New York State Museum Bulletin

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CHARLES C. ADAMS, *Director*

THE SAND AND GRAVEL RESOURCES OF NEW YORK STATE

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Assistant Geologist, New York State Museum

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INTRODUCTION

Although sand and gravel are among the commonest and best known of our natural resources few persons appreciate the importance that these resources have attained within the past several years. From a value of a little over $2,000,000 in 1919 a steady increase has been shown until the present yearly production for New York State is in the neighborhood of $10,000,000. In fact, with the continually increased use of concrete for building and for road construction it is evident that sand and gravel deposits are destined to become very valuable, especially when located conveniently for transportation.

Fortunately New York has very large deposits of sand and gravel scattered throughout the State, many of which are of excellent quality. The origin of these deposits and their manner of deposition form one of the very interesting pages of geological history and a proper appreciation of what has happened thousands of years ago makes prospecting today for new deposits much easier.

Generally speaking, the production of sand and gravel on a large scale is merely a problem in excavation. While it is true that the deposits show considerable variation in character and composition, and the final product sought sometimes determines the method of excavating, still it would seem, to the uninitiated, that there should be no more than half a dozen economically sound methods of digging sand and gravel. Yet among the two hundred producers in the State, one might be tempted to say without much exaggeration that there are two hundred different ways of handling this problem. Because of the interest shown by the producers in this vexing question a chapter is devoted to methods of production and preparation.

The literature on sand and gravel is quite voluminous and no attempt is made in this report to include a full bibliography nor to give a complete series of footnotes showing the sources of the information. Recent bulletins by Dake ('18) and Teas ('21) contain excellent bibliographies and these, together with the geological bulletins of the New York State Museum, should be consulted if additional data are desired.

During the field work practically all of the sand and gravel operations in the State were visited and the writer wishes to thank the producers for the many courtesies they extended. In addition, Captain W. A. Treadwell of the testing department of the State Bureau of Highways permitted the use of his files covering thousands of tests of sand and gravel. Without his cooperation the preparation of this report would not have been possible.

Doctor Ries of Cornell University read the manuscript and it is a pleasure to acknowledge this service.

NATURE OF SAND AND GRAVEL

Sand

Sand is commonly thought of as unconsolidated rock material consisting essentially of small grains of quartz or quartzite. When the particles are very fine the mass is called silt and when they are more than one-quarter of an inch in diameter gravel is the term applied.

This usual idea of sand accurately describes a large number of deposits such for instance as the highly siliceous unconsolidated sands occuring on Long Island, but it fails completely in many other cases. The sands of the Hudson valley often show a very high percentage of shale particles and only a small amount of quartz; the coquina and coral sands of Florida are nearly pure lime carbonate; the gypsum sands of Texas and Oklahoma are composed of calcium sulphate—yet all of these deposits are true sands.

The degree of consolidation in sand deposits also varies within rather wide limits. Sands differ chiefly from sandstones in that the latter are consolidated; consequently there are all gradations from loose quartz sands through friable sandstones to indurated sandstones and even quartzites. Many sand and gravel operators in New York are compelled to shoot their banks with dynamite because of the cemented character of the material, and they would be greatly surprised if it were said they operated a quarry rather than a sand and gravel pit.

Hence it is evident that the popular conception of what constitutes sand must be considerably modified. Sand is really a condition of division of the constituent particles. A pulverized fire-brick, provided the size of the particles were included between .05 mm and 2.0 mm (approximately 270-mesh and 8-mesh screens) would be a true sand. In fact, such material is sometimes known as "brick sand." In this report then the term "sand" is used to indicate any granular rock material falling within the above size limits regardless of its chemical composition or manner of origin. A sand deposit would be composed of such material, the greater part being in a loose, unconsolidated state.

Gravel

When the fragments of any unconsolidated deposit are larger than one-quarter of an inch in diameter they are called gravel. Pebbles four or five inches in diameter are usually termed cobbles, while boulders range from ten inches to several feet in diameter. The coarse aggregate used in concrete usually falls within the limits of one-quarter of an inch to three inches.

Generally gravels are composed of the more resistant rock types such as granite, quartzite, sandstone, etc., although some very excellent gravels show a high percentage of limestone. The pebbles are usually well rounded because of the wear and abrasion which they have undergone as they were rolled and tumbled about during transportation.

The following classification groups sand and gravel into the grades that are rather widely used in New York State.

TABLE 1 **Classification of Grain Size**

TERM APPLIED	SIZE OF APERTURE	
	Retained on	Passing
No. 4 gravel	2¾″ circular	3¾″ circular
No. 3 gravel	1½″ circular	2¾″ circular
No. 2 gravel	¾″ circular	1½″ circular
No. 1 gravel	⅜″ circular or ¼″ square	¾″ circular
Torpedo sand or Torpedo gravel	⅛″ square	¼″ square
Coarse sand	20 mesh	8 mesh
Medium sand	70 mesh	20 mesh
Fine sand	270 mesh	70 mesh

Numerous other classifications have been proposed (Searle '23, p. 211), the size of the screen opening usually being specified in millimeters and all of the gravel grouped under one heading. This method does not seem to be of much service to the sand and gravel producers since they are more familiar with the usual screen nomenclature and are accustomed to sizing gravel as well as sand into different grades.

Some question arises as to where to draw the line between silt and fine sand. It is thought that any material passing the 270 mesh screen (approximately .05 mm) would act as silt and be undesirable in either asphalt or concrete sand, even though silt is often considered to be composed of particles whose maximum size is less than .03 mm.

ORIGIN OF SAND AND GRAVEL DEPOSITS

Weathering

All rocks at or near the earth's surface are continually being subjected to mechanical stresses and chemical action. Such disintegration and decomposition are known as weathering and even the stronger and more durable rocks finally succumb to those slowly acting irresistible forces of nature. The resulting broken fragments are picked up by moving water, ice and wind and when deposited form gravels, sands, silts and clays. With the lapse of time and under certain suitable conditions of pressure and cementation, these sands may become sandstones, the gravels harden to conglomerates and the muds form clays and shales.

The unconsolidated sands and gravels of New York originated from the destruction of some preexisting rock mass and under other circumstances might have been transformed into entirely new hard rocks. They represent an arrested cycle occurring between the destruction of an older rock mass and the upbuilding of a new one.

Sand and gravel deposits that have been made available by the disappearance of the water in which they were deposited, still are subject to change because of weathering. Almost any sand and gravel bank will show this effect of weathering by an increase in iron staining, clay content and general decomposition toward the surface of the ground. This often necessitates deeper stripping and more careful washing. On the other hand, many of the best molding sands of the State owe their value to weathering action which has altered the admixed shale fragments into a colloidal, sticky bonding material. Below the influence of weathering this same sand is sharp, weak and unfit for molding use.

For convenience in treatment, weathering may be divided into two types, mechanical and chemical.

Mechanical weathering. In the pore spaces of rocks near the surface is water which upon freezing expands, thus exerting a tremendous pressure. With repeated freezings and thawings the rock gradually crumbles into small particles. A majority of rocks are composed of more than one mineral and even in a mild climate the unequal expansion of these different minerals will finally cause the rock to disintegrate. This is especially true in arid regions because here the daily range of temperature is extreme.

The gouging action of boulders held in moving glaciers, the abrasive power of the wind when laden with fine dust, the grinding of pebbles and boulders on each other and on the river bed as they are rolled along, and the continual beat of the waves on the shore all tend to break down the continuity of a rock mass, reducing it to clay, sand and gravel.

Since all the minerals of any given rock are not of equal hardness, the softer, more friable minerals tend to become pulverized and carried away. This results in a partial concentration of the more resistant minerals, such as quartz, and the resulting sand and gravel deposit has a somewhat different composition than the parent rock from which it was derived.

Often, however, mechanical weathering yields a product similar to the source rock, it being merely the same rock broken into particles. Examples of this occur in northwestern New York, where the gravels show a high percentage of local reddish Medina sandstone; in the Hudson valley, where the sands are largely broken fragments of the surrounding Hudson River shales and slates; and in southern New York, where the gravels are characteristically full of flat, shaly sandstones derived from the neighboring rock ledges.

Chemical weathering. Rain water is slightly acid in character due to a small amount of carbonic acid that it acquires in passing through the atmosphere. No rock is able to resist continued exposure, as rain dissolves some of the constituents and loosens the bond, thus permitting an easier removal of the more resistant minerals by the mechanical action of wind, water and ice. Rain moreover keeps the surface of a rock comparatively clean by washing away all corroded material, thus exposing fresh minerals to further weathering.

As rain water passes down through heavy vegetation and decayed plant life it acquires humic acids, which either directly or indirectly exert a marked chemical action on the surrounding rocks, dissolving and decomposing them. Many rocks, which are seemingly unaffected by strong acids in laboratory experiments, break down completely when exposed to the dilute solutions of nature for a long period of time.

Quartz, one of the more resistant minerals, is usually only slightly affected. Granite for instance, is often so badly weathered that the residue consists only of iron stained clay and quartz sand. It is because of chemical weathering, more than any other one agency, that the majority of sand and gravel deposits contain such a large percentage of quartz and other resistant minerals.

From the above brief outline it is evident that weathering tends to be destructive in its action; that rock masses are broken into smaller fragments; that some of the material goes into solution; and that the identity of the parent rock is often destroyed. These processes are operating today just as efficiently as in the hundreds of thousands or millions of years of past geological history. Their effect in one year or one lifetime is small, but even the most resistant rock is destroyed eventually. Sands and gravels are one result of weathering.

Deposition of Sand and Gravel Deposits

The principal agencies which aid the collection of sand and gravel into commercial deposits are wind, water and ice. Transportation and deposition of sediments by these agents are so intimately related and interlocked that the two processes can best be discussed together, although emphasis should be placed upon the depositional phase, because it has largely controlled the present characteristics of New York sand and gravel deposits. Thus an understanding of the fundamentals of sedimentation is helpful in directing development and in locating successful operations.

All deposits of sand and gravel in New York may conveniently be considered according to the active agent in their disposition. They are:

1 Wind deposits
2 River deposits
3 Delta deposits, formed at the mouth of rivers
4 Lake deposits
5 Marine deposits, formed by seas
6 Glacial deposits
7 Glacial river deposits, formed by the waters from melting glaciers

1 **Wind deposits.** Wind may transport dust great distances and in addition, fine sand may be rolled along the ground, forming sand dunes. Because of its low density, only 1/800 that of water, the transporting capacity of a given volume of the atmosphere is relatively small; because of its great extent and occasional high velocity, however, large sand deposits are frequently accumulated.

Considered as a whole, dune deposits are quite well sorted. When examined in detail, however, it is found that the sands on the windward side of the dune are coarser than those on the leeward. The sand grains themselves are usually well rounded and have a frosted appearance due to continual abrasion. A very characteristic feature is the cross-bedding which plunges at high angles in many directions, such beds being wind-truncated above and inclined to the horizontal below. A majority of wind-blown sands will show on testing 80 per cent of the grains between the 80 and 40-mesh sieves (Boswell '18).

Dunes are formed most readily where the scarcity of vegetation is pronounced and where the winds have a prevailing direction. On the old sand plains at Albany, Forestport and Rome ideal conditions must have prevailed for dune formation, since today we find in these districts many ancient sand dunes which have been anchored by vegetation and are no longer active. Their commercial value is limited to the fine grades of core and filter sands and in some cases asphalt sand.

Active dunes are not common, but at Selkirk on the eastern shore of Lake Ontario, an excellent dune deposit is now being formed. The sand is highly siliceous, white in color and is blown from the beach by prevailing westerly winds. In many respects this deposit is similar to the famous Michigan City core sands.

2 **River deposits.** Rivers and streams are nature's great carriers of sand and gravel. A slight increase in their velocity gives an amazingly increased transporting power. It has been found experimentally that the dimensions of a particle which a stream is able to transport varies as the fifth power of the velocity; thus, if a stream that could just carry a one-inch pebble had its velocity doubled, it would be able to move a boulder more than 30 inches in size. This experimental evidence explains the common occurrence of boulder and large pebble lenses in sand deposits; flood conditions of brief duration would furnish boulders and pebbles while the usual velocity of the water would build thick beds of sand.

A river is rarely loaded to capacity. Where the volume of water is large and the velocity low, as illustrated in the lower part of the

Mississippi river, the average load is found to be .07 per cent of the volume. Under more favorable conditions, such as exist in the Rio Grande river, records show a suspended load of 10 per cent by volume, which compares very favorably with the usual 12 to 15 per cent of solid material that is carried by pipe lines in most hydraulic operations. In this connection it is interesting to note that experimental data have demonstrated an increase in stream capacity of about six times by merely doubling the velocity (Gilbert '14). This should furnish food for thought to any producer who is operating a sand sucker and who wishes to increase his daily capacity. Even allowing for increased friction in the pipe, a doubling of the working velocity of the water should far more than double the amount of material delivered to the screens.

River deposits are formed to best advantage in the lower areas of the course. Here the river is building sand bars and shoals; occasionally during freshets it overflows its banks and spreads out a thin veneer of flood plain deposits. Many of the rivers and streams in New York have recently cut into their old courses and are thus bordered at higher elevations by sand and gravel terraces marking their previous levels. Some of these, especially in southern New York, are being operated as commercial deposits.

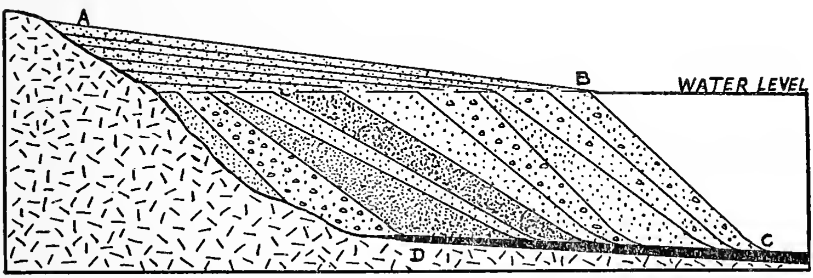
Flood plain deposits as a rule increase in coarseness as the river bank is approached. Generally they are too fine in texture and contain too much clay and silt to be of economic value. In southwestern New York, however, in a narrow strip along the flood plain of the Allegany river, molding sand is being dug, the best deposits occurring in the bends of the river. Such deposits quickly change to silt and clay within a short distance from the river bank.

In many parts of the United States the river bed itself furnishes excellent sand and gravel, but in New York few operators have tried this source of supply. Formerly, large quantities of sand and gravel were dredged out of the Niagara river near Buffalo, but recently government restrictions have stopped this production. A few small local operators are securing material from nearby streams and some investigation is now being made of the possibilities of the larger rivers. One great advantage of this type of deposit is that if properly located the excavation made by a drag-line or dredge in one season will be entirely refilled during high water of the following spring. The difficulty in New York is that a majority of the large rivers drain areas of shale and thinly bedded sandstones and such sources usually make the sand and gravel of the river bed undesirable.

As a rule river sands occur in pockets and lenses associated with gravels and silts in a rapidly alternating series. Moreover, they often contain a considerable quantity of dirt, and are not so satisfactory to operate as some other types of deposits.

3 **Delta deposits.** A river flowing into a body of standing water, such as a lake or the ocean, immediately has its velocity checked and drops its load of débris. Deltas result from a river supplying more material than can be handled by the waves and currents of the water into which it empties.

The following diagram is a cross section of an ideal delta and shows the steeply sloping delta front formed by the foreset beds. In sand and gravel operations the topset and foreset beds are of greatest value; under favorable conditions they may form deposits of several hundred feet in thickness.



Structure of a delta built into a glacial lake. *AB* represents gently dipping topset beds; *BC* steeply dipping foreset beds; *DC* the horizontal bottomset beds of clay and fine silt.

In large deltas the conditions are so extremely complex that foreset and topset beds are often not sharply defined. Moreover, as a delta is extended outward and upward by continued additions, the exposed portion is built over the former submerged part and the foreset beds cover the previous bottomset beds. Thus a vertical section through a delta deposit, such as is often exposed on a bank face, would show a series of steeply dipping beds, the foresets, overlain and underlain by beds of different character.

Because of the complex glacial lake history of New York a sand and gravel deposit will often consist of a series of deltas, one above the other, representing different lake levels. These deltas may not have been built by the same stream or the drainage area may have changed from time to time, so that the final resulting deposit will show considerable variation both in size and in composition of the sand and gravel. For instance, a delta deposit may be furnishing an excellent grade of core sand, when suddenly a bed high in limestone content will be encountered, which may increase in thickness as the deposit is developed until it is no longer of value for core sand. Or a deposit may be opened and a plant built to take care of a bank content of 50 per cent gravel. As the bank is developed the gravel may begin to decrease in amount and the producer is at a loss to know in which direction to look for a coarsening of the deposit.

Since delta deposits are exploited by producers in New York more than any other type, the fundamental principles of delta deposition are of great importance. In general, the foreset beds dip toward still water and away from the source of supply and a careful study of local conditions will often save serious financial loss. As a whole, delta deposits constitute one of the most satisfactory sources of sand and gravel in the State.

4. **Lake deposits.** Lakes act as huge settling basins and the deposits formed in them are thinner and more uniform than river-laid material. The velocity of the tributary streams, shifting lake currents and the size of the sedimentary particles are the controlling factors and the separation of sand and clay is often very complete.

Recently, Kindle ('25) has presented some interesting data secured during a study of the bottom deposits of Lake Ontario. He finds that the effect of wave action extends to a depth of considerably more than 100 feet and that due to this power, as well as to offshore currents, sands and gravels may be formed at a considerable distance from the shore line. Several producers are at present dredging sand and gravel from Lake Erie and Lake Ontario.

In addition, wave action is continually changing the shore line. It has been estimated that the impact stress of a wave may be as great as 6000 pounds a square foot. During a violent lake storm the material scoured from one part of the beach and deposited at another is enormous. There is a constant tendency for the promontories to be worn away and the embayments filled, with a resulting shortening of the shore line and the development of a lake beach.

One such beach, formed by the predecessor of Lake Ontario, is quite a prominent topographic feature near Rochester. In fact, the famous Ridge road running east and west from Rochester follows this old lake beach, which is about 125 feet above the present lake level. In several places along this road, sand and gravel pits have been opened.

5 Marine deposits. Although a majority of the rock formations covering New York State have been laid down in a marine environment, so far as unconsolidated deposits are concerned, few are of any significance.

Several thousand years ago a narrow arm of the sea extended through the Hudson and Champlain valleys to join a broader arm of the sea which reached up the St Lawrence valley. In this Champlain sea, sands and gravels were deposited. Later withdrawal of the sea, due to a slow rising of the land, has preserved some sands and gravels as elevated fossil beaches. In addition, dredging operations are being carried on in Long Island sound and in the bays fronting the Atlantic Ocean. Also a few of the present ocean beach deposits are being utilized as local sources of supply.

Marine sands are characterized by a relatively good degree of sorting, the bedding usually being uniform and the variation vertically, not great. In many parts of the United States they constitute extremely valuable deposits.

6 Glacial deposits. Material transported by glaciers is carried on the surface of, within or underneath the ice. There is essentially no limit to the competency of glacial ice since it is able to transport rock masses weighing thousands of tons, and the total quantity of débris moved is enormous.

On melting, this load is dropped. If the ice is moving at approximately the same rate as it is being melted, the glacier's front remains stationary and a hummocky ridge or "moraine" is built from the constant additions of rock débris. Ice produces no sorting of the material it carries and therefore few glacial deposits are used by sand and gravel producers. Glaciers are directly responsible, however, for furnishing a majority of the sands and gravels of the State and it should be remembered that only the sorting action of water is necessary to make such material of commercial value.

7 Glacial river deposits. Water pouring from a melting glacier picks up and reworks a vast amount of unsorted glacial débris. This finally is deposited in stratified or layered beds and often is quite free from clay. Some of the material so deposited has such characteristic features that a special nomenclature has been developed although many geologists, to avoid controversy, make no distinction and call all such deposits "stratified drift." Since the manner of deposition usually affects the value of a sand and gravel deposit, a brief outline of the different conditions under which melting ice may furnish commercial deposits, is necessary.

Esker. This is a term applied to ridges of water-laid material formed in the beds of heavily loaded streams that drained the melting ice sheet. Some may have been deposited in ice-walled channels, open to the sky, but most of them were built in tunnels within the glacier itself. When the ice melted these deposits were left as long, narrow ridges. The material is usually coarse sand and gravel and well washed. A few esker deposits are worked in New York, the one at Springville, Erie county, being an example.

Outwash deposits. When the ice front paused for a considerable time upon a gently sloping surface, the débris-laden streams deposited layers of sediment over the plain.

The simplest form of outwash accumulation is a fan-shaped deposit made by water issuing from the ice front at a single point. Such a stream, because it is greatly overloaded, drops sand and gravel as soon as possible, building up a cone of gentle slope. A melting glacier usually has a large number of streams issuing from its front, each building a fan-shaped deposit, and within a distance of two or three miles these fans unite to form a broad outwash plain.

An excellent illustration is the great outwash plain which covers the southern half of Long Island, extending in an almost flat, unbroken stretch for over 100 miles. Many commercial sand and gravel pits are operated in this type of deposit, the material being quite clean. One drawback to such deposits is their low percentage of gravel, the amount decreasing as the distance from the former position of the ice front increases. Furthermore, outwash deposits are apt to have a small thickness, although where the ice front has been stationary for a long time, surprisingly thick, horizontally bedded accumulations are formed.

Occasionally such material may form the sand plains of true delta deposits or it may be carried far down the river valleys as "valley train" drift. Some of the deposits in southern New York are of this latter type.

Till moraine. A glacier advances only when the rate of motion of the ice is greater than the rate of melting of the ice front; otherwise it retreats. Thus in New York State even during the northward retreat of the Pleistocene glacier, the ice itself was still constantly flowing southward, bringing additional rock débris.

Whenever the ice front remained stationary due to the rate of melting counterbalancing the forward motion of the ice, all the load was dropped at about one place and a huge mound was built up, This is called a moraine. If the material in this mound is unsorted it is known as a till moraine and is of no value for sand and gravel production. Such a moraine forms the present divide between a part of the drainage of the St Lawrence and Susquehanna river systems, and as will be explained later, exerted a very important control over the glacial lakes and their valuable deposits.

Stratified moraine. Often so much water is formed at the end of a stationary ice front that the morainal material is well washed and sorted. Such deposits are of great value. For example, deposits on the northern part of Long Island furnish sand and gravel for some of the largest operations in the United States.

The simplest type is formed by a stream issuing from the ice front at a considerable elevation above the base of the ice. Several of the resulting cones may join and make an uneven morainal ridge extending for several miles. The backbone of Long Island is formed from this type of material and in general carries more gravel than is found in the outwash plains immediately to the south.

Kame. This is a term of Scottish origin that is applied to mounds and hills of stratified material. Glacial geologists differ considerably in their ideas regarding this type of deposit. Some consider a kame to have been usually formed in standing water and of the nature of incipient deltas. In fact, the terms "subaqueous moraine" and "kame moraine" have been used to describe this condition. Others dislike the idea of standing water and limit kames to those deposits formed by débris-laden streams emerging from the margin of the ice, the water sometimes rising like great fountains because of pressure. Kames are seldom as much as 200 feet high.

It would seem that the term "kame" has been used to cover such a great variety of widely varying conditions that its present usefulness is doubtful. It is thought that delta deposits and stratified moraines include what have usually been called kames in the field, and more concisely show the manner of origin.

THE RECENT GLACIAL PERIOD

That New York State was at one time almost completely buried under glacial ice is well known by sand and gravel producers. Every day they are handling erratic boulders and gravels of igneous and metamorphic rocks which they realize must have been transported great distances from the seat of origin—distances so great and rocks so large that nothing except ice could have been the carrying agent. Fifty years ago it would have been necessary to prove this invasion of the ice; today it is regarded as common knowledge.

Concerning the interesting details of glaciation, however—its possible causes, length of duration, attendant glacial lakes etc.—a surprising lack of knowledge exists. The fact of glaciation is well known, but its proper setting in the earth history of New York is little appreciated. It would therefore seem well worth while to present briefly some of the outstanding ideas concerning the Glacial Period and its effect upon the sand and gravel deposits of the State.

Geological climates. At the very outset it is essential to gain a true perspective of our so-called "Ice Age" so that it may be fitted into its proper niche in geological time. When it is remembered that the earth has a readable history, preserved in the rock beds, dating back some hundreds of millions of years it is not surprising to find that there have been other glacial periods. In fact seven glacial periods are well established, the earliest one having occurred more than a hundred million years ago while the last one, the Ice Age, came to an end in New York in Pleistocene time, some twenty or thirty thousand years ago. At least some of these previous glacial periods must have affected New York and at least one of the periods was of greater severity and duration than the last glaciation which contributed the sands and gravels. Thus it would seem that glacial periods are a part of the orderly evolution of the earth and the Pleistocene glaciation should not be regarded as unique.

Throughout some periods of earth history the usual climate was warm and mild, with small difference in temperature between the tropics and the poles. New York at such times had a subtropical climate, while Greenland had a temperate warm one, as shown by the fossil remains preserved in the rocks. This genial climate extending from pole to pole has been the rule, and in the usual warm periods glaciers were unknown. It is indeed fortunate that we are living in the last stages of a glacial period and thus have an opportunity to study many active glaciers. If we had lived in a time of the usual warm climate we should have had no key to explain the glaciation of earlier periods and all of our familiar glacial phenomena would doubtlessly have been a closed book. This relative uniformity of climate for millions of years is difficult to understand and it would appear as though the energy of the sun had been rather constant throughout the ages, not cooling off through continued contraction and loss of heat.

Interspersed in this usual warm climate occur the seven glacial periods, which were of relatively short duration. By relatively short is meant a lapse of time of the magnitude of 100,000 years. Considering for instance the Pleistocene glaciation, with which we are most familiar, records show several advances and retreats of the ice, the periods of extreme glaciation being separated by longer intervals of warm climate, the whole extending over a total time of approximately 150,000 years. These warm interglacial periods may have lasted five times as long as the glacial advances; at least we know they were of sufficient duration for the climate to be much warmer than it is now. Fossil remains of this age include the saber-tooth tigers, camels and tapirs in Alaska, while the sea-cow of the tropics has been found as far north as New Jersey.

Scientists do not agree as to how many advances and retreats of the ice occurred during Pleistocene glaciation. In the Western States there seemingly were several, some geologists declaring there were a half dozen, but in the East there seems to be evidence of only two major advances and retreats of the ice sheet separated by a long, warm, interglacial period. This whole complex sum of advances and retreats is known as the Ice Age or "Recent Glacial Period" and this title is purposely repeated to emphasize the fact that we are still in the final stages of a glacial period.

Cause of glaciation. A multitude of theories have been proposed to explain geological climates. The very fact that there are so many theories proves that our present climate is a rather poor key to use in interpreting past events. Even the reason for the usual warm geological climate seems to be beyond our grasp.

It is not difficult to think of causes that would raise or lower the temperature of the earth as a whole. The difficulty is to think of a cause which will raise the temperature of the polar regions some 50°F. while leaving the equatorial regions about as they are today and thus bring about a distribution of climate such as we have had throughout the most of geological history. The great difference between Central Africa and the Central Arctic is that in Africa water is water while in the Arctic water is ice. If therefore we could propose some way to regulate the presence or absence of ice at the poles the hard part of the problem would be solved.

Two viewpoints immediately arise. Is glaciation due to (1) falling off in the earth's supply of heat or (2) to a redistribution of the heat because of changes in atmospheric oceanic circulation.

Undoubtedly a variation in the amount of heat received from the sun would very directly affect our climate. It has been demonstrated that during a time of great sun-spot activity, storms increase and the climate becomes colder. Evidently we have here a means of explaining minor fluctuations in climate, but that this alone should account for a glacial period seems rather unlikely.

On the other hand, past geological records show a frequent agreement between great crustal disturbances, when mountains were slowly uplifted, and glaciation. An elevation of the land would naturally tend to change the prevalent winds and, just as our mountains do today, would cause a chilling of the surrounding atmosphere with consequent formation of snow and ice. Incidentally such snow and ice fields would act as huge refrigerators, making it easier for additional snow and ice to accumulate.

Whatever the cause or causes that brought on glaciation, it seems very probable that the same influences and forces are acting around us today, doubtlessly with greatly different intensity than formerly, and that glaciation results when several such causes act together giving a tremendous combined effect. The reason for glaciation is a closed book at present but that the Ice Age represents a cataclysm of nature is far from the truth.

Effects of glaciation. As the ice crept back and forth over the northern part of North America, previous drainage lines were blotted out or clogged, until today we can very accurately outline the 4,000,000 square miles covered by glaciers if we simply refer to any geography and notice the extent of the lake areas. The obliterating and impeding of river drainage were caused partly by the overriding of the ice itself and party by the immense amount of rock-débris left behind during each northward retreat of the glacier.

Before the advent of the ice, New York presented a considerably different picture than it does today. Practically no lakes, waterfalls or gorges were in existence and the valleys were occupied by large, well-established rivers. While it is certain that a dominant master river occupied the Ontario valley, no positive evidence has been found to show whether it reached the ocean by way of the St Lawrence or by a southwesterly flow into the Mississippi area; the present data seem to show a flow to the southwest, which would make the St Lawrence a minor stream with its headwaters in the region of the Thousand Islands. The Finger lakes area, with its remarkable arrangement of some fifteen parallel valleys, is the clogged remnant of a former river drainage. Whether these former rivers flowed south into the Susquehanna or north into the Ontario valley is not definitely known, although a northward drainage seems quite probable for the majority.

Moreover, considerable areas in New York must have been at a higher elevation than they are at present. Positive proof of this is found in the southeast part of the State, where the inner gorge of the Hudson valley has been traced 100 miles eastward into the ocean, beyond the mouth of the present Hudson river. The Atlantic coast line was then some hundred miles farther east, Long Island did not exist and the whole region must have been more than 1000 feet higher than it is today. Even as far north as the Highlands, the Hudson river shows a filling of its old channel to approximately 800 feet. It seems likely, therefore, that a large portion of New York was at a higher elevation than now.

With the coming of glaciation much of the drainage was changed and thousands of lakes were brought into existence. Since Professor Fairchild in a series of New York State Museum Bulletins has given the results of an extensive study of this problem and since it is beyond the scope of this report to discuss adequately these interesting changes, only the salient features will be here considered.

Glacial ice flows as though it were a viscous substance, the general direction of movement being away from the centers of accumulation. At the time of greatest ice extent this movement was toward the south and southwest, and the major valleys of the State controlled and directed the flow of the lower part of the ice mass. Where such valleys were parallel with the flow of the ice, that is, had a north-south direction, an easy path of movement was offered, and here the glaciers accomplished a notable amount of erosion, leaving the tributary streams in "hanging valleys." Excellent illustrations of this selective deepening are shown in the Finger Lakes area, where some of the north-south lakes have been scoured below sea level leaving the east-west side streams lagging 300 or 400 feet above.

The remarkable thing is not that glaciers scoured the north-south valleys, since the erosive power of moving ice when armed with boulders and gravel is well established, but that most of this erosion seems to have been accomplished during the first major advance. The last advance of the ice, called the Wisconsin, had seemingly little erosive force and in some places did not remove the loose weathered deposits left behind by the first ice mass. Its noteworthy achievement was accomplished during the retreat, as the Wisconsin ice sheet dropped an immense amount of rock débris all over the State. Indeed the larger part of the sand and gravel deposits are connected with this final retreat of the ice, although on Long Island some of the most important sands and gravels are attributed to a previous period of glaciation.

Extinct glacial lakes. The present drainage divide separating the streams flowing south into the Susquehanna from those flowing north into the St Lawrence, is partly composed of morainic material and represents a former position of the glacier's front for a considerable period of time. As the ice retreated from this position, each north-sloping valley was filled by a glacial lake, the ice itself forming a dam to the north, and the level of the lake was determined by the height of the discharge to the south. With the continued retreat of the ice northward toward lower ground, these lakes coalesced to form increasingly larger and larger lakes at successively lower levels, since the impounded water always sought the lowest level for its discharge. Finally the ice retreated northward far enough to impound a great body of water called Lake Warren, which covered central and western New York and discharged westward into the Mississippi. One of the last stages was represented by Lake Iroquois, the predecessor of Lake Ontario, which discharged eastward through the Mohawk. Records of these old lake levels are strikingly preserved in many fossil delta and beach deposits.

Evidence of hundreds of extinct glacial lakes is scattered through the State, and since these lakes acted as enormous settling basins, the débris carried by torrents from the melting glacier was sufficiently well sorted and washed to form commercial sand and gravel deposits. Today thousands of delta deposits all over the State attest the intrinsic worth of this complicated glacial lake history. In the detailed description of the sand and gravel operations an effort will be made to bring this out more vividly.

Recent changes. When the ice sheet melted away from New York much of the area had subsided and was lower than it is today. It is supposed that the excessive weight of the ice, acting over a period of scores of thousands of years, eventually depressed this segment of the earth's crust. During this period of subsidence the Hudson valley was depressed to below its present level, the lowlands of Long Island were under water and an arm of the sea extended through the Champlain and Hudson valleys. Since then a gradual warping and uplifting, due to removal of the weight of ice, has excluded the Champlain sea and left the State as we see it today. Champlain sea beaches containing marine shells and whale bones are found at about 500 feet above sea level near Lake Ontario. That this slow uplifting is still active is proved by actual surveys made in the northern Great Lakes region.

Since the final retreat of the ice from New York, weathering has changed the glacial deposits to some extent. In some instances weathering has been beneficial, as for example the molding sands of the Hudson valley, which owe their bonding strength to this action. In other cases weathering has been detrimental, forming a zone of rotted material and increasing the cost of stripping. Moreover, surface water percolating through the sands and gravels has dissolved lime from the blue-gray limestone pebbles and deposited it again at lower levels, tightly cementing the surrounding material. This is the reason so many operators are at times forced to blast the pit face. Fortunately the retreat of the ice happened such a short time ago that weathering has not had long enough time to be seriously effective and a majority of the glacial sands and gravels are in excellent condition for commercial development.

TESTING SAND AND GRAVEL

Unfortunately, methods used to determine the different properties of sand and gravel are often far from complete or satisfactory. Within the past few years an immense amount of research has been carried on, with the result that the value of testing sand and gravel has been firmly established, although the methods of testing are still constantly changing. Today the sand and gravel industry stands on the threshold of important advances in technic, largely because of this investigation into the seemingly uninteresting realm of properties and tests.

The following discussion is purposely made as nontechnical as possible because it is felt that the subject is important enough to merit a wider acquaintanceship than it has so far received.

Sampling

Nothing can take the place of proper sampling and, no matter how carefully later testing is carried out, the results are worse than worthless if the sample has been improperly secured; literally worse than worthless because improper sampling may condemn an intrinsically good product, or may cause an investment in a sand and gravel bank of no commercial value. The very nature of the conditions under which sand and gravel deposits are formed usually guarantees quick changes in both texture and composition so that a uniform bed of any extent is decidedly the exception, and a representative sample is difficult to obtain.

The usual sand and gravel producer is not interested in sampling until several cars of his material have been turned down because of incorrect sampling and he has paid a large demurrage bill and thrown the sand and gravel away. Even this relatively simple matter of sampling a car or boat is often improperly done. Under the usual type of loading chute, gravel will pile up in the center of the car and the coarser, flatter particles will tend to segregate on the sides; sand if loaded rather wet will tend to puddle in the top layers, and if in a dry condition will segregate with the coarser material on the sides. Thus the common method of taking a "grab sample" from a convenient corner of the car is unfair. It would be better to sample the car during unloading or better still to take several small samples at intervals from the chute as the car is loaded.

Stock piles present another problem in segregation, as the coarser and flatter material collects on the sides and especially at the base of the piles. Stock piles of sand where exposed to the weather for several months often show considerable washing and leaching. A few grab samples taken from the most convenient place, the sides and base, are certainly not representative.

If a deposit is worked as a bank or pit and is not washed, the sample should be taken by trenching the open face so as to represent all the material suitable for use. Care should be taken to eliminate any stripping or top-zone of rotted material as well as any material that has fallen along the face from the top. Where the bank face is quite high this method is often not practical and moreover under such conditions the producer is often able to load selectively and a mixed and quartered sample of the whole face is not a real indication of what could be produced.

