

STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

**Publication 41. Geological Series 35.
MOLDING SANDS OF MICHIGAN
AND
THEIR USES**

BY
GEORGE GRANGER BROWN, Ph. D.

PREPARED UNDER THE DIRECTION OF
R. A. SMITH, State Geologist

IN COOPERATION WITH THE DEPARTMENT OF
CHEMICAL ENGINEERING UNIVERSITY OF MICHIGAN

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE
GEOLOGICAL SURVEY DIVISION FOR 1936.

PART II TESTS OF MICHIGAN SANDS

Gratiot County	13
Hillsdale County	13
Huron County	14
Ingham County	14
Ionia County	15
Iosco County	15
Isabella County	15
Jackson County.....	16
Kalamazoo County.....	17
Kalkaska County	17
Kent County.....	17
Lake County	18
Lapeer County.....	18
Leelanau County	18
Lenawee County	18
Livingston County.....	18
Macomb County	19
Manistee County	19
Mason County	20
Mecosta County	20
Midland County	20
Missaukee County.....	21
Monroe County.....	21
Montcalm County	21
Montmorency County	21
Muskegon County	22
Newaygo County	22
Oakland County	22
Oceana County	23
Osceola County.....	23
Oscoda County	24
Otsego County	24
Ottawa County.....	24
Presque Isle County.....	25
Roscommon County.....	25
Saginaw County	25
St. Clair County	26
St. Joseph County	27
Sanilac County	27
Shiawassee County	28
Tuscola County	28
Van Buren County	29
Washtenaw County	29
Wayne County.....	30
Wexford County	32
Chapter IX. The Northern Peninsula	32
Alger County.....	32
Baraga County	33
Chippewa County.....	33
Delta County.....	33
Dickinson County	34
Gogebic County	34

Contents

Chapter VII. Tests of the Michigan Sands	2
Explanatory Statement	2
Maps	2
Description by Counties.....	2
Methods of Sampling.....	2
Methods of Testing.....	2
Method of Reporting Tests	3
Significance of Tests	3
Chapter VIII. The Southern Peninsula.....	3
Alcona County	3
Allegan County	4
Alpena County	5
Antrim County	5
Arenac County	5
Barry County.....	5
Bay County	6
Benzie County	6
Berrien County.....	6
Branch County	9
Calhoun County.....	9
Cass County	9
Charlevoix County	9
Cheboygan County.....	10
Clare County.....	10
Clinton County	10
Crawford County.....	11
Eaton County	11
Emmet County	11
Genesee County.....	12
Gladwin County	12
Grand Traverse County.....	13

Houghton	35
Iron.....	35
Keweenaw County.....	35
Luce County	36
Mackinaw County	36
Menominee County	37
Ontonagon County	37
Schoolcraft County	38

Figures

Figure 30. <i>Pit of Garden City Sand Co., Showing top foot of clay loam, as indicated by shovel, over brown sand and clay (Sample 37).....</i>	7
Figure 31. <i>Pit of Garden City Sand Co. Showing clay loam thrown into bottom of dug over pit in foreground of right digging. The brown sand (Sample 37) and the white sand (Sample 41) at the bottom of pit.</i>	7
Figure 32. <i>Sand Bank in pit of Burt Core Sand Co. Showing layers of clay and rust in top of yellow sand stratum under top soil.</i>	14
Figure 33. <i>Steam shovel loading dinky cars at Burt Core Sand Company's pit near Vassar.</i>	14
Figure 34. <i>Method of screening and loading from dinky cars onto railroad cars—Burt Core Sand Co.</i>	14

Chapter VII. TESTS OF THE MICHIGAN SANDS

EXPLANATORY STATEMENT

MAPS

The two maps, one of the Northern Peninsula and one of the Southern Peninsula were prepared as an aid in locating the deposits from which the samples were taken and in giving a general perspective of the sand resources of the state. The areas of molding sand as indicated on the map must not be interpreted too literally, but simply as a rough indication of the areas where such sand might be found. For these reasons the maps must be considered simply as auxiliary to the more detailed statement in the text.

DESCRIPTION BY COUNTIES

Because a classification of the sands of Michigan according to their methods of formation, uses or physical properties would be difficult and of little use to the reader, the following description of the sands of Michigan follows a geographical division of the state into its two natural main divisions (the Northern and Southern Peninsulas), each of which is sub-divided according to counties which are described in alphabetical order. By the use of the map and index, all available information is made readily accessible by this method.

The location from which the sand was taken has been given in as definite and exact terms as possible. Peculiar local conditions have been indicated whenever such observations were made.

METHODS OF SAMPLING

In taking the sand samples the methods used were in general those outlined in Chapter II. It is obviously impossible to sample and test every individual pocket or deposit of glacial sand. However, an effort was made to sample so far as possible the representative sands of each district in order to obtain a general idea of the probable characteristics and utility of the sands found in different parts of the state. The samples obtained, by trenching the space of the exposure, from the auger or post-hole digger, or by other means, were generally reduced by careful quartering on a large canvas to about thirty or thirty-five pounds. The reduced sample was bound in a small tightly woven sack of awning material, properly labelled inside and out, and carried in the car until a freight office was reached. The small sacks were then combined in larger sacks and shipped to the laboratory.

METHODS OF TESTING

Through a cooperative arrangement with the American Foundrymen's Association some samples were tested under their auspices at the Bureau of Standards, Washington, D. C. and at Cornell University, Ithaca, N. Y. Most of the samples taken during the first year's work were tested at these two laboratories. The samples collected during the latter part of the field work were tested mostly in the laboratories of the Department of Chemical Engineering at the University of Michigan. For purposes of comparison, many of those samples forwarded to Washington or Ithaca were also tested in the Michigan laboratories. In one or two cases it will be noted that the test results do not agree at all, obviously due to confusion in the numbers used for purposes of identifying the samples, as all samples shipped to Ithaca were numbered when received at Cornell University.

The methods used for testing have been described in Chapter IV. All three laboratories supposedly used the same method for determining the fineness of grain, and the permeability of the sand. But the method of separating clay as used at the Bureau of Standards was such that most of the pan material and fines were included as "clay" causing the Bureau to report too high clay content and too low fines and pan material. Bond strength was determined by the transverse or cohesiveness test of the American Foundrymen's Association in the laboratories of the Bureau of Standards and Cornell University, but the automatic compression test described in Chapter IV was used on those sands tested in Ann Arbor. As this compression test loads the sample at a low rate, 2.69 pounds or 1220 grams per minute, the compressive strength as determined on these samples is less than the

compressive strength determined by Dietert's method described in Chapter IV.

METHOD OF REPORTING TESTS

A description of the sands found in each county will be found in the text. The actual results of the physical tests are tabulated for convenience at the end of the report. The sample numbers in this table correspond to the sample numbers on the map and are arranged in ascending order corresponding to the order in which the counties and samples are described in the text. The second column giving the laboratory number is the number used to identify the sample as collected in the field and the number used to identify the sample when forwarded to Washington or Ithaca. All tests are included, the laboratory in which the test was made being indicated in each case.

In addition to the samples collected for the present investigation, the properties of those samples collected by Dr. Ries and reported in the bulletin by Ries and Rosen¹ are also included, Table XLII.

It will be observed that the screen analysis as reported by either the Bureau of Standards or Cornell University includes the clay in figuring the 100 percent. Since the A.F.A. Fineness Factor is based upon the grain size exclusive of clay as 100 percent, the screen analysis as made in Ann Arbor are reported on the basis of 100 percent including only the clay-free sand grains.

¹Michigan Geological Survey (1908).

SIGNIFICANCE OF TESTS

It should be borne in mind that the following tests are simply preliminary tests on a particular sample selected from a deposit as located in the description and on the map. The results reported simply indicate the general characteristics, and by comparison with the specifications given in Chapter VI, the possible economic value of the sample selected. Any particular deposit must be carefully sampled and tested before the economic value of such a deposit may be properly demonstrated.

This report is intended simply to indicate the general characteristics of Michigan sands and the possible uses for these sands, but not to prove up any particular deposit for any purpose.

Chapter VIII. THE SOUTHERN PENINSULA

The greater industrial development in the Southern Peninsula has stimulated and justifies a far more intensive search for molding sand and other similar materials having an economic value, than in the Northern Peninsula. The Southern Peninsula has been thoroughly investigated and those areas in which molding sand deposits of sufficient extent to have

economic value are likely to be found have been indicated.

The lacustrine deposits along the east shore of Lake Michigan from St. Joseph to Grand Haven seem to make satisfactory molding sands when containing sufficient clay to possess the necessary bond. Such deposits are worked commercially at Allegan and Riverside, and Coloma in Van Buren County. Similarly the lacustrine deposits extending inland about twenty miles from the Ohio State line as far north as Port Huron may yield satisfactory sands in some places. Such deposits are worked commercially at Mt. Clemens.

River silts in the glacial deposits seem to be the next most hopeful source of molding sand in the Southern Peninsula. Deposits of this nature have been worked at Dimondale in Eaton County southwest of Lansing for some time.

Small pockets of molding sand may also be found throughout the moraine deposits particularly, on the slopes of the moraines or drumlins. Generally the outwash aprons or plains do not contain sufficient bond to contain molding sand. The till plains may be considered as practically equivalent to the moraine deposits so far as being the source of molding sands.

The river deltas are usually so non-uniform and contain so much fine material classified as silt, as to be generally unsuited for molding sand.

Except for a few sands bonded by iron oxide as found in Houghton County in the Northern Peninsula the durability of Michigan bonded sands when used as molding sand is considerably less than that of molding sands which have been developed by the process of weathering, as represented by the Ohio, Illinois, and New York sands. However, the increasing cost of transportation and the decreasing quality of these out-state sands may tend to encourage the use of local molding sands particularly if their properties may be improved or restored by synthetic or artificial means.

ALCONA COUNTY

About one-third of the area of Alcona County is sandy till and about one-fourth clayey till. Sample one (1) taken near Spruce about eight or nine miles west of the Detroit and Mackinac Railroad in section 6 of T. 28 N., R. 8 E. is representative of the sand that may be found in these land laid moraines. It is not well sized as the moraine material contains stones of all sizes, sand, and fine material through clay. As has been indicated in such deposits the sand and clay may be rather well mixed and might possess such physical properties as to be useful as a molding sand. The samples were taken from trenching and from a small pit at the side of a road. As shown in the table of test data this sample possesses a fairly high bond.

Sample two (2) taken on the township line, T. 28 N., R. 8-9 E., five miles west of Black River, represents a light yellow sand somewhat similar to that found on the plains

but containing more pebbles and more clay bonding material. This sample was taken from an outcrop where the road cuts through small mounds of moraine deposited material and is believed to be representative of some of the lighter sands found mixed with moraine and boulder clay.

Although some of the sand found in Alcona County may yield usable molding sand for local purposes there is slight chance of any workable deposits of molding sand being found in this county.

ALLEGAN COUNTY

The surface of Allegan County is about sixty percent sandy or sandy till, representing both moraine deposits and sandy drifts with some sandy lake beds and river silts running about twelve to fifteen miles up the Kalamazoo and Rapid Rivers. In this county the sandy drift seems to be at least partially deposited from the outwash of the glaciers and, where properly mixed with clay from the moraine deposits as south and west of Allegan, may yield commercial molding sand in some areas. At least one such deposit is now being worked by the Clean Cast Sand Company, with offices in the Transportation Building, Chicago, Illinois.

Samples six (6) and seven (7) were taken in 1923 from the pit owned by Mr. Hale in N. W. $\frac{1}{4}$ Section 32, T. 2 N., R. 13 W., two miles southwest of Allegan on the Pere Marquette railroad. At that time sand was removed by a truck and sold for \$1.30 per ton, to C. W. Young Foundry, Allegan, and the Burr Machine Works of Holland, among others. The pit was first opened that year (1923), and as the sand seemed to be fine and smooth and having a good bond, its use as a molding sand was expected to increase. The deposit covers about one hundred acres or more to a depth of one to five feet.

In 1925 this same pit was again visited and sample thirteen (13) collected as representing the molding sand then being shipped from the pit. It was reported that the sand was mixed with coarser sand for use in some foundries. Most of the production was hauled into town by truck, and the daily capacity was rated at fifty tons.

Samples fourteen through eighteen were kindly furnished by the courtesy of Mr. Paul G. Bachner of the Clean Cast Sand Company, representing the material shipped from the pit in 1924. Sample fourteen identified as Clean Cast Company No. 0, is considered to be the basic loam sand of the deposit which is shipped clear if desired or blended with one of two other sands to give it an open structure. Sample sixteen identified as Clean Cast No. 1, sample seventeen identified as Clean Cast No. 2 F, and sample eighteen identified as Clean Cast No. 2, are the blends as shipped from this pit. At the time these samples were supplied the largest sale was of No. 0 and next of No. 2 represented by samples fourteen and eighteen. These sands are used for light automotive castings, light machinery castings of many kinds, for brass and for stove and furniture castings.

Comparison of these sands with Albany No. 1 indicates that the Clean Cast sand has a higher bond, a lower permeability, and lower fusion point. Clean Cast No. 0 fusing at about 2600° F., No. 1 at about 35° higher, and No. 2 at about 2700° F., while Albany No. 1 showed a fusion point of slightly over 2700°. Sample fifteen is Clean Cast No. 0 after it has been heated to 600° F. for two hours. As Clean Cast No. 0 is the bonding sand used in preparing these blends, this was the only one which was tested for durability.

The bond strength was reduced to less than half of its original value.

Sample three (3) taken from Section 25, T. 1 N., R. 11 W., about one mile west of Plainwell is representative of the sharp yellow sand deposited through this region by the glacier. In some places it is free from stone, and in other places it is very gravelly and full of larger stones. Sample four (4) taken two and a half miles northeast of Plainwell in the southeast quarter of Section 8, T. 1 N., R. 11 W., is representative of a deposit of clean sand ranging from white to red in color underlying approximately twenty acres or more. The depth of the sand in this deposit was not determined but it is at least four feet at the bottom of the knoll.

Sample five (5) taken from a small bank of very clayey sand from the pit of the Zeeland Brick Company, Section 8, T. 3 N., R. 14 W., just west of the Pere Marquette Railroad is an interesting sample representing that stage of classification which must be considered as intermediate between clay and sand. Formerly a few carloads were shipped out for foundry use but the bank has not been worked since 1923.

Sample eight (8) represents in a general way the sandy drift and outwash found west of the large moraine deposits in the central part of the peninsula. Sand of this type covers a large area running north through R. 15 W. from the county line to Fennville. Samples nine (9) and ten (10) taken about six miles west of sample eight in Section 10 of T. 1 N., R. 16 W., represents the sand underlying a relatively large area which appears to be an old lake bed which has been weathered to give a somewhat rolling country. The deposit seems to be a mixture of sand with some clay bond and might be used under some conditions for molding sand. Sample eleven (11) from Section 13, T. 4 N., R. 16 W., is an almost white dune sand containing practically no bond and seems to be representative of the dune sand which extends along Lake Michigan shores from Holland to Saugatuck. It is interesting to note that sixty percent of this sand passes a number 40 mesh and is retained on a number 70 mesh sieve indicating the uniform size of wind blown material. Allegan County, and many other counties in the state, afford excellent examples of the relative efficiency of wind, water and ice in separating sand into uniform sized grain.

Sample twelve (12) from Section 14 of T. 4 N., R. 12 W., six miles west of the Lake Shore and Michigan Southern Railroad and about one half of a mile south of Burnet

was tested at Michigan and at the Bureau of Standards with somewhat different results for reasons noted. The screen analysis of this sample is also a bit puzzling as it seems to be composed of a mixture of two different sands, one having a grain fineness of 70 mesh and the other somewhere between 140 and 200 mesh. Although such screen analyses may be common in artificial mixtures few natural sands have been observed with this type of grain size distribution.

ALPENA COUNTY

The surface of Alpena County is composed mostly of boulder clay and moraine deposits with some sandy drift south of Spratt near Nenelon River. About four miles back from the lake shore as far north as the City of Alpena are found sandy deposits from the old glacial lake bed. Sample 19 from Sections 23, 24, 25, 26, of T. 30 N., R. 7 E., is representative of this lake sand to the west of Devils Lake.

Sample 20 from Sections 8, 16, 17, 19 of T. 31 N., R. 6 E., one mile north of Lachine was taken from a layer of mixed white and brown sand about three feet in thickness overlying typical yellow plains or glacial outwash sand. The deposit consists of a few inches of white sand, then a few inches of brown containing chunks cemented together, apparently by iron oxide. These chunks do not exist in definite continuous layers, although generally following the contour of the surface. Indications are that this deposit is undergoing transformation into a naturally bonded sand, but being practically free from clay and possessing little bond cannot now be used for molding sand.

Sample 21 from Section 4 about one mile north of Sample 20 is taken from a thin deposit, a few inches in thickness, which appears to be a weathered boulder clay containing large quantities of sand. It seems reasonable to expect that either Samples 21 or 22 taken from this section is representative of the sand which was formerly used locally as a molding sand in casting brass.

Sample 22 was taken from the same section as 21 but from a formation similar to that shown by Sample 20. Sample 20 represents the white unbonded sand and sample 22 represents the rusty yellow sand occurring in chunks. Samples 21 and 22 are similar in many ways except that sample 21, evidently a boulder clay deposit, is not sized to anywhere near the uniform product as is 22, which is evidently a water deposited sand, probably from some glacial outwash.

Along the lake shore as in Sections 14 and 15 of T. 31 N., R. 8 E., are found large quantities of clean sand somewhat similar to sample 19. This sand is used locally in Alpena as a core sand. The local foundry reported that sand similar to sample 21 and 22 was used as a molding sand and that it was considered superior to molding sand now being shipped in from Ohio.

There are large deposits of clean sand along the lake shore and elsewhere used for building sand and core

sand in many parts of the county. Samples 21 and 22 from the glacial deposits are representative of the small pockets of molding sand that may be found in various parts of Michigan. Although occasionally suitable for local use these deposits generally possess little economic value as is evidenced by the present practice of the foundry in Alpena which imports molding sand from Ohio rather than use the inconsistent material found locally.

ANTRIM COUNTY

About one-third of the surface of Antrim County may be classed as sandy till. Most of it is extremely variable. Sample 23 from Section 6 of T. 31 N., R. 5 W., about three miles west of the G. R. & I. Railroad represents the white clean sand found around Boyne Falls, in a rather limited area, under about three to four feet of yellow sand. The formation is generally pockety, typical of moraine deposits. Sand is found in pockets with clay, gravel and stone to a depth of fifteen to twenty feet and possibly more. Sand also occurs in ridges through the lowlands. The ridges seem to have been deposited either directly under the glacier or at its extremity and are generally similar to moraine deposits.

Sample 24 from Section 4 of T. 30 N., R. 5 W., about three-quarters of a mile northeast of Simmons along the G. R. & I. Railroad is a deposit of clean yellow sand covered by three to four feet of brown sand and containing clay and gravel. Its general formation is similar, to that there sample 23 was taken. The sand is generally similar, although coarser than sample 23. Both of these samples appear to be water deposited, having fairly high distribution factors.

A comparison with sample 21, having a fineness distribution factor of .264, will serve to emphasize the difference in classification brought about by water deposition as compared to moraine deposits as represented by samples 21 and 22.

ARENAC COUNTY

The surface of Arenac County is mostly sandy, clayey lake beds and contains deposits of sand similar to those found in Bay, Midland and the eastern part of Gladwin County.

BARRY COUNTY

The surface of Barry County is mostly sandy till laid down by the glaciers. Samples 25 and 26 were taken from Section 9, T. 2 N., R. 8 W., about four miles from the Chicago, Kalamazoo and Saginaw Railroad, along the main highway and Cedar Creek. The sand is fine, light yellow in color and contains little bond. The sample was taken from the cut which here exposes about 30 to 40 feet of sand. The sand is generally covered by three to four feet of sandy gravel and may be found in pockets over an area of four to five square miles.

The differences in screen analyses reported from the laboratories at Ann Arbor and Washington, are probably most evident in comparison of these two samples, taken from the same deposit by the same man at the same time, and intimately mixed before quartering and separating for shipping.

The physical appearance and feel of this sample indicates that it contains much less than thirty percent of clay. Being a fine sand, containing relatively large amounts of silt and fine grained sand particles, the method of siphoning the clay from the sand grain used by the Bureau of Standards carried off a relatively large amount of silt or sand grain with the clay, tending to make the clay content appear high and the pan material and the material on a 270 mesh low.

Sample 27 from Section 28, T. 4 N., R. 8 W., was taken from a bank on the side of the road fifty yards east of the main highway. The sample represents fine sand lying in strata about three feet thick and four feet below the top of the hill. Preliminary investigation indicated that this sand might be found under an area of approximately ten acres.

Samples 28 and 29 from Section 25, T. 4 N., R. 10 W., about one mile east of Middleville and the Michigan Central Railroad, are representative of many pockets of sand found in the till plain. These samples are 1 from a stony, reddish-yellow clay-sand mixture, at least fifteen to twenty feet deep in places. The clay seems to run in streaks over the yellow sand, clearly indicating that the clay and sand were deposited more or less together by the glacier.

In Section 30, T. 3 N., R. 7 W., about four and a half miles east of Hastings, and three-fourths of a mile south of Morgan and the Michigan Central Railroad, is an exposure of about thirty-five to forty feet in a cut made for the highway, of coarse unbonded yellow sand which runs into gravel in places. The deposit is full of stones, typical of moraine deposits.

