South Dakota
Geological and Natural History Survey

Freeman Ward, State Geologist

CIRCULAR 15

Sand and Gravel Deposits
in
Eastern South Dakota

1.—Origin.

2.—Along the Yellowstone Trail in Edmunds County.

By

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EXPLANATION

The Survey issues two series of publications as follows:

BULLETINS.—Some subjects have been investigated a longer time, full data have been gathered, such preparatory or experimental work as was necessary has been entirely or nearly finished. In other words, the study of the subject is actually completed or so nearly so that the results can be relied on and published with a degree of confidence as to their value; and the treatment is full and thorough. In such a case the matter is published as a bulletin.

CIRCULARS.—But often during the progress of the work enough information is at hand to be of value to those interested, yet not enough for a complete treatise. A part of a county or a part of a certain subject may be finished, perhaps, and publication waiting for the complete investigation of the whole county or the whole subject. There may be a demand for statistical matter, or lists of references, or current information, etc., which would hardly do for a formal bulletin. Such partial reports, summary reports, reports of progress, lists, or unit fragments of larger subjects, etc., are handled in circulars.

It is planned to publish the circulars frequently and the bulletins at longer intervals. With this arrangement much information will reach the public with a minimum of delay.

Inquiries may be addressed to the State Geologist, Vermillion, S. D.

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INTRODUCTORY NOTE

One of the most important factors, if not indeed the most important, in the development of a country is good transportation. This is amply proved by the backwardness of all sorts of human activities in remote regions, and the vast quantities of valuable resources in many parts of the country lying undeveloped for lack of adequate transportation. Railroads form an important part of our transportation system but good roads are fully as important, if not more so, for they allow rapid and easy communication between the farm and the town and between nearby towns. They make hauling over short distances by truck possible, thus saving the many handlings and delays incident to short freight hauls by railroad.

Realizing this, our state is rapidly pushing the construction of good roads. The trunk lines are laid out and nearly all graded. Many long stretches have been graveled and in time all of them will be. Some county roads have been graveled and many more will be as soon as possible. A gravel road, however, is rather expensive, the cost running between $1,500 and $2,000 a mile under favorable conditions. A large part of this expense is hauling the gravel, so that the less the hauling the less will be the cost of the road. The reduction of this item of expense is best accomplished by a knowledge of the location and character of the workable deposits near the road to be graveled. As an example of what an advantageously located pit may mean, there is one on the Yellowstone Trail in Brown County which saved $20,000 on one contract alone.

As traffic increases on the highways, it will be necessary to make concrete roads. All gravels are not suitable for concrete, the character of the gravel used determining to a great extent the durability of the concrete. For this use or for any other project involving concrete gravels it would be of decided advantage to know what deposits can be used for such work and what deposits are unsuitable.

Gravels are one of the State's most important resources, directly as a source of revenue from deposits which are worked commercially and indirectly as a means of increasing trade and communication over good roads. It is important, therefore, to have information concerning the production and possibilities of these materials. The places where excavation and preparation of sands and gravels now form an important industry and the places where such an industry can be developed are incompletely known. A more nearly complete knowledge would not only help local interests develop their gravel resources but would stimulate the exploitation of deposits by outside capital on a scale not always possible locally.

To supply information on the location, amount and quality of gravels, the present value and future possibilities of the industry, the South Dakota Geological and Natural History Survey has undertaken a survey of the deposits of the eastern part of the State. Field work was begun in the summer of 1923 and will be pushed as rapidly as

funds will allow. The information thus obtained will be on file at the office of the Survey and will be published from time to time, so that it will always be available to persons desiring it.

Since this is the first of a series of reports on South Dakota sands and gravels, the origin and form of these deposits will be briefly considered. This will be followed by a description of the deposits found along the Yellowstone Trail in the western part of Edmunds County.

1.—ORIGIN OF SANDS AND GRAVELS

GENERAL STATEMENT

All the gravels of South Dakota east of the Missouri River were deposited by waters coming from an ice sheet which covered that part of the State not very long ago, geologically speaking. At that time ice sheets, similar to that which now covers Greenland, covered northern Europe and North America. Ice sheets moved out from centers in Canada across northern United States approximately as far south as the Missouri and Ohio rivers.

South Dakota was covered by a lobe of ice which moved down the James River Valley, as far south as the Missouri, and from this axis spread over the coteaux which border that depression, eastward to the Big Sioux Valley and westward to the Missouri Valley. This moving ice carried vast quantites of rock material which had been worn and torn from the territory over which it moved. As the ice sheet melted it dropped this debris, leaving a sheet of clay mixed with sand and boulders over almost all of the State east of the Missouri. This material is known as *glacial drift* or *till.*

The ice did not melt away all at once, however, but melted at the outer edge of the lobe, causing the edge to recede farther and farther northward until it disappeared from the State altogether. The geological record shows that there were three times when the rate of melting just balanced the rate of forward movement of the ice, and at such times the debris which the ice was carrying was piled up in hummocky ridges along the ice front. These ridges are known as *terminal moraines* and their location is shown on the accompanying map (Fig. 1). The terminal moraines are not equally developed all around the ice front, being well developed in many places, of which the Bowdle Hills in Edmunds County, the Vermillion Hills in Lake County and the hills west of Peever in Roberts County are examples, while in others they are hardly discernible even to a trained eye. Between the terminal moraines the ice deposited a more or less uniform sheet of drift known as the *ground moraine.* The surface of the ground moraine, like that of the terminal moraine, is characteristically made up of undrained depressions and hummocky hills but is much less rough than the terminal and in places becomes almost a plain.

While these moraines were forming, the waters from the melting

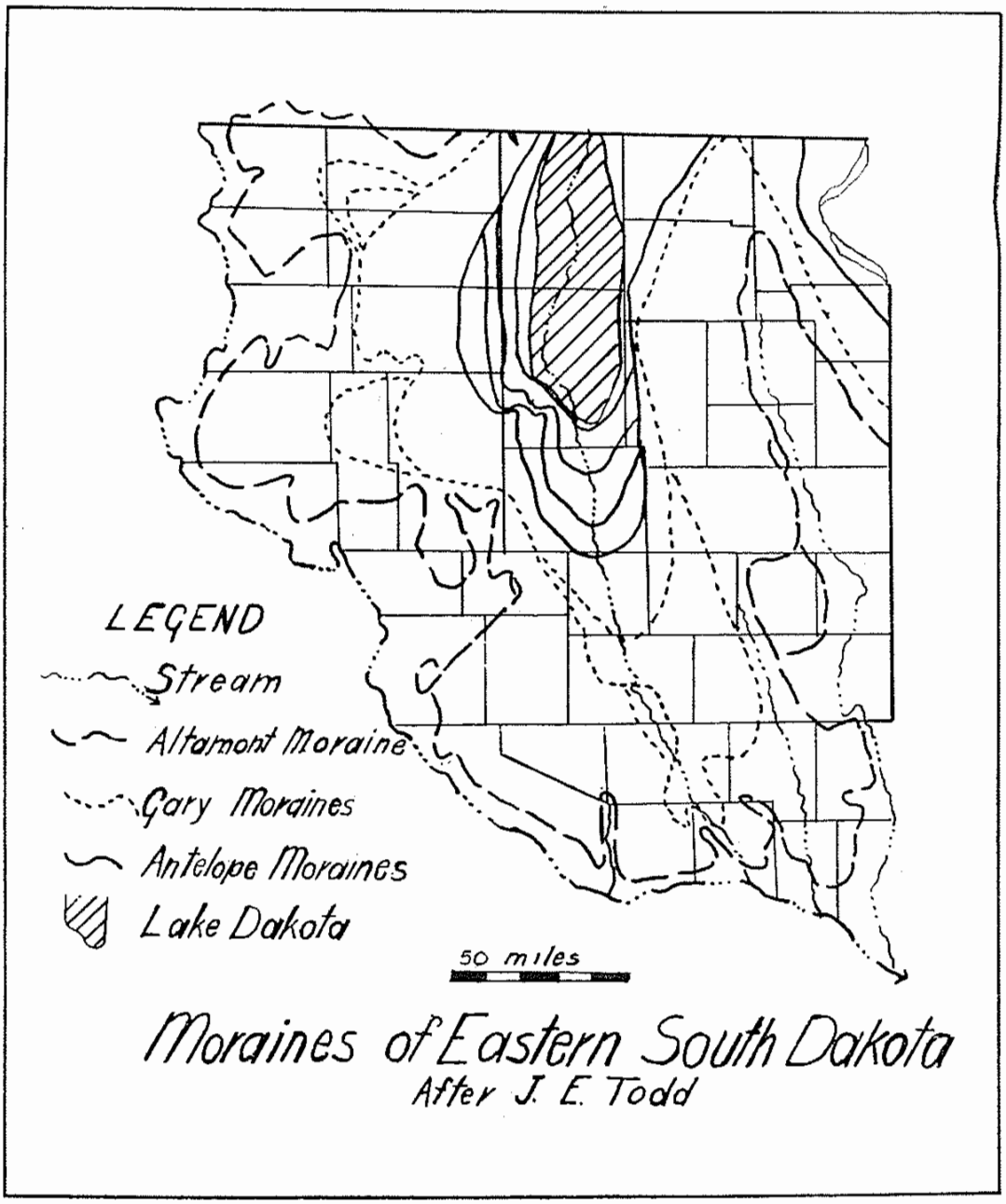

Fig. 1. Moraines of Eastern South Dakota

ice were able to work over the debris that the ice carried, sorting it into gravels, sands, and clays. Some of this material was deposited in cracks of the ice but most of it was carried away from the ice and deposited in front of the terminal moraines, either as broad sheets of gravel or in the channels leading away from the ice front. The larger sand and gravel deposits are found in physiographic forms known as kames, eskers, outwash plains and valley trains. The origin and appearance of these forms will be considered separately.

