PLEISTOCENE GRAVELS

OF

THE RED RIVER VALLEY

A Thesis

Presented to

The Faculty of Graduate Studies

The University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

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September 1952

ACKNOWLEDGMENTS

This thesis was prepared under the direction of Professor E. I. Leith, Department of Geology, The University of Manitoba, to whom the writer is indebted for guidance and helpful criticism.

Collection of samples was made possible by kind permission of operating companies at the pits concerned. Transportation facilities were supplied by the Manitoba Mines Branch.

Acknowledgment for helpful advice is made to members of the Department of Geology, to Dr. J. D. Allan, formerly Chief Geologist, the Manitoba Mines Branch, and to Professor J. H. Ellis, Department of Soils, The University of Manitoba, who supplied a base map of Manitoba gravel deposits.

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CHAPTER I

INTRODUCTION AND METHOD OF STUDY

I. INTRODUCTION

GENERAL STATEMENT This thesis is based on field and laboratory studies of several Pleistocene gravel deposits in southeastern Manitoba. The deposit near Birds Hill receives special attention.

North American topography has been greatly influenced by the widespread glaciation of the Pleistocene epoch. Ice-sheets of this epoch extended over the northern part of North America in four successive advances, named in order the Nebraskan, Kansan, Illinoian and Wisconsin glacial ages. With each recession of the ice-sheets a mantle of glacial till remained, to be overridden and modified by the next age of glaciation. The drift deposited by the Wisconsin ice-sheet remains today virtually unaltered over large areas of Canada and northern United States. In Manitoba the drift is found as unmodified till, moraines, outwash deposits and lake clay deposits of glacial Lake Agassiz, which developed against the face of the retreating ice-sheet. Also remaining are the elevated beaches of glacial Lake Agassiz.

The Birds Hill gravel deposti near Winnipeg is a feature unusual to the surrounding countryside. It is of interest academically as to origin, and also commercially as a source of sand and gravel. The origin of Birds Hill aroused the curiousity of Warren Upham, first in 1887 while he was engaged in a study of glacial Lake Agassiz for the Geological and Natural History Survey of Canada, and later in 1909 when he revisited the vicinity as a member of The British Association for the Advancement of Science. Upham's discussion of the nature and origin of the Birds Hill deposit, which was presented to the Geological Society of America in 1910, is the only known report on the deposit.

In discussions with Professor E. I. Leith of the University of Manitoba it was agreed that a study of some of Manitoba Pleistocene gravels, particularly the Birds Hill deposit, would be of academic and possible commercial value.

A field study of the areas concerned was made by the writer in late September and early October of 1950. Laboratory study was conducted at the Geology Department of the University of Manitoba in 1950 and 1951.

Four different locations representing deposits of diverse origins were examined, and these deposits will be dealt with as separate units. Discussion and conclusions relating one deposit to another will be presented in the final chapter.

<u>GEOGRAPHIC LOCATION</u> The localities in Manitoba where

gravel deposits were examined and sample collections made are noted in Figure 3, page 4. All locations are readily accessible by road.

PREVIOUS WORK The first recorded observations upon the glacial and postglacial geology of southern Manitoba, western Ontario and adjacent parts of the United States were made by Keating (1823), Owen (1848), Palliser (1857), Hind (1858), and Dawson (1873)[1]. They recognized the abundant evidence of glaciation, and also the former existence of a great glacial lake in the Red River Valley. This lake was later named Lake Agassiz in memory of Professor Louis Agassiz.

In the area under study glacial Lake Agassiz is the largest single factor defining post-glacial modification of original glacial deposits. Any study of glacial deposits in the Winnipeg area must, therefore, be preceded by a knowledge of the history of this ancient lake.

The position of the southern outlet of the lake, now occupied in part by Traverse and Big Stone Lakes, was pointed out by G. K. Warren (1868). N. H. Winchell (1872) suggested that the glacial lake developed in consequence of an ice barrier remaining to the north.

In the years 1879 to 1889 Warren Upham (1895) carried

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[1] Figures in brackets refer to Bibliography

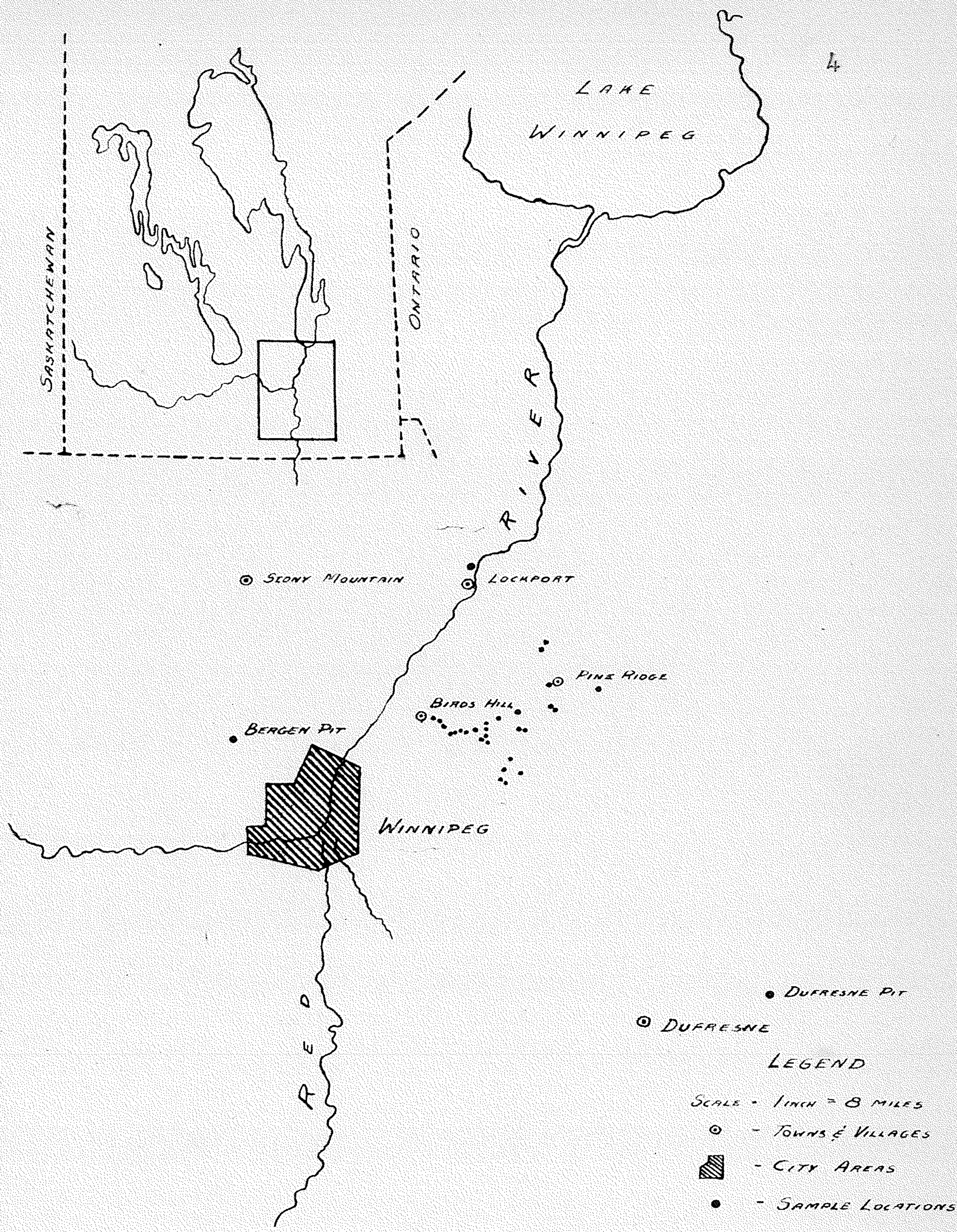

FIGURE 3

GEOGRAPHIC LOCATIONS FROM WHICH SAMPLES WERE OBTAINED out a detailed examination of glacial and related deposits existing in Manitoba, North Dakota and Minnesota. He described that as the great continental ice-sheet receded from North America, the meltwaters were not immediately carried away, but remained to form a glacial lake in front of the face of the retreating ice. In its early stages the lake occupied only the southern end of the Red River Valley, and drained southward into the Mississippi basin. Upham believed that as the ice receded northward the lake grew in this direction, and gradually expanded over large portions of North Dakota, Minnesota and southern Manitoba. At times the lake attained a depth of over 500 feet. Old beaches now found throughout the areas mentioned represent successive levels of the lake. The upper beaches, Upham stated, represent successive lake levels as the southern outlet of the lake was eroded downward. A lower series of beaches record later outlets to the north and east as recession of the ice-sheet allowed drainage in this direction. The lowest beaches are the result of final drainage through the Nelson River channel to the present level of Lake Winnipeg.

Upham believed that recession of the ice-sheet was followed by regional uplift of the previously covered areas. The results of this general uplift are most pronounced in the northern parts of the area, giving rise to an increasing elevation northward of the old lake beaches. The upper or Herman beaches exhibit the greatest degree of deformation, with the lower Grand Rapids beaches sloping but gently southward. Upham placed the time of beach deformation largely within the period of ice withdrawal. A later account of the raised beaches of glacial Lake Agassiz has been made by W. A. Johnston (1946).

While Upham was engaged in the explorations concerning Lake Agassiz he noted the unusual nature of the Birds Hill gravel deposit. He later examined the hill in detail and in 1910 presented a paper describing the deposit to the Geological Society of America.

Upham suggested that a glacial stream, existing at the time when the front of the continental ice-sheet paused in the Winnipeg vicinity, deposited the gravels which now form Birds Hill. He considered the hill an esker-like deposit, the result of a stream flowing eastward from a large fissure in the ice-front. This would be previous to the opening of the northward channels of the glacial lake, and therefore lake levels at the time would be defined by the upper Herman beaches. These beaches in southern Manitoba are approximately 400 feet above the highest altitude of Birds Hill. If the uplift which followed retreat of the continental ice-sheet was regional and uniform over the entire area, then it would appear that the Birds Hill gravels were laid down beneath at least 400 feet of water. Upham did not believe such deposition would be possible, and thought rather that the deposit was first laid down upon the upper ice surface, then gradually sank to the present position as the underlying ice melted away. He (1910, page 422) stated:

> It (the Birds Hill deposit) was not deposited in the still waters of a deep lake, between channels rising from the land surface; for then the esker gravel and sand and the frontal lower plain adjoining the east end of the esker could not have been spread out as they are now found. Fluvial currents, such as could only exist above the surface of the adjoining Lake Agassiz, brought and laid down the modified drift of the ridge and its terminal plain. Afterward, by the completion of the melting and retreat of the ice border here, on each side and beneath the esker and plain deposits, they were allowed to sink gradually about 500 feet, until they rested on the land.

No other scientific discussions of the deposit are known to the writer. W. A. Johnston (1934) mentioned the Birds Hill gravel deposit as a source of commercial sand and gravel.

Ernst Antevs (1929), in an interesting discussion of ice recession in Manitoba, suggested that the ice-sheets which extended over Manitoba were the result of growth outward from centres in the Districts of Keewatin and Patricia. The probable line of contact of these ice-sheets was northeast from the Lake of the Woods to the lower part of Lake Winnipeg, and hence along the axis of this lake northward. Antevs believed that during the waning stages of glaciation this junction existed as a zone of weakness, along which decay took place most readily, and into which glacial Lake Agassiz extended northward. Ice recession continued eastward and westward from the margins of this northern extension.

II. METHOD OF STUDY

<u>SAMPLING</u> Sampling was carried out in accordance with a procedure outlined by Krumbein and Pettijohn (1938). The method entails cutting a channel of uniform width in the pit wall, 4 to 6 inches wide and to a depth the diameter of the largest cobble or pebble. The length of this channel sample is determined by sedimentary changes within the deposit. The sand or gravel, loosened with a shovel or adze, is allowed to fall on a tarpaulin spread below the section to be sampled. At each change of sedimentation, material collected on the tarpaulin is bagged and labelled. The normal weight of a sample is five to ten pounds.

Difficulty in sampling was encountered with the coarser gravels, in that cutting to the diameter of the largest cobble resulted in an extremely bulky sample. There is also a tendency to include a greater amount of finer material than the natural proportion, so that a true sample is not obtained.

<u>PETROLOGIC CHARACTER</u> The larger pebbles and cobbles over

0.046 inches diameter were separated from the smaller by shaking through a Tyler Standard screen of the above size mesh. These larger gravel particles were again separated by visual inspection into two groups, the limestone, and the igneous and metamorphic rock types. The percentage of limestone present was estimated by weight. The smaller size ranges, those passing through the 0.046 inch screen, were examined with the aid of a binocular microscope. The mineral and rock type present, approximate shape characteristics, and other features possibly peculiar to the particular sample were noted. All samples were washed clear of adhering rock flour and silt previous to examination.

<u>HEAVY MINERAL CONTENT</u> Separation of the heavy minerals was accomplished by selective flotation in bromoform. Preliminary examination revealed that the heavy minerals occur only below the 0.0232 inch screen, therefore study was restricted to the material from below this screen size. The percentage of heavy minerals, as compared with the light fraction from which they were separated, was calculated by weight. In order to make positive the identification of minerals present, a preliminary study was made of 10 samples mounted in Canada Balsam. Later samples were mounted temporarily in a mixture of one part of glycerine to two parts of water.

MECHANICAL ANALYSIS The weight of sample employed for mechanical analysis varied proportionally with the weight of the original sample and hence also with the coarseness of the material analysed. As often as possible one-quarter of the original was used, cut from the original with the aid of a Jones Sample Splitter. Where the size of the gravel particles exceeded the half inch width of the splitter troughs, hand quartering was employed to reduce the coarser fraction to a proportion equivalent to that cut from the finer materials with the sample splitter. After treatment in this manner the weight of the sample ranged from 300 to 1500 grams. These representative fractions of the original samples were shaken for ten minutes through Tyler Standard screens. The results of the analysis were recorded as cumulative logarithmic diagrams, and from the resulting curves the median, the 25 and 75 percent quartiles were obtained. With these figures the Arithmetic Quartile Deviation, the Geometric Quartile Deviation (Sorting Coefficient) and the Logarithmic Quartile Deviation were calculated.

SHAPE ANALYSIS Considering the great number of particles to be analyzed a rapid method was essential for comparing values of shape and rounding. Roundness values were obtained by comparing the pebble, or the projected image tracing of the pebble, to a series of visual standards.

Ten drawings grading in degree of roundness from 1 to 0, by W. C. Krumbein (1941, pages 64-72) were used. Sphericity values were calculated by a method devised by W. D. and M. H. Pye (1943, pages 28-34). This method, for the larger particles above the 0.371 inch screen, entails measurement of the shortest, the intermediate and the longest particle diameter. This wa s done with the aid of a sliding block micrometer. The three axis lenghs were then referred to the prepared chart which accompanied the article mentioned immediately above. Sphericity values were read directly from this chart. Particles below the 0.371 inch screen were analyzed with the aid of a lantern slide projector. Particles were placed on a glass slide and the image projected downward on paper, to be traced directly.. The longest and the shortest diameters were then measured and the results applied to a prepared chart, similar to the one mentioned previously and also accompanying the article by W. D. and M. H. Pye. Sphericity values were then read directly. Ten grains from each screen and the pan were analysed in this manner, the average of these values was taken as the value for the individual screen size.

Measurement of sphericity by the methods outlined above fails to take into consideration irregularities of particle surfaces, with the result that values obtained by this method tend to be somewhat higher than those obtained by conventional means. In addition a break in continuity will be noted where the method changes from the use of three dimensional to two dimensional measurements. Two dimensional measurements, of necessity less accurate than three dimensional measurements, have been found to result in slightly higher values. As the methods are used consistently throughout the study, however, results remain relative and error is eliminated for practical purposes.

ACID SOLUBLE CONTENT A study was made of the acid soluble content of the fine material from a series of samples taken along the length of the Birds Hill deposit. Material was that which had passed through the 0.0232 inch screen. This was treated with a cold, dilute solution of hydrochloric acid. The content of acid soluble material was then calculated. An attempt was made to establish a possible gradient of acid soluble content among the finer materials with linear distance along the deposit.

CHAPTER II

GRAVEL DEPOSITS NEAR LOCKPORT, BERGEN AND DUFRESNE

1. LOCKPORT

INTRODUCTION AND LOCATION The Dominion Government Locks at the Village of Lockport are located on the Red River approximately 17 miles to the north of Winnipeg. Three samples of sand and gravel were collected from a pit on the western side of the river about one half mile north of the Locks and 200 yards west of the road which parallels the river on the western side. The location is noted in Figure 3.

FIELD STUDY Gravel at this point is medium coarse and fairly well rounded, grading downward in the section to fine sand. The entire deposit is overlain by a thick mantle of clay. The predominant rock type among the gravel pebbles is light buff, fine grained, hard, dense dolomitic limestone. Minor amounts of granitic and dioritic materials are also present. The stratification is poorly defined and the bedding which could be detected dips 20 degrees toward the east.

LABORATORY STUDY Dolomitic limestone pebbles compose about 95 percent of the coarser gravels. The remaining pebbles are of granitic and dioritic materials. The finer size ranges are composed dominantly of carbonate powder with lesser quantities of fragmental clear and milky quartz, quartzose and dioritic fragments, and hornblende.

The sand present is composed chiefly of limestone particles with abundant clear quartz among the finer size ranges. Carbonate powder is an important constituent of the finer fractions, with minor amounts of fresh feldspar, magnetite and the pyriboles.[1]

Heavy minerals present in the gravel samples, are in order of decreasing abundance, brown hornblende, pyroxenes, magnetite and biotite. All these minerals are fragmental and have freshly broken appearances. Rare quantities of subrounded pink garnet and yellowish, rounded monazite are also present. Sand samples contain the same heavy minerals, with additional small amounts of rounded brownish-green tourmaline and few broken zircon crystals.

From the mechanical analysis of the two gravel samples sorting coefficient values of 2.31 and 1.73 were obtained. These values, above the 2.5 margin of normal sorting defined by Pettijohn (1949, page 24) indicate a good degree of sorting. Sands are well sorted, as indicated by a sorting coefficient value of 1.22. The logarithmic frequency curves representing the mechanical analysis of the sands and gravels are illustrated in Figure 4.

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1 In this thesis the word "pyriboles" refers to unidentified amphibole and pyroxene minerals.

Shape analyses show no change in sphericity with decreasing grain size for either the sand or the gravel. There is a decrease in the degree of rounding for both the sand and the gravel with decreasing grain size. For the gravel sample a decrease of from 0.55 on the 1.050 inch screen to 0.37 on the 0.0058 inch screen was noted.