BAY COUNTY

Bay County includes considerable areas of sandy lake beds which yield material of commercial value. The industrial development in the Bay City district, is sufficient for a number of local sands to be used for various purposes. The Bay City Electric Steel Casting Company uses a so-called silica sand, Sample 31, which seems similar to sand dredged from the Tittabawassee River (Sample 206) used by the Bay City Iron Works as a core sand. The exact location from which this sand was taken is not known but it was reported to be near Saginaw. The Bay City Iron Works formerly used Michigan City sand exclusively for cores but found it too fine for propeller castings. The sand (206) obtained from the river bed proved satisfactory for this purpose.

For a molding sand this company uses a Zanesville number four molding sand purchased in 1924 at fifty cents per ton f.o.b. and freight charges at \$3.15. A

sample of this Zanesville sand was collected and is reported as sample 311, laboratory sample 2152.

Sample 32 taken from Section 26 of T. 15 N., R. 5 E., one mile northwest of Kawkawlin, represents a bank of clean sand owned by Mr. Joe Rocarius, and used for making cement blocks. Some sand is also sold in Bay City. The bank is about eight feet thick and covers probably twenty acres. The deposit is evidently a sandy lake bed of well classified material.

The Laetz Foundry Company of Bay City, making iron, brass, and aluminum castings, uses a local sand for core sand and a Zanesville number three for iron castings. Sand received from a small pit, somewhere north of Bay City, was reported as being a fair molding sand.

The Bay City Foundry and Machine Company also uses a Zanesville number three sand for molding and Michigan City and local sands for preparing cores.

BENZIE COUNTY

Benzie County is more than one-half covered with sand till, sandy lake beds, or sandy outwash plain. Sample 33 from Section 7, T. 26 N., R. 14 W., about one mile west of Honor, and one-half mile from the railroad, is a clean sand found in depths up to twenty to thirty feet in places, and covering about twenty to twenty-five square miles north of Crystal Lake.

Sample 34, from Section 34, T. 26 N., R. 14 W., is a clean white sand, free from bond, found in the glacial outwash plain around Frankfort, and along the Ann Arbor Railroad. Samples 33 and 34 are very similar except that sample 33 has been somewhat discolored and weathered as compared to sample 34. A comparison of the tests reported on sample 33 at Cornell laboratories and sample 34 by the Bureau of Standards, with these facts in mind, may be taken as another indication that the Bureau of Standards separated the clay substance from the sand grains in such a way as to include considerable amounts of fine sand grains with the clay substance.

BERRIEN COUNTY

The surface of Berrien County is made up largely of glacial outwash and boulder clay, with some sandy lake beds along the river valleys leading back from St. Joseph. An interesting delta formed by the river now known as St. Joseph is found in T. 5 S., R. 18 W. The interesting dunes found along the lake shore in the southern part of the county and also to the north running from the Indiana state line north to Stevensville in an almost unbroken band contain large volumes of well sized sand.

With these deposits frequently in close proximity, it might be expected that some of the old lake beds might contain bonded sand usable as molding sand, as the sandy materials might be washed and mixed with the clay bonding material and then redeposited in quiet

bays. This seems to be the method by which the sand near Coloma now used by the Garden City Sand Company and by Kerlikowski was deposited.

Sample 35 taken from T. 7 S., R. 21 W., east of the Pere Marquette Railway, is a light yellow bank sand free from bonding material, and seems to be a water deposited sand. There are large quantities of sand similar to sample 35 in this district, not counting the dune sands which are very plentiful. About six miles east of this locality, in section 36, T. 7 S., R. 19 W., red sand in thin layers about eight inches thick is found under about four feet of clay in what appears to be a boulder clay or till plain.

Sample 36 from section 15, T. 6 S., R. 19 W., represents a glacial deposit in a sandy till plain, containing some stone and clay. The sample was taken from the upper two feet of the deposit. Underneath this layer unbonded sand containing pebbles and bearing water is found. Sample 36 seems to possess most of the properties of molding sand which is removed from this district.

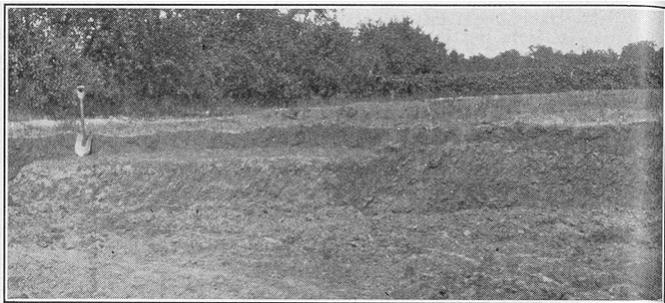


Figure 30. Pit of Garden City Sand Co. showing top foot of clay loam, indicated by shovel, over brown sand and clay (Sample 37)

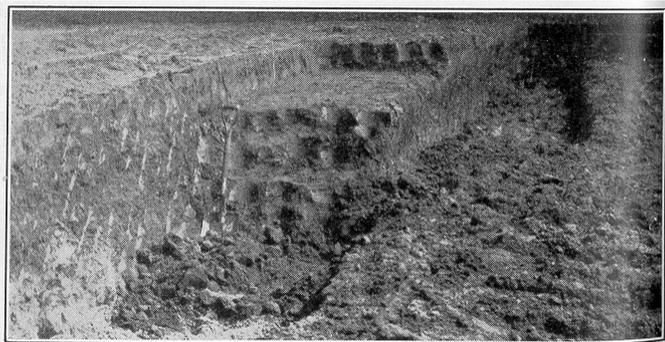


Figure 31. Pit of Green City Sand Co., showing clay loam thrown into bottom of dug over pit in foreground of right digging. The brown sand (Sample 37) and the white sand (Sample 41) at the bottom of pit.

Samples 37 and 41 were taken from the pit of the Garden City Sand Company of Chicago, in section 24, T. 3 S., R. 18 W., in September, 1923. These samples were taken from the old sandy lake bed which extends in a bank about three miles up the Paw Paw River from St. Joseph. The top foot of the deposit is clay loam, which is rejected and shoveled back into the pit, after the sand is removed, as a fill. Under the clay loam is a layer of brown sand and clay mixture about three to five feet

thick from which sample 37 was taken. Under the brown sand is found a coarser white sand represented by sample 41. The method of working this deposit is clear from the photographs, figures 30 and 31. The mixtures of the upper brown sand and the white beach sand below are prepared by loading so many spades of beach sand to so many spades of brown or bonding sand according to the requirements of the purchaser. Usually the mixtures are prepared containing up to 50% of the white beach sand. The mixed load is then trucked about one quarter of a mile across the road to a siding on the Pere Marquette Railroad. Here the truck is dumped and the sand put through a roll crusher and screened to break up the lumps of sand before loading.

In 1923 this pit was shipping molding sand into Illinois, Wisconsin, as well as in Michigan, at a price of \$1.25 to \$1.50 a ton. About three cars a day were loaded with the six trucks then used to carry the sand to this railroad siding. Over a period of ten years up to 1923 approximately twenty acres of this deposit had been dug over.

Sample 37, representing the upper brown sand found in the pit of the Garden City Sand Company, was tested at the Cornell laboratories with the results as indicated. A duplicate sample, identified as No. 38, was tested in the University of Michigan with similar results. The methods of determining the clay content used at Cornell University and at the University of Michigan give generally concordant results, whereas the clay content reported by the Bureau of Standards is high. Because this sand is the bonding sand used in preparing the commercial molding sand shipped from this pit duplicate samples, numbers 39 and 40, were heated to 600° F. for two hours and fourteen hours respectively, losing 48 and 62 percent of their bond strength and 69 and 68 percent of permeability respectively. This is a rather high loss on heating and indicates that the bond in the sand is not very durable. From practical consideration this may be partly compensated by using a sand containing relatively large quantities of bond as indicated in the discussion of durability.

In 1925 the Garden City Sand Company's pit was again visited. At this time approximately five acres of the deposit were left. Sample 42 taken at that time is representative of the molding sand then being shipped from the pit, apparently about a 50-50 mixture of the brown bonded sand, sample 37, and of the beach sand (41). Sample 42 heated to 600° F. for two hours lost 73 percent of its bond strength and gained 120 percent in permeability. Comparison of sample 42, representing the mixed molding sand as actually shipped from the pit, with sample 39, representing the high bond sand used in preparing the commercial blend, clearly indicates the differences in results obtained from durability tests on different mixtures of the same materials.

There appear to be a number of similar deposits of sand in this area near Riverside. Definite deposits were located about one-eighth of a mile south from the pit of

the Garden City Sand Company and about two miles west of the latter deposit.

Sample 43 from section 19, T. 3 S., R. 17 W., one and one-half miles west of Coloma and about one-half mile north of the Pere Marquette Railroad was taken from a bank on the south side of the road, and represents a stratum about three feet thick found one foot below the surface. It is apparently only a small pocket of a few yards in width found in the sandy lake bed and is generally similar to the other deposits worked for molding sand in this district.

The Kerlikowski pit, in section 26, T. 3 S., R. 18 W., has been worked for about nineteen years. The formation and the sand are very similar to that in the Garden City Company's pit, except that the brown bonded sand exists in a stratum about two feet thick. Similar to that of the Garden City Company, this sand is covered by about one foot of clay soil or loam and underlain by beach sand. The deposit is handled in much the same way as that of the Garden City Company's and the sample (44) taken from Kerlikowski's pit has much the same properties as sample 42 taken from the pit of the Garden City Company.

Sample 45, taken from east cut of a country road in section 5, T. 4 S., R. 18 W., about one hundred yards east of the Pere Marquette Railroad and three miles northeast of Benton Harbor, is very similar to the samples taken near Riverside except for the fact that it possesses a coarser grain. Here the formation seems to be about two feet thick as in the Kerlikowski pit.

Another deposit of similar sand is that represented by sample 46, taken from the southeast quarter of section 2, T. 5 S., R. 19 W., on the farm of George G. Clemens, just east of the Michigan Central Railroad tracks. This sample contains more clay than 45 and possesses a higher compressive strength. This deposit has been worked for over thirty years, and in 1925 there appeared to be not more than one hundred car loads left. This sand has been used by the Studebaker Corporation, General Motors, and several Michigan, Illinois, and Indiana foundries, in amounts varying from one to two hundred and fifty cars per year. In this locality the bonded sand occurs in a layer about five feet thick. Another sample (47) taken from the same farm but on the west side of the Michigan Central right of way, represents a layer of bonded sand about six or seven feet thick underlying about one and a half acres which had not been developed when visited in 1925. This sand is finer and contains less clay than that represented by sample 46, but should prove equally satisfactory when properly adapted, or when used for purposes not demanding such a high permeability.

Sample 48 from section 20, T. 3 S., R. 17 W., within the city limits of Coloma, fifty yards north of the county road and about two hundred yards south of the Pere Marquette Railroad, represents a high bonded sand found in a layer about four feet thick three feet below the surface of the ground. It appears to be a large deposit of

highly bonded sand. Durability tests as indicated by sample 49 from this deposit classes it as similar to the sands found further west near Riverside.

Sample 50 from section 20, T. 4 S., R. 17 W., taken from the east and west banks of a cut in a county road, represents a finer, highly bonded sand found in a stratum five feet thick, about one foot below the surface. This deposit also appears to be relatively large and to contain considerable quantities of ferric oxide.

Sample 51, Section 29, T. 4 S., R. 17 W., taken from a cut on the county road three miles southeast of Millburg and six miles east of Benton Harbor, is a coarser sand containing less clay, found in a stratum about four feet thick two feet under the surface. This deposit lies on the east side of the road and extends forty or fifty yards along the road and quite a distance eastward. The test indicates that this sand might be used as a molding sand for purposes somewhat similar to sample 46 on the Clemens farm.

Sample 52 is a fine light sand from the pit of E. J. Moody in Section 31, T. 6 S., R. 17 W., about one-half mile south of the Benton Harbor and St. Joseph Electric Railroad, but the owner refused to part with any information regarding the uses of this sand.

Sample 53, section 27, T. 6 S., R. 17 W., three and a quarter miles southeast of Berrien Springs, is a coarser sand containing little bond in a patchy deposit about one foot thick two feet below the surface.

Sample 54 is a fine sand containing about 60 percent of clay, found in a stratum two feet thick and two feet below the surface in section 3, T. 6 S., R. 18 W., on the east bank of the main highway one-quarter of a mile west of the Southern Michigan Electric Railroad and two miles east of the Pere Marquette Railroad. Another similar deposit is represented by sample 55 in section 16, T. 5 S., R. 18 W., on the east bank of the road one mile east of the Southern Michigan Railway and four miles southeast of Benton Harbor. Sample 56 in section 15, T. 6 S., R. 18 W., is another similar sand from a stratum about three feet thick outcropping for one hundred feet along the road. The great similarity between sample 56 and sample 54 indicates that there may be relatively large quantities of sand similar to these samples along this part of the St. Joseph River.

Sample 57 from section 10, T. 7 S., R. 19 W., about a half mile south-west of Glendora and a quarter of a mile west of the Michigan Central Railroad, was taken from a cut on the west side of the county road from Baroda and Galien. It is a coarser sand having a wide working range from about 7½ to 9½ percent moisture. The deposit is about two feet thick and found two feet below the surface. The area of this deposit was not determined although it is apparently relatively small. This sample and also 58 appear to be more like the glacial deposit than the lacustrine deposits found in this county. Sample 58, section 36, T. 7 S., E. 19 W., on the main highway about one and a half miles east of Galien and one and a quarter miles east of the Michigan Central

Railroad, was taken from the north side of the highway and represents a deposit about three feet thick four feet below the surface extending for at least fifty yards along the road.

In addition to the samples mentioned above the four samples collected and tested by Ries in the report on foundry sand of 1908 should be included. These samples identified as R. 12, R. 13, R. 23, and R. 56 from Vrooman's pit near Riverside, core sand from Niles, Garden City Sand Company, Vineland, and from Kerlikowski's pit respectively, are included in the table of test data.

BRANCH COUNTY

The surface of Branch County is mostly clay and sand drift with some outwash sand and land laid moraine. Sample 59 north of Batavia is a gravelly sand running to clean gravel below. Evidently a glacial deposit poorly classified as to grain size, this sample seems representative of the district. Sample 60 is somewhat similar but contains more clay and accordingly possesses a higher bond and lower permeability, Sample 60 was taken from section 18, T. 6 S., R. 7 W., from a pit about three feet deep in the roadside.

The opinion expressed by the foundry foreman in Coldwater, Michigan, that Michigan molding sand had been used due to war necessity as it occurs only in small local deposits, and after first use possesses little bonding power, is perhaps particularly adapted to these sands found in the glacial deposits of Branch County. Foundrymen with this background of experience prefer a heavy coarse Illinois sand for heavy casting or frequently a Zanesville or Ohio sand. The foreman of the Homer Furnace Company stated that this foundry was returning to the use of Albany sand.

CALHOUN COUNTY

The surface of Calhoun County is largely sandy till. Sample 61 is a stony, yellow, unbonded sand found in mounds of thirty feet or more in height, in section 29, T. 4 S., R. 6 W., on the road between Tekonsha and Burlington and the Michigan Central Railroad and the St. Joseph River. There appear to be large quantities of sand similar to sample 61 in the southeastern part of Calhoun County.

Sample 62 is another sample of similar unbonded sand found in section 21, T. 4 S., R. 8 W., about one and a half miles northwest of Athens near the railroad. Sample 63 represents a somewhat finer sand, also free of bonding material taken from a twenty foot cut in section 30, T. 2 S., R. 6 W., one mile east of Ceresco near the Michigan Central Railroad. The sand in this district appears to be glacial outwash material and is frequently used for structural material in this locality.

Sample 66 from section 12, T. 2 S., R. 6 W., three miles north of Marshall is similar to sample 63. It is covered by dark yellow sand and mixed with streaks of clay. This

deposit covers one hundred acres or more to a depth of about twenty-five feet in mounds. The Fleck Foundry Company of Marshall has used this sand for making cores. Mr. Adams of this company reports there is more of the same type of sand on the Jewett farm one and one-half miles southwest of Marshall. When visited in 1923 this foundry was using molding sand from Allegan.

Ries sampled fine grained molding sand from Coldwater Street in Battle Creek, identified as R. 19, and a heavier sand as R. 28. Sample R. 19 seems to be somewhat similar to sample 66 and to samples 64 and 65, but of a finer grain.

In the northwest part of the county, identical samples 64 and 65, as tested by the Bureau of Standards and at the University of Michigan respectively, were taken from section 22, T. 1 S., R. 8 W., about one mile north of Urbandale west of the Wabascon Creek. This deposit of fine grain brown sand containing some bonding material is found mixed with sand and gravel in ridges covered by about one to four feet of coarse sand. In places the formation from which the samples were taken extends to ten or twelve feet in depth.

Comparison of the clay content reported from the Bureau of Standards on sample 64 and reported on the duplicate sample 65 from the University of Michigan again indicates a thoroughly consistent discrepancy due to the Bureau of Standards reporting too high a clay content.

CASS COUNTY

The surface of Cass County may be classified as largely sandy till and gravelly loam. In many ways the sand found in Cass, Kalamazoo, Calhoun, Branch, and St. Joseph counties are very similar, as these counties are completely covered with glacial drift or morainic deposits. Sample 67 in sections 2 and 3, T. 8 S., R. 13 W., contains some clay and gravel running to more clay at a depth of eight to ten feet. This sample was obtained by trenching the bank on the roadside for a distance of about eleven feet down from the top. Sample 68 from section 12 of T. 8 S., R. 14 W., was obtained from a pit about six feet deep. Here the sand contains some clay near the top and less at a lower depth.

CHARLEVOIX COUNTY

The surface of Charlevoix County is composed largely of till and moraine deposit. For a short distance back along the lake shore deposits of beach sand similar to sample 90 from Petoskey is found.

Sample 69 in section 27, T. 33 S., R. 6 W., one and a half miles northwest of the center of Boyne City along Pine Lake was taken from an area of yellow clean sand extending to a depth of about thirty or thirty-five feet. Here the sand is generally free from stone or gravel and extends along Pine Lake towards Boyne Falls for about ten square miles. Somewhat similar sand was observed one-quarter of a mile northwest of Sharon along the right

of way of the G. R. & I. Railroad. Here the sand is not uniform, running to gravel and clay in some localities. The sand occurs in low ridges and seems to have been deposited by streams running under the glacier.

CHEBOYGAN COUNTY

The southern part of Cheboygan county is covered with clay and sand till and some moraine deposits. The northern part of the county is largely covered with sandy and clayey lake beds as the old glacial lake shore line south of Indian River.

Sample 70 represents a lake-washed gravelly sand from section 15, T. 37 N., R. 1 W., six miles southeast of Cheboygan on the county road to Grace and Orchard Lake. The sand is probably about thirty to forty feet in depth ranging from red-yellow sand to white sand of a coarse texture and free from bond. The sample was taken from the upper six feet of the deposit on the Apple Growers Association property. This particular deposit covers an area from thirty to forty square miles.

Sample 71 represents the clean white sand found to a depth of six to eight feet over considerable area in the district around Black Lake. This sample was taken from the northern end of the lake in T. 36 N., R. 1 E.

Sample 72 taken from the northeast quarter of section 14, T. 34 N., R. 3 W., about four miles northwest of Wolverine along the Michigan Central Railroad and the Sturgeon River is almost the same texture as sample 71, just described. Sample 72 was taken from the west bank of Sturgeon River which reveals layers of sand and gravel to a depth over forty feet. At the top of the deposit is a layer of gravel about two feet six inches thick underlain by yellow sand about eight or ten feet thick below which is white sand. The sand is composed of smooth round grains and practically free from bond.

Sample 73 is also similar to Samples 71 and 72 so far as size of grain is concerned and is also composed of smooth round grains free from bonding material. Sample 73 was taken from Section 34, T. 37 N., R. 2 W., about one-quarter to one-half of a mile northwest of Mullett Lake Station.

Sample 74 from Section 12, T. 37 N., R. 2 W., was taken along a section road, three-quarters of a mile southwest of the Michigan Central Railroad and two miles by road southwest of the city limits of Cheboygan. The sample was taken from the face of a cut along the side of the road and represents a stratum of about four feet thick of fairly uniform sand lying under a small knoll. Similar deposits under several knolls were encountered in the immediate vicinity. The sand stratum lies about five feet below the surface and covers a determined area of one acre. Probably the deposit covers a much larger area.

A somewhat similar sand not quite so fine, was found in Section 14, T. 34 N., R. 3 W., one-quarter of a mile west of the Michigan Central Railroad, near where Sample 72 was taken. Sample 75 was taken from the face of a cut on the west side of the road. The deposit lies under a

small east and west moraine about twenty feet below a top of a hill, and is about four feet in thickness. As this deposit seems to possess molding sand possibilities, a duplicate sample (76) was heated to 600° F. for two hours. The results of this test indicating that the sand loses about sixty percent of its bond strength and about 55 percent of its permeability show the sand to possess little durability.

CLARE COUNTY

Clare County is completely covered with moraine and glacial till, a large part of which is sandy, generally unbonded, and known as plains sand. Sample 77 from Section 34, T. 18 N., R. 4 W., 9.7 miles southeast of Harrison and 5.5 miles north of Clare on the main highway was taken from the west face of a cut in the road on a hillside. The sample was taken by trenching through the stratum which is five feet thick and four feet under the surface. The sand stratum is very irregular being a mixture of sand and sandy clay. It extends for about fifty yards along the road and probably covers about five acres.

CLINTON COUNTY

The surface of Clinton County is composed largely of clayey till. Under these conditions it might be expected that where sand is found it is likely to contain clay, particularly if the deposit has been mixed in deposition. Sample 70 from Section 33, T. 6 N., R. 2 W., about one and one-quarter miles northeast of Dewitt, one mile west of the interurban tracks, and seven miles north of the city limits of Lansing, was taken from the face of the west cut on the side of the road and represents a small pocket deposit covering an area of about one acre. The pockets run about twelve to eighteen inches thick and are found generally on the slope of the glacial knob. This is a fine grained sample, containing about ten percent of clay.