FORMS OF SAND AND GRAVEL DEPOSITS

Kames.—These deposits are usually found in or near terminal moraines, having been formed at the edge of the ice or in very slowly moving or stagnant ice. A stream flowing along on top of a glacier

may empty itself into a great hole or moulin in the ice. It soon fills the moulin with the debris it is carrying and when the ice melts, this material slumps down, forming a beehive-shaped hill, varying in size from a very small hill up to one 100 feet high and covering 25 acres. Or the stream may plunge over a cliff at the edge of the ice, piling up the stones and boulders it carries at the bottom of the cliff. When the ice melts this debris will slump down into a hill, much the shape of the one just described. These beehive-shaped hills are known as kames and can be found scattered here and there throughout the terminal moraine. There is no definite order to their arrangement and the only difference between them and many of the other hills of the moraine is that they are composed of gravel instead of boulder clay. In many cases kames are in groups, so that where one is found others are likely to occur in the vicinity.

Kames contain a variety of materials but most of them are coarse, because the clays, silts, etc., have been washed out by the glacial waters. In some kames sand is found, while others are composed of very coarse material, cobbles being common and boulders up to a foot or two not uncommon. In most cases, however, the material is gravel, varying in size from a tenth of an inch to two inches in diameter. As a class, kames furnish a good source of gravels, the greatest drawback being that they are often too small to be worked profitably. When they are large enough or occur in a group they may be quite profitably worked, and some of them are now being exploited on a large scale in South Dakota.

Eskers.—Sometimes tunnels are hollowed out in the bottom of stagnant or nearly stagnant ice by streams formed from its melting. These tunnels become entirely or partly filled with the debris the streams are carrying, and when the ice melts away, a long, narrow ridge is left, which follows the undulations of the underlying topography. Some eskers are quite level on top and resemble a railroad grade but more often the crest is undulating. The sides slope steeply but symmetrically away from the crest. Eskers vary considerably in size, the length ranging from less than a quarter of a mile to many miles, the width at the base from fifty to several hundred feet and the height from a few feet to one or two hundred.

The material in eskers is very much like that in kames. Indeed the similarity in material and the sinuous shape has caused them to be called serpent kames by some geologists. No general statement covering the sort of material in all eskers can be made, but it tends to be coarse. Coarse gravels, cobbles and small boulders are more common than are the finer gravels and sands.

Eskers are a good source of gravel, the greatest drawback, in many cases, being the coarseness of the materials. This can be overcome for many purposes by crushing and so is not so serious an objection as might seem.

Eskers occur typically back of a terminal moraine and run roughly at right angles to it but there are many exceptions to this rule. They often end abruptly in the moraine and in many cases

in a group of kames. In some places they occur singly and in others may be found in groups. There is no order or arrangement in their distribution along the terminal moraine nor among those that occur in groups except that these last run roughly parallel to each other.

Outwash Plains.—When terminal moraines are forming and the melting ice furnishes abundant water, a sheet of sands and gravel is spread in front of the moraine. These sheets are known as "outwash plains" because they are composed entirely of materials washed from the debris carried by the ice and because the surface is typically a plain sloping away from the front of the moraine at an appreciable angle. These plains are quite large, in most cases covering many square miles.

Outwash plains form one of the best sources of gravel. The large volume of material allows almost unlimited operations from any pit that is opened. The material is more uniform in size throughout the deposit than either the kame or esker gravels. The average material is a medium grained gravel, though there is a tendency for it to become coarser near the moraine and finer farther away. Sand is found usually in minor amounts but is apt to be more abundant near the outer edge of the plain.

Outwash plains do not occur all along the front of a terminal moraine but are rather local occurrences. They are found in front of big moraines quite frequently and may also be found well developed where the terminal is but poorly developed. They always occur on the side of the terminal away from that occupied by the ice. Some of the deposits in the vicinity of the Big Sioux Valley are of this type.

Valley Trains.—Valley trains have an origin quite similar to that of outwash plains. The materials are carried down a valley by the waters from the melting ice and deposited in the valley, instead of in a sheet in front of the ice. The deposit often fills the valley to considerable depths. The materials composing valley trains vary in size from the coarsest gravels to silts and clays. The sands and gravels probably form the largest part of these deposits, because the finer materials are washed away into the large rivers and to the oceans. In general the materials are fairly well sorted, though many pits opened in them show sand, gravel, and cobbles inter-stratified. The coarser materials, however, tend to be deposited near the ice front, while the finer are deposited farther down stream.

Valley trains are found in many of the larger valleys and in some of the smaller, in and near glaciated regions. Many of the channels in the eastern part of this state are filled with glacial debris and belong to this class. No more definite location for them can be given.

Valley trains that were deposited last may still be found filling the bottoms of the valleys but those deposited earlier in the Glacial Period have been washed out by waters which flowed down the same valleys later, leaving only small remnants perched as terraces high up on the bluffs of the present valleys. This condition holds in

many of the valleys in the southern part of the glaciated area in this State. The gravel deposits which have been opened in the lower Vermillion Valley are examples of such terraces.

PROSPECTING FOR SANDS AND GRAVELS

From the foregoing it can be seen that a knowledge of the glacial features of the State is a great aid in locating quickly sand and gravel deposits. The surveys that have been made will offer some help, but they have not advanced to the place where they furnish reliable information of this character. The best maps for this purpose are the United States Geological Survey's folios covering a large part of the James River Valley.[1]

Part of Todd's work has been reviewed in the field and it has been found that many of the channels indicated do not contain gravels, while in many of those that do, the gravel is found only in terraces on the valley bluffs. Many of these deposits occur only locally, instead of filling the valleys, as indicated on the maps. The terminal moraines as traced by Todd are shown on the map (Fig. 1). Evidence disclosed since the work was done shows that some modification of these lines will be necessary, but until better information is at hand they will indicate the more favorable locations for kame and esker deposits. The location of these deposits on the moraines, however, is so uncertain that it is scarcely worth while searching for them if other sources of gravel are available. The description of the shape of these features, which has already been given, is about the only guide that can be used in locating them.

2.—SOME GRAVEL DEPOSITS ALONG THE YELLOWSTONE TRAIL IN EDMUNDS COUNTY

ACKNOWLEDGMENTS

The following report is the result of five weeks' field work during the summer of 1923. The work was a detailed reconnaissance, locations being made with an odometer and checked on section corners, and the results plotted on township plats. The gravel tests were made in the laboratories of the Department of Civil Engineering of the University of South Dakota under the direction of Professor R. V. Newcomb and Instructor E. J. Stocking. Acknowledgments are due other members of the staff of that department and also to the State Highway Commission for valuable co-operation. The courtesy of the citizens of Edmunds County in supplying information and in aiding the progress of the survey in many other ways is greatly appreciated.

[1] J. E. Todd—U. S. G. S. Folio No. 156 Elk Point Folio.
U. S. G. S. Folio No. 97 Parker Folio.
U. S. G. S. Folio No. 96 Olivet Folio.
U. S. G. S. Folio No. 99 Mitchell Folio.
U. S. G. S. Folio No. 100 Alexandria Folio.
U. S. G. S. Folio No. 113 Huron Folio.
U. S. G. S. Folio No. 114 DeSmet Folio.
U. S. G. S. Folio No. 165 Aberdeen-Redfield Folio.

LOCATION

The area here described includes a strip of territory one township wide and six townships long, along the Yellowstone Trail in Edmunds County. The eastern boundary is three miles east of Ipswich and the western is the Edmunds-Walworth County line. The area includes T. 123 N, in ranges 68 W. to 73 W., inclusive. Some descriptions of gravel pits in T. 123 N., R. 67 W. and in T. 122 N., R. 70 W. are included because of their possible use in graveling the Yellowstone Trail and roads leading into it.