DISCUSSION OF RESULTS Traces of stratification, good sorting and a fair degree of rounding suggest either stream or beach deposition. Geographical position on the banks of the Red River, which occupies the lowest topographic levels in the Red River valley, eliminate the latter possibility. Deposition by the Red River, which has wandered little from its present course since Pleistocene time, and carries only material of silt size, would seem unlikely. It is suggested then that deposition of the deposit was by streams of meltwaters directly at the retreating front of the last Pleistocene ice-sheet. The abundance of unstable heavy minerals such as pyroxene and amphibole is in accordance with such a glacial-related origin.

2. BERGEN

INTRODUCTION AND LOCATION The road leading to the Village of Stony Mountain trends north from the junction with Highway No. 7 approximately three miles northwest of Winnipeg.

Several samples of sand and gravel were obtained from a pit 150 yards to the west of this road and one mile north of the above-mentioned junction. The location is noted in Figure 3, and is approximately one and one half miles northeast of the village of Bergen.

<u>FIELD STUDY</u> A 12 foot vertical section at the location reveals coarse, subrounded gravel overlain by a 4 foot thickness of lacustrine clay. The predominant rock type composing the gravel is a buff colored dolomitic limestone. Pebbles of granite are in minor quantities. Stratification is generally poor. At the base of the section, however, a 1 foot layer of sand exhibits marked torrential cross bedding which dips toward the east. The countryside surrounding the deposit is flat prairieland.

<u>LABORATORY STUDY</u> Approximately 84 percent of the gravel is composed of light yellow to buff, hard, dense dolomitic limestone pebbles. The remainder of the pebbles are granite and granitoid gneiss. Quartz and quartzose material comprise about 35 percent of fine material and carbonate powder makes up the greater part of the remainder. Fresh feldspar, pyriboles and magnetite are noticeable in the finer fractions.

The heavy mineral content of the sands and gravels are recorded in Table II. Pyroxene and amphibole minerals are the dominant heavy minerals present.

Mechanical analysis of the gravel revealed a normal degree of sorting with sorting coefficient values within the 2.5 to 4.5 range. The lower layer of coarse cross bedded sand shows a sorting coefficient value of 2.0. Figure 5 illustrates the logarithmic frequency curves of a typical gravel sample from the deposit and the cross bedded sand. The statistical characteristics of these and other curves obtained by the mechanical analysis of the gravels are summarized by Table V.

Sphericity values obtained change little either from sample to sample or with the grain diameter. The normal value is about 0.85. Roundness values decrease from 0.52 to 0.35 with decreasing grain size, in this respect similar in magnitude of variation with the Lockport gravels.

DISCUSSION OF RESULTS The glacial nature of the deposit is suggested by the presence in the heavy mineral analysis of such unstable mineral types as pyroxene, and the thick overlying cover of lacustrine clay points to an undisturbed condition since deposition of the clay in glacial Lake Agassiz. Mechanical analysis of the sands and gravels show sorting coefficient values normal for materials of a fluvial origin, and the presence of cross bedded sands confirms this suggestion. Considering the above, the gravels were probably transported to the present location by fluvial currents at the front of the receding ice-sheet in much the same manner as those previously described at Lockport.

3. DUFRESNE

INTRODUCTION AND LOCATION The Village of Dufresne is located 25 miles south and east of Winnipeg on No. 12 Highway. Two samples were obtained from a gravel ridge eight and one half miles east of the village. The position of the ridge is noted on Figure 3.

FIELD STUDY The ridge from which the samples were taken rises about 50 feet above the countryside to the west. It slopes appreciably to the west but not to the east, and has the appearance of a west-facing beach terrace. The western slope of the ridge is strewn with large gneissic boulders.

Gravels are coarse and poorly rounded. The predominant rock type among the pebbles is a light buff dolomitic limestone. Granite pebbles, chiefly a muscovite-biotite variety, are a minor constituent. Weathering of the gravel has been extensive. The limestone pebbles are much pitted with solution cavities and often cemented to form a loose conglomerate. One sample of this material was collected.

A road cut adjacent to the pit and roughly parallel with the trend of the ridge has exposed a sand lens within the gravel. A sample of this sand was obtained.

LABORATORY STUDY Coarser parts of the gravel average 87 percent light buff, dense dolomitic limestone pebbles. A muscovite-biotite granite is predominant among the remainder. Weathering has attacked the latter to an extent that it is now a loosely friable mass, which is easily crumbled in the hand. Subrounded quartz, quartzose material, fresh feldspar, muscovite, biotite and the pyriboles are present in the finer screen sizes. Clear quartz makes up 40 percent of the pan material, and the remainder is fine carbonate powder with minor amounts of the previously mentioned minerals.

The sample of sand studied is of a similar composition, with subrounded clear quartz the most abundant mineral among the finer size ranges.

Heavy minerals identified from the gravel sample are hornblende, pyroxenes, dolomite, biotite, magnetite, and a few small rounded particles of black tourmaline. The sand contained, in addition, several small pink garnets, a few small crystals of zircon and one or two very small well rounded particles of monazite.

Mechanical analyses of the samples indicate a normal degree of sorting for the gravel (Sorting coefficient 3.81) and a well sorted degree for the sand (Sorting coefficient

1.41). The cumulative logarithmic curves representing the mechanical analyses are shown in Figure 6.

Shape analyses give sphericity values for the gravel which remain constant at approximately 0.85. The values for the gravel decrease slightly with decreasing grain diameter. The roundness of gravel particles is constant near the 0.50 value, for sand the values decrease moderately with decreasing particle diameter.

DISCUSSION OF RESULTS Shape analysis of the Dufresne gravels indicate a lesser degree of sediment maturity than the Lockport or Bergen gravels. As larger particles are known to be abraded more rapidly than smaller, changes in shape characteristics for a given sample with decreasing particle diameter express to some extent the degree of abrasion to which sediments have been exposed. For this deposit values are largely constant, reflecting lack of extensive abrasion. Such a change of values was noted, however, in the Lockport and Bergen gravels. Extensive weathering of the Dufresne gravel suggests that materials susceptible to decomposition were not removed previous to deposition. These characteristics, in addition to topographic shape, suggest a beach origin for the deposit. Johnston (1946) placed the Ossawa beach of glacial Lake Agassiz in the vicinity, and it is likely that this gravel deposit forms part of the Ossawa beach. Boulders on the west-facing slope are glacial erratics concentrated on the beach slope by wave action or by the shoving of surface ice.

TABLE I

SHAPE ANALYSES - LOCKPORT

Screen size	SPHERICITY A	SPHERICITY B	SPHERICITY C	ROUNDNESS A	ROUNDNESS B	ROUNDNESS C
1.050	-	-	.78	-	-	.56
0.742	-	.82	.78	-	.55	.53
0.525	-	.76	.79	-	.50	.54
0.371	-	.77	.83	-	.53	.57
0.185	-	.92	.92	-	.56	.50
0.093	.71	.89	.89	.38	.53	.51
0.046	.89	.91	.92	.50	.52	.47
0.0232	.90	.92	.84	.36	.48	.49
0.0116	.84	.83	.87	.39	.42	.42
0.0058	.82	.80	.78	.36	.36	.37

TABLE II

HEAVY MINERALS - BERGEN

Mineral	Sample Number A	B	C	D	E
Augite	X				
Dolomite	X	X	X	X	X
Garnet	X	X	X		X
Hornblende	X	X	X	X	X
Magnetite	X	X	X	X	X
Monazite		X			X
Pyroxenes[1]	X	X	X	X	X
Rutile	X				X
Tourmaline	X	X		X	X
Zircon	X				X

[1] Unidentified Pyroxenes

Screen sizes are in inches

TABLE III

AVERAGE SPHERICITY - BERGEN

Screen size	Sample Number A	B	C	D	E
1.050	-	-	-	.77	-
0.742	-	-	-	.81	.79
0.525	-	-	.82	.79	.82
0.371	-	-	.83	.80	.76
0.185	.90	.93	.90	.92	.91
0.093	.87	.90	.91	.91	.89
0.046	.84	.85	.91	.84	.90
0.0232	.84	.83	.86	.84	.87
0.0116	.93	.86	.87	.85	.86
0.0058	.82	.83	.81	.81	.86

TABLE IV

AVERAGE ROUNDNESS - BERGEN

Screen size	A	B	C	D	E
1.050	-	-	-	.52	-
0.742	-	-	-	.53	.52
0.524	-	-	.52	.54	.54
0.371	-	-	.51	.53	.51
0.185	.56	.52	.55	.57	.51
0.093	.48	.54	.55	.55	.48
0.046	.48	.43	.45	.48	.54
0.0232	.48	.54	.49	.43	.47
0.0116	.36	.43	.40	.41	.44
0.0058	.37	.40	.41	.44	.35

Screen sizes are in inches.

TABLE V

BERGEN GRAVELS

STATISTICAL CHARACTERISTICS OF MECHANICAL ANALYSES

Sample	Footage	Median	Q1	Q3	Quartile Deviation Arith.	Geom.	Log.
A	Basal	32.50	4.70	72.00	33.65	3.91	.5926
B	0.0-1.0	00.75	0.44	1.75	0.65	1.75	.2997
C	1.0-2.0	03.50	1.25	11.00	4.87	2.97	.4722
D	2.0-6.5	15.50	5.40	75.00	34.80	3.73	.5713
E	6.5-7.5	04.70	1.60	11.50	4.95	2.68	.4283

TABLE VI

SHAPE ANALYSES - DUFRESNE PIT

Screen Size	SPHERICITY A	SPHERICITY B	ROUNDNESS A	ROUNDNESS B
1.050	.76	-	.50	-
0.742	.83	-	.51	-
0.525	.84	-	.52	-
0.371	.80	-	.50	-
0.185	.91	-	.56	-
0.093	.87	.89	.56	.56
0.046	.86	.89	.58	.55
0.0232	.85	.83	.50	.53
0.0116	.89	.81	.50	.45
0.0058	.87	.84	.48	.43

Screen sizes are in inches.

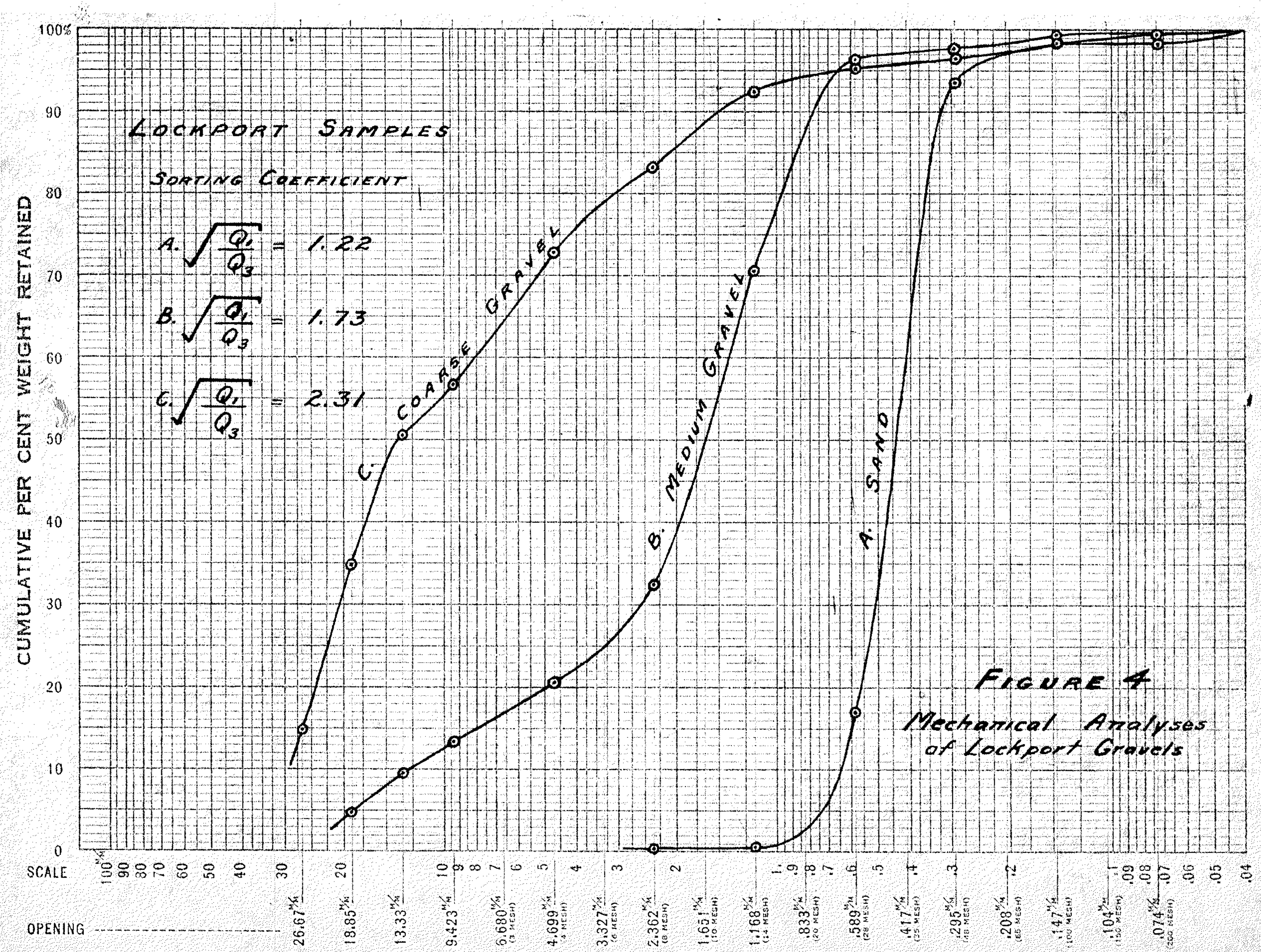


FIGURE 4
Mechanical Analyses of Lockport Gravels

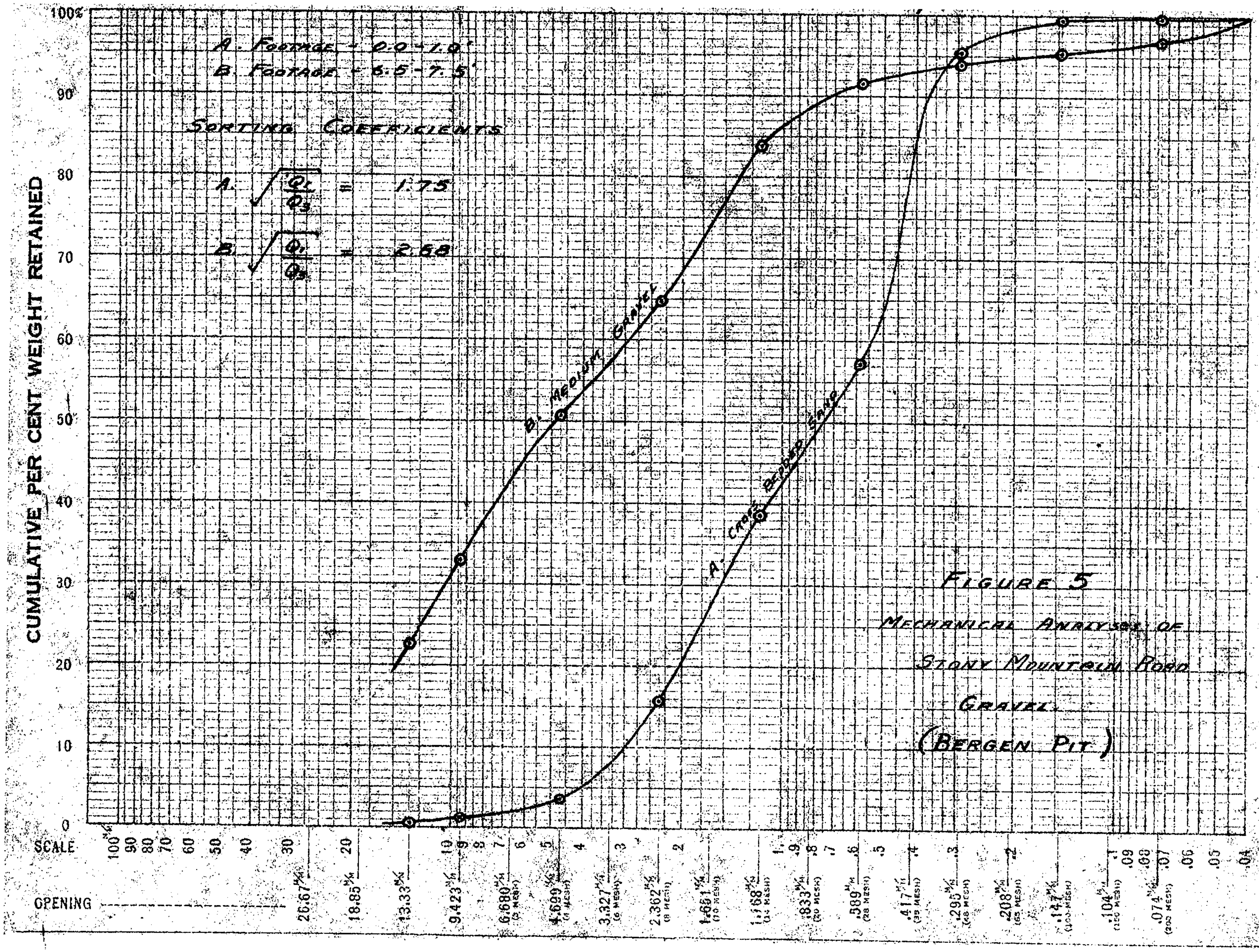


Figure 5
Mechanical Analysis of
Stony Mountain Road
Gravel
(Bergen Pit)