Sample 79 from Section 28, T. 8 N., R. 4 W., on the bank of Hayworth Creek, four and one-half miles southeast of Maple River on the county road to St. Johns, represents an exposure of sand deposited in an old lake bed or as a river silt. The sand stratum is about three feet thick and about two feet under the surface. Below the sand is found sandy gravel. This particular deposit covers ten acres but it seems reasonable to expect similar sand in various places throughout a band about a mile and a half wide running along the Maple River and Hayworth Creek up to the point where this sample was taken and then easterly to Duplain where this zone of water-deposited sand again follows Maple River up and down stream to the county line. Similar sand outcropping along the bank of the stream for about two miles, and Sample 80 from Section 8, T. 8 N., R. 3 W., just south of Maple Rapids on the St. Johns Road, exhibit much the same formation and properties except for being much coarser. Sample 80 was taken from the east side of the road and may be classed as a molding

gravel. Here the stratum extends almost to the surface and is from twelve to eighteen inches thick covering quite an extensive area, at least one-half mile along the road.

Mr. Handley, Manager of the Industrial Foundry Company of St. Johns kindly furnished samples 320 through 324 representing the sand used in his foundry and shipped in from without the state. As these sands are not Michigan sands they are tabulated separately for purposes of comparison.

Sample 321 is fresh molding sand from Gallipolis, Ohio. The heap sand (about 6 to 12 months old) of a molder using this sand is represented by sample 322. Sample 320 is fresh New Cumberland, Ohio, sand. Sample 323 is the corresponding heap sand (about 4 months old) of a molder who uses about three wheelbarrow loads of fresh sand per week, and sample 324 that of a molder doing the same work but averages about six similar loads of new sand per week. The freight rate on these sands is about \$3.15 per ton.

CRAWFORD COUNTY

Crawford County being entirely covered with glacial outwash plains and glacial till presents much the same formation and type of sand as found in the adjacent county. Sample from Section 6, T. 26 N., R. 4 W., just outside of the city limits of Grayling to the north and near the Michigan Central Railroad represents a yellowish to red sand changing to white at greater depth found on the sides of river banks, road cuts, and similar exposures throughout this district and is generally similar to other deposits of sand in the north central part of the Southern Peninsula.

EATON COUNTY

Eaton County is largely clay till similar to Ingham County. In such localities small pockets of clay-sand mixtures possessing sufficient bond and permeability to be used as molding sand may be found. Sample 82 from Section 10 of T. 3 N., R. 3 W., within the town limits of Dimondale, one-half mile west of the Lake Shore and Michigan Southern Railroad, on the Grand River, is a clean sand from a stratum in a large gravel pit. The sand layer runs from five to six feet thick, over and underlaid with strata of heavy gravel. The sand is extremely fine and several carloads were sold to the Reo Motor Company of Lansing for use in polishing. In 1925 this gravel pit, owned by Mr. Potts, was worked.

Sample 83 from the same section but just out of the limits of Dimondale about one mile northwest of the Lake Shore Michigan Southern Railroad was taken from a deposit of glacial outwash along the Grand River. This deposit, now owned by Mr. Art Shively, was worked by a former owner and several carloads were shipped apparently exhausting this deposit. Immediately south of the old pit there is a stratum about three to four feet thick, ranging from a clay loam on the surface to what

appears to be a light molding sand. The sample was taken from vertical borings through this stratum. The material so obtained was carefully mixed and quartered. The deposit covers approximately five acres with the probability of other similar deposits in the same neighborhood.

Sample 84 from the southwest quarter of Section 2, T. 3 N., R. 3 W., was taken from a deposit owned by Mr. Miller on the Grand River just southeast of the bridge and three miles from the north limits of Dimondale. The deposit is very similar to that represented by Sample 83 but the sand appears somewhat heavier or coarser. About four acres are covered with a thickness of three to four feet underlying six or twelve inches of top soil. Several carloads were shipped out some years ago to Albion. Miller was offered one dollar per ton f.o.b. Dimondale about 1920 but at that time considered the price inadequate.

Sample 85 from the southwest quarter of Section 1, T. 4 N., R. 3 W. about one mile and a half west from Lansing city limits on the north bank of the Grand River, was taken from the farm of C. F. Davis and represents a stratum of sand two to three feet thick underlaid with gravel and overlaid with six to twelve inches of clay loam. The general formation of the deposit and the feel of the sand are very similar to that represented by Sample 84 from Miller's deposit.

Ries has tested a number of these sands as reported in the Survey of 1907. Sample R5 and R52 reported as coming from Ingham County represents the under sand of Cory's pit near Dimondale and considered unsatisfactory by Lansing foundries. The pit was located along the Grand River and the deposit which underlay the lower edge of the slope bordering the river was probably river silt. It was nearly exhausted of molding sand in 1906, having been worked since 1895. Samples R7 as formerly used by the Hildreth Pump and Motor Works, and R36 formerly used by the Lansing Wheelbarrow Works, are located in Eaton County and described as representing molding sand from Reeve's pit 2½ miles west of Lansing. Samples R44 and R47 are also taken from this district but in Ingham County.

EMMET COUNTY

The surface of Emmet County is composed largely of sandy till plains and sandy lake beds.

Sample 86 from Section 27, T. 39 N., R. 4 W., about one and one-half miles southwest of the city limits of Mackinaw City near the lake shore is probably a wind blown lake deposited (dune) sand. The yellow to white sand is found in layers about ten to twenty feet deep overlying a reddish clay which comes to the surface in places. The sand is composed of smooth round grains containing little bonding material. The sample was taken from Brook's farm and seems to be generally representative of a large deposit covering three or four square miles.

Sample 87 from Section 24, T. 39 N., R. 4 W., was taken from a similar deposit just south of Mackinaw along the main highway. The sand is composed of smooth round grains, generally similar to that of Sample 86. It appears to be a sandy lake bed rather than dune sand. The sand is at least twenty to thirty feet in thickness and is streaked with limestone which outcrops in a strip about a half mile along the lake shore.

Sample 88 from Section 31, T 38 N., R. 5 W., three miles east of Cross Village, and nine miles west of Levering, is apparently very similar to Sample 88. The deposit here is ten to twenty feet in thickness and covers probably twenty to thirty square miles along Sturgeon and Cecil Bays.

Sample 89, taken one and one-quarter miles south of Pellston, Section 10, T. 36 N., R. 4 W., and Sample 90 from the shore of Little Traverse Bay between Bay view and Petoskey in Section 33, T. 35 N., R. 5 W., are sharper sands of about the same grain size and appear to be deposited in old lake beds rather than as dunes, although the latter may represent dune sand which has been washed by the waters of the lake. The uniform size of grain possessed by sample 89 may indicate that this is the case. The deposit south of Pellston shows about one to two feet of compact brown sand, probably similar to Sample 75 from Cheboygan County, which is underlain by three to four feet of white sand above the main deposit from which the sample was taken. There are large quantities of this sand in the deposit which is at least thirty to forty feet thick.

Sample 90, near Petoskey, is used by the Antrim Iron Company. Samples 86, 88, 89 and 90 all appear suitable for use as core sands and indicate the large quantities of well classified clean sand to be found in Emmet County.

GENESEE COUNTY

The surface of Genesee County is mostly clay till with some lake deposited sand and probably river silts exposed along the Flint River as far as Mount Morris and Pine Run.

Sample 91 from Sections 5 and 6 of T. 8 N., R. 6 W., about five miles east of the Grand Trunk Railroad, is a light yellow sand found in a fairly uniform deposit about twenty feet deep.

Sample 92, Section 3, T 7 N., R. 5 E., about three hundred yards west of the county road, was taken from borings from the top and side of a knoll. This sand represents a stratum about four feet thick covering approximately one and one-half acres, bearing an overburden of eight inches of clay loam and on top of the knoll about three feet of loose sand. The property is owned by Art. Seymour.

Sample 93, from Section 17, T. 7 N., R. 6 E., about equidistant from Flint and the Grand Trunk Railroad represents screenings from an old gravel pit in a moraine deposit.

Sample 94, from Section 32, T. 8 N., R. 7 E., out Stewart Avenue was taken from the face of a cut on the south side of the road. This deposit represents sand as found in boulder clay plains and consists of four feet of alternating strata of loose sand and compacted (bonded) sand. About one acre was available in 1925, but this has probably been occupied by buildings since then.

Sample 95, taken from the northwest quarter of Section 32, represents sand deposited in boulder clay as a small pocket about three feet thick. A duplicate sample, No. 96, was tested for durability, as this material seemed to possess sufficient bond to be considered as a possible molding sand. The test indicates that this sand loses about twenty-five percent of its strength on heating to 600° F. for two hours. Apparently this bond is more durable than that possessed by most of the Michigan sands.

Sample R35, from Section 9, T. 5 N., R. 6 E., was taken by Ries in the survey of 1907, as representing molding sand, from the farm of Frank Sadler at Linden. This sand rarely ran more than one foot in depth and was all shipped to a foundry at Fenton where it was used satisfactorily for the medium and heavy castings.

The foundry of the Buick Motor Car Company uses a mixture of Allegan sand and Zanesville sand Grade F-1, as sold by the Thompson Company, in making up their heap sand. This foundry consumes about one hundred and twenty-five thousand tons of sand per year.

The Flint City Waterworks uses filter sand (sample 328) obtained from Ottawa, Illinois, purchased through the U. S. Silica Company of Chicago at four dollars per ton f.o.b. Ottawa (1925). The freight increases this amount by about two dollars and ninety cents per ton. The water supply is filtered through about thirty inches of this sand which may be used successfully from ten to twelve years. In operating the filters about two percent of water filtered is necessary for washing.

GLADWIN COUNTY

The surface of Gladwin County is mostly sandy as laid down in an old lake bottom. Toward the northwest part of the county boulder clay and moraine deposits are found similar to those in the central part of the state.

Sample 97 from T. 17 N. on the range line about two miles northeast of Billings represents a yellow rusty sand covered by an inch or two of white sand in a deposit running to clay at a depth of about four or five feet. The structure of this deposit seems to indicate molding sand in the process of formation.

Sample 98, also from T. 17 N. one mile Southeast from Billings, represents a yellow sand mixed with layers of red clay under a three or four foot stratum similar to that indicated by sample 97. Both of these samples are similar to Sample 170 from Midland County.

GRAND TRAVERSE COUNTY

The surface of Grand Traverse County is mostly sandy and clay till except for an old delta of the Boardman River running north from Keystone to Traverse City. The three samples, 100, 101, and 102, taken from this county are clean unbonded sand of fairly uniform size distribution. Sample 101, from Section 15, T. 27 N., R. 11 W., about one-half mile south of the city limits of Grand Traverse was taken from the old delta of the Boardman River. Sample 100 from Section 33, T. 26 N., R. 10 W., one mile north of Kingsley, was taken from a large area of yellow sand about thirty to forty feet deep, apparently glacial outwash. Sample 102 from Section 9, T. 26 N., R. 12 W., one-half mile north of the Pere Marquette Railroad between Grawn and Interlochen represents the light yellow sand found around the small lakes in western Grand Traverse County and eastern Benzie County which is apparently glacial out-wash similar to sample 100.

GRATIOT COUNTY

The surface of Gratiot is composed of approximately equal areas of glacial moraine and till, and clay and sandy lake beds, the western half being covered by the glacial deposits and the eastern half by the old lake beds.

An interesting deposit in the boulder clay plain or glacial drift is represented by sample 103 taken from the southwest quarter of Section 35, T. 12 N., R. 3 W., about three-quarters of a mile north of the Pere Marquette Railroad just north of the city limits of Alma. This deposit was worked for molding sand for a number of years up to 1918. From 1918 until 1925 no sand was removed. In 1925 sand was being delivered to a foundry in St. Louis at \$4.00 per cubic yard delivered. It was also reported that some of this sand had been used previously by an aluminum foundry in Alma. The deposit is found in a flat along the Pine River on land belonging to J. E. Sharper and probably covers an area of at least eight acres. Test data indicates that this sand has a rather wide working range, but the foreman of the foundry using it in St. Louis reported it to have a too high clay content for best results.

The St. Louis foundry uses Albany sand No. 2 (sample 325) and Zanesville Red Top (sample 326), the Albany sand costing from \$8.00 to \$9.00 per ton delivered. The domestic sand at \$4.00 per cubic yard or \$3.00 per ton offers considerable saving if it approaches the durability of the Albany sand. However, this is not likely.

The foreman of the Williams Foundry Company of Alma, Michigan, reported that sand from the pit represented by Sample 103 is used exclusively for making brass and aluminum castings and has been found more satisfactory than the Albany sand which had been previously used. The fact that the local sand has proved satisfactory for brass and aluminum, but not so satisfactory for cast iron would indicate that its major

deficiency compared with Albany sand is its low durability.

Samples 104 and 105 were taken from the gravel pit of Mr. Louis Ackers of St. Louis, located in the northeast quarter of Section 24, T. 12 N., R. 3 W., about one mile north of the Pere Marquette Railroad and within the city limits. Sample 105 has been used for road gravel and represents a stratum of about two feet thick overlying the somewhat finer stratum represented by Sample 104. It was reported that this latter material had been sold to a local foundry in former years.

Sample 106 represents a similar deposit in the northeast quarter of Section 24 on the property of Miss Elsie Harriman.

Sample 107 represents a stratum about fifteen feet thick under about six inches of top soil, covering about two acres just outside of the city limits in Section 24. The sample was obtained from borings in the glacial deposit on the south side of the road on property owned by Sherman Hawk. The sample and deposit seem similar to that represented by Sample 103 near Alma, except that it seems to contain less clay. It possesses a reasonably wide working range and might prove satisfactory as a molding sand for some purposes.

HILLSDALE COUNTY

Practically the entire surface of Hillsdale County is covered by glacial deposits. Sample 108 from Section 10 of T 6 S, R 2 W, just south of North Adams, represents a sand of high clay content found in the till plain. The sample was taken from a trench and pit in the roadside to a depth of five feet when blue gray hard sand or possibly shale was encountered. Sample 109 from section 21, T 5 S, R 1 W, is a glacial outwash sharp sand taken by trenching the side of a bank on a hillside. The deposit seems to run about fifty feet deep of rather well sized sand.

The Alamo Gasoline Engine Company of Hillsdale uses Albany sand for molding and Michigan sand for making cores. It was reported that a small pocket of local sand had been worked and used when mixed with the Albany sand. A large deposit of sand considered satisfactory for this foundry was reported as located east of town. The Alamo Gasoline Engine Company intended to work this deposit but the owner of the farm made the price prohibitive.

Sample 110 taken from the southeast quarter of Section 25, T 6 S, R 3 W, just within the city limits of Hillsdale may represent the deposit referred to by the Alamo Gasoline Engine Company. The sand is found about two to five feet below the surface in a stratum about one to three feet in thickness and covers probably ten acres. The sample was obtained from a bank on the side of the paved road from property owned by W. H. Goose. The deposit seems to be in a glacial deposit and suitable for use as a molding sand.

HURON COUNTY

The surface of Huron County is composed largely of the old glacial lake bed, which in this locality is generally clayey. Sample 111, from the southeast quarter of Section 4 of T 1.5 N, R 9 W, about one mile from Sebewaing, represents the material taken from a vertical face of a three foot stratum on the side of the road. The sand is found under loam and is underlain by loose sand. The deposit extends for at least twenty-five acres in the lake clay area. This sand has a good working range and should prove satisfactory as a molding sand.

Sample 112 from Section 33, T 18 N, R 12 W, about four miles west of Kinde and the Pere Marquette Railroad, was obtained from the bottom of a cut at the roadside representing a stratum about five to six feet thick covered with about a foot of top soil. The deposit appears to be a mixture of fine sand and clay, properly classified as a clayey lake bed and is probably not usable as a molding sand unless mixed with other material. Even then the fines contained in Sample 112 indicate a low permeability in any such mixture. Sample 113 from the northwest quarter of Section 6, T. 18 N., R. 13 E., about three-quarters of a mile south of Port Austin on the Pere Marquette Railroad, is also representative of the fine sand and clay mixtures found in these old lake beds. This sample was taken from borings in a field on the property of Andrew Goretski. The deposit covered at least twenty acres under about eight inches of top soil.

The Port Crescent Sand Company at Port Crescent operates on the dunes along the shore, shipping the sand by boat. Most of the sand is used as core sand in the Detroit and Cleveland districts. The sand is cut from the face of the pit and loaded into dump cars, which are unloaded onto a belt conveyor which carries the sand through screens. The screened product is conveyed onto the dock on another belt conveyor. The capacity of the plant is about fifteen to twenty thousand tons per week. This dune sand (sample 114) has a high distribution factor of .87 which is similar to that of the dune sand found along Lake Michigan, (see sample 35.).

INGHAM COUNTY

The surface of Ingham County is largely glacial till or boulder clay plains with some moraine deposits. For this reason, we may expect only relatively small deposits of bonded sand.

A number of samples were taken from Ingham County by Dr. Ries in the survey of 1907. Samples R5 and R52 from Section 30, T 3 N, R 2 W, were obtained from Mr. Croy's farm along the Grand River in Eaton County. The deposit was found under the lower edge of the slope bordering the river and was classified as probably a river silt which had not been added to for some time. The molding sand was found under about one to two feet of loamy soil in a stratum about two feet thick and over coarser sand. The samples were taken from the under sand reported to be of no value. This deposit had been

worked since about 1895 and was practically exhausted in 1907 or in 1908.

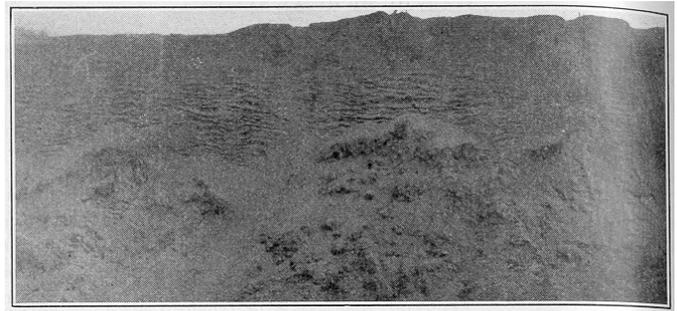


Figure 32. Sand band in pit of Burt Core Sand Co. Showing layers of clay and rust in top of yellow sand stratum under top soil.

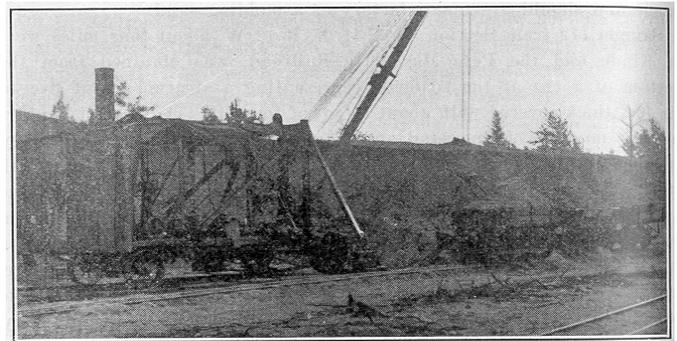


Figure 33. Steam shovel loading dinky cars at Burt Core Sand Co. pit near Vassar.

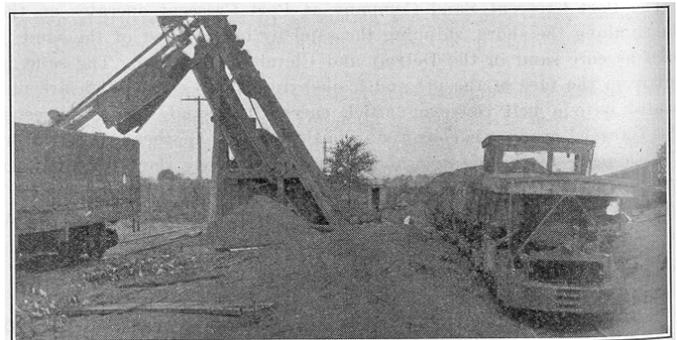


Figure 34. Method of screening and bonding sand from dinky cars onto railroad cars, Burt Sand Co.

There are a number of molding sand deposits in the vicinity of Lansing. Ries reports the following screen analysis of a sand from the Gillette property, two miles northwest of Lansing which was formerly used as a substitute for a mixture of the two Ohio sands, whose screen analysis are also tabulated for comparison:

Screen Sizes	Sand from Gillette Property	Ohio	Sands
Percent on 20 Mesh.....	0.00	.04	.56
Thru 20 on 40.....	.01	.22	.93
Thru 40 on 60.....	.20	.88	9.99
Thru 60 on 80.....	.99	1.45	19.46
Thru 80 on 100.....	10.85	1.11	15.97
Thru 100.....	87.90	98.30	53.49

This deposit was reported as being very similar to that on Croy's property, near Dimondale, and is also an old river silt.

Other samples of similar molding sand were reported as Samples R7 and R36 in Eaton County from the Reeves' property, two and one-half miles west of Lansing. The former was used by the Hilldreth Pump and Motor Works and the second by the Lansing Wheelbarrow Works. Samples R44 and R47, from Section 5, T. 4 N., R. 2 W., also represents similar river silts used for molding sand. Sample R44 was taken from the property of George Christopher in the northwest part of Lansing. Sample R47 was taken from the property of H. Vornberg, Lot 21 of the large subdivision in the northwest part of Lansing. Although similar to the other sands the last one had not been used when reported by Ries.