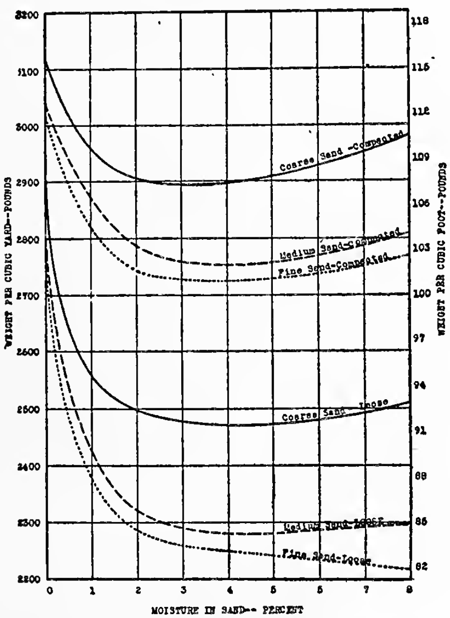
In molding sand deposits the digging is often done by hand and a wagon load may represent a composite loading from several different parts of the pit. Manifestly, such conditions make the securing of a representative sample in the field extremely difficult. In fact, correct sizing up of sand and gravel deposits in the field is a difficult problem in the solution of which experience counts for more than rules and regulations. Since within a month the entire character of the face may change, the practice of requiring sampling and testing only every year or so is not sound.

Samples of run-of-bank material in which the sand and gravel are combined should weigh at least 100 pounds or measure one cubic foot; where the sand and gravel is taken separately, one-half cubic foot is usually sufficient. It should be remembered that the common method of reducing the size of a representative sample, by coning and quartering, is effective only when the entire pile is very thoroughly mixed.

Weight

Where there are no nearby facilities for weighing loaded cars the weight of a cubic yard of sand or gravel is of considerable importance to the producer. Poor judgment results in overloaded cars with a consequent penalty, or in underloaded cars with a loss in freight. The United States Geological Survey has calculated the average weight of a cubic yard of sand to be 2665 pounds, and that of gravel to be 2820 pounds. In New York the weights of a cubic yard of sand vary from about 2700 pounds to as high as 2800 pounds; gravels vary from 2600 pounds for the Hudson valley district to 3200 pounds in the western part of the State, with 2800 pounds as a fair average; a mixture of sand and gravel often weighs in the neighborhood of 3000 pounds a cubic yard. All these weights are based on dry material.

A standard test has been advanced by the A. S. T. M. which consists in tamping the material a certain specified way and a determined number of times into a cylindrical metal measure. The net weight of the material in this cylinder is found by weighing it on a sensitive balance. Knowing the volume of the cylinder in cubic centimeters, one can compute the unit weight of the material. This is done by obtaining a factor from dividing 62.35 pounds, the weight of a cubic foot of water, by the weight of the water required to fill the cylinder; multiplying this factor and the net weight of the material in the cylinder gives the weight of a cubic foot of the sand or gravel.



Curves showing effect of different conditions on unit volume weight of sand

While this is of value, the producer is really interested in the weight of his material as it is loaded in the car, with varying amounts of moisture. Even clean concrete sands bulk considerably when damp; in molding sands, this is still more pronounced. By absorption, a film of water is held around each grain, which acts as a cushion, thus tending to keep the grains apart, and a cubic yard of damp sand will be 15 to 30 per cent lighter than a cubic yard of the same sand when dry. Any sand will bulk with increasing dampness up to a certain point and then will decrease until when really wet, a cubic yard will weigh approximately the same as an equal amount of dry sand.

Further factors that influence this troublesome property of bulking are the method of loading, that is, whether the sand is loose or compacted, and the grading of the grain sizes. The above diagram, published by the Stewart Sand Co., Kansas City, Mo., and copied from Rock Products of September 1927, illustrates these variables and should be of practical help in determining the weight of damp sand (Goldbeck '27).

Cleanness

What may be an impurity in some sands, may be necessary for the usefulness of others. Clay or silt, beyond a certain small percentage, is considered detrimental in concrete sands, and sands containing an appreciable amount are said to be dirty and require washing. In contrast, many molding sands owe their value to a claylike bonding material, and when this decreases the sand is said to be sharp and must be rebonded artificially for commercial use. A small quantity of iron oxide in sand has generally no harmful effect but when more than one-half per cent is present such sand is unfit for even the cheaper grades of glass. The cleanness of sand or gravel then is measured by the amount of harmful impurity, the harmfulness depending on the use to which it is put.

Clay and silt. Several methods for determining the amount of clay and silt have been proposed, the one used by the New York State Highway Bureau being given below. All percentages of loam and silt used in this report, except those for molding sand, were determined in this manner.

Fill a 200 cc graduate with 140 cc of pure water and then add sand until the 200 cc graduation is reached by the water level. Shake thoroughly for one minute and let settle for 24 hours. The clay and fine silt will usually show a sharp line of separation from the sand and the volume can be read directly. This quantity of clay and silt is expressed as a volume percentage of the sample.

If the amount of loam and silt is high, over 5 per cent by volume, an additional sample is tested by placing 500 grams of the dried sand in a large dish, covering with sufficient water (about 300 cc) and agitating vigorously. After it has settled for 15 seconds the water is siphoned off, care being taken not to pick up any sand. This process is repeated until the wash water is clear. Save all of the wash water, allow the loam and silt to settle for 24 hours, siphon off the excess water and evaporate the residue to dryness at 105°C. Weigh and express as the percentage of silt and loam by weight. The result should be checked by also drying and weighing the washed sand sample.

Sand may be rejected if it contains more than 3 per cent by weight of loam and silt.

The amount of clay in the molding sands tested for this report was determined by the method of the American Foundrymen's Association, which is as follows:

Fifty grams of molding sand, dried at least one hour at a temperature which shall not be lower than 105° nor higher than 110° Centigrade, are put into a one-quart milk bottle or preserving jar, smooth on the inside with no sharp shoulders in the neck, to permit the sand to be easily removed with a small stream of water. 475 cubic centimeters of water and 25 cubic centimeters of a standard solution of sodium hydroxide (made by dissolving 10 grams of sodium hydroxide in 1000 cc of water) are added, and the bottle or jar is covered and securely sealed. In using a preserving jar a rubber disc is employed, which fits into the inside of the glass cover. The receptacle is then placed in a shaking machine, making about 60 revolutions per minute, in such a manner as to allow it to be upended at each revolution. At the end of one hour the receptacle is removed, the cover unsealed, and the sand adhering to the cover is washed into the receptacle. The receptacle is then filled with water, permitting the stream to stir up the contents, and allowed to stand for 10 minutes, when by means of a siphon extending to within 2.5 centimeters (approximately 1 inch) of the bottom of the receptacle, the water is siphoned off. More water is added, filling the receptacle, and at the end of 10 minutes siphoned off. Water is added again, and at the end of five minutes siphoned off. This process of five minutes standing and siphoning is repeated until the water remains clear at the end of the five minute period.

The grain remaining in the bottle or jar is washed on to a filter-paper, in a nine centimeter Buchner's funnel, is drained by means of suction, then wet with alcohol, and transferred, together with the filter-paper, to a large glass, and dried for one-half hour at a temperature which shall not be lower than 105°C., nor higher than 110°C. The dried grain is weighed, and the difference between its weight and that of the original 50-gram sample is ascertained to determine the clay substance.

This would seem like a long, complicated method but many molding sands are so well bonded with clayey material that any short cut does not give satisfactory results.

Organic matter. Even in small amounts organic matter is often a harmful ingredient. It may occur as particles of coal, leaves or finely divided parts of plants scattered through the sand, or as a thin, almost imperceptible film coating the sand grains. Washing usually reduces the percentage of organic matter, but when it is in the form of fine coal, especially designed tables and jigs are necessary. Sometimes screening will reduce the organic content. Samples 6850 and 6851 in the concrete sand test tables illustrate this point, sample 6850 having been screened.

The New York State Bureau of Highways tests for organic content all sand used in its construction work by the following method:

Fifty cubic centimeters of a standard 3 per cent solution of sodium hydroxide is poured into a glass tube 2½ inches in diameter and 50 grams of dried sand added. This is shaken vigorously and allowed to stand 24 hours. At the end of this period the color in the clear solution is compared with the following standard color chart and expressed as a numeral.

1 Clear	6 Rich amber
2 Trace	7 Dark amber
3 Pale amber	8 Red
4 Light amber	9 Dark red
5 Amber	10 Black

The present attitude seems to be to use this test as a warning that the sand may give trouble and not as a final basis of rejection. Usually if a sand gives a high color, additional strength tests are made and the sand is watched very closely. In general a high color value is associated with a low concrete strength.

Durability and Strength

These two properties, although not by any means identical, may be conveniently treated together. The service to which concrete is subjected, whether to resist tensile or compressive stresses, abrasion, impact, the weather etc., has a very important relation to the durability and strength of the coarse aggregate—the gravel. In a recent report submitted by the subcommittee on gravel of the American Concrete Institute, after discussing several strength and durability tests, the following conclusion was given:

It does not seem unreasonable to suppose that, except for soft, friable and partially disintegrated particles and particles which are not durable on exposure to the weather, any material which has withstood the action of the elements necessary for the formation of gravel consists of particles hard enough for usual service in concrete.

In the same report the subcommittee suggests:

The judgment of the durability of a gravel might be based on

1 The percentage of particles which will not stand the weather as measured by a suitable accelerated freezing and thawing test.

2 The percentage of soft, friable and laminated particles which will not withstand a suitable impact test or pressure test.

3 The percentage of light-weight particles which will be floated by a liquid of a suitable specific gravity—about 1.95.

It is recognized that there probably would be much overlapping of these three tests, that is, particles eliminated by one of them would also be eliminated by one or both of the others.

In the New York State Highway Bureau the following abrasion test is made with the restriction that gravel for concrete work shall not contain slate or schist and shall have a percentage of wear of not more than 15 per cent. All of the percentages of wear or abrasion figures used in this report are based on this method of testing.

The aggregate shall first be screened through screens having circular openings 2 inches, 1½ inches, 1 inch, three-quarters inch, and one-half inch in diameter. The material of these sizes shall be washed and dried. The following weights of the dried stone shall then be taken—1250 grams of the size passing the 2 inch and retained on the 1½ inch screen, 1250 grams passing the 1½ inch and retained on the 1 inch screen, 1250 grams passing the 1 inch and retained on the three-quarters inch screen, 1250 grams passing the three-quarters inch and retained on the one-half inch screen. This material shall be placed in the cast-iron cylinder of a standard Deval machine. Six cast-iron spheres 1.875 inches in diameter and weighing approximately 0.95 pound each shall be placed in the cylinder as an abrasive charge.

The duration of the test and the rate of rotation shall be 10,000 revolutions at the rate of 30 to 33 revolutions per minute. At the completion of the test the material shall be taken out and screened over a one-sixteenth inch mesh sieve. The material retained upon the sieve shall be washed and dried and the percentage of loss by abrasion of the material passing the one-sixteenth inch mesh sieve calculated.

Shale has long been recognized as unsatisfactory in a concrete aggregate and many states limit the amount to from 3 to 5 per cent. Since shale has a specific gravity of about 1.6 compared to 2.0 for quartz particles, a separation may be effected by using a heavy liquid like zinc chloride with a specific gravity of 1.95. This will float the shale and permit an estimation of the amount present.

To simulate natural conditions and test the soundness of gravels an accelerated freezing and thawing test has been suggested and is in quite general use.

Immerse ten small particles of the gravel in a saturated solution of sodium sulphate for 20 hours and then dry for 4 hours at 100°C. Crystals of sodium sulphate will form in any cracks in the specimens and tend to break them. Repeat the treatment 5 times. Samples which exhibit marked checking or disintegration shall be considered to have failed.

It would seem that this test in its present form is too severe as it often determines material to be unsound that has withstood a severe climate for years. Incidentally, some states permit the use of material that fails in the sodium sulphate test but withstands the actual freezing and thawing test.

Summing up, it appears to the author that the present methods of testing the durability and strength of gravels are not very satisfactory. Indeed he is inclined to agree with the conclusions reached by the subcommittee quoted above, except that too many cases of failure of concrete have lately been traced to unsound aggregate. This failure may perhaps be due to a more severe stress being exerted upon the gravel after it has been cast in concrete, than it was exposed to in the gravel bank. In other words, it does not seem safe to assume that seemingly fresh gravel from Nature's testing laboratory would always stand up under the complicated stresses to which concrete may be subjected. Some sort of test is needed, if only to bring out the microscopic flaws that are invisible to our eyes.

Life. Under this same general heading of durability, the life of molding sands and the methods used to determine longevity should be considered. This is of importance to foundrymen since two molding sands of approximately the same green strength may burn out at different rates, due primarily to a difference in bonding material. Naturally the sand that stands up the best and has the longest period of use, other things being equal, is the most economical to buy.

A satisfactory testing method to determine the relative life of molding sands has not as yet been developed. One scheme (Nevin '26) that has been tried successfully is to make a series of castings in different molding sands, testing the sands for strength after each casting and continuing in this manner until the sand is useless. The greater the number of castings that may be poured, the better the life of the sand. In this way excellent comparisons may be made, but the method is too slow.

There has also been suggested a short-cut method, based upon the varying abilities of different types of bonds to rehydrate and become sticky again after heat treatment. This test is still in the experimental stage and its practical value has not yet been demonstrated.

It would seem to be to the practical interest of the foundry industry as a whole to find out the relative durability of the sands in common use throughout the United States.

Lithology

Since sands and gravels are composed of a great variety of rocks and minerals, the percentages of these constituents often give an excellent clue to their origin, use and possible defects. A lithological and mineralogical separation of sand requires considerable skill, the use of heavy liquids of varying density and a microscope with a series of refractive index liquids. In the hands of an experienced petrographer this method of attack yields extremely valuable results.

Fortunately the composition of a gravel is more easily determined, the only requirement being a knowledge of the common rocks and minerals. From 100 to 200 pieces of gravel may be selected at random, ranging in size from one-half an inch to two inches, and separated into the various rock types, the percentage of each being noted. A long box divided into a series of compartments is of aid in making this determination.

A number of the gravels used by the New York State Bureau of Highways are tested in this manner, the value of the results naturally depending upon the training of the operator. In addition, it is often of great help to separate a gravel sample into groups of excellent, good, fair, poor and unfit material, depending upon its lithology. The separation of material in a bucketful of gravel composed of pieces taken at random from a stock pile or bank will usually make extended laboratory testing unnecessary.

There is no present single laboratory test for gravel which will give such conclusive results as to the quality of the material as this simple method when handled by an experienced person.

Permeability

Sands and gravels possess the property of allowing gases and liquids to pass through them. This rate of flow is known as "permeability" and is of special importance in molding sands, molding gravels and core sands. A sand of high permeability has good venting qualities because of its openness, which in turn has no connection with the porosity, as a fine textured sand might have a high porosity but a low permeability. The natural characteristics of the sand and its binders, the density with which these are packed, and the percentage of moisture used in tempering are important factors in regulating the degree of permeability. One method of determining permeability is to measure the rate of flow of air through a standard specimen of sand under given pressure. The permeability figures in this report were determined in this manner.

Briefly, the apparatus used is a simple gasometer which is so weighted that a pressure of 10 centimeters is registered on a manometer tube when the circuit is closed. The time required to pass 2000 cubic centimeters of air through a standard molding sand specimen is noted, as well as the back pressure set up in the manometer tube.

This standard sand sample is compacted under easily simulated conditions so that comparable test pieces of the same height, volume and degree of ramming are always obtained.

In this test, permeability is expressed as the volume of air per minute, per gram, per square centimeter pressure, per unit volume in the specimen.

$$\text{Perm.} = \frac{\text{cm}^3 \text{ of air x cm height specimen}}{\text{grs. pressure x cm}^2 \text{ area x minutes}}$$

Since the amount of air used (2000 cc) and the height and area of the standard specimen are always constant, this simplifies to

$$\text{Perm.} = \frac{501.2}{\text{grams pressure x minutes}}$$

A more rapid method may be substituted by inserting a carefully calibrated gold-lined orifice in the apparatus. Then by the use of a table the permeability may be read directly, thus doing away with the necessity of recording the time required to pass 2000 cc of air.

No other one test has been of such practical help to the foundry industry as this test of permeability. Using this method the foundryman may blend and temper his heap sand so as to keep daily within certain narrow permeability limits, thus reducing his loss through poor castings. On the other hand, the producer is able to keep a close check on the molding sand as it comes from the bank, changing his loading conditions if it is becoming too "tight" or too "open." In the present effort to rebond burnt-out molding sands and to make a synthetic molding sand from a mixture of sharp sand and clay loam, the permeability apparatus has proven to be invaluable.

Cohesiveness

The ability to stick together or cohere upon proper tempering with water is the criterion that distinguishes molding sand and gravel from all other sands and gravels. Its destruction by burning out during casting immediately returns the sand to the waste heap, a molding sand no longer. Too much bond, too small an amount of bond, the wrong kind of bond or the improper tempering of the bonding material is undoubtedly a daily cause of foundry losses. Any method that will test strength or cohesiveness is therefore of great value.

In this report the method advocated by the American Foundrymen's Association is used.

Briefly, the method consists in ramming up a bar of tempered molding sand under very carefully standardized conditions. This bar is then slowly pulled over the edge of a metal plate and the segments, as they break off, are caught separately and weighed. The stronger the sand the larger the segment that overhangs before breaking, which thus gives a comparative method of determining the cohesiveness of a group of molding sands. The strength is expressed directly in grams.

This above method, while giving excellent results, requires about 3000 grams of sand and is rather slow. Lately rapid compression and tension tests have been suggested to take the place of the bar test, and standard methods of procedure have been outlined.

Naturally the question arises as to which test best simulates the stresses that actually exist in the foundry. The bar method is a cross-breaking test with a failure in tension, although compression and shear are also present; the tension method tests the sand in its weakest relation and any small errors in manipulation or flaws in the specimen make the results worthless; the compression method is very rapid and gives consistent results, but tests the sand in its strongest relation.

In actual molding practice tensile stresses are thought to produce most of the failures, although in pouring large castings compressive and shearing stresses are known to occur. Unfortunately such a difference exists between molding sands that it does not seem possible to transform tension results into compression results, or vice versa, by using a constant empiracle figure. As yet the research committee of the American Foundrymen's Association has not decided whether to recommend the compression, tension or bar test.

Refractoriness

The mineralogical composition of sand and gravel has a very direct bearing upon the resistance of concrete to high temperatures. It has been found (Hull '20) that the expansion of quartz gravels under heat produced spalling, requiring for protection a layer of fireproofing at least two inches thick. Unprotected concrete columns with gravel aggregate lost 75 per cent of their strength after a severe fire. The entire question has been discussed in the Proceedings of the American Concrete Institute for 1925 under a committee report entitled Fire Resistance of Concrete, and further investigations are in progress.

In the case of sands used in steel casting and in fire sands used for furnace bottom linings, the refractoriness is extremely important; only the most siliceous sands, free from lime and other fluxing materials, may be used. Even in the relatively low heats to which core sands are subjected an amount of lime over 5 per cent usually gives trouble.

As a bonded sand is subjected to progressively higher heats, a microscopic examination shows an initial shrinkage of the bonding material and cracking away from the quartz grains, followed by the vitrification of the bond, the evidence of increasing fluidity, the attack of this glass upon the quartz grains and their gradual absorption by the glass. The Bureau of Mines at Columbus, Ohio, and the Mines Branch at Ottawa, Canada, have both investigated refractoriness and find that sands break down more quickly under a partially reducing atmosphere than under either oxidizing or completely reducing conditions.

Several test methods have been tried, the usual one being to mold the sand as received and also the separated clay substance into cones. These cones are heated in a furnace, allowing at least two hours to reach a temperature of 1500°C., after which they are slowly cooled and examined.

A very ingenious scheme is that suggested by C. M. Saeger jr, who applies heat to the surface of a bar sample of sand through a platinum ribbon heated by an electric current. The ribbon is held against the bar for four minutes at a time, each contact being made at a different part of the bar, and at successively higher temperatures, until the sintering point of the sand is reached.

Mortar Tests

Fine aggregate of concrete, the sand, is tested for the strength it develops in a mortar 1:3 mix after setting seven and 28 days. These mortars made of natural sand are compared with mortars made from the same cement and standard Ottawa sand mixed in the same proportions and of the same consistency.

The New York State Bureau of Highways has lately been testing strength by tension, but previously all strength tests were compression. Throughout this report compression figures are given, since far more compression tests were available. All sand that is used by the State must show a developed strength at the end of 28 days at least equal to that of standard Ottawa sand.

Following is the procedure of testing:

Tension test. The briquets for the tension test shall be molded in the standard mold as used for testing Portland cement, and shall be wiped with an oily rag before using.

Immediately after mixing, the mortar shall be placed in the molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar shall be heaped above the mold and smoothed off with a trowel; the trowel shall be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold shall then be turned over and the operation of heaping, thumbing and smoothing off repeated.

Tests shall be made with any standard machine. The briquets shall be tested as soon as they are removed from the water. The bearing surfaces of the clips and briquets shall be free from grains of dirt or sand. The briquets shall be carefully centered and the load applied continuously at the rate of 600 pounds a minute.

Briquets that are manifestly faulty or which give strengths differing more than 15 per cent from the average value of all test pieces made from the sample and broken at the same period shall not be considered in determining tensile strength.

Compression test. A cylindrical test piece two inches in diameter and four inches in length shall be used in making the compression test. The mortar shall be placed in the molds in four layers about one inch in thickness, each layer being thoroughly compacted, but not rammed by a steel tamper. The steel tamper shall have a total length of about six and one-half inches. It shall be one inch in diameter for one and one-quarter inches and shall weigh approximately three-quarters of a pound. The surface of each layer shall be roughened before the addition of the next layer. In compacting the test pieces, no mixing water shall be forced out of the mortar. In finishing the test piece, mortar shall be heaped above the mold and smoothed off with a trowel. As soon as the test pieces from one sample are molded, the top of each mold shall be covered with a piece of glass which shall be brought to a firm bearing on the fresh mortar. The cover glasses shall remain in place until the molds are removed.

Tests of mortar cylinders shall be made in any testing machine which is adapted to meet the specified requirements. The test pieces shall be broken as soon as they are removed from the water. The ends of the test cylinders shall be smooth, plane surfaces. The metal bearing plates of the testing machine shall be placed in direct contact with the ends of the test piece. During the test a spherical bearing block shall be used on top of the cylinder. In order that a uniform distribution of the load over the test cylinder may be secured, the spherical block shall be accurately centered. The diameter of the spherical bearing block should be only a little greater than that of the test piece. The test piece shall be loaded continuously to failure. The moving head of the testing machine shall travel at the rate of not less than 0.05 or more than 0.10 inch a minute.

Cylinders that are manifestly faulty, or which give strengths differing more than 15 per cent from the average of all test pieces tested at the same period and made from the same sample, shall not be considered in determining the compressive strength.

Storage.—Unless otherwise specified, all test pieces immediately after molding shall be placed in a moist closet for from 20 to 24 hours. Cylinders or briquets shall be kept in molds on glass plates in the moist closet for at least 20 hours. After 24 hours in moist air the briquets or cylinders shall be immersed in clean water in storage tanks of noncorroding material. The air and temperature shall be maintained as nearly as practicable at 21°C.

Discussion. While there is some common underlying element between tension tests and compression tests, still the relationship is not close, and there seems little likelihood of being able to change from one to the other merely by using a constant. For instance, tension tests of neat cement usually show a falling off in strength after 28 days while compression tests on the same mixture show no such retrogression. This lack of agreement between tension and compression is further emphasized if we consider the loss of strength due to increase in the amount of mixing water (Hatt '25). In this example the strength in compression diminished 39 per cent and in tension only 13 per cent, while the water was being increased.

It is certainly a matter of interest whether tension tests or compression tests best predict the action of mortars and concrete under actual service conditions. Indeed, engineers are not at all certain that the resistance against a single load applied once (such as in test method) is a real measure of ability to withstand hundreds of thousands of smaller stress applications such as occur during use.

A recent statement appearing in one of the leading technical publications summarized this whole question as follows: "Since the sand when used in concrete is subjected chiefly to compressive stresses it is probable that a compressive test is a better criterion of the value of a sand than the tensile test." Applied to a protected column in a building, where the stress is practically constant compression of a predetermined amount, this statement is doubtlessly true, but applied to a concrete pavement it falls far short of the facts. In reality a pavement is subjected to a very severe combination of stresses, the predominant stress changing with conditions; pavements must resist direct tension, compression, shear and cross-bending stresses, surface abrasion, the impact of traffic and the influence of the weather. That the simple breaking of a test cylinder under compression is a real clue to what a sand will do in a concrete highway or in a breakwater is not borne out by experience. About all that can be safely inferred is that a high resistance to compressive stress is an indication of a high quality concrete.

Grain Size and Screen Tests

Since the grading of a sand or gravel is known to influence greatly its value for many uses, the necessity of a reliable mechanical analysis is at once apparent.

The usual method of determining the size of sand and gravel particles is by sieving or screening. Separation into sizes may also be accomplished by differential settling against a current of water, which gives especially good results when the sample is of fine texture. In this latter method, called elutriation, a constant amount of water is passed through flasks of increasing size; the current is swiftest in the smallest flask and here only the largest grains can settle; as the current decreases, due to the increasing size of the flasks, smaller and smaller grains settle out; the process is continued until a complete separation is effected.

Since the grain size is generally determined by screening, and since this method is used to size sand and gravel in this report, a general outline of the manner of procedure seems worth while.

Screen tests. Various bases have been proposed for the starting point in screen scales, some using one inch, the United States Bureau of Standards using one millimeter, and the Tyler Standard Series starting with the 200 mesh screen—.074 mm opening.

The ratio between the different sizes of the screen scale has been taken as the $\sqrt{2}$ or 1.414, as recommended by Rittenger. This makes the area or surface of each successive opening in the scale just double that of the next finer or half that of the next coarser sieve. Another advantage in this selection of ratio is that by skipping every other screen, we have a ratio width of 2 to 1 and by skipping three sizes we get a ratio of 4 to 1, thus making it easy to grade sands and gravels to any degree of nicety and still maintain a true mathematical proportion.

In Table 2 this mathematical relationship is brought out and the series of screens used in this report for molding sands and concrete sands and gravels are compared with the standard series.

TABLE 2 Screen Sizes

Tyler Series: Standard $\sqrt{2}$		Tyler Series: Ratio 2 to 1		U. S. Bureau of Standards for Concrete Sands		A.F.A. Molding Sands Series		N. Y. Highway Bureau for Concrete Sands	
Mesh	Millimeter opening	Mesh	Millimeter opening	Sieve no.	Millimeter opening	Sieve no.	Millimeter opening	Sieve no.	Millimeter opening
3"	80.0	....	....	3"	76.0	....	....	2½"	....
2"	53.3	....	....	2"	50.8	....	....	....	....
1½"	37.7	....	....	1½"	38.0	....	....	1½"	....
1"	26.67	....	....	1"	25.4	....	....	....	....
¾"	18.85	....	....	¾"	19.4	....	....	¾"	....
½"	13.33	....	....	....	....	....	....	....	....
⅜"	9.423	....	....	⅜"	9.5	....	....	....	....
¼"	6.680	....	....	....	....	....	....	¼"	....
4	4.699	4	4.699	4	4.76	....	....	....	....
6	3.327	....	....	....	....	6	3.36	6	3.3
8	2.362	8	2.362	8	2.38	....	....	....	....
10	1.651	....	....	....	....	12	1.68	....	....
14	1.168	14	1.168	16	1.19	....	....	....	....
20	.833	....	....	....	....	20	.84	20	.84
28	.589	28	.589	30	.59	....	....	....	....
35	.417	....	....	....	....	40	.42	....	....
48	.295	48	.295	50	.297	....	....	50	.29
65	.208	....	....	....	....	70	.210	....	....
100	.147	100	.147	100	.149	100	.149	100	.149
150	.104	....	....	....	....	140	.105	....	....
200	.074	200	.074	200	.074	200	.074	....	....
250	.052	....	....	....	....	270	.053	....	....

Recently the United States Bureau of Standards revised its tolerance limits of the size of opening for each screen, thereby permitting the Tyler Series to be recognized by that bureau. This should lay at rest a lengthy controversy as to which series to use, although from a history of events it would appear that the Tyler Series was first established.

The screen sizes for molding sands follow the United States Bureau of Standards Series except that there has been added a 100 and 200 mesh sieve, thus breaking the continuity of the series. The screen series used by the New York State Bureau of Highways does not follow any definite progression.

For sands and gravels used by the State the following method is employed in screening:

Upon receipt, the sample is thoroughly air dried and mixed. If much gravel is present 10,000 grams is used and if only sand, then 5000 grams is taken and screened through the ¼" sieve.

The gravel is screened separately, beginning with the ¼" and progressively going to the larger sieves. The amount passing through each sieve is expressed as per cent by weight.

The sand is also screened by hand, one sieve at a time, the amount passing through each sieve being expressed as per cent by weight.

Molding sands, after the clay and fine silt have been washed out, as described on page 27, are screened as follows:

The dried, clean grain (50 grams less the clay substance) is placed on the first of a series of sieves, United States Bureau of Standards nos. 6, 12, 20, 40, 70, 100, 140, 200 and 270. These sieves are placed in a Ro-tap testing-sieve shaker, or other machine the use of which may yield identical results. This machine is run for 15 minutes, and the amount remaining on each sieve is weighed and expressed in percentage. The portion passing the no. 270 screen is known as minus 270.

For molding sands containing no clay or bonding substance, such as a core sand, 100 grams of dried material are placed in the nest of sieves in the Ro-tap and shaken 30 minutes. The amount remaining on each sieve is weighed and expressed in percentage.

Grading of Grain Size

It is quite obvious that in a group of screen tests in which the sand and gravel are expressed either as the percentage passing through or as the percentage retained on each sieve, one may see that some samples are coarse textured and others very fine; that some are unsuited for concrete; that others are adapted to certain types of molding. Such a tabulation of screen tests, however, does not permit of accurate comparisons nor does it aid in separating sands of similar character. This weakness being recognized, attempts have been made to formulate methods of grading and specification limits, which, so far as grain size is concerned, would tend to bring out the suitability of sand or gravel.

Grading by specification. The easiest solution of this grading problem would appear to be by defining just what sizes would constitute, for example, a good concrete sand. A number of the large buyers of sand and gravel have endeavored to do this. For instance, the New York State Bureau of Highways specifies that "a concrete sand shall be so graded that when dry 100 per cent shall pass a ¼-inch square mesh sieve; not more than 25 per cent by weight shall pass a no. 50 sieve; and not more than 6 per cent by weight shall pass a no. 100 sieve. Sand may be rejected if it contains more than 3 per cent by weight of loam and silt." Other similar specifications for grout sand, cushion sand, gravel for concrete, asphalt sand etc. are enforced. With such a "cut and dried" set of limits it would be a very simple matter to scan through a series of screen tests and grade the material, selecting the good and poor samples.

The difficulty is, however, that the sand and gravel industry does not today know enough about its materials to draw up fair specifications. Eventually such a method of grading will be entirely feasible, but with the present lack of definite knowledge, grading by specification would either be so broad that little good would be accomplished or it would be so unnecessarily narrow that great hardship would result to the producer. The present large amount of research on testing methods has as its objective a betterment of sand and gravel products with a consequent elimination of wayside pits, but its real underlying motive is the establishment of specifications. When that time comes, grading will be a far easier matter than it is today.

Grading by average fineness. One of the common modes of grading is by the use of an average fineness figure, in which, by one of several methods, a single figure is arrived at that is supposed to express the average size or percent of fineness of the particles screened.

This scheme has recently been tentatively adopted by the American Foundrymen's Association and its salient features are based on the Scranton method which is familiar to many foundrymen. In this method the weight of sand on each screen was multiplied by the mesh number of the screen through which it had passed, the products were added and their sum divided by the total weight of sand. The resulting figure was approximately the average mesh of the grains.

The present tentatively adopted procedure is to make the standard A. F. A. fineness test by removing the clay and screening the grain. Multiply the weights of percentages of sand on the various screens by the appropriate factor listed below. Add the products. Divide by the sum of the weights or percentages. The dividend is the A. F. A. grain fineness number. Below are listed the multipliers for the corresponding mesh numbers.

TABLE 3 **Multipliers**

Multiply per cent remaining on no.	6 mesh by	3
Multiply per cent remaining on no.	12 mesh by	5
Multiply per cent remaining on no.	20 mesh by	10
Multiply per cent remaining on no.	40 mesh by	20
Multiply per cent remaining on no.	70 mesh by	40
Multiply per cent remaining on no.	100 mesh by	70
Multiply per cent remaining on no.	200 mesh by	100
Multiply per cent remaining on no.	270 mesh by	200
Multiply per cent remaining on pan	by	300

This grain fineness number of a sand is approximately the number of mesh per inch of that screen which would just pass the sample of sand if its grains were averaged in size. It is approximately proportional to the surface area per unit weight of a sand, exclusive of clay.

TABLE 4 Sample calculation

MESH NO.	PER CENT SAND ON THE SCREEN		MULTIPLIER	PRODUCT
On 6	.64	×	3 =	1.92
12	28.78	×	5 =	143.90
20	20.98	×	10 =	209.80
40	16.16	×	20 =	323.20
70	20.38	×	40 =	815.20
100	3.06	×	70 =	214.20
140	0.60	×	100 =	60.00
200	0.20	×	140 =	28.00
270	0.28	×	200 =	56.00
Pan	0.60	×	300 =	180.00
	91.68 = Total sum			2032.22 = Total product

$$\frac{2032.22}{91.68} = 22 \text{ or Grain fineness number}$$

Furthermore, molding sands are definitely graded into classes by dividing into zones the calculated grain fineness number and the determined clay content percentage. This has been done for some of the molding sands in this report.

TABLE 5 Grain fineness classification

GRAIN CLASS	GRAIN FINENESS ZONE
No. 1	200 to 300
No. 2	140 to but not including 200
No. 3	100 to but not including 140
No. 4	70 to but not including 100
No. 5	50 to but not including 70
No. 6	40 to but not including 50
No. 7	30 to but not including 40
No. 8	20 to but not including 30
No. 9	15 to but not including 20
No. 10	10 to but not including 15

TABLE 6 Clay content classification

CLAY CLASS	CLAY CONTENT ZONE
A	0.0 to but not including 0.5
B	0.5 to but not including 2.0
C	2.0 to but not including 5.0
D	5.0 to but not including 10.0
E	10.0 to but not including 15.0
F	15.0 to but not including 20.0
G	20.0 to but not including 30.0
H	30.0 to but not including 45.0
I	45.0 to but not including 60.0
J	60.0 to but not including 100.0

The molding gravel from Millville, N. J., whose screen analysis has been given above, has a clay content of 8.1 per cent and a fineness figure of 22 and would be graded as a no. 8-D Millville, N.J., sand.

Among several advantages which seem to favor this scheme of grading may be mentioned the following: calculation is easy; a definite numerical figure is obtained which readily lends itself to zoning into grades; the grain fineness numbers are approximately proportional to their surface area per unit weight and represent the number of mesh per inch of that screen which would just pass the sample if its grains were averaged in size; any screen series can be used without greatly affecting the result; no graph paper is required.

A distinct disadvantage is that the grain fineness number conveys no information as to the distribution of the sand grains on the various screens. This question of distribution is important as it very directly affects the use of the sand. Moreover, investigation has demonstrated that the so-called "clay substance" often contains a large amount of fine silt which would act differently than true clay. Also it is questionable if the weighting of the finer sizes, as this method does, will lead to the grading desired.

Grading by fineness modulus. Suggested some time ago by Professor Abrams, this function gives a measure of the relative size and grading of particles and has been used extensively in concrete mixtures to improve their quality. It, together with the water-cement ratio, has reduced concrete making to scientific principles. In fact this method is applicable to many problems dealing with sands and gravels and should have a wider use.

The fineness modulus is the sum of the percentages in the sieve analysis of the aggregate divided by 100. The sieve analysis is determined by using the following sieves from the Tyler Series: 100, 48, 28, 14, 8, 4, 3/8′, ¾″ and 1½″ mesh. By using the above series each sieve has a clear width of opening just double that of the next finer sieve.

In the following table the sieve analysis and fineness modulus of several concrete aggregates are shown. The sieve analysis is expressed in terms of the percentage of material by weight coarser than each sieve.

TABLE 7 **Method of calculating fineness modulus**

SIEVE SIZE	PER CENT OF SAMPLE COARSER THAN A GIVEN SIEVE			
	A	*B*	*C*	*D*
100 mesh	91	100	100	98
48 mesh	70	100	100	92
28 mesh	46	100	100	86
14 mesh	24	100	100	81
8 mesh	10	100	100	78
4 mesh	0	95	100	71
⅜ in	0	66	86	49
¾ in	0	25	50	19
1½ in	0	0	0	0
Fineness Modulus	2.41	6.86	7.36	5.74

Concrete aggregate *D* is made up of 25 per cent of sand *A* mixed with 75 per cent of pebbles *B*. Equivalent grading would be secured by mixing 33 per cent sand *A* with 67 per cent coarse pebbles *C*.