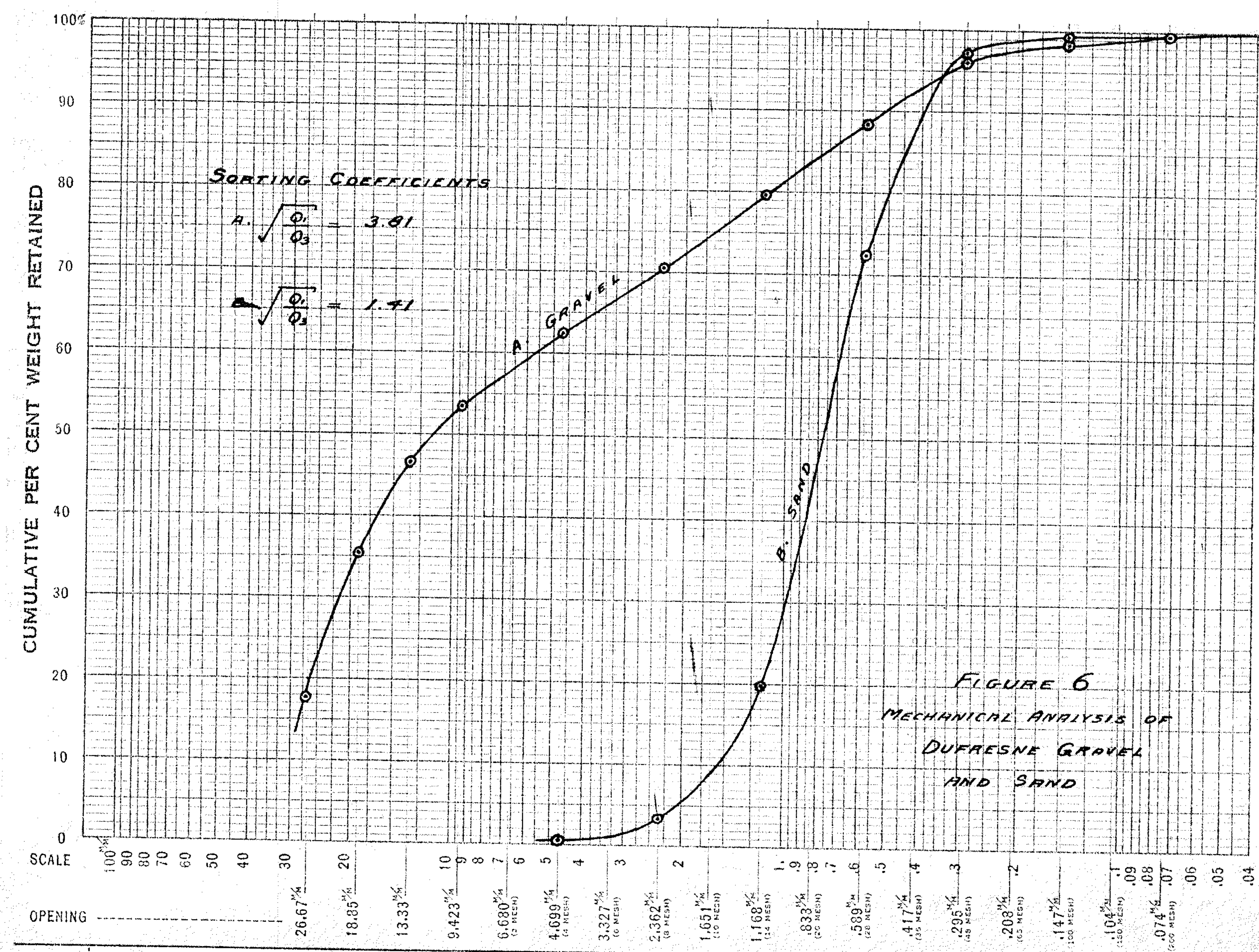


FIGURE 6
MECHANICAL ANALYSIS OF DUFRESNE GRAVEL AND SAND

CHAPTER III

THE BIRDS HILL GRAVEL DEPOSIT

1. INTRODUCTION AND TOPOGRAPHICAL DESCRIPTION

<u>INTRODUCTION AND LOCATION</u> The Birds Hill gravel deposit is located immediately adjacent to the village of Birds Hill, 8 miles northeast of Winnipeg. The deposit commences immediately to the east of the Birds Hill railway station and extends continuously 4 miles eastward. At several places along the hill deep excavations have exposed excellent sections of sand and gravel. Roads constructed in connection with excavation operations provide routes of easy access. A field study was made of the deposit and samples were taken at numerous localities. Locations from which samples were taken are given in Figure 3, and also noted on Figure 2, the topographic map of the Birds Hill vicinity.

<u>TOPOGRAPHY</u> Birds Hill (Topographic map, Figure 2) begins as a gentle slope immediately to the east of the village, rising to a height of about 50 feet above the surrounding countryside and extending, with an average width of 1200 feet, approximately a mile in a southeasterly direction. The height of the hill then diminishes to about 15 feet, an altitude maintained for only a short distance, after which the hill rises again 50 to 60 feet above the plain

and continues for two miles in an easterly direction. At this point the elevation again drops to about 20 feet. Width of the hill throughout this 2 mile distance ranges from 1000 feet in the western part to 1500 in the central, the hill becoming increasingly low and broad toward the east. After a distance of 2000 feet at the lower elevation, the hill appears again to the northeast trending in a northeast direction. Here the altitude is about 50 feet above the surrounding plain. The hill then flattens and widens to become an elevated sandy plain covering approximately 16 square miles of area northeast of the main hill.

One and one-half miles south of the termination of the main body of Birds Hill a second prominence occurs, known locally as the Moose Nose Hill. This prominence is two thirds of a mile in width and a mile in length, and consists of a rounded, gently sloping hill rising about 70 feet above the surrounding countryside. The axis of elongation of the hill is in a north-south direction. The northern end of the hill flattens into a low, clay covered area. Two thirds of a mile in a direct line to the north another prominence rises to 60 feet above the level of the surrounding plain. This hill, one and one-half miles long and one-half mile wide, is elongate in a northeasterly direction and merges into the sandy plain mentioned previously.

These two main features are shown in Figure 2, the one hill passing continuously southeast and eastward from Birds Hill station into the sandy plain, and the other passing northward through the axis of Moose Nose Hill also into the plain. These two systems of hills will be designated respectively the west and south arms of Birds Hill.

2. FIELD STUDY

WEST ARM OF BIRDS HILL Throughout the first mile of its western end this arm of the deposit is composed of sand and gravel, with an overlying cover of boulder clay and surface gravel. The bulk of the gravel is extremely coarse with cobbles as much as 8 inches in diameter. Here and throughout the deposit dolomitic limestone makes up 75-85 percent of the gravel. Cobbles and pebbles are normally well rounded to sub-angular, and the spaces between the larger particles are filled with sand and rock flour. Stratification is conspicuous and horizontal, with secondary cross bedding within the horizontal member. Cross bedding slopes toward the east dipping at angles from 15 to 30 degrees. Bedding is massive, the thick beds of homogeneous horizontally stratified coarse gravel present at Location 1 are illustrated in Plate 1A, page 35. The lower parts of the sections are composed of somewhat finer material than the upper parts.

An interesting feature of this western end is an overlying blanket of boulder clay, 10 feet in average thickness, consisting of extremely fine yellowish clay with abundant angular boulders. These boulders, dominantly of Paleozoic limestone, range in size from a few inches to eight or more feet in diameter. They show little or no wear by water action. Upham (1910) noted this overlying till-sheet and traced it, through several breaks in continuity, 3700 feet eastward along the western end and northern side of the hill.

The surface of the deposit is covered by a thin mantle of stratified gravel, two feet in average thickness.

Towards the eastern end of the first mile, the gravel becomes increasingly fine in character, with interbedded sand in layers and lenses. Cross bedding, dipping toward the east, is conspicuous, especially with the finer materials. At the end of the mile the sand is replaced by glacial till.

Within a few hundred feet the till is again replaced by stratified sand and gravel, which forms a flattened ridge 1200 feet wide and 60 to 70 feet above the surrounding countryside. This ridge extends slightly over two miles to the east. The western end of the ridge is composed of stratified sand and gravel, the stratification is horizontal, with some cross bedding dipping to the east. The gravel is medium coarse, with some cobbles 4 to 6 inches in diameter, and sand is abundant as lenses and layers.

Commencing 2000 feet from the western end of the area described above, an underlying mass of till appears as a central core to the deposit, (Location 7). This till consists of rounded limestone and granite boulders, cobbles, pebbles and clay, in an unsorted and unstratified mass. The till, undesireable for commercial purposes, remains as a central spine in the general excavation of the surrounding gravel. The top of the till mass is 25 to 30 feet above the level of the surrounding countryside.

To the north of the till mass an excavation has uncovered a thickness of 30 to 40 feet of unstratified sand with lenses of coarse gravel (Location 6). The sand is overlain by a 4 foot layer of stratified coarse gravel, the stratification dipping 10-20 degrees toward the north.

Continuing northeasterly, at Location 8, sand much the same as at Location 6 is overlain and interstratified with coarser gravels. Throughout the remainder of the 2 mile interval the pits are slumped and overgrown with vegetation. No exposures could be found and no samples were taken. At the end of the interval the ridge passes into lower ground.

Three-quarters of a mile to the northeast of the termination of the previous ridge excavations in a prominent elevation again reveal well stratified sand and gravel. Here cyclic alternation of coarse and fine material occurs, with much cross bedding and lensing (Location 9, Plate IB, page 37). The stratification shows dips 15-20 degrees to the north. The gravels are medium to fine in size and well rounded. Approximately 75 to 85 percent of the gravel pebbles are dolomitic limestones, the remainder are granite and granitoid gneiss.

The above prominence passes into a low, gently rolling sandy plain stretching to the north and east. Only surface samples were available. These consisted in the areas near the previous ridge of grey-buff coarse sand, composed chiefly of limestone fragments, with lesser amounts of granite and diorite. Among the smaller grains rounded quartz, fresh feldspar and hornblende are present. Many large boulders are scattered about the surface near Location 25.

Three-quarters of a mile further to the northeast (Location 26) the sand is finer than the above mentioned, but still consists largely of dolomitic limestone with conspicuous quartz and feldspar.

One and one-quarter miles beyond this point (Location 27 and 28) the sand is also grey-buff, very fine, with quartz and feldspar quite conspicuous. Here the topography is gently rolling.

At the Pine Ridge School corner (Location 29) a north-facing slope is composed entirely of very fine grey-buff sand with some included angular dolomitic limestone particles up to three-eighths of an inch in diameter. Quartz, fresh feldspar, and some hornblende are noticeable.

<u>SOUTH ARM OF BIRDS HILL</u> The hill to the south of Birds Hill, known as the Moose Nose Hill, is the beginning of the south arm of the Birds Hill deposit. The hill, previously described on page 29, is about a mile in length and two-thirds of a mile in width, and rises some 70 feet above the surrounding countryside. The hill has been extensively excavated over the greater part of the western half and a smaller part of the eastern. Dredging now removes gravel from 30 feet below the surface of a pond in the western pit. The level of the water here is at least 50 feet below the crest of the hill, therefore the gravel deposit must extend well below the level of the surrounding plain.

At the southern end the hill consists of sand and gravel, well stratified and dipping approximately 20 degrees toward the north. Gravel pebbles are chiefly Paleozoic limestone, well rounded to subrounded, with the interstices between the particles filled with carbonate sand and powder. The sand and gravel are overlain by 2 to 3 feet of sandy clay and 2 feet of poorly stratified surface gravel.

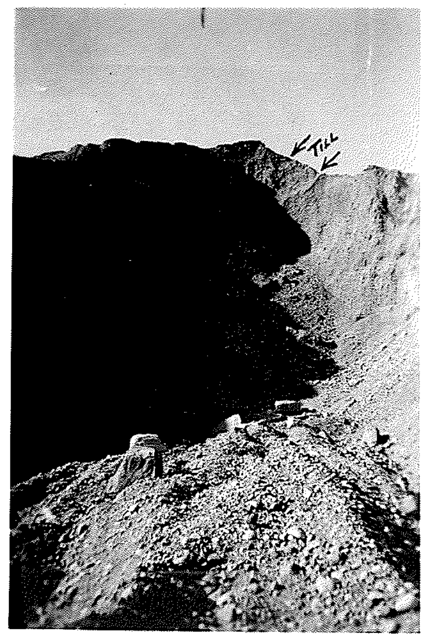
About 900 feet north of the southern end of the hill a recent excavation has uncovered a thick deposit of fine gravel and sand, with well defined stratification dipping northeast. The stratification is defined by the orientation of the coarser pebbles in bands one-half inch to two inches wide. A remarkable feature in this pit is a false bedding effect on the eastern wall. Here ground waters have percolated down through the gravels, along channels of easier access, depositing quantities of fine carbonate material. The result is dense masses of gravel and fine material in braided bands up to a foot in thickness, all dipping sharply southeast across the true bedding. The true bedding is preserved within the dense bands, but is largely obscured by the fine material and the overall apparent dip to the southeast. This feature is well illustrated in Plate III on page 39.

At Location 15, approximately 1000 feet further to the northeast, stratification is horizontal with secondary cross bedding dipping to the north. Layers of very fine light grey-buff carbonate sand are abundant, with limestone fragments and clear quartz the noticeable constituents. Gravel particles are chiefly limestone, medium in size and well rounded.

The Moose Nose hill flattens at the northern end into low, clay covered terrain. A mile to the north, excavations in a prominent height of land again reveal thick accumulations of stratified sand and gravel. The western side of this hill (Location 19) consists of stratified gravel and interbedded sand, dipping 10 degrees to the northeast. Here the pebbles and cobbles are as much as three inches in diameter, well rounded, and are dominantly Paleozoic limestone. The sand is fine, composed chiefly of limestone and quartz particles, with abundant fresh feldspar and basic minerals. Grain size of the sand is coarser than that at Location 15 and there is less fine powder. On the eastern side of the hill (Location 20) excavations have exposed an accumulation of well stratified sand and fine gravel. The stratification is defined by layers of well rounded pebbles and cobbles, the layers usually only one cobble in thickness. The sand between bands of cobbles is coarse and composed of fragments, predominantly limestone, with lesser granite. The dip of the stratification is southeast at 25 degrees. Location 20 is illustrated in Plate IIA, page 38.

Immediately to the north of the above height of land the sandy plain mentioned in the discussion of the west arm of Birds Hill extends in a direct continuation with this south arm of the deposit.

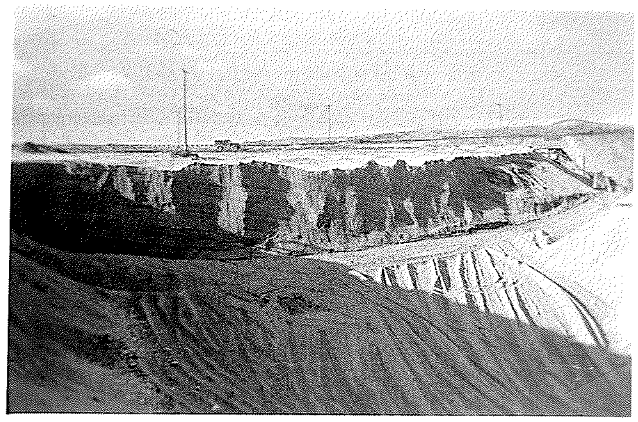
PLATE I



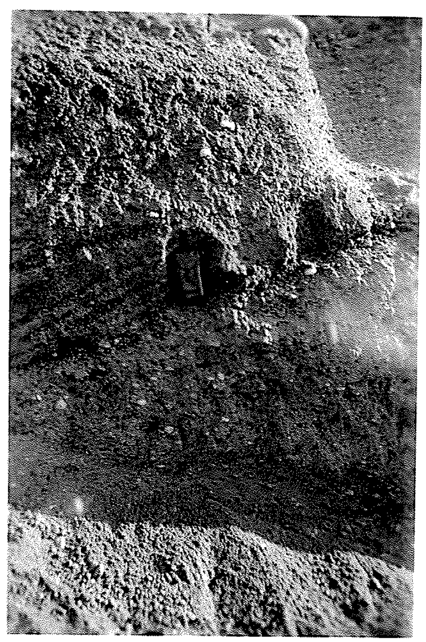
"A" Location 1, Birds Hill
Illustrating the overlying mantle of till. The till-sheet is approximately 10 feet in thickness at this locality.

"B" Location 9, Birds Hill
Illustrating well developed stratification of fine material, dipping gently north.

PLATE II

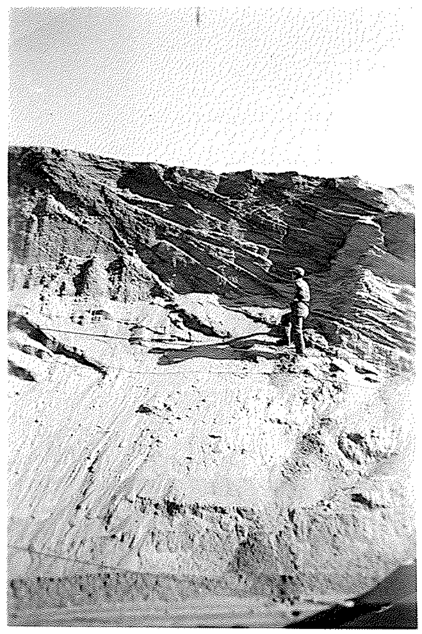


"A" Location 20, Birds Hill
Alternating bands of fine and coarse material dipping strongly to the northeast.



"B" Location 19, Birds Hill
Current bedding of medium sized gravel and fine sand.

PLATE III



Location 17, Birds Hill

False bedding effect produced by percolation of ground water. True bedding dips toward the northeast (left of photograph); false bedding dips to the southeast.

3. LABORATORY STUDY

PETROLOGY AND MINERALOGY Throughout the extent of the western arm of the deposit all gravels average 71 percent dolomitic limestone. The limestones present are generally light buff in color, dense, hard and appear to be derived from Ordovician and Silurian formations. Cobbles with salt hopper impressions which are quite common in the Silurian rocks outcropping in Manitoba, were noted at Location 1. The remaining coarse gravel pebbles are granite, granodiorite, granitoid gneiss and fine grained diorite. A dark quartzose granite dominated the non-sedimentary rock types present.

With decreasing grain size the amount of clear quartz and quartzose material becomes greater. Above the 0.0116 inch screen the composition is 65-70 percent limestone, the remainder igneous and metamorphic rock types. Below the 0.0116 inch screen limestones continue to persist as individual particles, with increasing quantities of clear quartz, fresh feldspar and hornblende. On the extremely fine screens, and on the pan, limestone rock flour composes the greater bulk of the material present, with abundant clear quartz, minor feldspar and basic minerals.

There is little lateral change in composition along the western arm, except for an increasing dominance of clear quartz on the 0.0029 inch screen and the pan. The increase of the clear quartz content is estimated as from 25 percent at Location 1 to 45 percent at Location 9. No marked vertical changes in petrologic composition were noted. The surface gravels, however, are almost entirely composed of limestone. At Location 1, this rock type comprises 93 percent of the surface two foot thickness.

The sheet of boulder clay which overlies much of the western end and northern side of the western arm, is composed mainly of limestone particles and rock flour. The fine material below the 0.0116 inch screen has a 61 percent content of carbonate. Minor amounts of clear quartz and basic minerals are present among the very fine material. The numerous large angular boulders within the clay are dolomitic limestone, with a few smaller rounded boulders of granite.

Petrologically the gravels composing the Moose Nose Hill are similar to those of Birds Hill. Dolomitic limestone makes up 77 percent of the particles above the 0.371 inch screen, the remainder is granite. Clear quartz is more abundant with decreasing size of the particles, 50 percent of the total on the 0.0058 inch screen and 70 percent on the pan. Minor feldspar and basic minerals were noted throughout. Magnetite is quite abundant.

Sand layers and lenses are conspicuous in the Moose Nose Hill. The larger particles of this sand, above the

0.0232 inch mesh, consist of freshly fractured grains of limestone and quartz, with limestone slightly dominant. Dark particles in this range are fragments of fine grained basic rocks and quartzose material containing hornblende and biotite. Quartz is increasingly abundant on the finer screens, increasing to 75 percent of the total material on the pan. Quartz is noticeably more well rounded than the limestone, some grains approaching nearly spherical shapes. Feldspar, magnetite and hornblende are minor constituents. The remaining material is a very fine carbonate powder.

