An Investigation of the Physical and Chemical Properties of Manitoba and Saskatchewan Sands.

By

Reay P. Quinn B.Sc.

Presented in partial fulfillment of the requirements for the Master of Science degree in the University of Manitoba.

April 1928.

Table of Contents.

1. Introduction and Purpose of Thesis.

In the last few years an increasing amount of work has been done in connection with sedimentary rocks and their disintegration products, and it is only in the most recenttimes that their value in the work of correlation and identification is being fully realized. Most of the work, however, has been done by the British workers and on local sediments, while in this country little has been attempted along these lines.

Sand comes under the heading of mechanical sediments and is of considerable geographical distribution. It may occur as loose unconsolidated product or may be found in various stages of consolidation varying from a closely packed sandstone, held together by means of a hard cementing material, to one that will crumble in the fingers. Thenature of the sand varies considerably from a chemical and a physical standpoint and this variation may be attributed to the following:-

(1) The hardness of the material composing the grains.

(2) The distance the grains have travelled.

(3) The agents by which the grains have been transported.

The purpose of thisinvestigationis to show how the physical and chemical properties, of sands, which are based on the above factors may be used as a means of correlation and identification of sands of similar horizons.

Recent work done by Trowbridge and Mortimore [1] has shown these properties to be of primary importance in oil sands. Working on four typical series of sands they showed that it is possible to differentiate these by physical characters alone and suggest "That most Paleozoic sands at least, possess such constant or uniformly varying charateristics, that comparision with, or interpolation in a known series of analyses will permit the correct placing and correlation of most specimens analyzed". In this investigation these same principles are applied to Pleistocene and Cretaceous sands, and an attempt made to show how sands of similar horizons possess certain definite recognizable characteristics peculiar to those horizons.

2. <u>Collecting of Samples</u>.

Most of the samples were collected during the summers of 1926 by correspondents and the remainder in 1927 by the author while examining Pleistocene deposits of Manitoba and Saskatchewan, under Mr. W. A. Johnston, of the Geological Survey of Canada. In most cases the sample was taken from an outcrop or exposure on the surface or from a cut- bank, but some samples were obtained from quarry cuts, drill holes or from the foundries where these sands are used commercially. A vertical section of the exposure was taken in order to obtain a fairly representative sample of the sand. The samples were then quartered down to suitable amounts and left unwashed.

3. Nature of Sand and Locality.

The sands were obtained from the three main sandstone horizons occurring in Manitoba. Starting with the oldest, these are thexx Winnipeg Sandstone, the Dakota and the post-glacial sands such as eskars, outwash deposits, and beaches, of late Pleistocene age.

The Winnipeg rests on the eroded Pre-Cambrian surface and is very similar to the Ottawa Illinois sand of Middle Ordivician age. It is a clean looking sand, composed mainly of quartz, the grains being well rounded. Outcrops occur at Black Island, Punk Island, Grindstone Point and Elk Island on Lake Winnipeg and at the north end of Runnxinghouse Lake. Samples were taken from Black Island, Grindstone Point, and from a limestone quarry at Garson. Samples of sand from Ottawa Illinois were also used.

The Dakota Sandstone rests on the eroded surface of the Devonian Limestone and is of Upper Cretaceous age. The sand is a fine greenish sand high in quartz. Outcroppings are found on Swan River, Steeprock River and Red Deer River. At Boissevain and Turtle Mountain there is a sandstone horizon of Foxhill, Cretaceous age. This is aa loosely consolidated sandstone that is used commercially for building purposes. At Estevan, in Saskatchewan, a sandstome horizon occurs, thought to be of Fort Union, Upper Cretaceous age. This is a soft, friable sandstone containing concretionary nodules of iron stone.

From Swan River two samples were taken at different depths, and one each from Boissevain and Estevan, Saskatchewan.

The Pleitocene sands are found as present day surface formations and are of Late Pleistocene age. There are four types of these, the esker, outwash, beach and wind blown deposits.

The esker type of sand is derived from deposition of sediments in the channels of glacial rivers walled by ice.

The outwash type was deposited at the margin of the glacial moraine just beyond the ice limit.

Beach Sands are from ridges left by the retreating glacial lakes, in this case mostly Agassiz or Souris.[2]

Pleistocene deposits are found widely distributed throughout Manitoba. Samples were taken from the following localities:-

No.	Locality.	Description.
1	Bird's Hill	esker
2	Smith Siding	outwash
5	Vivian	esker
7	Smith Siding	outwash
8	Bird's Hill	esker
12	Beausejour	esker
18	Mile 80, G.W.W.D.R'y.	outwash
19	Marchand	beach

1 INCH = 30 MILES

No.	Locality.	Description.
21	St. Anne	Beach
23	Melbourne	Wind Blown
26	Marchand	Beach
51	Molsom	Out-wash
53	Woodlands	Esker
54	Rose Isle	Beach
62	Stonewall	Beach
63	Firdale	Wind Blown
66	St. Rose du Lac	
67	Grand Beach	Beach

The localities from which these samples were taken are shown on the accompanying map.

4. Mechanical Analyses.

(1) Method of Analysis.

In making the mechanical analyses the sieves used were of the 20, 40, 60 etc. mesh, the finest being the 200. The sample was quartered down until a representative amount remained and 50 gms. of this was weighed out and passed through the various sieves, one at a time, the amount passing through each being weighed. The sieves were all shaken by hand, the time and other variable features being kept as nearly constant as possible.

A series of analyses by means of an elutriator was taken but the results obtained did not warrant further use of this apparatus in connection with sands. Although it was satisfactory for extremely fine sands, it was found that with the coarser sands the results lacked consistency. The instrument used was one similar to the Crooks apparatus described by Holmes.[3]

Method of recording results.