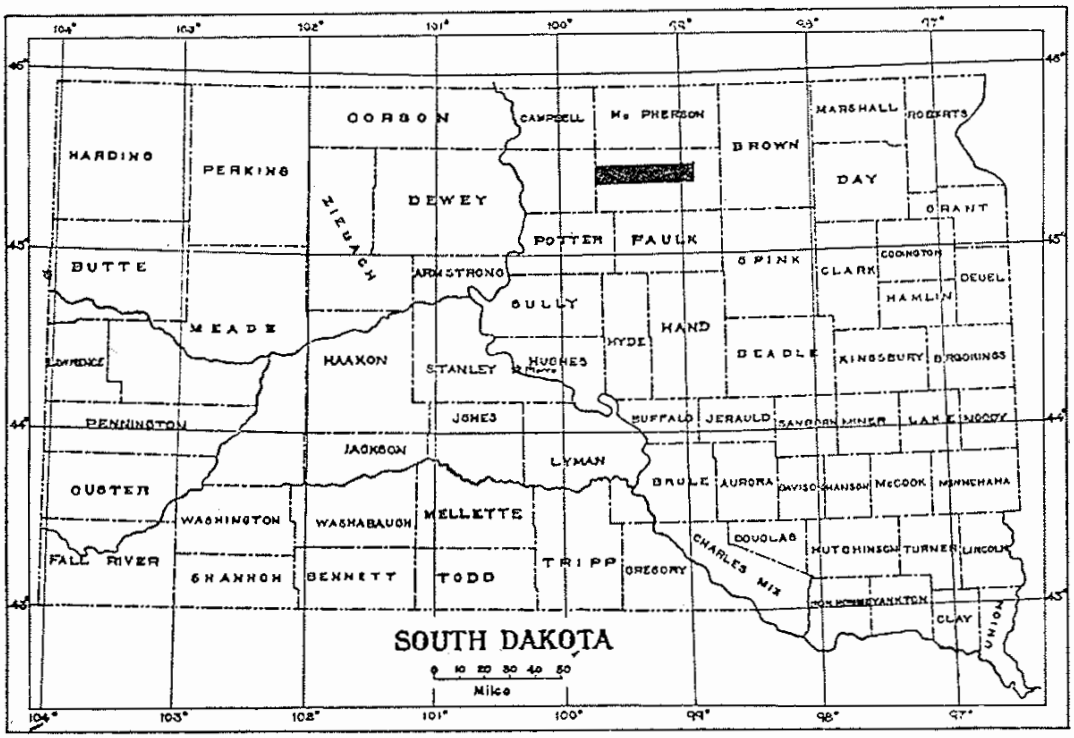

Fig. 2. Index Map
Black portion shows location of area mapped

PREVIOUS WORK

This area has never been surveyed geologically except in a very general way. A reconnaissance survey was made by J. E. Todd about 1896. He traced the moraines across this area and made some general notes on their accompanying deposits.[1] But his work is not sufficiently detailed to locate sand and gravel deposits satisfactorily from his map or his descriptions.

On the east this area joins that mapped by Todd in greater detail in the Aberdeen Redfield Folio,[2] and certain of the gravel filled channels shown in this folio are continued in the area covered by this report. The adjacent territory on the north, west, and south sides was covered only by the reconnaissance which includes this area.

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[1]J. E. Todd, The Moraines of the Missouri Coteau and Their Attendant Deposits: U. S. G. S. Bull. 144 (1896).

[2]J. E. Todd, Aberdeen-Redfield Folio: U. S. G. S. Folio No. 165 (1909).

GLACIAL FEATURES

There is at least one example of each of the common physiographic forms that result from glaciation. While most of the area is covered with ground moraine, one big terminal moraine, the Bowdle Hills, crosses it just east of Bowdle, and possibly a second smaller one east of Roscoe. Three esker fields occur in the Bowdle terminal moraine and kames are found scattered here and there in both terminal moraines. In front of the Bowdle Hills occurs a typical outwash plain reaching from the town of Bowdle to the western edge of the county. A better understanding of these features will be obtaned from a detailed description of the area.

Ipswich Township, T. 123 N., R. 68 W.—This, the most easterly township, lies on a very gently undulating part of the ground moraine. The hills are so low and the depressions so shallow that much of the surface appears flat. More careful scrutiny reveals the low, rounded swells in the surface with the broad, shallow, undrained depressions between them. The difference in elevation from the top of the hills to the bottom of the hollows varies from two to eight feet, the average being about five feet. The depressions are from two to three hundred feet in diameter and usually roughly circular in ground plan.

In the extreme eastern end of the township this plain is cut by an old channel, evidently an old spillway for waters from the ice that formed the Antelope Moraine a few miles to the east. These waters entered the township in the southeast half of sec. 1, flowing westward, turned immediately southwest to the southeast quarter of sec. 14, and then southeast, leaving the township in the southeast half of sec. 24. They left a steep sided, flat bottomed valley averaging a little over a quarter of a mile wide and twenty to thirty feet deep, forming a rough arc in the eastern part of the township. Only a very small stream meanders through the valley now.

The plain west of this valley is broken by a number of stream valleys trending about S., 60° E. In the northern half of the township these valleys empty into the old channel just described, but the valleys of the southern half leave the township without joining any major valley. None of these valleys is over five miles in length and none has a permanent stream. In depth they range up to twenty feet and this makes them the most pronounced feature of the topography with the exception of the old spillway. They appear to have been formed since glacial times.

A north-south line can be drawn about a half mile east of the west line of the township, which would indicate the change from the flat, smooth topography which characterizes most of the township to a rougher topography. The ground moraine type of surface still prevails, but the hills are sharper and the depressions deeper. Instead of the five foot relief common east of the line a relief of seven to ten feet is the rule. The diameter of the depressions is only a half to two-thirds of that of the depressions to the east. Some

depressions are elongate in ground plan instead of circular and trend generally in an east-west direction. They are not open at either end but look as though glacial waters had played some part in their formation. In summary this township may be said to possess three topographic divisions, the nearly flat plain cut by small valleys covering most of the area, the old spillway for glacial waters in the extreme east, and the slightly rougher topography in the extreme western part.

Huntley Township, T. 123 N., R. 69 W.—This township lies entirely in ground moraine. There is a general slope to the east, which is sufficient to be quite noticeable even on casual observation. It appears to one traveling westward that he is ascending the back side of a low terminal moraine, the crest of which is about two miles ahead. On reaching that point, however, the crest appears to have moved a few miles farther west. No crest occurs in this township, the slope persisting from the eastern to the western side.

The surface is much like that described in the extreme western end of Ipswich Township. In general the relief increases toward the west, but this is not a striking characteristic of the topography. The hills vary from eight to twenty-five feet in height, the average being about fifteen feet. In some spots it is sharp enough to resemble the topography of a terminal moraine. The depressions are roughly circular but many elongated ones occur. These last are from a quarter to a half mile in length and have flat bottoms 100 to 600 feet wide. They trend in a west-east or northwest-southeast direction. In many cases they form lines of depressions with low divides between the different basins. An auger hole made in one of the most pronounced of the valley-like depressions, 0.3 mile west of the southeast corner of sec. 27, gave the following section:

2½ feet	Black, mucky soil.
1½ feet	Marl, very limy, light grey. No shells brought up in auger core.
1½ feet	Limy silt much like above but less lime.
½ foot	Till. Color much like above. Limestone and quartz pebbles; also oxidized iron.
6 feet total.	

It will be noted that there is nothing in this section which would not be expected in an ordinary swamp or small lake deposit. The material does not indicate that this was a stream channel, though the physiographic form suggests it. While these are not true stream valleys, it is very probable that glacial waters helped in their formation.

Only three stream-made valleys of any consequence cut the surface. One is in the southwestern part of the township in secs. 29, 30, and 32, one in the southeast, from secs. 21 to 36, and a third farther north, from secs. 4 to 14. They are very pronounced where they can be traced, the smallest reaching depths of twenty to twenty-

five feet. Only the second valley mentioned runs out of the township and joins a major valley. The other two form well developed valleys for more than two miles and then lose themselves in the hills and hollows of the ground moraine. None of these valleys contains a permanent stream.

"The Big Slough" is the most striking physiographic feature in the township. It is a great depression about 100 feet deep, which includes all of sec. 6 and parts of secs. 5 and 7 in this township, and most of secs. 31 and 32 in the township north of this one. (T. 124 N., R. 69 W.) The bottom is occupied by two large swamps on the east side and some morainic hills rising fifteen or twenty feet above the swamps on the west side. The slopes on the east are quite steep and descend directly to the swamp. On the south end they form a great amphitheater occupying almost the entire northern half of sec. 7 and are gentle enough to be cultivated. The west side rises abruptly from the morainic hills in the bottom but is not as steep as the east side. The depression narrows to the north and tapers away into the hills of the upland without abrupt slopes. The only material found in the slopes and bottom was stony till. In some places this contained many small, rounded pebbles which weathered out so as to resemble gravel on the surface. Fresh, deep road cuts on the east and south sides and fair exposures on the west side show nothing but till.

The origin of the "Big Slough" is not clear. It may have been formed by the melting of a huge block of ice which became lodged in the drift. Pits with such an origin are known but are more apt to be associated with the outwash than with the ground moraine. It may be a part of a pre-glacial valley which became filled with drift, this depression being a place which was incompletely filled. If similar depressions trending in about the same direction and forming a line occur to the north or northeast, the last explanation would be the most plausible.

Bryant Township, T. 123 N., R. 70 W.—In this township there is a continuation of the topography described in Huntley Township, the general surface rising steadily to about the middle of the township, where it reaches a crest. The topography on the crest is slightly rougher than in the country to the east, and in the southern part of the township it has a belt of rough topography, a half to one mile in width, the hills of which are twenty to twenty-five feet high and very abrupt. This belt disappears a little north of the center of the township. Stony till and boulders are a little more common along the crest than elsewhere and some of the hills are composed of sand and gravel. Their material and beehive shape class these hills as kames.

In front of the crest the surface descends abruptly for a quarter of a mile or more to the west and terminates in a trough-like depression which contains a line of swamps. This, in secs. 7 and 8. Viewed from the west the crest stands up as a conspicuous ridge, which can be traced northward and southward as far as the eye can see.