A similar deposit was visited in the summer of 1925 in Section 4, T. 4 N., R. 2 W., one mile north of the city limits of Lansing. The sample (115) was taken from the face of a small pit on Walker's property. The molding sand stratum runs from fifteen to twenty-four inches in thickness and seems to cover about five acres. The total area is in a subdivision being gradually taken up by residences. The total production of this pit is used by the Superior Brass and Aluminum Casting Company, 811 Jerome Street, Lansing. For making brass and aluminum castings this company finds the local sand (sample 115) more satisfactory than the Albany sand, but not as satisfactory for iron castings. The foreman reported that he believed there was a deposit of heavy sand near the old race track between Lansing and East Lansing.

A similar deposit (sample 116) yielding a coarser and stronger sand is found one mile west of the city limits in Section 7, T. 4 N., R. 2 W., on the property of J. G. Stortz, and that adjoining him on the east belonging to Schneeberger. The sand lies in a narrow deposit about twenty yards wide following the banks of the Grand River for about a half a mile. It is two to three feet thick in places and covered with eighteen inches to two feet of loam soil. Stortz has sold it to local foundries for a number of years at \$2.50 per cubic yard.

As the freight rate from Zanesville, Ohio, to Lansing is \$2.50 per ton for sand shipped in carload lots, it is seen that the local sand can be supplied at a cost less than the freight alone on the Ohio sand.

The Michigan Brass & Iron Company reports that they have always used local molding sand, probably similar to Sample 116, for coarse work, at a price of about \$2.50 delivered to the plant. Albany sand is used for the fine work. Sand from Dimondale, Eaton County, was formerly used and is reported to have been very satisfactory. It is no longer used because of the expense of the relatively long haul compared to the sand from the Lansing district.

The Capitol Casting Company, 500 South Hosmer Street, Lansing, uses a Zanesville sand, No. 1, for light bench work and Zanesville No. 4 for floor work. A sample of the Zanesville No. 1 is reported as No. 317 for purposes of comparison. This foundry has used local Michigan sands and found them to be much less durable than the Zanesville sand for iron castings.

The Novo Engine Company, Porter Street, Lansing, has also found Michigan molding sands unsatisfactory because of their low durability causing much waste. This company now uses two grades of sand from the Lancaster Coal and Sand Company of Lancaster, Ohio, for molding. No. 1-X (fine) and No. 4 with 307 bond, as represented by sample 318. This sand is reported to give very satisfactory service and costs \$1.50 f.o.b. Lancaster plus freight of \$2.52. Core sand is obtained from Michigan City and from Bridgeport, Michigan. These sands are mixed about one part Bridgeport sand and two parts of Michigan City sand, as the mixed sand seems to require less oil for making satisfactory cores.

In using the Lancaster sands in the foundry, the Novo Engine Company discards no sand but simply adds new sand to replace losses and maintain the desired properties. About one-tenth Sea Coal is mixed with the sand before it is used. Sample 319 represents the heap sand as used in the Novo Foundry.

Sample 316 was obtained from the Gerson & Carey Foundry, 411 East Kalamazoo Street, Lansing, as representing the molding sand considered satisfactory by this company.

IONIA COUNTY

Except for a band about three or four miles wide, following the Maple River across the county, Ionia County, is practically covered with glacial drift and moraines. Sample 117 from the northwest quarter of Section 34, T. 5 N., R. 7 W., just southeast of Lake Odessa village limits, and about one hundred yards north of the Pere Marquette Railroad, represents a patchy deposit of sand found in thin layers in the glacial deposits. The rather high distribution factor, .769, and the structure of the deposit indicates that it is probably a water laid deposit found with the boulder clay.

IOSCO COUNTY

The surface of Iosco County is about sixty percent sandy, most of which is represented by old lake beds. The north central part of the county is covered with unbonded plains sand. Sample 118 was taken as representative of this unbonded sand in the southern part of the county. The thirty-six percent of clay reported to be found in this sample by the Bureau of Standards is an obvious error in clay determination or possibly a confusion in samples.

ISABELLA COUNTY

Isabella County is practically covered with glacial deposits except in the eastern part northeast of Mt. Pleasant, this area represents an old lake bed with an old delta on the Chippewa River extending northeast from Mt. Pleasant.

Sample 119 was taken from a cut in the road in Section 13, T. 14 N., R. 6 W., about three-quarters of a mile from

Coldwater River. The sand is white, well sized, and seems to be consistent to a depth of from twelve to twenty feet. The upper two to three feet showed some gravel and was not as well sized as the lower layer. The general structure and the high distribution factor (.85) indicate that this deposit was water laid, probably from a stream flowing from an old glacier. This sand seems to cover a large area and represents a glacial outwash apron.

Sample 120 represents the yellow sand found in Section 2, T. 14 N., R. 4 W., about two miles northeast of Mt. Pleasant just west of Isabella Village. There are large areas of this yellow sand covering probably twenty square miles along the Chippewa River. It evidently was deposited on the old lake bed by the river or lake waters. Weathering has progressed in the upper two or three inches of the deposit to such an extent as to develop a rusty sand, having appreciable bond to a depth of two or three inches.

JACKSON COUNTY

Jackson County is almost entirely covered with glacial deposits, about one-half of which may be classified as sandy till.

Four samples of molding sand were collected by Dr. Ries in the neighborhood of Jackson. Sample R 27, from the W. McGill farm at Leoni, five miles east of Jackson, represents a limited deposit of molding sand about two feet thick underlying a few inches of soil. Ries reports that this sand was excellent for general work although not as durable as might be wished, and had been used for making castings up to three tons.

The Jackson Pressed Brick Company worked a sand pit about two miles west of Jackson which is represented by Sample R25. The test on this sand indicates that it may make a satisfactory core sand as well as a material for making sand lime bricks.

Samples R3 and R4 obtained from small pits in the drift south and north of Jackson, respectively, were used as core sands by the Holden and Weatherwax Company, using one part of oil to thirty-five parts of sand by volume, as reported in the survey of 1907.

Sample 121 from Section 14, T. 3 S., R. 1 W., was taken from the face of a sand pit on the road to Vandercook Lake about one and one-half miles south of Jackson. This pit is owned by William Blake of Vandercook Lake and was being worked in 1925 to obtain asphalt sand in preparing asphalt for city pavements. The deposit is evidently waterlain, and apparently in an outwash plain, about eight feet thick under about five feet of coarser sand. The deposit covers approximately four acres, about one-half of which had already been removed in 1925.

Sample 122 from the northwest quarter of Section 21, T. 2 S., R. 2 E., on the county road about two and a quarter miles north of Grass Lake, represents a variable deposit

running from gravelly clay on top to loose sand below, which is typical of glaciated areas.

Sample 123 from the northwest quarter of Section 21, T. 2 S., R. 1 E., four miles northeast of Jackson on the county road to Portage Lake, represents a stratum of sand about three feet thick underlying about three feet of clay, and covering about five acres. Samples 122 and 123 contain sufficient clay to develop a fair bond. But the grain distribution covering coarse and fine material as indicated by their low distribution factor makes them unsuited for molding sand.

Sample 124 from Section 20, T. 2 S., R. 1 W., about three miles northeast of Jackson was taken from several places in the face of a sand pit in the side of a twenty foot sand hill. The deposit covers about five acres under about six inches of top soil. About ten carloads were removed by August 1925. The sand is clean and well sized and probably was deposited as a part of an outwash apron from the glacier.

Sample 125 from Section 8, T. 3 S., R. 3 W., about one-half mile south of the Michigan Central Railroad on the Albion-Concord Road, is an unbonded sand as found in this water laid moraine. The seven percent of clay as reported by the Bureau of Standards is obviously an error.

Sample 126 from Section 31, T. 2 S., R. 1 E., about one mile east of Jackson city limits, is a similar light yellow but coarser sand containing some clay. This sample was tested by the Bureau of Standards and in the University of Michigan laboratories with the results as reported. The latter tests were conducted very carefully according to the specifications of the American Foundrymen's Association and report 19.3 percent of clay. The tests of the Bureau of Standards report 31.27 percent of clay and much less fines than were found in the University laboratories. The same comparison can be made on Sample 127, which was likewise tested at the Bureau of Standards and also at the University of Michigan. These comparisons with others clearly indicate that the separation of clay was so conducted at the Bureau of Standards as to remove a large amount of the pan material and other fine material which should have been reported in the screen analysis rather than as clay. The peculiar irregularities shown in the screen analysis obtained at the Bureau of Standards on Sample 126 on the 100 and 140 and 200 mesh screens were not observed in the later tests in the University laboratories. This might be due to errors in the screen analysis, but the same discrepancy being evident in Sample 127 seems to indicate rather serious irregularities in the method or screens used at the Bureau when testing these samples.

Sample 127 from three miles southeast of Jackson was taken from a deposit of white coarse sand streaked with brown sand, and covered with about one to two feet of brown stoney sand. The sample seems to be practically free from bond and seems to have been taken from a glacial outwash deposit.

Sample 128 from Section 12, T. 4 N., R. 2 E., about three miles southeast of Norwell, is a glacial deposit of sand and gravel practically free from bond, extending to a probable depth of fifty feet or more, and typical of the district east of Jackson. There are a large number of gravel pits in these glacial deposits, from which road building material and structural material have been taken in large quantities.

KALAMAZOO COUNTY

The surface of Kalamazoo County is entirely covered by glacial deposits, most of which are loam and appear to be outwash aprons.

Sample 129 from the section line of Sections 28 and 29, T. 1 S., R. 11 W., about five miles north of Kalamazoo, represents the poorly sized unbonded yellow sand found in this district to a depth of at least twenty-five feet.

Sample 130 from Section 26, T. 1 S., R. 9 W., about one and one-half miles east of Augusta on the main highway and the Michigan Central Railroad, was obtained from a cut in the road. This sand seems to be very similar to that represented by Sample 129, except that it is more uniformly sized.

Within the city limits of Kalamazoo in Section 23, T. 2 S., R. 11 W., is an interesting deposit found at the base of a high hill or slope on the north side of the main highway. Sample 131 was taken from the heavy sand found at the base of this slope and contains nearly nineteen percent of clay. This sample shows a high bond and was tested for durability as indicated by the results of Sample 132, which is identical with Sample 131, except that it has been heated to 600° F. for two hours. The results of this test indicate that this sand has little durability, as it loses sixty-two percent of its compressive strength and fifty percent of its permeability by this heating. The deposit from which this sample was taken is typical of slope mantle deposits, it is a mixture of the materials washed down the slope and the weathered remains of the sand originally at the base.

KALKASKA COUNTY

Kalkaska County is practically covered with unbonded sand, deposited as glacial moraine or outwash, which when cut over is locally referred to as pine barrens. Samples 133 and 134 are both yellow sands, unbonded, and of uniform size, in many ways similar to the dune sands found along Lake Michigan. Sample 133 from Section 4, T. 27 N., R. 7 W., about one mile north of the limits of the town of Kalkaska, is representative of a large area of yellow unbonded sand, covered by about one to four feet of white sand in various places. To the southwest the deposit seems to run to gravel, and at a depth of forty feet clay is usually found. Northwest of this area in T. 28 N., R. 8 W., the yellow sand is about five to ten feet thick and is found over stony blue clay.

Sample 134 from Section 8, T. 25 N., R. 6 W., just south of Sharon is also representative of the sand found in these pine barrens.

KENT COUNTY

More than two-thirds of the surface of Kent County is composed of sandy till, most of which is largely glacial moraine. A narrow band about a mile and a half north and south of the Grand River is evidently water deposited material, probably river silt deposited by the Grand River.

Sample 136 from northwest quarter, Section 28, T. 7 N., R. 11 W., was taken from the white unbonded sand found beneath the clay in the pit of the Grand Rapids Clay Products Company, near the eastern edge of Grand Rapids. The clay is about thirty feet thick and the sand underneath the clay from which the sample was taken seems to extend to a great depth.

Sample 137 from Section 32, T. 6 N., R. 9 W., about one mile north of Alto is a fine yellow unbonded sand covered by about one to six feet of gravel and sand. The depth of the yellow sand from which the sample was taken, is probably twenty-five feet or more. Both these samples, 136 and 137, are very uniform in their grain distribution. Sample 138 is a fairly coarse sand and 137 a rather fine sand. Both of these samples should prove very satisfactory as core sand or for other purposes where sand of uniform grain distribution is required.

Sample 138 from Section 14, T. 1 N., R. 12 W., represents the light yellow uniform unbonded sand obtained from a pit north of the city limits of Grand Rapids. This sand has a very high uniformity coefficient (.938) and is likewise suitable for use as a core sand. Sample 139 from Section 12, T. 5 N., R. 12 W., ten miles south of Grand Rapids, is very similar to sample 137, and seems to run to great depths over an area of perhaps five square miles.

Sample 140 was taken from a stratum found under about two feet of clay on the east side of the main highway about two and three-tenths miles southwest of Sand Lake and one mile west of the G. R. & R. Railroad in the southwest quarter of Section 7, T. 10 N., R. 10 W. Here the highway cuts through a small hill exposing the strata of sand and clay. The sample contains twenty-three percent of clay and possesses a high bond strength with adequate permeability. This sample when tested for durability as indicated by the data for Sample 141, shows a loss of seventy-one percent in bond strength on heating to 600° F. for two hours. Unfortunately Michigan bonded sands possess little durability, and this sample seems to be no exception.

In the survey of 1907 Ries reported Sample R61 from a ridge known as the Black Hills, near the river and in the southwestern part of Grand Rapids. Ries reported a number of small pits located in this district, and that the sand was not regarded as satisfactory molding sand because of its tendency to burn on to the castings.

LAKE COUNTY

The surface of Lake County is largely sand deposited either as moraine material or as glacial outwash. The sand is generally unbonded, light yellow in color, and with rather uniform grain distribution.

Sample 142 from Section 3, T. 17 N., R. 14 W., about two and one-quarter miles south of the Pere Marquette Railroad near the Marquette River may be taken as generally representative of this district.

LAPEER COUNTY

The surface of Lapeer County is largely clay and sandy till with an area of lake clay covering about thirty-eight miles to the east and south of Lapeer, and another very similar area in T. 10 N., R. 11 E., about two miles east.

Sample 143 from Sections 5 and 6 of T. 10 N., R. 11 E., about two miles east of Silverwood and just south of the Pere Marquette Railroad, was taken from about the eastern limits of this area of lake clay. The sample was taken from a trench and a pit in the roadside and is representative of what appears to be a moraine containing some pebbles and clay.

Sample 144 from Sections 20 and 21, T. 9 N., R. 10 E., was taken from the cut in the county road six miles east of Columbiaville and eight miles north of Lapeer. The sample represents a stratum about one foot thick in the moraine area and covers one acre. Sample 144 shows a high bond but rather low permeability.

Sample 145 from Section 28, T. 9 N., R. 10 E., is very similar to Sample 144. Sample 145 was taken by trenching the face of a cut on the east side of the county road, and is representative of a stratum about four feet thick and about two feet under the top soil.

Sample 146 from Section 9, T. 8 N., R. 10 E., about four and one-half miles north of Lapeer and from three to four miles south of where samples 144 and 145 were taken, is a finer sand of about the same formation. Here the stratum is about eighteen inches to two feet thick and about one foot under the surface, and underlain by stiff clay.

So far as could be determined none of the local sands are used in the foundries in Lapeer or Imlay. The Imlay Foundry and the Bostick Stove Company of Lapeer manufacturing automobile parts use Zanesville molding sand. Sample 329 is representative of the sand used by the latter company. This foundry uses bank sand from Vassar in Tuscola county, and sharp sand from Port Huron in preparing cores. The Vassar sand has a slight bond and is not used unmixed. The Imlay Foundry also uses bank sand from Vassar which is mixed with about equal quantities of sharp sand from Manistee for making cores.

LEELANAU COUNTY

Leelanau County is covered mostly by sandy till. Sample 147 from Section 27, T. 32 N., R. 11 W., about one-half mile north of Northport, represents the dune sand found on the northern end of the Leelanau peninsula. The sample was taken from the bottom of the slope on the east side of the peninsula where the sand contained a small amount of bond. Here the dune sand was covered by about one to two feet of brown sand, which may have been derived from the adjacent moraine deposits. The dune sand runs to a depth of thirty to forty feet or more, and covers an area of at least five or six square miles. The high distribution factor (0.95) is typical of the uniformly sized dune sand which is frequently used as core sand.

LENAWEE COUNTY

Lenawee County is covered with glacial deposits in the northwestern two-thirds and with old lake beds, generally clayey in the southeast one-third.

Sample 148 from Section 3, T. 6 N., R. 4 E., was taken from the bank of the Raisin River, about one and one-half miles south of Tecumseh, just below the mill dam. The sample was taken from the river bank about two feet below the surface and represents a stratum about one to one and one-half feet in thickness. Here the surface is clay loam and below the sand is found hard clay. The deposit seems to underly an island and covers about three acres. It is somewhat patchy, being mixed with unbonded sand in some places.

Sample 149 from Section 34, T. 5 S., R. 4 E., is very similar to sample 148, and was taken from the banks of the Raisin River about one mile south of Tecumseh between the by-road and the south fork of the Raisin River. Here the bonded sand is covered with loose sand and is underlain with sandy gravel. The stratum represented by the sample is about two feet thick and covers about one acre. Both deposits are patchy and appear to be river silt.

The Lenawee Sand and Gravel Company operates a pit about one mile south of Tecumseh producing three grades of gravel and two grades of sand. Washed sand from this pit is used for plaster and concrete in Detroit and Toledo. The deposit is easily workable to a depth of eighty feet, and the present layout has a capacity of between eight hundred and one thousand tons per day.

Two foundries in Tecumseh reported that they use Michigan City sand for core sand, and molding sand from Toledo and Conneaut, Ohio. Formerly local deposits of molding sand had been used but had proved generally unsatisfactory.

LIVINGSTON COUNTY

Livingston County is almost entirely covered with glacial deposits mostly clayey till. Around Portage Lake in T. 1 N., R. 4 E., are found large deposits of unbonded yellow

sand, apparently glacial outwash. Sample 150 from Section 20, T. 1 N., R. 6 E., on the main highway about four miles south of Brighton, and sample 151 from Section 19, T. 2 N., R. 6 E., about one mile north of Brighton, represent the glacial sand containing little bond found in this district. These deposits occur in drumlins running northeast and southwest. In places the gravel pits show a depth of seventy-five to one hundred feet. The samples indicate that the sand is of fairly uniform grain size and is probably a waterlaid deposit.

Sample 152 from Section 11, T. 4 N., R. 4 E., was taken from the east side of the road running from Byron to Howell, between the highway and the railroad. The sample was obtained by trenching the face of the exposure and represents a stratum about three feet thick covered by one foot of sandy loam.

Sample 153 from Sections 1 and 2 of T. 2 N., R. 4 E., about one and one-quarter miles west of the Ann Arbor Railroad was taken in a similar manner from the face of a cut on the side of the county road from Howell to Pinckney. Here the stratum is four feet thick and is found about three feet below the surface. These samples seem to be of about the same grain fineness, but sample 153 has a much lower distribution factor and seems to possess a higher permeability, a higher bond strength and a wider working range.

Sample 154 taken from two miles south of where sample 153 was obtained seems to possess practically the same properties as sample 153 except a slightly higher grain size distribution factor. Sample 154 was taken from sections 13 and 14 on T. 2 N., R. 4 E., two and three-quarters miles south of Howell on the county road from Howell to Pinckney. The sample was taken from the face of a cut on the side of the road at various points along the fifty yard exposure of the stratum which here is about six feet thick covered by about one foot of clay. The deposit was taken from a knoll which covers about three acres in a boulder clay plain. Sand from this deposit was tested for durability by heating to 600° F. for two hours, as indicated by sample 155. Comparison of the results indicate that this sand loses about thirty-eight percent of its bond and seventy percent of its permeability when subjected to the durability test

Sample 156 from Section 35, T. 1 N., R. 4 E., about one and one-quarter miles south of Pinckney on the county road from Pinckney to Dexter, was taken from the face of a cut on the north side of the road at various points along the bank. Here the stratum is about one foot thick and about two feet under the surface and covers an area of about one acre. The sand represented by Sample 156 is the same type as 153 and 154, but coarser and containing less clay. Sample 156 shows a high permeability and a good bond strength, and was taken from an area which seems to be glacial outwash. All of these samples from south of Howell seem to possess approximately the same qualities and to have been deposited in much the same way.

MACOMB COUNTY

Macomb County is practically covered with glacial lake deposits, most of which are of a clayey mixture. The Mount Clemens Sand and Supply Company operate a concrete block factory obtaining sand from an interesting deposit covering thirty-two acres in this lake clay area. The plant produces concrete blocks, tiles, and bricks, using four machines having a capacity of six hundred blocks per day per machine, and were installing four more machines in 1925. The sand deposit is covered by about one foot of top soil, under which is found two feet of molding sand as represented by sample 157, eight feet of clean sand represented by sample 158, and from one to two hundred feet of similar material represented by sample 159. It is estimated that there are between one and five million tons of recoverable sand on this property, which is in the city limits of Mount Clemens on Roe Street about one-eighth of a mile west of the Grand Trunk Railway, in what would correspond to Section 10, T. 2 N., R. 13 E. The molding sand 157 is a fine sand possessing moderate bond and permeability, and seems to serve as a satisfactory sand for some uses.

Sample 160 from the southwest quarter of Section 32, T. 5 N., R. 12 E., was taken from the face of a cut on the side of the county road from Romeo to Oxford, about three miles west of Romeo. This sample represents a variable deposit about two feet thick under two feet of top soil in a small moraine area. Tests of this sample indicate that this sand has a good bond and permeability and might be suitable for molding sand. Accordingly a duplicate sample (161) was tested for durability. This sand loses about seventy-five percent of its maximum bond strength when heated to 600° F. for two hours, but this test has practically no effect on its permeability.

In the survey of 1907 Ries reports a sample (R23) from Section 11, T. 1 N., R. 13 E., as a lake sand used in preparing cores.