Grading by plotting. There are some advantages in the graphic method of showing data obtained in screen analysis. Such plotted curves may either show the actual amount of material retained on each sieve or they may be smooth curves showing the total material passing through or retained on each sieve. In the latter case they are called cumulative curves, and the following analysis of a core sand illustrates the difference in expression.

TABLE 8 **Expression of percentages retained on sieves**

MESH	ACTUAL PERCENTAGE RETAINED ON	CUMULATIVE PERCENTAGE RETAINED ON	CUMULATIVE PERCENTAGE PASSING THROUGH
6	0.0	0.0	100.00
12	0.0	0.0	100.00
20	0.0	0.0	100.00
40	1.90	1.90	98.10
70	26.60	28.50	71.50
100	35.16	63.66	36.34
140	27.48	91.14	8.86
200	4.98	96.12	3.88
270	2.10	98.22	1.78
Pan	1.78	100.00	0.0

In a recent paper (Nevin '25*b*) the author has described the several methods used in plotting and will here only briefly summarize the advantages of each method. The broken curve method, showing the actual percentages retained on each screen, has the advantage of vividly expressing an analysis, which is important in grading closely similar sands or in comparing the work done by different types of crushers. The cumulative curves allow easy interpolation between screen sizes because they are smooth curves; also the slope of the curve as well as the area it covers gives an excellent idea of the distribution of the sand grains. H. A. Baker '20, after carefully reviewing the different methods of grading, concludes that any scheme which ignores the distribution of the sand, such as an average fineness method, gives very misleading information; and that the only proper way to grade a sand is by plotting a cumulative curve and considering the area it incloses.

Chemical Analysis

While physical tests of sand and gravel are undoubtedly the most important and furnish the best information, still chemical tests may at times be indispensable. It is not within the province of this report to discuss how chemical tests should be made, but it is important to know when they should be undertaken.

Few if any natural sands are of sufficient purity to be used as a source of glass without being washed. In fact, it is the exceptional sand that will have a low enough percentage of iron, even after careful washing, to be fitted for use in glass making. It is only by chemical analysis that the value of a probable glass sand may be determined, and the efficiency of glass sand washing plants is constantly checked in the same way. Each loaded car of glass sand shipped in New York State is sampled for a chemical analysis in at least three different places during loading. Thus it is evident that for glass sands a chemical analysis is of greater help than physical tests.

The same is true, but to a lesser degree, for furnace sands, core sands and steel sands. Unless such sands show a high percentage of silica and a low amount of lime, potassium and sodium they are rejected. Usually a careful chemical analysis is necessary to determine the amount of possible fluxing material but often a simple field test with dilute hydrochloric acid will demonstrate the presence of too much lime. This lime may be in the form of shells such as commonly are found in beach and lake sands, or it may occur as little limestone pebbles and limestone sand particles scattered through a deposit, and when present to an amount of several per cent will effervesce when touched with acid.

Practical experience has shown that more than 5 per cent of fluxes will cause trouble in any sand that is subjected to high heat, hence the value of a chemical analysis either to prove or disprove the fitness of a sand for such use.

Other Tests

Among other properties that are sometimes tested may be included specific gravity, porosity and brittleness. In Bulletin 1216 of the United States Department of Agriculture for 1924 may be found descriptions of the methods used under the headings Apparent Specific Gravity Test, Percentage of Voids or Porosity Test, and Impact Test for Gravel. Such tests are usually considered of minor importance but for special investigations they are often of value.

USES OF SAND AND GRAVEL

Concrete

Within the past few years the use of concrete as a building material has shown a remarkable increase and each year new uses are being found. Decided progress has recently been made in the study of the effect of sand and gravel in concrete mixtures. A brief survey of the requirements for sand and gravel aggregate is given as an aid in selecting the best available materials.

Gravel or crushed rock, the coarse aggregate, forms the bulk of the concrete and the large interstices or voids between these gravel particles are filled by sand, the fine aggregate; the small voids between the sand grains being in turn filled with cement. By choosing the proper amounts of coarse aggregate, fine aggregate and cement and thoroughly mixing with the right amount of water, a strong, dense, impermeable concrete is formed. The apparent simplicity of concrete has led many to use almost any type of sand and gravel in almost any proportion, with a resulting poor product that early requires replacement.

Grading of the aggregate. Investigation (Taylor '25) has demonstrated that the relative proportions of grains of different sizes have a great influence on the amount of cement needed and on the final strength of the concrete. Formerly it was considered necessary to have these percentages distributed so that there would be present equivalent amounts of each grain size, that is, a uniform grading. In addition, stone of large size was thought to make the strongest concrete; a graded mixture, in which the maximum size of the stone was two and a half inches in diameter giving stronger concrete than a mixture where the maximum stone was one inch in diameter.

With these ideas in mind, large users of sand and gravel have drawn specifications for concrete aggregates. Today many state highway departments and city engineers are requiring sand and gravel producers to meet certain definite specifications regarding the amount of material in each grain size. That such requirements have resulted in greatly improved concrete is undoubtedly true, but the tendency has been to make these specifications too inflexible and thus many sources of supply have been needlessly turned down.

Professor Abrams ('19) has demonstrated that although good grading in both the sand and gravel is helpful, it is of less importance than the necessity of having a coarse sand. Of two sand grains the larger one will have less surface area, in proportion to its volume, than the smaller. Thus the total surface area of a given volume of coarse sand will be much less than the surface area of an equal volume of fine sand, and will require much less cement to develop the same strength.

Professor Abrams's conclusions, reached after three years of experimenting, during which time many thousands of tests were made, are in part given below, as they throw an entirely new light on the question of grading.

1 The fineness modulus (see page 42) of the aggregate furnishes a rational method of combining materials of different size for concrete mixtures.

2 Aggregates of equivalent concrete-making qualities may be produced from materials of widely different size and grading. In general, fine and coarse aggregates of widely different size or grading can be combined in such a manner as to produce similar results in concrete.

3 The aggregate grading which produces the strongest concrete is not that giving the maximum density (least voids). A grading coarser than that giving maximum density is necessary for highest concrete strength.

With such a series of experiments to prove that aggregates of widely differing grading and size may be combined to give excellent results, it would appear that some of the present specifications for concrete sands and gravels are entirely too narrow and should be revised. Incidentally it would seem worth while for the producers to become familiar with this flexible system of grading, by use of the fineness modulus, and thereby be able to arrange their loading to meet any fair specification.

Cement-water ratio. No one fact in the design of concrete mixes is more striking than the weakening effect of excess mixing water. The influence of the amount of mixing water is so fundamental and so outweighs differences in aggregates and the grading of aggregates that the assumed strength of concrete for the purpose of design can be defined by the number of gallons of water to a sack of cement in the mixture.

The old method of stating proportions, such as 1-2-4 (1 cement, 2 sand, 4 gravel) and mixing with water until workable, is about to be discarded in favor of the water-cement ratio. With this scheme an engineer obtains the strength desired by specifying the gallons of water to a bag of cement, leaving it to the contractor to obtain a well-graded aggregate; and it is a matter of economy for the contractor to obtain a well-graded aggregate, since otherwise, with the water-cement ratio fixed, he is forced to use a large amount of cement to make his mixture workable.

With the present great demand for concrete roads, early high strength is important, so that the road may be thrown open to traffic without delay. This may be accomplished by (1) low water-cement ratio; (2) use of additional cement; (3) use of as coarse aggregate as possible. Concrete pavements are now laid in Chicago and opened to traffic in three days. The mixture contains four and one-half gallons of water to a sack of cement and about two barrels of cement to a cubic yard of concrete.

Summing up: (1) A low amount of water gives strong concrete; for instance, increasing the quantity of water 13 per cent causes the same reduction in strength in an ordinary concrete mixture as the omission of one-third of the cement. (2) A well-graded, coarse aggregate requires less cement and water to make it workable. Thus we see that the water-cement ratio and the fineness modulus or grading of the aggregate go hand in hand.

Cleanness. By far the larger amount of sand and gravel used in New York State is now washed to remove loam, silt, clay and organic matter. Yet some investigators claim that fine material, such as silt, may be a real benefit in lean mixtures with Portland cement and add to the strength of the concrete. Undoubtedly it gives a smoother finish.

Clay or silt, provided it is free from organic matter, will not react chemically with the cement and may be present in considerable quantities without producing an appreciable effect upon the strength of the concrete. It is always a dangerous element, however, and many concrete failures have occurred where silty sands have been used. This is especially true in concrete highway construction where the presence of clay and silt in the aggregate plays an important part in the production of surface scaling.

An interesting illustration occurred in a southern state where a 10-mile stretch of trial concrete was laid in a dirt road region. A beautiful, white sand was shipped from a neighboring state at considerable expense. Within two years the surface began to scale and within five years it had to be entirely resurfaced. The trouble lay in a high silt content of the imported sand. The sad part was that during the road grading an excellent deposit of coarse, clean sand was uncovered but was not used because of a tinge of brown color.

It is common practice to limit the amount of loam and silt to 3 per cent by weight and to regard with suspicion any sand that shows an organic color test. This is the right attitude to take and with further research the need of thorough washing of concrete sands and gravels will be completely vindicated.

Shale particles. Of especial interest to many sand and gravel producers in New York is the effect of shale in the concrete aggregate. In districts where the particles are predominately shale it has been claimed that they will make as good concrete as quartz particles, provided the surface is clean; in other words the strength of the mortar is the strength of the concrete.

The Iowa State Highway Commission has found that the compressive strength of concrete decreases as the percentage of shale increases. Its observations on pavements constructed with shale-bearing aggregates show that much of the shale comes to the surface and is removed by weathering in a few years, leaving surface pits.

Many states have a shale limit of from 0.5 to 1 per cent by weight for the coarse aggregate. Shale in the fine aggregate often is unnoticed, although most specifications require concrete sand to be composed of hard, durable particles, which certainly does not apply to shale.

Flat, thin particles. Throughout the greater part of central, southern and western New York flat, thin, shaley sandstone pebbles are found scattered in the gravels. Particles of this shape, even though otherwise suitable, are a source of weakness in concrete. Even where well bedded in the mortar they may be loaded like beams within the mass, and early breakdown will occur because of flexural failures.

Moreover, such slab-sided pebbles have a tendency to work toward the top during the pouring of concrete roads and, not being firmly embedded because of their shape, break out and leave surface pits. Such gravels always have a high abrasion loss and usually cause trouble when present in abundance. It is partly because of this type of material, that crushed rock often shows up better in tension tests of concrete than does gravel aggregate.

Cemented aggregate. In a glaciated area where outcroppings of limestone are common, the sands and gravels when finally deposited, often show a considerable percentage of limestone. This sometimes is taken into solution and later deposited as a cement in certain favorable places in a deposit. The resulting cemented sands and gravels look almost like a mass of concrete, with the disadvantage that the cement is usually not so durable. When put through a crusher, compound fragments result and the product is not of first-class quality. Usually such material is left in the bank or hand-picked from the belt, as its use in concrete tends to reduce the breaking strength.

Strength. Is the strength of the mortar the strength of the concrete? Investigation has shown that such is not the case, since mortar tests usually are 10 to 20 per cent greater than the concrete strength. This may be due to several causes, among which are

1 Failure of the bond between the mortar and the coarse aggregate. This may be caused partly by dirty surfaces, lean mixtures or too much water.

2 Weakness in the aggregate itself. Preliminary tests of the aggregate for durability, toughness, weather-resisting ability, hardness, etc. usually demonstrate such a weakness. Aggregates containing large amounts of shale and thin, flat sandstones would come under this general type.

3 Chemical effect of the aggregate. Coatings and a content of colloidal organic matter greatly reduce the strength of concrete.

Summary. A *coarse*, well-graded aggregate that is clean, free from shale and composed of durable, uncemented particles will give an excellent concrete when tempered with a *minimum* amount of water.

Mortars

Since the coarser sands produce the strongest brick and stone masonry mortars, the grains should be as large as the thickness of the joint will permit. Sands whose grains are mostly between 10 and 20-mesh are probably the best, and less than 20 per cent should pass the 80-mesh sieve. In fact, the best mortar sands are practically the same as the fine aggregate of concrete mixtures, since in concrete the sand and cement act as a true mortar.

The present practice of producers is to ship finer sands for mortar work than may be successfully used in concrete. Many masons prefer the finer sands since they make a smoother mortar and work better in close joints. As far as grading and cleanness is concerned, the principles developed for concrete mixing, apply about as well to mortars.

The presence of soluble salts is undesirable in sands used in making mortar, as a scum is formed after drying. Much of the efflorescence found on brick walls is not due to soluble salts in the bricks, but to those in the mortar, which have been absorbed by the bricks and later have risen to the surface. For the same reason, sands dredged from the ocean, unless thoroughly washed with fresh water, usually give trouble when used in mortars.

Plasters

This group includes such terms as stucco, gypsum plasters, lime plasters and cement plasters, and is here limited to those types which contain an admixture of sand. Such plasters are required to cover large areas and to retain their appearance without checking or becoming permeable. Lack of adhesion and cracks in ceiling and wall plasters are usually, according to Searle ('23) due to lack of care or skill in the preparation of the plaster and particularly the use of (1) too small a proportion of sand and (2) sand containing too much fine material. This is brought about by the outer surface of the plaster drying rapidly and contracting, due to loss of water, thus closing the pore spaces and tending to retard the drying of the interior. Stresses are developed and cracks appear, unless the plaster has been kept open by an admixture of sand. If this sand is too fine grained or of insufficient amount, its usefulness is greatly reduced.

Factors such as grading and coarseness of grain, so essential for strong concrete, are not so important in plaster sands, since strength is not the major consideration. Sand for plaster should usually pass a 10-mesh sieve and no grain should be thicker than the plaster coating. Organic material and soluble salts are especially to be avoided. Except in finishing coats, the color is not important.

Asphalt Pavements

Approximately 80 per cent of the wearing surface of a sheet asphalt pavement is composed of sand. The grading of this sand is of great importance and many cities and states have their own asphalt mixing plants where the material is prepared according to close grading specifications. These specifications are usually drawn to quite narrow limits which may vary somewhat with the conditions of use to which the road is subjected. As a general rule, the heavier the traffic the finer the sand used, as coarse grains soon fracture and break down.

Asphalt sands are usually thought of as fine-grained. In fact, they are often produced by using some type of cone classifier or special settling tank. Large percentages of material on the 50, 80, and 100-mesh sieves are the characteristic feature according to Richardson ('05), one of the best authorities on asphalt pavements.

The filler which is used to occupy the voids beween the sand grains may be either fine sand or limestone dust and should pass the 200-mesh sieve. About 15 to 20 per cent of this 200-mesh material is used in the mixture, care being taken to allow for any such material that may be in the asphalt binder itself; for instance, Trinidad asphalt contains 35 to 40 per cent of fine inert matter.

Difference in the shape of the grain and the character of its surface account for many poor asphalt sands that seemingly should be ideal. Various kinds of surfaces behave quite differently toward asphalt cement. Smooth, polished surfaces permit little adherence of the asphalt, while porous surfaces give an exceedingly strong contact but of course use more cement.

The shape of the grains has a marked influence upon the stability of the asphalt surface. Richardson ('05) pointed this out several years ago and suggested that the addition of 200-mesh material would counteract the tendency of round grains to move. More recently, Nicholson ('27) has enlarged this idea, stating that the stability is entirely dependent upon the proportion of the area of the surfaces of the grains that is in contact under pressure. Sharpness of grain has a marked influence upon the stability of the asphalt mix and this influence persists even after the addition of limestone dust. He believes that relative stability is not dependent upon the density of the asphalt mixture.

Few producers in New York operate pits solely for asphalt sand, most of the production coming from a final settling of the fine material washed out of the concrete sands. Many plants are making no effort to save and classify this fine material. It would seem that, in at least some instances, an asphalt sand market could be easily established.

Road Construction

In some states a very important use of sand and gravel is in surfacing roads. Formerly more than 50 per cent of the surfaced roads of the United States were constructed of sand and gravel and today many of the southern and western states are still using this method. In New York State not many roads are at present so surfaced.

Road gravel. The most essential quality of a good road gravel is a binder of high cementing value. Clay is the commonest material used for a binder, but, considering all kinds of weather, it is probably the poorest. If present in excess of 10 per cent it will make mud and allow the gravel to move. Ideal clay gravels contain only enough clay to coat the pebbles, with no free lumps.

Even though gravel should be entirely lacking in clay, the dust abraded by traffic will often render the gravel surface hard and durable. Gravels that come from the pit with the pebbles cemented together, will recement in the road and become harder than they were in the pit. Tests of specimens of this kind always show that there is much lime present and usually iron also, both of which are excellent cementing materials.

It is necessary that road gravel should be largely composed of pebbles of sufficient durability to resist traffic wear. Sometimes gravels near the surface of the gravel bank are so weathered and rotted that they should be discarded. The gravels in New York are excellent for road surfacing, with the exception of those containing shale and soft sandstone. These latter break up readily into clay and sand and, when present in large amounts, will soon cause a road to go to pieces.

Sand-clay roads. The stability of sand-clay roads depends largely upon the type and amount of sand used. With proper sand selection, such roads are hard and durable in all kinds of weather, comparing favorably with gravel roads, but often the so-called sand-clay road is little better than a mudhole.

Sand makes up about 80 per cent of the mixture and there should be just enough clay to fill the voids between the sand grains. An excess of clay allows the sand grains to move under pressure; roads with too small an amount of clay lack bonding strength. In either case the road quickly disintegrates.

In general, the most satisfactory sand is coarse-textured and of angular grain. The best way to determine the value of a sand-clay mixture is to make a short strip of test road and watch the effect of weather and traffic.

Molding

Sands and gravels used in molding are the smallest expense in making a casting, but they are a most important item. Poor sands, the wrong type of sand, incorrect tempering and ramming are daily causing large losses through imperfect castings. The sand as it comes from the pit is rarely used without mixing, and is usually added, a little at a time, to a sand already in use, to replace the burnt-out grains and to strengthen the heap.

The old-time experienced hand molder has given way to quantity machine production and the tendency is to use a particular type of sand for each kind of casting and for each different method of molding. It is not unusual to find the same pattern cast by four different foundries in four different types of sand, and all securing excellent castings, the variation in the grade of sand used being due to different methods of molding.

With the change in molding technic, methods had to be devised to test the physical character of sands and gravels, so that the type best suited for a particular piece of work might be used. In selecting a molding sand or molding gravel the factors usually considered are grain size, grading, permeability, cohesiveness, durability and refractoriness.

Grain size. There is a general relation between the average grain size of molding sands and gravels and the size and type of casting that is poured. For instance, the finer sands are used for small castings of gray iron, brass and aluminum; the medium grades for radiator and bathtub work; and the coarse sands and gravels for the largest, heaviest castings. Although this relation exists, molding practice may upset such a generalization. Thus, fine sands may be used for quite large castings if properly opened up with vent wires; and medium grade sands are often used for small castings, a good surface finish being obtained by applying a special facing mixture. The coming practice will be to use coarser and coarser sands to be assured of easy venting and of withstanding the abuse that quantity machine molding entails.

The present A. F. A. method uses an average fineness figure (see page 40) to divide sands and gravels into classes. Thus a means is given of correlating foundry use with sieve analyses.

Grading. In conjunction with the average fineness of the particles, the distribution or grading on the various sieves should also be considered. Of two sands with the same average fineness figure, one may give an excellent, smooth finish to a casting while the other because of a few large-sized grains may form a pitted surface. Again, of two sands with the same average fineness figure and the same silt and clay content, one may vent badly while the other may make perfect castings, due to a difference in the distribution of the grain sizes.

Permeability. The ability of molding sands and gravels to pass gases is known as permeability and is measured as outlined on page 32. If the gases can not escape easily, scabs and blowholes are formed on the surface of the casting.

Permeability is largely influenced by the shape, size and distribution of the particles. The finer sands have usually a much lower permeability than the coarser sands and are thus limited to small castings, where ease of venting is not so important.

Fine silt, when present in any abundance, reduces the permeability and makes the sand or gravel close and tight. Hence it has been the common practice to attribute low permeability for any grade to the presence of a large amount of silt and clay. So far as the presence of clay is concerned, this idea is not entirely correct, since with proper tempering the clay bond will coat the sand grains and will not clog the pore spaces. An example of this may be seen in the Millville gravels, which often have a considerable amount of clay bond but which give a permeability higher than clean coarse Ottawa sand.

Indeed it is sometimes unfair to attribute low permeability to the presence of fine silt, as the grading or distribution of the grain sizes may be the controlling factor. Whenever there is sufficient diversity of grain sizes so that there are enough particles of any one size to fill the interspaces between those of the next larger size, the sand will have a lowered permeability.

Permeabilities of bonded sands and gravels show a wide range, starting with about 5 for the finest sands and increasing to over 1000 for some of the gravels. It has been the usual custom to speak of high, low and medium permeabilities by roughly dividing this entire range of from 5 to over 1000, without considering the fineness grade of the sand, yet in actual practice the grade of the sand and its permeability are closely linked together. Foundrymen usually change their order to a coarser grade simply to obtain increased permeability. Moreover, in placing an order for any particular grade, an open sand is often specified since for each grade of sand there exists high and low permeabilities.

Therefore, since permeability is so intimately associated with the fineness grading of molding sands, both from a practical as well as from a theoretical viewpoint, it would seem advisable to think of permeability in terms of the fineness grades.

For instance, a permeability of 13 would be high for a fine Albany sand and such sand would be considered open; for a stove plate

Albany, a permeability of 13 would be the usual amount; for a medium grade Albany, 13 would be quite low and the sand would be considered tight. A permeability of 13 by itself, without the fineness grade of the sand being given, would have little meaning.

Cohesiveness or bonding strength. The presence and behavior of the bonding material is the criterion that distinguishes molding sand from all other sand. That the bonding material is not necessarily clay has been appreciated for some time, yet the terms "clay bond" and "clay substance" are rather widely used. Our present knowledge tends to show that this bond is usually a mixture of oxides and hydroxides of iron, alumina and silica in a state of extremely fine division. We call these colloids and think of them as having a netlike or spongy arrangement, with the inherent ability to take up many times their volume of water.

As determined by the A. F. A. method (see page 33), bonding strength may vary from less than 100 grams for weak sands to more than 500 grams for very strong sands. From 150 to 200 is the usual strength of the commercial molding sands.

The grading or fineness of the sand enters into the real bonding strength in only a minor way; the controlling factors are the quality and amount of the bonding material. That is, we can expect to find just as strong sands in the coarse grades as in the fine grades, if there is enough bond present to coat all the grains. Occasionally sands of comparatively low bonding strength stand up well during molding and retain the outlines of very intricate patterns. This has been explained by the angularity of the sand grains, since this type would withstand cutting action and transmit molding pressure easily. In fact a subangular grain, such as is found in Albany molding sands, tends to interlock and form a good face with a surprisingly small amount of bonding material.

Relation of water to bonding strength and permeability (Nevin '25*a*). In former times, and even to a considerable extent at present, the amount of water required for tempering a sand has been left largely to the judgment of the molder or foundry foreman. There are now an increasing number of foundries, however, where the water content of the sand is closely controlled because it is realized that certain defects in castings are traceable to an incorrect moisture content. All sands do not temper alike and each one gives the best results with one certain water content. Lack of knowledge of these facts has no doubt sometimes resulted in a new sand being condemned unfairly, because it was tempered with the wrong amount of water.

At first glance it would seem that the former practice of adding just enough water to make the sand cohere is correct, but with recently devised testing methods it has been demonstrated that many sands reach their best strength and permeability with the addition of 2, 4 and even 6 per cent of water above the point where formerly they would have been considered correctly tempered. This additional water does not appear to clog the pores and make the sand tight, as claimed by some foundrymen, but in reality, up to a certain point, opens up the sand.

As water is added to a molding sand both the permeability and cohesiveness show a progressive increase up to a certain maximum and then, with the continued addition of water, they decrease either slowly or rapidly, depending upon the type of the bonding material. Sometimes the same percentage of water will give both maximum permeability and maximum cohesiveness, but often this ideal condition does not happen.

It would seem that the best sands for foundry practice are those that develop their maximum cohesiveness and permeability with the same amount of tempering water. Among such sands certain ones show a relatively small variation in both permeability and strength over quite a wide range in the amount of tempering water. Such sands are ideal and will stand the abuse of machine molding. Others show a rapid change in either the permeability or cohesiveness, or sometimes in both, with a small variation in the water content. These sands require careful watching so that the tempering of the heaps may always give the best results.

Those sands which develop their maximum cohesiveness with one amount of water and the maximum permeability with another, always present something of a problem as the choice must be made as to which of these physical properties to sacrifice, especially if there be several per cent difference in their best water content.

Durability (Nevin '26). The ability of molding sands and gravels to withstand the effects of repeated pourings of metal without becoming quickly burnt out and worthless, is known as durability or life. Other things being equal, the finer sands stand up best, as they are used for light castings and are thus subjected to a smaller heat effect. Different types of metal also exert a considerable influence on the life of molding sands, as some have a strong corrosive action.

Fundamentally, the type and amount of bonding material are the controlling agents. Certain sands that have an enviable reputation for long life possess the ability to rehydrate and become sticky upon the addition of water, even after many castings have been poured.

Naturally the foundryman endeavors to select sands that have a long life since they require relatively small additions of new material.

Refractoriness. Because of the fluxing action of the bonding material, a molding sand usually fuses in a narrow zone surrounding the casting. When the fusion is marked, the sand sticks tightly to the casting and must be cleaned off at considerable expense. Such sands are avoided as much as possible. On the other hand, certain sands, although having their bond entirely destroyed immediately next to the casting, do not adhere when the casting is pulled and thus remain behind to contaminate the heap, quickly reducing its strength.

The ideal sand is one which is refractory enough not to fuse tightly to the casting, but which, nevertheless, has fused sufficiently to adhere and be pulled out when the casting is drawn. Such sands peel off nicely, leaving a smooth finish, and the burnt sand may be discarded, thus leaving the heap in excellent condition. Most of the well-known commercial molding sands are of this character.

Cores

To form molds for the interior spaces in castings, core sands are used. These may be either naturally bonded sands or, as is more often the case, sharp, pure sands to which a binder must be added. A variety of artificial core binders are on the market, and practically all of them require baking at a low heat, when mixed with sand, to develop their strength.

Cores are made in a wide variety of shapes and sizes. Depending on the size of the core and the surface finish desired, core sands include the very finest of sands, as well as the medium to coarse grades and even fine gravels.

Satisfactory cores must be strong when placed in the mold, and yet should crumble apart after being subjected to the high heat of casting, so as to be easily removed. Organic binders meet these requirements successfully, as they are largely destroyed by the casting temperature. Where "green sand cores" or naturally bonded sands are used, a very small amount of bond is preferable, as otherwise the core will bake hard and be difficult to remove.

High permeability is exceedingly important, because the cores are surrounded by a considerable mass of molten metal and also the burning out of organic binders forms a large volume of gas. The best permeability is obtained where the sands are free from silt and clay and are approximately of one grain size. Some core sands are shipped directly from the pit, but it is the exceptional deposit that does not require washing and sizing. Many of the rounded grain dune sands and beach sands are used extensively and almost any siliceous sand, if washed and screened to the desired size, will make satisfactory cores.

The amount of lime and other fluxes in the sand must be kept under 5 per cent to prevent the cores baking and becoming hard. Another physical property that is often overlooked is the condition of the sand grains themselves—whether the surfaces are hard and smooth rather than soft and porous. In the latter case, a large excess of binder is needed to develop the proper strength, as much of it will be absorbed by the porous grains. This item should always be checked when new sources of core sand are sought.

Refractory Materials

Furnace bottom sand. In open-hearth furnaces used for making steel and in furnaces for malleable iron, the bottom is formed of sand and crushed silica rock. A total thickness of about three feet is built up, and near the top, sand is the main material. The purpose of the sand hearth is to form a bottom that will not react with the metal and yet will absorb any slag remaining after tapping the furnace.

Only the more siliceous sands may be used for this purpose, usually analyzing 95 per cent or better of SiO_2. Fluxes, such as magesium, calcium, sodium and potassium, are not desirable and should be less than 2 per cent in amount. Angular to subangular grains are more satisfactory, since rounded grains do not have so high an angle of repose and it is necessary to maintain a steeply sloped "bank" on the sides of the open-hearth.

Fire sand. This group is sometimes included under furnace bottom sand but is here separated so as to include only those refractory sands that have some natural bonding material. Usually this bonding material is clay, and the more nearly it is a true fire clay the better. Such sands are used for lining and patching furnaces, ladles, and surfaces subjected to high heat.

Steel sand. Any pure, highly siliceous sand that does not contain a large percentage of fine material, may be used as molds for steel castings. Four per cent or more of high grade fire-clay is added to give the sand coherence. Since the heat of steel casting is extremely high, steel sands must be at least 96 per cent SiO_2 and most of the commercial sources of supply run 98 per cent or better. A large amount of fine material, even though it is of a siliceous nature, is not desirable because fusion occurs more readily. Many of the glass sands make excellent steel sands.

Pig beds. As molds for casting pig iron and as feeders or runners to the pig beds, a siliceous sand of fairly high refractoriness is used. Any clean, sharp sand that is low in fluxing material is usually satisfactory.

Silica bricks (Ross '19). For some purposes silica bricks are superior to fire bricks made of fire clay since they are more resistant to corrosion and have a slightly higher thermal conductivity. According to Searle ('23), they are especially good in furnaces where strength is required at high temperatures, since they do not soften gradually as do fire clay bricks, but retain their shape to a high temperature and then fail suddenly. The chief disadvantage of silica bricks is that they are unable to withstand sudden changes in temperature.

Any pure siliceous sand, such as a steel sand, is satisfactory. Whenever a variety of grain sizes or a graded mixture of grains is present, less bonding material is required. The bond is lime and the amount is kept as low as possible.

Filtration (Hazen '03)

A majority of cities in the United States which use surface sources, such as lakes and rivers, as their chief water supply, have installed sand filtration plants to remove suspended material and bacteria.

Sand filters are built to three feet or more in thickness and consist of layers of coarse gravel or broken stone at the bottom, grading into fine sand at the top. The sand bed should be at least one foot thick and composed of carefully graded and washed material that has passed strict specification.

Effectiveness of a sand filter is due to two factors: (1) the retention of suspended matter in the pore spaces between the sand grains, and (2) the formation of slimy, jellylike vegetable and colloidal material which further reduce the size of the pore spaces and so arrest a large portion of the bacteria.

The grading of a sand filter is important, since it directly controls the uniformity of flow through the filter, as well as the rate of filtration. A coarse sand filters rapidly but gives only partial purification, while a very fine sand gives good purification but filters slowly, soon becomes clogged and requires frequent changing.

Hazen, in 1892, established two factors, the "effective size" and the "uniformity coefficient," which he states control the filtering action of a sand bed. The "effective size" is expressed in millimeters and is such that 10 per cent of the sand by weight is finer and 90 per cent coarser; in other words, it is the size of screen opening through which 10 per cent of the sand would pass. The "uniformity coefficient" is the *ratio* of the size of opening of which 60 per cent is finer to the size of opening of which 10 per cent is finer (the effective size). If all the grains were exactly the same size, the uniformity coefficient would be unity.

These factors are determined most readily by plotting the screen analysis as cumulative percentages on logarithmic paper. Printed plotting forms with this ruling are furnished by manufacturers of testing sieves.

Some difference of opinion exists as to the specification limits to enforce, but usually an effective size between 0.4 and 0.6 millimeters and a uniformity coefficient between 1.3 and 1.6 give the best results.

Wind blown and beach sands furnish an excellent source of supply because they are usually well sorted. To meet the rigid specifications generally enforced, it is necessary for filter sands to be washed and screened to close sizes. Many plants produce filter sand as a by-product and wherever proper screening facilities are at hand this would seem to be worth while, since a premium over ordinary building sand is paid. Of course, to be profitable, it is necessary to use a deposit which has a large amount of the size of sand required.

Clay Products (Searle '23)

Sand is used quite extensively in the clay industry for the following purposes:

1 To reduce the plasticity and shrinkage of clay. The sand should be fine-grained, leaving no residue on the 80-mesh sieve. Sometimes as much as 30 per cent sand is added.

2 Fine sand is sprinkled in the mold to prevent the bricks from sticking.

3 To prevent tile, pottery, bricks etc. from sticking together during drying and burning, sand is often used to separate them.

4 As an ingredient in some glazes, pulverized sand forms a minor constituent.

Glass Making (Weigel '27)

In some states glass sands form a very large tonnage and are an important economic product. In New York State there were formerly 10 glass factories obtaining their supply of glass-sand from as many different local pits. Today only one small sand operation has survived.

Practically all sands for glass manufacture must be washed to remove impurities, which are abundant in the fines. It is generally the practice to discard any sand over 20 mesh, and to limit through the 100 mesh to 5 or 10 per cent.

For the best grade of optical glass iron oxide should be less than .03 per cent; for plate and flint glass less than .05 per cent; for window glass less than 0.3 per cent; for green glass less than 0.5 per cent; and for amber glass less than 1 per cent. Calcium and magnesium oxides are kept below 0.5 per cent and silica should be 98 per cent or better.

Ballast

An interesting change has recently been brought about in the ideas regarding washing gravel for ballast. Formerly it was thought that less than 20 per cent sand permitted the pebbles to shift under a load. Accordingly one-third sand was always mixed with the gravel. Today the amount of sand is limited to 3 per cent and stability of the road bed is secured by a proper grading of the gravel. This is of importance to New York producers since a large amount of washed gravel is annually sold to the railroads.

The present standard specifications for the United States are:

Gravel for ballast shall be so prepared that all dust, dirt and loam are removed, that all aggregates that will not in every position pass through the 1½-inch ring are either rejected or crushed and returned to the ballast and that the resultant product conform to the following:

Where the percentages of crushed material run between nothing and 20, the ratios of the various sizes of aggregates to the whole shall be as follows:

1/10 to ¼ in. 25% to 40%
¼ to ½ in. 20% to 30%
½ to 1 in. 20% to 55%
1 to 1½ in. 0% to 35%

Where the percentages of crushed material run more than 20 and less than 40, the ratios of various sizes of aggregates to the whole shall be as follows:

1/10 to ¼ in. 10% to 30%
¼ to ½ in. 20% to 35%
½ to 1 in. 20% to 60%
1 to 1½ in. 0% to 50%

Where the percentage of crushed material is more than 40, the ratios of the various sizes of aggregates to the whole shall be as follows:

¼ to ½ in. 20% to 35%
½ to 1 in. 25% to 60%
1 to 1½ in. 5% to 55%

The amount of silt is limited to less than 1 per cent and the gravel aggregate must be sound and unweathered.

Abrasives

Sand-blast sand. Sand-blasting was first used for "frosting" glass and then later it was widely adopted for cleaning castings in the foundry, which is still its most important use. Recently the process has been used for engraving and carving on stone, for cleaning paint from wooden and metal surfaces, and for cleaning the walls of buildings.

Several grades of sand are used, the finest passing through 20 and being caught on 35-mesh, and the coarsest passing through 4 and being retained on 8-mesh. The sand should be composed of quartz, free from silt and fines, and may be used over and over until reduced to dust. Ability to resist shattering is important and although all quartz grains have about the same hardness, there is considerable difference in toughness. The only good test is in actual use under plant conditions.

Some difference of opinion (Eardley-Wilmot '27) exists as to the relative merits of sharp angular and smooth round grains. Angular grains are supposed to cut faster but wear away quicker, while rounded grains last longer and give a smoother finish although the speed of cutting is slower.

Glass-grinding sand. For rough preliminary grinding of plate glass, sand is universally used. Local or nearby sources of supply are drawn upon, since almost any clean sand will answer the purpose. Such sand is screened through a 20-mesh sieve to remove oversized grains and to prevent deep scratching.

Sandpaper. Before the introduction of emery and garnet paper, sandpaper had a wide use. Today it is practically limited to finishing woodwork and even here a crushed quartzite is more satisfactory than a natural sand.

Stone sawing and grinding. Any cheap quartz sand that is clean and from which the fines have been removed may be used for sawing and on the rubbing table. If the sand grains are all of about the same size, faster cutting results. The sand is usually screened through the 10-mesh and any material through 100-mesh is discarded.

Engine Sand

Engine or traction sand (Weigel '26) should be fairly uniform in size, and free from large clay lumps or foreign material that would choke the feed pipes. Dust, clay or other impurities that would tend to absorb and hold moisture should be absent.

Although engine sand must be free-running and absolutely dry when used, the bulk of it is shipped wet and dried at the storage station. An ideal engine sand would pass the 20-mesh and be retained on the 80-mesh. One railroad requires the sand to be 95 per cent quartz, and in such a case, some of the poorer grades of glass sand are used.