The ridge-like character of the crest, the type of topography on it, and the kames scattered over it show that this marks a halting place in the retreat of the ice front. Too little is known of the relation of this ridge to the known terminal moraines of South Dakota to say whether it is part of one of the big terminals or simply a local deposit. It is thought, however, that it may connect with the Gary Moraine, which is well developed farther north.

West of this morainic ridge a gently undulating ground moraine rises from the swamps to the west line of the township.

A large depression, similar to the "Big Slough" in Huntley Township, occurs in the north central part of this township. It is roughly elliptical in ground plan, with its axis running east-west. It is about two miles in length, three-quarters of a mile wide and 30 to 60 feet deep. A large part of the eastern half of sec. 5, all of sec. 4 and more than a quarter of sec. 3 are included in this depression. The east end contains a swamp, which receives the waters from an intermittent stream that drains the western part of the depression. The origin of this depression, like that of the "Big Slough," is not clear, the only plausible explanation being the possibilities of a buried ice block or a partly filled pre-glacial valley.

The glacial features of this township may be summarized as follows: Ground moraine with the same characteristics as that in the township to the east, extending to the middle of the township. Its surface gradually rises to a poorly developed terminal moraine which runs from the center of the south side of the township northward to about the middle and then swings northwest and leaves the township at its northwestern corner. The terminal moraine and the ground moraine to the east of it are broken by a large depression in the north central part of the township. West of the rather abrupt face of the terminal, the ground moraine rises in a long, gentle slope to the western side of the township.

Glen Township, T. 123 N., R. 71 W.—With the exception of a strip a half mile wide in the northern part of secs. 1 to 4, this township is covered entirely by ground moraine. The half mile strip referred to is the front of the terminal moraine which crosses Bryant Township and runs in an east-west direction just north of this township. This slope faces south except near the place where it leaves the township, where it turns to the southwest. Its surface is covered with morainic hills up to 30 feet in height. Boulders are strewn over it plentifully and very stony till is exposed in the road cuts.

The ground moraine covering the rest of the township may be divided into flat surfaced areas and areas with morainic surfaces. There are two flat surfaced areas trending northwest-southwest which form a line through the center of the township. The northern one occupies half of secs. 7, 8, 17, 18 and part of 12, while the southern one covers about a quarter of secs. 15 and 16, most of 21, 22, 26, 27, and half of 28 and 35. The surfaces of these areas either are horizontal or slope to the west, the latter slope being especially no-

ticeable in the southern area. They are broken by a few low smooth hills composed of stony till or impure gravel and sand. Two auger holes, one drilled at the northern and one at the southern part of this area, showed the following sections:

N. E. CORNER, SEC. 16

½ foot	Leached soil.
1 foot	Calcareous soil, silty.
1 foot	Dark gray, calcareous silt.
3 feet	Yellowish, calcareous silt.
1 foot	Heavy dark brown clay, very compact. Full of white calcite crystals, probably leached from above.
1½ feet	Very powdery yellow silt. Pebbles in last half foot stopped the hole.
8 feet total.	

500 FEET NORTH OF THE S. W. COR., SEC. 27

1 foot	Soil.
3 feet	Buff-gray silt, highly calcareous. A very thin streak of brown sand near the base.
2 feet	Gray silt with white mottlings and brown and red streaks.
6 feet total.	

These flat surfaced areas are partly surrounded by elongated swamps separated from their surroundings by steep banks 5 to 10 feet in height. No information was obtained on the stratification of these silts, but their composition and the nature of the surface under which they were found indicate that they were formed by the filling of depressions with fine outwash material.

The morainic surfaces are gently undulating, with a relief of less than 20 feet. They may be divided into two parts, one surrounding the flat surfaced areas just described and lying about 15 feet above them, the other a portion in the southwest corner of the township, which is separated from the surface to the east by a sharp rise of 30 to 40 feet. The line separating these two enters the township at the S. ¼ corner of sec. 32 and runs north a mile and a half to the center of sec. 29, where it turns to the northwest and leaves the township at about the W. ¼ corner of sec. 19. West of this line there is a gently undulating surface. This portion of the ground moraine and the terminal moraine in the northeast form the high portions of the township and between them lies the great sag which covers most of the township and contains the two flat surfaced, swamp-rimmed areas.

Cottonwood Lake Township, T. 123 N., R. 72 W.—Both ground and terminal moraines occur in this township. The line separating the two runs across the southwest quarter of the township, from the middle of sec. 35, northwest through sec. 28 to a point near the

northwest corner of sec. 29. Then it turns a little to the north and passing through sec. 19 leaves the township about a quarter mile north of the northwest corner of sec. 18. It is difficult to draw the line exactly, for the ground moraine surface grades into the terminal moraine surface to the west within a distance of half a mile.

The ground moraine surface is a continuation of that in the southwest corner of Glen Township but becomes rougher as it approaches the terminal moraine surface in the southwest. It is gently undulating, with a relief of 10 to 20 feet, with here and there individual hills or groups of them rising much more abruptly from their surroundings and resembling the topography of a terminal moraine. A depression occurs in the southeastern part of the township which is 30 to 50 feet deep, a quarter of a mile wide and four and a half miles long. Its general trend is northward. Entering the township near the southwest corner of sec. 36 it passes through secs. 26 and 23 and dies out among the hills of sec. 13. Its bottom is quite flat but contains shallow basins, most of which are swampy. It appears to be part of a pre-glacial valley which has been filled with drift. There is a line of small kames in a little valley in the southeast quarter of sec. 2. With the exception of the northernmost they are small and low and inconspicuous except for their typical kame shape. The largest one is about 25 feet high and 200 or 300 feet in diameter at the base.

The surface of the terminal moraine is very rough. The hills are knobby and rise sharply 40 to 50 feet. The depressions are typical kettles, being roughly circular in ground plan. In this character they differ markedly from the depressions of the ground moraine, which are irregular in shape and usually elongate. This is a part of what Todd called the Altamont Moraine and is supposed to be the outermost moraine left by the last (Wisconsin) ice invasion.

Bowdle Township, T. 123 N., R. 73 W.—*Altamont Moraine*: The main feature of this township is the big terminal moraine which occupies most of it. This is a continuation of the Altamont Moraine described in Cottonwood Lake Township. In Bowdle Township it varies from two to five miles in width and rises several hundred feet above its surroundings both on the east and on the west. It forms an imposing ridge which can be seen for many miles. It trends northwest-southeast, the crest running in a fairly straight line from the N. ¼ corner of sec. 4 to about a quarter of a mile south of the northeast corner of sec. 28, where it leaves the township and crosses the southwest corner of Cottonwood Lake Township. The eastern edge of the moraine has the same trend as the crest, paralleling it about a mile away. The western edge is not so distinct as the eastern, for the surface becomes less rough as it passes away from the crest and finally grades into an outwash plain. It forms a rough horseshoe, the northern end entering the township about the southwest corner of sec. 18. It then swings north and east to a point about a quarter mile north of the southwest corner of sec. 16, and

turning south near the middle of that section passes through the town of Bowdle; thence it runs southwest and leaves the township near the middle of the south line of sec. 32.

The surface of the terminal moraine is extremely rough, so rough indeed that much of it is not traversed by roads and wagon trails are few. It is composed of great hummocky hills so conspicuous that this part of the moraine is called locally "The Bowdle Hills." Between these hills are undrained depressions characteristic of terminal moraine topography. Most of them contain swamps, which are roughly circular in ground plan like those described in the moraine in Cottonwood Lake Township. The highest hills and roughest surfaces occur along the crest and from there eastward to the edge of the moraine. The relief here is 50 to 100 feet, while west of the crest it is reduced to 10 or 15 feet before reaching the outwash.

A long, narrow depression similar to the one described in Cottonwood Lake Township occurs on the front of the terminal moraine in the eastern part of secs. 27 and 34. It is a mile and three-quarters long, about 600 feet wide and 30 to 40 feet deep It runs north-south, parallel to the crest of the moraine. A gravel deposit near its northern end suggests that it may have been a channel for waters from the melting ice.

Eskers: Some of the most interesting features found in this township are the esker fields. Three of these occur, two on the front side of the terminal moraine and one just behind it. The northernmost of the first two is found in secs. 4 and 5, most of the eskers occurring in the N. W. ¼ of sec. 4. There are six or eight of them running over the hills and depressions of the moraine in characteristic fashion and a number of kames scattered among them. Most of them are short, all but two being under a quarter of a mile in length. Their trend varies from S., 20° E. to S., 20° W. for all but the largest one, which runs east-west. They are about 70 feet wide at the base and 15 to 20 feet in height. The largest esker is over three-quarters of a mile long and heads near the crest of the terminal near the center of sec. 4. It ends near the center of sec. 5 so near the eskers in the northwest quarter of that section that it is included in the field, though it is quite separate from it for almost its entire length.

The second field is less than a mile northeast of Bowdle in the N. E. ¼ of sec. 22 and laps over into secs. 15 and 23. Here are four small eskers, each about a quarter mile in length, 10 feet high and 50 feet across at the base. Their trend is west and southwest and all but the westernmost have a distinct curve somewhere in their length. This field and the one first described are probably the ones Todd referred to in his report on this region.