At Locations 19 and 20, on the hill to the north of Moose Nose, limestones make up 75 percent of the coarser clastics. Approximately 80 percent of the finer material is well rounded quartz. Angular particles of hornblende are common, and feldspar is a minor constituent. Carbonate powder is less abundant than in samples from previous locations.

The samples taken from the outwash plain to the north and east of Birds Hill are normally fine sand, yellow-grey in color and consisting of small, angular limestone fragments with small amounts of fresh feldspar, basic minerals such as hornblende, magnetite, and abundant rounded clear quartz in finer size ranges. Quartz normally makes up 50 of more percent of the material below the 0.0116 inch screen, and magnetite is a very noticeable constituent of these finer materials.

At the Pine Ridge School corner (Location 29) the sand is very fine with some larger fragments of limestone, granite and diorite. Limestone is predominant on the 0.0232 and 0.0116 screens, with clear quartz increasing to dominance below the latter screen size. Feldspar and hornblende are noticeable and magnetite is only a minor constituent.

The gravel samples obtained from Pine Ridge (location 33) are 95 percent limestone among the coarser clastics. The remaining coarse particles are granites. Clear quartz increases to 80 percent of the total material on the 0.0058 screen. Feldspar, hornblende and magnetite are noticeable among the finer materials. There are also a few small rounded grains of monazite. The sands at this locality are similar in composition, but with a greater quartz and magnetite content. Carbonate powder is not an important constituent.

In summary:

1. The gravels throughout the Birds Hill deposit are petrologically similar in character.
2. Approximately 75 percent of the gravel pebbles are composed of Paleozoic limestones. Limestones also constitute a large proportion of the finer

materials of both the sands and the gravels.

3. Subrounded clear quartz is increasingly abundant with decreasing particle diameter.
4. The relative amount of clear quartz in the finer material is progressively greater eastward along the deposit.
5. Unstable minerals such as feldspar and pyriboles are common throughout the gravels.
6. Magnetite is most abundant in the eastern end of the deposit and in the outwash plain.

HEAVY MINERAL ASSEMBLAGE The heavy minerals indentified consist of the assemblage listed in Table VII. Magnetite, green hornblende and dolomite persist in all samples, garnet in all except 1B. Magnetite differs only in abundance, appearing in greater quantities towards the eastern end of Birds Hill and in the outwash plain. Green hornblende appears in all samples in differing amounts with no gradation along the deposit. Dolomite occurs in all samples as rounded opaque fragments. Pink garnet is common, well rounded and occurring in sparse yet persistent quantities. Biotite and brown hornblende occur scattered throughout the deposit. Meagre quantities of reddish-brown, subrounded rutile fragments occur in the greater proportion of the samples, appearing most frequently in the eastern part of the deposit and in the outwash plain. Pyroxene minerals, chiefly unidentified varieties, are found in all samples. Augite was positively identified in many samples, hypersthene in two, and enstatite only in the Pine Ridge samples. Riebeckite was found at Location 9 and at Pine Ridge. Monazite appears in rare quantities as small, yellowish-green, well rounded grains in many of the samples, and notably in those samples from the outwash plain. Tourmaline is also found in many samples, and occurs most abundantly in those samples located towards the eastern end of the deposit. The tourmaline particles in the samples from the western arm of the deposit are small, black, opaque and are in well rounded, almost spherical grains. At Location 15 the tourmaline particles are similar, but are greenish-grey in color and are strongly pleochroic. Both types appear in the outwash plain. Zircon was identified in all but four samples, and appears as elongate, prismatic crystals, which are often broken and abraded.

The relative percentage by weight of heavy mineral content tends to increase progressively eastward along the deposit. Unusually high heavy mineral percentages were obtained at Location 31 and from the Pine Ridge.

In summary:

1. The heavy mineral assemblage is limited and contains many unstable mineral types.
2. High specific gravity mineral varieties, such as

magnetite and rutile, are more abundant in eastern parts of the deposit and the outwash plain.

3. Two different types of tourmaline occur in the deposit, one type from the west arm and the other from the south arm. Both types appear in outwash plain samples.

4. There is a progressive increase by weight of heavy mineral content eastward along the deposit.

MECHANICAL ANALYSIS Seventy-five samples were analyzed from twenty-nine locations along the length of Birds Hill, the Moose Nose Hill and the outwash plain. Sample locations are noted in Figure 2 and 3.

The gravels throughout the western arm of the deposit are normally sorted as values of the sorting coefficients are largely within the 2.5 to 4.5 range (Pettijohn, 1949, page 24). Well sorted sands are plentiful within the gravels. The sands of the outwash plain are extremely well sorted, with the exception of the samples taken from Pine Ridge.

Gravels of the south arm are somewhat more well sorted than those of the west arm, the average sorting coefficient along the south arm is between 2.5 and 3.0. However, at Location 19 and 20 the gravels exhibit extremely poor sorting. The results here may be anomalous, for field observations indicate that the gravels are fairly

TABLE VII

HEAVY MINERAL ASSEMBLAGE

MINERAL	LOCATION																					
	LOC. 1							LOC. 9						LOC. 15			25	27	29	31	33	
	A	B	C	D	E	G	H	A	B	C	D	E	F	A	B	C	A	A	A	A	A	B
Wgt. Percent																						
AUGITE	X		X	X	X			X		X	X	X		X	X	X	X	X			X	X
BIOTITE		X	X			X		X		X	X	X	X	X		X				X		X
DOLOMITE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
ENSTATITE																						
GARNET	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HYPERSTHENE		X																		X		
HORNBLENDE[1]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HORNBLENDE[2]	X	X	X		X			X		X			X				X	X	X			
MAGNETITE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
MONAZITE			X		X		X	X		X	X		X	X	X	X	X	X	X	X		
PYROXENES[3]	X	X	X	X	X		X		X				X	X	X	X	X	X	X	X	X	X
RIEBECKITE								X													X	X
RUTILE							X	X	X	X		X	X	X		X	X	X	X	X	X	X
TOURMALINE				X		X	X	X	X	X		X	X	X	X		X	X	X	X	X	X
ZIRCON		X	X		X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X

[1] GREEN [2] BROWN [3] UNIDENTIFIED

well sorted into coarse and fine beds, too thin for individual sampling.

The statistical characteristics of the logarithmic curves representing mechanical analysis of the samples are shown in Table VIII. The values of the sorting coefficients at various locations along the length of the west arm and the south arm of the deposit are shown in Figure 7. Typical frequency curves of the sands and gravels from the Birds Hill area are illustrated in Figures 8, 9, 10, 11 and 12.

In summary:

1. The gravels are normally sorted along both arms of the Birds Hill deposit, and grade eastward into well sorted outwash sands.
2. Gravels become increasingly finer in texture toward the east.
3. Neglecting the values at Locations 19 and 20, there is a slight gradational decrease in the value of the sorting coefficient eastward along the west arm of the deposit and northward along the south arm.

TABLE VIII

BIRDS HILL GRAVEL

Statistical Characteristics of Mechanical Analysis

Thickness of sample interval	Location	Median	Q1	Q3	Quartile Deviation Arith	Geom.	Log
0-6	1.A.	2.25	.83	17.00	8.08	4.40	.1487
6-15	B.	10.00	1.80	25.00	12.16	3.70	.5551
15-22	C.	16.00	3.10	29.00	12.90	3.05	.4655
22-30	D.	9.50	1.65	23.00	10.67	3.73	.5568
30-42	E.	40.00	17.50	70.00	26.20	2.03	.3073
42-58	F.	17.00	7.60	22.50	7.67	1.72	.2357
58-67	G.	3.30	1.35	7.50	3.07	2.36	.3724
67-72	H.	10.00	1.35	73.00	35.82	7.35	.8665
0-3	2.A.	9.58	2.00	28.50	13.25	3.77	.5769
3-8.5	B.	22.00	5.80	35.00	14.60	2.46	.3903
16.5-22.5	C.	.10	.07	.24	.085	1.86	.2707
0-6	3.A.	4.25	1.75	10.25	4.25	2.41	.3828
6-12	B.	.80	.52	1.30	.44	1.58	.1989
12-28	C.	15.00	2.70	27.00	12.15	3.17	.5000
28-32	D.	.30	.27	.35	.04	1.14	.0563
0-17	4.A.	3.80	.90	16.00	7.55	4.22	.6248
	5.Al.	5.00	1.00	9.00	4.00	3.00	.4771
0-5	A.	.95	.65	1.40	.37	1.47	.1666
6-11.5	B.	4.20	1.30	11.00	4.85	2.91	.4637
11.5-12.5	C.	3.25	.60	9.50	4.45	3.88	.5887

TABLE VIII (cont'd)

Thickness of sample interval	Location	Median	Q1	Q3	Quartile Deviation		
					Arith	Geom	Log
12.5-20.5	5.D.	10.00	1.75	22.50	12.87	3.58	.5546
	6.Sd.	.62	.42	.95	.26	1.24	.0926
	Grav	14.00	2.90	32.00	14.50	3.32	.5213
0-25	7.A.	.70	.22	4.50	2.14	4.52	.6554
0-10	8.A.	.94	.67	1.30	.63	1.36	.1439
10-30	B.	9.50	1.65	22.50	10.42	3.69	.5673
30-32	C.	.40	.30	1.50	.60	2.23	.3485
0-2	9.A.	.95	.52	2.00	.74	1.96	.2925
2-3.5	B.	.37	.23	.62	.18	1.64	.2153
3.5-4	C.	1.20	.65	2.25	.80	1.86	.2696
4-8	D.	.60	.45	1.00	.27	1.49	.1734
8-10	E.	1.40	.62	2.75	1.06	2.11	.3234
	Sand	.36	.27	.47	.10	1.31	.1187
	10.A.	.95	.57	2.25	.84	1.99	.2981
0-6	11.A.	.67	.40	1.16	.38	1.70	.2312
0-2	12.A.	.65	.51	.82	.15	1.27	.1031
0-7.5	13.A.	.93	.34	3.00	2.66	2.97	.4728
7.5-11.5	B.	17.50	1.16	23.50	11.17	4.50	.6533
0-2	14.A.	2.00	.72	7.00	3.14	3.12	.4939
2-8	B.	11.00	4.00	22.50	9.25	2.37	.3750
Sd lenses	15.A.	.19	.12	.27	.07	1.47	.1672
0-7	B.	9.50	4.00	17.50	6.70	2.09	.3204

TABLE VIII (cont'd)

Thickness of sample interval	Location	Median	Q1	Q3	Quartile Deviation Arith	Geom	Log
7-8	15.C.	1.70	1.10	3.25	1.07	1.72	.2352
0-2	16.A.	26.67	9.50	36.00	13.12	1.95	.2893
2-7	B.	1.75	.80	3.00	1.10	1.94	.2870
7-13	C.	.17	.08	.30	.15	1.90	.2790
13-18	D.	4.50	2.00	9.50	3.70	2.44	.3883
18-20	E.	.20	.09	1.85	.88	4.53	.6565
	17.A1.	.37	.13	.47	.17	1.95	.2899
GRAB	A.	.97	.45	2.00	.77	2.10	.3239
GRAB	B.	.80	.57	1.16	.29	1.42	.1524
GRAB	C.	1.75	1.08	7.80	3.36	2.69	.4293
GRAB	D.	.57	.43	.83	.20	1.39	.1428
0-2	18.A.	5.80	.87	16.50	7.82	4.36	.6390
2-2.5	B.	.45	.32	.65	.16	1.43	.1539
2.5-4.5	C.	1.75	1.30	2.25	.47	1.35	.1292
Cse top gr	D.	4.90	3.50	10.00	3.25	1.69	.2279
Fn top gr	E.	1.16	0.94	1.45	.25	1.24	.1292
Sd lenses	19.A.	.32	.26	.41	.07	1.24	.0948
Lower gr	B.	7.70	2.25	17.00	7.37	2.75	.4391
Sand	20.A.	1.58	.52	85.00	42.24	7.33	.8653
Sand	25.A.	.46	.35	.60	.12	1.30	.1140
Sand	26.A.	.37	.29	.49	.10	1.30	.1139
Sand	27.A.	.40	.32	.51	.09	1.27	.1026

TABLE VIII (cont'd)

Thickness of sample interval	Location	Median	Q1	Q3	Quartile Deviation Arith	Geom	Log
Gravel	28.A.	4.00	.53	22.00	10.73	6.44	.8090
Sand	29.A.	.38	.26	.55	.14	1.45	.1627
Gravel	30.A.	35.00	18.85	66.00	23.67	1.87	.2726
0-1	31.A.	.37	.24	.56	.16	1.53	.1840
1-2	B.	.92	.42	1.65	.62	1.99	.2981
Sand	32.A.	.096	.074	.125	.026	1.30	.1138
0-4	33.A.	.50	.34	.71	.185	1.43	.1567
4-5	B.	.75	.34	2.80	1.23	2.87	.4578