Sand-Lime Bricks

Briefly, the manufacture of sand-lime brick consists in mixing sand and hydrated lime, molding under pressure, and hardening in a steam bath to form a bond of hydrous silicate of lime. Five to 20 per cent of lime is used.

Sands for sand-lime brick should have most of the grains between 60 and 100-mesh (Peppel '05). More than 10 per cent of clay will cause the product to disintegrate easily under the influence of weather. In 1926 more than $150,000 worth of sand-lime brick was produced in New York.

Minor Uses

Although of considerable importance many special sands are produced in relatively small amounts. They usually command a better price than building sands and many companies not now producing these special sands might be able to supply a local demand by slight additions to their plants. Such by-products of the ordinary sand and gravel operation are of considerable value over a period of a year's business.

Parting sand. For partings in molds used in the foundry.

Facing sand. As a facing on molds to aid in giving a smooth finish.

Abrasive soap. Often the abrasive content of soap is fine sand.

Cushion sand. As a seat or cushion for belgian block, wood and brick pavements.

Blotting gravel. In the annual retarring of asphalt roads, pea-sized gravel is used as a blotter.

Roofing gravel. Formerly of wide use, with tar or asphalt as a binder.

Roofing sand. Used to coat composition shingles and as a surface agent to prevent the sticking of tar paper.

Filler sand. Widely used in fertilizer, paint and paste wood fillers.

Sand for pulverizing. Because of the cheapness of sand, it is often ground and sold as pulverized silica.

Chemical use. As a source of silica, pure quartz sand (SiO_2) is sometimes used. A larger use is in the preparation of sodium silicate or water glass. Some silicon carbide is also prepared from sand. Any chemical use requires pure quartz sand, such as a high-grade glass sand.

METHODS OF PRODUCTION AND PREPARATION

Introduction

Because this subject has always been an actively disputed theme among producers and doubtlessly will always continue to be, it is approached with hesitancy. An easy manner of escape would be merely to describe the different machines used, but this would hardly seem worth while since almost everyone is familiar with the equipment. Instead, an analysis of the methods used in New York will be attempted and the conditions under which a particular scheme seems to work to advantage will be outlined.

To lay down hard and fast rules regarding the best method for the development of a sand and gravel property is manifestly difficult. Local shipping conditions, the character and thickness of the deposit, the amount of overburden, the daily tonnage desired, the height of the ground water level and a dozen other equally important considerations all influence the method of production and preparation that is chosen. The fact that so many of the successful producers have recently changed their methods of development and plant treatment, or are contemplating such a change, is striking proof of the uncertainty and difficulty attending such a seemingly easy operation as the handling of sand and gravel in the best way.

After having visited the major operations scattered throughout the State, one has the advantage of a bird's-eye view that is helpful when contrasting and sizing up the schemes used to handle similar situations. If plant managers had the opportunity to go outside their territory and visit noncompeting plants, many good ideas could be exchanged, the methods of handling sand and gravel improved, and the cost lessened.

Location of Plant

The number of producers that would like either to move their plants a short distance or to turn them around to face another direction is large. Sometimes, it is true, improper location of the plant is due to carelessness, but usually the location has been given careful thought. It is surprising, therefore, to find so many plants poorly located.

One reason is a necessary change in the method of excavation. Plants that may have been properly located for one method of excavation are decidely in the wrong position when the method is changed. The resulting makeshift remedy invariably handicaps the daily production.

Another reason, which perhaps is more usual, is because of a change in the direction and character of the deposit. It is not unusual to find a plant stranded, so to speak, alongside of unusable material, with the best part of the deposit at a considerable distance. Again, some plants were built to handle material from one direction, while unfortunately the best part of the deposit proved to be in a different direction. The rearrangements necessary to overcome such a condition, such as more trackage, wing belts etc., always increase the cost of production and slow down the output. Careful sampling of the deposit should always be carried out before the plant is located.

The usual picture presented by a sand and gravel operation, with the plant on one side and development proceeding in only one direction, is caused often from necessity. The topography of the country, the need of storage space, the cost of increased trackage—all these tend to make the initial location at the edge, rather than in the center of the deposit. It would seem feasible, however, to have large operations with a 10 or 15-year reserve, located more in the center of things so that development could proceed in all directions. Even if a temporary small plant, a few hundred additional feet of main track and the handling of some material several times were necessary in order to make an initial excavation for the site of the permanent plant, the resulting increase in production due to a central location and short hauls would soon more than repay the extra expense.

Excavation and Transportation

Since some methods of excavation also carry the material to the plant as part of the same operation, it is more convenient to consider excavation and transportation together, even though they are dissimilar topics.

Stripping of overburden. A majority of the sand and gravel producers strip the vegetation, loam and weathered material from the surface of their deposits. In exceptional cases, where the bank face is high—75 feet or over—and the overburden that slides down and mixes in is relatively small, stripping is not necessary, and the final washed sand and gravel show no effect of its inclusion.

Three feet is a general average of the depth of stripping, although some deposits in places require the removal of six or eight feet of material. The thicker the underlying deposit, other things being equal, the more cover may be stripped without financial loss. An interesting operation at Dallas, Texas, strips nine feet of dirt to get 12 feet of sand and gravel.

The most expensive manner of stripping is by hand, but in certain molding sand and glass sand deposits this is the only satisfactory method. For small operations scrapers pulled by horses or tractors are used. In larger operations drag line cableways are occasionally used, but power shovels are the generally accepted practice, the material being carried away in trucks or in cars on temporary railroad tracks. An expert shovel operator is able to strip very closely and thus not waste good material. The disadvantage in this method is the double handling of the dirt as well as in finding a place to dump it. Figure 9 illustrates stripping with a power shovel mounted on caterpillar trucks, the dirt being carried away in pit cars.

One of the most economical ways to handle the overburden is by using a drag line excavator having a boom of sufficient length so that the stripping may be cast beyond the working face into the abandoned part of the deposit. With this method the stripping is handled only once and if the deposit is being excavated from above the working face, the same drag line may be used for digging sand and gravel. Figure 1 shows this type of operation, the picture being taken at an early stage, before the stripping was cast beyond the working face. Only two producers are using this method in New York State, although it has been used by several of the limestone quarries for some time. Its efficiency is attested by the fact that the pit at Dallas, already mentioned, is able to strip to such a depth of overburden for only 12 feet of sand and gravel.

The most economical method is to sluice off the overburden by a high pressure stream of water. This is most satisfactory where the land is sloping away from the pit and where there is sufficient water and a place to run the sluiced material.

Drag line scraper. Among the smaller producers the drag line scraper is a favorite method of excavation. No cableway is used, the scraper being pulled backward and forward, always resting on the sand and digging a deep narrow groove. The scraper may operate either on a high pit face above the general level of the plant site or excavate below the general surface level. Figure 2 illustrates this method of operation, the picture being taken as the scraper was pulled back empty.

Naturally since the scraper makes its own track, a considerable amount of material is left behind as ridges between any two successive set-ups (see figure 6). Such a drag line installation is usually arranged so that the excavated material is pulled up a slight incline and dumped in a hopper; from there it is fed onto conveying belts.

Where a large output is not desired the drag line scraper is the usual choice. Its main advantages are a relatively small investment and few working parts to get out of order.

Slack line cableway. For larger outputs, ranging from 200 to 800 yards a day, a permanent mast is installed, 50 to 100 feet in height, near the receiving hopper. A short mast on top of the washing plant is sometimes more convenient. In contrast to the simple drag line, the scraper here is carried on a cableway, hence the name. Figures 3 and 4 illustrate this method of excavation. Within a radius limit of about 800 feet this scraper acts as excavator, conveyor and elevator (see figure 5).

Material may be excavated above or below the point of delivery, and by shifting the "dead man" or tail tower, a wide sector may be covered. A cableway 500 to 700 feet long can excavate over an area of about three acres and besides has the great advantage of being able to dig to a considerable depth under water.

The cost of excavating with a slack line cableway depends upon the character of the deposit, the length of span and the size of the bucket. If electric power is available for the drum hoist, a further saving is made. The longer the span, the larger the bucket that should be used. With an average haul of 500 feet a two and one-half-yard bucket will deliver approximately 80 cubic yards an hour.

For the ordinary deposits and within a capacity of 200 to 800 yards daily, this type of operation is very efficient, the cost running from four to ten cents a cubic yard. It is surprising that more slack line cableways are not used in New York State.

Some of the disadvantages are:

1 Lack of flexibility in digging. Often several grades of sand and gravel may be separately dug at the bank if a shovel were used. This is important in handling rush orders and in preventing the washing plant from being choked by too much of one kind of material.

2 Beyond the usable radius of about 800 feet, the slack line cableway can no longer discharge directly to the washing plant. This means the addition of some type of conveyor, and the advantage of acting as a conveyor and elevator as well as an excavator is thus lost.

3 Drag line scrapers frequently leave the pit with steep grades and narrow ridges of untouched material, thus making rather expensive a

future change to a power shovel, when it is desired to increase the production (see figure 8.)

Drag line excavator or derrick scraper. Scrapers are sometimes suspended and operated from the end of a boom. In fact, power shovels are often furnished with interchangeable booms, so that they may be used as drag line excavators.

Such a system is more flexible and portable than cable drag lines, but the depth to which material may be dug and the radius of operation are not so great. The longer the boom, the less frequently is moving necessary. Digging may be carried to a depth of 40 feet or more and the excavator works excellently in that part of the deposit which may be under water.

Ease of movement from place to place is essential. This is accomplished by mounting it upon standard gage trucks, caterpillar trucks or by a walking device such as represented by the Monighan excavator (see figure 7). This latter type has the additional advantage of being able to operate on a soft, boggy bottom.

The first cost of drag line excavators is high, but on a tonnage basis, maintenance and operating costs are comparatively low. Because of their freedom of movement this type of excavator is also useful in loading stock piles and in stripping the overburden.

Power-operated grab buckets. Grab buckets, usually of the clamshell type, are widely used in excavating, in loading and unloading barges and in the general transferring of material around a sand and gravel plant. They possess the additional advantage of being able to operate to a considerable depth below water level and in fact, when used on floating dredges, are more efficient in deep water than centrifugal pumps.

Generally grab buckets are used on some type of easily movable machine but occasionally, where the deposit is very thick, a stiff-leg derrick is built. Near Boonville, where the deposits are more than 100 feet thick, this type of excavator works satisfactorily. Figure 10 shows a clamshell bucket that has an 80-foot mast and a 75-foot boom, and because of such a radius and since the deposit is very thick, it has been moved very seldom.

Power-driven shovels. For large production, especially where hydraulic methods are impossible, power driven shovels of big capacity are the best. Shovels with a dipper of one yard or less, are often used where other methods of excavation would be more economical, but for the excavation of more than 1000 tons daily, experience has proved the efficiency of shovels. The bigger the operation, the more truly does the the producer's problem become one of excavation. Power-driven shovels offer a flexible method of control. For instance, the Goodwin-Gallagher operation on Long Island, with a total daily production of 18,000 tons, maintains a battery of ten steam shovels; of course all are not often working at one time, but they are available when needed.

Various types of shovels are in general use. The present trend seems to favor those mounted on caterpillar trucks with a three to five-yard bucket. Electric shovels are in many places supplanting steam shovels because they are easier to operate, require less labor and use power only when actually working.

The difficult and troublesome part of shovel operations usually lies in the method of conveyance from the shovel to the plant. Whenever the shovel is waiting for an empty car, production is being curtailed; and whenever the plant is running short of material waiting for laden cars, the expense is mounting. Thus the real problem is to keep an even, continuous flow of material, with an empty car always in position for the shovel and with the main feed hopper to the plant never choked and never empty. In the smaller operations this is seldom attained but in the larger plants surprisingly little lost motion occurs.

One scheme is to use two strings of cars, each consisting of an engine and two or three cars, and while one string is being loaded at the shovel, the other is being dumped at the hopper. These two strings of cars shuttle back and forth, passing each other on a switch located between the shovel and the plant. Even so, the shovel has to wait while the empty string comes from the switch, but this time is usually spent in dressing the bank (figure 17).

Where the haul is longer and too much time would be lost in waiting for the empty cars to arrive, a circular track is laid, so that a string of empties may always be waiting for the full cars to pull out. Usually in such a case, more than two strings of cars are necessary. When properly timed, this method is very efficient.

Some producers use several trucks to take the place of haulage tracks and engines. This method is sometimes of advantage where most of the finished product is shipped in trucks and where a large fleet of trucks is available. Generally, however, such an arrangement is only a temporary makeshift (figure 18).

An ingenious method is used by Henry Steers, Inc., on Long Island and while not unique it is sufficiently new and worth while to merit a description in some detail. A five-yard shovel is used as the excavator and a working face of more than 1000 feet in length and 70 feet in height is maintained; in addition, the pit floor is kept as nearly level as possible. Parallel with the working face is a 30-inch conveyor belt in three sections of 700, 500 and 600 feet, or a total length of 1800 feet. Above this belt is a large movable hopper that is attached to the shovel in such a way that as the shovel moves, the hopper always keeps the same relative position. Figure 11 shows this arrangement.

As soon as the shovel has reached the farther end of the deposit, the first length of belt is moved over nearer to the face. It is built on skids so that it may be moved easily and very little time lost. The other two sections of the belt are moved at leisure after the shovel has started on a new cut.

Obviously this method results in a smooth, even feed to the plant, and since the fact that this plant can turn out 5000 tons of material daily, it is a very efficient operation. Only one other producer in New York is using this scheme. In this instance the production is on a much smaller scale, and the conveyor belt is carried above the working face, the digging being done by a drag line excavator. Figure 1 illustrates this condition. Where the topography is suitable it would seem that other operators could advantageously use this same general idea of excavation and transportation.

Working thick deposits. Before turning to a consideration of dredging and hydraulic methods of excavation, it would perhaps be of interest to consider the precautions used in working thick deposits. How high may a bank face be exploited without danger of sliding and burying the excavator? Since some deposits are 150 to more than 200 feet thick and since it is not unusual to have bad slides on high faces, such a question is of importance.

One solution is to work such deposits at two or more different levels, keeping each face at a height of 30 to 40 feet. At times this is necessary but whenever possible this is avoided as it is usually cheaper to dig the entire thickness from one level.

Where the bank is not cemented the usual procedure is for two men continually to poke the face of the deposit with long rods, causing it to keep a safe angle of repose. With a shovel or other type of excavator digging at the bottom, an experienced man with such a rod can keep the material above constantly feeding down toward the shovel. Figure 12 is an excellent illustration of the value of this method as here a bank over 200 feet in height is being operated without danger.

Another method is to use a miniature drag line attached to a heavy hook. This is swung out over the bank from above and jiggled up and down, thus loosening the face and causing it to seek an angle of repose. Working faces to a height of 70 feet and over have been kept in excellent condition in this manner.

One very common practice is to use light charges of dynamite, especially where the face is partly cemented. A small amount of dynamite mixed with a larger portion of black powder gives a better springing effect than "straight" dynamite. The blasting loosens the bank face, giving it an angle of repose, so that danger of sliding and caving is negligible.

Centrifugal pump or sand sucker. For the production of sand and gravel from lake and river bottoms, centrifugal pumps are installed on specially designed steamers and barges. Within certain limits they are very efficient excavators. The size of the pump is measured by the diameter of the intake and discharge openings, and for this type of work is between 10 and 20 inches, with the usual suction dredge operating a 12 or 14-inch line. Under favorable conditions a 20-inch pump will fill a 1200 cubic yard boat in four hours. A number of suction dredges are operated on Long Island sound, Lake Erie and Lake Ontario.

The flushing action of the pumps causes the sand and gravel excavated by this method usually to be well washed. Often it is sold without further treatment. When additional washing and sizing is necessary the material is unloaded at a land plant, or in rare cases the suction dredge has a built-in screening plant.

Occasionally on land a centrifugal pump is used, and in such an operation it may serve as excavator, carrier and elevator. Where a deposit extends to a depth of 10 feet or more below the permanent water level, an artificial pond can be created and if the sand and gravel is not cemented too strongly a centrifugal pump will be the most economical method of operation. Figure 13 illustrates a sand sucker excavating a bank, containing 60 per cent gravel, to a height of 50 feet above and 20 feet below the ground water level.

If the deposit is slightly consolidated rotary cutters, chain cutters and high pressure under-water jets are used to break the material. When a deposit is firmly cemented a centrifugal pump is not satisfactory and some other method of excavation should be used. High banks above the water level are loosened and kept at an angle of repose by a strong hydraulic stream, such as shown in figure 14.

From 10 to 15 per cent of solids are carried in the pipe line. If it is desired to increase production it is best not to disturb this ratio, but rather to increase the velocity of the water or install a larger outfit. Friction in the pipe is considerable and where the line is long or the lift to the top of the plant is high, a booster pump is a good investment. Figure 16 shows a booster pump installation that practically doubled the previous production of a six-inch pipe line.

In a majority of the excavation methods already described small units are not economical, but in a centrifugal pump land operation this generalization is not true. A comparatively small, inexpensive plant may handle a large amount of material. Figure 15 shows such a plant, which requires only two operators and delivers 500 tons of washed sand each day. Taking all features into consideration, a centrifugal pump land operation is the most economical method of production and where a deposit is unconsolidated and the ground water level permits a dredge to be floated, this method gives the best returns for the money invested, whether the project is large or small.

Ladder or bucket dredges. In excavating under water deposits where the material is more or less consolidated, ladder or bucket dredges are especially efficient. The first cost is greater than that of a suction dredge, but the producing capacity is very large, and excavating may be carried on at a depth of 45 to 50 feet below the surface. These dredges are often equipped with screening and washing machinery so that the finished product may be discharged into a scow alongside.

Hydraulic method. One operator in New York directs a strong jet of water against the working face, and carries the loosened material in troughs to the screening plant. The grade necessary to move the sand and gravel from the pit face to the plant is about two inches to the foot, as this particular deposit carries 60 per cent of gravel. If only sand were present one inch to the foot would be sufficient. Approximately 4 volumes of water to 1 of sand and gravel are required to prevent the sluiceways from clogging.

Unless the deposit is of great thickness or unless it slopes down toward the working face, the grade necessary to carry the material will soon require a height equal to the entire thickness of the sand and gravel. Only occasionally, therefore, may this method be used with success.

Elevation to the top of the plant. With certain excavation methods, such as the slack line cableway, sand and gravel from the pit are dumped into a hopper at the top of the plant; in a majority of cases, however, the excavated material is received at the bottom of the plant.

As elevators, belt conveyors are used most frequently, but when the material is wet the belt must have a flat slope, and is therefore rather long if the plant is high. Bucket elevators operate on a steep incline and are thus able to reach the top of a high plant in a relatively short distance, but they do not wear well (figure 19). A balanced skip has been suggested as the best scheme of elevation, but few New York producers have tried it.

Pumping is not often used, since it is not an economical scheme for high lifts. In fact, many centrifugal pumping operations discharge their load into some type of dewatering arrangement at the foot of the plant.

Treatment at the Plant

More than half of the present production of sand and gravel in the United States goes through a washing and grading treatment, and each year the proportion of pit-run material becomes less. Methods and machines are constantly being improved and as the cleaner sand and gravel deposits become exhausted, this treatment phase of the industry will be accorded a place of increasing importance.

Methods used for preparing sand and gravel are more or less based upon knowledge gained from ore dressing, with some necessary modification due to the fact that the finished product is the larger part of the feed. Big tonnage is the important element except for certain special sands, when cleanness and sizing are the controlling factors. Naturally a glass sand would go through a different sort of preparation than a concrete sand, but the basic laws of crushing, washing and sizing would be identical for both materials. Such broad principles are of general application and therefore are briefly considered, but no attempt is made to discuss special conditions affecting plant design.

Until about 15 years ago each sand and gravel operator was a pioneer, solving his own problems and guided by few or no criteria. Today the technical journals are fertile sources of information since they contain, even in a year's time, the description of hundreds of methods of plant treatment. Perhaps the man most familiar with the entire field is Edmund Shaw, ('23 and '26) editor of Rock Products, and his articles are used as a basis for the following discussion.

Crushing. Rock crushers are used in most sand and gravel plants to break up boulders, cobbles and large pebbles. Such oversize material is removed from the feed by a scalping screen and is sent directly to the primary crusher. Both jaw and gyratory crushers are used, each having some advantages, but where large production is desired the gyratory type is usually chosen. In New York State some of the cobbles are extremely hard, being metamorphic and igneous rocks which the ice brought down from the Adirondacks. The usual type of gyratory crusher, which is suspended from above on an eccentric, does not work well on such resistant rock, and more satisfactory results are obtained with the newer type of gyratory which has a straight throw from top to bottom.

Secondary crushers are used for breaking the gravel into desired grades. This work is usually done by gyratory crushers of smaller size or by discs and rolls. Before the popularity of concrete roads, some plants had an abundance of gravel, and rolls were used to reduce the small gravel to coarse sand. Of course today this has been largely changed and very little gravel is crushed to the size of sand grains, although a few plants are still doing this in order to coarsen their sand and make it eligible for concrete.

For special purposes fine grinding is used and in this connection three general laws are of application, regardless of the type of grinding machine (Martin '26).

Law 1 The surface produced is accurately proportional to the work done. Double the work done and the surface produced is doubled.

Law 2 The number of particles produced increases with the decreasing diameter, according to the compound interest law.

Law 3 The average shape of the particles produced in crushing remains the same whether they are large or small.

Washing and sizing. Although washing and sizing are usually carried on at the same time, they are two distinct processes. For instance in pure deposits and for certain purposes, sand may be screened and not washed at all; glass and filter sands are generally washed first and screened afterwards; and many sands and gravels dredged by centrifugal pumps are washed during this operation and sold without any screening.

Aside from soluble salts, which incidentally are readily removed by washing if a plentiful supply of water is obtainable, the main deleterious substances in sand and gravel are clay, organic impurities, shale and slate, soft sandstones and iron-bearing minerals. Gravels containing a high percentage of soft sandstone, slate or shale are not at present very valuable, as commercial methods for their removal have not been developed. Considerable research has been directed to this problem and doubtlessly some practical scheme will soon be developed for the removal of shale and slate, since the characteristic flatness of these rock particles and their specific gravity give some basis on which to make a separation. Iron oxides do not detract from the value of a sand except for making glass, and special washing methods are used for such material.

This leaves clay and organic matter as the chief impurities and it is to remove these that a majority of the sand and gravel washers are erected. Clay, which is present in almost every deposit, occurs as a film on the outside of the grains and pebbles, as hard, segregated lumps or clay balls and as soft clay scattered through the deposit. Soft clay and loam are easy to wash out, film clay may be removed by scrubbers, but clay balls are difficult to separate and usually require some form of log washer.

Organic impurity, if in the form of acids or soluble colloids, washes out easily; if present as bark, sticks and roots it may be floated away; but if in the form of coal or lignite, it requires special methods.

For close sizing between narrow limits, all types of screens—gravity, revolving, shaking and vibrating—are used. Generally gravel is screened through circular openings, and sand is screened through square meshes. Some agitation has recently appeared for a uniform screening of all sizes through square-meshed sieves, especially since this would aid in calculating the fineness modulus and in meeting specifications based upon that idea. This selection of circular or square openings for the gravel size is not of really great importance as the producer may choose a circular opening that would give the square mesh product desired. For instance, a one and one-half-inch square mesh product would require about a two-inch round opening.

Gravity screens. These can be made to do efficient work, but the screen area must be large and plenty of water must be used. Such screens may be set almost flat and the feed driven over them with a strong flow of water or they may be set at a 45 to 60 degree angle and the material driven against them. Both methods work well. The apertures of the screens should be slots and not round or square holes, the length of the slot being in the direction of the travel of the grains.

Revolving screens are the favorite type, not so much because they screen efficiently but because they are good scrubbers. The objection is that they blind easily, the centrifugal force present tending to drive the particles into the perforations. A roller hung in loose bearings so that it can always rest on the screen is one remedy that is often applied.

The most popular form is a series of conical trommels fastened to a common shaft set at an angle of about 22 degrees, and having the screens arranged from coarse to fine. Each screen has its own separate spray; the oversize is sent to a bin and the undersize is sent to the screen ahead (figure 22).

One disadvantage of the above system is that it requires considerable space both vertically and horizontally. For this reason, jacketed screens are being used, the inner jacket or main section having two and three-fourths inch holes and the others successively smaller holes to the sand screen size. No more than three jackets are combined in this way. These screens are usually built for heavy duty being gear driven around the main section, which leaves everything clear inside so that a four or six-inch pipe can be passed through to supply plenty of water (figure 19).

Another variation is to set a conical screen on a horizontal shaft, with the small end closed. The feed and discharge are both at the large end and jets of water play upon the material where it turns in the screen. Very few producers in New York are using this type of screen, but where used the product is washed quite clean.

Shaking screens formerly were used quite extensively and are efficient. On large tonnages of sand and gravel the vibration is a bad feature even when the strokes of adjacent screens are set to balance one another. Only one large producer in New York is using this method.

Vibrating screens are a comparatively recent development, but their success has been great. They are especially used on the finer sizing and may be employed for either wet or dry screening. Either the whole screen or the fabric alone may be vibrated, both methods being efficient. For close sizing of the finer grades of sand the screens can not be crowded to capacity and the material should be thoroughly dry, to avoid the effect of surface tension. It is expected that the use of vibrating screens will be greatly extended during the next few years and that they will supplant some of the present types of classifiers.

Scrubbers. To insure a clean product the material from many sand and gravel deposits must be put through a preliminary scrubbing to loosen the dirt film from the grains. Some types of scrubbers are a separate unit placed ahead of the screens, but many producers use the combination of scrubber and cylindrical screen. In this case a solid steel shell is placed ahead of the first screen and merely forms an addition, being driven as part of the screening unit (figure 19).

Most of the scrubbers used today are of the rotary type having lifters and short lengths of chain which agitate the material and slowly move the water, sand and gravel toward the discharge end. Sometimes, instead of lifters, pieces of angle iron are set like the threads of a screw, thus determining the rate of movement of the material. Baffle rings also are used to hold a body of material in the scrubber, as it is the rubbing of the grains and pebbles upon each other that really loosens the clay. A few designs permit a separation of the dirty water at the scrubber, before delivery of the material to the sizing screens, and thus give a cleaner product.

Washing sand. As we have seen, gravel is washed by filtration, but this scheme can not be applied to sands. Any filter with small enough openings to hold back the sand grains soon becomes clogged with clay or with silt and the washing ceases. Therefore sands are always washed by decantation. With this method the percentage of clay removed and the percentage left with the sand are proportional to the water removed and left with the sand. Hence it is possible to estimate the amount of water required to give a clean sand, provided the amount of clay is known.

Many forms of settling tanks are in use, in which the sand settles, allowing the water with the clay and loam to overflow. Simple rectangular bins or tanks that are filled with sand, permitting the dirty water to escape at the sides, are common. This type is not so efficient as the bin that has an adjustable overflow gate, which may be raised as the sand increases in depth, thus keeping a constant shallow flowsheet of moving dirty water. Operation is necessarily intermittent, and therefore two bins are used, one being emptied while the other is filling. Considered as classifiers, these belong to the surface current type, and the sand drops out as a roughly graded product with the coarser sand being near the feed inlet.

In large plants the settlers in which the sand is washed and caught are continuous in operation. These automatic tanks are often built in the form of a cone or a pyramid. In the cone type the inlet is at the center and the overflow of water and clay occurs around the periphery. In the pyramid type the flow is from one side to the other. The settled sand is maintained at a nearly constant depth by an automatic discharge valve. Such a tank will wash and dewater one grade of sand, and different grades can be produced by using a series of tanks. The usual scheme is to have a small tank receive the feed and classify a coarse grade and the overflow is then led into a larger tank where a finer grade is caught (figure 20).

Automatic sand settlers, in general, give a much cleaner product than hand-controlled operations. This is partly because the depth of the sand bed is kept nearly constant and partly because there is no danger of forgetting to close a valve in time to prevent the inrush of dirty water.

The drag type of sand tank, which has been adopted from ore dressing, is very widely used in New York State (figure 15). One big objection is the excessive wear on the cross-flights. Another scheme, the double-screw type of sand washer, has been used very satisfactorily in the glass sand industry and has recently been installed in several concrete sand plants. This washer consists of two spiral screws revolving in opposite directions and pulling the material up an incline from the washing tank. The use of water jets, which hit the sand as it is pulled up the incline, give an extremely clean product and doubtless this screw method of washing will be used more widely within the next few years.

In some washing devices a stream of water is introduced near the bottom of the tank and acts in conjunction with the surface flow. This method is really a hindered-settling classification and is especially useful for close sizing, as, for example, filter sands. In addition to better sizing, the rising current also tends to make the sand cleaner and will no doubt be used more extensively as some of the poorer deposits are opened and as the demand for cleaner sand increases.

Dewatering. One very troublesome problem in the treatment of sand is to get rid of the excess water. This may be partly accomplished in the drag line and double-screw types of washers by pulling the sand up an incline. The longer the incline above the water level, the better an opportunity for drainage. Automatic sand cones and tanks also partly dewater the sand, delivering it with a moisture content of about 25 per cent.

All the above-mentioned methods deliver sand in a dry enough condition for loading into railroad cars, but not dry enough for loading into barges. In fact some of the large operations on Long Island, where all of the material is shipped by barge, are forced to allow their sand to drain for at least 12 hours. This necessitates additional storage bins and in some cases additional washing tanks.

Furthermore, dewatering is something of a problem in handling the discharge from a centrifugal pump. With several thousand gallons of water a minute, containing only 12 to 15 per cent of solids, such as the average pump delivers, the usual washing plant is not able to make a satisfactory tonnage of clean material. Among the methods that are used to dewater such material are:

1 Pump to a sump and excavate the settled material with an elevator of the digging type, or pick it up with a clamshell bucket and drop it onto a conveying belt.

2 Pump to a dewatering screen at the head of the plant. This is the most economical and is used if the lift is not too high.

3 Pump to five or six settling boxes and let the overflow go over three sides. Have a gravel drainage in the bottom of each for the escape of the excess pore water. A gate at the side permits the settled material to run onto a conveyor.

4 Pump to a sump over a tunnel in which skips run.

5 Pump to barges and transfer by derrick to a hopper over a conveyor.

6 Drop the discharge into the water near the plant, dig it out and lift it to the screens by a drag line cableway.

Loading of the Finished Product

Not very long ago it was possible to form an estimate of the capacity of a plant from the size of its storage bins. Today this is far from a safe method as many of the very large plants, where from two to four cars may be loaded at once, have storage bins only slightly bigger than is necessary to take care of the output while cars are being shifted.

On the other hand, many producers still have large storage bins and these are specially useful if the haulage is by automobile truck. Figure 23 shows the loading chutes of a plant that delivers about 800 yards a day to trucks. Usually these bins are of steel or concrete, although wood is still used, even in the newer plants.

Open storage piles with a tunnel feed have recently been used to great advantage. This method has many points in its favor, not the least being the ease of storing a large reserve and the facility with which a mixed feed of more than one size material may be delivered. Either belts or skips may be used as conveyors. An ingenious scheme is the application of open storage to the loading of automobile trucks. Here a large underground tunnel is built of concrete and the trucks drive in at one end and out at the other.

An interesting contrast is furnished by two large adjacent plants on Long Island, both loading into barges. In one case the loading is all done with locomotives and pit cars. One reason for this is that much of the output is bank-run material. Thus the same equipment that is used in the pit is also used for loading the washed sand and gravel. The other plant, which is just as far removed from the barges, loads entirely by belt conveyor. Figure 24 illustrates this arrangement.

One producer had trouble in keeping gravel from segregating into coarse and fine layers as it was loaded into railroad cars. Indeed this is a common complaint and sometimes cars are rejected because of such segregation. The difficulty was overcome by using a large gasoline locomotive which jerked the cars back and forth several times during loading. In addition, the speed with which cars were placed was greatly increased, thus making this additional equipment well worth while. Doubtlessly this tendency of the gravel to segregate could have been overcome by changing the height and shape of the loading chutes.

Disposal of Waste

Whenever a sand and gravel plant is located in a city, the disposal of the clay and silt carried away by the wash water is a serious problem. Even when a considerable distance from towns, the producer is not permitted to discharge dirty wash water directly into streams or rivers, since this act is construed as stream pollution.

Some operators manage to evade the issue by allowing the discharge to meander over a flat or a swamp area, which is thus slowly aggraded. Others, where the topography permits, throw an earth breastwork across a ravine and use the dammed area as a catch basin. Still others build settling ponds and, by using a built-up gate, control the height of discharge, thus maintaining a continual flat slope so that the fine material may settle. Such a scheme works admirably except that the size of the settling pond is usually small and frequent dredging and rehandling of the settled material are necessary.

One of the best methods is to return the wash water to the worked-out part of the pit, retaining it there by a dike of waste material. Usually there is a considerable underground seepage so that the overflow does not present a serious problem. In order to make this method successful, a definite plan of development with this object in view must be initiated early in the operation of the pit.

DESCRIPTION OF THE MAJOR SAND AND GRAVEL OPERATIONS BY COUNTIES

Sand and gravel operations are so widespread and many of them are of such a temporary nature, that it is difficult to make a complete survey. The following deposits and operations, however, are representative and cover the more stable phases of the industry.

Albany County

Extensive operations are carried on in the production of sand and gravel for building and construction work. The deposits are often water-sorted morainal accumulations. For many years this county has been famous for its deposits of molding sand, and shipments have been made to all parts of the United States. These latter have a different origin and distribution.

At one time the territory around Albany must have been an immense sand plain, devoid of vegetation and covered with active sand dunes. Today some of this dune sand is used for plaster and mortar work, but usually it is too fine in texture for concrete.

Albany Gravel Co., Inc. On the northern outskirts of Albany, a deposit of sand and gravel with some boulders has been opened to a depth of about 125 feet. The upper part of this bank contains considerably more gravel than the lower part. Both drag line and steam shovels are used in excavating, the steam shovel being used for the selective loading of bank-run material, of which about 800 yards is dug each day (figure 25). The washing and screening plant (figure 23) has a capacity of about 800 yards a day and produces four grades of gravel, and concrete sand and plaster sand. The entire production is shipped by automobile truck and is the main source of supply for Albany and the vicinity.

Because of the proximity to the city, some trouble has been encountered in disposing of the silt and loam from the washing plant and the present remedy is to use a settling pond. Sample 6211 represents the concrete sand and sample 5893 the average run of the gravel. Because of a large percentage of shaley sandstone the abrasion loss is 22 per cent and indicates that this gravel is not the best type of concrete aggregate.

This same deposit reappears on the east side of the Hudson river in the city of Rensselaer, opposite Albany, and also can be traced to the northwest in a continuous line of elevations that reach 350 feet or more above the river level. Openings have been made in Rensselaer and at several points in the town of Colonie, adjacent to Albany, where considerable quantities of sand and gravel are obtained.

The Albany county molding sands represent the last of the glacial lake deposits, occurring in thin beds that overlie the lake clays and that are covered directly by the soil. They spread over extensive areas on the terraced plain that reaches back from the Hudson river toward the limiting valley ridges (Newland '16; Nevin '25).

Allegany County

Both concrete and molding sands are produced in this county under a variety of geological occurrences. The largest production of concrete sand comes from a thick glacial delta at Alfred, and locally a few small producers are obtaining sand from similar deposits. An interesting operation occurs at Fillmore, where concrete sand and gravel are taken from a creek with a drag line.

Molding sands are represented by both stream and river flood-plain deposits.

Alfred Sand and Gravel Co. Approximately one-half a mile north of Alfred Station occurs a high delta deposit that was formed during an early stage in the glacial lake history of Allegany county. This deposit has been opened to a depth of 100 feet and is rather clean, although only a small amount of gravel is present. The sand shows rapid variation from coarse to fine pockets. Stripping is necessary to a depth of three feet. This sand is not washed but is loaded onto automobile trucks by portable elevators and hauled to the Erie Railroad, one-half mile away. Sample 6352 is representative of both the sand and gravel.

L. S. Gelser and Son. At Fillmore, sand and gravel are dredged from Cold creek by a drag line. During the spring freshets sufficient material is brought down by the high water to fill the hole excavated during the previous season. Some control of the proportion of sand to gravel may be exercised by slightly shifting the tailpiece of the drag line either up or down stream. A crusher is installed and any size of gravel may be produced. Because of the distance from a railroad, most of the material is used locally or is made into concrete tile and posts. Sample 5745 represents the gravel and sample 6444 the sand. In this particular district the stream and river deposits carry a high percentage of flat sandstones, which somewhat detracts from the value of the gravel.