In recording the results of the mechanical analyses, the distribution of the various sizes of grains in each sand was shown graphically by a system of block designs, where the per centage of the grade was drawn against the size. This method was found to illustrate the sorting better than by the cumulative per centage graphs and could be used for purposes of comparision. The cumulative graphs were used however to show in a general way how the type sands of each group compare.

The majority of the sands were analyzed by means of the sieves mentioned but towards the end of the investigation a set of Tyler standard sieves was substituted. The Tyler screen size and the screen size of the set formerly used is shown:-

Tyler Set.		Old Set.	
Mesh	Openings in MM.	Mesh	Openings in mm.
14	1.17		
20	.83	20	.83
28	.59		
35	.42	40	.40
48	.29	60	.23
65	.21	80	.17
100	.15	100	.15
150	.10	150	.10
200	.07	200	.07

No satisfactory ratio could be found to transfer directly from one system to the other, but in view of the fact that four grades in each set are similar, namely the 200, 150, 100 and 20 mesh and the remainder correspond very closely the 35 and 40, and the 65 and 60, it would appear that this substitutinn would not make much material difference to the results. To illustrate this better an anylsis of the Black Island sand was made using both sets of sieves and block diagrams made to show how they compare as in Figure 5.

(3) Results of Mechanical Analyses and Discussion

The results of the mechanical analyses of the sands are shown by the block diagrams in Figs. 1 to 5. and an idea of how the type sands compare is given by the cumulative percentage graph in Fig. 6.

The percentage results of the analyses are shown on the following page.

In the case of the Palaeozoic sands the sorting was found tobe poor, if a sand is regarded as being well sorted when over 50 % occurs in one grade. From the block diagrams this poor assorting appears to be characteristic of the older Palaeozoic sands.

As pointed out by Sorby[4] "more or less perfect similarity in the size of the grains usually indicates a sorting of the material by a current at the very bottom of comparatively shallow water; whereas great irregularity

The percentage results of the mechanical, analyses are given below :-

No.	Size of mesh holding the sand.							
	20	40	60	80	100	150	200	200+
1.	18.3	23.71	41.79	14.02	1.00	.69	.31	.15
2.	.17	24.95	45.63	18.99	4.55	3.20	1.25	1.28
5.	.02	.14	.39	.92	.77	5.99	24.71	62.05
7.	.33	.27	3.52	14.67	17.34	30.90	19.99	13.01
8.	.08	15.46	65.26	15.27	1.53	.96	.52	.91
12.	.17	.54	1.78	16.61	22.64	34.01	11.58	14.65
18.	.08	.33	8.08	35.29	25.39	22.63	5.46	2.74
19.	6.94	43.19	32.85	8.84	3.06	2.50	1.46	1.13
21.	1.13	3.49	9.34	50.91	20.44	11.25	2.15	1.04
23.	.04	.12	1.22	19.11	25.42	34.45	15.64	4.01
26.	2.84	5.07	15.46	33.35	10.87	14.13	14.33	3.96
51.	.10	.13	.10	.11	1.71	10.78	31.49	55.38
53.	.36	8.11	45.72	36.88	6.86	1.90	.06	.04
54.	15.61	70.68	11.94	1.41	.11	.11	.05	.08
62.	.2	.51	.85	2.49	1.70	8.42	19.60	66.23
63.	.15	.75	1.24	.97	1.13	5.4	28.35	61.37
66.	.15	1.32	2.20	1.97	1.27	2.23	4.15	86.72
67.	9.69	10.54	6.30	26.63	29.85	16.62	.31	.05
52.	.07	.06	.45	10.88	30.72	43.42	12.72	1.59
72.	.02	.03	.82	10.66	24.52	49.23	13.03	1.69
Boiss.	.67	1.46	3.91	48.40	15.73	10.90	6.49	12.41
Est.	.49	1.16	18.51	46.63	10.01	9.49	6.14	9.82
9.	.22	8.82	28.85	39.66	11.29	5.59	4.74	.84

Percentage results of mechanical analysis contánued.

N6.	Size of mesh holding sand.							
	20	40	60	80	100	150	200	200+
13.	.01	8.82	28.85	39.66	11.29	5.59	10.46	1.69
50.	1.23	15.01	24.45	30.49	13.72	10.81	2.78	1.54
90.	.02	1.17	12.83	58.69	19.62	7.32	.32	.02

----

in the size indicates that the material was deposited from much deeper water, in which there was little current at the bottom". This would indicate marine or deep sea conditions as the possible origin of these Palaeozoic sands.

The Cretaceous sands were found to be better sorted than the Palaeozoic but are not in the class of a well sorted sand. Following the same line of reasoning and based on grading alone it would seem that these sands are intermediate between a marine or deep sea condition and a fluvial one or in other words brackish water.

With the Pleistocene sands conditions are somewhatdifferent from the older formations. The sands are comparatively young and there are four types, namely, the esker, outwash, beach and wind blown. The question arises however as to whether there is sufficient distinct difference in the grading of these types to definitely distinguish the one from the other. The sand is undoubtedly of post-glacial origin and this is in agreement with the general features of the grading. On the whole the sand seems to be fairly well assorted ranging from the case of the St. Rose-du Lac, an extremely well assorted sand to the Grand Beach which is poorly assorted. There is a noticeable variation in the size of the grain from fine to coarse that does not seem to bear any definite relation to the origin of the sand.

If regarded in the more restricted sense as type sands certain features common to the type are to be found.

In the esker type the sands are definitely well assorted but vary considerably as to size of grain as shown by the Bird's Hill and the Vivian.

In the outwash type the sands are not so well assorted but vary as to size of grain.

The beach sands are well assorted, with the exception of Grand Beach and there is a noticeable concentration of the coarser grains.

Only two samples of wind blown sand were available and of these one was well assorted and the other fairly well. The grains,however, are mostly fine, as would be expected in a wind blown deposit where the lighter grains are lifted easily and carried away.