The third field forms a belt about half to three-quarters of a mile wide back of the terminal moraine. This belt includes a large part of secs. 2 and 12. The eskers vary from a quarter to a half

mile in length and range up to 25 feet in height. Their trend is northwest-southeast, which is nearly at right angles to the trend in the other two fields. Some kame-like hills are also scattered about the area. These eskers were evidently formed in cracks in the ice which were made when it was compelled to rise over the terminal, and the drainage ran parallel to the cracks because it could not break over the terminal and run down the front as it did in the other two fields.

Ground Moraine: The ground moraine which covers most of the two townships to the east, crosses the extreme northeastern corner of this township. It occupies about two and a half square miles in secs. 1, 2, and 12. The third esker field, described above, lies in the western part of the area and the rest is composed of a typical morainic surface with no unusual features. The surface is gently undulating with a relief of 15 to 25 feet. Irregularly shaped swamps are scattered over it. It differs from the ground moraine farther east only in the presence of the esker field; otherwise it is not an important feature of the township.

Outwash Plain: In the southwest corner of the township there is an outwash plain which covers about a fifth of it and stretches westward into Walworth County. It is difficult to draw the exact boundary between the plain and the terminal moraine, for the gravels and the surface of the plain extend up into valleys in the front of the moraine, leaving spurs of drift between them. In general, however, the line forms the horseshoe described as the eastern edge of the terminal.

As it was formed by waters that poured from the ice front and flowed away to the west or southwest, it presents a flat surface, sloping quite perceptibly toward the west. At the west side of this township, in secs. 19 and 30, low rounded hills of drift break the surface. These are the tops of hills which were on an older moraine over which the waters swept, modifying it somewhat and depositing sands and gravels sufficient to cover most of its hills. One of these hills in the southwest corner of sec. 30, was estimated to be 100 feet high but the others were not more than 10 or 15 feet above the plain.

The surface of the plain is also broken by a shallow, trough-like valley which enters near the northeast corner of sec. 19, extends southeast for a mile, turns south, then southwest and leaves the township near its southwest corner. This depression is 6 to 10 feet deep and averages about 1,800 feet in width. Its bottom is quite flat and in places swampy. It is an old spillway for water coming from the north and was formed during the last stages of the formation of the terminal moraine, for it was cut in the surface of the outwash plain after that plain had been formed. The outwash plain is a very conspicuous feature of this township, its broad, flat surface contrasting sharply with the extremely rough character of the hills of the terminal moraine.

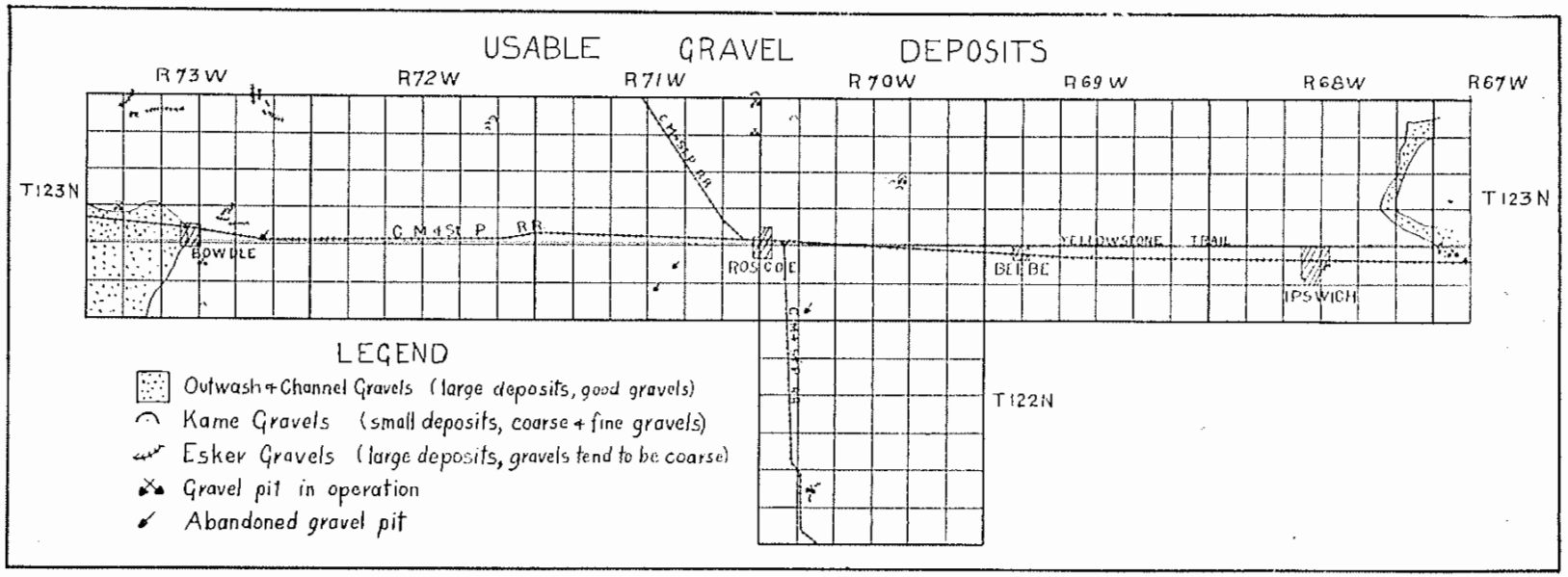

Fig. 3. Usable Gravel Deposits

Fountain Township, T. 123 N., R. 67 W.—The gravel deposits in this township were not studied. One pit located about the middle of the north line of sec. 30 will be described, however, because it furnishes the gravel for much of the Yellowstone Trail between Aberdeen and Ipswich. This pit is in the bottom of an old channel used by glacial waters which flowed from the ice that formed the Antelope Moraines, a short distance to the east. The channel here runs north and south and is three-quarters of a mile wide, as mapped by Todd. About half a mile north of the pit two channels unite to form this one. One of these smaller channels runs through the eastern part of Ipswich Township (see p. 11).

A representative sample taken from the pit gave the following analysis (see Table 1):

Sieve No.	Gr. Passing	% Passing	Gr. Retained	% Retained
200 mesh	11.5	1.15%	988.5	98.85%
100 mesh	31.5	3.15%	968.5	96.85%
80 mesh	37.0	3.70%	963.0	96.30%
20 mesh	211.5	21.51%	788.5	78.85%
10 mesh	316.0	31.60%	684.0	68.40%
¼ inch	543.5	54.35%	456.5	45.65%
½ inch	759.5	75.95%	240.5	24.05%
¾ inch	876.5	87.65%	123.5	12.35%
1 inch	1000.0	100.00%	0.0	0.00%

Apparent sp. gr. of aggregate above ¼ inch..... 2.44
Absorption per cent of dry weight (material above ¼ inch) 3.9 % (24 hours)
Amount of silt ..... 4.0 %
Organic matter .....A trace
Weight per cubic foot (dry) .....110.0 lb
Soft material.....28%; Medium hard.....38%; Hard.....34%
Hardness tested on material retained on ¼ inch.

Table 1

On the whole this is a very good gravel for road surfacing. There is a higher percentage of fine material than a perfect gravel should have and also a higher percentage of soft materials. This last is due largely to the presence of considerable shale in the deposit. Methods of eliminating this shale are being perfected so that the gravels may be used for concrete and similar purposes. The size of this deposit and the quality of the gravels make this one of the two most important deposits in the area surveyed.

Ipswich Township, T. 123 N., R. 68 W.—There are no gravel pits in this township and only one sand pit, now abandoned. The only possible large deposit is to be found in the old spillway in the extreme eastern part of the township. The channel runs directly into

the wider channel in which the big pit in Fountain Township is located. Four auger holes were drilled in the bottom of this channel, two near its southern and two near its northern end. Gravel and sands were encountered in all but one of these holes at depths of about four feet. The auger sections showed the following:

1. Auger section at southeast corner of sec. 1.

5 feet	Muck. The muck flowed into the hole so rapidly that it could not be drilled deeper.

2. Auger section near the south quarter corner of sec. 1.

1 foot	Very black soil, leached.
2½ feet	Black silt grading into a very light gray at the bottom of this section. Highly calcareous.
1½ feet	Gray sand, some small pebbles. Calcareous.
3 feet	Coarse sand and fine gravel. Sand makes the matrix. Pebbles up to size of a pea. Color buff to gray.
8 feet	Bottom of hole. Water caused sand to flow into the hole so it had to be abandoned.

3. Auger hole 1,000 feet west of the southeast corner of sec. 14.

2½ feet	Black oil grading from very black at the surface to a brown at the bottom of this section. Non-calcareous.
1½ feet	Very calcareous silt.
1 foot	Gravel and sand. Top of this foot shows coarse brown sand with pea size pebbles. Bottom of this foot shows same sand with pebbles up to 1 inch in diameter.
5 feet	Impossible to drill further because of size of pebbles.

4. Auger hole near the northwest corner of sec. 24. (1,500 feet east of hole No. 3.)

1 foot	Soil.
2 feet	Silt browned with humus. Becomes light gray near the bottom of this section.
1 foot	Very coarse sand and fine gravel. Pebbles up to ½ inch in diameter.
4 feet	Impossible to drill deeper. Pebbles prevented deeper drilling.