Belmont. On the Will Graham farm one mile south of Belmont is a yellow-brown molding sand suitable for medium-sized castings. This deposit is on a hillside. The overburden would soon become too great for profitable operation and the molding sand is not extensive along the face of the hill. Formerly this sand was used in a small foundry at Belmont.

Friendship. One and a half miles east of Friendship, on the Howbridge farm, there is a smooth, velvety molding sand suitable for small castings. Sample 379 is representative of the best of this material. The deposit is five feet thick and covers about an acre. The haul is one-half a mile to the Erie and Shawmut railroad. This sand has been used successfully in a local foundry, but because of the overburden and small extent it will doubtlessly never be developed.

Molding Sand and Sample 379

MESH	PER CENT RETAINED	WATER PER CENT	BOND STRENGTH	PERMEABILITY
6	0.0			
12	1.44			
20	0.54			
40	1.30			
70	2.00	6.2	147	11.4
100	5.16	8.4	163	16.7
140	10.56	10.9	146	14.7
200	16.30			
270	19.30			
Pan	30.56			
Clay	11.86	Grain fineness: 164		
		Grade: No. 2 E.		
Total	99.02			

Wellsville. For more than 30 years molding sand has been dug on the Robert Cromer farm in the outskirts of Wellsville. The deposit has been formed on the flood plain of the Genesee river and has a thickness of from two to four feet. About ten acres of material are available and some of the sand has been shipped on the Erie railroad, although most of it is used locally for general foundry work. Sample 394 represents the average run of this deposit and by careful selection a finer grade may also be produced.

Molding Sand Sample 394

MESH	PER CENT RETAINED	WATER PER CENT	BOND STRENGTH	PERMEABILITY
6	0.0			
12	0.0	4.2	Dry	22.7
20	0.70	6.2	136	47.0
40	9.90	8.3	132	52.0
70	18.80	9.2	Wet	40.0
100	18.96			
140	14.50			
200	7.44			
270	7.54	Grain fineness: 105		
Pan	9.64	Grade: No. 3 E.		
Clay	12.10			
Total	99.58			

Broome County

Sand and gravel deposits in Broome county are usually of an inferior quality and even when thoroughly washed, often make only second-class concrete. One reason is their large content of local shaley sandstone. The Stewart Sand and Gravel Co. operates the biggest plant and supplies Binghamton with a large amount of washed and screened material.

Stewart Sand and Gravel Co. At Chenango Bridge five miles north of Binghamton, a bank of sand and gravel has been opened to a depth of 30 feet. This deposit is a river type, formed during the retreat of the ice, when south-flowing rivers were burdened with an enormous mass of débris. Because of this overloading, such rivers built thick deposits of sand and gravel and later, when the load was lightened, eroded their courses to a lower level. Today the remnants of these deposits are seen as high river terraces 30 to 40 feet above the present river surface, and the operation of the Stewart Sand and Gravel Co. on the banks of the Chenango river is a typical example.

The former method of excavation was to dig to within two feet of the water level with a drag line, but now because the face is so far from the plant, a steam shovel is used. This shovel dumps the material into automobile trucks, which make a short run to the drag line, which in turn conveys the material to the plant. Doubtlessly such an arrangement is only temporary. The deposit carries 60 to 70 per cent of gravel and the plant turns out three sizes of gravel, and a concrete sand. A jaw crusher is used to break the gravel. Approximately 400 gallons of water a minute are needed to take care of the loam and silt. Production varies from 30,000 to 60,000 cubic yards a year, most of the material being trucked into Binghamton, although two years ago some sand and gravel was shipped on the Delaware, Lackawanna and Western Railroad. Reserve material to take care of four or five more years is available. No recent gravel tests are on file but samples 6726 and 6727 are characteristic of the sand.

Cattaraugus County

A variety of sand and gravel deposits occur in Cattaraugus county including glacial delta and river flood plain types. In addition to large tonnages of concrete aggregates, this county furnishes the only other large supply of molding sand, outside of the Hudson river district.

J. E. Carroll Sand Co. About three miles north of Franklinville, the J. E. Carroll Sand Co. is operating an up-to-date plant in an excellent sand and gravel deposit. Of glacial lake origin, this delta deposit extends four miles, with a width of one-quarter to one-half a mile, and is exceptional because of its uniformity and lack of clay seams. A total depth of 135 feet will eventually be excavated, the plan being to use two levels, the present upper level having a bank face of 70 feet. Figures 9, 26 and 27 illustrate the method of excavation as well as the uniformity and coarseness of the deposit.

The bank carries about 60 per cent of gravel, 10 per cent being seven inches in diameter, and the stripping averages three feet in depth. Three sizes of gravel, concrete sand and plaster sand are made and very seldom does an excess of any one size of material accumulate since the bank-run is close to a natural concrete mixture. The only drawback to the deposit is the degree of cementation, which is due to the large percentage of limestone pebbles. This necessitates frequent shooting of the face.

Two electric shovels are used in excavating, the material being carried to the plant in pit cars. A large primary gyratory crusher of the straight-throw type handles everything up to 18 inches. Two secondary smaller gyratories and a disc crusher are used for further reduction. Five storage bins of a total capacity of 1000 yards are arranged so that four railroad cars may be loaded at one time. The wash water is secured from three deep wells and 3000 gallons a minute are used. The plant capacity is about 100 cars a day, the production being shipped on the Pennsylvania Railroad. Sample 6386 represents the washed gravel and sample 6367 the washed concrete sand.

Olean Sand and Gravel Co. Two miles southeast of Machias on the Pennsylvania Railroad, the Olean Sand and Gravel Co. has opened a glacial lake delta deposit to a depth of 150 feet. Excavation is accomplished by both a drag line and a steam shovel, the latter dumping into pit cars. Figure 28 shows this unusual double method of hauling to the conveyor belt. The bank is coarse, averaging 60 per cent gravel, and large boulders are not infrequent. Situated on the side of a hill, this deposit has an excellent thickness but very little width, and only about two more years of reserve are in sight.

Plant capacity is 20 cars a day, three grades of gravel and a concrete sand being produced. Sample 6384 is the washed and screened gravel and sample 6290 represents the sand. A special crushing test was made by the Government in which a 10-gram sample of sand (10 to 20-mesh) was placed in a steel container and subjected to a gradually rising load up to 2500 pounds to the square inch; the amount passing the 20-mesh was considered as loss and this amount varied between 30 and 40 per cent.

Allegany Sand and Gravel Co. In the outskirts of Allegany, on a second terrace bordering the Allegany river, a small plant is operating. The face is 50 feet high and is strongly cemented in many places. In fact, a considerable portion of the material must be left undug because of its cemented character. About four cars a day is the plant capacity, the production being shipped on an electric line into neighboring towns. Two grades of gravel and a concrete sand are produced.

This deposit was formed by the river when it was overloaded during the melting of the glacier, and like many river deposits of southern New York, contains a large amount of friable sandstone. Sample 6765 represents the gravel and samples 6355 and 6346 the sand. Incidentally the sand has a reddish-brown color due to iron staining, and this coating, together with the lime present, accounts for the indurated character of the bank.

Molding sands. With Olean as a center, several deposits of molding sand have been exploited along the present banks of the Allegany river. These recent deposits should not be confused with the sharp sand and gravel laid down at a much higher level during the last part of the glacial period, as they were formed under entirely different conditions. The molding sands are found in a narrow strip along the river and represent material deposited during recent flood periods. Naturally, they quickly grade into silt and clay at a short distance from the river and the best deposits are found in old river bends, some of them being workable to a depth of 12 to 15 feet.

River bank sands often do not have the smooth, velvety feel of a weathered type of molding sand; they are usually low in permeability because of a large content of river silt; and they are not especially good as to color because of a lack of sufficient oxidation of the colloidal iron. Rapid changes in texture and the presence of lenses of sharp sand make it necessary carefully to select and thoroughly blend the usual run of the bank. For this reason most of the production is dug by hand, although one deposit is uniform enough for a drag line.

In addition to the American Radiator Co. and Whitehead Brothers Co., several small producers are shipping sand, among whom may be mentioned C. C. Hatch at Vandalia. Near Portville several undeveloped deposits are known to occur, including two acres on the William Rowe farm, ten acres on the Burnham farm, five acres on the Slingerland farm and three or four acres on the Quiraren farm.

While undoubtedly there is a considerable tonnage of untouched molding sand still available, this district will hardly assume an important place in the molding sand industry because the sand is not of the best quality. In other words, Cattaraugus county molding sand would seem to be limited to a small shipping radius where the freight rates are favorable and where the material may be delivered cheaply.

American Radiator Co. Across the river from Olean, the American Radiator Co. has opened a deposit of molding sand to a depth of 12 feet. A drag line is being used and the material is conveyed across the river by an aerial tramway. Sample 380 represents this sand and it has been used successfully for medium-sized castings. Unfortunately the deposit is almost exhausted.

Molding Sand Sample 380

MESH	PER CENT RETAINED	PER CENT WATER	BOND STRENGTH	PERMEABILITY
6	0.0			
12	0.0	3.9	....	27
20	0.0	6.1	141	42
40	1.88	8.0	128	49
70	18.04	9.0	....	44
100	21.86			
140	18.36			
200	10.34	Grain fineness: 115		
270	9.08	Grade: No. 3 E.		
Pan	9.65			
Clay	10.90			
Total	100.10			

Whitehead Brothers Co. At Vandalia this company is digging molding sand by hand to a depth of about six feet. Sample 381 is characteristic. On the other side of the river about two miles farther south, Whitehead Brothers Co. is also operating on the Hope farm. The molding sand here is usually strongly bonded but sometimes gives trouble because of low permeability. Sample 382 is the best of this deposit.

Molding Sand Sample 381

MESH	PER CENT RETAINED	PER CENT WATER	BOND STRENGTH	PERMEABILITY
6	0.0			
12	0.0	6.0	135	28
20	0.0	8.3	149	33
40	2.10	10.3	140	38
70	19.80	12.1	....	36
100	21.60			
140	16.00			
200	10.10	Grain fineness: 115		
270	9.10	Grade: No. 3 E.		
Pan	10.14			
Clay	11.20			
Total	100.04			

Molding Sand Sample 382

MESH	PER CENT RETAINED	PER CENT WATER	BOND STRENGTH	PERMEABILITY
6	0.0			
12	0.0	5.9	150	20
20	0.0	8.1	160	33
40	1.96	9.9	147	36
70	12.66	11.6	....	27
100	19.00			
140	16.40			
200	11.84			
270	10.54	Grain fineness: 131		
Pan	13.14	Grade: No. 3 E		
Clay	14.26			
Total	99.80			

Cayuga County

With the exception of the sand and gravel obtained from the shore of Lake Ontario near Fairhaven, all of the production of Cayuga county is used locally, the largest center being around Auburn. Carrol Brothers and the Syracuse Sand Co., formerly operating extensively at Port Byron, had to abandon their workings because the sand became too fine.

Ludke Brothers. Five miles north of Auburn, Ludke Brothers are using a drag line to excavate a sand and gravel deposit to a depth of 35 feet. The bank runs about 50 per cent gravel and requires only one foot of stripping. The washing and screening plant has a daily capacity of 300 yards and produces no. 1 and no. 2 gravel and a concrete sand. Sample 6638 is a trifle finer than the concrete sand is now running.

Eldridge and Robinson. Just north of Fairhaven, on a spit along the shore of Lake Ontario, sand and gravel are being dug with a steam shovel. This material has been brought in by off-shore currents and heaped up by wave action within the past few years. Only 15 per cent sand is present, the bulk of the deposit being flat pebbles of sandstone. A screening, crushing and washing plant handles 600 yards a day, most of the production being loaded onto barges and taken to Oswego.

One interesting sedimentation feature is the scarcity of coarse sand. Extensive dredging tests have been made in the harbor and along the shore and with the exception of the small amount of sand in the gravel, no sand coarser than 100-mesh has been located. Sample 5388 represents the gravel and sample 5389 the sand.

J. W. Robinson. Three miles east of Auburn an interesting operation is being run. A 50-foot bank, which is slightly gravelly at the base, is excavated by a six-inch sand sucker to a depth of 20 feet below the water level. The gravel is taken out by a gravity screen and the sand is caught in two settling tanks. Concrete, plaster and a fine size of core sand are produced. Sample 2909 represents the run of the bank before washing and classifying. Two feet of stripping are removed by flushing with a high pressure jet of water, and this method is giving satisfaction. As noted already under the general discussion of stripping, such a scheme, in a favorable location, is very economical.

Patrick Walsh. Two miles south of Auburn sand is being obtained with a drag line. Two deposits are opened, each having a face of 20 feet, and the material is screened to remove an occasional clay streak and gravel lense. Plaster and brick sand, such as represented by sample 6336, is dug from one deposit, while a fine-textured core sand, such as sample 404, is produced from the other. Both deposits are on the Patrick Walsh farm.

Core Sand Sample 404

MESH	PER CENT RETAINED
6	0.0
12	0.02
20	0.07
40	0.98
70	12.38
100	30.80
140	20.91
200	13.55
270	9.21
Pan	11.81
Total	99.73

Chautauqua County

Molding sand, core sand and concrete aggregates are produced in this county and with the exception of the foundry sand, all of the material is used locally.

Builders Supply Co. In the outskirts of Jamestown the Builders Supply Co. is operating a sand and gravel plant with a capacity of 1000 yards a day, using two shifts. The deposit was formed in one of the glacial lakes and has been tested to a depth of 125 feet. At present the upper 65 feet is being dug with a steam shovel and runs about 60 per cent gravel. The washing and screening plant produces three grades of gravel, concrete sand and building sand. Some of this material has been shipped on the electric line, but a majority is trucked. Sample 6896 represents the concrete sand and sample 6897 the gravel.

Dunkirk. A small bank operation is being carried on two miles southeast of Dunkirk by Sebold Brothers. The deposit is 20 feet thick and is mostly sand. A drag line operated by a tractor is used in excavating. The sand is washed and screened, sample 7040 being representative.

In addition, sand is dredged from Lake Erie and brought into Dunkirk on barges. Sample 391 is the best of such material and is of sufficient purity to be used as a core sand. The dredging location could not be exactly learned.

Core Sand Sample 391

MESH	PER CENT RETAINED	
6	11.50	Dry permeability: 102
12	6.70	
20	6.36	
40	27.00	
70	26.64	
100	11.90	
140	5.76	
200	1.04	
270	0.70	
Pan	2.12	
Total	99.72	

Fredonia. A small washing plant was being constructed at Fredonia by John Gassett. It is designed to take care of local demands.

Levant. On the Willets farm a very fine-textured molding sand has been dug for a number of years. The thickness runs from six inches to two feet with an average depth of 18 inches, and represents a weathered layer. The material is dug by hand and is underlain by a fine, sharp gray sand. Sample 393 is the bank run material and sample 392 the same sand from a used heap in the foundry of the Ellerson Brass Co. Because of its fine texture and low permeability, the sand is suited for very small brass, iron and aluminum castings, where a smooth finish is desired. Shipment is on the Erie Railroad.

Molding Sand Sample 392

MESH	PER CENT THROUGH	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	1.44	6.1	156	8.8
20	1.30	8.3	169	10.7
40	2.54	10.2	172	9.4
70	5.10			
100	7.54			
140	14.60			
200	15.30			
270	19.54			
Pan	23.74			
Clay	8.36			
Total	99.46			

Grain fineness: 170
Grade: No. 2 D

Molding Sand Sample 393

MESH	PER CENT THROUGH	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.54	6.8	142	4.2
20	0.44	8.8	175	5.8
40	0.90	10.9	166	4.9
70	0.98			
100	1.04			
140	3.04			
200	5.60			
270	20.80			
Pan	53.44			
Clay	11.76			
Total	98.54			

Grain fineness: 247
Grade: No. 1 E

Kennedy. Formerly the Buckeye Sand Co. shipped molding sand from Kennedy but at present has discontinued this production. The haul is about one mile and the sand is similar to that at Levant.

Chemung County

Only one plant of any size is operating in this county. Two miles southeast of Horseheads the G. M. Baldwin Sand and Gravel Co. has opened an old glacial lake delta deposit. The face is over 200 feet in height and runs about 50 per cent gravel. No stripping is done and the face is excavated with a drag line. The washing and screening plant has a capacity of 200 yards a day and all of the production is hauled by truck, a large percentage going to Elmira, which is five miles away. Sample 7000 represents the sand and sample 7001 the gravel.

Chenango County

At present no commercial production of sand and gravel is obtained from this county. Formerly the Chenango Valley Sand and Gravel Co. operated a bank at Sherburne. Scattered small pits take care of local demands, and since there are no large towns in Chenango county these pits have not been developed.

Clinton County

Along the shore of Lake Champlain, as well as at higher levels above the lake, are found scattered sand and gravel deposits of excellent quality for building purposes, but they are of limited extent. The higher deposits represent deltas that were formed when the lake was much deeper. No screened and washed material is produced in Clinton county, with the exception of tailings from the Chateaugay Iron Co. at Lyon Mountain. Sample 6964 represents the average run of these tailings.

In addition the Rutland Railroad uses for ballast some bank-run material from Cherubusco.

Columbia County

Part of this county is included in the Hudson valley molding sand district (Nevin '25) and molding sand is being shipped from Stuyvesant. Aside from small sand and gravel pits opened for local use, there is no production.

Cortland County

In the neighborhood of Cortland several glacial lake delta deposits have been opened. No permanent screening and washing plants are operating in this county and no sand and gravel are shipped.

Delaware County

A considerable quantity of sand and gravel is scattered through this county, but only one deposit has been opened on a commercial scale. About three miles east of Hancock, along the bank of the east branch of the Delaware river, the Hawk Mountain Sand Co. is operating a small washing and screening plant for concrete sand and gravel. Samples 6183 and 6340 represent the washed sand, and 6387 the gravel. A large part of the gravel has been derived from nearby sandstone beds and this makes the abrasion loss rather high, although the sandstone is sound and not of a shaley or friable nature.

Dutchess County

Along the high banks of the Hudson river concrete sands and gravels are of common occurrence and such deposits are opened for local use. Formerly at Poughkeepsie, the Poughkeepsie Sand and Gravel Co. had a washing and screening plant but this is not being operated at present.

In addition, molding sand is being produced at Camelot and Clinton Point. These deposits are of the typical weathered type so common in the Hudson river valley (Nevin '25).

Erie County

Concrete sand and gravels are produced in large tonnages under a variety of conditions and by diverse methods in Erie county. The largest production is obtained from Lake Erie; formerly a considerable amount was also dug from the Niagara river, but recent government restrictions have made this source of supply no longer available. Among the companies dredging from the lake are the Squaw Island Sand and Gravel Co., Seneca Washed Sand Co., and the Buffalo Gravel Corporation. This latter is one of the largest of its kind in the country and the washing and screening plant, recently installed, has some very interesting features.

Buffalo Gravel Corporation. All the present production of this company is being dredged with centrifugal pumps from Lake Erie. In order to present some idea of the magnitude of the operation a list is given of the dredging equipment.

NAME	YARDS CAPACITY	SIZE OF PUMP INCHES
Steamer "Weston M. Carroll"	1000	14
Steamer "Crescent"	500	12
Steamer "Lakewood"	1200	20
Steamer "Victoria"	750	14
Steamer "Hyman"	450	12
Barge "Pennsylvania"	650	14
Barge "Kathryn"	600	12

In addition, two tugs and several barges are used and formerly the dredge "Elco" of the digger type, with a daily capacity of 1500 yards, operated in the Niagara river off Squaw Island.

By using all of the equipment a daily production of 5500 to 6000 yards is possible and the yearly output is in the neighborhood of 900,000 yards. The larger part of this material is used in Buffalo, trucks being the chief method of transportation. Shipments may also be made by water and on the Erie and New York Central railroads.

The sand and gravel run rather fine in texture, not much being over two inches in size. About 20 per cent of the gravel is flat, but the abrasion loss is relatively low. Sample 6602 represents the gravel and sample 6601 the sand.

The steamers and barges are emptied by a traveling crane with the exception of the Steamer "Lakewood," which is equipped with a self-unloader. This boat has two long tunnel bins for the sand and gravel, one on each side of the keel, and a four-yard scraper is drawn back and forth in each of these tunnels by lines that run to a hoist in the hold. The scrapers discharge into a hopper over the end of a conveying belt, which in turn empties onto an outboard conveyor belt. This outboard belt is supported on a boom frame and can be raised to build the storage pile to a considerable height. The "Lakewood" holds 1200 yards and can be emptied in four hours, but considering the initial cost of installation of the self-unloader and its rapid depreciation, it would seem to be a questionable economy.

About 75 per cent of the material dredged from the lake is sold as a natural concrete mixture without further treatment but in 1927 a new washing and screening plant was put into operation and doubtlessly sized material will now assume a larger proportion of the production.

Because of the steamer and barge operations, the plant was designed to receive and store some 8000 tons of raw material without interrupting other work. Also, since these barges are used to carry the finished product, this plant must be able to load out heavy tonnages without interfering with plant production or delaying the boats. In addition, loadings into trucks and railroad cars must be handled. Truly these requirements presented a problem and its solution resulted in a unique plant.

Unloadings from the barges are piled over a concrete tunnel 250 feet long and from here the material is conveyed to the crusher house, where it is discharged onto a scalping screen. After crushing the oversize, the broken gravel is returned to the main feed belt and conveyed to the top of the screening plant 67 feet above the ground. Three sizes of gravel and coarse and fine grades of sand are separated, the different sizes going to concrete storage bins 20 feet in diameter by 40 feet in height. These bins may feed into automobile trucks or railroad cars, or by a conveyor, elevated 50 feet above the ground, may be discharged into open stock piles. The stock piles feed into a tunnel, the material being conveyed to a loading tower at the water front.

The plant is designed for a capacity of 3000 yards a day. On first view one is surprised at the height of the temporary storage bins and the large amount of conveyor belt (some 2000 feet). Also one can not fail to be impressed with the safety features and general up-to-date equipment. Its economy of operation, however, remains to be demonstrated.

Springville Sand and Gravel Co. One mile southwest of Springville this company has opened an esker deposit to a depth of 65 feet. About 20 per cent of the bank is gravel, a large proportion being pea size. Excavating is done with a three-quarter-yard steam shovel. The plant sizes two grades of gravel, a concrete sand and an asphalt sand. Production is about ten cars a day, one car being asphalt sand. Sample 6965 is the concrete sand and sample 6960 the gravel. A large percentage of sandstone makes the abrasion loss high. Shipment is on the Buffalo, Rochester and Pittsburgh Railroad.

Sterrett Sand and Gravel Co. Adjacent to the above operation the Sterrett Sand and Gravel Co. is using the same esker deposit. This esker extends for about one and one-half miles with a width of one-eighth mile. Here a six-inch sand sucker is used, the working face being 50 feet above and ten feet below the water level, as illustrated in figure 16. The sand is washed through a hummer screen, and the plant produces two sizes of gravel and a concrete sand. The capacity is ten cars a day and only two men are required to operate the plant. Sample 6259 represents the concrete sand and sample 6274 the gravel. Shipment is on the Buffalo, Rochester and Pittsburgh Railroad.

Carroll Brothers. Two miles southwest of Clarence, Carroll Brothers have just completed a new plant with a 30-car daily capacity. A clam and two steam shovels are used in excavating and the material is transported to the plant in pit cars. The bank is 25 feet in height, carries 50 per cent gravel and is full of clay lumps and dirt. To insure a clean product, some 3000 gallons of water a minute are used and all of the material, except the asphalt sand, is cleaned in a double-screw type of washer. Three grades of gravel, concrete sand, plaster sand and asphalt sand are produced. Shipment is on the West Shore Railroad.

The total depth of the deposit is about 80 feet and since it appears to be only slightly cemented, it is planned to use a centrifugal pump in the near future.

Genesee Sand and Gravel Co. Five miles east of Bowmansville the Genesee Sand and Gravel Co. is operating two plants. The older plant is used as a washer, while the new plant has two hummer screens and merely separates the sand and gravel as it comes from the bank. The main pit is 80 feet in height and has 60 per cent gravel, but no crusher is used. Two sizes of gravel, grit for road-blotting, concrete sand and plaster sand are produced. Capacity is about 800 tons and all of the material is trucked into Buffalo. Samples 6637 and 6187 represent the concrete sand and sample 6738 the washed gravel.

Akron. Four miles east of Akron, where the West Shore Railroad crosses Tonawanda creek, occurs a yellow-brown molding sand. This is found on both sides of the creek, and is a typical weathered type of molding sand having a depth of 18 inches to two feet. Some of this sand has been used in a small foundry at Akron and it is suitable for the general run of small castings, sample 390 being representative. A considerable area is covered by this weathered sand but most of the best material is on the Tonawanda Indian Reservation.

Molding Sand Sample 390

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	6.1	166	14.3
20	0.0	8.1	175	15.7
40	0.86	10.3	167	14.7
70	6.26			
100	12.24			
140	16.08	Grain fineness: 144		
200	21.44	Grade: No. 2 D		
270	20.80			
Pan	15.74			
Clay	5.90			
Total	99.32			

Clarence Supply Co. One-half a mile south of Clarence, the Clarence Supply Co. has opened a deposit of sand and gravel to a depth of 30 feet. At present a shovel and clam are used in excavating, but an eight-inch sand sucker has recently been installed. The deposit carries about 30 per cent gravel and no crusher is used. The screening and washing plant produces three sizes of gravel, concrete sand and building sand. Capacity is 500 tons a day and most of the material is hauled one-half a mile to the West Shore Railroad. Sample 6743 represents the gravel and sample 6742 the washed concrete sand.

East Aurora Sand and Gravel Co. Just outside East Aurora a small sizing and washing plant is being installed, but was not in operation when visited. This plant is intended to take care of local demands and no outside shipments are contemplated.

Essex County

Lying mostly in the Adirondacks, Essex county has a large amount of sand and gravel, but little is produced commercially as the demand, within a reasonable shipping distance, is small.

Doud Concrete Products Co. This property was formerly operated under the name of the Northern Arts Stone Co., and is located in the outskirts of Saranac Lake. The deposit is an esker and carries about 50 per cent gravel. It has been opened to a depth of 30 feet, the excavating being done by teams with scrapers. The material is not washed, the screening plant producing three grades of gravel and a concrete sand. Capacity is three cars a day, shipments being made on the Delaware and Hudson Railroad to Plattsburg. Sample 6710 represents the concrete sand.

Boyce and Roberson. This operation, also in the outskirts of the village of Saranac Lake, was formerly carried on under the name of the Meagher Coal and Ice Co. The face is 50 feet high, the gravel being crushed and screened into three grades. All the material is used locally although a siding could be installed if the demand warranted. Sample 6303 represents the concrete sand and sample 6304 the gravel.

Ticonderoga. West of Ticonderoga there are large delta deposits of sharp gray sand which usually contain a considerable amount of lime-stone pebbles. This material is used locally and makes a good concrete aggregate and building sand.

Along Lake Champlain this same sand has been washed down from the hills and worked over sufficiently to remove some of the lime content. It has been used satisfactorily for core sand in the foundry at Ticonderoga, sample 377 being representative.

Core Sand Sample 377

MESH	PER CENT RETAINED	
6	0.0	Dry permeability: 134
12	trace	
20	2.90	
40	46.14	
70	34.60	
100	7.54	
140	2.50	
200	0.70	
270	0.60	
Pan	2.10	
Clay	2.44	
Total	99.52	

Whalonsburg and Willsboro. One-half a mile north of Whalonsburg and on the high flats around Willsboro a fairly good molding sand occurs. Sample 378 is the average type, although some of the material is considerably coarser in texture and weaker in bond. The deposits are found 40 to 50 feet above the present level of the Bouquet river and owe their character to the influence of weathering. None of this material has been used on a commercial scale and perhaps 100 acres are available. Shipment could be made on the Delaware and Hudson Railroad.

Molding Sand Sample 378

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	6.7	120	27
20	1.04	8.7	131	38
40	8.34	10.5	136	42
70	30.04	13.2	126	30
100	17.54			
140	18.86			
200	6.74	Grain fineness: 88		
270	6.44	Grade: No. 4 B		
Pan	5.54			
Clay	5.56			
Total	100.10			

Franklin County

Large deposits of sand and gravel are present in many places in Franklin county, but no market has been developed and at present no washing and screening plants are in operation. At Santa Clara, Smith & Trotter are installing a sand sucker and sample 6961 represents the bank run material. At Malone, John Para is supplying material locally, all of it being dry screened. This deposit carries 30 per cent gravel and has been opened to a depth of 40 feet. Sample 6682 represents the concrete sand.

Formerly the New York Central Railroad secured bank-run ballast at a number of points in the county but recently this practice has been discontinued.

Fulton County

No large sand and gravel operations are conducted in this county, local demand being taken care of by small pits worked for the most part by hand. Sample 6850 represents a screened sand and sample 6851 the same sand unscreened, from a local pit outside of Johnstown. The increase in strength due to screening is interesting.

Genesee County

Around Batavia the sands are quite high in loam and silt and therefore are not satisfactory. Sample 4904 illustrates such a sand, being taken from a small pit operated by F. B. Parker.

At LeRoy there is an excellent deposit of sand and gravel which has been opened on a small scale by E. J. Boatfield and also by Dean Munt. The bank runs about 60 per cent gravel and the material is dry screened, sample 5798 representing the concrete sand.

The only commercial plant in the county is that operated by the J. E. Carroll Sand Co. at Attica.

J. E. Carroll Sand Co. Three miles northeast of Attica a delta deposit has been opened to a depth of 150 feet. The bank carries 30 per cent gravel, all of small size, is not cemented and contains no clay streaks. Excavating is carried on by a clam and a drag line. This would seem to be an ideal deposit for a sand sucker.

The washing plant makes three grades of gravel, concrete sand, building sand and asphalt sand. A vibrator is used to size the building sand and settling tanks separate the asphalt sand. A quantity of pea-sized gravel occurs in the bank and this is crushed in rolls and mixed with the concrete sand to coarsen it. Capacity is 40 cars a day and shipments are made on the Erie and New York Central railroads. Sample 6610 represents the concrete sand and sample 6611 the gravel.

Greene County

A large part of this county lies in the Catskill mountains and contains considerable sand and gravel, but the demand is negligible. Aside from local pits along the Hudson river, the deposits have not been opened.

Molding sand is dug at Coxsackie and Hotaling and is of the weathered 18-inch layered type characteristic of the Hudson valley (Nevin '25).

Hamilton County

Containing no large towns and lying entirely in the Adirondack mountains, Hamilton county has no sand and gravel deposits that have been developed. Enormous deposits are known to exist but there is no present demand for their exploitation.

Herkimer County

No washing and screening plants are in operation in this county. Along the Mohawk valley several small pits are operated to supply local demand.

Jefferson County

At Calcium, the New York Central Railroad is operating a steam shovel to supply bank run material for its own use. Three miles southeast of Watertown a large deposit of sand and gravel was laid down in former Lake Iroquois during the Glacial period. This is partly a delta deposit and partly a bar deposit due to the wave action of the lake. This deposit has been opened by O. B. Colwell, Peter Bigham and George Newman. The upper 12 to 15 feet is 60 per cent gravel and the lower 20 feet is sand. All the material is trucked to Watertown and none of it is washed. Because of the competition of crushed stone quarries, very little of the gravel is crushed at present. Samples 5829 and 6408 represent the usual run of the sand.

Kings County

Being thickly populated, this county produces little sand from pits or banks. The Atlantic Coast Sand Co. and the Jacobus-Grauwiller Co., however, are dredging sand with centrifugal pumps from bars on Rockaway shoals. This is an excellent white sea sand and after washing and sizing it is sold as engine sand, filter sand, concrete sand, plaster sand, core sand and polishing sand.

Lewis County

Aside from small local pits, Lewis county produces no sand or gravel.

Livingston County

East and southeast of Caledonia there is a very extensive delta deposit at about the 600-foot level and this is being operated on a large scale. The sand and gravel here is of excellent quality and very evenly bedded, having been deposited under uniform conditions.

Molding sand is found scattered along the heights bordering the Genesee river and a small tonnage is produced for local foundries.

Consolidated Materials Corporation. Three miles east of Caledonia this corporation is excavating sand and gravel with a one and one-quarter-yard electric steam shovel. Figure 29 illustrates the method of operation and the uniform, level-bedded character of the bank. The present pit face is some 1500 feet from the plant, transportation being by pit cars. The bank is 25 feet high and there is enough reserve material for several years operation.

Capacity of the washing and screening plant is 25 cars daily. Three grades of gravel, concrete sand and plaster sand are produced. Sample 6772 represents the washed sand and sample 6773 the washed gravel. Shipment is on the Lehigh Valley Railroad.

Valley Sand and Gravel Company at Wadsworth. This is a new plant, figure 32 illustrating the method of excavating the gently dipping delta beds. A ten-inch sand sucker is used, the bank being 50 feet above and 20 feet below the water level. The pit runs about 60 per cent gravel, is not cemented and contains no clay streaks. Three grades of gravel and a concrete sand are produced, the combined output being 30 cars a day. Shipment is on the Lehigh Valley Railroad. Sample 5641 represents the washed gravel, while sample 5642 is the washed sand.

Valley Sand and Gravel Corp. at Canawangus. Here a three-yard drag line is used to excavate a 60-foot face, the digging being stopped just above the water level. This deposit is similar to that at Wadsworth. The plant has a capacity of 50 cars daily, three grades of gravel and a concrete sand being produced. A primary gyratory crusher handles the boulders and a 36-inch disc crusher is used to break the smaller sized gravels. A 25 to 30-year reserve has been demonstrated by testing and the deposit is notable for its uniformity. Sample 6220 represents the washed and screened gravel and sample 6219 the washed sand. Shipments are made on the Pennsylvania Railroad.

Livonia. Near the town of Livonia several small pits are operated and some of the material is used to make concrete blocks. Sample 6859 represents the average run of the sand and gravel in this district, the sample being taken from the pit of John Shelley. If washed, such material would be acceptable for concrete aggregate.

Sonyea. On the Verne Weidman farm and on the land connected with the Craig Colony Epileptic Asylum, 20 acres of fairly coarse molding sand occurs to a depth of from four to six feet. This is an old stream deposit and is full of lenses of sharp sand and clay seams. Some of the sand is deficient in bonding strength but in places it is quite cohesive. All the land underlain by good material is heavily timbered and the haul to the Dansville and Mount Morris as well as to the Pennsylvania railroads is about one mile. The sand has been used in local foundries, samples 386 and 402 being representative of the best material.

Molding Sand Sample 402

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	1.00	4.1	....	52
20	0.74	6.7	178	55
40	7.44	8.6	156	87
70	25.56	10.4	....	52
100	15.66			
140	13.24			
200	5.90			
270	5.26	Grain size: 93		
Pan	7.74	Grade: No. 4 F		
Clay	16.36			
Total	98.90			

Molding Sand Sample 386

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	4.1	137	12.4
20	0.0	6.1	163	17.3
40	1.76	8.4	147	15.2
70	11.14			
100	13.44			
140	13.14			
200	14.04	Grain size: 155		
270	15.84	Grade: No. 2 E		
Pan	20.00			
Clay	10.56			
Total	99.92			

Hunts. A weathered, yellow-brown molding sand occurs on the farms of E. L. Bailey and Dell Chapman to a depth of two feet. Although it is very spotted in character, a considerable acreage exists and the haul to the Erie Railroad is about one mile. Sometimes the lower part is contaminated with shale particles since the sand often rests directly on shale rock, but in many places sand of excellent quality could be produced. Sample 383 is the average of the material which could be used for small castings requiring a smooth finish.

Molding Sand Sample 383

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	6.1	172	7.7
20	0.0	8.3	197	9.0
40	1.10	9.7	192	11.8
70	4.16	12.4	....	8.8
100	6.90			
140	14.74			
200	14.28			
270	20.28	Grain fineness: 186		
Pan	28.04	Grade: No. 2 E		
Clay	10.04			
Total	99.54			

Mount Morris. On the high flats bordering both sides of the Genesee river a weathered type of molding sand has been dug for local use. The depth is about two feet and the sand has a "mealy" feel and low strength. Sample 401 is typical of the bank. The haul to the Pennsylvania Railroad is about one mile and perhaps as much as 100 acres could be dug over, although it is difficult to form an accurate estimate because of the spotted character of the sand.

Molding Sand Sample 401

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	4.5	....	52
20	0.0	6.4	138	102
40	3.02	8.5	108	96
70	40.40			
100	22.44			
140	11.36			
200	5.10	Grain fineness: 78		
270	4.24	Grade: No. 4 D		
Pan	4.06			
Clay	9.36			
Total	99.98			

Madison County

Rock Cut Stone Co. Four miles south of Cazenovia the Rock Cut Stone Co. is excavating an old delta deposit with a steam shovel. The face is 50 feet high and digging is stopped just above the water level. This deposit borders the West Shore Railroad for a distance of two or three miles and where opened carries about 50 per cent gravel. Transportation to the plant is all by conveyor belts, two wing belts being used in addition to the main conveyor. Three sizes of gravel, building sand and asphalt sand are turned out by the washing and screening plant, which has a daily capacity of 20 cars. Sample 6164 is the washed sand and sample 6163 the washed gravel.

