enough to be thrown out in blocks. Generally the rock is so friable that it could conveniently be worked by hydraulic methods. This sandstone is well situated for quarrying and transportation, as it is close to the tracks used jointly by the Chicago, St. Paul, Minneapolis and Omaha and the Illinois Central railroads. The Dakota sandstone is exposed also at the base of Prospect Hill in the Missouri River bluffs, and the top of the formation is low in the bluffs of Big Sioux River, opposite Riverside Park. Fuller descriptions of the Cretaceous sands, clays, and limestones of this region and a map of their distribution is given in a local publication.[a]

Kansas.—Probably nowhere in the United States is there at present a greater need for a local supply of glass sand than in southeastern Kansas. In the gas belt there are 10 window-glass factories and 8 flint or bottle and jar factories in Kansas and 1 factory across the line in Indian Territory. All these are obtaining sand from eastern Missouri, and in addition to the selling price of the sand the consumers are paying three to three and one-half times that amount in freight charges. Besides the disadvantage of the high cost of sand these plants are at times subjected to a sand famine, due to the inability of remote producers to fill their orders promptly and to the inability of railroads to move the material when it is needed. The sandstone in the Buxton formation has been thoroughly prospected with a core drill at several localities near Fredonia. A typical section revealed by this drill is as follows:

Section of drill hole in Buxton formation near Fredonia, Kans.

	Ft.	in.
Light-brown, slightly coarse-grained sandstone	3	1
Light yellowish-gray, medium-grained sandstone, with a few iron-oxide specks near top and bottom of bed	4	10
Brownish, medium-grained, speckled sandstone, considerably stained by iron oxide	7	2
Gray calcareous sandstone	0	6
Total	15	7

[a] Burchard, E. F., Geology of Dakota County, Nebraska: Proc. Sioux City Acad. Sci. and Letters, vol. 1, 1904, pp. 135–184.

In January, 1907, a trial of this sand was begun at the works of the Fredonia Window Glass Company. The sand was hauled by wagon to the works and was found to make glass of excellent quality.

Near the town of Fall River the Buxton sandstone is exposed at several places by the drainage system of Fall River. The sandstone here is about 20 feet thick and is parted near the middle by a thin clay seam. The upper bed of sandstone is generally iron stained, especially at the top and immediately above the clay seam. Below the clay seam is 4 to 5 feet of very clean, grayish-white, angular sandstone, rather friable. This deposit is close to the Frisco Railroad tracks. West of the town it would have to be quarried from a pit, but east of the town it rises in a bluff that stands about 30 feet above railroad level. Associated with the sandstone, but somewhat above the beds just described, is a limestone, probably the Painterhood,[a] which might be quarried at the same time and used for glass making. Analysis of a small sample of this rock by George Steiger, of the United States Geological Survey, is as follows:

Analysis of limestone from Fall River, Kans.

Silica (SiO_2)	2.56
Alumina (Al_2O_3)	1.55
Ferric oxide (Fe_2O_3)	.50
Ferrous oxide (FeO)	.47
Magnesia (MgO)	.06
Lime (CaO)	51.98
Water (H_2O)	1.36
Carbon dioxide (CO_2)	41.13

Missouri.—Just south and east of the town of Versailles, Mo., lies a belt of saccharoidal sandstone, which is exposed at the top of the escarpment overlooking the ravines at the headwaters of Little Gravois Creek. This sandstone is almost everywhere capped by iron-stained quartzite, in some places cherty. The rock strikes northeast-southwest and has a low dip to the southeast. It is overlain in places by cherty beds and a very fine-grained sandstone or "cotton rock." The sandstone is regarded as the equivalent of the Roubidoux sandstone, of the Ordovician system, although some of the beds may be sandstone of Carboniferous age that has been deposited in connection with the thick masses of cannel coal that are found here in pockets or sink holes. The apparent thickness of the sandstone reaches 25 feet in places, although the actual thickness may be less than this, since the exposures are principally on hillsides that slope in the direction of the dip. Below the cap of quartzite the sand is white and friable,

[a] Schrader, F. C., and Haworth, Erasmus, Economic geology of the Independence quadrangle, Kansas: Bull. U. S. Geol. Survey No. 296, 1907.

except near joint planes, where it is somewhat iron stained and harder. The sand is white to yellowish, water-worn, and partly subangular; 100 per cent of the grains pass a 20-mesh sieve, 23 per cent pass a 40-mesh, 23 per cent pass 60-mesh, and 11 per cent pass 80-mesh. Therefore the sand, although uneven, is mostly of medium grain. The beds most suitably located for working are in the south half of sec. 32, T. 43 N., R. 17 W., where the rock outcrops within one-fourth mile of the Chicago, Rock Island and Pacific Railway.