From these sections it seems clear that the gravels found in the bottom of the channel in Fountain Township continue up into this channel at least as far as the south line of sec. 1. The thick muck deposit found in the southeast corner of that section may be simply a big hollow in the top of the gravels, in which case they might be found under almost the entire part of the channel in this township. No idea of the thickness of these gravels could be ob-

tained but, judging from the depth exposed in the pit in Fountain Township and the three feet found in the northern end of the channel, it should be from 3 to 6 feet at a minimum. The auger sections show very little about the quality of the materials but because of their similarity in origin and their proximity to the Fountain Township pit it is probable that they will run somewhat the same.

The four feet more or less of cover and the presence of considerable water in the channel would not make these as desirable gravels to work as might be wished. Neither of these, however, is an insurmountable obstacle and if the need for these gravels arises, they should prove a valuable source of materials.

Minor Deposits. Along the east side of the channel in secs. 12 and 13 is a terrace of poorly sorted sand, gravel and clay. This terrace is about a quarter mile long and 200 feet wide and its top is about 6 feet above the bottom of the channel. The following section was observed in a road cut a quarter mile east of the southwest corner of sec. 12:

1	foot	Soil.
½	foot	Gravel.
1	foot	Clay with pebbles (till-like).
½	foot	Gravel. 90% sand, 5% pebbles, 5% clay.
½	foot	Clay with pebbles (till-like).
2½	feet	Sand and gravel. Sand 90%, gravels 10%.
6	feet	total.

This deposit will not do for gravel but might be screened and used for cement work. One pit was opened in it and the material used satisfactorily for a concrete wall. The deposit is too small and too impure to be used for commercial purposes.

The only other gravels in the township are small deposits found in some of the stream valleys. One of the best of these lies in sec. 4 near its north quarter corner. It forms a terrace on the north bank of the valley, which makes a sharp bend at this point. It is 300 feet long and 100 feet wide, its long axis being north and south. A recent road cut exposed the following section:

1½	feet	Gravel, coarse and fine mixed.
3½	feet	Sand, clean, well sorted.
5	feet	total.

This deposit, while not large, is very good material and can be used locally for road work, concrete, etc., to good advantage.

Another small deposit occurs near the south quarter corner of sec. 9 near the bottom of a stream valley. This is a very small deposit formed as a bar in the bottom of the valley and covered subsequently by clay washed from the bluffs above. Small deposits like these may be expected in any of the valleys, but they are not large enough to be worked commercially.

Huntley Township, T. 123 N., R. 69 W.—No gravel deposits sufficiently large to be of commercial importance were found in this

township. Some small patches were encountered as terraces in the stream valleys but they were all less than five feet thick and covered very limited areas. The gravels were very poorly sorted both as to size and composition. Examples of such deposits are to be found in the following places:

1. 1,000 feet west of the southeast corner of sec. 24.
2. 100 feet west of the south quarter corner of sec. 11.
3. Southeast quarter of sec. 21.

Bryant Township, T. 123 N., R. 70 W.—While no very extensive gravel deposits occur in this township, there are a number of small deposits which may prove worth working. These may be divided into two classes according to their origin: (a) the kame sands and gravels, and (b) gravels and sands formed in drainage channels. The former are the most important and occur near the crest of the terminal moraine which crossed the middle of this township. Kames are scattered over this ridge as shown on the map (Fig. 1) but only two areas are thought to contain good gravel deposits. One of these is in the northeast quarter of sec. 15, where there is a series of low rounded hills which are known to be composed of gravel. A pit has been opened in the most northern one, 1,600 feet east and 300 feet south of the northeast corner of the section. This pit showed the following section:

1 to 3 feet	Sandy soil.
2 inches to 5 feet	Yellowish sand with pebbles scattered through it. This sand is thin near the top of the hill and thick near its base.
5½ feet	Gravels. Bottom of the gravels not reached in the pit but probably not over 10 feet thick at a maximum.

A representative sample from this pit gave this analysis:

Sieve No.	Gr. Passing	% Passing	Gr. Retained	% Retained
200 mesh	18	1.8%	982	98.2%
100 mesh	38	3.8%	962	96.2%
80 mesh	42	4.2%	958	95.8%
20 mesh	301	30.1%	699	69.9%
10 mesh	405	40.5%	595	59.5%
¼ inch	609	60.9%	391	39.1%
½ inch	824	82.4%	176	17.6%
¾ inch	970	97.0%	30	3.0%
1 inch	1000	100.0%	0	0.0%

Apparent sp. gr. of aggregate above ¼ inch..... 2.60
Absorption per cent of dry weight (material above ¼ inch) 2.4 % (24 hours)
Amount of silt ..... 4 %
Organic matter ..... A trace
Weight per cubic foot (dry) .....126.1 lb
Soft material.....11%; Medium hard.....50%; Hard.....39%
Hardness test made on material retained on ¼ inch.

Table 2

This gravel runs a little high in fine material for a perfect road gravel. It is better in quality than the gravel in the Fountain Township pit, because there is only about half as much soft material. On the whole, it is a good gravel and should prove very useful, especially ...d graveling. At a conservative estimate this hill should contain about 11,000 cubic yards of gravel or sufficient for about 8 miles of road 12 feet wide with an eight-inch course of gravel.

The other kames in this quarter section are about an eighth mile away from this one, one almost due south and the other about S. 60° W. from it. That they are kames is shown by the liberal sprinkling of pebbles over their surfaces, especially near their tops. Neither hill has been opened but they would probably show over five feet of gravel if tested. They are not so large as the one which contains the pit but are from 100 to 300 feet in diameter and would make a valuable addition to the supply, should that kame be used.

The second deposit is in a single kame at the east quarter corner of sec 6. The hill covers about one acre and is about 10 feet in height. It rises very abruptly on the east side and though not so abrupt on the west, it stands out conspicuously from that side also. It has not been opened but gravels washed from it are found on the road which crosses its base and have also been plowed up on its top. An auger hole near the top penetrated 1½ feet of gravel and then went into sandy material which was too dry to drill. The depth of gravel in this hill is unknown but hills of similar origin in most cases are made entirely of sands and gravels and so it is not unreasonable to expect a thickness of nearly 10 feet in this one. The gravel exposed is all fine, the pebbles ranging up to 1½ inches in diameter. The quality and amount of gravel indicated make this hill worth testing, should gravels be needed in the vicinity.

At two places in the township the drainage into big swamps has deposited gravels and sands but neither of them is large enough or of good enough quality to be worked on a large scale. One is in the bottom of the big slough near the E. ¼ corner of sec. 4. It is a terrace 600 feet long and 100 to 200 feet wide on the south side of the little valley which drains the western end of the slough. It is composed of fine sand and some fine gravels and might be worked for sand but will not do for road gravels. The second deposit is near the northeast corner of the S. W. ¼ of sec. 32 at the southern end of one of the swamps which lie in front of the terminal moraine. A pit has been opened here and is worked a little locally. The deposit is really a stony till instead of a gravel and while the pebbles are abundant enough for some purposes there is too much clay to make it desirable for the ordinary uses to which gravel is put.

The only deposits in this township which can be recommended for testing or exploitation are the two kame areas described above.

Montpelier Township, T 122 N., R. 70 W.—This township was not systematically surveyed but one deposit will be described which, because of its location, might prove of value in graveling the Yellowstone Trail and other roads in the vicinity. The deposit is 6½ miles

south and 1½ miles east of Roscoe, in the S. E. ¼ of the N. W. ¼ of sec. 29. It is an esker deposit, lying in the boot of a great depression. The ridge rises sharply above the swamps lying on both sides of it. It is curved in form. Starting against the east wall of the depression, it runs west 550 feet, then turning south runs 200 feet farther to a gap which a small stream has cut in it. South of the gap it runs more than 200 feet in a direction a little east of south and is lost among morainic hills. It is more than 900 feet in length, from 100 to 150 feet in width and from 15 to 20 feet in height. Using average figures for the computation, the volume of the esker is about 35,400 cubic yards.

For about 200 feet at both the northern and southern ends, small boulders are scattered over the surface, indicating some coarse materials in the deposit but the amount of small pebbles between the boulders shows that a large part, if not the major part of the deposit at these places is composed of medium size gravels. Most of the esker is composed of fairly uniform, medium grained gravel. A pit has been opened at the bend near the middle of the ridge where 10 feet of gravel is exposed. The following analysis (Table 3) is from this pit and will give a fair idea of the material.

Sieve No.	Gr. Passing	% Passing	Gr. Retained	% Retained
200 mesh	9.5	.95%	990.5	99.05%
100 mesh	23.5	2.35%	976.5	97.65%
80 mesh	29.0	2.90%	971.0	97.10%
20 mesh	406.0	40.60%	594.0	59.40%
10 mesh	578.0	57.80%	422.0	42.20%
¼ inch	838.0	83.80%	162.0	16.20%
½ inch	976.0	97.60%	24.0	2.40%
¾ inch	1000.0	100.00%	0.0	0.00%
1 inch	1000.0	100.00%	0.0	0.00%

Apparent sp. gr. of aggregate above ¼ inch 2.49
Absorption per cent of dry weight (material above ¼ inch) 1.9 % (24 hours)
Amount of silt ..... 5.2 %
Organic matter ..... A trace
Weight per cubic foot (dry) .....111.1 lb
Soft material.....4%; Medium hard.....26%; Hard.....70%
Hardness test made on material retained on ¼ inch.