SORTING COEFFICIENT GRADIENT

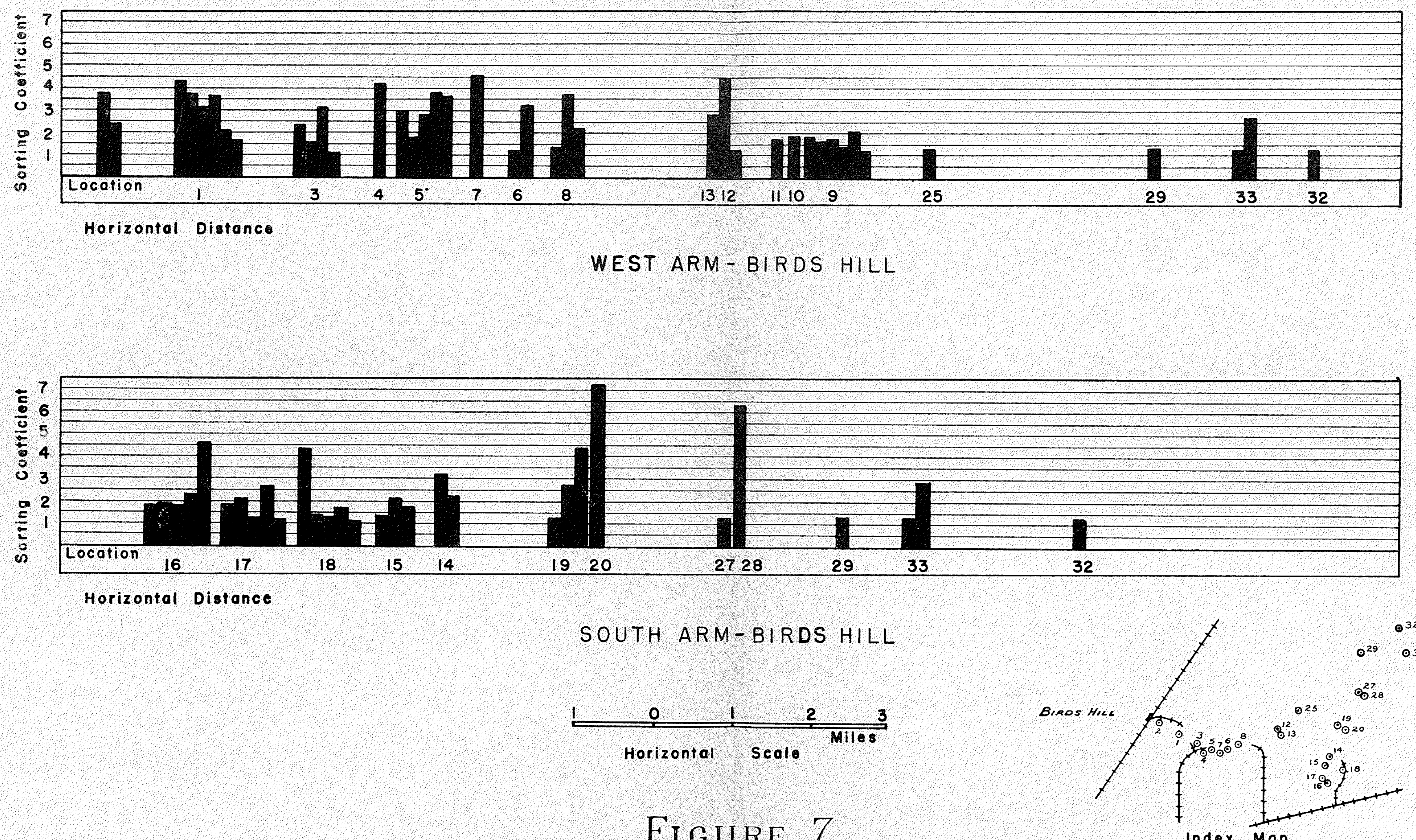


FIGURE 7

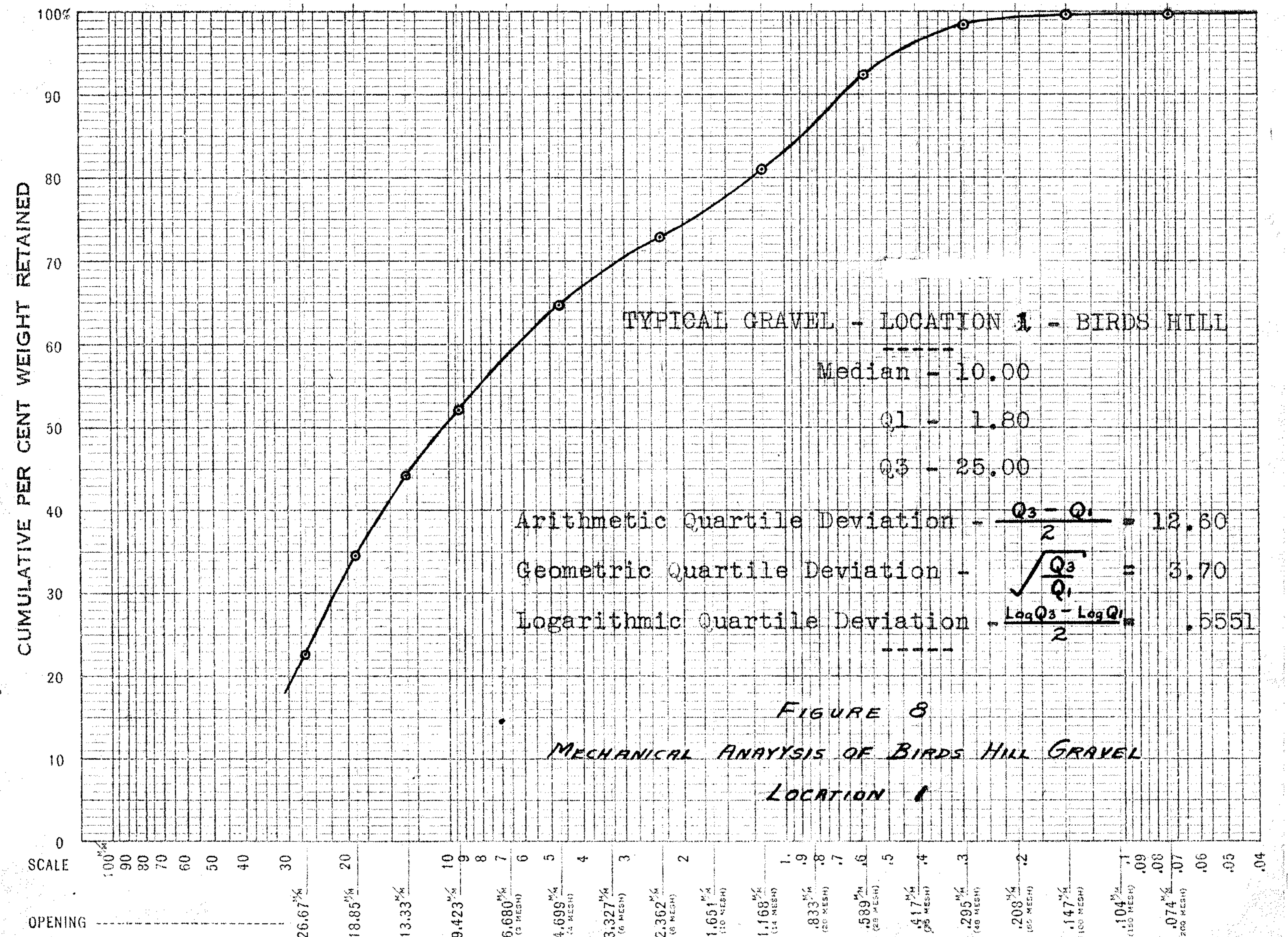


FIGURE 8

MECHANICAL ANAYYSIS OF BIRDS HILL GRAVEL

LOCATION 1

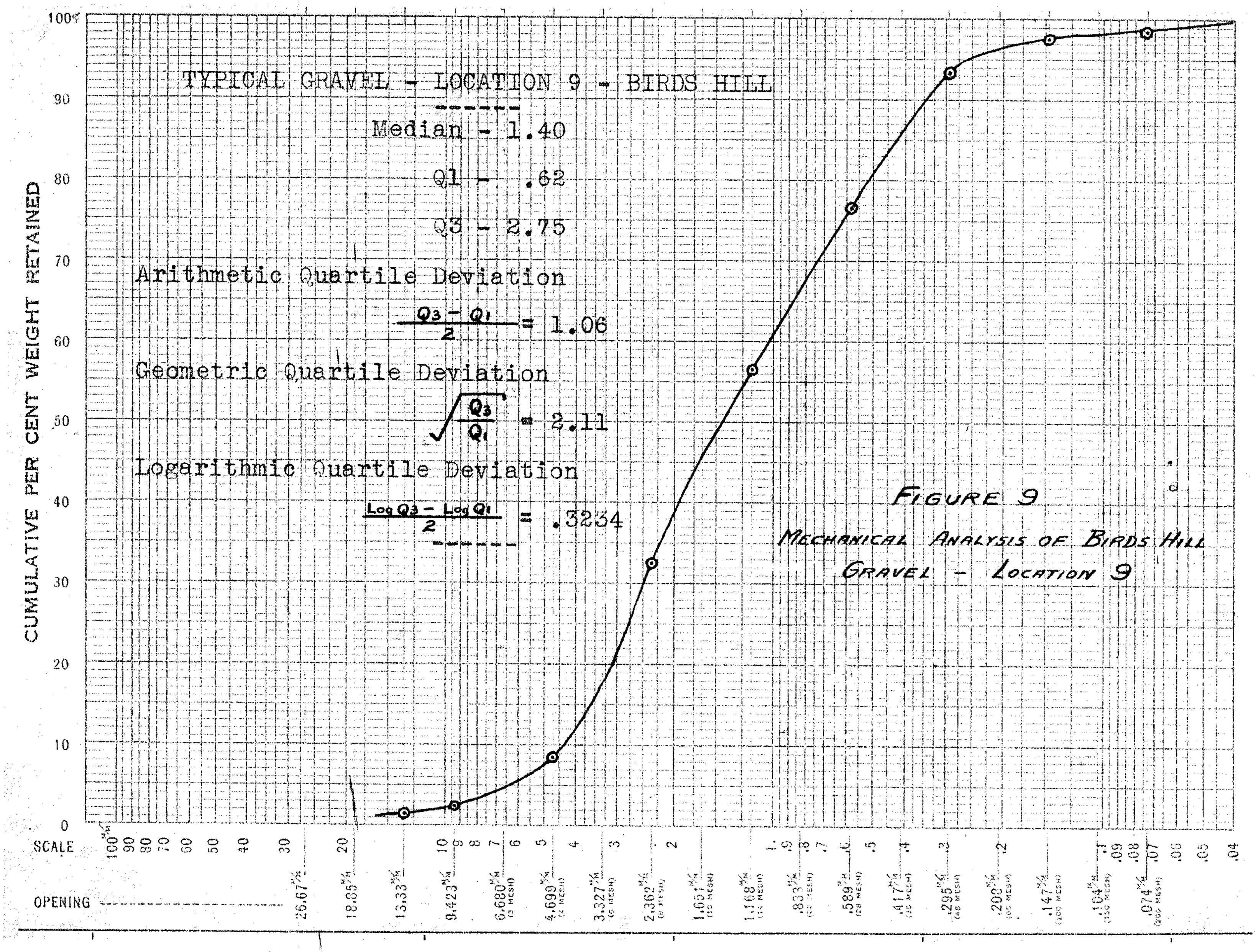


FIGURE 9

MECHANICAL ANALYSIS OF BIRDS HILL GRAVEL - LOCATION 9

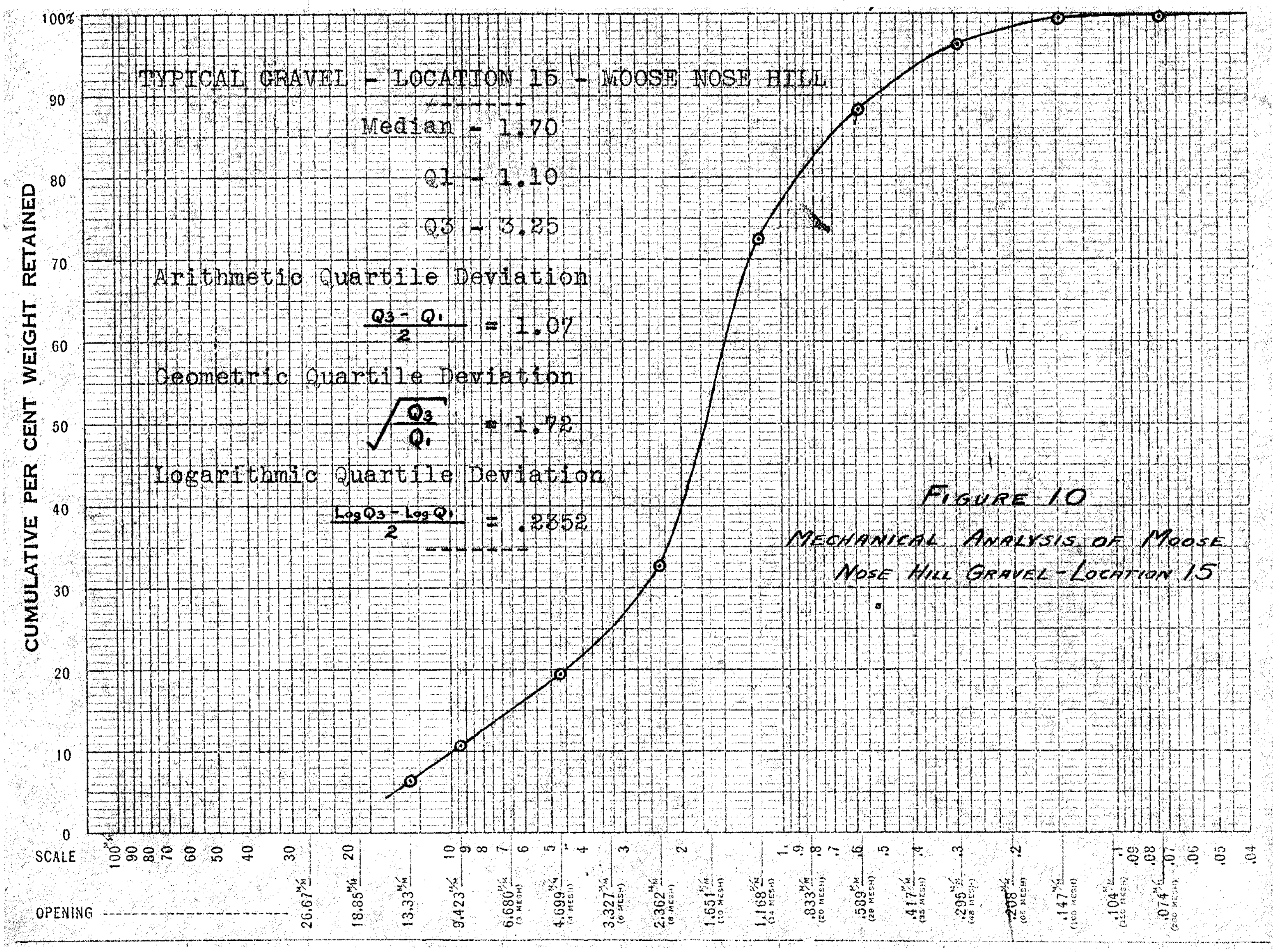


FIGURE 1.0

MECHANICAL ANALYSIS OF MOOSE NOSE HILL GRAVEL - LOCATION 15

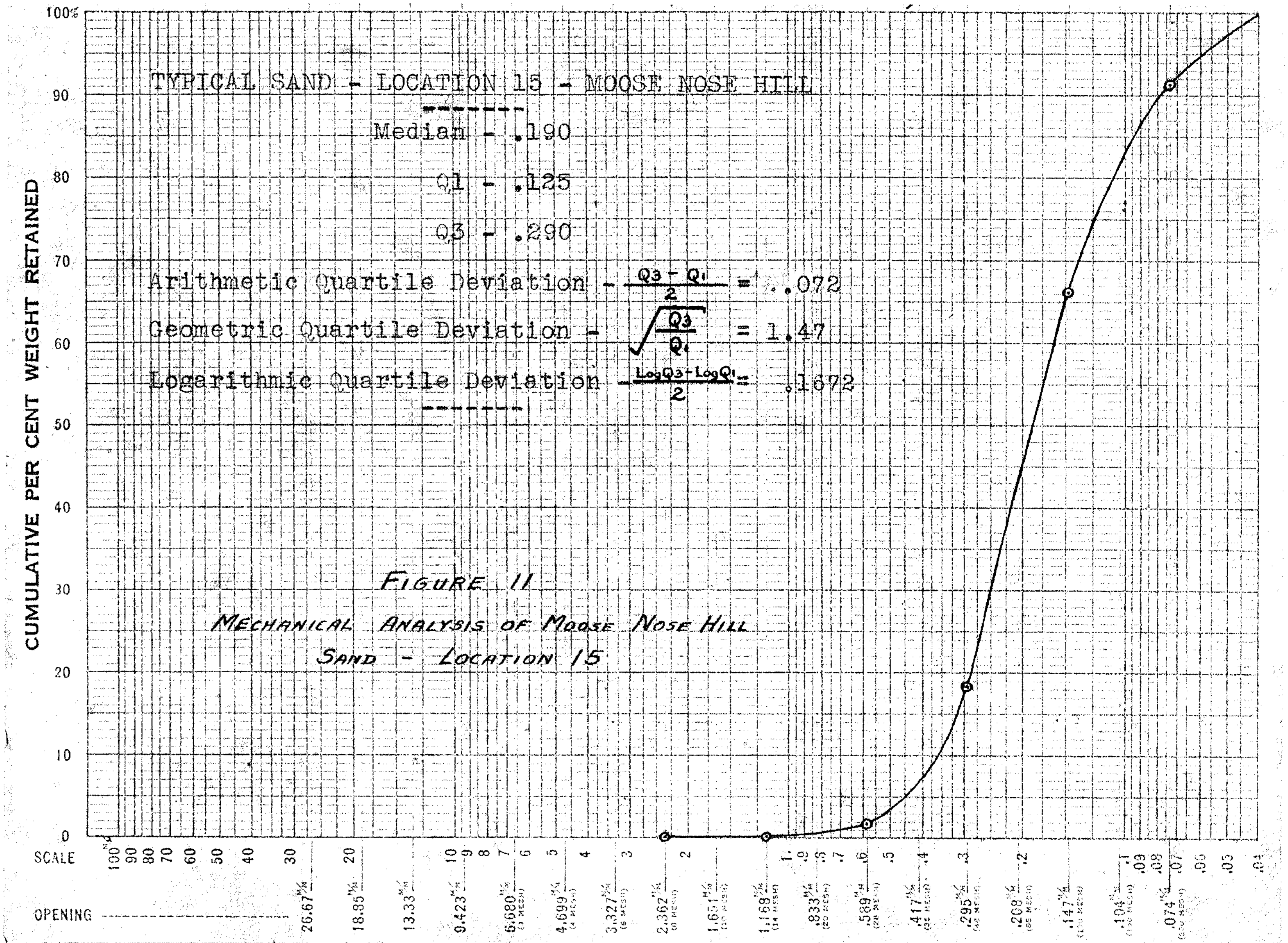


FIGURE 11

MECHANICAL ANALYSIS OF MOOSE NOSE HILL SAND - LOCATION 15

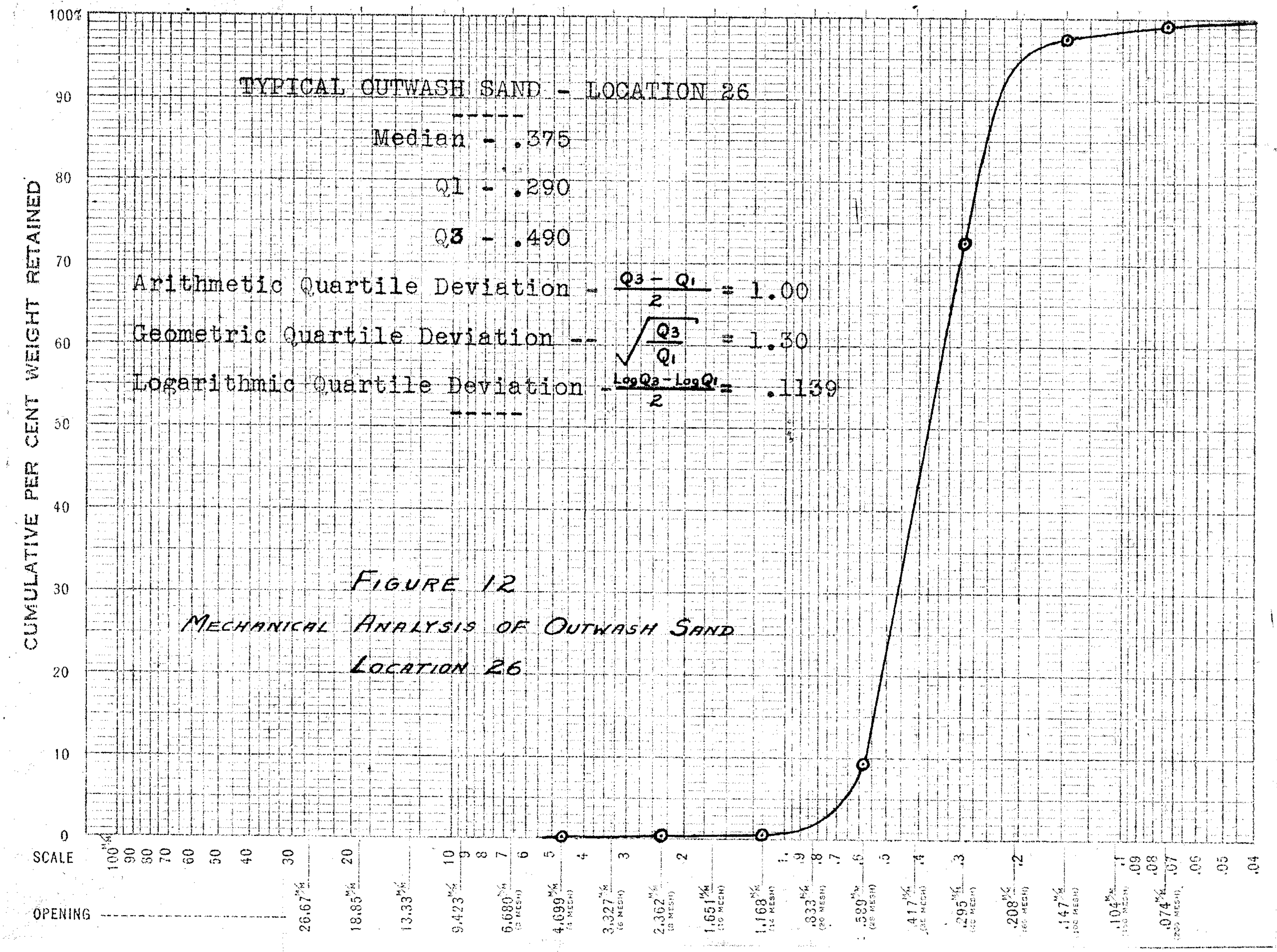


FIGURE 12
MECHANICAL ANALYSIS OF OUTWASH SAND
LOCATION 26

SHAPE ANALYSIS Rounding and sphericity of the particles from each screen fraction at several points along the deposit were investigated. The results of the shape determinations are shown in Tables IX to XV inclusive.

Sphericity values are largely within the 0.80 to 0.90 range, with little or no change vertically in the sections or laterally along the length of the deposit. Also, there is little change with size gradation within the individual sample.

Roundness values also show little or no change vertically in the sections or along the length of the deposit. Roundness values do, however, decrease with decreasing grain size. The change was noted from a value of approximately 0.60 on the 1.050 inch screen to 0.38 on the o.0058 inch screen.

The results of shape anlyses may be summarized as follows:

1. There are no sphericity changes vertically in section or laterally along the deposit, or with decreasing grain size.
2. There are no roundness changes vertically in section or laterally along the deposit.
3. There is, however, a distinct roundness change with decreasing grain size. The roundness of smaller particles is considerably less than that of the larger.