MANISTEE COUNTY

Except for a few small areas of sandy and clayey lake beds, one surrounding Arcadia, another south of Portage Lake, Manistee County is practically covered by glacial deposits, most of which may be classed as sandy till.

Sample 162 from Section 10, T. 24 N., R. 16 W., represents the yellow sharp sand containing little bond found in an outwash apron about six miles southeast of Bear Lake. The sand extends to a depth of twenty feet in some places and covers an area of about 8 to 10 square miles, most of which is covered by about one to two feet of brown sandy loam extending to the north and east of Bear Lake. A somewhat similar and coarser sand is represented by sample 163 from Section 16, T. 21 N., R. 16 W., about one and one-half miles east of East Lake. Here the sand is white, unbonded and representative of two townships of pine barrens. A cut south of East Lake showed this sand to extend to a depth of fifty feet. It was also reported that the Ford Motor Company purchased this sand at sixty cents a ton

f.o.b. in 1923, paying seventy dollars per carload freight to Detroit over the Pere Marquette Railroad. If so, it was probably used as a core sand for which purposes it should prove entirely satisfactory. Similar sand is found in the glacial outwash in Section 28, T. 22 N. R. 16 W., about five miles northeast of Manistee on the main highway. Here the sand extends to a depth of fifty feet in places and is practically free from bond.

MASON COUNTY

In general the surface of Mason County is very similar to that of Manistee, being composed largely of sandy till. The two samples obtained from Mason County are also generally similar to sample 163 from Manistee County. All of these samples were taken from a sandy till which is not definitely formed as outwash from the ice border and is in many ways similar to old sandy lake beds.

Sample 164 from Section 24, T. 18 N., R. 18 W., one mile east of Ludington on the Pere Marquette Railroad, represents the sandy till in this locality. Here the sand is light yellow in color, free from bond, and extends to a depth of at least twenty to thirty feet over relatively large areas. The top soil is very light and similar to the sand from which the sample was taken.

Sample 165 from Section 17, T. 18 N., R. 15 W., was taken by trenching the face of a cut showing an exposure of thirty feet of light yellow unbonded sand, along the main highway, one and one-half miles northwest of Walhalla. In Section 15, T. 18 N., R. 16 W., just east of Custer in the boulder clay area covering the central part of the county, some bonded red sand was encountered indicating that there may be small patches of bonded sand in this boulder clay area, although no samples have been obtained and tested to verify this statement.

MECOSTA COUNTY

Mecosta County is entirely covered by glacial deposits, most of which are sandy gravel typical of outwash plains and moraines.

Sample 166 from Section 9, T. 14 N., R. 8 W., was taken from an outwash apron about two miles west of Mecosta on the main highway, about one-half mile south of the Pere Marquette Railroad. Here the sand is yellow in color, free from bond, but containing some gravel. The deposit from which the sample was taken is covered by about two to three feet of gravel and extends to a depth of at least thirty feet in places. The land has been cut over and is described as pine barrens.

MIDLAND COUNTY

The surface of Midland County is composed of about three-fifths of sandy lake bed and about two-fifths of clayey till. There is an interesting ridge of sand and clay, apparently a water laid moraine which runs south southeast from about one mile west of Billings in

Gladwin County through Larkin in Midland County and a point about one mile east of Midland to Smiths Crossing where it swings west running west southwest about one-half mile north of Cozyville as far as Porter on the Pine River.

Sample 170 was taken from a sandy lake bed west of this ridge in Section 28, T. 16 N., R. 1 E. Here the surface is composed of one to two inches of white sand below which is found a layer of yellow sand about four to ten inches in thickness, then three to eight inches of limonite crust and a layer of sand over four feet thick. Sample 170 represents the limonite crust and the lower sand obtained from a pit.

Similar sand from the sand ridge was sampled as sample 167 in Sections 8 and 9 of T. 13 N., R. 2 E. Here the sample was taken from a pit about ten feet deep.

On the property of the Dow Chemical Company in Section 21, T. 14 N., R. 2 E., along Tittabawassee River in the southeastern part of Midland, is a bank of light yellow sand, generally similar to samples 167 and 170, and formerly used by the iron foundry.

East of Midland along the Chippewa River in Section 19, T. 14 N., R. 1 E., about one-quarter of a mile south of the main highway and seven-tenths of a mile west of Midland at Oxbow on the Chippewa River sample 168 was taken from the face of an old sand and gravel pit. The sand is about three feet thick, covered with about one foot of loam and underlain with gravel. Sample 168 was taken from the three foot stratum of sand and represents the sand formerly used by the Dent foundry in Midland as a molding sand. This deposit appears to be of considerable extent. The Dent Foundry continues to use local sand for making cores, but at present is using Zanesville No. 4, as a molding sand (sample 311). Comparison of the properties of the Zanesville sand and sample 168 indicate that the Zanesville has a higher bond strength and a high permeability being a somewhat coarser sand. In addition it may be concluded that the Zanesville sand possesses a higher durability, although no such statement was made by the foundry superintendent.

Sample 169 from Section 19, T. 14 N., R. 1 E., also was taken from a similar stratum of sand about four feet below the surface along the Chippewa River about three-tenths of a mile west of Midland. This stratum contains a fairly uniform sand, which possesses a high bond, although a low permeability. A durability test made on sample 169 indicates a loss of seventy-five percent of its bond strength and a gain of one hundred percent in permeability when heated to 600° F. for two hours.

The foundry of the Dow Chemical Company uses a Zanesville sand (sample 312) for casting Dow metal, which is cast at a temperature not over 1240° F. The similarity in properties between sample 312, representing the Zanesville sand used in the Dow Chemical Company's foundry and the properties of

sample 169 obtained from about three-tenths of a mile west of Midland, would indicate that it might be economical for this company to substitute the local sand (sample 169) as it would probably possess sufficient durability for casting at this relatively low temperature. It was stated that the Zanesville sand was mixed with local sharp sand for use in the foundry.

MISSAUKEE COUNTY

Missaukee County is covered with glacial deposits containing a good deal of boulder clay with sandy sections being in the minority. Mr. Minthorn formerly operated a brickyard making soft mud bricks in Section 7, T. 22 N., R. 7 W., about one mile south of Lake City and about half of a mile east of the railroad. He obtained sand (samples 171 and 172) for use in his molds from a small pit about one-half mile down the road from the old brickyard. The sand seems to be mixed with an appreciable amount of fines and clay and to be free from gravel. Comparison of the results reported on samples 171 and 172, tested at the University of Michigan and at Cornell University, indicates the substantial agreement in the tests made by these two laboratories. As this sand possesses a good bond and fairly high permeability, a durability test was made on a triplicate sample (173) indicating that this sand loses sixty percent of its bond strength on being heated to 600° F. for two hours but that its permeability is practically unaffected.

MONROE COUNTY

The surface of Monroe County is entirely covered with sandy and clayey lake beds. Sample 174 from Section 29, T. 6 S. R. 7 E., about two and one-half miles southeast of Dundee and one-half mile east of the Ann Arbor Railroad was taken from a variable deposit of lake sand about two to ten feet in depth. This sand is underlain by clay in some places and elsewhere by quick sand and gravel. The tests indicate that it possesses some bond which is probably due to the high content of fines or silt.

The foundries in Monroe obtain their molding sand from Ohio and core sand from Saginaw, Port Huron and Manistee. The same practice is followed by the foundries in Milan and Dundee, except that the Dundee Brass and Aluminum Foundry obtains all sands from Ohio.

In addition to the surface deposits, the Middle Monroe or Sylvania Sandstone is found in an outcrop running northeast and southwest across the county extending east of the Huron River into Wayne County and east under the Detroit River. In many places this sandstone is exceedingly pure silica and is being used as a glass sand by a number of glass works. The sandstone is not uniform and varies in purity in different places. Its thickness varies from about thirty to three hundred feet. The Ross Silica Company operates a quarry in the Sylvania sandstone in Section 25, T. 5 S., R. 8 E., east of Scofield and D. T. & I. R. R. The quarry is about

twenty-eight or thirty feet in depth and the company's property covers about forty acres. Here the sandstone extends to a depth of sixty feet or more and is known to cover from two hundred to three hundred acres. During the past twenty-five years, about sixteen or seventeen acres have been worked to a depth of about thirty feet. The sandstone is covered by yellow sand about two to ten feet in thickness. The Ross Silica Company employs about fifty men and the sandstone is recovered by a steam shovel in the pit, crushed, washed with water in screw conveyor, dried in tunnel tills about fifty to sixty feet long, screened and shipped. The product is used by the Ford Motor Company for making plate glass and also by some foundries as a sharp silica sand. It was also reported that some brickyards use this crushed sandstone, probably for sandlime brick.

The Michigan Silica Company also quarries the Sylvania sandstone in Section 15, T. 5 S., R. 10 E., across the Huron River in Wayne County. Analysis of this sandstone are included in the description under Wayne County.

MONTCALM COUNTY

The surface of Mont calm County contains both clay and sand till, deposited as moraine, out wash, or till plains formed under the ice sheet. Sample 175 represents the light yellow unbonded sand found in the sandy till southeast of Greenville. The sample was taken from Section 34, T. 9 N., R. 8 W., three miles north of Belding. The sand extends to a depth of thirty or forty feet and is covered by about a foot of darker yellow sand.

MONTMORENCY COUNTY

Montmorency County is covered largely by moraine deposits and the soil is generally sandy.

Sample 176 from the northwest corner of Section 24, T. 30 N., R. 1 E., represents a light yellow to white sand extending in a ridge running north northwest from the south center of Section 24 through Section 14. At the northwest end of the ridge it runs to gravel. The sample was taken from the sand on the property of the Kneeland Bigelow Company. The deposits through this moraine are extremely variable as is to be expected.

Similar sand was found in the plains in T. 30 N., R. 3 E. and R. 4 E. Around Hillman the sand is similar but even lighter in color. North of Atlanta and west towards Gaylord in Otsego County, and around the Twin Lakes, the sand is white and similar to white beach sand.

Sample 177 was taken from Sections 34 and 35, T. 29 N., R. 1 E., in glacial outwash area around Lewiston. Sand and gravel are found in the southwest quarter of the county in this glacial outwash area which is somewhat less variable than that to the north in the moraine. Sample 177 was taken from a pit about five feet deep.

MUSKEGON COUNTY

The southwestern part of Muskegon County is covered by lake sand as represented by sample 179, which appears to extend to great depth in many places. The northeastern part of the county is covered by glacial deposits, largely outwash plains from which samples 178 and 180 were taken.

Sample 178 from Section 4, T 12 N., R. 17 W., about two and one-half miles north of Montague represents a uniform yellow sand containing little bond.

Sample 179 from Section 17, T. 9 N., R. 16 W., about two and one-half miles south of Muskegon Heights represents the light yellow unbonded sand found in the old lake bed in this part of the county. The light yellow sand is covered by a slightly darker sand in most places.

Sample 180 from Section 11, T. 12 N., R. 15 W., about two miles north of Holton on the state highway, represents a large area of light yellow sand practically free from bond. The deposit is generally covered by one to two feet of a slightly darker sand, and appears to be free from gravel in the immediate locality where the sample was taken, although there are a number of gravel bluffs in the district.

NEWAYGO COUNTY

Newaygo County is entirely covered by glacial deposits, mostly moraine and outwash which are for the most part sandy.

Along the state highway about a quarter of a mile southeast from Field Station on the Pere Marquette Railroad Sample 181 was taken from Section 14, T. 14 N., R. 12 W., as representing the light yellow, fairly uniform, unbonded sand found in this glacial outwash area.

About one-half mile south of Newaygo and three-quarters of a mile east of the Pere Marquette Railroad, sample 182 was obtained in Section 31, T. 12 N., R. 12 W., as representative of the glacial outwash sand found south of Newaygo. The sand is light yellow in color, free from bond, and very similar to that represented by sample 181, except that it is considerably coarser and less uniform in grain size distribution. The glacial outwash covers large areas in Newaygo County and probably contains sand similar to these samples in most places. The moraine deposits also contain sand which is frequently mixed with clay and extremely variable.

OAKLAND COUNTY

Practically all of Oakland County is covered by glacial deposits except the southeast corner cut by a line running northeast and southwest through Rochester. Most of this area in the southeast corner of the county is covered by lake deposited sand and clay with some waterlaid moraine and an interesting river delta about two miles south southeast of Rochester.

The Ward Sand and Gravel Company operates a large gravel pit covering some three hundred acres just east of Oxford, Section 26, T. 5 N., R. 10 E. The deposit seems to be glacial outwash and very extensive. This company handles about ten thousand tons of material per day of which about eight thousand tons are shipped, six thousand tons as gravel and about two thousand as sand. Most of the sand and gravel is shipped to Detroit and used for purposes of construction. The company has been operating since 1923 and now ships more material than the combined total of four other pits in the vicinity.

The pit has a depth of about one hundred feet but the same clean deposit extends to at least fifty feet below the present floor of the pit. The scale of operation may be estimated from the fact that the electric power used in this pit costs \$9,000 per month and the present outlay for plant is approximately two million (\$2,000,000) dollars. It is estimated that there are one hundred million tons of gravel in this deposit.

The gravel is washed from the face of the pit by a three-inch stream of water and dredged by a pump working on the injector principle using air. The plant uses about seventy thousand gallons of water per hour for this operation. The water rises in the pit to within forty feet of the surface. The dredged gravel is handled by means of air lifts and injectors and screened wet to produce sand and gravel.

The clean gravel used for road work and concrete was sold to dealers at sixty-seven cents per ton f.o.b. pit and to contractors at eighty cents per ton f.o.b. in August 1925.

The sand is separated by a hydraulic process producing four grades which were sold to dealers at forty-two cents per ton f.o.b. pit and contractors at fifty-five cents per ton in August 1925.

The asphalt sand represented by sample 183 is the finest sand produced by this process. Sample 184 representing the sharp sand is the next coarser grade and is sold to foundries for core sand as well as for construction purposes. Sample 185 represents a still coarser grade known as torpedo sand, and sample 186 a still coarser sand known as ballast sand.

Sample 187 from the northwest quarter of Section 20, T. 2 N., R. 9 E., was taken from a moraine deposit about six miles southwest of Pontiac and one-quarter of a mile north of the Grand Trunk Railroad, exposed in a cut on the north side of the county road to Pontiac. The sample was taken from a deposit under a small knoll about two acres in extent. The sand stratum is about three feet thick and lies two feet under the surface. Tests indicate that this sand contains about sixteen percent of clay and sufficient bond to be used as a molding sand for some purposes.

Sample 188 is from the sharp sand of the Pontiac Brick Company of Pontiac, used in concrete work. Sample 189 was also taken from The Pontiac Brick Company

and represents the sand used for making sand-lime bricks, being a finer sand than that used for concrete. Both samples were taken from Section 6, T. 2 N., R. 10 E. The brick plant has a capacity of about thirty-four thousand sandlime bricks per day. About three parts of sand to one of lime, by volume, are used in making these bricks which are colored red by the addition of three percent by weight of Venetian red when so desired.

Three samples of sand were taken near Rochester in the survey of 1907 (samples R 11 and R 15 and R 29). The deposit is described by Dr. Ries as an extensive kame deposit occurring along the Michigan Central Railroad about one-half mile southeast of Rochester. The ridge extends along the railroad for some miles but the material composing it varies from sand to gravel in many places. The pit from which these samples were obtained was worked by G. Beal. The section of the pit was: (1) red loam, one and one-half to two feet, (2) cross bedded sand and gravel containing pebbles up to one and one-half inches, about four feet, under which was (3) a bed of sand about five feet thick. The first and second beds were mixed together and shipped to Detroit for use as cores (R15) in the car wheel foundry, as was also the third or bottom layer. A mixture of one-tenth of the first layer and nine-tenths of the second layer was used as core sand and in the manufacture of sandlime bricks, which mixture is represented by sample R11. The base of the pit was about twenty feet above the railroad track, and at the level of the track a twelve foot bed of fine sand was exposed from which sample R29 was obtained. This stratum was covered by two feet of sandy loam and one and one-half feet of gravel. This fine sand from which sample R29 was taken was known as 100 fine and was shipped to several foundries in Detroit.

This deposit is now operated by the Rochester Sand and Brick Company of Detroit. The company owns a deposit of about one hundred and thirty-three acres and is operating the deposit on a rather extensive basis. In 1926, 380,000 cubic yards was the net total production, most of which was sold as an asphalt sand. In addition to the 380,000 cubic yards actually shipped about 18,000 cubic yards of material was rejected because it was too coarse for this purpose, and at least 20,000 cubic yards because it was too fine. It is possible that this fine sand may later be used, at least partially, in the production of sandlime bricks which is also carried on at the deposit.

The asphalt sand was sold at fifty cents per cubic yard f.o.b. in 1926, and some sand sold as core sand was marketed at sixty cents per ton.

It is difficult if not impossible for a sand pit to produce one hundred percent of marketable sand product. Usually at least ten percent and frequently more of the gross production is discarded. The Ward Company of Oxford and the Rochester Sand Company are no exceptions to this statement.

The Wilson Foundry and Machine Company of Pontiac make the Willys-Knight motor and castings for the Overland motor. The foundry has seven cupolas and uses about thirty thousand tons of core sand and fifteen to twenty thousand tons of molding sand per year. The bank sand is obtained from Port Huron and sharp sand from Grand Haven. All the molding sand is obtained from Conneaut, Ohio, through the Peerless Sand Company. The freight rates on sand from Ohio vary from \$2.60 to \$2.80 per ton. Sample 330 represents the No. 0 grade from the Peerless Sand Company of Conneaut, Ohio, used by the Wilson Foundry and Machine Company for aluminum castings. Sample 331 is the No. 1 grade used for gray iron castings and sample 332 represents No. 5 grade used for gray iron castings. Sample 333 is rejected grade No. 5 sand, which has become so contaminated with core sand and deteriorated to such an extent that it is no longer considered fit for use as a molding sand. The foundry is so operated that the sand is used until it has produced a fixed ratio of its weight in castings. The average ratio is six pounds of castings to one pound of molding sand.

OCEANA COUNTY

Oceana County is covered largely by glacial deposits with some lake sand in the southwest corner and in the northeast corner. The surface is till most of which is a light sandy soil practically free from bond.

Sample 190 from Section 6, T. 16 N., R. 15 W., about three miles northwest of Hart was taken from the light yellow sharp sand found in hills and occasionally mixed with gravel. The sample contains about five percent of clay which is probably due to the washing action of the lake waters which formerly covered this area east of Pentwater. The sand is at least thirty feet deep in this location.

OSCEOLA COUNTY

Most of Osceola County is covered by terminal moraine deposits with some boulder clay and glacial outwash. Most of this may be classified as sandy till, some clayey till, with comparatively few sandy sections.

Sample 192 from sections 15 and 16, T. 17 N., R. 7 W., eight miles north of Barryton in Mecosta County and about two and one-half miles southwest of Chippewa on the Pere Marquette Railroad was taken from the property of Dave Kitts and represents the yellow to white sand obtained in the glacial outwash near the boulder clay plain to the north. The sand is streaked with small deposits of red clay, some of which was included in the sample. The deposit was sampled by sinking a small pit along the roadside. Although Cornell University reported a test on this sample, as indicated in Table XL, it is believed that this report is in error due to confusion of sample numbers, either in shipping the sample to Cornell or in identifying the sample after it had been received.

A very similar deposit was sampled (sample 193) in Section 9, T. 18 N., R. 7 W. This sample was taken from the bank of the creek flowing into the Muskegon River. The sand is yellow to white in color apparently free from gravel after the first five to six feet has been penetrated. It should be noticed that the report of the tests on this sample from the Cornell University indicates that it is very similar to sample 192 as tested at the University of Michigan, thereby confirming the field report which is used as a basis of these descriptions. This fact substantiates the contention that the apparent disagreement in the results of the tests on sample 192 is probably due to a confusion in identification of these samples.

Sample 194 was taken from the pit of the Crescent Gravel Company in sections 19 and 30, T. 17 N., R. 9 W. The sample was taken from section 30 in the glacial outwash deposits southeast of Hersey. Except for being a coarser sand this sand is similar to the other obtained in this county.

OSCODA COUNTY

The surface deposits of Oscoda County are largely sandy being composed of glacial outwash, moraine and till or bonded clay with a small area of sandy drift in the northeast corner.

Sample 195 from Section 31, T. 27 N., R. 1 E., represents the light yellow to white sand found in the outwash plain at Snyder's Resort near Bear Lake. The sand is of varying depth, up to fifteen or twenty feet in most places, and extends over a large area particularly to the south. It is gravelly in spots and may contain strata of clay. The sample was obtained by sinking pits into the deposit.

About a half mile north of Luzerne sample 193 was taken from the northeast quarter of section 23, T. 26 N., R. 1 E. The sand here is very similar to that represented by sample 195. It is light yellow to white in color and runs six feet or more in depth. Sample 196 was obtained from a pit and auger borings. Its physical properties classify it as almost identical with sample 195 obtained to the north. There is evidence of a clay subsoil north of Luzerne which frequently comes very near the surface toward the east.

At Comins, Section 20, T. 28 N., R. 3 E., a clean sharp sand is obtained from a flowing "boiling" spring and used locally for chicken gravel.

OTSEGO COUNTY

Otsego County is covered by glacial outwash through the central part with moraine deposits to the south and north with some areas of sandy till. Most of the soil may be classified as gravelly loam and sandy till.

Sample 197 from Section 20, T. 29 N., R. 3 W., represents the yellowish sand found over a layer of white sand and gravel in a long cut along the side of the road

and the Michigan Central Railroad south of Otsego Lake. This sand is free from bond, contains smooth grains, and is extremely uniform in size distribution. It is evidently a water-deposited sand, probably deposited from a stream issuing from the glacier and flowing at a uniform rate.