The above results will show that in the more recent sands there is too much variation in the size of the grains and the grading for these characteristics to be of any definite correlative value, while in the older sands the Cretaceous and Palaeozoic these properties are comparatively constant and should serve as definite criteria for recognition of the sand horizon.

(5) Chemical Analyses.

(1) Method of Analysis.

A chemical analysis was made of several type sands for the purpose of determining how the chemical composition varied. The method used in these analyses followed closely that outlined by Washington[5]. The minerals determined were silica, iron, aluminum and calcium. A chemical determination of the heavy minerals present was not made as they usually occur in small amount and more satisfactory results can be obtained by microscopic work.

Following Washington's outline the sand was first quartered, and powdered to a very fine flour, a sample of approximately one gram being taken. This was [redacted] fused with sodium carbonate and the silica recovered as an insoluble silicate after addittion of hydrochloric acid. The iron and aluminum were first precipitated together by means of ammonium hydroxide and later the iron recovered from this precipitate with potassium hydroxide. If the iron and alumina ran very low in percentage no separation of the iron from the alumina was made.

The sands used were ;-

Melbourne	Wind Blown	Pleistocene
Grand Beach	Beach	Pleistocene
Marchand	Beach	Pleistocene
Dakota	Dakota	Cretaceous
Black Island	Winnipeg Sandstone	Palaeozoic

The sands were unwashed and not treated in any way before analyzing.

A series of analyses was made with the various grades of the Black Island sand for the purpose of determining whether there was any change in the chemical composition throughout the different sizes of grain. It was thought to be possible that a concentration of silica or iron in some particular grade might occur such as the higher percentage of silica in the larger grades due to the high specific gravity of the heavy minerals in this size and to the inability of the wind to lift them easily. In the case of the iron, if it occurs as a mineral, say magnetite, its high specific gravity would suggest a concentration in the finer grades. On the other hand if the iron occurs as a coating on the grains of silica, the concentration of the iron would most likely be inthe coarser grades. Tylor standard sieves were used in screening the samples for these analyses.

(2) Results and Discussion.

	Melbourne.	Grand Beach	Marchand	Beausejour	BL.Island	Dak.
SiO_2	86.7 %	92.1 %	71.8 %	83.7	98.0	97.0
Al & Fe		5.7		7.26	1.5	1.2
Al	5.95		8.5			
Fe	2.86		2.1			
Ca	6.22	2.8	6.8	6.17	1.2	.9
Moisture			.1		.08	.1

From the above table a distinct difference will be seen in the chemical composition of the first four Pleistocene sands and the last two Palaeozoic and Cretaceous. In the older sands the silica percentage is much higher, while the iron, alumina, and calcium are proportionally lower. Since sands consist mainly of quartz and felspar, if they have travelled a considerable distance the felspars will be largely decomposed leaving the more stable quartz and a concentration of the heavy minerals which have resisted weathering. In a similar way the iron and alumina would also be worn away from an older sand. This decomposition of the felspar would indicate that the sand must have been subjected to conditions favorable to breaking down of the more easily decomposed products, as for example desert conditions. Thus from an examination of the chemical composition of the sand some indication is given as to the possible comparative age and to the conditions through which it has passed.

The high silica percentage of the Grand Beach sand is probably due to the presence of some of the Palaeozoic Winnipeg Sandstone which is near and goes to make up a part of this sand.

The low total percentage of the Marchand is due to material of a peat like nature which forms a part of this sand and is not taken into account in the analysis.

In the analyses made made of the Black Island grades the results obtained were;-

	28 mesh	35	48	65	100	150	200 & over.
SiO_2	97.4	98.1	98.5	98.5	98.1	98.5	90.2 %
Al & Fe	1.3	1.6	1.3	1.3	1.7	1.5	4.47
Ca	1.4	1.2	.8	.8	1.0	1.0	2.93

With the exception of the 200 mesh, it will be seen that there is a slight increase in iron and silica from the coarse to the fine grades, with a corresponding decrease in calcium; but the chemical decomposition changes very little throughout the different sizes of grains. In a the very fine grade a definite change is noted with a decrease in silica and an increase in iron and alumina and calcium. Although some change of this nature would be expected here due to concentration of the heavy minerals, especially magnetite, in the finer grades, such a change as this was not looked for and it is doubtful if it can be taken as applying to the sands ingeneral, although a duplicate analysis, run as a check, gave results very similar. The increase in calcium may be due to the breaking down of the limey material into a fine dust and a subsequent collecting of this into the finer grades.

In an effort to check up on the finer grades, analyses weremade of the Dakota sand and the following results obtained ;-

	100 mesh	200 and over
SiO_2	97.3 %	96.8
Fe & Al	1.3	2.3
Ca	.4	.4

From the results obtained in the analysis of the Dakota sand it will be seen that although there is a slight increase in iron and alumina in the finer grades and a decrease in the amount of silica there is not as great a change as was noticed in the Black Island sand. This increase of iron in the Black Island finer grades may have been due to a concentration of iron in the sample used but it is not thought that this increase of iron would apply to the sands as a class. This has been shown to some extent by the analyses made of the Dakota, and more work would have to be done along these lines, taking several type sands, before any generalization or definite statement could be made regarding this particular phase of the investigation

(5) Roundness and General Appearance of Sands Under the Microscope.

Probably no other characteristic serves so well to tell something of the age, origin and conditions through which it has passed as the shape and surface markings of the sand. From the rounding of the sand grains one gets a good idea of the extent of abrasion and attrition to which the sand has been subjected and can decide therefore the kinds of conditions that prevailed at sometime throughout its its history.

It has been pointed out by by Sorby[6] that, " we must distinguish between the geological history of thegrains and that of the deposit in which they last found lodgement. It is conceivable that sand grains may pass through one or several cycles of developmental history, from the mechanically crushed glacial sand to the highly finished aeolian product, from the sharp, angular, freshly appearing granule to the ellipsoidal or spherical, frosted and pitted type of granule. The conditions and nature of the grains themselves may not accord with that of the deposition in which they occur, aeolian sands sands being blown out to sea, or shore deposits seized by the winds and made into dunes". Thus in most sands dealt with especially of the older formations th there are found several sets of conditions to contend with and it is necessary to try to decipher these from the markings and roundness of the grains.