Madison Sand and Gravel Co. Just west of Solsville a very interesting plant is being operated, figure 1 showing the general arrangement. The deposit is an old glacial delta and has a width of about one-half a mile and a length of two miles, with gravel making about 50 per cent of the total bulk. Excavation is with a Monighan drag line equipped with the latest type of walking device. At present the height of the bank is 50 feet, and the excavated material is conveyed on a belt above the working face. There is about two feet of overburden and the drag line strips this when the plant is not running. Three sizes of gravel, concrete sand, mason sand and asphalt sand are graded by the washing and screening plant.

An effort is made to produce as large a proportion of crushed rock as possible, gyratory crushers of the Telsmith type being used. Capacity is 30 cars a day, the material either being trucked by automobile or shipped on the New York, Ontario & Western Railroad. The only unsatisfactory feature of the operation is the large amount of cemented material in the bank. Sample 6755 is the washed concrete sand and sample 6647 the gravel, the latter having 98 per cent of the pieces broken and thus being in the crushed rock classification.

Monroe County

The Irondequoit river east of Rochester has cut a deep valley and exposed thick deposits of sand, containing some gravel. This old sand plain was formed during one of the last stages of the glacial lakes and many of the deposits show typical delta bedding. A large part of the sand and some of the gravel required in Rochester is secured from this source and many small pits have been opened to supply the demand.

Also, near Scottsville, a large area of sand and gravel occurs, but this is really an extension from the deposits in Livingston county. Plans are being made to develop this territory on a much larger scale.

Perry-Baetzel Sand Co. Southeast of Pittsford, near Bushnell Basin, a pit has been opened to a depth of 100 feet. The top 40 feet is a very fine textured sand and the rest of the deposit, although coarser, contains very little gravel. Stripping is necessary to a depth of five feet and all of the production is pit-run material, which is trucked into Rochester. Sample 3672 is representative of the sand.

At Bushnell Basin several small pits are being operated along the canal. Sand is plentiful but it should be washed to remove the silt and organic material.

Newport Sand and Gravel Co. This company has opened a high-grade deposit near Rochester. The bank is 20 to 25 feet in height and carries 30 per cent gravel. A small washing and screening plant is in operation and has a daily capacity of 750 tons. All the material is trucked into Rochester. Since this deposit will be worked out this year, no tests of the sand and gravel are given.

Elam Sand Co. Six miles southeast of Rochester this company is excavating a deposit of sand and gravel, using three steam shovels. The material is not washed but some of it is screened. A large part of the production is pit-run material, all of it being trucked into Rochester. Sample 6344 is the screened concrete sand.

H. D. Hutcheson Co., Inc. Five miles east of Rochester, at the head of Irondequoit bay, a 60-foot thickness of sand and gravel has been opened. The bank carries 50 per cent gravel but because of clay streaks it is not being operated this year. A small washer is installed and sample 5788 represents the washed gravel and sample 5239 the washed sand.

Star Sand and Gravel Co. Among several small pits near the Hutcheson operation, that of the Star Sand and Gravel Co. is the largest. A 100-foot face is being excavated by two steam shovels and a small washing plant is installed. Very little gravel is present in the deposit except in lenses near the bottom, where it is usually cemented and requires shooting. Asphalt sand, plaster sand, concrete sand and pit-run material are being trucked by automobile.

Honeoye Falls. Two miles north of Honeoye Falls on the Trent farm a sand and gravel bank has just been opened. The present height of the pit is 30 feet and runs about 60 per cent gravel. The Lehigh Valley Railroad is nearby and since the deposit extends for at least one-quarter of a mile it will doubtlessly be developed more extensively.

Scottsville Sand and Gravel Co. Near Scottsville a plant is being rebuilt to wash and size concrete aggregates. The bank is at present 30 feet in height and a spur has been run from the railroad so that outside shipments are contemplated. The bank carries about 60 per cent gravel and is slightly cemented. Production will be in the neighborhood of 15 cars a day. Samples 6067 represent the average character of the sand and gravel.

American Brick Co. Near Coldwater the American Brick Co. is digging four or five feet of a medium-textured sand by hand, and hauling it into Rochester to be used in facing brick molds and to reduce the shrinkage of their brick clay.

Lake Ontario Sand Co. Near Charlotte the Lake Ontario Sand Co. is dredging sand from the lake with a centrifugal pump. This sand is white and is used widely for building purposes and as a core sand in the foundry. Sample 388 shows the screen analysis and permeability. Sometimes the lime content is rather high for a core sand, this being due to the inclusion of small fresh water shells, so that the chemical analysis may be considered as only partially representative of the sand. The following analysis was furnished by the Lake Ontario Sand Co.

Chemical Analysis of Core Sand

SiO_2	93.38
Al_2O_3	2.56
$CaCO_3$	2.01
Fe_2O_3	1.31
$MgCO_3$	.21
Organic	.53
	100.00

Core Sand Sample 388

MESH	PER CENT RETAINED	
6	0.0	Permeability: 128
12	trace	
20	0.44	
40	5.50	
70	41.64	
100	39.50	
140	9.94	
200	1.40	
270	0.30	
Pan	0.20	
Clay	0.36	
Total	99.28	

Montgomery County

Tests on sands around Fonda and Amsterdam have usually shown that washing is desirable, but at present practically none of the sands and gravels in this county are washed. Sample 6671 taken from the Van Epps pit just outside of Fultonville is characteristic of the best material. Aside from sands for local use there is no production in the county.

Nassau County

Of all the counties in New York State, Nassau produces the greatest amount of sand and gravel and it, together with the adjoining county of Suffolk, supplies the enormous tonnage shipped into New York City. Long Island is composed of glacial sands and gravels with a few interbedded clays, all resting upon Cretaceous deposits, so that there is an almost inexhaustible supply of such materials. The glacial history (Woodworth '01, Fuller '14) of the deposition of these sands and gravels is far from simple but forms an interesting chapter in geology, with which anyone prospecting for new sources of supply should be familiar.

Several advances and retreats of the ice have been recorded in the sediments of Long Island, and the last or Wisconsin stage did little more than leave a thin cover over the previous more economically important sands and gravels. Of these Wisconsin deposits, the Harbor Hill moraine is most conspicuous as it forms the backbone of the island, extending as a series of hills across the northern part. Included in this morainic material are numerous large boulders which often cause considerable trouble when underlying sands and gravels are excavated.

Practically all the large operators along the sound are obtaining their production from the Manhasset formation, which consists of the Herod gravels (50 to 70 feet thick) overlain by the Hempstead gravels (50 to 75 feet thick), and separated from them by till indicative of a period of glacial activity. In some of the pits this break between the two gravel members is still further emphasized by the presence of huge boulders. It has been suggested that these Manhasset gravels and sands were deposited as stratified moraines or as huge outwash plains when the ice front was stationary not far from the present northern shore of Long Island.

Considered as a whole, the sands and gravels of Long Island are notable for their horizontal bedding, a characteristic of outwash plains. In many of the deposits gravels compose less than 20 per cent of the formation, a majority of the pebbles measuring less than two inches, and a large preponderance of pea size gravel is present. Quartz pebbles predominate, many of them being stained yellow by iron oxide giving rise to the term "yellow gravels" by which they were formerly known. Next to the quartz, granite and gneissic pebbles are most abundant and a majority are in a fresh, unweathered condition. The source of these Long Island gravels, which are so entirely different from all others in New York, is thought to have been the Cretaceous formations, with the addition of small amounts from Connecticut.

In the southern half of the island, south of the Harbor Hill moraine, it is very difficult to distinguish between sand and gravel deposits of the different ice stages as they all show horizontal bedding, outwash characteristics, and have a high quartz composition.

Goodwin-Gallagher Sand and Gravel Corporation. On Hempstead harbor, two miles north of Roslyn, Goodwin-Gallagher is operating one of the largest pits in the world. The bank is being operated in two levels; the upper level of 60 feet carries 25 per cent gravel and this material is usually sent through the washing and screening plant; the lower level of about 100 feet is mostly sand and is either merely screened or else sold as pit-run material. Production is about 18,000 yards a day at full capacity and all of this is shipped by barge (figure 42).

Two separate plants are used to screen and wash the product, which consists of three grades of gravel and concrete sand. These plants are unusual only in size and in that they use rolls to crush the gravel. The sand is run into settling bins from classifiers and allowed to stand 24 hours before being loaded into barges.

Excavating is done with steam shovels, of which there are ten, and the workings are kept dry by a dike of waste material thrown up to shut off the flooded part of the pit. Incidentally the wash-water is run into this abandoned portion and the silt and clay are allowed to settle. The bank face is caved by men with long iron rods and occasionally a small shot is also necessary.

Transportation to the plant and to the barges is accomplished with engines and pit cars. Sample 5694 represents the gravel and sample 6487 the sand.

Nassau Sand and Gravel Co. Just south of the Goodwin-Gallagher operation the Nassau Sand and Gravel Co. has opened a pit to a depth of 185 feet. About half-way up the face there is a clay seam full of large boulders, and this break is used to place the shots and thus keep the face with a safe angle of repose. Two steam shovels do the excavating and transportation to the plant is by pit cars. The upper part of the bank runs about 30 per cent gravel. Four grades of gravel and a concrete sand are produced. No material is stripped, as the thickness of the deposit and subsequent washing make it unnecessary. Production is 3000 yards a day and all the material is shipped by barge. Sample 5516 is the washed gravel and sample 5523 the washed sand.

O'Brien Brothers Sand and Gravel Co. Immediately north of Goodwin-Gallagher, the O'Brien Brothers Sand and Gravel Co. is operating three steam shovels in a pit with a bank face of 180 feet. Stripping is 10 or 12 feet and the bank is kept at a safe angle by shooting. Gravel runs about 15 per cent and most of the production is bank-run material. The washing and screening plant makes three grades of gravel and a concrete sand. All the production is shipped by barge. An interesting feature is the method of loading the finished product which is all done by long conveyor belts as shown in figure 24.

Lynbrook. Until recently a large tonnage of sand and gravel has been produced yearly at Lynbrook but some of the deposits are about worked out. This, together with the encroaching building operations, has greatly reduced production. Among the companies still operating may be included Long Island Sand and Gravel Co., Grant Park Gravel Co., Hewlett Sand and Gravel Co., H. J. Taylor, Lynbrook Gravel Co., Rockaway Sand and Gravel Co., P. and R. Sand and Gravel Corporation, Belcher Brothers, and Dent & Kent, Inc. All these companies are operating in a small way and supply local demands by automobile trucking. The banks run 15 to 20 feet in height, carry about 20 per cent or less of gravel, and none of the production is washed although much of it is screened. Samples 4930, 4931, 4932 and 4933 represent the screened sand and sample 4930 the gravel.

In addition, Hendrickson Brothers are operating at Lynbrook, but their production is washed as well as screened. An eight-inch sand sucker is used. The bank is 15 feet above and five feet below the water level. Gravel runs about 30 per cent of the production and nothing is crushed, the grades being grit, screened gravel and concrete sand. Production is about 500 yards a day. Sample 6485 is the gravel and sample 6486 the sand.

Mineola. In the neighborhood of Mineola several producers have opened sand and gravel pits but none of them has a washing plant, although practically all of the production is screened. Hunt-Drury Gravel Corporation, De Pasquali Brothers, Hygrade Sand and Gravel Co., and the Drury Manufacturing Co., Inc., are the main operators. The sand and gravel banks average 20 feet in height, being typical outwash plain material. All the production is used locally, with the exception of that from the Drury Manufacturing Co., which is made into cement blocks and cement bricks. Sample 6566 is the best of the sand and sample 6750 is the average run of the gravel.

Valley Stream. Here Hendrickson Brothers have opened a new plant for sand with a daily capacity of 100 yards. A six-inch sand sucker is used and sample 6802 represents the average run of the bank.

Floral Park. The Rockaway Gravel Co., Inc., is starting to operate an eight-inch sand sucker on a 30-foot face. Gravel runs about 15 per cent of the production. Sample 7113 is the concrete sand.

Westbury. Using a drag line, the Westbury Sand and Gravel Co. is excavating a 60-foot bank of sand and gravel. The material is screened but not washed or crushed, although the bank runs 20 per cent gravel. Production is about 300 yards a day. The concrete sand is represented by sample 6881.

Glen Cove. Near this place Hinkle and Finlayson are operating a small sand bank to a depth of 30 feet. The production is screened but not washed and all of it is used locally for concrete and plaster.

Formerly the Carpenter Sand Bank and the Louis Christ Fire Sand Co. were shipping small amounts of furnace sand, but this production has been discontinued. The material is a very fine-grained, white, silty sand containing a considerable amount of white clay as a bond. Excellent results were obtained wherever this sand was used. Upon hasty examination this deposit appears to be a sandy Cretaceous clay, and if it is a glacial deposit it is of very unusual character.

Willard Sand and Gravel Co. Just north of Farmingdale, the Willard Sand and Gravel Co. is operating a drag line that is excavating a bank 12 feet above and 95 feet below the water level. Gravel runs about 30 per cent and two grades of gravel, grit, core sand, concrete sand, plaster sand and engine sand are produced. The washing and screening plant has a capacity of 350 yards a day. Shipments are made on the Long Island Railroad. Sample 6564 is the washed concrete sand and sample 5517 is the washed gravel.

Central Park. The Long Island Construction Co. has just opened a new washing and screening plant at Central Park. Excavating is done with a drag line and the production is transported by truck. The plant has not been in operation long enough to determine its capacity.

Niagara County

With the exception of local pits around Lockport and North Tonawanda, no sand and gravel banks have been developed in this county.

Oneida County

Two centers of production have been developed in Oneida county, one between Boonville and Forestport and the other between the east end of Oneida lake and Rome. Both these districts are sand plains that represent old beaches and deltas of the glacial lakes. The Forestport sand plain was deposited in an early level of Forestport lake around 1250 feet, while the large plain at Rome represents the beaches of a later glacial lake called Lake Iroquois, at about the 500-foot level. These deposits often show typical delta bedding (figure 30) and they constitute a very important source of supply.

Boonville Sand Corporation at Boonville. This plant has a capacity of 40 cars a day. The finished product is shipped on the New York Central Railroad. Figure 12 is a general view of the plant and pit. Excavating is done with a stiff-legged derrick having a mast of 80 feet and a boom of 75 feet. The height of the bank is over 200 feet, the top 60 feet carrying 50 per cent gravel and the rest of the bank being largely sand. Since the bank is not cemented, a safe angle of repose is maintained by men with long iron rods, who continually prod the bank above where the excavating is being done and thus keep the material sliding down. The gravel is screened and washed but not crushed, three sizes being made. Sample 5514 is representative. The sand is not washed but is sized by vibrating screens into concrete sand, plaster sand, brick sand, three grades of core sand, asphalt sand and engine sand. Sample 6958 represents the concrete sand.

Boonville Sand Corporation at Forestport. The bank here is 60 feet high. A slack line cableway is used for excavating (figure 4). Not much gravel is present in the deposit, the washing and screening plant producing mostly sand, although two grades of gravel are separated. Several grades of core sand, an asphalt sand, plaster sand, concrete sand and brick sand are produced, all the material being washed. Until recently some trouble resulted from the concrete sand being too fine, but now a special size is caught between the one-fourth-inch and 3/32-inch screens and used to coarsen this product. Capacity is 15 cars a day. Shipments are made on the New York Central Railroad.

Clean Sand and Gravel Co. This company is operating a screening and washing plant two miles south of Boonville and has a daily capacity of 10 cars. The bank is 50 feet high. Excavating is done with a clamshell bucket. Unfortunately this deposit has recently become quite fine and gravel can no longer be produced commercially. A coarse and fine sand are separated and often asphalt sand is selectively loaded directly from the bank. Quite a large percentage of shaley sandstone was noticed in the oversize boulder pile. Shipments are made on the New York Central Railroad. Sample 6224 is the concrete sand.

Oneida Sand Co. At Alder creek the Oneida Sand Co. is operating a sand pit with a bank face of 130 feet. Figure 10 illustrates the method of excavating by a stiff-legged derrick equipped with a clamshell bucket. The sand is roughly selected at the pit and the screening plant separates concrete sand, plaster sand, engine sand and asphalt sand. About 10 per cent gravel occurs in the upper part of the bank, while the lower part is very fine in texture and furnishes most of the asphalt sand. Capacity is 30 cars a day. Shipment is on the New York Central Railroad. Sample 6957 is the concrete sand.

Byam's Gravel Bank. Just north of Rome a small screening and washing plant is operated by E. J. Byam. The bank is 15 to 20 feet in height, carries 60 per cent gravel and is underlain by seven feet of very fine silt. A drag line is used to excavate. Two sizes of gravel and a concrete sand are produced. This is one of the few deposits near Rome that contains much good gravel. All the material is used locally and is trucked by automobiles.

Rome. In addition to the Byam Gravel Bank, Fike Brothers, M. Ganier, A. L. Gifford and Son, and Henry Hannicker have opened small pits but do not wash the sand and gravel. All this production is used locally and sometimes contains too much fines and organic matter to be really first-class. Sample 5251 is from the Gifford pit.

H. H. McKee and Sons. At Humaston, a very interesting foundry sand pit is being operated by H. H. McKee and Sons. The deposit is over 60 feet in thickness and is excavated with a slack line cableway. A few clay seams are present and this material usually coheres sufficiently to be screened out with a closely spaced grizzly. The sand is very low in lime content, of a slightly reddish cast and is used successfully as a fire sand and furnace bottom sand. Sample 265 is the sieve analysis. Shipments are on the New York Central Railroad.

Recently a blending plant was built at this place and an artificial molding sand is being manufactured by mixing local clay with the fire sand. Very encouraging results have been obtained where this blended sand has been used in the foundry and it is suitable for all types of medium-sized iron castings. It remains to be seen whether this experiment will pay as the plant is expanded to larger tonnages.

Fire Sand Sample No. 265

MESH	PER CENT RETAINED	
6	0.0	Permeability: 75
12	0.0	
20	0.0	
40	1.90	
70	26.60	
100	35.16	
140	27.48	
200	4.98	
270	2.10	
Pan	1.04	
Clay	0.40	
Total	99.66	

G. W. Bryant. Near McConnellsville, G. W. Bryant has opened a foundry sand pit to a depth of over 60 feet and is excavating with a drag line. The production is sold for core sand and fire sand, sample 264 being representative. Shipments are on the New York Central Railroad.

J. Grimes. This core sand pit is operated near McConnellsville, but on a small scale. The sand is similar to that at the Bryant pit. Shipments are on the Lehigh Valley Railroad.

Core Sand Sample 264

MESH	PER CENT RETAINED	
6	0.0	Permeability: 40
12	0.0	
20	0.0	
40	1.60	
70	13.00	
100	33.80	
140	16.10	
200	18.60	
270	12.10	
Pan	3.24	
Clay	0.36	
Total	98.80	

G. Adam Miller. Some engine sand is produced at Sylvan Beach, the material being the fine-grained sand that is periodically dredged from the canal at the head of Oneida lake.

Onondaga County

Near Syracuse, on both sides of the Onondaga valley, there is found a series of glacial delta deposits and lake terraces from which are produced a large part of the concrete aggregates used locally. These deltas are found at five different elevations, the most prominent occurring at the 500-foot level. Among the operators are W. F. Saunders and Sons, Inc., Lowery Brothers, Hogan, Butler, McCarthy Brothers, James Knox and James Ready. None of these operators is washing his product, although screening is done to separate the gravel. Samples 5549 and 5860 are representative of the sand. All the production is trucked by automobiles.

S. F. Clough Sand and Gravel Co. At Onondaga Castle, just south of Syracuse, S. F. Clough is operating the only washing plant in the district. A sand sucker is used to dig the sand, of which coarse and fine grades are separated. A steam shovel is used for 60 per cent of the output and the material so dug is merely screened to take out the gravel. Height of the bank is 100 feet. Sample 6249 is the concrete sand.

Ontario County

East and northeast of Geneva there are found the remnants of an old glacial sand plain, which, since it occurs at the 500-foot level, was formed in Lake Iroquois, the immediate predecessor of the present Great Lakes. A majority of the sand in this territory is too fine for concrete work, but some of it has been weathered sufficiently to form a molding sand of poor quality.

Nathan Oaks and Sons. At Oaks Corners this company is operating a small but very efficient sand plant. The deposit is part of the sand plain mentioned above, and it is being excavated by a six-inch sand sucker to a height of 10 feet above and a depth of 10 feet below the water level. Figure 15 shows the general arrangement of the plant. Gravel forms only about 2 per cent of the deposit. The total production of the plant is 10 cars a day. The haul to the New York Central Railroad is one-half a mile and to the Lehigh Valley Railroad one mile. This sand is unusually coarse for this district and sample 6260 is representative of it.

Hill Sand and Gravel Co. At Fishers this company formerly operated a small screening plant and shipped its product on the New York Central Railroad. Clay to a depth of 20 feet was stripped from the top and used to manufacture drain tile and brick. Underlying the clay is 50 feet of sand followed by 20 to 30 feet of gravel, which in places is badly cemented. Some filter sand was selectively dug at the bank face. Sample 5564 is the concrete sand.

Orange County

Newburgh Building and Supply Co. On one of the high terraces bordering the Hudson river this company is digging sand and gravel with a drag line and has exposed a thickness of 100 feet. A washing and screening plant with a 250-yard capacity is separating two grades of gravel and a concrete sand. Most of the production is sold locally, although shipments can be made on the Erie Railroad. Sample 6193 is the concrete sand.

Otisville Sand Co. At Otisville this company is operating a drag line and has a bank face of 25 feet. The upper six feet is full of large boulders and represents an old stream deposit, while the underlying part carries 50 per cent gravel and is a delta deposit. The screening and washing plant has a capacity of ten cars a day and produces three grades of gravel, core sand, engine sand, concrete sand and building sand. Shipments are on the Erie Railroad. Sample 6788 is the crushed gravel and sample 6226 the concrete sand.

At Port Jervis, Shaw and Reynolds have opened a sand and gravel pit and installed screens but no washing plant. Sample 6808 is the concrete sand. At Huguenot, C. J. Vaninwegen is supplying bank run material, of which sample 6244 represents the sand. Near Roseton the Jova Brick Works and at Warwick, Stephen S. Decker are supplying local demands from small pits.

Orleans County

Along the Ridge road, which incidentally follows the beach terrace of former Lake Iroquois, several small sand and gravel pits have been opened. These banks are from 20 to 25 feet in height and carry about 50 per cent gravel. W. J. Gallagher makes a dry screen separation on some of his material, while C. H. Pickett and Sons and O'Donell Brothers are at present producing bank run material. All the sand and gravel is trucked by automobiles and is used locally at Medina and Albion. Sample 6644 is representative of the district.

Lyndonville. East and south of Lyndonville there occurs a molding sand layer from 18 inches to two feet in thickness. The color is from yellow-brown to reddish brown. Sample 389 is representative of the best material. Although a considerable area is covered by this sand it is very patchy in occurrence and without a detailed survey no estimate of the probable acreage is possible. The New York Central Railroad runs through the northern edge of the territory.

Molding Sand Sample 389

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	4.4	155	7.5
20	0.50	6.4	170	13.0
40	2.60	8.5	166	17.3
70	9.14	9.8	....	13.0
100	18.96			
140	17.00			
200	9.74			
270	10.80	Grain fineness: 147		
Pan	20.40	Grade: No. 2 E		
Clay	10.80			
Total	99.94			

Oswego County

Much of the sand in this county is too fine for concrete work, but is suitable for mortar and brick work. The best pits are near Fulton.

Massaro Washed Sand and Gravel Co. Two miles east of Fulton this company is producing pit-run material from a 12-foot bank, with a steam shovel. The deposit carries about 30 per cent gravel, of which sample 6546 is representative.

Fulton Sand and Gravel Co. At Fulton this company is screening sand and gravel from a 30-foot face which carries about 50 per cent gravel. A concrete sand and three grades of gravel are produced and all of this material is used locally. Much of the bank is cemented. The capacity of the plant is 100 yards a day.

Minetto. Around Minetto there is considerable sand but much of it is too fine for concrete. Pat Fraser and Butler Brothers are operating here in a small way.

Oneida Lake Sand Mines. At Cleveland, Bernard Delahunt is operating the only plant for producing unconsolidated glass sand in New York State. The deposit is a continuation of the large sand plain between Rome and Oneida lake. Years ago this district was the center of a considerable glass sand industry in connection with local glass manufacture.

The depth of usable sand is about 15 feet. Two feet of stripping is taken off by hand. An eight-inch sand sucker is used to excavate and the sand is caught in one of a battery of four settling boxes, each box having a 30-car capacity. These boxes are 36 feet wide, 85 feet long and 5 feet high. Usually four days are required to fill each box. At the discharge end an adjustable gate is used to regulate the slope of the sand surface and the depth of the moving water.

Near the overflow several cars of sand are dug and sold for engine sand as this part runs too high in iron content for a glass sand. The rest of the settled sand is dug by hand and loaded into box cars on the New York, Ontario & Western Railroad. In addition to glass sand, core and blast sands are also produced. Following is a chemical analysis and sieve test of the glass sand.

The following analyses were furnished by the Oneida Lake Sand Mines:

Average Analyses of Four Glass Sand Samples

	PER CENT
SiO_2	97.0 to 97.6
Fe_2O_3	0.3 to 0.35
Al_2O_3	1.2 to 1.4
CaO	0.09 to 0.11
MgO	0.15 to 0.18
Loss on ignition	0.2 to 1.1

Sieve Analysis of Glass Sand

MESH	PER CENT RETAINED
6	0.0
12	0.04
20	0.07
40	1.53
70	34.38
100	47.30
140	14.16
200	1.67
270	0.51
Pan	0.25
Total	99.91

Selkirk. On the east shore of Lake Ontario there is an extensive area of sand dunes and beach deposits, which are quite similar to those of the famous Michigan City core sand district. Recently New York State has taken over the best of this territory for a state park and therefore the opportunity for commercial development has been lost. The sand is clean, white and suitable for core work in foundries. Sample 398 is the dune sand and sample 399 is from the beach. Figure 33 illustrates the usual character of this deposit.

Core Sand Sieve Tests

Sample 398 MESH	PER CENT RETAINED	*Sample* 399 MESH	PER CENT RETAINED
6	0.0	6	6.34
12	0.0	12	0.0
20	0.0	20	0.0
40	0.80	40	1.60
70	54.20	70	61.22
100	38.54	100	28.10
140	5.04	140	2.00
200	0.60	200	0.20
270	0.10	270	0.06
Pan	trace	Pan	0.06
Clay	0.46	Clay	0.32
Total	99.74	Total	99.90
Permeability: 156		Permeability: 178	

South Granby. A weathered type of molding sand is found here on the higher knolls. It runs into clay on the lower slopes. Some of this sand is quite fine in texture and strongly bonded and is suitable for brass work and small iron castings. The deposits are probably not extensive, but the short haul to the Delaware, Lackawanna and Western Railroad should make a small scale operation profitable. Sample 397 illustrates the usual properties of this sand.

Molding Sand Sample 398

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	4.2	....	4.2
20	0.0	6.2	182	5.1
40	0.40	8.3	172	7.5
70	0.60	9.9	....	5.8
100	1.94			
140	5.60			
200	9.14	Grain fineness: 237		
270	22.10	Grade: No. 1 E		
Pan	48.20			
Clay	11.30			
Total	99.28			

Otsego County

The only deposit of importance is operated by the Mohawk Limestone Products Co. at Bloods Mills. The bank is 80 feet high and carries 20 per cent gravel. The washing and screening plant has a capacity of four cars a day and produces three grades of gravel and a concrete sand. Shipments are on the Southern New York Power and Railroad Corporation into Oneonta (sample 6641).

Putnam County

No sand and gravel tonnage of any consequence is produced in this county.

Queens County

Aside from small local pits, the only production of importance is from Rockaway Beach by the Astell White Sand Co. and the Rockaway White Sand Co. This sand is of excellent quality and is used for building purposes, core sand and engine sand.

Rensselaer County

Some molding sand, dug by Whitehead Brothers at Van Hoesen and Reynolds (Nevin '25) is shipped outside the county, but most of the other sand and gravel is used locally. Production centers are at Rensselaer and Troy.

Rensselaer. Among the operators here may be mentioned S. A. Dunn and Sons, Inc., A. Larraway, A. E. Boucher, and W. N. Onderdonk. Except Boucher, who uses sand dredged from the river, all the producers are operating small pits and trucking their product into Albany. As a rule the sand is rather fine in texture and often is weak in strength tests for concrete. Sample 6440 is representative.

Clemente Bros. One mile east of Troy, Clemente Brothers are operating a sand pit with portable loaders and a one-yard shovel. The face is 75 feet in height. All of the product is trucked into Troy. Sample 6603 is the average run of the bank sand.

Valley View Sand & Gravel Co. Just north of Brunswick Center a delta deposit has been opened to a depth of 40 feet, although tests show that the deposit extends to a depth of 90 feet. The washing and screening plant has a capacity of 200 yards a day and makes coarse and fine sand and one grade of gravel. Excavating is done with a drag line. The bank carries 30 per cent gravel.

Among other producers near Troy are J. T. Murray, J. R. Williams Sons, and Richard S. Pickering, all of whom are operating small pits.

Richmond County

There is no large commercial production of sand and gravel in this county, but morainal outwash deposits and modern sand beaches occur along the eastern shores, south of Clifton, that may be turned to account.

Rockland County

Except for local use, as the Ward pit at Stony Point, no sand and gravel banks are worked at present in Rockland county.

St Lawrence County

In adjacent pits the Ogdensburg Brick and Sand Co. and Charles Dillingham are digging sand by hand. The face is about 10 feet in height and the stripping is two feet. Formerly this sand was used to reduce the shrinkage of brick clay and to face brick molds, but now it is used only for building purposes. Sample 6339 is the average run of the bank.

Captain A. R. Hinckley is dredging gravel from the St Lawrence river with a clamshell bucket and bringing it on barges into Ogdensburg.

Saratoga County

Since this county is part of the Hudson river district, the occurrence and origin of the molding sand in Saratoga county has already been described (Nevin '25). Figure 38 illustrates the usual 18-inch layered bed, stripped of loam and ready for digging, and such deposits are now being worked at Elnora, Jonesville, Mechanicville, Crescent, Schuylerville, Bemis Heights, Burgoyne, Round Lake, Stafford Bridge, Vischer Ferry, Cramers, Ushers, Coons, Schuyler Junction, Cedar Bluff, Saratoga Springs and Gansevoort.

As the best and most available deposits of molding sand are being slowly worked out in the districts further south in the Hudson valley, Saratoga county has recently shown a steady growth in production, until it is now leading the State in total tonnage produced. Since future molding sand reserves in this county are of considerable interest, a hasty reconnaissance was made in order to see if there were any appreciable untouched deposits.

Along both sides of Fish Kill creek, east of Saratoga Springs, there is a large amount of molding sand at an elevation of 275 to 300 feet, some of which has already been opened. New territory should be carefully prospected as the best molding sand is quite scattered and there is an abundance of weak, worthless dune sand found in this area.

Northeast of Saratoga Springs toward Gansevoort and Glens Falls is a promising district lying between and along the Delaware and Hudson Railroad and the Saratoga Springs-Glens Falls electric line. Incidentally this electric line is of standard gage and freight is hauled on it. Samples 372 and 375 represent the stronger, less permeable grades while samples 373 and 374 are the weaker, more open types. In the near future some of these deposits no doubt will be developed on a commercial scale.

Molding Sand Sample 372

Mesh	Per cent retained	Per cent water	Strength	Permeability
6	0.0			
12	0.0	4.5	...	10.7
20	0.0	6.4	175	14.7
40	4.24	8.3	156	17.3
70	5.06	10.1	...	18.4
100	9.64	11.4	...	19.0
140	16.14	12.3	...	14.7
200	17.64			
270	23.88			
Pan	18.26	Grain fineness: 161		
Clay	4.80	Grade: No. 2 C		
Total	99.66			

Molding Sand Sample 375

Mesh	Per cent retained	Per cent water	Strength	Permeability
6	0.0			
12	0.0	4.3	138	7.9
20	0.0	6.4	176	13.0
40	0.30	8.1	173	12.2
70	0.86			
100	4.00			
140	14.64			
200	20.84			
270	23.04			
Pan	27.14	Grain fineness: 192		
Clay	8.76	Grade: No. 2 D		
Total	99.58			

Molding Sand Sample 373

MESH	PER CENT RE-TAINED	PER CENT WATER	STRENGTH	PER-MEA-BILITY
6	0.0			
12	0.0	4.3	...	42
20	tr	6.2	142	58
40	12.56	8.4	127	67
70	40.66	9.5	...	63
100	17.44			
140	9.00			
200	4.04			
270	4.34			
Pan	5.30	Grain fineness: 75		
Clay	6.24	Grade: No. 4 D		
Total	99.58			

Molding Sand Sample 374

MESH	PER CENT RE-TAINED	PER CENT WATER	STRENGTH	PER-MEA-BILITY
6	0.0			
12	0.0	4.0	...	47
20	tr	6.2	127	67
40	11.44	8.2	110	62
70	34.14			
100	22.50			
140	12.80			
200	6.20			
270	4.84			
Pan	3.74	Grain fineness: 78		
Clay	4.50	Grade: No. 4 C		
Total	100.16			

Tory Hill Sand and Gravel Co. At Willow Glen the Tory Hill Sand and Gravel Co. is mining a 125-foot bank of sand and gravel by the hydraulic method. Gravel makes up about 60 per cent of the deposit and excavating is done with strong jets of water, the sluiced material being carried in sloping troughs to the washing and screening plant at the bottom of the hill. Capacity is 15 cars a day and shipments are made on the Delaware and Hudson Railroad. Two grades of gravel, similar in composition to sample 6222, and a concrete sand, represented by sample 6223, are produced. A new plant is being built and will be in operation during 1928. Occasionally the sand contains too high a percentage of fine material for concrete work, but the new plant will no doubt remedy this defect by better washing.

John Finucci and Sons. This company is operating the old Sheridan pit at Waterford and the present washing and screening plant has a capacity of 200 yards a day. The upper 100 feet of the bank carries 50 per cent gravel and the lower 30 to 50 feet is mostly sand. Examination of the gravel shows from 15 to 20 per cent shale present, which in sample 5613 is included in the undetermined amount. Two grades of gravel and a concrete sand (sample 5612) are produced. All this material is trucked for local use.

Corinth. In the vicinity of Corinth there is an abundance of sand, due to the presence of a glacial sand plain. Very few deposits have been opened and no large operations are being carried on at present.

The Corinth Sand Co. at South Corinth is shipping a small tonnage of core sand and furnace bottom sand, sample 402 being a sieve analysis of this material.

Core Sand Sample 402

MESH	PER CENT RETAINED
6	0.0
12	0.10
20	0.15
40	5.67
70	39.65
100	29.46
140	12.41
200	5.62
270	3.50
Pan	3.25
Total	99.81

Saratoga Springs. The Chase pit is being operated by E. W. Stiles to a depth of 25 feet. All the production is bank run material and the deposit contains very little gravel and a number of silty streaks.

Mechanicville. Here Frank Poucher is locally selling bank run material that he is excavating with a clamshell bucket.

Cohoes. Peter Holohan is operating a small sand pit by hand and trucking the material into Cohoes.

Schenectady County

Neil F. Ryan. At Scotia, Neil F. Ryan has built an up-to-date washing and screening plant with a capacity of 800 yards a day, as illustrated in figure 34. Two grades of gravel, represented by sample 5767, core sand and concrete sand, similar to sample 5991, are produced. Storage is in bins and open stock piles and all of the production is handled by trucks.

The bank face is 60 feet in height and carries 60 per cent gravel. This is an old glacial river deposit, the beds showing typical fluviatile conditions and being quite coarse in texture because of the fast water. Figure 36 is a general view of the pit.

Pattersonville. One of the oldest sand and gravel pits in the Mohawk valley is operated here by W. W. Barclay. Excavating is with a steam shovel and the present bank face is 40 feet in height. The material is screened but not washed and concrete sand is the main production. Capacity is about 10 cars a day and shipments are on the West Shore railroad. Although gravel constitutes 20 per cent of the deposit, it can not be used because it is full of shaly, decayed sandstone. Sample 6174 is the concrete sand.