About one and one-half miles south of Vanderbilt Station on the Michigan Central Railroad, sample 198 was taken from Section 34, T. 32 N., R. 3 W. This sand is found in much the same formation as sample 197, being a yellow sand to a depth of four to ten feet over white sand extending to a depth of at least thirty feet. In places it is covered and mixed with gravel and is generally much less uniform in grain size distribution than sand south of Otsego Lake where sample 197 was taken. The sand grains are round and smooth and the sand area extends north and northeast of Vanderbilt over considerable territory. This deposit is evidently glacial till and not definitely water deposited as was sand represented by sample 197.

Sample 198 is probably more typical of the sand to be found in Otsego County than the extremely uniform sized material represented by sample 197. Further investigation of the sand found in Sections 34 and 35, T. 49 N., R. 3 W., indicated that gravelly, yellow and white sand in much the same order as has been described is to be found through the district. Mr. H. Arntz reported having driven a well 200 feet through this sandy gravelly soil.

OTTAWA COUNTY

The surface of Ottawa County is mostly sandy lake beds, with some dune sand north and south of Grand Haven along Lake Michigan. An interesting delta formation is evident between Lamont and Allendale, as laid down by the Grand River during the glacial period when the lake covered this land. Sample 201 from the southwest quarter of Section 20, T. 7 N., R. 13 W., about three and one-half miles east of Allendale and sample 202 from Section 24, T. 7 N., R. 14 W., about three-quarters of a mile east of Pearline, represents sand found in this old delta. These samples exhibit rather high bond and contain sixteen and twenty-four percent of clay respectively.

Sample 201 was obtained from a deep cut on the north side of the road and represents a stratum about four feet thick found ten feet below the surface, about two-thirds of the way down from the top of the hill. The immediate district is very hilly and the soil for most part is known to be heavy clay. Sample 202 was taken from a cut on the south side of the road and represents a stratum about one foot thick apparently underlying a small area. Here the surface appears rolling with most of the soil being heavy clay. Sample 201 is much finer than Sample 202.

Sample 199 from Section 21, T. 8 N., R. 15 W., represents the light yellow lake deposited sand found in the north and west central parts of Ottawa County, and the southwestern part of Muskegon County. Sample 199 was taken about two and seven-tenths miles west of

Nunica on the state highway about a quarter of a mile south of the railroad. Here the sand is found in low hills varying from a few feet to thirty feet in height. Very similar sand is found further south in Section 36, T. 7 N., R. 16 W., along the state highway and the Pere Marquette Railroad about 1.8 miles south of Agnew, where sample 200 was obtained. Most of this lake sand found through Ottawa County appears to be satisfactory as a core sand. This is borne out by the fact that the Home Furnace Company, and the Bus Machine Works of Holland, Michigan, use local sand as core sand in their foundries. The Home Furnace Company uses molding sand from Allegan and the Bus Machine Works uses molding sand from Hamilton, Allegan County, and St. Joseph, Berrien County.

PRESQUE ISLE COUNTY

The surface deposits of Presque Isle County are composed of boulder clay, moraine and sandy lake beds. Sample 203 from Sections 31 and 32, T. 34 N., R. 2 E., about four and one-half miles south of Onaway, represents the somewhat pebbly yellow sand found in what appears to be a moraine deposit. The sand is of variable thickness running from three to four feet or more towards the south. In general, the same type of sand continues to the south through the plains running light on the ridges and thicker in the valleys or hollows. At a depth of three or four-foot red clay is usually found.

ROSCOMMON COUNTY

The surface deposits of Roscommon County are composed largely of sand laid down as glacial outwash and moraine with some boulder clay. Samples 204 and 205 are practically identical and represent the sand as found in the glacial outwash plain south and west of Houghton Lake. Sample 204 was taken from a deposit of white sand covered by a yellow sand in Section 6, T. 22 N., R. 4 W. Here the yellow sand was from three to four feet thick over the white sand. Sample 205 was taken from the yellow sand found in the northeast quarter of Section 19, T. 22 N., R. 3 W., along the south shore of Houghton Lake, the sand is free from stone or gravel and is practically uniform for a depth of at least ten or twelve feet after the top layer of dark sand is removed. In general, the sand seems to be composed of smooth round grains and is very similar throughout this district, at least from Houghton Lake to Roscommon, with boulder clay being found northeast, and in small areas, southwest of Houghton Lake and also about three to four miles south of Roscommon.

SAGINAW COUNTY

The surface deposits of Saginaw County are entirely water laid. With the exception of a band of waterlaid moraine, about four or five miles wide and lying just north of the Tittabawassee and Cass rivers, all of the surface deposits may be classified as lacustrine, most of which is clayey.

Sample 206 was obtained through the foundry of the Bay City Iron Works and represents the core sand used by this foundry as obtained from a dredge working on the Tittabawassee River near Saginaw.

Sample 207 taken from Section 8, T. 12 N., R. 4 E., about three and one-half miles west of Saginaw and one mile west of the Pere Marquette Railroad represents a light yellow sharp sand found to a depth of eight to ten feet mixed with layers of darker colored sand and used in making sandlime bricks. This sand is generally similar to that represented by 206 except that it is much finer. In the survey of 1907 Dr. Ries obtained a sample of light core sand used for making sandlime bricks near Saginaw, which is very similar to sample 207 taken from northwest of the city. The sample obtained by Ries was taken from Section 34, T. 12 N., R. 4 E., and possessed the properties as given in Table XL.

Sample 208 from Section 27, T. 12 N., R. 3 E., about twelve and one-half miles west of Saginaw on the state highway, represents the sand found in the pit of the Saginaw Brick Company. The deposit is about six to ten feet thick and covers about five acres, of which one and one-half acres have been dug over. This sand is a very clean sand and generally similar to sample 206 representing the sand dredged from Tittabawassee River, except that sample 208 represents a slightly finer grained sand.

Sample 209 from Section 19, T. 10 N., R. 6 W., about one mile west of Birch Run is also similar to sample 208. This sample was taken from a small mound about fifty feet wide, one hundred feet long and ten feet high on the property of Mr. Young. During the war this sand was used by some of the local foundries but has not been used since. A similar sand found on the property of Mr. Briggs was also worked during the war but has not been worked since that time.

The Jackson and Church Iron Works of Saginaw uses Zanesville sand for molding sand. It was reported that this foundry had formerly used molding sand from Lansing, and also from Alma in Gratiot County. Local sand similar to that represented by R32, 206 or 207, obtained near the limits of Saginaw City is used as core sand.

Wickes Brothers Company uses an Ohio molding sand identified as Hocking Valley and marketed by the Garden City Sand Company of Chicago. This company also reported having used molding sand from Alma in the past. Core sand is obtained from a bank along the Gratiot road on the property of Mr. Behring. It was reported that Mr. Behring had previously tried to prepare synthetic molding sand by mixing this bank sand with clay but that the result was not successful.

The A. S. Bartlett Company uses a Zanesville No. 5 sand for molding-sand with the properties as given for sample 315, which was kindly supplied by this company.

ST. CLAIR COUNTY

The surface deposits of St. Clair County are composed largely of clayey lake beds which also include some sand. South of Atkins is a formation which appears to be an old delta of the Black River. Sample 210 taken from Section 30, T. 7 N., R. 16 E., on the Pere Marquette Railroad about two miles east of Abbottsford, appears to be representative of the bank sand found in this district. The sample was taken from a deposit formerly owned by Fred Black but when visited in August 1923 was owned by the Otto City Sand and Brick Company of Port Huron. The sand is found in a ridge which is apparently an old beach running almost south southwest between the Pere Marquette and the Grand Trunk Railroads about a mile east of Goodells and a mile and a half west of Spartan. The deposit shows the presence of some clay in layers and is generally not quite as uniform as that represented by sample 211. The deposit was worked for core sand but when visited was at least temporarily abandoned.

Sample 211 from Section 1, T. 6 N., R. 15 W., represents the sand as found in a new pit being opened in August 1923 by the Otto City Sand and Brick Company, near the Grand Trunk Railroad along the same beach ridge as that from which sample 210 was taken. The sand deposit appears to contain considerable clay pockets, and the layers containing clay are more pronounced than in the deposit near Juniata in Tuscola County. In fact this statement applies equally well to the northern part of the beach where sample 210 was taken. Sample 211 was taken from a trench on the side of the bank. This sand appears cleaner and more satisfactory for core sand than the deposit to the north and apparently was being worked in preference to the latter.

Sample 212 from Section 8, T. 6 N., R. 17 E., and Section 13, T. 6 N., R. 16 E., represents the lake deposited sand west of Port Huron which has been used as a core sand for ten to twelve years. When visited September 1923, six or seven men with three teams were employed by the Reynolds and Bailey Sand Company in shipping about six to ten cars of core sand per day. The Connors and Trulisse Company was then shipping about two cars per day. The sand seems to extend to a great depth and is somewhat finer than that found farther west and south of Abbottsford. Sand from this deposit is used by the Home Foundry in Port Huron. No local sand was used as a molding sand in Port Huron.

In the report for 1907 Dr. Ries reported that the foundries in Port Huron imported all of their molding sand although using local core sand. A fine grained bonded sand was obtained from north of Port Huron near the cemetery and identified as sample R48. Ries reported this sand as probably of lacustrine origin and found in a deposit barely over a foot in thickness. At that time this sand was used for general work.

Sample 213 from Section 34, T. 6 N., R. 14 E., about one mile northwest of Memphis on the Pere Marquette Railroad and the county road to Capac, represents the bonded sand as found in the lake clay area throughout this district. The sample was taken from a stratum about two to three feet thick found under one foot of top soil. The deposit ran into heavy clay at a greater depth and covered about five acres. In many ways this sample is probably similar to sample R48 reported by Ries.

Sample 215 from the southwest quarter of Section 14, T. 4 N., R. 16 E., about one and three-quarters of a mile south of the Michigan Central Railroad and three miles southwest of St. Clair is also representative of the bonded sand found in the lake clay area. Here the deposit is rather variable covering about fifty acres. Samples 216 and 217 were taken from the same deposit at slightly different positions. All samples were taken from the stratum found from about eighteen inches to three feet below the surface. It was reported when visited in 1925 that a local company was prepared to work this deposit for a molding sand but the plans did not materialize due to trouble in obtaining a satisfactory lease.

Sample 218 from the northeast quarter of Section 23, T. 4 N., R. 16 E., about three miles south of St. Clair is also representative of the lacustrine deposits in this district. Samples 215, 216 and 217 from property belonging to Gilbert Bobbins, and sample 218 from property belonging to Albert Schunk, and sample 219 from the property of Mr. Van Horn, were all taken from practically the same formation in this lacustrine deposit. Comparison of the properties of these different samples indicates that the sand is consistently of fine grain size and of varying clay content. A few carloads have been taken from the property of Albert Schunk as represented by sample 218. Here the stratum is about three feet thick under one foot of top soil and covers about ten acres along the north shore of the Bell River. Sample 219 was taken from the south side of the Bell River from the property of Mr. Van Horn. Here the stratum is about eighteen inches to two feet thick under one foot of top soil and covers about twenty acres. This deposit was being worked in 1925 by the Michigan Molding Sand Company of Port Huron.

The number of places in which bonded sand is found in St. Clair County clearly indicates that these lacustrine deposits, generally classified as clayey lake beds, may be considered as the likely areas to search for molding sand deposits. The sand obtained from such deposits should not be expected to prove as durable or as generally satisfactory as molding sand obtained from thoroughly weathered deposits where the bond has been developed during the weathering process instead of being simply mixed with the sand during deposition as is probably the case in these clayey lake beds,

Sample 214 from the northwest quarter of Section 1, T. 5 N., R. 14 E., about one-quarter of a mile east of Memphis, on the Pere Marquette Railroad switch represents the sand as washed out of the gravel from

the Shanahan pit. When visited in 1925 there were probably three hundred carloads of similar sand in a pile, with more being accumulated. Because this sand was not used but regarded as a waste material in the production of gravel. Although the sample was taken from within the limits of Macomb County it is representative of the sand found in the waterlaid moraine material running north and south through Memphis, and was erroneously classified as a St. Clair County sample.

ST. JOSEPH COUNTY

The surface deposits of St. Joseph County include mainly glacial out-wash with some moraine and sandy drift deposits. All of the samples obtained from St. Joseph County were taken from areas of glacial out-wash.

Sample 220 from Section 32, T. 6 S., R. 12 W., just south of the Michigan Central Railroad represents a sandy, pebbly drift, containing some clay and rather similar to the boulder clay deposits found to the west in Cass County. This sand shows good permeability and a fairly high bond strength for such a sand. Compared to Albany sand No. 3 of about the same texture it shows a higher bond and higher permeability at a lower moisture content and might be regarded as equivalent to an Albany No. 3 open sand. Its durability, however, would probably be less than that of the Albany sand.

Samples 221 and 222 are taken from the glacial outwash east and northeast of Three Rivers. Sample 221 was taken from the property of Mr. Gross on the hillsides surrounding a marsh in the central southern part of Section 21, T. 6 S., R. 11 W., about a half mile south of the Michigan Central Railroad and southeast of Three Rivers. The deposit is composed of small irregular pockets of highly bonded sand about four or five feet below the surface of the hill. The pockets are about one and one-half feet in thickness and are found in beds of practically unbonded clean loose sand. The sample shows the sand pockets to contain a highly bonded high clay content sand which might be satisfactory as a molding sand.

Sample 222 was taken from the pit owned by Elmer Schultz on Huffman Street, Three Rivers, just north of Portage River in the southwest quarter of Section 8, T. 6 S., R. 11 W. This sand is found as a stratum between layers of gravel in a gravel pit. The stratum is about two feet thick, patchy, apparently small and would probably prove inadequate except for local use. This sand is used as a core sand by the Fairbanks Morse Foundry. The foundry uses Ohio sand from Columbus and Zanesville for making their molds.

Sample 223 from the northwest quarter of Section 7, T. 5 S., R. 11 W., about nine-tenths of a mile south of Flowerfield Station on the Lake Shore and Michigan Southern Railroad, was taken from the cut on the east side of the state highway, and represents a highly bonded sand found in pockets about one foot thick. It is

slightly coarser than sample 221, but otherwise very similar to it. Many of these sands would be satisfactory for molding sand, but being found only in small pockets difficulty would be experienced in trying to deliver a reasonably uniform sand for use in a foundry unless a reasonably large uniform deposit could be located. Sample 224 is identical to sample 223 except that it has been heated to 600° F. for two hours in order to determine the durability of these highly bonded sands found in St. Joseph County. The results as given in Table XL indicate a loss in bond strength of sixty-five percent and a loss in permeability of twenty-four percent, indicating that these sands possess little durability.

SANILAC COUNTY.

The surface deposits of Sanilac County include mostly boulder clay to the southwest, from which area sample 229 was taken with clay and sand lacustrine deposits toward the east. There is also a band of moraine deposits east of the Pere Marquette Railroad and Black River represented by sample 228.

Sample 225 was taken from Section 19, T. 9 N., R. 16 E., two miles east of Amadore on the Pere Marquette Railroad. The deposit here is composed of fine light yellow to white lacustrine sand containing little if any bond. The sand from which the sample was taken is covered by about ten feet of yellow sand and extends to a depth of at least twenty feet. The deposit contains pockets of gravel particularly beneath the sand. In other places the sand is underlain by clay. A cut through the formation shows the sand stratum extending to a depth of about forty feet. Samples 225 and 226 represent different samples obtained by quartering the same field sample, 225 being tested at the University of Michigan. The high clay content as reported from the Bureau of Standards is again evident in these samples.

Sample 227 from Section 17, T. 9 N., R. 16 E., about two miles north of Amadore just west of the Pere Marquette Railroad was taken from the property of Bob Flynn. This sand appears to have been deposited as a beach sand from an old glacial lake. It is practically free from bond, fine grained, and rather similar to sample 225. The deposit appears uniform and has been worked for some undetermined purpose. The light yellow sand is covered in most places by a few feet of brown sand.

Sample 228 from the southeast quarter of Section 19, T. 14 N., R. 15 E., about four miles southeast of Lyndon, was taken from borings on the west side of the state highway in what appears to be a moraine deposit. The stratum is about three feet thick under one foot of top soil and covers probably twenty acres or more. This sample contains over eighteen percent of clay and seems to possess a high bond strength and fair permeability for a fine grained sand.

Sample 229 from the north center of Section 15, T. 10 N., R. 14 E., on the state highway about two miles north of Peck represents the moraine and boulder clay deposits in the southwestern part of the county. The

sample was taken from borings which were mixed and quartered. In general this sample is very similar to the sand represented by sample 228. It is finer grained and contains somewhat less clay, possessing a slightly lower bond and lower permeability.

SHIAWASSEE COUNTY

Practically all of the surface deposits of Shiawassee County are glacial moraine and boulder clay plains. There is a narrow band of glacial outwash material running approximately east and west about six miles north of the south county line, and some waterlaid sand deposits along the Maple River.

Sample 230 from the south edge of Section 25, and sample 231 from the northwest quarter of Section 36, T. 8 N., R. 2 E., represent a five to eight foot stratum of fine bonded sand found in the moraine deposit about twenty feet below the surface. The samples were taken from the property of Mr. Mat Bittell and Mr. Mike Rourke respectively. These samples were taken from the face of the bluff along the Shiawassee River about three miles north of Owosso and three-quarters of a mile east of the Michigan Central Railroad. The stratum from which the samples were taken is covered by about twenty feet of gravelly clay, and appears to be rather uniform, particularly on the property of Mr. Rourke where sample 231 was taken. Here the stratum seems to be covered by boulder clay. On the property of Mr. Mat Bittell where sample 230 was taken the material seems to be covered by a moraine deposit. It was reported that the sand from the latter location had been previously tried by the Malleable Iron Works of Owosso.

Interviews with the various foundry superintendents in Owosso indicate that no Michigan molding sand is used in this city. The Standard Foundry on South Washington Street uses Albany No. 1 as represented by sample 327 and Zanesville sand. The Malleable Iron Works use Zanesville sand containing from thirty to forty percent of clay. It was reported that the Clean Cast Sand from Allegan possessed too much bond for satisfactory use by this company. The Malleable Iron Works use approximately five thousand tons of various kinds of sand per year. Zanesville sand costs \$1.75 f.o.b. with freight at \$2.52. The Independent Stove Company on Bradley Street uses Albany sands exclusively which cost \$1.75 to \$2.00 per ton f.o.b. plus freight of \$4.10. Sand from Allegan had been tried but it was reported that this sand did not possess sufficient durability.

TUSCOLA COUNTY

The surface deposits of Tuscola County include clayey lake beds in the northwest, a lake sand and beach sand running northeast and south southwest, of the Cass River, and boulder clay and moraine deposits in the southeastern part of the county. At a number of places the lake deposited sand is recovered and marketed as a core sand.

The Burt Core Sand Company of Vassar operates a sand pit three miles east of Vassar just north of the Pere Marquette Railroad right of way. Sample 521 was taken from this pit in Section 15, T. 11 N., R. 8 E., and represents the product of this pit as sold to Warner E. Thompson Company of Detroit. The overburden of soil which runs from a few inches to two feet in thickness is removed. Under this top soil is found a layer of rusty sand of a few inches thickness which seems to have been formed by weathering of the sand and clay at the top of the deposit. Underneath this rusty sand is found about fifteen feet of unbonded sand which is recovered by a steam shovel and loaded into dinky cars, screened and loaded into railroad cars and marketed as a core sand. Underneath this stratum of yellow sand is found some white sharp sand which was once the surface, as roots and a rusty crust are found on top of the white sand and below the yellow sand. This clearly indicates that the yellow core sand was either later blown in or otherwise deposited over the old surface. The sand is known locally as the blow sand because it is so readily blown around by the wind. This fact and the high uniformity of the sand grains indicate that it is probably dune sand which has later been covered by vegetable growth. The sand ridge runs northeast and southwest following the old shore line which might indicate that it was water deposited as a sand bar or old beach, but the general appearance indicates it to be wind deposited. It was reported that this sand was mixed with fine sand for cores and with clay for use as a molding sand for aluminum castings. When visited in 1923 about six cars a day were being shipped to the foundries in Detroit, Flint, and Saginaw.

Sample 233 from Section 17, T. 11 N, R. 8 E., is very similar to sample 232 and represents the yellow sand found in the upper three to four feet in this locality about two miles west of the Burt Core Sand Company's pit.

Fred Black of Goodells worked a sand pit just east of Juniata on the Pere Marquette Railroad in Section 30, T. 11 N., R. 9 E. Using twelve teams on scoops, one team moving cars, one man distributing load in the cars, and one man running a gasoline engine which drives a belt conveyor used as a loader, about twenty cars a day were shipped from this pit. When visited in August 1923 Black was operating on a 99-year lease paying one dollar (\$1.00) per car royalty. His labor costs were about \$10.00 per car, and he received about \$14.00 per carload f.o.b. The blow sand is avoided in working the deposit as this appears rather dirty as compared to the lacustrine sand which composes the main part of the deposit. As this sand is very similar to that represented by sample 232 from Vassar, and is evidently a water deposited sand there is some question about considering the sand at Vassar as wind deposited in spite of bearing the name of "blow sand". Sample 234 was taken from the pit of Fred Black at Juniata. Strips of clay about four to six inches apart are evident through a good part of this deposit and give a scaly appearance to the dry bank. It is reported that the bulk of the sand lies

to the southwest of Juniata and Black expects to operate in that district in the future.

Sample 235 from the southeast quarter of Section 21, T. 11 N., R. 7 E., about four miles southwest of Vassar and one-half mile north of Tuscola, was taken from the face of a cut on the side of the road. The sample was obtained by vertically trenching a stratum about four feet thick, one foot below the surface and underlying a flat knoll which appears to be waterlaid moraine. This sample is extremely fine grained and seems to possess appreciable bond.