Table 3

This analysis shows a higher percentage of fine material than any of the previous analyses. It is probable, however, that the gravels in the pit average finer than for the deposit as a whole. The amount of soft material is much less than in any of the previous analyses. This character offsets the fineness so that this may be considered as a very good gravel either for road surfacing or concrete.

Glen Township, T. 123 N., R. 71 W.—No large deposits of either sand or gravel occur in this township and only one in which the gravel is worth exploiting. This deposit is in a kame four miles

north of Roscoe, 600 feet west of the northeast corner of sec. 1. It is in a low rounded hill which is indistinct in shape from the surrounding morainic hills. A pit has been opened in its northern side, the gravel being used in Roscoe and vicinity. No stripping is done, the cover being allowed to fall in as the gravel is excavated. A generalized section of the pit shows:

½ to 4 feet — Cover. Soil and silt.

5 feet — Gravel. Not well sorted, though the coarsest gravel runs in streaks. A few boulders one foot in diameter included in the deposit but the average of the coarser materials is 5 or 6 inches. Coarse material makes about 5 per cent of the deposit. Rest is medium and fine gravels and some sand.

The following analysis (Table 4) was run on a representative sample from the pit:

Sieve No.	Gr. Passing	% Passing	Gr. Retained	% Retained
200 mesh	17	1.7%	983	98.3%
100 mesh	80	8.0%	920	92.0%
80 mesh	84	8.4%	916	91.6%
20 mesh	379	37.9%	621	62.1%
10 mesh	561	56.1%	439	43.9%
¼ inch	672	67.2%	328	32.8%
½ inch	766	76.6%	234	23.4%
¾ inch	913	91.3%	87	8.7%
1 inch	1000	100.0%	0	0.0%

Apparent sp. gr. of aggregate above ¼ inch.....2.72
Absorption per cent of dry weight (material above ¼ inch) 1.9 % (24 hours)
Amount of silt ..... 4.3 %
Organic matter ..... A trace
Weight per cubic foot (dry) .....119.5 lb
Soft material.....6%; Medium hard.....15%; Hard.....79%
Hardness tested on material retained on ¼ inch.

Table 4

This gravel runs too high in fine material to be a first class road material. It does not run high in soft materials and so in this respect is fairly good quality. It would make a very usable gravel, however, especially since gravels are so scarce in this township. The greatest drawback is the small amount of material in the deposit. The maximum volume could not be expected to exceed 3,000 cubic yards.

A mile south of this deposit, in the southeast corner of sec. 1 there is a deposit of terrace gravels. This deposit is near the base of the front slope of the terminal moraine and appears to have been formed as a terrace by waters flowing in an old spillway heading in the bend which the terminal moraine makes here. This terrace was

eroded after its formation so that there are now left four hills as remnants, three north of the section line road and one south of it. The tops of these hills are all at the same level, showing that they belonged to the same terrace. The easternmost hill is at the corner of the section and contains two pits which are worked locally. The second hill is very small and lies 700 feet west of the corner, and the westernmost hill lies a quarter mile from it. The fourth hill lies about 100 feet south of the road and a little east of south of the third hill.

The gravels are very poorly sorted and are much mixed with clay. A generalized section is as follows:

3	feet	Black soil with pebbles scattered through it. Pebbles ¼ inch and less in diameter.
½	foot	Fine gravels. Pebbles less than ½ inch in diameter.
2	feet	Gray silts with some small pebbles.
3	feet	Gravels and coarse sands. Not well exposed. Average size of pebbles ¼ inch. Pebbles make 80% of the volume, the rest is coarse sand.

The pebbles were composed largely of limestone and shale, with lesser amounts of quartz and more resistant rocks. There is too much fine material in this deposit to make it useful as a road gravel.

Two kame-like hills lying about two miles southeast of Roscoe contain some gravelly material in quality much like that in the terrace just described. The easternmost hill is 400 feet east of the W. ¼ corner of sec. 26 and the other about 350 feet west of the same ¼ corner in sec. 27. The first hill is low and rounded, rising but slightly above the flat surface surrounding it, but the second stands out very conspicuously, as it rises abruptly to a height of 15 feet. There is an abandoned pit in this hill from which considerable material has been taken. No section was available as the pit was badly fallen in and grown over by weeds. Several small exposures showed only very dirty gravel. From the information available, neither of these hills could be recommended for exploitation.

A pit has been opened and is occasionally worked for local use 2,000 feet east of the southwest corner of sec. 27. The deposit is small. Under a cover of two feet of silt, fine gravel occurs. The pebbles run up to one inch in diameter but average ½ to ¼ inch. They are embedded in a matrix of silty sand which makes a large proportion of the deposit. Though a better gravel than that in the kame-like hills just described, it is too fine to make good road surfacing material. None of the deposits in this township with the exception of the small kame deposit first described can be recommended for exploitation unless other gravels are unavailable.

Cottonwood Lake Township, T. 123 N., R. 72 W.—Though gravel pockets are abundantly exposed in the road cuts of this township, especially in the southwestern part, there is only one workable deposit. This is in the S. W. ¼ of sec. 2. A shallow valley runs

diagonally across this quarter section in a northeast direction and in this valley there are several kame-shaped hills, which are strung along its entire length. Most of them are low but can be easily recognized by one looking for them, but the northernmost stands out conspicuously because of its greater height and dome shape. These characters and the gravels sprinkled over its surface show that it is a typical kame. It lies between the road and the stream channel, 200 feet west of the E. ¼ corner of sec. 2, in front of a small yellow house. A small pit opened on the west side shows pure gravel with sand streaks. All sizes of pebbles up to small boulders six inches to a foot in diameter are present. The gravels exposed are on the whole coarse, the pebbles averaging about one inch in diameter. This gravel, however, is no coarser than that which was used from the pit in Fountain Township (123-67), which is being used on the Yellowstone Trail east of Ipswich with good results. This kame contains something over 9,000 cubic yards of gravel.

At least three of the other kame-like hills lying in this quarter section are known to contain gravel. The amount in these hills was not estimated but they are about a third the size of the big kame and together would probably equal the amount of gravel in the big kame. While the deposits are not large, the position of this gravel field might make it valuable.

Bowdle Township, T. 123 N., R. 73 W.—This township contains gravels in great abundance. In the forming of the Altamont Moraine gravels were strewn all over its front so that nearly every road cut discloses some. Most of them are small pockets and even the largest of them is much less important than if it occurred farther east because of the proximity of much greater deposits.

Esker Gravels. The esker gravels form one of the most important classes from the standpoint of amount of gravel which they contain. As has been stated, there are three of these fields. The one in sec. 2 contains six eskers varying from a quarter to a half mile in length and up to 25 feet in height. No accurate measurement of the amount of gravel in this deposit was made, but a conservative estimate would place it in excess of 40,000 cubic yards. The esker field in the N. W. ¼ of sec. 4 is composed of many short gravel ridges and kame-like hills. They should contain about as much gravel as does the preceding field. The long esker which runs from near the center of sec. 4 into this field is estimated to contain 162,000 cubic yards. Altogether this field should produce about 200,000 cubic yards. In the field just northeast of Bowdle there are four low, narrow eskers. They stand up as sharp ridges which are easily distinguished. Northeast of the eskers in the S. W. ¼ of sec. 14 are some kames which were evidently deposited at the same time as the eskers. Though none of these hills or ridges is as large as those of the other two fields, the area should produce more than 65,000 cubic yards.

Any or all of these fields contain enough gravel to make commercially valuable deposits if the gravel were of good quality. How-

ever, the chief characteristic of gravels formed as these are is the coarseness of the materials. Small boulders are strewn over the surfaces of the eskers and kames just described and what little gravel is exposed is in most cases quite coarse. The finer gravels are present and may make 50 to 75 per cent of the deposit or even more, as is the case with the esker described in T. 122 N., R. 70 E. Even the coarser material is of such a size, however, that it would be easily handled for crushing. Should they be used for road surfacing either screening or crushing would have to be resorted to in order to get material of the proper size.

The eskers are easily distinguished by their ridge shape, which makes them very conspicuous. At certain seasons of the year they are covered with a vegetation coarser and darker colored than that of the surrounding country. This is due to the fact that the gravels which they contain do not hold water as do the more clayey materials of the surrounding regions.

Outwash Plain Gravels. The gravels of the outwash plain in the southwestern corner of the township are perhaps the best suited for road materials of any found in the area covered by this report. There is an unlimited supply of them and they are almost devoid of the coarse materials which so often characterize the kame and esker deposits. The exact line separating the gravels from the glacial drift is rather difficult to draw, as the gravels run up valleys on the front of the moraine and also feather out near their edge. The line on the map (Fig. 1) is drawn as nearly as possible at the edge of the gravels. The deposits may not be thick enough to work everywhere near the line but within a quarter mile of it thicknesses of 7 to 15 feet occur and similar depths can be found over the entire area except in the vicinity of the three drift hills mapped in secs. 19 and 20. The depth of the gravel is known in only a few places. It must vary, however, because it was deposited on a morainic surface, nearly all of the hills and hollows of which were completely covered with gravel. The three hills mentioned above, however, are the tops of drift hills of this morainic surface which were not covered and now stand as islands of drift surrounded by gravel. A half mile west of Bowdle a well was drilled 16 feet and did not reach the bottom of the gravel. A mile west of this well another is reported to have gone through 21 feet of gravel into a blue clay. A mile south of this last well, near the northeast corner of sec. 31, a dug well 7 feet deep did not reach the bottom of the gravel.