Cushing Stone Co. In the same river deposit in which the Ryan pit is located, the Cushing Stone Co. has opened a 50-foot face with a drag line and a steam shovel. Capacity of the washing and screening plant is 20 cars a day and shipments are made on the Boston and Maine Railroad. Three sizes of gravel and a concrete sand are produced, the deposit being quite coarse, carrying 65 to 70 per cent gravel.

Molding sand. In Schenectady county molding sand is produced at Scotia, South Schenectady, Niskayuna and Schenectady. These deposits are of the weathered type so common to the Hudson valley (Nevin '25).

Schoharie County

The production of sand and gravel in this county is limited to local needs.

Schuyler County

The only available sources of sand and gravel are the high level glacial deltas which are found bordering the present lakes. At Watkins, John M. Roe has opened a deposit of this type to supply local demands, sample 6530 representing both the sand and gravel.

Seneca County

Aside from small pits for local use, no commercial production of sand and gravel occurs in Seneca county, although glacial deltas are present. North of Waterloo is found an extension of the sand plain from Geneva and some of this material has been weathered sufficiently to make a molding sand of poor quality. Sample 395 represents the best of this weathered sand.

Molding Sand Sample 395

MESH	PER CENT RETAINED	PER CENT WATER	STRENGTH	PERMEABILITY
6	0.0			
12	0.0	4.1	....	27
20	0.0	6.2	133	36
40	1.36	8.2	129	30
70	10.84			
100	22.84			
140	22.36	Grain fineness: 142		
200	14.10	Grade: No. 2 D		
270	10.38			
Pan	11.74			
Clay	5.20			
Total	98.82			

Steuben County

Corning Sand Co. At East Corning an old river deposit has been opened to a depth of 20 feet. Gravel constitutes about 10 per cent of the bank. Three sizes of gravel and a concrete sand are separated by dry screening. The haul to the Erie Railroad is one-half a mile and to the Delaware, Lackawanna and Western Railroad one-quarter of a mile. Capacity is about 100 yards a day. Sample 5515 is the gravel and sample 5526 the sand.

Scudder and Jenks. At Painted Post, on the second level above the Chemung river, a gravel and sand bank has been developed to a depth of 30 feet. A portable washing and screening plant with a 200-yard daily capacity was used to deliver concrete aggregate for local road work, but at present it is not being operated. Haul to the Erie and to the Delaware, Lackawanna and Western railroads is about one mile.

Louis Beufve. In the outskirts of Hornell an old glacial delta deposit has been opened to a depth of 25 feet, although the face of this delta is some 200 feet in height. At present the material is only screened and used locally, but plans are being made to open this deposit from the bottom so as to use its entire thickness. Sample 5114 represents the gravel and sample 5112 the concrete sand. Shipments could be made on the Erie Railroad by hauling one-half a mile.

Suffolk County

What has been outlined under Nassau county regarding the occurrence of sand and gravels on Long Island applies equally well to Suffolk county and therefore will not be repeated. The major sources of supply in the northern part of the county are the Herod and Hempstead gravels of the Manhasset formation, while the southern part of the county is limited to the relatively thin outwash plain deposits of the Wisconsin glacial period.

In the near future some of the larger companies now operating in Nassau county are planning to extend their activities into Suffolk county and it would not be surprising to see eventually this county lead all others in New York State in shipments of sand and gravel.

Seaboard Sand and Gravel Corp. Using a small spit of land for the location of its screening and washing plant, the Seaboard Sand and Gravel Corporation is dredging a bank face on Long Island sound near Port Jefferson. A 20-inch centrifugal pump is used on the face, which extends 100 feet above and 30 feet below the level of the sound. Some 12,000 gallons of water a minute are needed and 10 per cent of solids are carried in the feed pipe to the top of the plant. Three grades of gravel as well as coarse and fine sands are separated, all of the production being shipped in barges, The deposit carries 30 per cent gravel, with a preponderance of pea size, and near the top many boulders are found, these being from the Harbor Hill moraine. A large settling tank holding 1200 yards and having a depth of 10 feet is used to catch the fine sand, some of which is sold as asphalt sand, filter sand and engine sand. Sample 5936 represents the gravel and sample 5937 the concrete sand. Capacity of the plant is 8000 yards in 18 hours.

Farmingdale Sand and Gravel Co. At Farmingdale a washing and sizing plant, with a capacity of 450 yards a day, is separating three grades of gravel and two grades of sand. A drag line is used as the excavator, digging being stopped at a depth of 30 feet, which is just above the water level. Later it is expected to use a sand sucker to obtain the remainder of the deposit. Gravel constitutes about 25 per cent of the bank and since few large pebbles are present a crusher is not used. Shipments are made on the Long Island railroad. Sample 6325 represents the gravel and sample 6326 the concrete sand.

Great Eastern Gravel Corporation. Opposite Port Jefferson the Great Eastern Gravel Corporation is dredging sand and gravel from the harbor bottom with a floating clamshell dredge and loading the material onto barges. Sample 5519 represents the gravel and sample 5522 the average run of the sand.

Henry Steers, Inc. Near Northport this company has one of the best sand and gravel operations in the State. The deposit carries from 30 to 40 per cent gravel at present and the face is 70 feet in height. About the same thickness will be opened as a second level after the present workings have been depleted. The method of excavating is very efficient and is described on page 70 and illustrated in figure 11. The bank face is kept at a safe angle of repose by a hook swung on the end of a cable from the top of the bank, and jiggled up and down across the face.

Two grades of gravel, a blast grit (one-quarter of an inch), a finish grit (one-eighth of an inch) and a concrete sand are separated by the washing and sizing plant. No effort at present is made to catch the fine sand. Sample 5090 represents both the concrete sand and the gravel. Capacity is about 5000 tons a day and all shipments are made by water.

Smaller operators. Among the smaller producers who are supplying local demands may be included the Heling Sand and Gravel Co. at Lindenhurst; the Montauk Sand and Gravel Corporation at Montauk; John Abrew at Bay Shore; Central Park Sand and Gravel

Company's new 500-yard plant at Farmingdale; and the R. W. S. Corporation with a 200-yard plant at Huntington. These producers screen their product but do not use a washing plant.

Sullivan County

Very little sand or gravel is produced in this county even for local use.

Tioga County

On a previous river level above the Susquehanna river at Barton, William Hopkins formerly operated a sand and gravel pit to a depth of 30 feet. Gravel constitutes about 60 per cent of the deposit and is firmly cemented in many places. Sample 6263 represents the screened concrete sand.

Nichols. Here the Delaware, Lackawanna and Western Railroad formerly operated extensively for railroad ballast. The deposit is on the first terrace above the Susquehanna river and was dug to just above the water level, which gave a bank face of 25 feet. The ballast was washed and the sand was allowed to accumulate in a large waste heap.

At present the Scranton Sand Co. is reworking this storage pile of sand and in places is rewashing it. Some 25,000 yards of sand are still left and shipments are made on the Lackawanna Railroad.

Tompkins County

The only sand and gravel deposits of value in this county are found in glacial deltas which border the valleys at a number of different elevations. All the production is used locally.

At Buttermilk Falls, E. M. Rumsey and Son have installed a small screening and washing plant and are excavating a thick delta on the east side of Cayuga valley. Sample 4929 represents the run of the bank before washing.

At Ithaca the Reynolds Sand and Gravel Co. built a small washing plant in 1927, and sand and gravel are being dug from an enormously thick delta on Fall creek. This delta has been operated at different levels for a number of years, but the sands and gravels have always given trouble in concrete work because of not having been washed.

Ulster County

Rosoff Sand and Gravel Co. At Marlboro this company has opened an old glacial delta deposit along the Hudson river. The height of the bank is 115 feet and about 40 per cent gravel is present.

Excavating is done with a steam shovel and the washing and sizing plant makes three grades of gravel and a concrete sand. About two acres are dug over yearly to maintain the daily capacity of 3000 tons. Shipments are either by barge on the Hudson river or on the West Shore Railroad. Sample 6203 represents the gravel and sample 6202 the concrete sand. This sand carries a large percentage of Hudson river shale particles and is sometimes rejected on this account.

Dwyer Brothers and the Wilbur Sand Co. At Kingston, Dwyer Brothers and the Wilbur Sand Co. are both operating in the same pit, along the bank of Rondout creek. The face is 100 feet high and no washing plant is used, the product being only dry screened. The upper part of the deposit contains more sand, and this is used largely by the Wilbur Sand Co. Shipments are made by barge, but a large part of the production is used locally. Sample 4497 is the concrete sand.

Among the smaller producers should be included A. S. Wolven at Saugerties and Robert Main and Co. at Connelly. In addition a small amount of molding sand is produced at Kingston and formerly some was dug at Marlboro.

Warren County

There is no important commercial production of sand and gravel in this county at present.

Washington County

Aside from local production near Smiths Basin, very little sand and gravel is produced in Washington county.

Wayne County

Formerly at Palmyra the New York Central Railroad dug a large amount of sand and gravel but at present this is abandoned. Doubtlessly private enterprise will reopen this pit in the near future.

At Sodus Point core sand, engine sand and building sand are dredged with a clamshell bucket. This sand is of excellent quality but the production is not large at present.

Westchester County

Croton Sand and Gravel Corporation. At Croton-on-Hudson this company has opened a sand and gravel deposit to a depth of over 100 feet. A drag line is used for excavating, and the washing and sizing plant produces two sizes of gravel and a concrete sand. Sample 6561 is the concrete sand. Formerly shipments were made by water, but the harbor has silted recently so only local demands are being taken care of at present. The capacity of the plant is 300 yards a day.

Abandoned plants. Just north of Peekskill is found the old plant of the Tidewater Sand and Gravel Co. Four or five years ago this company was a large producer of washed and screened sand and gravel, and shipments were made by water. Today only bank run material is being dug for local consumption. Sample 5122 is the gravel and sample 6943 the concrete sand.

Among other abandoned plants in this county are those of Allen Whiteman at Peekskill and the Triangle Sand Co. at Mamaroneck. Some pit run material is also being produced by this latter company at Bedford.

Wyoming County

The only large plant in this county is operated by the Silver Springs Sand and Gravel Co. at Silver Springs. Extending to a depth of over 120 feet, the deposit is not cemented and shows no clay seams. Excavating is with a drag line and the bank runs 50 per cent gravel. The washing and screening plant produces three sizes of gravel and a concrete sand, sample 6314 representing the gravel and sample 6315 the sand. Capacity is 12 cars a day and shipment is on the Erie Railroad.

Yates County

Aside from glacial delta deposits along Seneca lake, which have been opened for local use, very little sand and gravel is produced in Yates county.

PROSPECTING SAND AND GRAVEL

Many producers do not realize the necessity of thoroughly prospecting a sand and gravel deposit before buying the property. Plans for an expensive plant have often been drawn and a hundred or more acres of land purchased on the showing of one test hole. Such methods can not be too severely criticized for, in general, failure is certain to result.

The time and money spent in preliminary examinations and tests of sands and gravels are the best possible insurance for the success of the plant and in no other way may the purity, degree of cementation, variation in texture and thickness of the deposit be discovered without considerable financial loss. Most practical producers have learned by experience how quickly sands and gravels may change in texture and purity within a short distance and yet these same men are often unable to estimate the worth of their reserve acreage simply because they do not concede the value of prospecting.

A surprising number of producers are operating on a month to month basis, so to speak, never knowing what change the deposit may undergo during the next 30 days of work. For this same reason, some operators are in the embarrassing position of having incorporated as a sand and gravel company and developed a good sale for gravel, only to discover that the deposit has changed to sand so that gravel can no longer be profitably produced.

Adequate prospecting not only determines the amount and character of the reserve, but it also forms a basis for deciding upon the location of the plant structure, as well as the design of the plant best suited to handle the material, and the amount of wash water necessary to insure a clean product. Manifestly, advance examination should also control the method of excavating at the pit.

For convenience, the prospecting of sand and gravel deposits in New York State may be considered under two general headings: deposits forming under water and bank deposits.

Deposits Forming under Water

Stream and river deposits. Rate of flow of the stream or river, its size and amount of material transported must be considered in the selection of the location of a dredging plant, since these factors control the replenishment of such deposits. Large rivers such as the Susquehanna, for instance, will bring down sufficient sand and gravel during one high water stage to replace all the material that has been removed during months of operation.

By a study of the currents in the river it is usually easy to determine the best places to obtain sand, as well as the areas of important gravel deposits. Where the river is broad and sluggish for a considerable distance, a deposit of finer texture is to be expected rather than in the narrow, swift courses. In the quiet reaches just beyond the shoals and on the inside of the river curves, sands and gravels are usually found in abundance. Therefore prospecting should be directed with these generalizations in mind.

A depth of more than four feet of sand and gravel in the river bed is necessary before a pump and loading facilities should be installed and unfortunately the available supply of material is often overestimated. When ascertaining the depth of sand and gravel a man in a boat with a long iron rod can usually tell when an underlying clay bed has been reached, by the ease with which the rod may be pushed downward. In fact, with a little experience, one may outline fairly well the sandy and gravelly areas by a gritty feel when tested with an iron rod, and tell the thickness rather accurately if the gravel is not too large in size.

An estimate of the amount of sand and gravel carried daily by a river may be obtained by sinking a large box to the level of the stream bed and measuring the quantity of material deposited in a given length of time. Similar tests may be made during a freshet, which will give some idea of the amount of sand and gravel that may be counted on to replace that excavated.

As many of the rivers and streams in New York carry a very high percentage of flat, rather friable sandstone pebbles, careful testing of the quality of the sands and gravels should be undertaken before any investment in equipment is made.

Lake and bay deposits. From the Great Lakes, from Long Island sound and from the Rockaway shoals a considerable tonnage of sand and gravel is produced by dredging. Most of this material is obtained from shoals and bars and in certain favorable locations, wave action, longshore and bottom currents continually bring new sand and gravel to replenish the worked-over areas. In a majority of cases, however, considerable shifting of dredging operations is necessary during the season. Hence it is often necessary to prospect for new deposits.

The government lake and harbor maps are of great help in searching for sands and gravels, as they not only accurately show the depth of water but also quite frequently indicate the type of bottom material present. Additional data may be obtained by using a rowboat and taking samples with a telegraph snapper or with a small orange-peel bucket. The "snapper" is a simple and inexpensive instrument which has been used in connection with submarine cable laying. It is dropped on the bottom by means of a hand line and closes when jarred, under the impulsion of strong springs. Ordinarily it brings up only a handful of material so that if larger samples are desired the small orange-peel bucket, weighing 25 to 30 pounds, should be used. An example of what may be accomplished by prospecting in this manner has recently been demonstrated by Kindle ('25) in his studies on the bottom deposits of Lake Ontario.

Bank Deposits

Delta deposits. As previously pointed out, glacial deltas constitute an excellent and widespread source of sand and gravel in New York State. Usually a familiarity with the glacial lake history of a region makes prospecting for undeveloped deltas a matter of no great difficulty. Since these deltas really represent former lake levels, by using a topographic map and knowing the elevation of the lake levels, one may prospect a large amount of favorable territory within a short time.

The real difficulty arises when an effort is made to determine the proportion of sand to gravel, the amount of cementation, the purity of the material and its variation from place to place. Delta deposits may have a thickness of over 150 feet and they may be a composite of several deltas made at different lake levels. Or during the upbuilding of a single delta, drainage conditions nearby may have changed several times with the result that the final deposit may show large thicknesses of cemented, dirty sand; beds containing 60 per cent or more gravel with a large proportion of limestone pebbles; clean coarse sand with no lime; sand with 20 per cent gravel; thick beds of fine-textured sand with clay partings—or any other of a multitude of combinations.

With such a diversity of materials, correct testing of a delta deposit is very necessary. One common method of examination is to bore a series of holes with some type of well driller or core sampler, and keep a record of the different materials encountered, with an estimate of their thickness. Sometimes this is misleading, since any coarse sand passed through will continually seep down the sides of the hole and tend to give a fictitiously coarse appearance to a considerable thickness of underlying sands. Several examples have come to the attention of the writer, where such prospecting methods were used and the deposit bought as a concrete sand proposition, the purchaser discovering later that the concrete sand represented a few thin layers and that the bulk of the deposit was entirely too fine. A better method of testing is actually to dig down through the delta, shoring up the sides of the hole as progress is made. Such a careful testing will sometimes show the advisability of working the face in two levels so as to take advantage of the presence of two entirely different types of material.

After a delta has been opened, some control of the coarseness or fineness of the material excavated may be exercised by remembering that the foreset beds dip toward still water, which is usually away from the source of supply. As soon as the direction of this former supply is discovered, a coarsening of the deposit will result if excavating is carried that way.

River bank deposits. Because of constantly shifting currents, river bank deposits are extremely variable in composition and texture. The best deposits are found in the bends of the old river courses and sometimes a careful study of local conditions makes it possible to outline promising areas for prospecting.

Many of the south-flowing rivers were so choked with glacial débris-laden waters that there have been preserved valley train deposits which may be found as first and second terraces above the present river level. A topographic map is of considerable aid in prospecting for such deposits and when located they should be thoroughly examined by digging test holes.

Stratified moraine and outwash deposits. These deposits are of importance on Long Island. Any one prospecting for new sources of supply should have Professional Paper 82 of the United States Geological Survey, which describes and maps the glacial deposits of this district. These deposits also occur in the interior of the State and are the source of a considerable output of building and concrete sand. By remembering that stratified moraines and outwash plains become thinner and finer in texture and further they are formed from the ice front, one can usually roughly outline the best territory for intensive prospecting. The thinner deposits may be adequately tested by using a sand auger or posthole digger, but the thicker deposits should be test-pitted by hand digging.

THE SAND AND GRAVEL INDUSTRY

Although New York has an enormous reserve of untouched sands and gravels, it must be remembered that only a small percentage of this acreage really constitutes commercial deposits at present. Transportation must be available. It is not at all uncommon to find good material passed over and preference given to less easily worked and poorer deposits simply because of a difference in freight rates. Inferior quality also reduces a large part of the total reserve, as the removal of deleterious material is so expensive that only in occasional instances is the price received for the finished product sufficient to offset the cost of such removal. Finally, many deposits are not workable on a large commercial scale because they are too patchy and are not uniform over a big area, thus greatly increasing the expense of operation. Even now, in spite of all the tremendous potential reserves, good commercial deposits of sand and gravel in New York are becoming scarce.

When the operation of a sand and gravel pit was a "one-man" enterprise, it was usually sufficient to know that a 15-year reserve was assured. Before that was exhausted, the operator would have found another deposit that could be opened. Today a big company must look a long way ahead if it is to protect and take advantage of its reputation for supplying excellent material. A sand and gravel deposit should be recognized as a shrinking asset, and a large company with many interests to protect must locate new deposits before they are out of the market, even though it still has a considerable reserve. By doing this at the proper time a company may continue to operate almost indefinitely and should capitalize its prestige by selling its product under a distinctive trade name.

Not many years ago all sand and gravel operations were discontinued during the late fall but with the recent satisfactory use of cement in cold weather, a large tonnage of aggregate is now sold in the winter months. In fact, some of the large companies on Long Island, where salt water is available, are able to operate the entire year. In the future it would seem that more adequate storage facilities are necessary at the plant, not only to take care of the possible winter demand, but also to save all overproduction of any particular size. Many of the present plants are hampered by the sand piling up if a large gravel order should be filled and vice versa. A preponderance of pea-size gravel in the Long Island deposits is often embarrassing to those operators who have not allowed for this condition. Eventually a use will doubtlessly be found for such material, but at present it merely serves as an excellent illustration of the widespread need in the industry for more adequate storage of the surplus.

Another not distant change in plant design will be brought about by the increasing use of specifications for concrete aggregates. Unless the producer changes the method of delivering his finished product so as to be able to mix any size of material in any proportion, he will lose orders. Already several companies have recognized this necessity of meeting specifications, and have designed the feed of their finished product so that they are able to load any grading desired.

Perhaps the outstanding future development in the industry will be an increase in the amount of washed sand and gravel, which will go hand in hand with a betterment of the finished product. Wayside pit production and poorly prepared material have been a very harmful form of competition, for there are always those who will buy such material merely because it is cheap and who are either not affected by or are unmindful of the fact that the concrete made from it may be unsound.

The best of workmanship can not counteract the use of poor aggregates and the best of aggregates can not make up for faulty mixing and placing. It costs more money to make good aggregate, yet the product obtained with good aggregate and poor workmanship may not be so reliable as that obtained with poor aggregate and good workmanship. Usually the blame for unsatisfactory results has been heretofore placed on poor aggregates, but with the recently developed control methods and tests, the sand and gravel industry is now able to place the blame for failures where it really belongs and is in a position to meet any fair type of competition.

Production Statistics

With the continued increase in the use of concrete, the sand and gravel industry has shown a very rapid expansion until the present yearly value produced in New York State is about $10,000,000. Following is the production of sand and gravel from 1919 to 1926 (Hartnagel '27; Newland and Hartnagel '28).

Total Production of Sand and Gravel

YEAR	SHORT TONS	VALUE
1919	3 987 987	$2 246 880
1920	6 127 018	4 338 457
1921	6 021 229	3 673 127
1922	8 303 392	5 085 312
1923	10 730 225	7 291 076
1924	13 397 540	8 583 193
1925	14 966 616	9 750 433
1926	19 334 360	11 585 652

Building Sand

YEAR	SHORT TONS	VALUE
1919	1 974 827	$705 603
1920	3 192 796	1 489 248
1921	3 818 671	1 815 086
1922	4 588 446	2 171 806
1923	5 491 031	2 661 227
1924	8 542 247	4 330 551
1925	9 376 634	4 788 322
1926	11 975 851	5 647 668

Gravel

YEAR	SHORT TONS	VALUE
1919	1 484 782	$859 809
1920	2 026 622	1 381 773
1921	1 499 610	1 024 007
1922	2 340 771	1 531 396
1923	3 438 631	2 644 095
1924	4 097 554	3 111 593
1925	4 764 339	3 710 610
1926	6 516 770	4 662 803

Molding Sand

YEAR	SHORT TONS	VALUE
1919	418 319	$609 730
1920	590 577	1 232 721
1921	288 354	447 481
1922	579 999	855 682
1923	731 896	1 212 798
1924	607 089	1 040 735
1925	671 610	1 147 072
1926	671 748	1 171 821

Fire or Furnace Sand

YEAR	SHORT TONS	VALUE
1919	....	....
1920	39 772	$56 574
1921	21 240	34 660
1922	17 479	14 193
1923	15 005	10 817
1924	5 743	4 481
1925	10 260	8 850
1926	24 300	20 220

Other Sands

YEAR	SHORT TONS	VALUE
1919	110 059	$71 738
1920	277 251	178 141
1921	393 354	351 893
1922	776 697	512 235
1923	1 053 662	762 139
1924	144 907	95 833
1925	143 773	95 579
1926	145 691	83 140

According to figures published by the United States Bureau of Mines, the amount of sand and gravel produced in the United States for 1925 was 172,000,000 short tons valued at over $107,000,000. Of this total, New York's contribution amounted to approximately nine per cent.

In the production of molding sand New York was surpassed by Ohio and Illinois, but in the total tonnage of all kinds of sand and gravel, New York led all of the states. An interesting comparison of the value of this total production is illustrated in the following table where, for instance, New York leads Pennsylvania in total production by more than 2,000,000 tons, yet is surpassed by Pennsylvania in the value of the product by nearly $2,000,000.

Total Production of Sand and Gravel, 1925

STATE	SHORT TONS	VALUE
New York	14 966 616	$9 750 433
Illinois	14 954 536	8 140 090
California	14 077 849	8 752 528
Pennsylvania	12 604 065	11 438 788
Indiana	12 054 740	5 275 743

TABLE 9 Concrete Sand Tests

SAMPLE	LOCATION	PER CENT SAND PASSING THROUGH					LOAM VOL.	LOAM WT.	ORGANIC COLOR	COMPRESSION-POUNDS A SQUARE INCH			
										7-day		28-day	
		¼	6	20	50	100				Sample	Ottawa	Sample	Ottawa
2909...	Auburn	100	95.0	55.0	20.0	4.0	3.7	......	2	470	707	1125	1550
3672...	Rochester	100	95.0	55.0	16.6	2.4	4.6	......	2	705	931	1635	1664
4497...	Kingston	100	95.4	53.0	5.4	0.4	3.8	......	1	4285	3744	6000	6000
4904...	Batavia	100	90.4	44.0	12.8	3.8	9.9	......	1	4533	4336	6000	5790
4929...	Ithaca	100	87.4	41.0	15.0	3.4	9.4	......	1	4625	3126	6000	5806
4930...	Lynbrook	100	80.0	50.0	21.2	0.8	tr	......	2	3905	3126	6000	5806
4931...	Lynbrook	100	92.0	66.4	19.6	0.6	2.2	......	1	3253	3126	6000	5806
4932...	Lynbrook	100	90.0	56.0	12.4	0.4	3.3	......	1	4023	3126	5913	5806
4933...	Lynbrook	100	81.0	49.6	19.4	0.2	3.2	......	1	4283	3126	6000	5806
5090...	Northport	100	87.4	44.0	7.0	0.6	4.3	......	1	2330	1089	3738	1908
5112...	Hornell	100	96.0	52.4	3.4	1.0	4.8	......	1	1850	1089	2823	1908
5239...	Rochester	100	89.4	46.6	20.8	7.0	4.3	.....	1	1973	1019	3295	1741
5251...	Rome	100	97.6	88.4	16.6	1.0	3.7	......	2	543	940	955	1808
5389...	Fairhaven	100	99.8	62.4	3.4	0.2	tr	......	1	1368	1310	2985	2400
5522...	Port Jefferson	100	96.4	65.0	4.4	0.4	tr	......	1	1000	860	1980	1510
5523...	Port Washington	100	98.2	71.0	21.0	4.0	3.9	......	1	1035	985	2030	1633
5526...	Corning	100	98.2	76.0	20.0	4.4	7.3	2.3	1	1095	860	2225	1510
5549...	Syracuse	100	99.0	79.0	8.0	3.0	6.4	......	......	1390	860	2198	1510
5564...	Fishers	100	94.2	57.0	17.0	3.6	4.7	......	1	1593	860	2770	1510
5612...	Waterford	100	94.2	44.8	8.0	2.6	3.9	......	1	1035	874	2250	1712
5642...	Wadsworth	100	93.0	47.0	3.0	1.4	6.0	......	1	845	650	1578	1322
5798...	LeRoy	100	94.4	52.0	7.4	3.2	4.7	......	1	2510	2158	3753	3563
5829...	Watertown	100	99.6	50.0	3.4	1.0	3.8	......	1	1950	1499	3218	2631
5860...	Syracuse	100	94.0	49.4	3.4	1.4	5.5	......	4	1845	1422	3245	2645
5937...	Port Jefferson	100	98.6	68.0	7.0	1.0	tr	......	1	1785	1254	2843	2502
5991...	Scotia	100	97.6	87.8	17.8	4.4	4.0	......	3	1893	1254	2665	2502
6067...	Scottsville	100	88.4	44.4	6.4	2.4	6.5	2.9	1	2300	1324	3808	2505
6164...	Ballina	100	88.0	55.0	19.0	4.4	8.9	4.4	1	2603	1770	4208	2684
6174...	Pattersonville	100	96.5	69.4	5.0	2.0	3.9	1.3	1	2020	1770	3828	2684

TABLE 9 (*continued*) Concrete Sand Tests

SAMPLE	LOCATION	PER CENT SAND PASSING THROUGH					LOAM VOL.	LOAM WT.	ORGANIC COLOR	COMPRESSION-POUNDS A SQUARE INCH			
										7-day		28-day	
		¼	6	20	50	100				Sample	Ottawa	Sample	Ottawa
6183...	Hancock..........	100	94.0	68.0	12.0	3.0	8.3	2.8	1	1715	1770	3385	2684
6187...	Bowmansville..........	100	96.0	51.0	12.0	3.5	2.9	......	1	2340	1448	4388	2699
6193...	Newburgh..........	100	96.4	67.4	25.4	6.0	4.8	1.6	1	1775	1448	3355	2699
6202...	Marlboro..........	100	98.6	32.8	6.4	1.8	2.7	......	1	1850	1448	3410	2699
6211...	Albany..........	100	92.4	49.2	17.0	4.2	......	1.8	1	1870	1448	3710	2699
6219...	Canawangus..........	100	90.0	32.0	6.4	2.8	4.7	......	1	2825	1448	4578	2699
6223...	Willow Glen..........	100	92.0	38.4	9.8	3.2	2.9	......	1	2198	1448	3643	2699
6224...	Boonville..........	100	97.2	80.6	19.0	2.6	3.2	......	1	1533	1448	2800	2699
6226...	Otisville..........	100	91.0	59.4	15.6	2.6	4.9	......	2	1805	1448	3463	2699
6244...	Huguenot..........	100	96.0	53.0	2.4	0.2	1.9	......	2	1565	1530	3372	2660
6249...	Syracuse..........	100	90.5	54.0	8.0	1.4	6.9	2.2	1	2030	1530	3285	2660
6259...	Springville..........	100	86.0	52.4	15.4	2.0	4.7	......	1	1685	1530	3198	2660
6260...	Oaks Corners..........	100	97.0	71.4	2.8	0.6	2.8	......	1	1803	1530	3220	2660
6263...	Barton..........	100	87.0	58.0	10.4	2.7	7.8	2.3	1	2230	1530	3690	2660
6290...	Machias..........	100	83.2	46.0	15.4	4.4	5.5	2.4	2	2793	1530	4628	2660
6303...	Saranac Lake..........	100	98.0	68.0	12.8	1.8	tr	......	1	1800	1530	2738	2660
6315...	Silver Springs..........	100	87.0	37.0	4.0	1.2	5.9	1.6	1	2060	1530	3205	2660
6326...	Farmingdale..........	100	90.2	51.0	5.3	1.0	3.0	......	1	2155	1530	3508	2660
6336...	Auburn..........	100	95.6	70.6	18.6	1.8	3.6	......	2	1457	1360	2760	2632
6339...	Ogdensburg..........	100	99.6	62.0	18.0	5.6	4.7	2.8	1	2480	1734	4128	2970
6340...	Hancock..........	100	91.0	57.4	14.8	3.0	5.8	1.8	1	1805	1734	3233	2970
6344...	Rochester..........	100	99.6	27.4	3.4	1.4	2.0	......	1	1958	1254	3435	2502
6346...	Allegany..........	100	96.8	83.4	10.0	2.0	1.9	......	1	1808	1734	2823	2970
6352...	Alfred..........	100	98.6	62.0	14.2	4.0	4.5	2.1	1	2438	1740	3363	3000
6355...	Allegany..........	100	93.4	68.0	8.0	2.0	1.6	......	1	2100	1734	3343	2970

6367...	Franklinville	100	93.0	54.0	10.8	1.8	2.0	0.9	1	2463	1734	3715	2970
6408...	Watertown	100	98.6	74.0	14.8	4.0	7.7	3.7	1	2288	1734	3425	2970
6440...	Rensselaer	100	98.4	78.4	33.6	6.2	3.7	......	1	1920	1351	2640	3108
6444...	Fillmore	100	80.0	36.4	16.3	7.5	4.5	......	1	2458	1635	4025	2557
6486...	Lynbrook	100	92.0	62.0	12.4	1.0	2.0	......	1	2088	1635	3373	2557
6487...	Port Washington	100	86.0	62.0	19.0	2.6	2.0	......	1	2175	1635	3308	2557
6530...	Watkins	100	89.2	48.4	19.0	5.6	7.8	3.4	2	2195	1635	3338	2557
6561...	Croton	100	94.0	59.0	17.0	2.4	1.9	......	1	1878	1621	3358	2245
6564...	Farmingdale	100	92.0	69.0	15.6	1.6	1.9	......	2	1795	1621	3223	2245
6566...	Mineola	100	92.4	60.4	14.6	1.6	1.0	......	1	1840	1621	3143	2245
6601...	Buffalo	100	80.0	41.0	24.0	4.4	4.0	......	1	2398	1228	4210	2616
6603...	Troy	100	93.4	50.8	9.4	2.2	3.8	......	1	1503	1228	2948	2616
6610...	Attica	100	69.6	46.0	25.0	5.4	3.0	......	1	2133	1228	3993	2616
6637...	Bowmansville	100	94.6	67.4	28.0	8.0	2.0	......	1	2108	1630	3155	2260
6638...	Auburn	100	89.0	54.0	23.4	6.4	5.7	2.1	1	2047	1381	3988	2410
6641...	Bloods Mills	100	96.0	26.0	5.4	2.6	6.1	1.5	1	1558	1381	3268	2516
6644...	Medina	100	95.4	58.6	11.2	1.8	2.9	......	1	1810	1381	3385	2516
6671...	Fultonville	100	95.0	73.4	5.8	2.4	4.8	......	1	2255	1555	3138	....
6682...	Malone	100	98.0	74.0	13.4	2.0	2.8	......	1	1760	1610	2420	2414
6710...	Saranac Lake	100	93.0	49.4	14.0	5.0	4.8	......	5	1770	1630	2933	2260
6726...	Binghamton	100	97.4	64.0	2.0	0.6	3.6	......	1	1280	1630	2333	2260
6727...	Binghamton	100	89.0	53.0	13.0	3.0	5.6	1.8	1	1703	1630	3210	2260
6742...	Clarence	100	82.0	38.0	13.4	3.9	5.7	1.7	1	2700	1630	3458	2260
6755...	Solsville	100	93.2	50.0	6.6	1.0	4.5	......	1	1393	1323	2915	1960
6772...	Caledonia	100	90.0	36.0	5.0	1.8	4.8	1.8	1	2593	1555	3500	2248
6802...	Valley Stream	100	99.0	78.0	13.4	1.0	2.8	......	......	938	1394	1808	2095
6808...	Port Jervis	100	96.8	53.6	8.0	1.6	5.5	......	1	1765	1394	3075	2095
6850...	Johnstown	100	97.0	57.0	10.6	3.0	5.2	1.8	1	2068	1394	2995	2095
6851...	Johnstown	100	99.4	89.0	21.4	3.0	4.3	......	6	1098	1394	1773	2095
6859...	Livonia	100	89.2	46.6	5.6	1.6	11.2	......	1	2848	1394	3673	2095
6881...	Westbury	100	90.0	48.8	8.8	1.0	4.4	......	1	1695	1274	3248	3059
6896...	Jamestown	100	88.0	38.6	11.8	6.2	6.3	3.1	1	1805	1351	4100	3108
6943...	Peekskill	100	94.8	55.4	15.8	3.6	......	......	1	1533	1436	3030	2481
6957...	Alder Creek	100	96.4	62.4	15.6	2.2	3.2	......	1	1770	1436	2780	2481
6958...	Boonville	100	94.0	54.4	11.0	1.6	tr	......	1	1735	1436	2945	2481
6961...	Santa Clara	100	98.2	60.0	20.4	1.8	tr	......	1	1653	1436	2730	2481
6964...	Lyon Mountain	100	96.0	27.6	10.2	4.8	4.0	......	1	2125	1436	2570	2481
6965...	Springville	100	97.2	63.8	16.0	3.6	5.3	......	4	1558	1436	2545	2481
7000...	Horseheads	100	94.0	51.0	13.6	3.8	3.9	......	1	2010	927	2833	1548
7040...	Dunkirk	100	90.0	50.6	17.4	2.2	2.0	......	2	1445	649	2178	1571
7113...	Floral Park	100	94.6	71.0	18.0	1.4	2.0	......	2	......	......	......	....