The degree of roundness or sphericity of the grains would indicate how much the sand has been buffeted about by the waves or blown about by the wind. It is generally accepted that particles transported by wind are more rounded than those transported an equal distance by water, but that much smaller grains will be rounded by wind than by water owing to the cushioning effect of the water. According to Grabau[7] "Since particles .1 mm. or less in diameter are not reduced by mutual attrition in water, it follows that rounded grains below this size must in general be regarded as wind worn grains". This is in agreement with Mackie's[8] conclusions while Galloway[9] showed by experiment that it is possible to wear sands in water down to .05mm; and states that the presence of a few grains of less than .1mm. in a sandstone is without significance.

From a microscopic examination of the sand grains the following conclusions are arrived at as indicating the history and age of the sand.

In the Palaeozoic sands, the grains are found to be smooth, well rounded with frosted and pitted surfaces which would indicate subjection tolong continued erosion as would occur under shifting desert conditions. This wind erosion however might have been much earlier than the deposition of the formation as the frosting and pitting of the grains would be little affected by water.

In the Cretaceous sands there is not much indication of erosion or weathering and little evidence of frosting and pitting. The grains are fractured, being in the main of the sub-angular type. The nature of the grains would not suggest that the sand had been subjected to desert conditions.

The Pleistocene sand grains show the least erosion and are the most fractured of any examined. In most cases they are sharply angular, the corners showing little evidence of rounding, but occasionally a rounded grain may be observed which has probably been originally present in the parent bed beforeglaciation took place. This is well shown in the Grand Beach sand which has grains which are well rounded and undoubtedly of Winnipeg Sandstone age. Usually there are fresh looking cleavage faces and little indication of decomposition.

Several Pleistocene sands were tested for porosity as a means to more accurate roundness measurements. The method used was one followed by G. C. McCartney of the University of Manitoba. The time taken for air to pass through the sand while a constant amount of water flowed from a dropping funnel was measured and the reciprocal of this gave the porosity of the sand. From this the comparative roundness or angularity could be determined by regarding a high degree of porosity as an indication of angularity and a low porosity as an indication of roundness. As standards for comparing the sands used, glass beads were taken as representing the ideal case of rounding and crushed quartz as the ideal case of angularity. The same size of grain, namely 60 - 80 mesh or approximately .3 - .2 mm. grains was used in each case. The following results were obtained and these are shown graphically in Fig. 12.

Sand	Porosity
Crushed quartz	.01075
Bird's Hill (1)	.01063
Bird's Hill (2)	.010
Woodlands	.00980
Melbourne	.00934
Smith Siding	.00934
Ste. Anne	.00877
Grand Beach	.00864
Mile 80 G.W.W.D.	.00854
Beausejour	.00775
Glass beads	.00826

The Beausejour sand is shown to have a lower porosity than the glass beads but a microscopic examination of this sand showed that the grains are not perfectly round (see Fig. 9). The low porosity figure is in all probability due to the fine material in the sand which screening would not remove entirely. This phase of error must be taken into consideration in al the sands. Despite this fact and with the exception cited above, this method of determining angularity agrees very well with the microscopic examination and has the advantage of showing definitely how the various sands compare.

In the Pleistocene sands there seems to be more of a tendency to rounding in the beach sands than in the others, particularly the wind blown sands which are sharply angular. It was also observed that the coarser sands are more rounded than the finer, and that in the individual samples the coarser grains were more rounded than the finer ones.

(7) <u>Heavy Mineral Content</u>.

From the standpoint of correlation, particularly in limited areas where the different beds in the same formation are to be determined, the heavy mineral content of the sands is of primary importance. Although this phase of correlation was one of the last of the sand criteria to be developed, probably more has been done in this field in the last few years than in any other, especially in work on oil sands. In the case of distinguishing between deposits of short range the variation in heavy mineral content alone may be sufficient evidence for correlation, but in attempting to connect up long range deposits, it is doubtful if this property in itself would be enough to warrant assigning the formation to definite horizons.

The heavy minerals are found to be concentrated in the finer grades of the sand and to vary little from the sand grains in roundness. They consist of the amphiboles, zircon, tourmaline, rutile, magnetite, ilmenite, garnet, pyrite, biotite, muscovite, apatite and staurolite and the total percentage may vary from a mere trace to as much as ten percent of the sample. Sometimes however it is found that there may be considerable concentration of one mineral, usually pyrite, in a sand, even in such quantity as to mask the presence of the other minerals.

The amphiboles, especially hornblende, probably serve as the best markers in the younger sands. This mineral is more easily decomposed than most of the other heavy minerals and its presence or absence in a certain sand may be regarded as criteria indicating the history of that sand. In the older sands such as the Winnipeg Sandstone only traces of hornblende were found and in the Dakota it was rare, while in the Boissevain, Estevan and Pleistocene sands it is the most common of the heavy minerals. Hornblende may remain in a sand such as the Boissevain due mainly to the small amount of travelling to which that sand has been subjected, and although it is a considerably older sand than the Pleistocene, the percentage of hornblende in the Boissevain is higher than the average Pleistocene. The Pleistocene sands on the other hand may have travelled considerably, but have not had the time for the hornblende to be decomposed completely.

The variety of heavy minerals present may also be taken as showing the history of the sand. In the Winnipeg Sandstone there is a comparatively low heavy mineral content. In the Dakota there is a slightly greater variety of heavy minerals present and in the Boissevain and Pleistocene the greatest variety of minerals. are found of any of the sands examined.

(8) Conclusions and Summary.