TABLE IX

AVERAGE SPHERICITY - LOCATION I - BIRDS HILL

Screen size	SAMPLE NUMBER A	B	C	D	E	F	G
1.050	.76	.73	.78	.76	.75	.70	.76
0.742	.78	.81	.77	.79	.77	.91	.75
0.525	.76	.75	.74	.75	.74	.68	.77
0.371	.80	.71	.75	.79	.79	.80	.83
0.185	.74	.86	.88	.90	.94	.90	.91
0.093	.85	.89	.90	.90	.87	.91	.89
0.046	.87	.85	.85	.86	.88	.89	.83
0.0232	.89	.87	.81	.85	.86	.88	.89
0.0116	.85	.85	.83	.85	.88	.86	.83
0.0058	.79	.66	.83	.80	.84	.84	.78

TABLE X

AVERAGE ROUNDNESS - LOCATION I - BIRDS HILL

Screen size	SAMPLE NUMBER A	B	C	D	E	F	G
1.050	.60	.61	.59	.60	.63	.40	.58
0.742	.65	.65	.63	.61	.61	.70	.57
0.525	.64	.62	.58	.60	.64	.30	.58
0.371	.54	.61	.57	.57	.60	.45	.62
0.185	.63	.63	.62	.59	.59	.50	.50
0.093	.53	.59	.53	.55	.54	.49	.52
0.046	.57	.49	.52	.51	.51	.45	.43
0.0232	.50	.47	.45	.41	.50	.49	.46
0.0116	.49	.44	.39	.38	.46	.42	.36
0.0058	.41	.38	.38	.33	.33	.36	.32

TABLE XI

AVERAGE SPHERICITY - LOCATION 9 - BIRDS HILL

Screen size	SAMPLE NUMBER A	B	C	D	E	F
1.050	-	-	-	-	-	-
0.742	-	-	-	-	-	-
0.525	.77	-	-	-	-	-
0.371	.82	-	.81	-	.79	-
0.185	.92	.88	.90	.93	.93	-
0.093	.87	.90	.86	.93	.87	.89
0.046	.86	.88	.89	.91	.88	.91
0.0232	.89	.88	.88	.89	.86	.87
0.0116	.88	.88	.86	.86	.86	.84
0.0058	.83	.86	.83	.81	.87	.82

TABLE XII

AVERAGE ROUNDNESS - LOCATION 9 - BIRDS HILL

Screen size	SAMPLE NUMBERS A	B	C	D	E	F
1.050	-	-	-	-	-	-
0.742	-	-	-	-	-	-
0.525	.57	-	-	-	-	-
0.371	.57	-	.61	-	.53	-
0.185	.63	.62	.61	.56	.54	-
0.093	.54	.55	.50	.51	.58	.52
0.046	.48	.46	.53	.49	.48	.47
0.0232	.46	.39	.48	.45	.46	.43
0.0058	.37	.41	.38	.41	.41	.41

TABLE XIII

SHAPE CHARACTERISTICS - LOCATION 15 - BIRDS HILL

Screen size	Sphericity A	Sphericity B	Sphericity C	Roundness A	Roundness B	Roundness C
1.050	-	-	-	-	-	-
0.742	-	.77	-	-	.59	-
0.525	-	.75	-	-	.54	-
0.371	-	.78	-	-	.59	-
0.185	-	.91	.88	-	.58	.53
0.093	-	.87	.85	-	.47	.55
0.046	-	.89	.87	-	.52	.48
0.0232	.90	.89	.87	.51	.51	.51
0.0116	.91	.90	.85	.46	.43	.42
0.0058	.80	.84	.85	.35	.37	.39

TABLE XIV

AVERAGE SPHERICITY - OUTWASH PLAIN SANDS

Screen size	SAMPLE LOCATIONS 25	27	29	31	33A	33B
1.050	-	-	-	-	-	-
0.742	-	-	-	-	-	-
0.525	-	-	-	-	-	.75
0.371	-	-	-	-	-	.83
0.185	-	-	-	.90	.85	.89
0.093	.89	-	.91	.88	.89	.87
0.046	.91	.87	.87	.87	.88	.86
0.0232	.89	.88	.89	.85	.85	.90
0.0116	.88	.86	.85	.87	.94	.90
0.0058	.84	.85	.80	.83	.81	.77

TABLE XV

AVERAGE ROUNDNESS - OUTWASH PLAIN SANDS

Screen	SAMPLE LOCATIONS					
size	25	27	29	31	33A	33B
1.050	-	-	-	-	-	-
0.742	-	-	-	-	-	-
0.525	-	-	-	-	-	.57
0.371	-	-	-	-	-	.57
0.185	-	-	-	.53	.52	.62
0.093	.58	-	.57	.50	.54	.62
0.046	.51	.52	.56	.52	.52	.52
0.0232	.48	.50	.48	.46	.50	.46
0.0116	.40	.46	.46	.42	.38	.43
0.0058	.47	.43	.46	.42	.36	.42

ACID SOLUBLE CONTENT The fine fractions (material below the 0.0116 inch screen) of a number of samples from locations along both arms of the Birds Hill deposit were treated with cold, dilute hydrochloric acid to remove the acid soluble material. The results of this investigation are shown in Figure 13. The figure indicates a decreasing trend of acid soluble material toward the eastern end of the deposit and into the outwash plain.

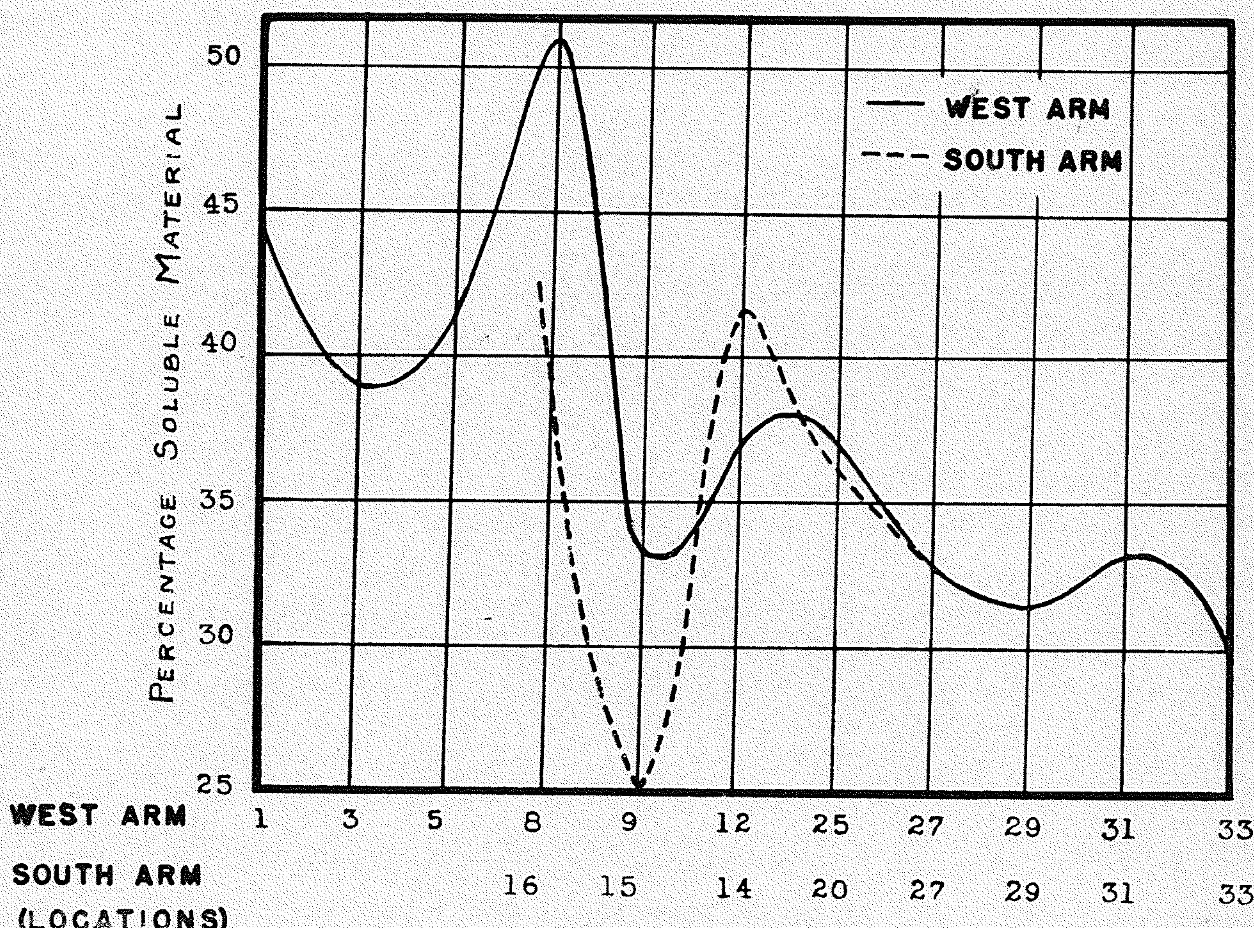


FIGURE 13

Graphical representation of acid soluble material below the .0116 inch screen

BIRDS HILL

4. DISCUSSION OF RESULTS AND CONCLUSIONS

FIELD STUDY. Birds Hill has the shape of a long, narrow ridge rising forty to fifty feet above the adjacent countryside and extending almost continuously, about four miles in an east-west direction. The hill terminates at the eastern end in a low, broad, slightly elevated plain. Upham (see Previous Work) suggested that the hill was the result of deposition along a stream which flowed eastward from the retreating front of the final Pleistocene ice-sheet. The long, narrow ridge called Birds Hill represents deposition along the lower reaches of the former stream channel. The broad plain at the eastern end of the hill represents the delta or the outwash plain of the stream.

Cross bedding within the Birds Hill deposit confirm Upham's suggestion that waters of the stream flowed eastward. The horizontal stratification of exceedingly coarse material, with abundant cross bedding, throughout the western end of the deposit indicates powerful fluvial currents. That these currents decreased toward the east is suggested by the increasing predominance of fine material in this direction along the deposit.

There is a close relation of the Birds Hill deposit to glacial conditions. Till occurs as a thin blanket of boulder clay overlying the western end and part of the northern side of the hill, and ridges of till also underlie the deposit at several localities, notably Location 7. The overlying till suggests a moderate readvance of the ice-sheet following deposition of Birds Hill. This readvance was probably more in the nature of a local shifting rather than a large scale regional advance. The underlying ridges probably represent subglacial accumulations overridden by the ice-sheet in its advancing stages. It is conceivable that these ridges created zones of weakness in the ice above along which the streams depositing Birds Hill were later initiated.

Moose Nose Hill, to the south of Birds Hill, with distinct current bedding dipping northward, may represent a second stream channel similar to the one which deposited Birds Hill. The direction of flow of the stream as determined in this work indicates that the stream probably terminated in the same outwash plain as the Birds Hill deposit.

<u>PETROLOGIC STUDY</u> Petrologic similarity is the striking characteristic of the gravel deposits of Birds Hill and vicinity. Approximately 75 percent of the gravel pebbles, sands and very fine materials are Paleozoic limestone. The petrologic uniformity of the deposit suggests that there was a common rock source throughout the lifetime of the depositing stream, and also that transport distances were short, for outcrops of Paleozoic limestone occur in

the vicinity.

Clear quartz is a mineral found in all samples, the amount present increasing with decreasing particle diameter in the individual sample, and the relative amount present in each sample increasing with distance along the deposit. These characteristics express firstly the greater degree of abrasion to which minererals from eastern parts of the deposit have been exposed. The increase in abrasion is presumably a consequence of the downstream position of the eastern parts of Birds Hill.

Unstable minerals such as feldspar and the pyriboles are common minor constituents of the sands and gravels. This is a common feature of glacial and glacial associated deposits, for decomposition is held to a minimum by the low temperatures prevalent at the time of deposition. The presence of unstable minerals also indicates rapid transport and deposition.

HEAVY MINERAL ASSEMBLAGE Most prominent heavy minerals, both in frequence of occurrence and quantity present, are the unstable pyroxenes and amphiboles. Such unstable minerals have already been discussed immediately above. High specific gravity and more resistant minerals, such as magnetite and rutile, occur most abundantly in eastern parts of the deposit and the outwash plain. These minerals, however, occur only as very fine microscopic grains. Their increasing abundance eastward may be attributed to a marked current velocity drop in this direction. The high specific gravity minerals, by virtue of their extremely fine size, were carried in suspension over the length of the upper stream channel. As stream velocity decreased the high specific gravity of the silt-sized heavy mineral particles caused their deposition among the sand-sized light mineral and rock fragments. This is true for the heavy mineral assemblage in general, for there is a progressive concentration in the amount of all heavy minerals eastward along the deposit. The greater degree of abrasion to which the transported rock fragments were exposed in the downstream direction would produce greater concentration of heavy minerals downstream, for abrasion of transported rock fragments is the source of all heavy minerals in the deposit.

Two separate and distinct types of the mineral tourmaline were noted. A black, opaque variety appearing as small well rounded grains along the western arm of Birds Hill, and a greenish-grey, pleochroic variety found at Location 15 on the southern arm. Both types are present in outwash plain samples. Such a manner of occurrence lends strength to a theory of separate channels of deposition for Birds Hill and Moose Nose Hill, MECHANICAL ANALYSIS Gravels along both arms of the Birds Hill deposit are normally sorted, (Normal sorting is defined by Pettijohn, 1949, page 24) and also contain lenses and layers of well sorted sands. There is a gradational decrease in the predominant grain size eastward along the deposit, and also sorting coefficient values show a slight gradational decrease in that direction. Normal sorting has been described as a characteristic of river deposition (Pettijohn, 1949, page 197). Decreasing size diameter of the average particle and increased sorting characteristics in an eastern direction, a result of decreasing transport capacities, indicate that this was the downstream direction of the depositing stream.

SHAPE ANALYSIS Sphericity values show no change vertically in section, laterally along the deposit, or with decreasing grain size. This is the result of a homogeneity of composing rock type. It is also possible that the particles had attained a degree of shape equilibrium before entering the stream, and the shape characteristics changed little over the course of the stream, or over the total time of deposition.

Roundness determinations, however, reveal a distinct change in proportion to decreasing grain size. The values of the smaller particles are invariably less than the values of the larger. This decrease of roundness with decreasing grain size is a characteristic normal to all transported clastic sediments (Pettijohn, 1949, page 404). The rate of abrasion is much greater for larger fragments, hence at any point of transport a disparity will exist between the roundness of the larger and the smaller particles. The magnitude of this disparity is there fore a measure of the maturity of a sediment. This relationship is well marked in the Birds Hill gravels, hence the assumption is that particles composing the deposit had been subjected to a good deal of abrasion previous to deposition, probably previous to entrance into the stream channel. The majority of the smaller particles present are the result of fragmentation of larger units, while in transport by glacial ice and later by glacial stream currents.

ACID SOLUBLE CONTENT Examination of the acid soluble content of the finer screen sizes reveals a decreasing quantity of such material towards the eastern end of the deposit. This is the result of the greater natural solution of acid soluble material in the downstream direction. The increasing abundance of clear quartz eastward is in part a result of such a process.

CONCLUSION Field observations and laboratory examinations of the Birds Hill and adjacent gravel deposits indicate that:

1. Birds Hill is the result of deposition by a large, swift, east-flowing stream. The hill represents deposition near the mouth of the stream, and the low, elevated plain to the north and east of the hill represents the outwash plain deposit of the stream.
2. There is a suggestion that a second channel of deposition also existed. This channel coincided with the axis of the present Moose Nose Hill and also terminated in the outwash plain. The stream may or may not have existed at the same time as the one depositing Birds Hill.
3. The predominant amount of the material composing the deposits is of local origin, and transport distances have been short. Shape analyses, however, reveal a certain degree of sediment maturity and suggest the possibility that the materials present may have undergone some abrasion prior to entrance into the final depositing stream channel.
4. Relation of the Birds Hill deposit to glacial till in the vicinity places the time of the streams' existence at the time when the retreating continental glacial front was in the area. There is a suggestion that sub-glacial till accumulations may have initiated the fissures in this ice-front

which defined the depositing streams.

The relation of the Birds Hill deposit with other glacial deposits in the Winnipeg area, and with ice recession over Manitoba in general, is discussed in the following Chapter.

CHAPTER IV

RELATION OF GLACIAL DEPOSITS IN THE WINNIPEG AREA TO ICE RECESSION IN MANITOBA

RECENT THEORIES OF CONTINENTAL GLACIATION As pointed out by R. F. Flint (1942) the views regarding the growth and recession of continental ice-sheets have changed considerably within recent years. The modern concept is one of growth by marginal accumulation from a centre rather than outflow from a centre. Glaciation initiates where temperatures and precipitation are favorable for the accumulation of ice, and as the area of the ice mass expands, the points of maximum precipitation move outward with the boundaries of the mass. These boundary areas are regions where the mixing of cold and relatively warm air create conditions most favorable for precipitation. Movement of the ice mass is continuous, but initiated from the boundaries, not from the centre. Material eroded by the base of the ice may be carried great distances by remaining in the front part of the mass. However, the greater bulk of the transported material is carried but a short distance before being overridden or incorporated into the stagnant inner areas of the ice-sheet. At any given time the greater bulk of material contained within the ice over any area is of local origin. The predominance of local Paleozoic limestones in gravel deposits of the Winnipeg area is an example of this latter process.

As long as conditions are such that precipitation exceeds melting at the front of the ice-sheet the sheet continues to move forward. Eventually the front advances to a geographical position where in consequence to climatic conditions an equilibrium between accumulation and melting is attained. Here terminal moraines may be built up, consisting largely of local material with a small amount of material which has been transported greater distances within the ice. Under these conditions of equilibrium a small rise in the climatic mean temperature will result in unbalance with disruption of the mechanism of marginal accumulation. Deprived of driving force, the ice masses stagnate and shrink away. In consequence of temperature decrease gradient northward, shrinkage of the North American Pleistocene ice-sheets would be in this general direction. Over large areas at any given time, however, masses of ice will be stagnant and wasting. At times in this general regression conditions may adjust to allow local readvances of the ice-sheet. This situation is typified by the till mantle existing over the western end of Birds Hill.

Stagnation has become an accepted part of the more recent concepts of glacial withdrawal. No definite ice front retreating toward the centre of glaciation is necessary, instead there will be a marginal area of the ice-sheet breaking into several shrinking masses. There will be a number of minor fronts, associated with these shrinking masses, retreating in various directions. Drift will be deposited as moraines, scattered ground drift, and outwash features at these minor fronts. As the ice fronts may be retreating in any direction, it is not necessary that such deposits have any definite directional orientation. Glacial deposits, therefore, may give little evidence of the nature of the retreat of the main ice-sheet, but only the nature of the retreat of the small mass with which they have been associated.

DISTRIBUTION OF GLACIAL DEPOSITS IN SOUTHEASTERN MANITOBA

Figure 1 is an illustration of the Pleistocene gravel deposits in the Winnipeg area. These deposits occur along both sides of the broad, shallow Red River valley. They represent in part the abandoned beaches of glacial Lake Agassiz, and in part outwash features of retreating glaciation. Birds Hill is approximately in the centre of the valley, and it assumes the shape of a delta, trending first southeast, then northeast, and gradually broadening in these directions. There is no surface connection whatsoever of Birds Hill with the glacial deposits along the borders of the Red River valley. However, field examinations in the area to the northwest of Birds Hill indicate that the surface covering of lacustrine clay is largely underlain by stratified sand and gravel.. These gravel deposits are probably related in some manner to glacial recession over the are, and this possibility will be discussed later.