Table 10 Gravel Tests

Sample number	Per cent passing through				Lithologic percentage						Per cent abrasion loss
	2¾"	1½"	⅝"	¼"	Sandstone	Limestone	Gneiss	Dolomite	Quartz	Undetermined	
4929.....	100	93.8	76.8	52.5	60	30	.....	.....	.....	10	......
4930.....	100	97.9	86.1	51.7	....	....	.....	.....	90	10	......
5090.....	100	90.2	69.6	49.6	10	....	30	.....	50	10	12.5
5114.....	100	80.0	50.7	31.1	70	20	.....	.....	.....	10	5.9
5122.....	100	94.0	34.3	2.8	70	....	.....	.....	20	10	9.6
5388.....	100	97.2	81.9	62.2	80	10	.....	.....	.....	10	......
5514.....	100	47.0	8.0	0.5	....	40	50	.....	.....	10	7.8
5515.....	100	87.3	36.4	9.5	60	30	.....	.....	.....	10	7.8
5516.....	100	93.5	41.0	16.2	....	....	40	.....	50	10	......
5517.....	100	93.2	20.7	0.0	....	....	10	.....	90	.....	7.0
5519.....	100	74.7	11.0	1.0	....	....	10	.....	90	.....	......
5613.....	100	96.1	81.5	56.8	60	10	.....	.....	10	25	......
5641.....	100	69.0	19.2	3.7	50	20	.....	10	.....	10	......
5694.....	100	63.5	16.5	1.5	....	....	40	.....	50	10	12.4
5745.....	70.6	60.0	45.1	31.9	90	....	5	.....	.....	5	11.4
5767.....	100	64.5	11.8	0.5	50	20	10	10	.....	10	13.8
5788.....	100	26.0	0.0	0.0	70	15	5	.....	.....	10	3.6
5893.....	100	72.7	12.7	0.0	70	20	.....	.....	.....	10	22.0
5936.....	100	63.8	6.2	0.0	....	....	15	.....	80	5	12.4
6067.....	82.8	72.7	65.0	52.5	60	10	.....	20	.....	10	13.6
6163.....	100	59.5	15.1	1.1	35	55	.....	.....	.....	10	11.8
6203.....	100	64.5	14.0	8.5	50	35	.....	.....	.....	15	15.0
6220.....	100	73.7	18.0	2.5	20	35	5	35	.....	5	12.2
6222.....	100	70.1	4.6	1.6	30	10	30	20	.....	10	19.0
6274.....	100	89.8	35.0	1.7	30	60	.....	.....	.....	10	14.7
6304.....	100	93.6	79.3	59.3	....	....	90	.....	.....	10	10.4
6314.....	100	75.5	15.5	0.0	75	15	.....	.....	.....	10	9.4
6325.....	100	82.7	37.4	5.5	....	....	40	.....	50	10	6.0
6352.....	97.0	71.2	14.2	0.0	60	25	5	10	.....	.....	6.4
6384.....	100	77.5	3.5	0.0	60	30	.....	10	.....	.....	3.2
6386.....	100	64.0	13.5	0.0	30	60	.....	5	.....	5	8.2
6387.....	95.0	65.4	10.7	1.0	95	....	.....	.....	.....	5	12.6
6485.....	100	93.1	53.5	15.6	....	....	5	.....	90	5	6.4
6530.....	97.0	90.7	72.5	56.0	75	20	.....	.....	.....	5	11.8
6546.....	97.1	76.4	35.2	11.6	80	10	5	.....	.....	5	6.0
6602.....	100	93.1	66.9	39.5	40	45	5	.....	.....	10	6.0
6611.....	100	53.0	1.8	0.0	30	40	15	10	.....	10	8.8
6647.....	100	63.2	14.2	3.2	40	50	.....	5	.....	5	9.6
6738.....	100	80.0	1.0	0.0	20	60	5	10	.....	5	8.2
6742.....	100	64.7	20.2	10.0	15	60	5	15	.....	5	17.4
6750.....	100	69.4	10.4	0.0	5	....	40	.....	45	10	9.2
6765.....	100	72.0	7.0	0.0	65	20	5	5	.....	5	12.0
6773.....	100	80.4	26.2	2.0	65	15	10	5	.....	5	8.4
6788.....	100	72.2	1.8	0.0	90	....	5	.....	.....	5	6.4
6859.....	96.9	81.0	62.3	40.9	25	70	.....	.....	.....	5	6.4
6897.....	98.6	64.5	12.2	0.2	50	40	5	.....	.....	5	6.4
6960.....	100	71.1	29.6	0.1	60	30	5	.....	.....	5	13.6
7001.....	100	73.2	37.7	10.5	35	45	10	.....	.....	10	7.0

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Figure 1 Excavating from the top of the pit-face *Courtesy of the Madison Sand and Gravel Co.*


Figure 2 Drag line scraper operation. A favorite method of the small producer


Figure 3 A Sauerman slack line cableway excavating a delta deposit

Figure 4 Slack line cableway type of operation *Courtesy of the Boonville Sand Corp.*

Courtesy of the Boonville Sand Corp.

Figure 5 Automatic dumping feature. No conveyor belts are needed

Courtesy of the Consolidated Materials Corp.

Figure 6 Worked out part of a deposit in which a drag line has been used

Courtesy of the Monighan Machine Co.

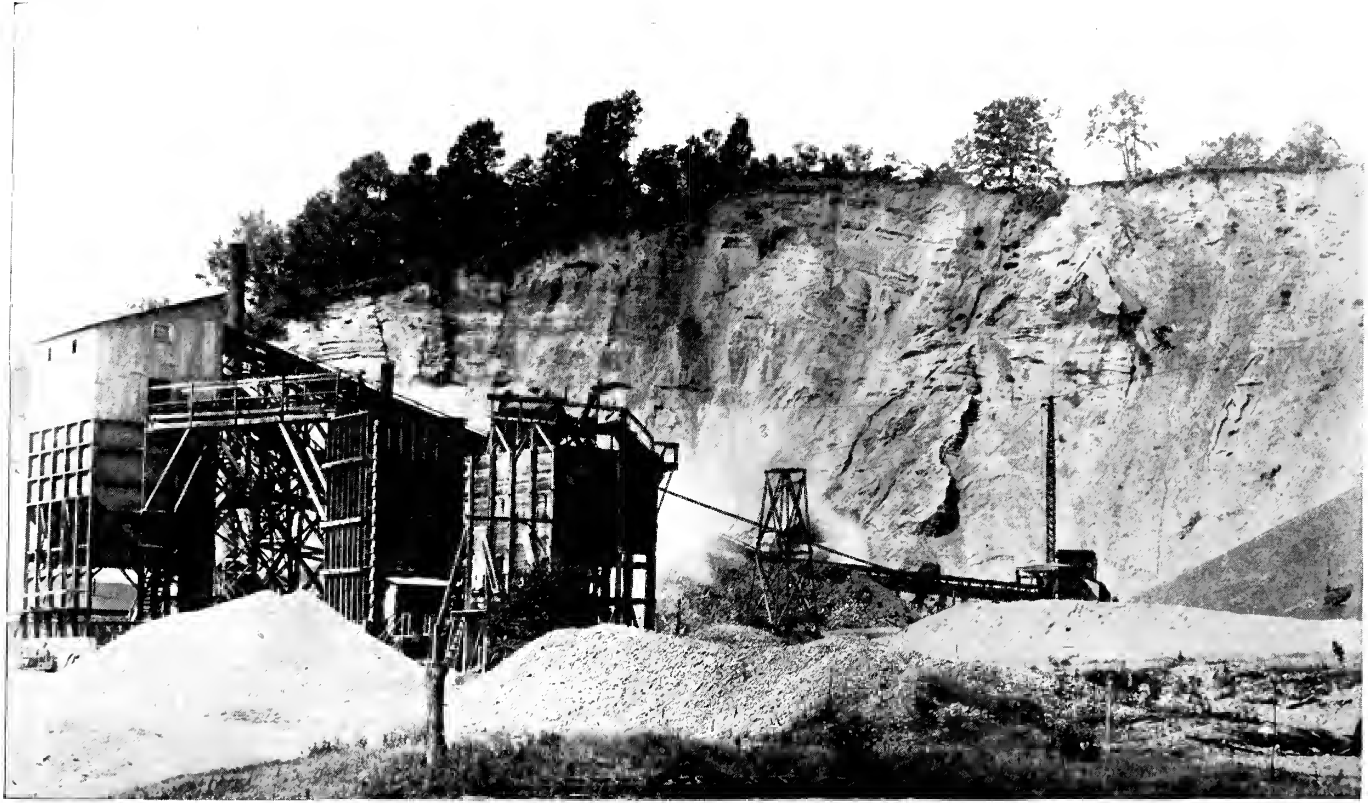
Figure 7 Monighan drag line excavator in operation

Figure 8 A drag line operation showing the ridges of unexcavated material

Courtesy of the J. E. Carroll Sand Co.

Figure 10 A stiff-legged derrick with a clamshell bucket dumping into a hopper protected by a grizzly

Figure 11 An efficient method of excavating and conveying material. For a detailed description see page 70

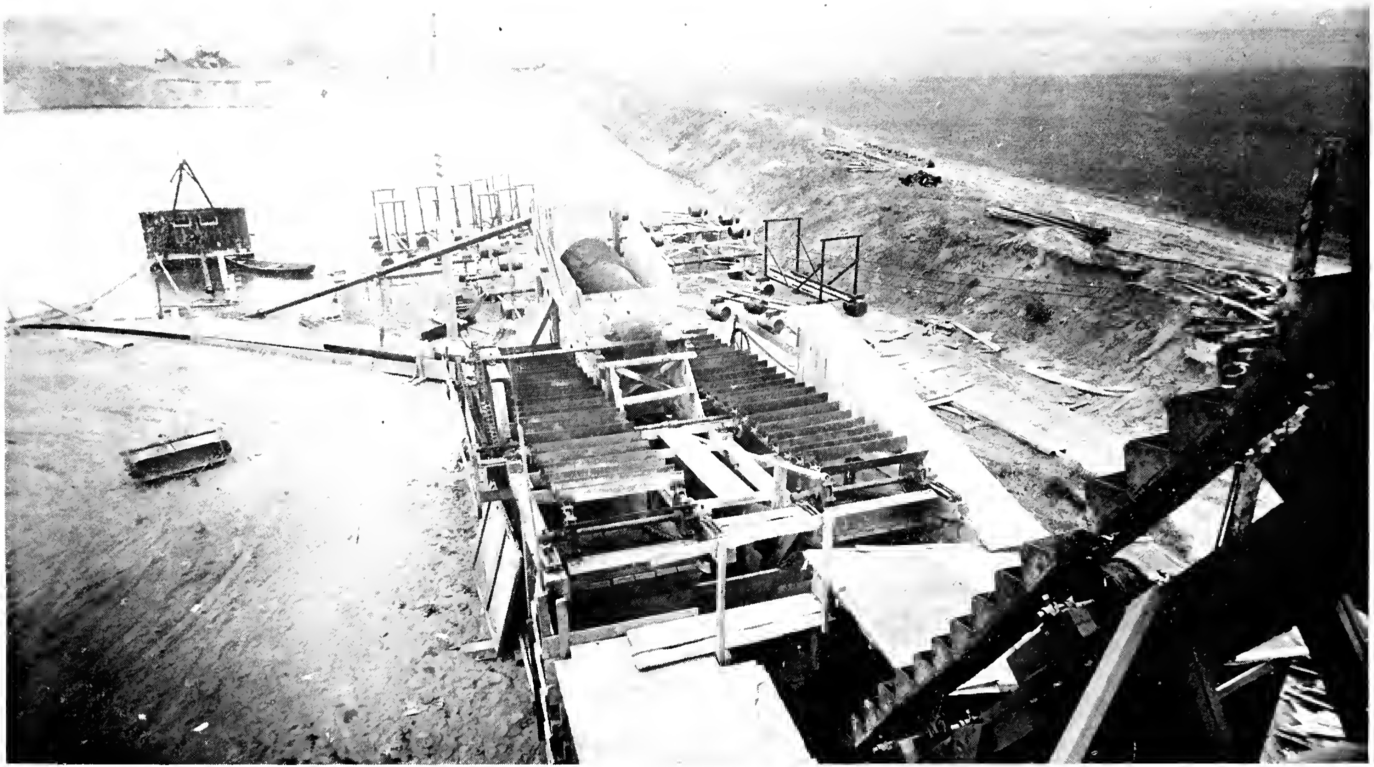


Courtesy of the Boonville Sand Corp.

Figure 12. A 200-foot working face. An idea of the size of the excavation can be formed from the 80-foot mast of the stiff-legged derrick.

Figure 13 Centrifugal pump excavating a 70-foot deposit which carries 60 per cent of gravel

Figure 14 Hydraulic jet loosening a 50-foot face. This lessens the danger from sliding and also feeds material to the pump



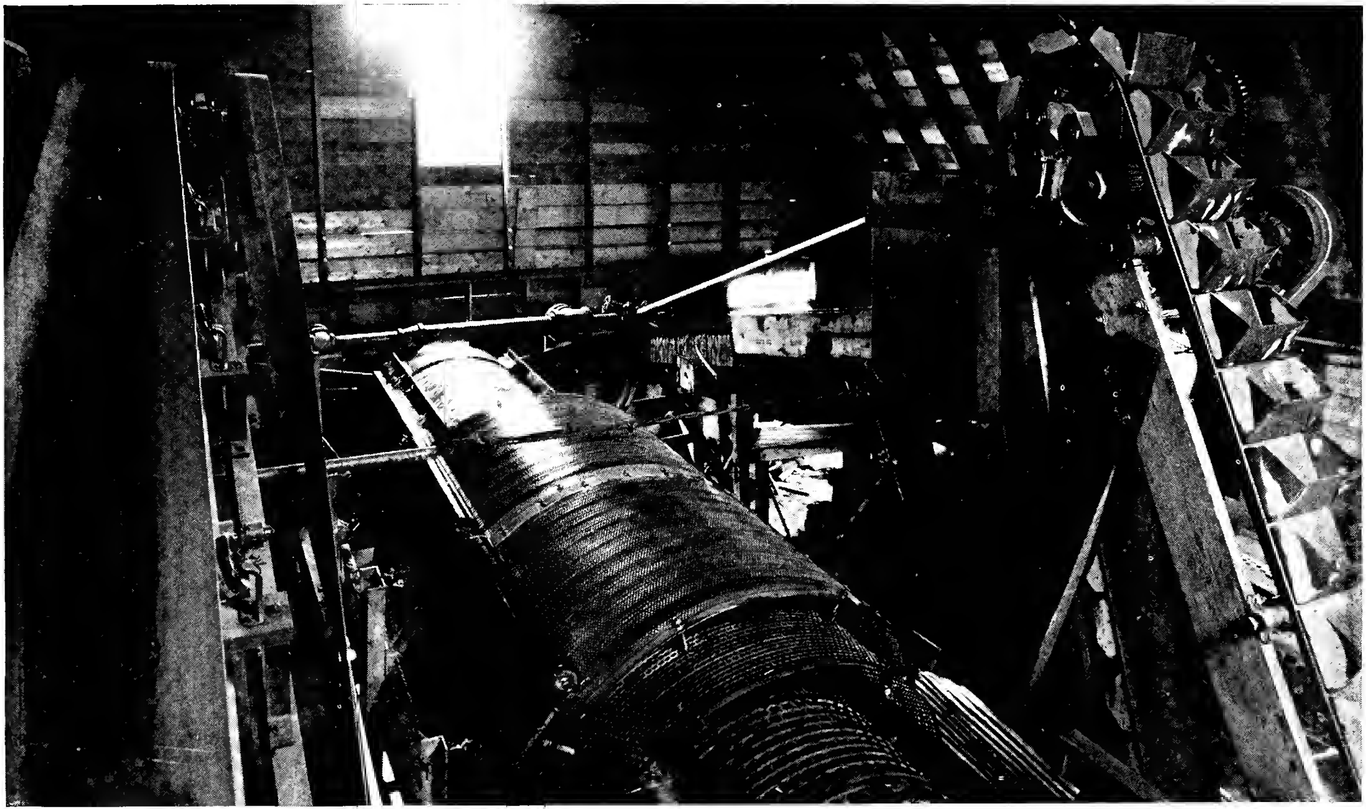
Courtesy of Nathan Oaks and Sons

Figure 15 An inexpensive but efficient sand-sucker operation that delivers 500 tons of washed material daily

Figure 16 A doubling in production of this six-inch pipe line was secured by installing the booster pump shown in the foreground

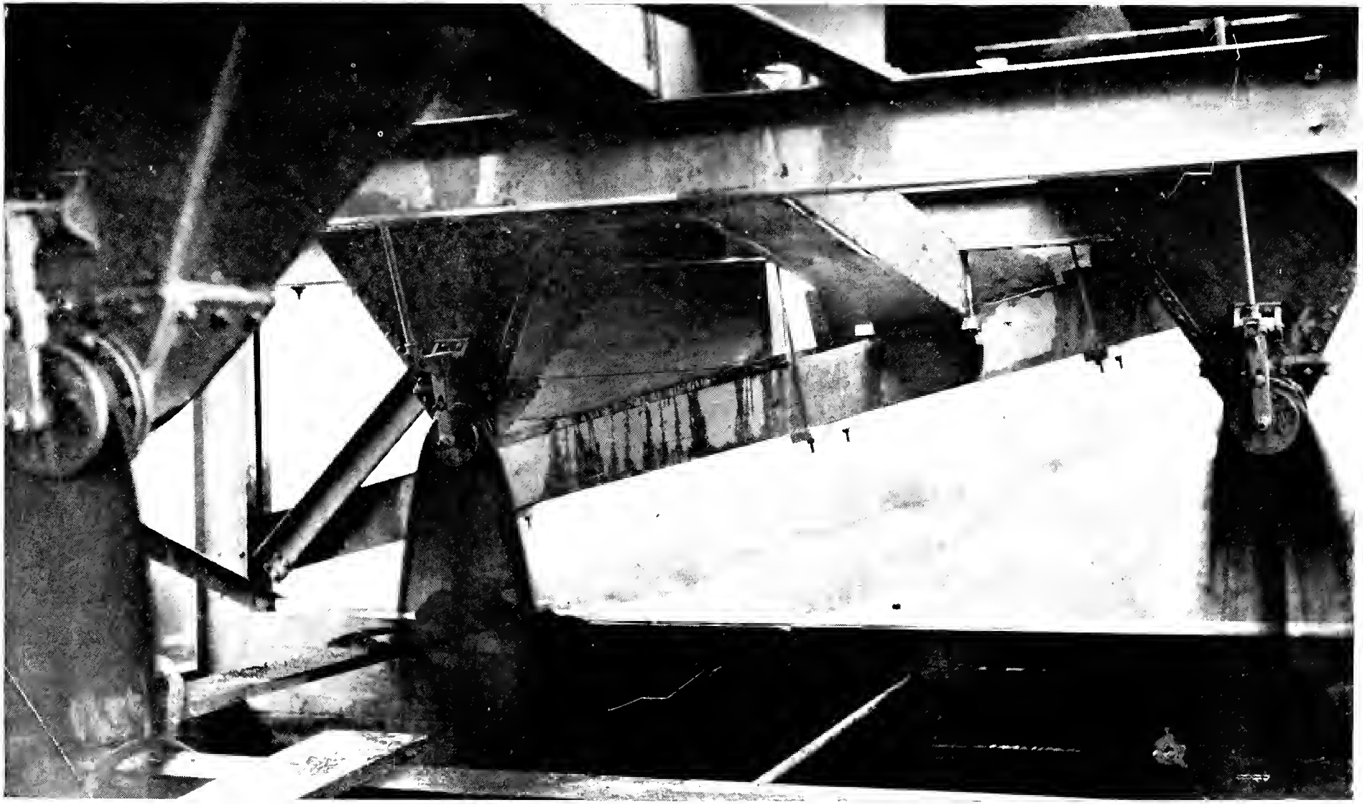
Figure 17 Steam shovel loading a string of pit-cars

Figure 18 Power shovel loading a truck which serves as the conveyor to the plant



Courtesy of Rock Products

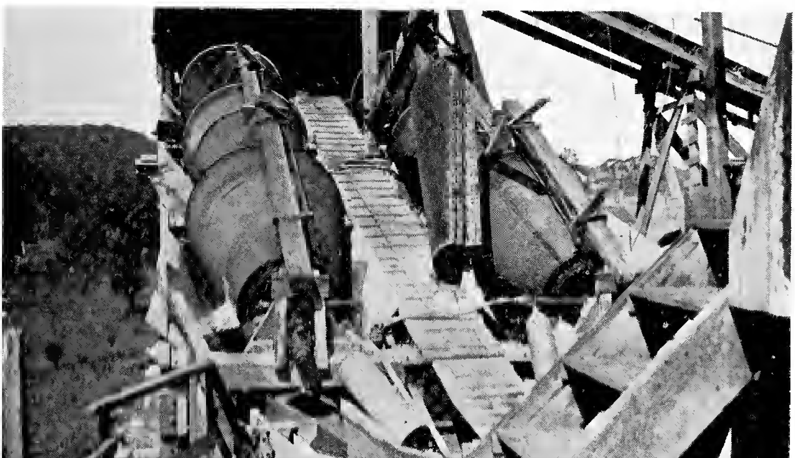
Figure 19 Plant conveyor, main screen and elevator from the crusher. The screen is a cylindrical jacketed type with a scrubber.



Courtesy of Rock Products

Figure 20 Automatic sand tanks discharging

Figure 21 A belt conveyor feeds the material from the pit and a bucket elevator lifts the broken gravel from the primary crusher



Courtesy of Rock Products

Figure 22 Two batteries of conical trommels

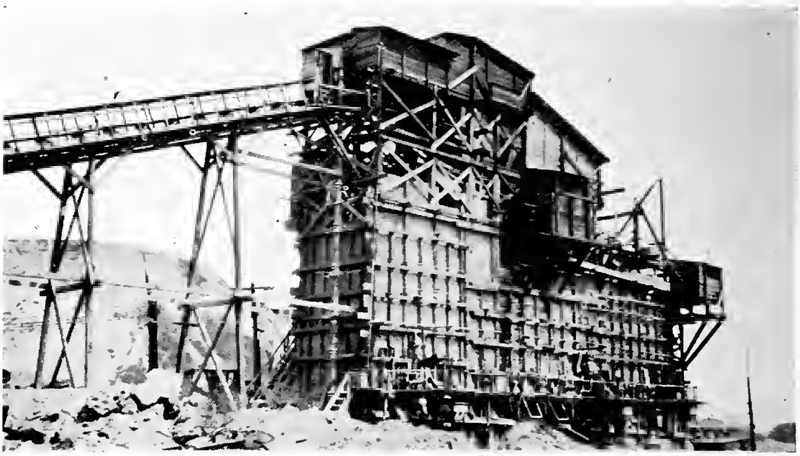


Figure 23 Loading chutes that deliver about 800 yards a day to automobile trucks

Courtesy of O'Brien Bros.

Figure 24 Loading by conveyor belt onto barges

Courtesy of Sauermann Bros.

Figure 25 A drag line operation

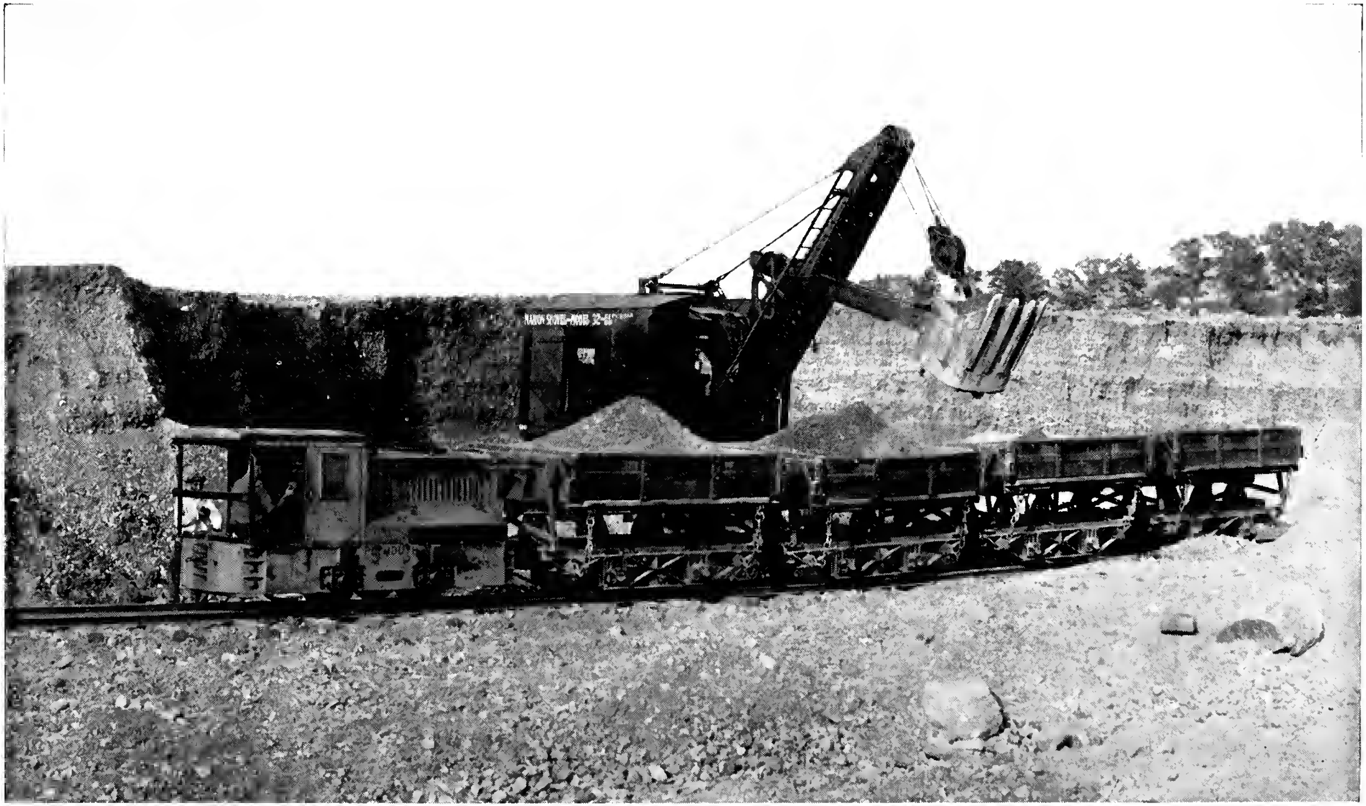
Courtesy of J. E. Carroll Sand Co.

Figure 26 A coarse sand and gravel delta deposit with a total thickness of about 135 feet. The present face is 70 feet in height and two levels will be used to get the entire thickness

Courtesy of J. E. Carroll Sand Co.

Figure 27 An electric shovel excavating in a cemented, hard delta deposit. The level bedding planes are unusual

Figure 28 Excavating being carried on simultaneously by a steam shovel dumping into pit cars and also by a drag line



Courtesy of Consolidated Materials Corp.

Figure 29 An electric shovel excavating a 25-foot face in a uniformly bedded delta deposit

Courtesy of the Boonville Sand Corp.

Figure 30 A typical delta deposit showing high angles of the foreset beds

Courtesy of the Boonville Sand Corp.

Figure 31 Faulting in a delta deposit that is overlain by much coarser river-bed material

Figure 32 A sand-sucker operation in gently dipping beds of a delta deposit

Figure 33 Sand dunes along the beach of Lake Ontario at Selkirk

Figure 34 An up-to-date washing and screening plant showing both open stock pile and bin storage. All of the production is hauled by automobile truck

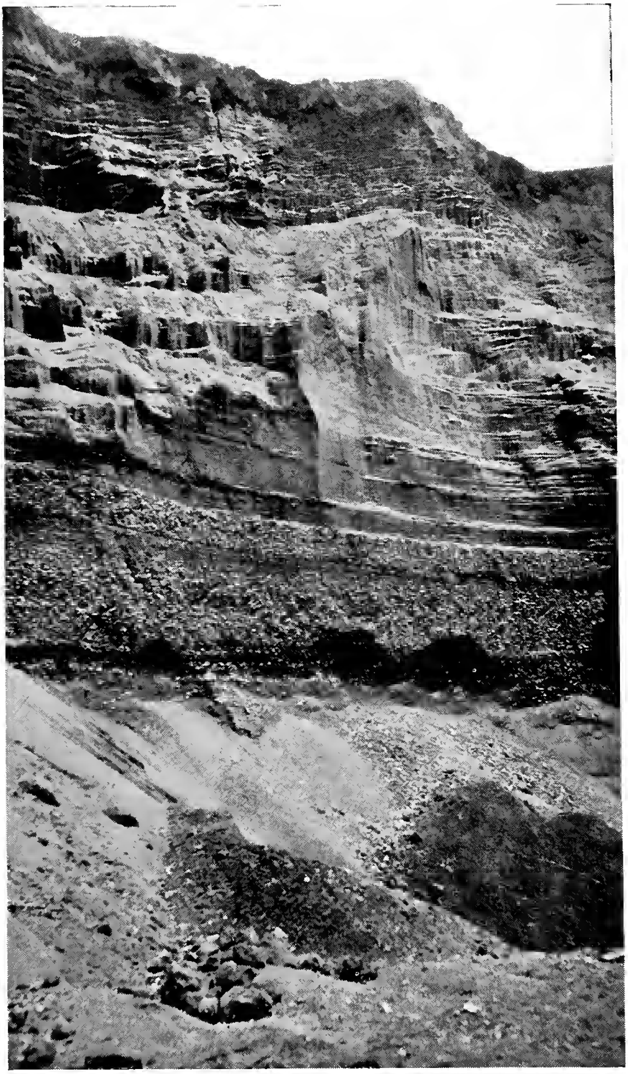


Figure 35 A delta deposit showing a distinct change in the source and character of the material during its upbuilding

Figure 36 An old glacial river deposit. Pit cars dump into the hopper in the foreground which feeds onto the plant conveyor belt

Figure 37 A river deposit of molding sand that does not owe its value to weathering

Figure 38 A typical layer of weathered molding sand so common to the Hudson river valley. The stripping and loading is all done by hand. This weathered layer tends to follow the topography.

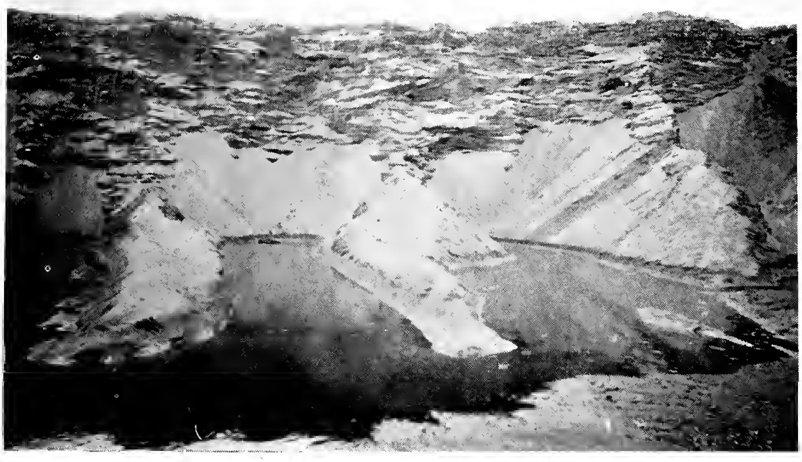


Figure 39 Cross-bedding in a delta deposit

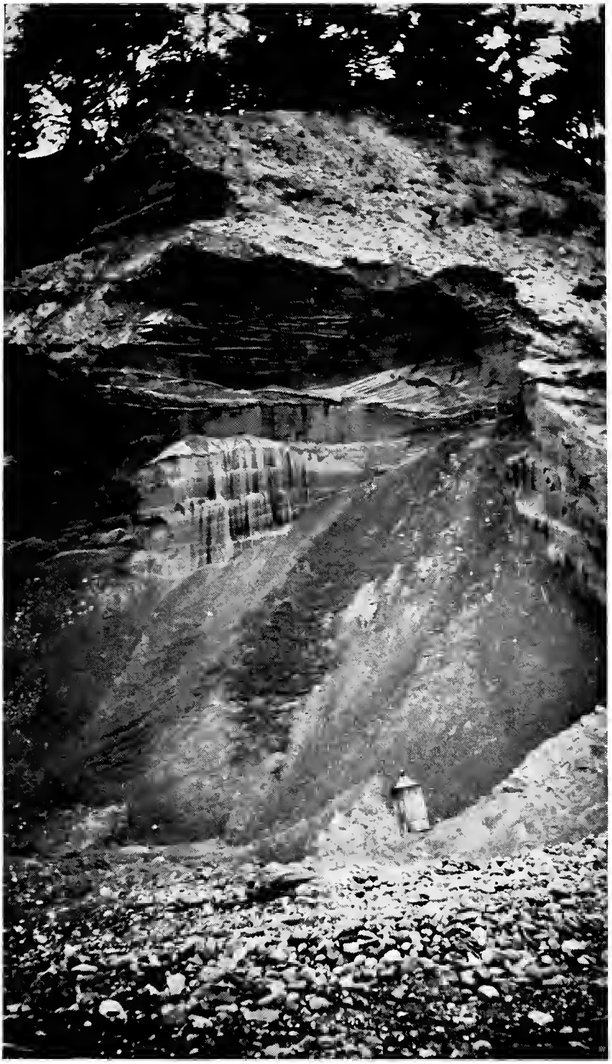


Figure 40 Cross-bedding in a delta deposit

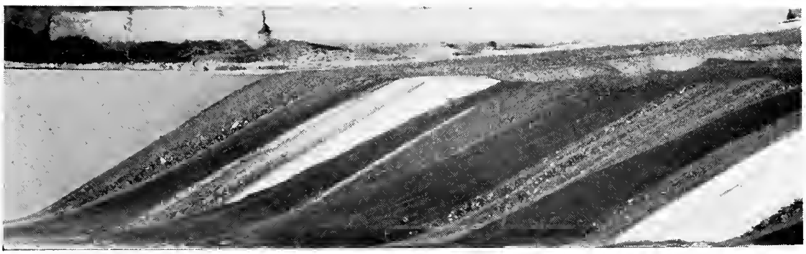


Figure 41 Section of a delta formed in a glass tank in the laboratory

The steeply dipping foreset beds and the flat, ripple-marked topset beds illustrated here are very familiar to those sand and gravel producers who are exploiting delta deposits in New York State. It should be emphasized that these foreset beds dip away from the direction of the incoming material and toward still water. The topset beds should in general increase in thickness and coarseness toward the source of supply. The variations in the size of the delta material as well as the variation in the angle of the foreset beds are caused by changing the character of the sediment and the velocity of the transporting stream of water.

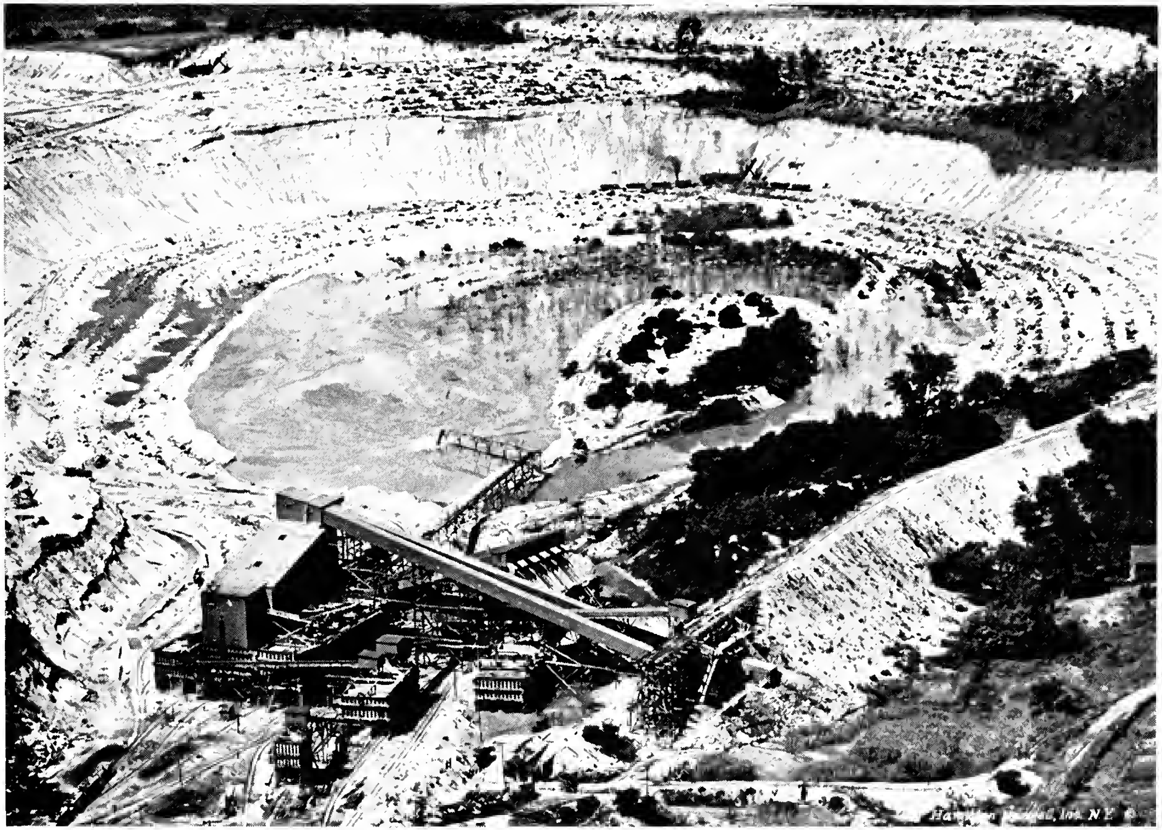


Figure 42 Airplane view of the Goodwin-Gallagher sand and gravel plant, two miles north of Roslyn, Nassau county. This is one of the largest plants in the world.

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