It has been attempted in this investigation to show how sands may be correlated and identified, and some knowledge obtained of their origin and history from a consideration of the physical and chemical properties. It must be remembered that in most cases it is necessary to consider all the properties as well as the various beds from any one horizon; and it must not be understood that an individual sample or characteristic will always be representative of the whole group. With this viewpoint in mind it is possible to assign to a definite horizon any sand examined, providing a reasonable section of the specimen, both geographically and geologically, is available. Sands vary considerably in physical properties in a very short distance, but there is a uniformity of variation that must always be taken into consideration.

In the case of the Winnipeg Sandstone, the sand was found to be poorly assorted, the largest percentage in any one size being the grains of .17 mm. or 80 mesh. The chemical analysis shows a high percentage of silica averaging 98 %, with small amounts of iron, aluminum and calcium. The chemical content was found to vary very little throughout the grades, with the exception of the finest grade. The grains are classed aswell rounded and show evidences of frosting and pitting. In the heavy minerals there is a marked absence of hornblende, also the heavy minerals are comparatively few in number. From this data it is assumed that the sand is an old one geologically, and that at one time it has been subjected to shifting desert conditions as well as marine conditions. It is similar to the St. Peters Sandstone of Middle Ordivician age with which it is correlated.

The Dakota sands are fairly well assorted and fine grained, over 40 % of the sand being 150 mesh or .1mm in size. The sand has a high percentage of silica, over 96 %, with small amounts of iron , aluminum and calcium present. There is little change in the chemical composition throughout the grades , but there is a slight increase in iron and corresponding decrease of silica in the finer grades. The grains are sub-angular and show little evidence of erosion with little frosting and pitting, they also show fracturing. Of the heavy minerals magnetite is the most abundant while hornblende is rare. There is a greater variety of heavy minerals in the Dakota than in the Winnipeg Sandstone but the heavy mineral content is not so high. The high silica content would indicate a comparatively old sand , where the softer felspars have been decomposed, but the greater variety of heavy minerals suggests a younger sand than the Winnipeg Sandstone. That the sand has not passed through a period of desert conditions is is shown by the small amount of frosting and pitting and by the sub-angular grains, but the sand must have been subjected to some erosional agencies to remove the hornblende and felspars. This may have been accomplished under marine conditions, as marine sands usually show little evidence of hornblende.

In the grading and roundness of grains the Boissevain resembles the Dakota although the grains in the Boissevain are more angular than those in the Dakota. In the heavy mineral content and chemical composition there is a marked difference in the two sands. By far the most dominant heavy mineral in the Boissevain is hornblende. The chemical composition as given by Parkes[10] shows only about 40 % of silica with 30 % of calcium and the remainder made up of carbonates, magnesium and iron. A consideration of these facts shows that the Boissevain sand has been subjected to an entirely different set of conditions from that of the Dakota; the the angularity of the grain and the high percentage of hornblende and calcium indicating little travel and small effects of erosional agencies. It would seem that the sand has remained where laid down under fresh or brackish water conditions.

The Pleistocene sands are well assorted, often much as 80 % of the sand being in one grade. They vary from extremely fine sands to extremely coarse, depending to a certain extent upon the type; the coarse usually indicating beach sands and the fine, wind blown. The chemical composition varies considerably but the silica content is not usually over 85 %. This does not seem to be a suitable criterion for correlation. In the Grand Beach sand there was 92 % of silica but this is most likely due to the presence of grains of the Winnipeg Sandstone which is near at hand and for this reason the Grand Baech can not be regarded as a typical Pleistocene beach sand. The grains are mainly angular and show fracturing. The degree of angularity varies from near that of crushed quartz to approaching the roundness of glass beads but these figures, which were based on porosity, are due more to the fine material in the sands filling up the pore spaces than to the well rounded sand grains.

No evidence of erosion is found in the grains but slight indications of frosting and pitting are apparent. This may be due to grains of older formations being present or to wind action on the grains, but the degree of frosting and pitting does not compare with that shown by the Winnipeg Sandstone.

There is a much greater variety of heavy minerals in the Pleistocene sands than in the other horizons and a marked predominance of hornblende.

That the sand is not an old one is shown by the angular grains, and the presence of a large amount of hornblende in the heavy minerals, by the great variety of heavy minerals , as well as by the low silica content.

The similarity of these factors in the various types of Pleistocene sands makes it difficult to assign an unknown sample to a definite [illegible] type, but the following generalizations may be useful in this respect although it must be remembered that the differences in these types are gradational and not definite.

Beach sands usually have a concentration of grains in the coarser grades. They are the least angular of the Pleistocene sands but are not well rounded.

The esker and outwash sands are betterassorted than the beachsands but they may be either fine or coarse grained.

The wind blown sands are fine grained, well assorted and the grains are sharply angular.

There is not enough difference in the heavy mineral content of the Pleistocene sands to make any long range correlations.

There is too much variation in the chemical composition to use this as an aid to correlation.

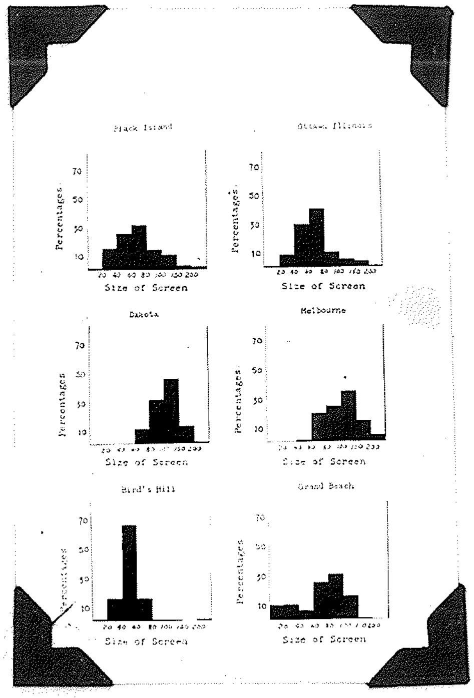

Fig. 1.