Sample 230 from Section 17, T. 11 N., R. 8 E., was taken from about the same location as sample 233, one mile east of Vassar about two years later in 1925. This sample taken in 1925 from the pit of the Burt Core Sand Company represents a screened sand as loaded on the cars from the pit. The pit is on the north side of the road and was practically exhausted. The sand extends to the south and it was estimated that there were at least 25,000 carloads still available in this deposit. The sand is taken from the pit with a steam shovel, loaded on dump cars screened and loaded on railroad cars. This plant has a capacity of about five to ten carloads per day. The old pit of the Burt Core Sand Company about two miles east of this as represented by sample 232 was completely exhausted and the pit in Section 17 was put into operation in March 1925.

Sample 237 also from Section 17, one mile east of Vassar, was from a stratum of sand underlying that from which sample 236 was obtained. The sand represented by sample 237 occurs in a stratum about eight to twelve feet thick. This sand is fine grained and contains appreciable bond, and might be used as a fine grained molding sand.

VAN BUREN COUNTY

Van Buren County is practically entirely covered by glacial deposits.

Sample 238 from Section 15, T. 3 S., R. 13 W., was taken from the glacial outwash about two miles west of Mattawan and represents a coarse yellow sharp sand containing little bond, found in these glacial outwash plains. The deposit here is about ten to fifteen feet deep and covers a large area from Paw Paw to Kalamazoo and to the southwest. A duplicate sample of the same deposit identified as sample 239 was tested in the laboratories of the University of Michigan with results quite different from those reported by the Bureau of Standards in so far as clay content and uniformity coefficients are concerned. The dry permeability of 73.9 as recorded by the Bureau is considered a typographical error. The high clay content as reported from the Bureau has been noted before.

Sample 240, Section 8, T. 2 S., R. 15 W., about one and one-half miles east of Bangor, was taken from a stratum one foot thick found about two feet below the surface in a cut along the side of the road. The formation is

evidently a glacial deposit either till plain or moraine and the sample seems to be similar to sample 5 from Allegan County. It is extremely fine grained, possessing a rather high clay content and low permeability, caused evidently by the high percentage of pan material or fines contained in the sand.

Sample 241 from T. 3 S., R. 16 W., on the section line between Sections 12 and 13 along the state highway three miles east of Hartford is also a glacial deposit of fine sand containing some clay. The deposit is of variable depth but appears to be about ten feet deep in one cut where the road cuts through a bank. This sample was tested by the Bureau of Standards and the University of Michigan with generally concordant results regarding permeability, bond, and the coarser sized particles. A wide discrepancy in clay content is noticed and can be explained only on the assumption that in siphoning the clear water above the sand when separating the clay from the sand grains, a large amount of silt as represented by the 270 mesh and pan was included with the clay in the Bureau of Standards' test.

Sample 242 from Section 11, T. 1 S., R. 15 W., one mile northwest of Berlamont and about three miles west of Bloomingdale is a sandy clay or clay sand mixture found in the glacial moraine. Sample 243 in Section 6, T. 1 S., R. 15 W., represents the sandy drifts found east of Lacota. The sand extends for a large area and apparently to a great depth east of Lacota and north of the Black River extending into Allegan County as far as Fennville and the Kalamazoo River. It is a light yellow unbonded sand of rather uniform grain size and apparently very suitable for core sand.

A gravel pit in the moraine about two and one-half miles northwest of Paw Paw (Section 34, T. 3 S., R. 14 W.) showed layers of yellow sand about 2 to 3 feet in thickness underlain by about one foot of red clay, then three to four feet of gravel, one to two feet of red clay and more gravel. In this district from Allegan south to St. Joseph the moraine and glacial deposits include relatively large amounts of clay which may become mixed with sand in the lake washed areas, forming fairly satisfactory deposits of molding sand.

The National Motor Casting Company of South Haven used bank sand from Saginaw and dune sand from Michigan City with a molding sand from Ohio.

WASHTENAW COUNTY

The surface of Washtenaw County is practically covered with boulder clay and moraine deposits with small areas of glacial outwash. In the southeastern corner of the county some lacustrine clay and sand areas are found.

Sample 245 from Section 22, T. 2 S., R. 3 E., one mile east of Sylvan represents the coarse yellow sand found in the moraine and till to a depth of about thirty to fifty feet and generally covered by a few feet of gravelly sand with pockets of gravel and stone in places.

Sample 246 from Section 7, T. 4 S., R. 6 E., about seven-tenths of a mile southeast of Saline on the county road to Milan, represents the lacustrine clay deposits exposed by a cut on the east side of the road. The sample was obtained by borings which were mixed and quartered. The stratum is about three feet thick and covered by about two and one-half feet of top soil. The material is extremely fine grained, being composed mostly of silt and sand and has an extremely low permeability.

Sample 247 from Sections 14 and 23, T. 3 S., R. 7 E., was taken from borings in the flat north of the Huron River about one mile southeast of Ypsilanti city limits on the county road just north of bridge over the Huron River. The deposit lies in the old delta of the Huron river and covers an area of at least twenty acres which is bordered by shallow gravel deposits. The stratum from which the sample was taken is about two to three feet thick and found one foot below the surface. The sample is a rather fine grained sand containing eighteen percent of clay. It possesses a high bond and moderate permeability with a rather wide working range as it shows practically constant bond and permeability from five to ten percent moisture content.

Sample 248 from Section 9, T. 2 S., R. 6 E., was taken from a ditch on the east side of the county road about two miles north of Ann Arbor and one-quarter of a mile north of the Ann Arbor Railroad. The deposit is found in a small moraine about three feet under the surface. The stratum from which the sample was taken is about two feet thick. The sample indicates that this sand is very similar to the sample near Ypsilanti (sample 247) except that it does not possess quite such a wide working range, particularly as to permeability.

Sample 249 from Section 20, T. 2 S., R. 6 E., was taken from within the city limits of Ann Arbor in about the 1000 block on Pontiac street. Here the stratum from which the sample was taken is about three feet thick and found one foot under the surface. It was sampled by trenching across the face of the cut at the side of the street. This sample is also similar to samples 247 and 248 except that sample 249 contains more clay and a higher bond strength. All of these samples with the single exception of that taken near Ypsilanti contain too much silt or fine material to be satisfactory molding sand and the sample taken from the old delta of the Huron River does not contain sufficient bond for this purpose.

The American Furnace and Foundry Company at Milan uses a sand identified as Red Top No. 3 from the Zanesville district obtained through W. E. Thompson Company, for its molding sand. Sample 334 (Table XLI) was supplied by this foundry as representative of this Red Top No. 3. Sample 335 was also kindly furnished by the Superintendent of the American Furnace and Foundry Company and represents the Eclipse sand from the Zanesville district also obtained through W. E. Thompson Company of Detroit. In preparing molds these two sands are mixed in different portions depending upon the class of work. This company makes

only gray iron castings up to four hundred pounds in weight. It was reported that one car of Port Huron molding sand obtained through the Stevens Company of Detroit was used with unsatisfactory results as it was too light for their work. The freight rate on the molding sand from Conneaut is \$1.89. Manistee sand is used in preparing cores.

Sample 336 was kindly supplied by the Ypsilanti Foundry Company and represents a very fine sand from Louisville, Kentucky, used by this foundry for casting piston rings. The freight rate on this sand is \$3.02 per ton. This company uses a sand obtained from Conneaut, Ohio, through the Ayres Mineral Company for their heavier work. Freight rate on this sand is \$2.39 from Conneaut, and on Nash sand from Zanesville is \$2.14.

Sample 337 was supplied by the National Foundry and Machine Company of Ypsilanti as representing the Michigan City core sand used in preparing their cores. This foundry casts automobile cylinder heads and manifolds, mainly for the Chrysler Company, and uses principally Conneaut and Nash sand from Zanesville in preparing molds. Zanesville sand is reported to be of poorer quality than formerly. This has been confirmed by a number of foundries.

The Ann Arbor Foundry Company uses Zanesville and Conneaut sand and also reports that the Zanesville sand is not as satisfactory as formerly.

WAYNE COUNTY

Wayne County is entirely covered by lacustrine deposits, most of which are sandy at least at the surface, except for some glacial moraine deposits in the northwest corner of the county. The middle Monroe or Sylvania sandstone is found very near the surface in the southeast corner of Wayne County. At some places this sandstone is extremely pure silica and is quarried to produce a glass sand.

The Michigan Silica Company operates a quarry in the Sylvania sandstone in the east central part of Section 15, T. 5 S., R. 10 E., about one-quarter of a mile east of Rockwood. This deposit has been worked for some time but only since 1925 by the present organization. In 1918 this silica rock was sampled by the U. S. Geological Survey taking samples from different parts of the pit as it then existed. An analysis of this composite sample was made by Professor Boswell of England with the results given as:

Silica (SiO ₂)	98.00	percent
Alumina (Al ₂ O ₃)	0.13	percent
Iron (Fe ₂ O ₃)	0.012	percent
Titania (TiO ₂)	trace	
Magnesia (MgO)	0.41	percent
Lime (CaO)	0.70	percent
Strontia (SrO)	0.02	percent
Potash (K ₂ O)	none	
Soda (Na ₂ O)	none	
Water (H ₂ O)	0.16	percent
Carbon dioxide	0.73	percent
	<hr/>	
	100.16	

This analysis would classify the Rockwood sandstone equal to any in the world as a glass sand. At that time the statement was made that the upper part of the deposit was better than the lower part. The northern part, or at least that north of the present pit of the Michigan Silica Company, is also regarded as of poorer quality. On January 17 1925, another sample was taken by breaking lumps against other pieces of the rock in the pit to avoid contamination and finally grinding the sample in a ball mill using flint balls.

This sample was carefully analyzed with the following results:

Silica (SiO ₂)	92.8	percent
Total Iron (Fe ₂ O ₃)	0.16	percent
Alumina (Al ₂ O ₃)	1.04	percent
Lime (CaO)	2.25	percent
Magnesia (MgO)	1.11	percent
Water and Carbon Dioxide (Ignition Loss)	2.73	percent
	<hr/>	
	100.09	percent
Acid Soluble	0.068	percent
Iron	0.079	percent
	<hr/>	
Average	0.073	

This sample was taken from that part of the quarry being worked in 1925 and was farther south and lower than the point from where the sample reported previously was taken in 1918. Comparison of these analyses clearly indicates that the Sylvania sandstone is not of uniform purity. The high lime offers no particular disadvantage but the higher iron content may be taken as indicating a poorer quality of glass sand.

A sample of the finished product being produced on January 17, 1925 gave the following analysis:

Silica (SiO ₂)	90.20	percent
Total Iron (Fe ₂ O ₃)	0.21	percent
Alumina (Al ₂ O ₃)	0.82	percent
Lime (CaO)	3.84	percent
Magnesia (MgO)	1.43	percent
Water and Carbon Dioxide (Loss on Ignition)	3.35	percent
	<hr/>	
	99.85	percent
Acid Soluble	0.10	percent
Iron	0.11	
	<hr/>	
Average	0.105	

This analysis indicates that the grinding operation necessary to prepare this material for market probably increases the iron content slightly. The higher lime and magnesia content are difficult to explain unless they indicate a slightly different composition in the material passing through the plant.

The sand is favorably received by glass manufacturers and the plant was producing about one hundred tons with a capacity of three hundred tons per day in 1925.

In order to quarry the sandstone it is necessary to remove about eighteen feet of stripping. This exposes the silica sandstone which extends to a depth of one hundred feet at this place. The quarry is about fifty-five to sixty feet deep. Drill holes are sunk from the top of the silica rock which is then dynamited and the broken rock picked up by two steam shovels, loaded onto pit cars which are hauled up an incline by means of a cable and dumped into a knobbed roll crusher. The crusher material falls directly from the roll crusher on to a stock pile of about 3,000 tons. From the stock pile the crushed rock is fed to a belt conveyor which carries the crushed rock to rotary screens. The fines go directly to a Dorr classifier, the intermediate sized material to a jaw crusher. After the material has been reduced to the proper size and thoroughly washed in the classifier, the sand slurry is pumped into drain bins where the water content is reduced to as low as four percent in the summer season. From the drain bins it is picked up by a clam shell bucket and dried in the Ruggles Coles drier. The dried product is then passed through a hummer screen where all material over 28 mesh is discarded. The final product is stored in a large concrete silo.

Sample 252 represents the crushed stone before passing the classifier, and sample 253 the final product. Most of the product goes to Ohio and was sold for about \$2.50 to \$2.75 per ton in 1925.

Sample 250 from Section 33, T. 1 S., R. 8 E., one and one-half miles southwest of Plymouth and property of Mr. Kaiser, represents the sand obtained from a variable sandy area containing pockets of clay sand mixtures. A gravel pit is on the same property adjacent to where the samples were taken.

Sample 251 from Section 13, T. 3 S., R. 8 E., three miles northwest of Romulus is very similar to sample 250 except that it is of more uniform grain size and is relatively free from bond. The sample was taken from the bottom of the Dallman gravel pit and represents the sand used by the Romulus Gray Iron Foundry and Machine Company as a core sand. Sand is found under the gravel at a depth of ten to twenty feet. This company reported that they had previously used local molding sand which was obtained from small pockets, but that poor results were obtained and that the Ohio sand can be imported as economically as the local sand can be purchased and hauled to the plant.

Sample 254 from the southwest quarter of Section 6, T. 3 S., R. 8 E., about two hundred yards south of the Michigan Central Railroad and four miles east of

Ypsilanti was taken from a small cut in the side of the road and represents the peculiar mixture of clay and sand found in the old delta of the Huron River. The sample is somewhat a composite sample being made up by mixing together the materials obtained from several places and through several different strata in the bank. For this reason the screen analysis of sample 254 shows a very low uniformity factor an irregular distribution of the grain size. The stratum from which the sample was taken is overlaid by about one foot of muck and underlain by a gray gravel.

Sample 255 from the southwest quarter of Section 19, T. 3 S., R. 8 E., just southeast of Rawsonville and the Huron River, also represents the sand obtained from the old delta, or present river flat. The sand stratum from which the sample was taken lies about six inches under the surface and extends to a depth of about three feet in the old delta. This sample contains more clay than sample 254, and accordingly shows a high bond and fair permeability. When heated to 600° F. for two hours this sample lost thirty percent of its bond strength and thirty-seven percent of its permeability. Although this does not indicate a high durability by any means, this sample has not lost as much of its bond strength in this durability test, as most of the Michigan samples. These results indicate that there might be small pockets of fairly satisfactory molding sand in the lake sand and clay areas of Wayne County. However, the deposits will probably be too small for economical working.

Sample 256 from Section 34, T. 1 S., R. 8 E., about two miles southwest of Plymouth, represents a similar type of sand containing somewhat less clay, found in a stratum about three feet thick and one foot under the surface.

A somewhat coarser sand of the same general characteristics with slightly less clay and a higher distribution factor is represented by sample 257 from Section 27, T. 1 S., R. 8 E. This sample was also obtained from a five foot stratum about one foot under the surface on the property of the Detroit Piston Ring Foundry of Plymouth. This foundry had previously tried to use this sand for molding but had found it unsatisfactory. It was reported to burn out quickly and to be lacking in durability. Practically the same report was made by the H. S. Lee Foundry and Machine Company which previously used local sand from its own property, but found it to burn up rapidly after a few heatings. The Lee Foundry now uses Zanesville and Conneaut sand. Core sand is obtained from the east shore of Lake Michigan. The American Ball and Foundry Company of Northville also uses Ohio sand for molding, and core sand from Manistee, Michigan.

Sample 258 from the southeast quarter of Section 18, T. 1 S., R. 9 E., about three miles northeast of Plymouth and three miles southeast of Waterford was taken from the north side of the road where the sand stratum, about three feet thick, is exposed about six or eight inches under the surface. The deposit is found in an old river delta and includes large quantities of silt or fines. Most

samples obtained from these river deltas contain large portions of fines. This is probably a very important contributing factor to the unsatisfactory results obtained when these sands are used as molding sands.

The Enott Foundry at Wayne reports that their molding sand comes from Ohio and their sharp sand from Port Huron and Manistee. Ford's plant at River Rouge obtains core sand from Port Huron, Vassar, and Manistee, Michigan. Most of the foundries in this district use Ohio molding sand but some use Albany sand. The Barton Brass Works in Detroit use molding sand from France and Massachusetts, and Conneaut, Ohio.

WEXFORD COUNTY

The surface of Wexford County is entirely covered by glacial deposits which include moraine, till plains and outwash aprons.

Sample 259 from Section 29, T. 33 N., R. 9 W., southwest of Gilbert represents the rather coarse light yellow, unbonded sand found in these glacial deposits. In places the sand is underlain by clay but generally by more sand or gravel. This sample indicates that the sand should be satisfactory for cores or for building purposes.

Chapter IX. THE NORTHERN PENINSULA

ALGER COUNTY

The surface deposits of Alger County are almost exclusively sandy till with some swamp and lake areas, some sandy gravel, and less than ten percent of waterlaid sand.

Sample 262 from Section 15, T. 47 N., R. 17 W., about twelve miles east northeast of Munising and six miles south of Lake Superior, was taken from a lake washed sandy area. The total depth of the sand is about fifteen feet or possibly more in places. Underneath the yellow sand, which was sampled from the side of the road, is found clay and in some places quicksand. The yellow sand from which the sample was taken is similar to that found over most of the northeastern part of Alger County.

Sample 263 represents a somewhat similar but reddish sand taken from Section 34, T. 47 N., R. 18 W., four miles east of Munising. The sand is found in distinct layers and the area is evidently a lake washed glacial deposit.

Sample 264 represents a coarser white sand taken from Section 36, T. 47 N., R. 20 W., west of Munising and about one-quarter of a mile from the railroad grade separation. This sample was taken from a glacial moraine above the lake limits. In many places the sand extends to a depth of twenty-five to thirty feet and is covered by about four to six feet of yellow sand. It is

practically free from bond and covers about eight to ten square miles.

BARAGA COUNTY

The surface of Baraga County is composed largely of sandy till and rough knobs. The sandy till is similar to that found in the adjacent counties.

CHIPPEWA COUNTY

In the northwestern part of the county there are large areas of sandy lake washed glacial deposits. Through the central part of the county in a band running northeast through Trout Lake and Rexford the surface is composed largely of sandy, gravelly, outwash plains. In the eastern part of the county the surface is composed largely of lake clay deposits and sandy lake washed areas.

Sample 265 from Sections 13 and 18 of T. 45 N., R. 1 W. and R. 1 E., respectively, thirteen miles south of Sault Ste. Marie, represents the reddish yellow sand overlying the white sand found over about twenty to thirty square miles covered by a lacustrine deposit extending about eighteen miles west from Munuscong Bay. The sand contains some clay, but not sufficient to develop an adequate bond for molding sand.

Samples 266 and 267 were taken from the white sand found in various places on top of the clay about three miles southeast of Brimley in Section 21, T. 46 N., R. 2 W. The sand contains about five to six percent of clay as indicated by the check tests run on these two samples in different laboratories.

Sample 268 from section 16, T. 45 N., R. 2 W., represents a similar white sand of smooth round grains practically free from clay found toward the west of the lake washed area, referred to above as extending in from Munuscong Bay.

Sample 269 from Section 20, T. 44 N., R. 4 W., was taken about one-eighth of a mile from the Minneapolis, St. Paul, and Sault Ste. Marie Railroad near the spur to the Scott quarry, and represents the coarser yellow sand containing about three or four percent of clay found in the lake washed area, covering about thirty square miles around Cordell. In this area the sand extends to a depth of at least twenty feet in most places. The county is low, level, and nearly barren of trees.

Sample 270 represents the sand found in the glacial outwash apron about one-half mile east of Trout Lake in Section 23, T. 44 N., R. 6 W. The sand is yellow and, where sampled, extends to a depth of at least thirty feet. In most places the yellow sand is found under about six inches of gray sand.

Although it would seem reasonable to expect some more highly bonded sand in the lake-clay area of Chippewa County, no material containing sufficient bond to recommend its use as a molding sand has as yet been found in this area.

DELTA COUNTY

The surface of Delta County is composed largely of sandy till and lake washed sandy areas, and about one-third of swamp and lake areas. North of Big Bay de Noc are found most of the lake washed or lacustrine deposits.

In this area sample 276 was obtained from the SW $\frac{1}{4}$, Section 3, T. 40 N., R. 9 W., three and six-tenths miles north of Nahma and two miles west of Isabella, about a quarter of a mile south of the Minneapolis, St. Paul and Sault Ste. Marie Railroad. The sample was obtained from an outcrop on the side of the knoll along the state highway exposing a stratum about two feet thick. The sand sample shows about twenty-six percent clay, a high bond, and adequate permeability to indicate its usefulness as a molding sand. A duplicate sample from the same deposit, (No. 277) was heated to 600° F. for two hours showing a loss in bond strength of thirty-one percent and in permeability of 71 percent. Compared to other Michigan sands this sample seems to possess an adequate durability.

Sample 275 from Section 7, T. 40 N., R. 22 W., represents the local sand obtained from the pit five miles northwest of Gladstone along the bank of the creek and owned by Tom Goedert, No. 5 Third Avenue, Gladstone. In 1923 this sand was used by the B. C. Chatfield Foundry Company of Gladstone. The sand was regarded as unsatisfactory as it washed out in the mold, but was used because it was the only local sand known to the foundry. Albany sand has been used by this foundry and the intention was to use Wisconsin sand.