GLACIAL RECESSION IN MANITOBA According to Ernst Antevs (1931) the ice-sheets which extended over Manitoba were the result of growth outward from centres in the Districts of Keewatin and Patricia.. The contact of these ice-sheets was probably along a line from the Lake of the Woods to the lower part of Lake Winnipeg, and thence northward along the axis of this lake. During the waning stages of glaciation this junction probably existed as a zone of weakness, along which decay took place most readily, and into which glacial Lake Agassiz extended northward. Ice recession was eastward and westward from the margins of this northern extension of the glacial lake.

As described by Upham (see page 5), glacial Lake Agassiz covered considerable areas of Minnesota, North Dakota and southern Manitoba. The northern boundary of the lake was defined by the receding ice-sheets, and in its earlier periods of existence the outlet of the lake was to the south, into the Mississippi basin. As the ice-sheets melted away, successively lower outlets were opened to the north, finally draining the lake to the present levels of Lake Winnipeg and Lake Manitoba.

In the waning stages of glaciation, great volumes of meltwaters poured from the retreating fronts, carrying quantities of material which had previously been contained within the ice. In response to decreased gradient, especially when flowing into bodies of standing water, the transported material, at and extending away from, the ice-front was dropped. Where cracks and fissures existed in the front, the meltwaters tended to follow and enlarge these areas. Some of these streams would expand in drainage area, gradually drawing more and more water from a greater area of the ice surface. Where such drainage patterns developed, great quantities of sand and gravel would be deposited along the lower reaches of the stream. The Birds Hill deposit was probably formed in one of these larger glacial stream channels.

Where large drainage patterns such as the above failed to develop, meltwaters flowed as small streams and rivulets down the face of the ice mass, depositing sheet-like layers of stratified material away from the glacial front. The deposits at Lockport and Bergen, to the northwest and west of Birds Hill, were probably formed by such smaller streams.

Field and laboratory work conducted in connection with this thesis have defined the Birds Hill deposit as a result

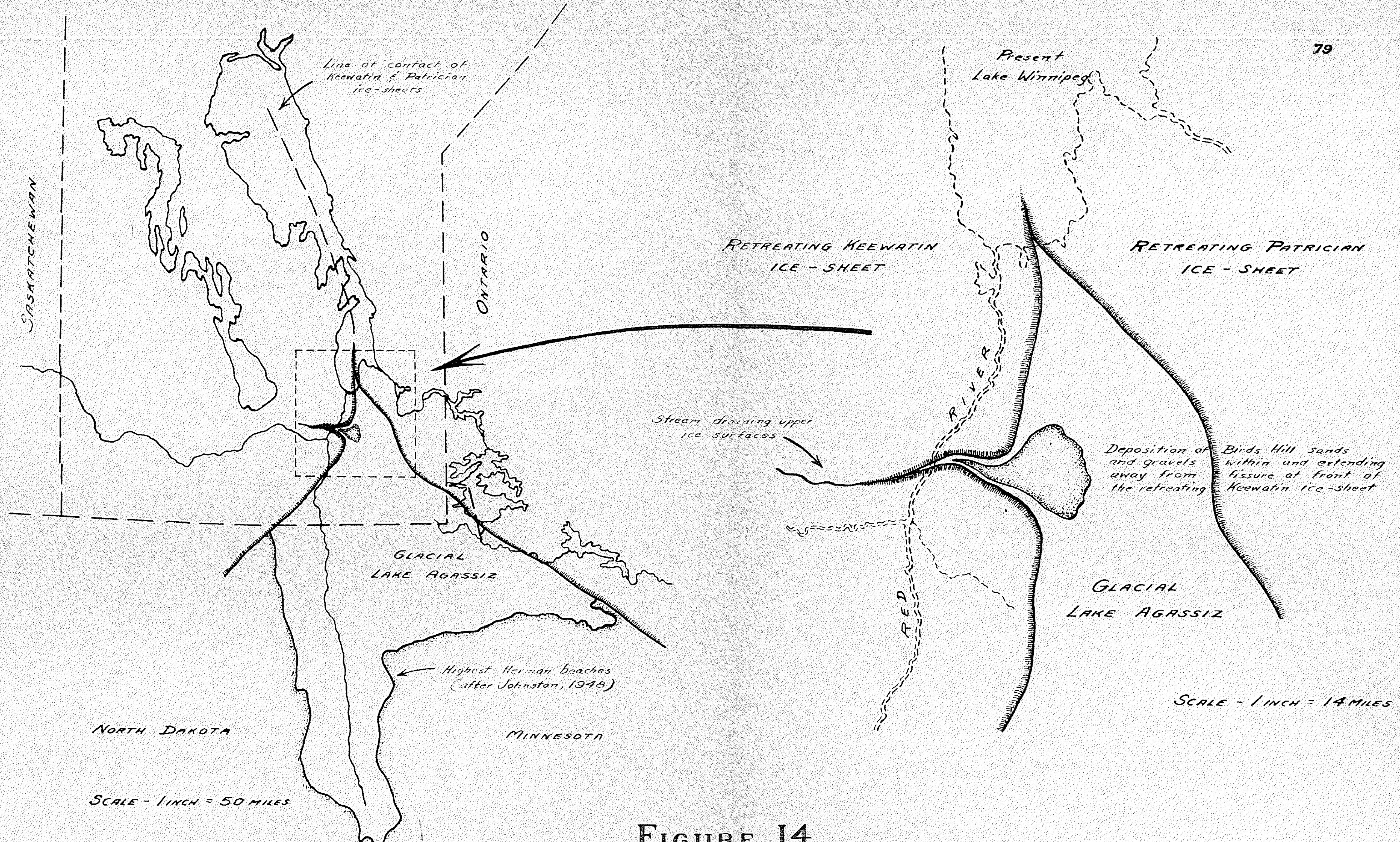


FIGURE 14

APPROXIMATE DISTRIBUTION OF GLACIAL ICE AND GLACIAL LAKE AGASSIZ AT THE TIME OF DEPOSITION OF BIRDS HILL of deposition near the mouth of a large, east flowing stream. There is evidence that the depositing currants, powerful at the western end of the deposit, declined rapidly in the downstream direction. There is every indication that the gravel deposits were made by a stream draining the upper surfaces of the retreating Keewatin ice-sheet. This stream, in the vicinity of Birds Hill, plunged into a fissure at the ice front and deposited its transported load of sand and gravel into the northern extension of Lake Agassiz. The east-flowing direction of the stream is supporting evidence for the northwesterly retreat of the Keewatin ice-sheet. The localized, thick and undisturbed sands and gravels of Birds Hill could have been deposited only under atagnant conditions of the ice-sheet over a period of several years. A local readvance of the ice-sheet following the period of deposition of Birds Hill is indicated by the mantle of till over the western end and northern side of the deposit. Major movements within the period of deposition would have destroyed the deposit.

At the time of formation of Birds Hill the front of the Keewatin ice-sheet probably existed near Winnipeg, and therefore at a time previous to the opening of the northern outlets of Lake Agassiz. Lake levels would then be at those levels marked by the highest, or Herman series of abandoned beaches. These beaches in Manitoba are some 400 feet higher than the highest point of Birds Hill. Under these conditions it would appear that deposition of Birds Hill occurred beneath at least 400 feet of water.

Upham (see page 7) did not believe the depositon of the material in Birds Hill could occur under such conditions. He suggested original deposition of the gravels as a superglacial esker on the upper ice surface, with subsequent lowering of the deposit to the present position by the melting of the underlying ice.

Flint (1930, page 106) discards the superglacial theory of esker origin where disturbance of stratification is lacking. No distortion of stratification was noted at Birds Hill, and it would seem unlikely that such a large body of finely stratified material could be lowered over 400 feet without showing some evidence of disturbance.

The deposit was probably laid down as now located. The steep gradient from the upper ice surfaces, coupled with great volumes of water, could readily account for current bedding of fine material over a distance of several miles, even beneath 400 feet of water. Rapid decline of initial velocities is shown by increasing abundance of fine material eastward along the deposit.

The levels of Lake Agassiz probably extended well into the fissure channel, and a marked change in the velocity of stream currents would occur where the stream entered the waters of the lake. There would be a consequent rapid deposition of the exceedingly coarse transported material where such a decline of stream currents occurred, and quantities of coarse material are now found at the western end of Birds Hill. Stream velocities along the remaining length of channel would be more in the nature of underwater currents, declining rapidly at first, then steadying to a constant outflow into the glacial lake. Currents created in the lake were of two directions (see figure 15, following page), outward currents the consequence of influx from the stream channel, and upward currents as a consequence of density differences. Such density currents are created in the following manner. Waters entering a glacial lake are only slightly above the freezing point, and therefore are below the greatest density for water. As a result these cold waters tend to rise above the slightly warmer waters of the lake. The waters entering at Birds Hill were forced to near the bottom of the glacial lake by the initial velocity of the stream, and would tend to rise steadily as they flowed outward into the lake. The effect is well explained by Twenhofel (1950, page 91), and is illustrated diagrammatically by Figure 15.

Sediments carried by the glacial stream would be de-

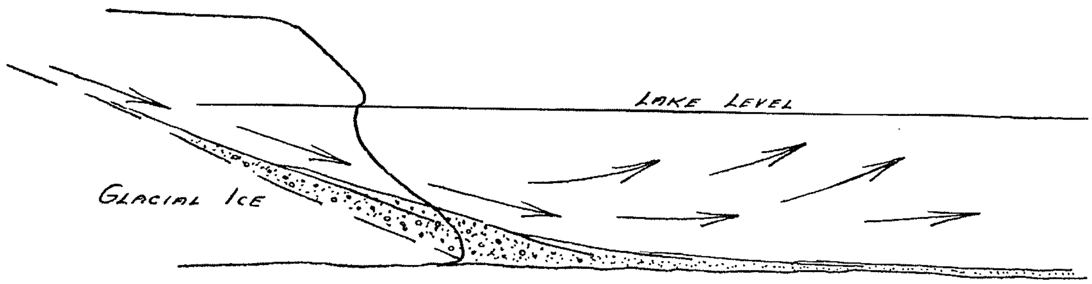


Figure 15

Currents developed by a glacial stream flowing into an adjacent glacial lake (After Twenhofel, 1950). The currents are of two directions; outwards as a result of stream velocity, and upward as a result of density differences. The water intering the glacial lake is only slightly above the freezing point for water, and so tends to rise in the slightly warmer lake water.

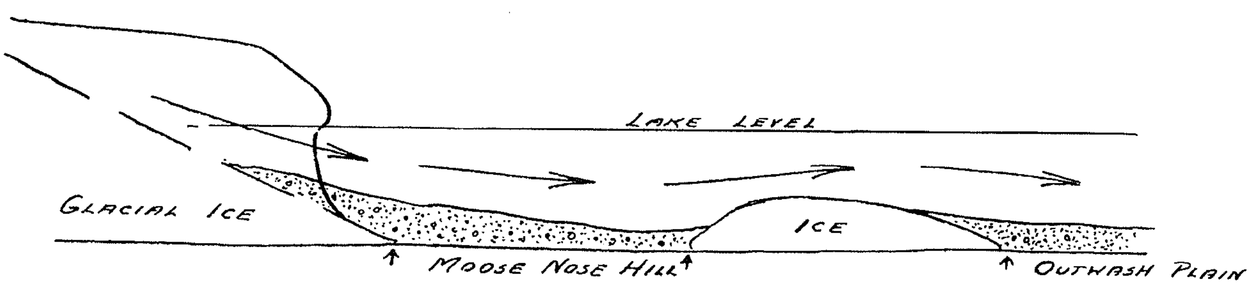


Figure 16

Possible origin of Moose Nose Hill. Water flowed from the upper ice surface into the glacial lake, depositing the sands and gravels of Moose Nose Hill, then continued over an outlying remnant of ice to deposit the sands of the outwash plain.

posited in a sequence defined by the size, weight and shape characteristics of the transported particles. The coarse, heavy particles would be dropped near the head of the stream, where velocities declined rapidly on entrance into the deep waters of the channel. Size and weight of deposited particles would decline downstream in proportion to velocity decline. Stream velocities would decline until coincident with current velocities in the lake waters, and sediments carried by stream currents of the same magnitude as lake currents, would tend to be carried far into the lake body. The broad expanse of horizontally stratified fine sand to the north and east of Birds Hill is the result of such a process. Tributary streams no doubt joined the main channel, and these would introduce lenses of coarse material into the main deposit. Where deposition continued undisturbed for long periods of time thick deposits of homogeneous material, such as the sand at Location 6, would result. Irregular lenses of coarse gravel probably represent frozen blocks of material laid down in smaller fissures, which, as the containing ice was worn away, were incorporated into the main mass of the deposit.

The Moose Nose Hill deposit is the result of deposition along a second stream channel which may or may not have existed at the same time as the stream depositing Birds Hill. The deposit may be only a part of the deposition along the course of a stream terminating over the elevated plain to the north, or it may be the deltaic deposit of such a stream. Study of topography would suggest the deposit as representative of part of a stream channel, a body of ice underlying that part of the stream north of the hill and south of the elevated plain where no gravel deposits are now found. Possibly waters flowed from the upper ice surfaces in a northeasterly direction, dropping the somewhat coarser transported material to form the Moose Nose deposit, then continued over underlying ice to spread the transported fines over the elevated plain to the north and east of Birds Hill. The condition is diagrammatically illustrated by Figure 16. In later stages of deposition, as current velocities decreased, Moose Nose Hill became the actual delta of the stream.

The lifetime of the glacial streams ended when the containing walls of ice were worn and melted away sufficiently to allow waters of the glacial lake to advance over the upper ice surfaces. Previous to this, as the ice above the lake level wasted away, the velocities of water entering the stream channels would decline and finer materials should compose the upper parts of the deposit sections. No vertical gradation to finer materials was observed at Birds Hill. However, as the lifetime of this stream was presumably cut short by a slight glacial readvance, the condition is not essential.

As recession of the Keewatin ice-sheet continued in the district, the front retreated in a northwesterly direction. The Lockport gravel deposit, and the flat-lying stratified masses of gravel represented by the pit near Bergen, are representative of outwash deposition from the face of the retreating ice-sheet. At the same time the Patrician ice-sheet retreated to the east and northeast, leaving scattered mounds of sand and gravel to the east of Birds Hill. Retreat of the ice-sheets, in keeping with theories of stagnation, may be visualized as progressive melting along the borders of glacial Lake Agassiz, rather than recession of the front of a moving ice-mass.

As the ice mantle continued to melt away glacial Lake Agassiz expanded to cover the greater part of southern Manitoba, as illustrated by Figure 14 on page 79. Levels of the glacial lake were defined by the levels of the successive outlets of the lake (page 5) and at each level a series of beaches were formed. The remnants of these beaches are represented by the long, sinuous gravel deposits noted in the upper left hand corner of Figure 1, and also at several localities to the east of Birds Hill on the same figure. The Dufresne gravel deposit is representative of the beach series defined by Johnston (1946) as the Ossawa series.

Great quantities of lacustrine clay were deposited under the waters of glacial Lake Agassiz, and these clays now form a thick cover over the greater part of southern Manitoba. Wave action of the receding lake waters washed prominences such as Birds Hill clear of silt and clay, and also developed a thin mantle of surface gravels in many localities.

In summary, a variety of sand and gravel deposits remain in the Red River Valley as evidence of the retreat of the final Pleistocene ice-sheet. The deposits examined at Bergen and Lockport are representative of the thin, deltaic masses of sand and gravel laid down by waters flowing directly from the front of the retreating ice-sheet. The elongate, sinuous Birds Hill deposit is evidence of a large, ice-walled stream that flowed from the upper ice surfaces into glacial Lake Agassiz. The Dufresne deposit is a portion of one of the beaches of Lake Agassiz, and represents an interval within the time of the lakes existence when its waters were receding to expose the flat prairie lands of the Red River Valley.