Nebraska.[a]—The most accessible and prominent exposures of Dakota sandstone in this State are near Ponca, Jackson, Homer, Tekamah, Ashland (at mouth of Salt Creek), Lincoln, and Beatrice, and in the southern part of Jefferson County. The sand is variably indurated. At places it contains siliceous cement and is a quartzite. There is much less calcium carbonate in the stone than is usually supposed. It may be said that ferric oxide is the prevailing matrix. Generally the sandstone is friable and easily crushed. It is thin bedded where interstratified with shales or clay and mostly massive in the upper and lower parts of the formation. At some places massive ledges grade laterally into arenaceous clays within a short distance. The color ranges from gray to the yellows and browns, varying with the amount of iron stain present. The iron oxide covers or coats the grains, but rarely occurs as an impurity in the quartz. The sands may be freed of iron by washing. The chemical analysis of a badly stained sample taken at Robbers' Cave, near Lincoln (see p. 382), shows that the sand, if washed, might be used for green or dark glass.

When sieved, most of this sand was caught on meshes 30, 40, and 50, so that it is of remarkably even grain. It is composed largely of quartz, except when clay and mica are found. These are present where the sand rock grades horizontally into clay. In general the friable sand rock is clean, except for the iron.

[a] Communicated by Dr. Geo. E. Condra, Dept. of Geol., Univ. of Nebraska, Lincoln, Nebr.

Analyses of undeveloped glass sand from various localities.

Location.	Sample.	Constituent.							Authority.
		Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Other items.	Total.	
ALABAMA.									
Gate City	Sand	99.80	0.75	0.31	0.05	0.10	[a]0.10	100.11	R. S. Hodges, University, Ala.
Do	Sandstone	97.22	1.88	.24	.06	.09	.21	99.70	Do.
Irondale	do	97.93	1.05	.19	.06	.33	.12	99.68	Do.
Trussville	Sand	98.05	.22	.20	Tr.	.78	.....	99.25	E. S. Campbell, Trussville, Ala.
Do	do	98.30	.98	.19	.09	.02	.09	99.67	R. S. Hodges, University, Ala.
North Birmingham	Sandstone	97.30	1.39	.33	.07	.18	.16	99.43	Do.
ARKANSAS.									
Guyon	Sandstone	99.52	Tr.	.054	Tr.	Tr.	[b].016	99.59	R. V. Pepperberg, University of Nebraska, Lincoln, Nebr.
FLORIDA.									
Beach sand, Gulf of Mexico at Pensacola.	Crude	99.65	.....	.....	[c]	.....	.....	99.65	George Steiger, United States Geological Survey.
IOWA.									
Sioux City, Springdale station.	Averaged	96.90	1.22	.28	.14	.05	[b]1.07	99.66	George Steiger, United States Geological Survey.
KANSAS.									
Greenwood County, SE. ¼ sec. 13, T. 28 S., R. 12 E.	Selected from different beds same vertical section.	98.24	.57	.35	.06	.04	.72	99.98	George Steiger, United States Geological Survey,
Do		97.81	.73	.35	.18	.05	.80	99.92	Do.
Do		98.02	.81	.26	.08	.06	.81	100.04	Do.
Fall River, ¼ mile east of Frisco railroad station.	.....	97.28	.96	.80	.13	.04	.73	99.94	Do.
MISSOURI.									
Versailles	Averaged	99.03	.40	.13	.29	.11	.44	100.40	George Steiger, United States Geological Survey.
NEBRASKA.									
Robbers' Cave, near Lincoln.	Crude	95.76	.48	1.81	.24	.16	[d]1.55	100.00	George Borrowman, University of Nebraska, Lincoln, Nebr.

[a] TiO_2. [b] Loss on ignition. [c] None. [d] Undetermined.