The deposit runs from six to eighteen inches in thickness and contains a total of about four to five carloads. Although this is reported to be the only deposit of molding sand within a considerable radius a large deposit was also reported up the west bank of the Escanaba River about one mile above the mill of the Escanaba Paper Company.

Two years later the Chatfield Machine and Foundry Company of Escanaba used molding sand from Berlin, Wisconsin, as represented by sample 310. This sand is used for iron work of all sizes and is reported to be satisfactory. Ohio sand is used in preparing the molds for brass castings. Aside from the fact that the Berlin, Wisconsin, sand contains more clay than the Michigan sand, it would seem that some of the Michigan sand would prove equally satisfactory for this grade of work.

Sample 274 was obtained from Section 17, T. 40 N., R. 22 W., within the limits of Gladstone, from a pit on the top of the hill, fifty feet north of the state highway. The stratum from which the sand was taken is about ten feet thick and is overlaid with about four feet of loose sand. It is estimated that this deposit covers approximately five acres. It is a much finer sand than sample 275 and contains about twice as much clay.

It was reported that there was formerly a pit from which molding sand was obtained near the paper mill of the

Escanaba Paper Company north of Escanaba. This is probably the sand reported by Dr. Ries in the survey of 1907. At that time four samples were obtained by Prof. C. A. Davis who described the deposit as "about fifteen to twenty feet high, composed of thin bedded limestone covering from one to five feet of silt". The rock was quarried and the molding sand was obtained in the vicinity of the quarry. The stratum from which the sand was obtained was only about one foot thick, the bottom being rather coarser and gravelly and containing a good many limestone fragments. The quarry is subject to overflow in the springtime and at that time the old silt is washed away and contaminated by coarser sands and gravel brought in by the flood. Sample R10 was taken from the west side of the opening on the west bank of the river, and was used in the local foundry of the Stevenson Company. Sample R46 was taken from the east side of the same opening about fifteen yards from where sample R10 was obtained. Here the stratum was about six to seven inches thick under about four inches of top soil. Sample R50 was obtained from the east side of the river about thirty or forty rods south of the quarry and opposite the head of a small island in the river. Here the surface deposit was four to six feet thick and contained some shattered limestone fragments. Sample R 51 also obtained from the east side of the river, about twenty feet above the river level, represented a layer of one to three feet thick on top of the limestone in the quarry of I. Stephenson and Company. The sample was obtained from about one foot below the surface. Samples R10 and R46 were used for ordinary foundry work but the deposits from which R50 and R51 were obtained were unworked at that time. As far as clay content is concerned, these samples reported in 1927 taken from the west bank of the river are similar to sample 276 taken from north of Big Bay de Noc, and these samples reported as taken from the east bank of the Escanaba River, are similar to sample 275 obtained from northwest of Gladstone.

Sample 271 from Section 1, T. 37 N., R. 24 W., along the main highway near the shore of Green Bay about five miles south of Ford River, represents the yellow unbonded sand found along the beach of Green Bay. The sand is generally from four to twelve feet thick overlying clay and in some places rock. Towards the north near Escanaba the sand runs deeper but generally is of the same characteristics. This sand is relatively coarse, of fairly uniform size, and should prove satisfactory as a core sand, or for other purposes where a similar sand is required.

Sample 272 is taken from northeast of Little Bay de Noc in Section 27, T. 41 N., R. 21 W., about three miles east of Rapid River along the main highway, and represents the yellow, sharp, unbonded sand found in this lake washed area. The sand here is very similar to that found along the shore of Green Bay and represented by sample 271. In this district north of Little Bay de Noc the sand extends to a depth of at least twenty to thirty feet.

Sample 273 was taken from the northwest corner of Delta County in the southwest quarter of Section 5, T. 43 N., R. 23 W., about four-tenths of a mile south of Lathrop. The sample was taken from a cut on the side of the road and represents a stratum about four to five feet thick found three to four feet under the surface of a knoll about five acres in extent. The overburden of three to four feet in thickness is composed mostly of unbonded sand and gravel. About half an acre of this overburden has already been removed. The road and the railroad right of way cover about one and one-half acres of the deposit. The tests indicate that this sand possesses sufficient bond and permeability to be used as a molding sand for some purposes. The uniformity of the grain size is rather low as the deposit is evidently of glacial origin, and may be classified as sandy loam found in the till plains.

DICKINSON COUNTY

The surface of Dickinson County is almost entirely covered by glacial deposits which have not been washed by the glacial lakes. Most of the surface may be classified as sandy till or sandy gravel with some rock knobs.

Sample 278 and sample 279 represent the yellow, rather fine grained sand containing four to five percent of clay found in the moraine northeast of the Menominee River in Section 1, T. 40 N., R. 30 W. The sand extends to a depth of at least ten to fifteen feet, and one cut along the river shows it to a depth of thirty to forty feet. The duplicate samples were tested independently at two different laboratories, with good agreement between the reported results.

GOGEBIC COUNTY

The surface of Gogebic County is composed largely of rugged rock formations and terminal moraines. These latter deposits are about two-thirds sandy till and one-third clayey till.

About three-fourths of a mile west of the Gogebic station of the Chicago and Northwestern Railroad in Section 26, T. 46 N., R. 42 W., sample 280 was taken from the sandy plain which contains yellow, sharp sand to a depth of at least fifteen to twenty feet. The sand occurs in layers mixed with reddish sand in some places, and practically free from bonding material.

Very similar sand is represented by sample 281 taken one mile east of Watersmeet along the Chicago and Northwestern Railroad and the state highway in Section 27, T. 45 N., R. 39 W. Both of these samples were taken from sandy plains in the moraine and represent sand probably suitable for core sand or other purposes requiring similar material.

Sample 282 from the southwest quarter of Section 32, T. 48 N., R. 44 W., along the state highway about nine miles north northeast of Bessemer and three miles south southwest of Tula, was taken from an area of sandy

loam which extends east from Gogebic Lake almost to the lake shore. This sample was taken from the south side of the road and represents a small pocket found under a small knoll in the midst of the till plain and is evidently a small deposit. The tests indicate that this sand contains about thirteen percent of clay, possesses a moderate bond and low permeability. The low value for the distribution factor indicates that the grain size distribution is not particularly uniform and that it is evidently a glacial deposit.

HOUGHTON COUNTY

Houghton County is practically covered with glacial deposits, most of which may be classified as sandy till formed by moraine and lake washed moraine deposits.

Samples 283 and 284 represent the red compacted sand found in ridges in the moraine along the shore of Lake Superior and were taken from the northeast quarter of Section 26, T. 53 N., R. 3 W., about three miles northeast of Arnheim and a quarter of a mile in from the lake shore. In places the red sand is overlaid with a few feet of loose yellow sand. One cut at the side of the road exposed the red compacted sand to a depth of thirty-five to forty feet. The two independent tests, one at Cornell and one at Michigan indicate that this sand has a fairly high permeability but relatively low bond. Its bond is far more durable than that of most of the other sands of Michigan as its bond is due largely to a high iron oxide content which is more durable than most clay bonds (see Fig. 25).

Sample 285 is a similar red sand streaked with clay, taken from a cut in Section 28, T. 55 N, R. 34 W., along the west side of the river, two miles west of Houghton. This deposit is evidently a lake washed moraine as the sand is not uniform, being streaked with stone, clay, gravel, and sharp sand including some white sand. The cut exposed the red sand to a depth of about twenty-five or thirty feet. The sand here is not so well compacted as on the east side of the peninsula as represented by samples 283 and 284, nor does it contain as much clay.

Samples 286 and 287 were taken from the low hills of red sand in the moraine about one mile southwest of Painesdale along the state highway, and from the northeast quarter section 36, T. 55 N., R. 35 W. The sand here is very similar to that found north of Arnheim on the east side of the peninsula in the moraine as represented by samples 283 and 284. The sand is found in very compact layers more or less mixed with stone. It shows somewhat lower bond strength and permeability as it is somewhat finer. The bonding material in these sands is largely ferric oxide, which is responsible for their high durability (Fig. 25).

Sample 288 represents the yellow sand, containing gravel in some places, as found in the southeast quarter section 29, T. 52 N., R. 36 W., on the south side of the Copper Range Railroad near Winona. This sample was taken from a moraine deposit containing very little bonding material, if any. The yellow sand extends to a

depth of twenty to twenty-five feet and is covered by about three to four feet of gravel. Some of the deposits near Winona appear to be glacial outwash.

Sample 289 from Section 1, T. 47 N., R. 56 W., about seven and eight-tenths miles east of Kenton, one hundred yards north of the Duluth South Shore and Atlantic Railroad, and two and one-tenth miles southwest of Sidnaw, represents the clean, sharp fine sand, free from bond, found in a stratum about two to three feet thick and two to five feet below the surface in this area of glacial outwash.

Sample 290 from Section 33, T. 48 N. R. 35 W., was taken from a cut in the road along the state highway one mile east of Sidnaw on the north side of the Duluth South Shore and Atlantic Railroad. The sand stratum is from one to two feet thick and found two feet below the surface under small knolls. The physical properties of this sand as determined by laboratory tests indicate that it is similar to sample 289 but containing about nineteen percent of clay with more coarser and finer material than is carried by sample 289. Sample 290 has a fairly high bond strength with low permeability. The deposits of this material are pockety and appear to be contained in the glacial moraine rather than in the outwash apron.

IRON COUNTY

The surface deposits of Iron County may be classified as about two-thirds sandy and gravelly till and approximately one-third clayey till, if we overlook areas of bed rock. Most of the area in the south central part of Iron County which may be classified as sandy loam contains relatively large amounts of gravel and stone. The areas of sand and clay which are apparently free from stone seem to be found generally in small pockets covering an area of only a few square rods and shallow in depth.

Sample 291 from Section 32, T. 43 N., R. 32 W., one mile south of Crystal Falls, represents the yellow sandy loam streaked with some white sand and stone found in this area.

KEWEENAW COUNTY

The red compacted sand reported found in the moraine deposits of Houghton County extends northward into Keweenaw County. In Section 35, T. 37 N, R. 32 W., two and one-half miles west of Mohawk and near the Mineral Range Railroad, about ten miles from Lake Superior, this red sand was observed to a depth of twenty to twenty-five feet and covered with four to six feet of yellow sand. The red sand is very hard and compact and generally similar to samples 283 and 284 found in Houghton County along the west shore of Keweenaw Bay. The surface of Keweenaw County is largely bed rock with a sandy till, lake washed, area along the northwest shore of Keweenaw Bay.

LUCE COUNTY

The surface deposits of Luce County are composed almost exclusively of lake washed sandy and gravelly till, with some clay areas in the southern part of the county, and some glacial outwash areas in the west central part.

Sample 292 from the northwest quarter of Section 33, T. 46 N., R. 10 W., about a quarter of a mile south of Dollarville and the Duluth South Shore and Atlantic Railroad, represents the yellow sand found along the state highway and in the vicinity of Newberry and Dollarville.

MACKINAW COUNTY

Mackinaw County includes large areas of swamp and lake land, some glacial lake clay, and some sandy till, but most of the glacial tills contain so much limestone as to be classified as limestone till.

Sample 293 from Section 13, T. 41 N., R. 4 W., represents the yellow sand streaked with white sand obtained from a cut along the road about five miles north of St. Ignace near the west shore of St. Martin's Bay about two and one-half miles east of the Duluth South Shore and Atlantic Railroad. The sand is apparently a lacustrine deposit of rounded grains containing little or no bonding material and extending to a depth of at least fifteen to twenty feet. The area over which this sand is to be found covers several square miles confined to a strip about a mile or so wide along the lake shore north of St. Ignace. Similar sand is also found northwest of St. Ignace as far as Brevort Lake.

Sample 294 from Section 49, T. 42 N., R. 1 W., is taken from a continuation of the lake deposited material north of St. Ignace about three and one-half miles west of Hessell along the lake shore. This area of lacustrine sand extends along the shore of St. Martin's Bay almost as far east as Hessell and as far north as Rockview.

About eight miles north of St. Ignace and north and east of Brevort Lake is an area of lowland from which sample 299 was taken. This sample was taken along the state highway about three and eight-tenths miles west of the Duluth South Shore and Atlantic Railroad and due north of Brevort Lake in Section 16, T. 42 N., R. 5 W. The deposit is at the edge of a swamp area and was exposed under a small knoll about a hundred feet wide under a heavy growth of hardwood timber. The sample was exposed in the face of a cut on the north side of the road. There are several similar deposits in this vicinity. Tests indicate that this sand is extremely fine grained and contains about five percent of clay. It possesses a low bond and fairly high permeability considering the fineness of the grain size.

Sample 298 was taken from another part of this lake washed moraine area about one and one-half miles northeast of Gilchrist in Section 7, T. 43 N, R 8 W. The sample was taken from a stratum four feet thick found three feet under the surface as exposed in the face of a cut along the side of the road. Similar material is found

under several knolls or moraines in the district, and in many places the stratum appears to be partially washed out by the action of the glacial lake which formerly covered this area.

Sample 297 was taken from the glacial outwash area which extends east from Epoufette about eight miles and composes the lake shore northwest of Brevort Lake for about ten miles. The sample was taken from Section 2, T. 42 N., R. 7 W., about three-quarters of a mile north from the lake shore. The sand is yellow in color and composed of sharp coarse grains, practically free from bond. It is covered with about one to two feet of white sand in many places.

Sample 295 was taken from SW¼ Section 21, T. 44 N., R. 8 W., slightly over two miles north of Garnett and the Minneapolis, St. Paul and Sault Ste. Marie Railroad. There is a rather large area of this lake washed sandy deposit extending northeast of the Duluth South Shore and Atlantic Railroad where this sample was taken. Except for being somewhat coarser this sand is rather similar to sample 270 taken near Trout Lake, and even more similar to samples 271 and 272 from Delta County representing similar lake deposits forming the sand plain along Green Bay and northeast of Little Bay de Noc. The sand extends to a depth of eight to ten feet in this area in Mackinac County west of the Fiborn quarry and overlying the limestone bedrock.

Sample 296 was taken from the southwest quarter, Section 12, T. 43 N., R. 10 W., along the Minneapolis, St. Paul and Sault Ste. Marie Railroad, about three and one-half miles east of Engadine, two and one-half miles north of the lake shore and just south of Millecoquins Lake. The sample was taken from the area of lake washed sand found along the lake shore west of Epoufette to within five or six miles of Manistique, but just at the border of an area of glacial outwash material and probably represents the lake washed and redeposited material obtained from the glacial outwash. In general characteristics it is similar to samples 295, 271, and 272 also taken from this lake washed deposit, but south of Millecoquins Lake, the sand appears to be well sized as represented by the high value for the distribution factor, (.923). The yellow sand from which the sample was taken is covered by a few inches of white sand, and extends to a depth of at least fifteen feet. Similar loose sand is found in many places along the highway from Gilchrist to Manistique.

MARQUETTE COUNTY

The surface deposits of Marquette County are composed largely of sandy till, sandy gravel, rock knobs, and swamp and lake areas. In the southeastern part of the county there are large areas of sandy loam similar to the same type of deposits found in the northwestern part of Delta County where sample 273 was taken. For this reason it seems reasonable to expect that other deposits of bonded sand may be found in this sandy loam area. In the central part of the county the deposits are mostly moraine and glacial outwash, some of which may

contain bonded sands as represented by samples 302 and 303, and elsewhere unbonded sand as represented by sample 301. There are relatively small areas of lake washed sandy deposits along the shore of Lake Superior as represented by sample 300 from north of Yalmar.

The northern part of the county contains rock knobs with moraine, glacial outwash deposits, and a continuation of the lake washed sandy areas in a narrow band along the lake shore.

In the survey of 1907 Dr. Ries reports two samples, R54 and R60, collected by Prof. C. A. Davis from a railroad cut of the Lake Shore and Indiana Railroad, just north of the Dead River in the northeast quarter of Section 12, T. 48 N., R. 28 W., about four hundred feet above Lake Superior. The bed which is exposed in the cut for about three hundred feet, having a steep face about thirty to forty feet high, is described as part of a sand plain or delta deposited in a temporary glacial lake. These samples indicate that this sand is composed of extremely fine grains and somewhat similar to American Snowflake Sand with which they were compared in the 1917 survey.

Samples 302 and 303 are likewise extremely fine grained sands possessing sufficient bond for use in preparing molds. Sample 302 was taken from Section 8, T. 47 N., R. 28 W., one mile east of Clarksburg and one-quarter of a mile north of the Duluth South Shore and Atlantic Railroad, about four-tenths of a mile west of the north curve of the road and nine-tenths of a mile southwest of the north county road on the state highway. The sample was taken from a cut in the road exposing the stratum about two feet thick and about one foot below the surface of a sand plain. This deposit of extremely fine grained sand covers about ten acres. Physical tests on this sample indicate that it has a fairly high bond strength with very low permeability which may be explained as due to its high content of fines and clay.

Sample 303 from Section 10, T. 47 N., R. 28 W., about five and seven-tenths miles west of Ishpeming and one mile north of the Duluth South Shore and Atlantic Railroad, was taken from a cut in the side of the road along the state highway. The deposit lies in the same sand plain from which sample 302 was taken and is generally of the same characteristics. It is fine grained, bonded sand exposed below the surface of a knoll by a road cut. There are apparently other pockets of similar material in this district.

Sample 300 from about the center of Section 1, T. 46 N., R. 24 W., just east of Yalmar and about three miles northwest of Skandia, represents a fairly uniform pink sand found in compact layers under about three to four feet of yellow sand, over a fairly large area running northwest almost as far as Marquette and is very similar to sample 263 taken from a similar sandy deposit near Singleton in Alger County except that sample 300 is of a finer sand of somewhat more uniform grain size.

Sample 301 from the southeast corner of Section 34, T. 48 N., R. 26 W., at Eagle Mills on the state highway and

the Duluth South Shore and Atlantic Railroad just east of Negaunee, represents the yellow sand found in the glacial moraine over a relatively large area and extending to a depth of thirty to forty feet and possibly more.

The Cleveland Cliffs Iron Works of Marquette, when visited in 1923, obtained sand from the river about three miles out of the city for casting pig iron. At that time it was reported that there was about enough sand left for one year's supply. This deposit had been used since about 1907. It is a yellow sand containing little bond, but sufficient for the purpose for which it is used. Beach sand had been tried but did not prove satisfactory because of its entire freedom from bonding material. The city of Marquette operates a rock crushing plant southeast of the city where the lower Huronian series outcrops in a bluff of solid quartzite about a hundred feet high. This quarry was used to obtain the stone for construction of the Saulte Ste Marie locks and has been in operation since 1907. When visited in 1923 the stone was being crushed and used almost exclusively for building roads.

MENOMINEE COUNTY

The surface of Menominee County is covered largely by clayey till and sandy till deposited by the glacier. For a short distance from the shore of Green Bay, a lake washed or lacustrine deposited sand is found very similar to samples 271 and 272 from Delta County.

ONTONAGON COUNTY

Most of the surface of Ontonagon County is covered by lake washed clayey till or lacustrine clay deposits. Less than one-third of the surface is covered with what may be classified as sandy till or sandy plains. The southern part of the county in the district of Robbins, Roselawn and Calderwood, is covered by moraine and glacial outwash material.

Sample 304 from Section 15, T. 46 N., R. 39 W., along the state highway one mile south of the Chicago and Northwestern Railroad and about two miles west of Barclay, was taken from this glacial moraine. The sand is yellow with sharp grains containing little bond and extends to a depth of four to fifteen feet over red clay. The deposit includes stone and gravel in some places, as is typical in glacial moraines.

Sample 305 from Section 12, T. 47 N., R. 38 W., was taken from the side of a road cut five and eight-tenths miles west of Kenton and fifty yards east of the small creek along the Duluth, South Shore and Atlantic Railroad. This sample contains sufficient clay to develop a fair bond, and possessing adequate permeability, it should be useful as a molding sand. The deposit is extremely variable ranging from heavy clay to loose sand, and occurs in a glacial deposit, probably of moraine origin. The deposit is perhaps fifty yards wide, by five hundred yards long.

SCHOOLCRAFT COUNTY

Aside from the swamp and lake areas which cover most of Schoolcraft County the surface is composed largely of sandy deposits, both water laid and glacial deposits. Some of the till plains contain so much limestone as to be classified as limestone till.

Sample 306 from Section 13, T. 45 N, R. 13 W., about six miles southeast of Seney, represents the red sand taken from a twenty to twenty-five foot cut where the road passes through some water washed moraine deposits. Much the same formation extends toward the east to the southern part of Luce County.

Sample 307 from Section 4, T. 47 N., R. 13 W., represents the dark yellow sand found to a depth of eight to ten feet in compact layers about eleven miles north of Seney. This deposit is evidently glacial outwash, and the yellow sand is streaked with white sand throughout the entire depth of the deposit. Below the dark yellow sand red clay is found at a depth of fifteen to twenty feet in most places.

Sample 308 from Section 22, T. 47 N., R. 13 W., six and one-half miles north of Seney and four and one-half miles south from where Sample 307 was taken, is Very similar to Sample 307 except that it contains coarser material and is not so uniformly sized. On the bank of a creek this yellow sand mixed with gravel is exposed to a depth of thirty to forty feet. This area of glacial out wash extends about twenty miles west and eight miles east of where these samples were taken.

Sample 309 from the northwest quarter of Section 31, T. 41 N., R. 17 W., about one-half mile southeast of Cook's Mill on the Minneapolis and Sault Ste. Marie Railroad, represents the sand found in these lake deposits along the shore similar to samples 272 and 276 of Delta County also from these lacustrine deposits. The sample is of yellow sand containing little or no bond and extending to a depth of about twelve to fifteen or twenty feet. The cliff east of Manistique rising to a height of fifty to sixty feet shows much the same kind of sand. The seven percent of clay reported for sample 309 is evidently in error. It should have been reported as silt rather than clay.