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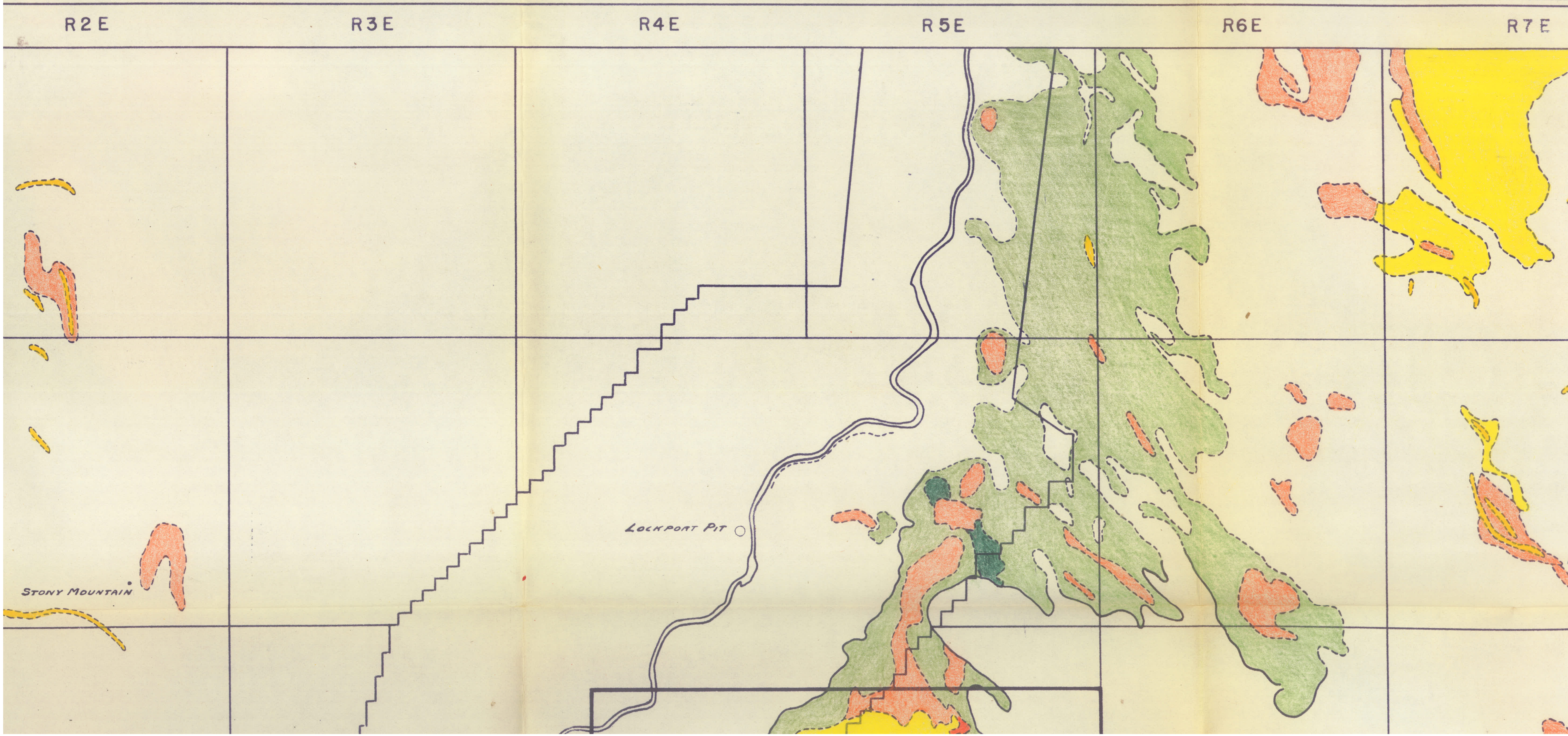
PLEISTOCE

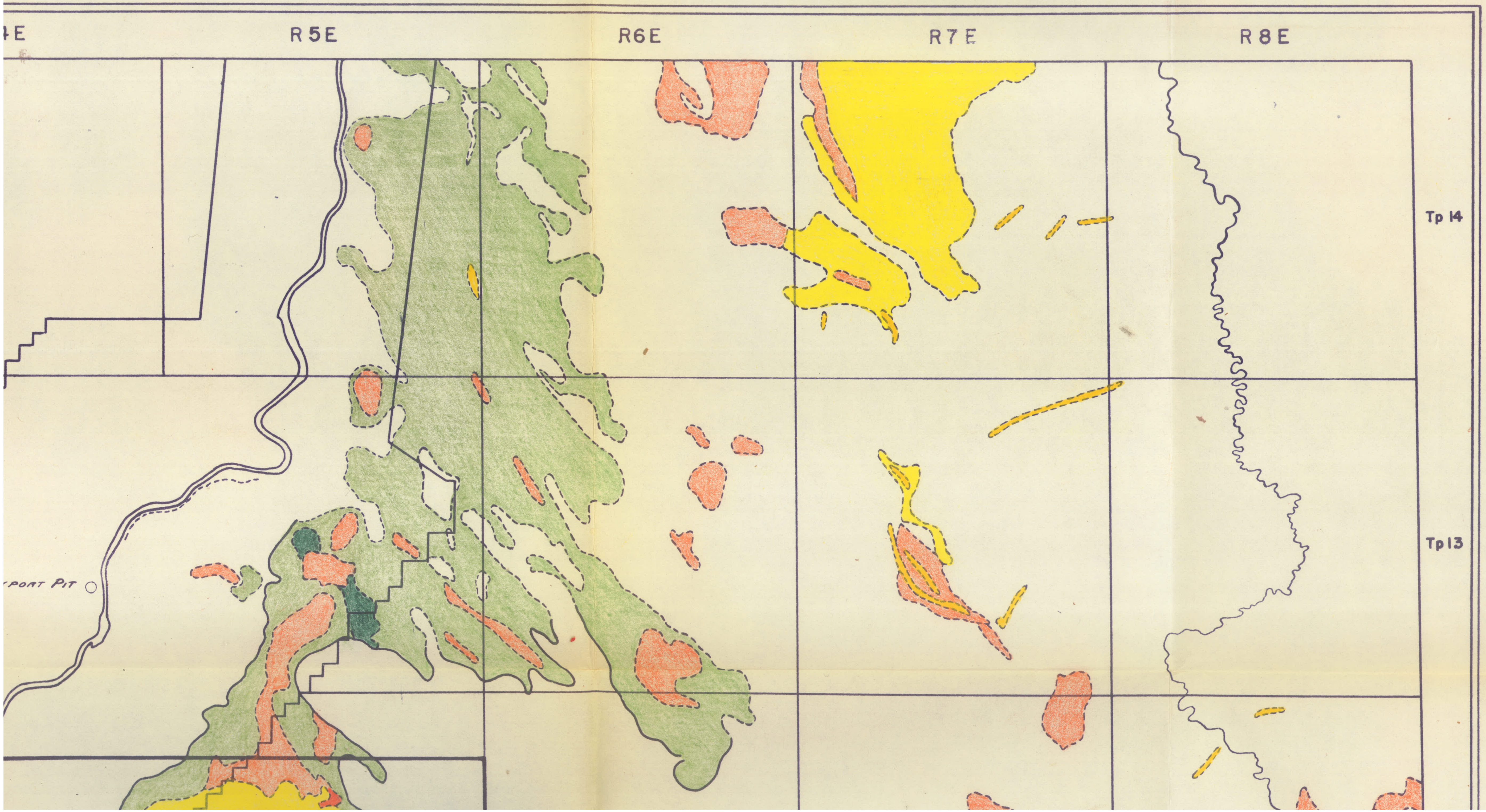
WINN

OCENE GRAVEL DEPOSITS

WINNIPEG AREA IN MANITOBA



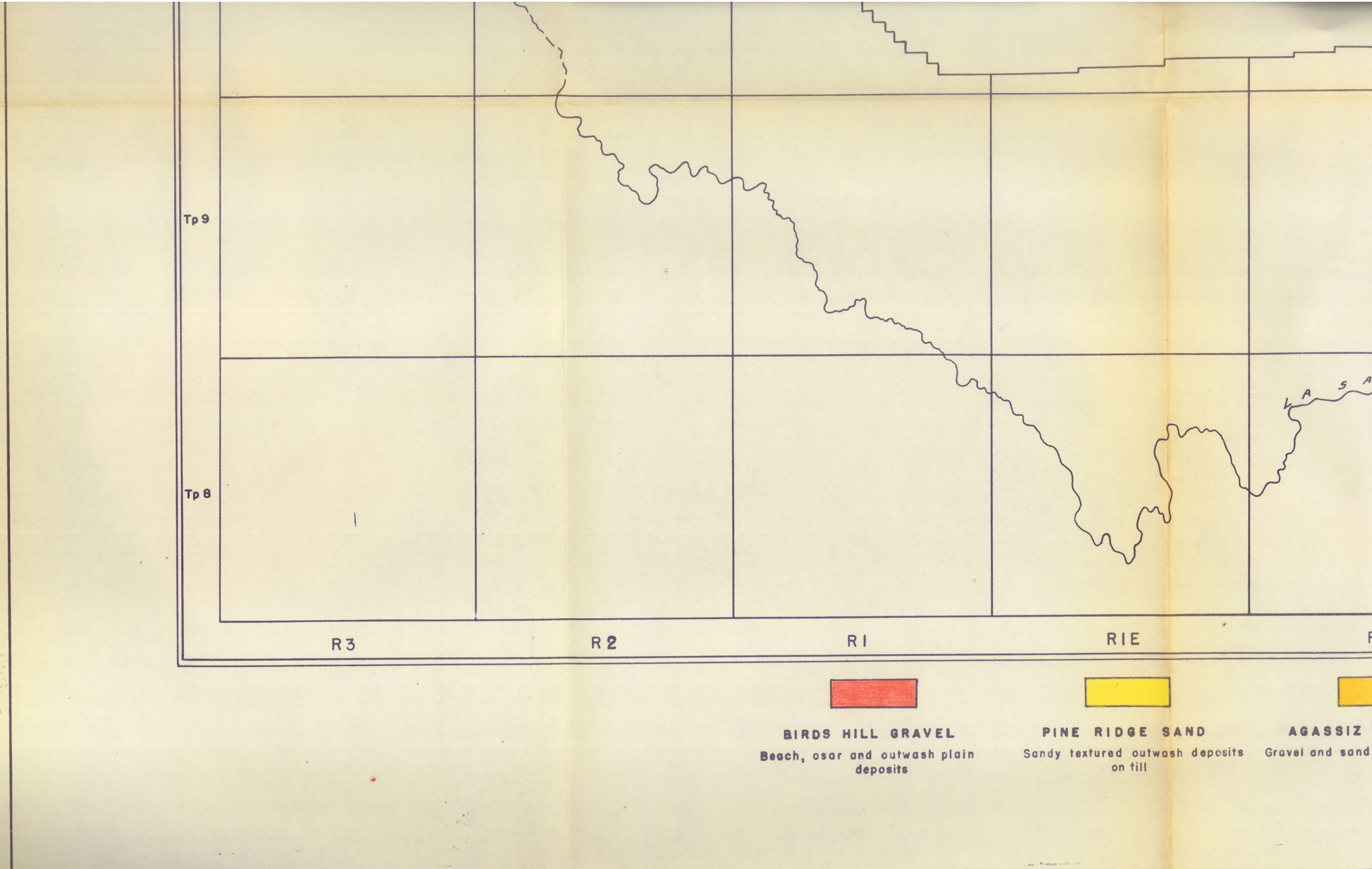
POSITS




Tp 12
Tp 11
Tp 10
Tp 9
ASSINIBOINE
RIVER
STONY MOUNTAIN HIGHWAY

BIRDS HILL
HIGHWAY PIT
RED RIVER
WINNIPEG
—OUTLINE OF BIRDS HILL SHEET—
SEINE RIVER
RIVER
DUFRESNE PIT
DUFRESNE


Tp 12
HILL
OUTLINE OF BIRDS HILL SHEET
Tp 11
Tp 10
Tp 9
DUFRESNE PIT
RIVER
DUFRESNE


Tp 9
Tp 8
R3
R2
R1
RIE
BIRDS HILL GRAVEL
Beach, osar and outwash plain deposits
PINE RIDGE SAND
Sandy textured outwash deposits on till
AGASSIZ
Gravel and sand

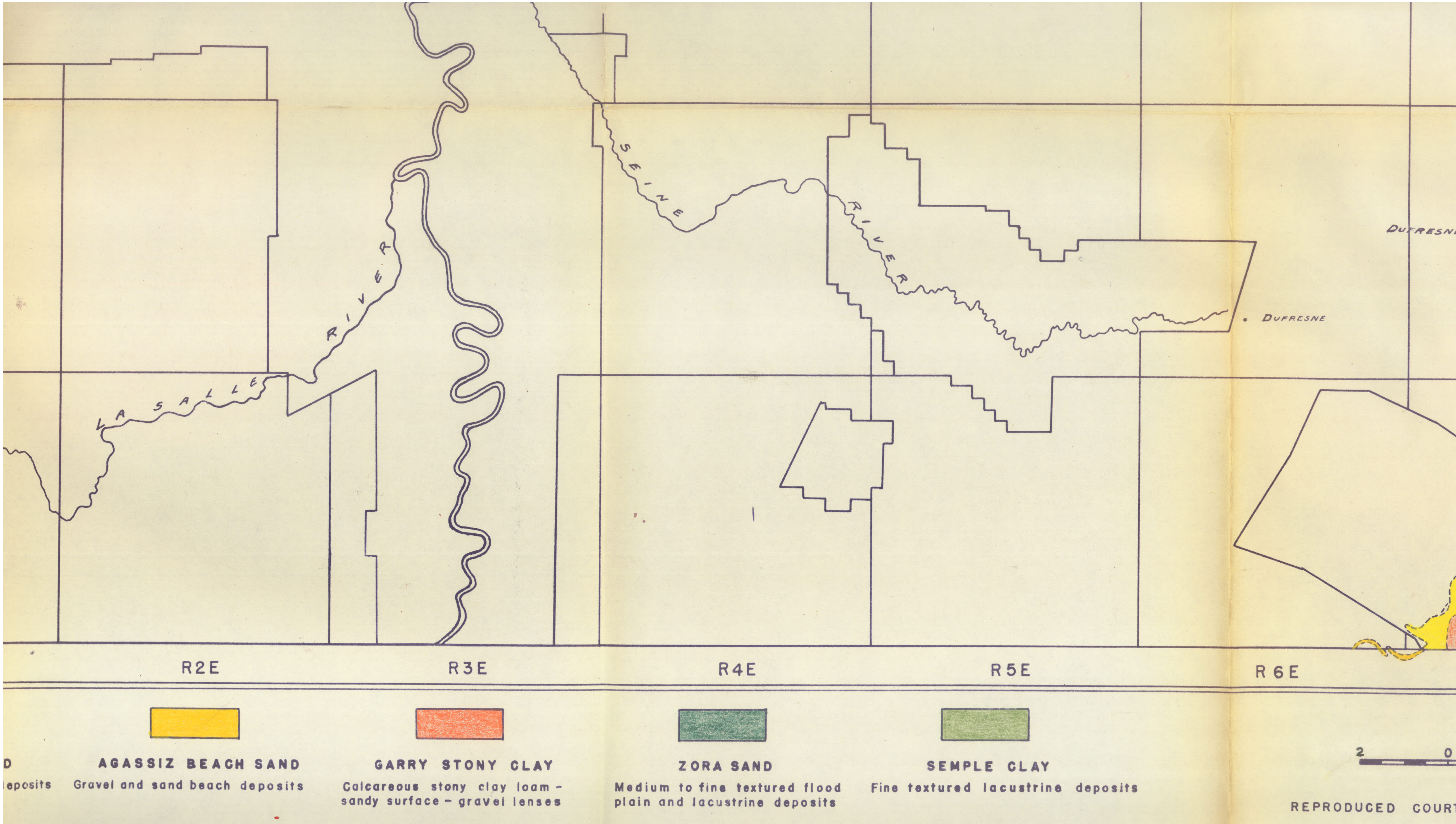
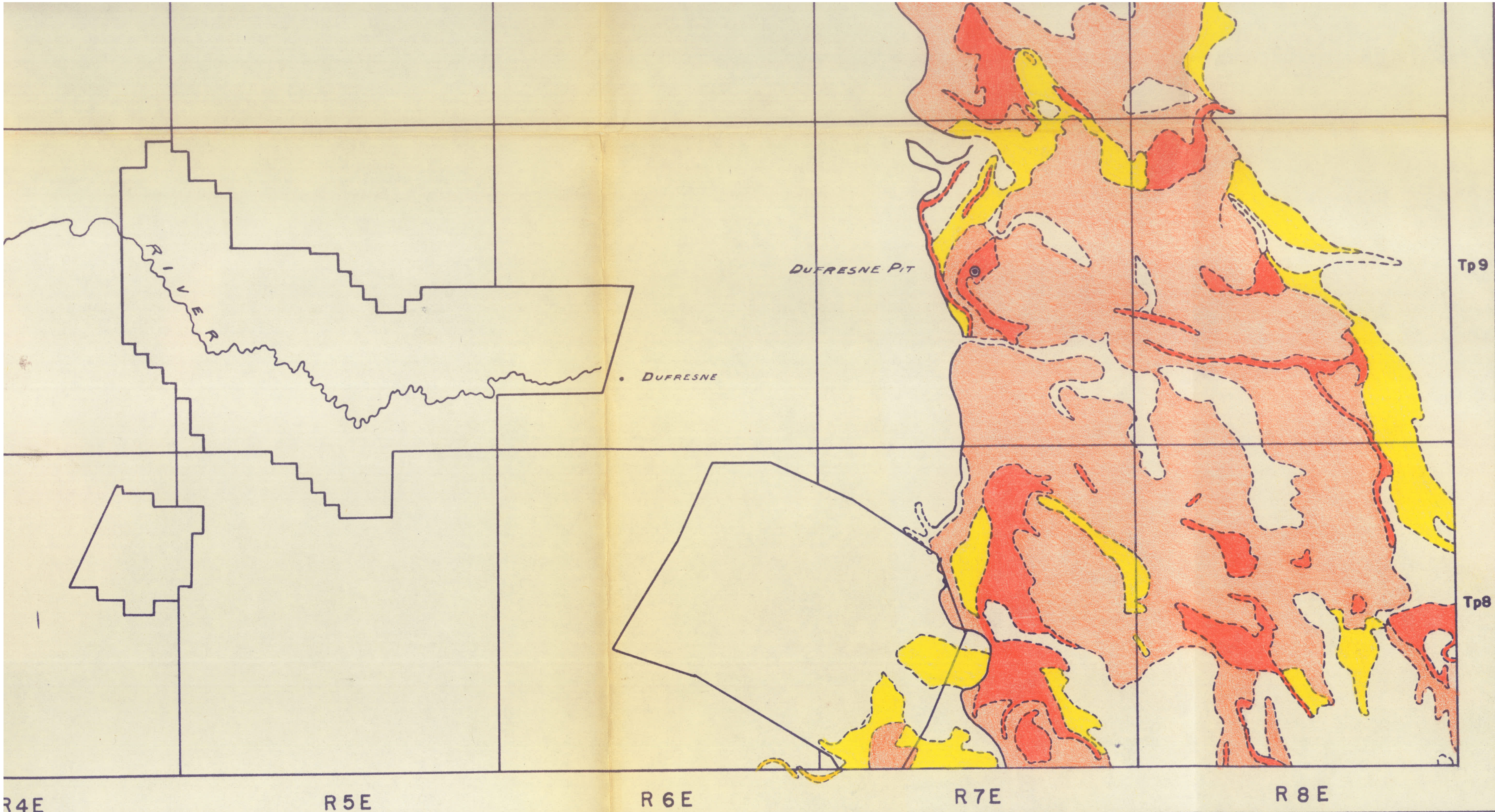

LA SALLE RIVER
SEINE RIVER
DUFRESNE
DUFRESNE
R2E
R3E
R4E
R5E
R6E
D
leposits
AGASSIZ BEACH SAND
Gravel and sand beach deposits
GARRY STONY CLAY
Calcareous stony clay loam - sandy surface - gravel lenses
ZORA SAND
Medium to fine textured flood plain and lacustrine deposits
SEMPLE CLAY
Fine textured lacustrine deposits
2 0
REPRODUCED COURTE
THE UNI

FIGURE 1



SAND
e textured flood
ustrine deposits

SEMPLE CLAY
Fine textured lacustrine deposits

SCALE
2 0 2 4 6
Miles

REPRODUCED COURTESY OF THE DEPARTMENT OF SOILS
THE UNIVERSITY OF MANITOBA


BIRDS HILL AREA
Scale
1 1/2 0 1
Contour Interval ------- 12 1/2 Feet
Contours ------ 837.5
Gravel & Sand Pits --
Railroad ------
Road --------
Sample Location ------ ⊙6
FIGURE 2
C. N. R.
True North
Magnetic North
PACIFIC RAILWAY
762.5
775
787.5
800
812.5
825
837.5
850

Pine Ridge School
PINE RIDGE
29
30
31
32
33
775
787.5
800
812.5
825
837.5
850
862.5
875
887.5

BIRDS HILL
CANADI
CANADIAN
MOOSE NO

MOOSE NOSE HILL
CANADIAN PACIFIC RAILWAY
25
26
27
28
19
20
14
15
16
17
18
800
812.5
825
837.5
850
862.5
875
887.5
900