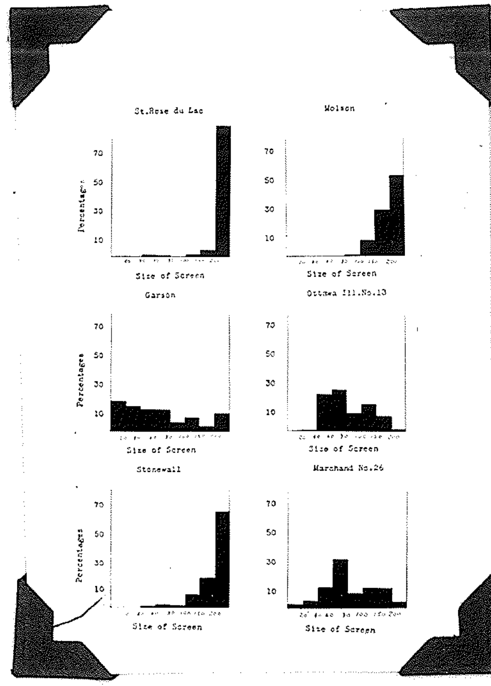

Fig. 2.

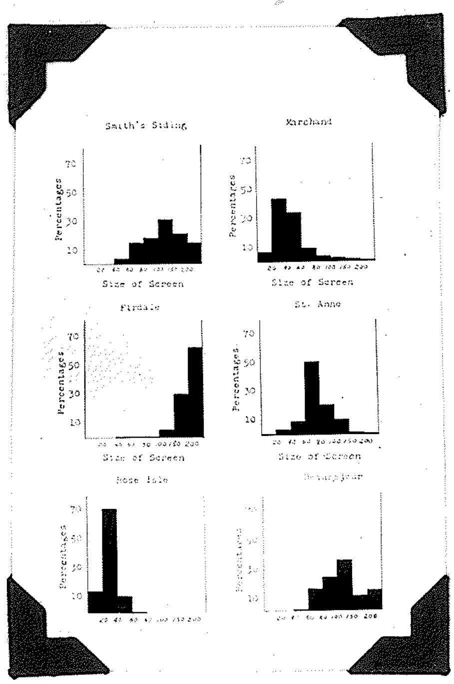

Fig. 3.

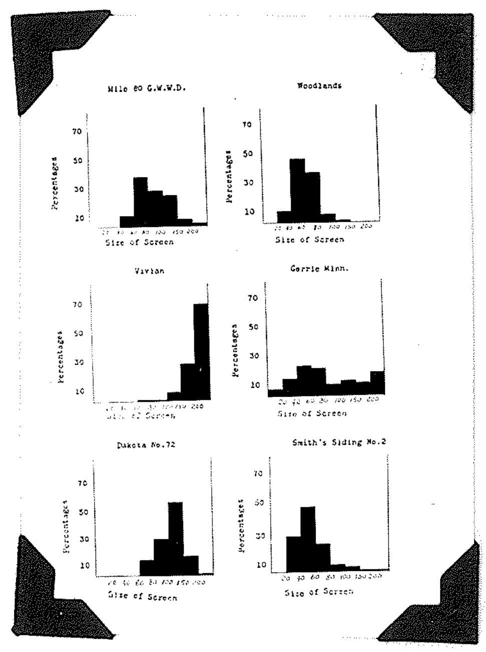

Fig. 4.

Figures 1 to 4 are block diagrams representing the grading of the sands. In these the old sieves were used

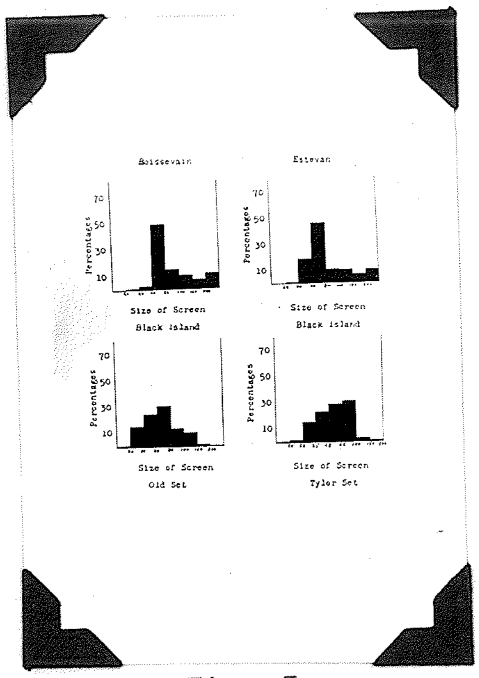

Fig. 5

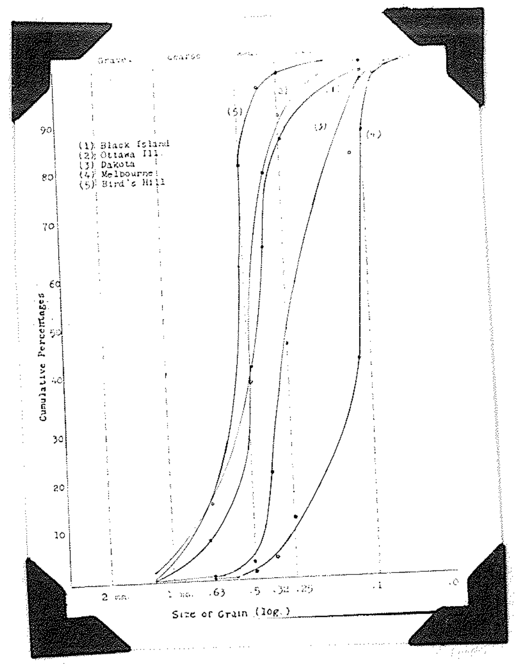

Fig. 6

In Fig. 5 block diagrams of the Black Island sand areshown using the old set of sieves and thè Tyler standard set. In Fig. 6 are cumulative percentage graphs of typical sands.