It would be impossible to compute the volume of this deposit without knowing the contour of the surface on which it lies. If a depth of 10 feet be assumed as an average for the six square miles covered by the gravels, a volume of 10,000,000 cubic yards would result, which is about as accurate an estimate as the data at hand will permit. The probability is that it will run considerably in excess of this figure. As the cover is nowhere over 5 feet thick and in most places is only 1 to 3 feet, it is a very easy matter to open and work pits almost anywhere in the area.

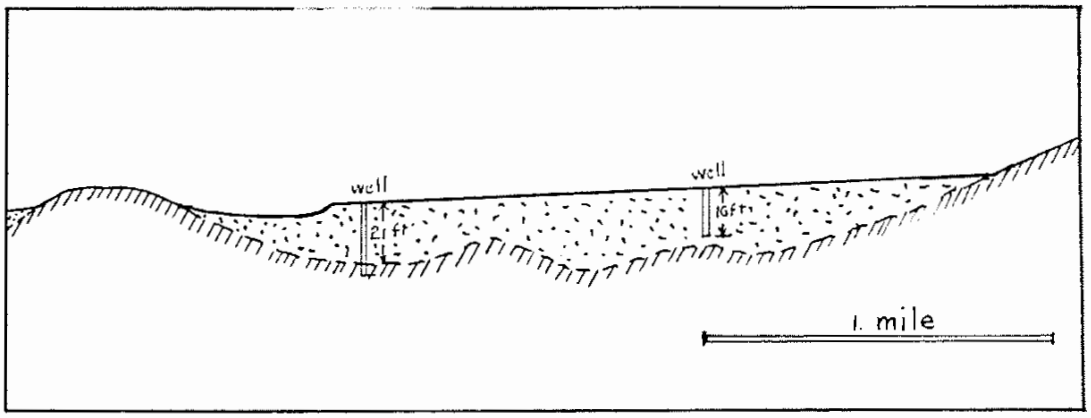

Fig. 4

Cross section showing relation of glacial till to gravels along the Yellowstone Trail (south line of secs. 19, 20, 21) from Bowdle to the west line of Edmunds County.

The deposit is composed of sand and medium to fine gravels. The sand occurs in considerable thicknesses in some places while in others it makes only average size beds. The thickest sand section observed was at the southeast corner of sec. 29 at the edge of the outwash plain. At this place there are six feet of brown to buff, medium grained (30 to 60 mesh) sand. Thin streaks of small pebbles averaging one-quarter inch in diameter were exposed at intervals of about two feet and scattered pebbles were found in the sand. The sand beds seen farther out in the outwash plain, in secs. 29 and 30, were from one to two feet thick, which is probably the average for most of the deposit.

The gravels are medium to fine grained, the pebbles ranging from the size of a pea to one inch in diameter, and are fairly well sorted. The following sections will give an idea of their character:

1. Railroad cut at the E. ¼ corner sec. 20.

1¼	feet	Soil with scattered pebbles.
1	foot	Gravels, pebbles 1½ inches and less in diameter
1	foot	Gray silts with iron stains.
1½	feet	Fine gravels.
4¾	feet	

2. Section in cellar of house, N. E. corner sec. 29.

2	feet	Soil.
3	feet	Medium grained gravel.
1	foot	Medium grained (30 mesh) sand.
½	foot	Gravels.
4½	feet	

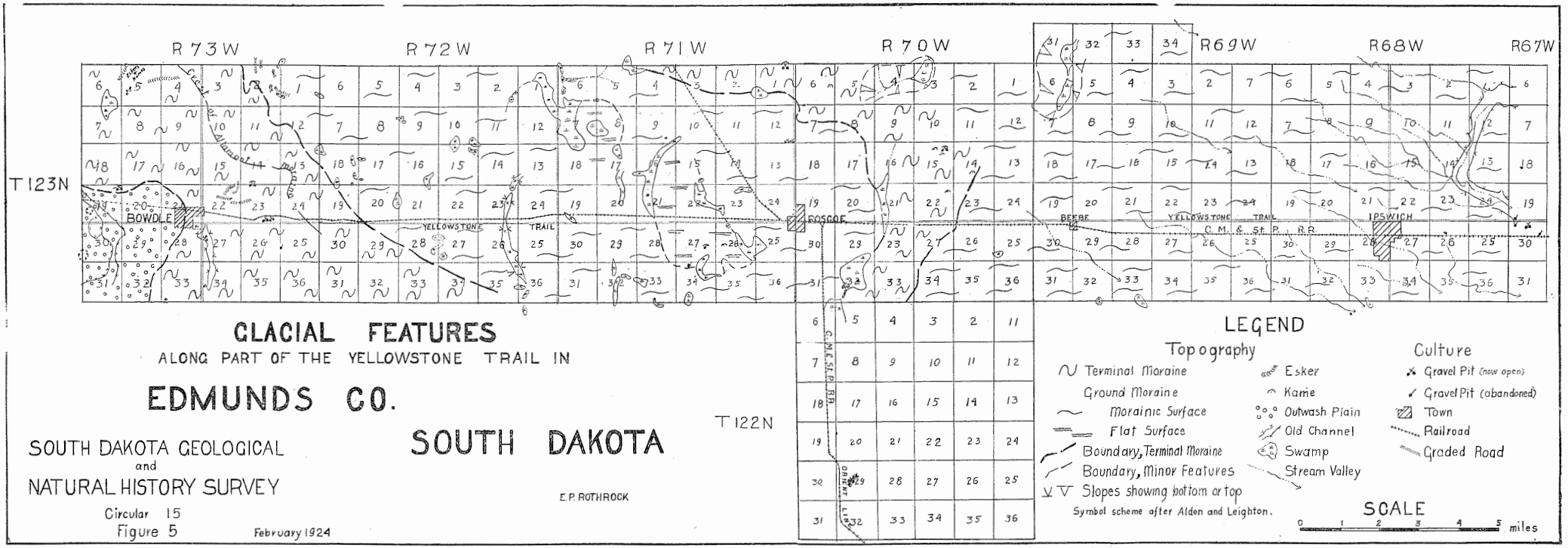

Fig. 5. Geologic Map

3. Auger hole. 300 feet S. of E. ¼ corner sec. 30.

4½ feet	Silty soil with cobbles scattered through it. Part or all of this is wash from the higher land to the southeast.
1½ feet	Buff, medium grained sand.
1 foot	Fine gravel in matrix of sand like above. Largest pebble brought up was ¼ inch in diameter.
2 feet	Fine gravel with some coarse sand. Pebbles average from ⅛ to ¼ inch in diameter.
9 feet	

4. Road cut. 250 feet W. of the S. E. corner sec. 30.

1 foot	Gravels, fairly clean. Maximum size of pebbles one inch. Average size ¼ to ½ inch.
2 feet	Finer than above. Pebbles run about the same size but matrix contains coarse sand and some clay.
3 feet	

These sections are too shallow to give an exact idea of the character of the deposit, but they may be taken as indicators of the sort of material to be expected deeper down. No large excavations have been made in this township, but the Milwaukee Railroad opened a big pit in the same deposit along its tracks in Walworth County, a mile west of the Edmunds County line. In this pit 13 feet of gravels were exposed and the bottom was not reached. The deposit here shows fine to medium gravels and considerable sand. It is made principally of medium size gravels (¼ to ½ inch pebbles), a small proportion of coarser gravel (2 to 3 inch pebbles), and considerable medium grained (30 mesh) sand. This pit helps verify the conclusions drawn from the shallow sections in Bowdle Township that the deposit is composed of medium to fine grained materials throughout and should make very good road material.

Summary.—A summary of the workable deposits in the area covered by this report is contained in the following table:

Location	Estimated volume cubic yards	Character of gravels			
		Size	Quality	Cover feet	Type of deposit
E. end of T. 123-68 and Sec. 30, T. 123-67	More than 700,000	Medium	Fair	3-4	Channel
N. E. ¼ sec. 15 T. 123-70	11,000	Rather fine	Fair	0	Kame
E. ¼ corner sec. 6 T. 123-70	5,000 to 10,000	Not opened	Not opened	1-3	Kame
Center sec. 29 T. 122-70	35,400	Medium	Very good	0	Esker
N. E. corner sec. 1 T. 123-71	3,000	Fine	Fair	½-4	Kame
E. ¼ corner sec. 2 T. 123-72	9,000	Coarse	Fair	½	Kame
N. E. ¼ sec. 2 T. 123-73	40,000	Not opened, Probably coarse		0-2	Esker
N. W. ¼ sec. 5 and center of sec. 4 to center of sec. 5, T. 123-73	200,000	Not opened, Probably coarse		0-2	Esker
S. W. ¼ sec. 14 and N. E. ¼ sec. 22 T. 123-73	65,000	Not opened, Probably coarse	Fair	0-2	Esker
S. W. quarter of T. 123-73	10,000,000	Medium to fine		1-4	Outwash Plain

Table 5