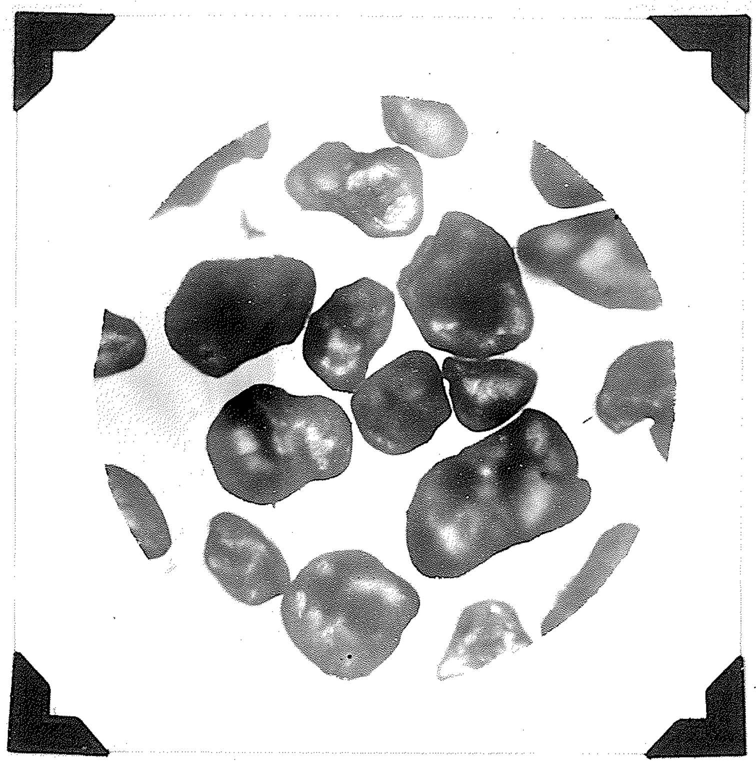

Fig. 7 Black Island sand

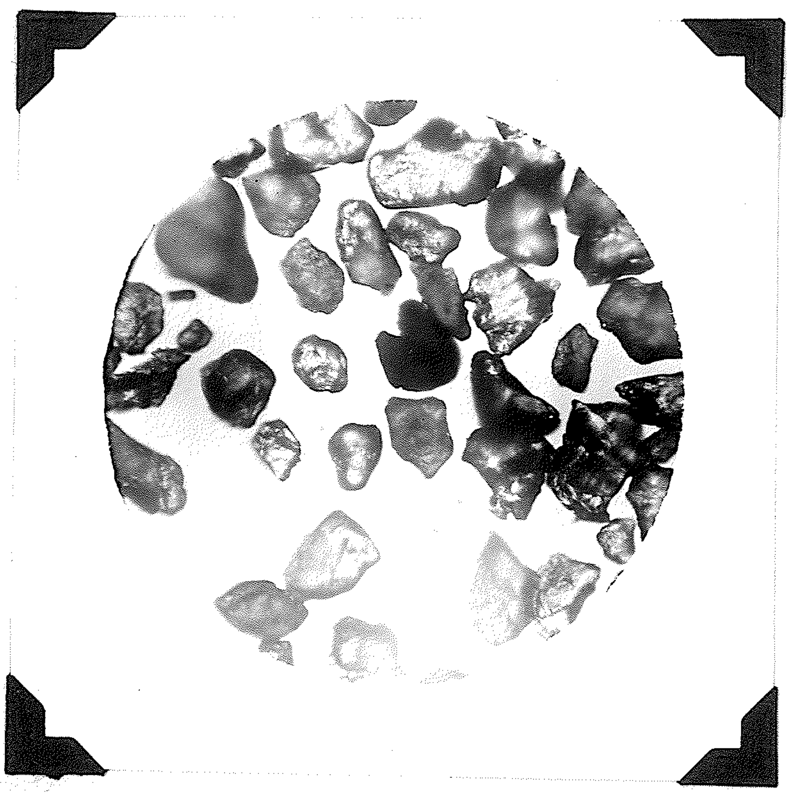

Fig. 8 Dakota sand

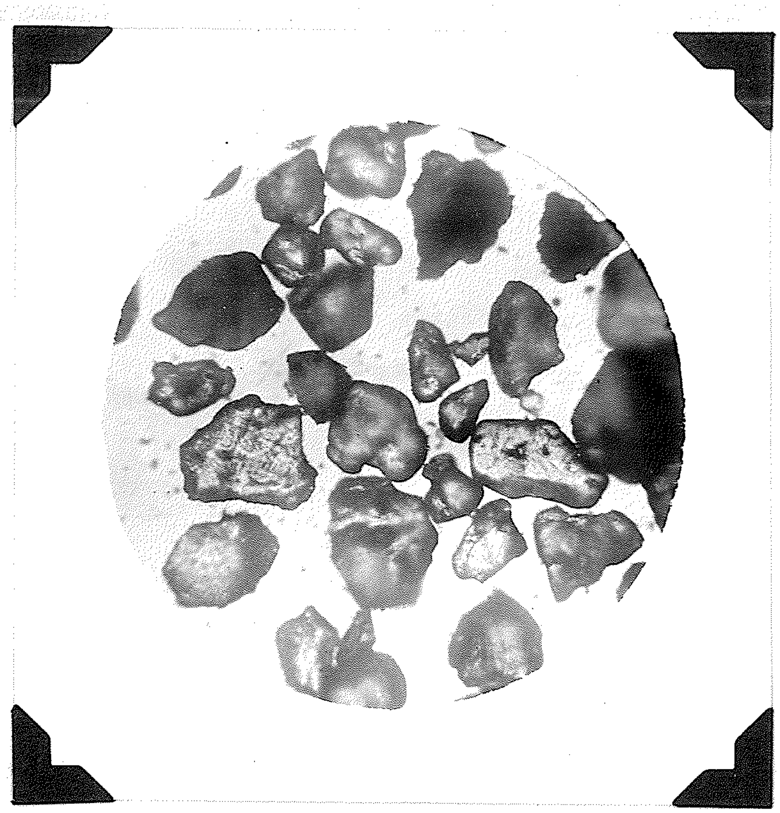

Fig. 9 Beausejour sand

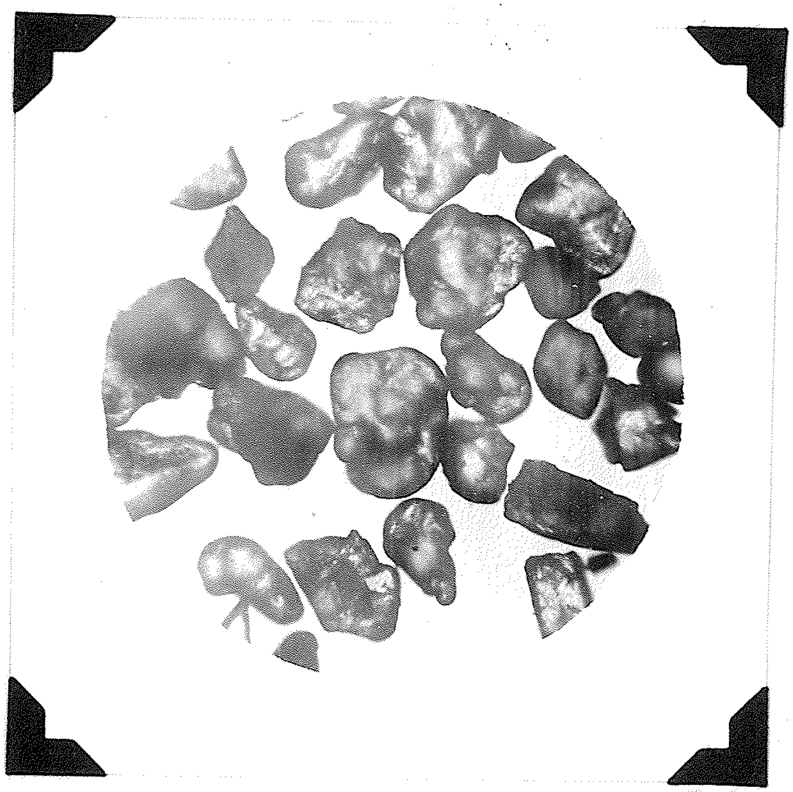

Fig. 10 Grand Beach sand

Fig. 11 Firdale sand

The above micro-photographs have a magnification of 50 diameters.

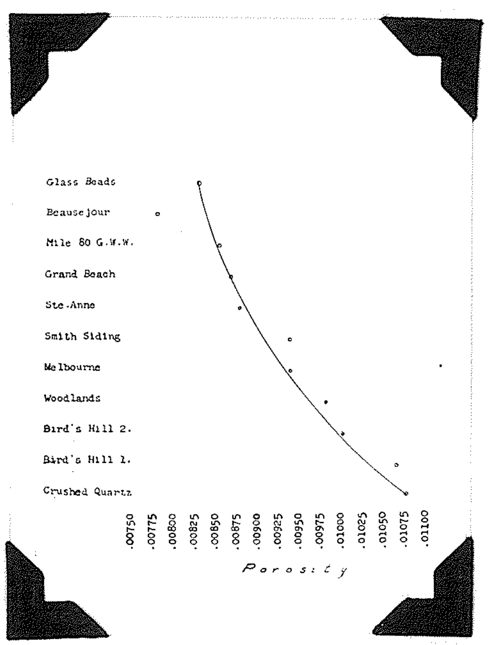

Fig. 12. Porosity Graphs

Bibliography and References.

1. Trowbridge,A.C.and M.E.Mortimer-Correlation of oil sands by sedimentary analysis; Econ.Geo.vol.20,1925
2. Upham,Warren-The Glacial Lake Agassiz;U.S.G.S. Mono.25
3. Holmes,Arthur-Petrographic methods and calculations.
4. Sorby,H.C.-Quart.Jour.Geo.Soc.vol.36,1880
5. Washington,H.S.-The chemical analysis of rocks.
6. Sorby,H.C.-Quart.Jour.Geo.Soc.vol.36,1880
7. Grabau,A.W.-Principles of stratigraphy.1913
8. Mackie,W.-On the laws that govern the rounding of particles of sand; Trans.Edin.Geol.Soc.vol.7,1897
9. Galloway,J.J.-Value of the physical characters of sand in the interpretation of origin;G.S.A.vol.33,1922
10. Parkes,W.A.-Building stones of Canada;vol.4 G.S.C.Bull.388
11. Ziegler,V.-Factors influencing the rounding of sand grains; Jour.of Geo.vol.19,1911
12. Udden,J.A.-Mechanical composition of clastic sediments; G.S.A.vol.20,1914
13. Kindle,E.M.-A neglected factor in the rounding of sand grains; Am.Jour. of Sc.vol.47,1919
14. Sherzer,W.H.-Recognition of types of sand grains; G.S.A. vol.21,1910
15. Boswell,P.G.H.-The distribution of heavy minerals in British sediments; L.G.S.1923
16. Wentworth,C.K.-The shapes of pebbles; U.S.G.S.Bull.7-30,1922
17. Gregory,H.E.-Notes on shapes of pebbles; Am.Jour. of Sc. vol.39,1915

18. Shaw,E.W.-Sorting in sedimentary rocks; G.S.A.vol.28,1917

19. Twenhofel,W.H.-Treatise on sedimentation,1926

20. Anderson,G.E.-Experiment on the rate of wear of sand grains;
Jour. of Geo.vol.34,1926