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WIND CANYON SAND

THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

A Thesis

Presented to

the Faculty of the Department of Geology

University of North Dakota

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science of Geology

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by

Gerald R. Baugh

January 1956

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WIND CANYON SAND

THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

ABSTRACT

The lenticular body of sandstone in Wind Canyon Theodore Roosevelt National Park, North Dakota, displays a variety of conditions that lend them selves to immaturity. It is these conditions and their genetic relations that the author pursued.

INTRODUCTION

Wind Canyon, one of the spectacular views in the south unit of Theodore Roosevelt National Park, exposes cliffs of white massive sandstone. The Wind Canyon sandstone occurs as a thick lenticular member near the top of the Tongue River formation of the Fort Union group of Paleocene age. The sandstone lens, except for the exposures in Wind Canyon are covered by terrace materials and other alluvium. Thus, the extent of the Wind Canyon sandstone lens is not known. However, lenticular bodies of similiar sandstone are exposed along tributaries of the Little Missouri River, south of Theodore Roosevelt National Park. Sandstone as used here is to denote an indurated (consolidated) rock composed of mineral or rock grains of both sand and silt size. The indurated (consolidated) sand and silt found in Wind Canyon is designated sandstone as it is of an aggregate of sand, which constitutes 95% of the sample.

The term sand is used here to denote an aggregate of mineral or rock grains greater than 1/16 mm. and less than 2 mm. in diameter and the term silt is used to denote an aggregate of mineral of rock grains greater than 1/25 mm. and less than 1/16 mm.

The sandstone in Wind Canyon although massive, in general appearance, contains zones of delicate cross bedding that are associated with concretions of marcasite. The concretions although widespread in the upper portion of the sandstone constitute merely a trace of the mass. The largest concretion seen in Wind Canyon is six inches long and three inches across.

The color of the Wind Canyon sandstone is essentially gray, although it has many black minerals in its matrix as well as fine grain sizes, ranging from approximately .038 mm. to 1 mm.

Although the sandstone in Wind Canyon is loosely cemented, there are small aggregates made up of three or more grains which are well indurated with a cement that was not broke down, as strong acid was needed and the acid would probably have effected the minerals.

The sandstone in Wind Canyon is surrounded by red clinkers, which were formed by the fusing and baking of sands and shales and clays when a bed of lignite immediately underlying them burned except on the northwest side where the canyon opens towards the Little Missouri River.

An 80 pound composite sample of the Wind Canyon sandstone was collected by Mr. Chester Brooks, of the National Park Service for investigation by the writer. The sample was coned and quarted and a mechanical analysis made as described below.

PREPARATION FOR MECHANICAL ANALYSIS

As the Wind Canyon sandstone is a loosely cemented sandstone, it was only necessary to roll it with a wooden rolling pin, applying slight pressure to the rolling pin. In disaggregating the sandstone for mechanical analysis, caution was taken to insure that the grains were not broken. The grains were inspected before and after they were disaggregated.

The 80 pound composite sample which was for envoirnment studies, was first coned and quartered. Opposite quarters were combined and the process repeated until the sufficiently small sample, which was to be placed in a Jones sample splitter, was obtained. The sufficently small sample was placed in a Jones sample splitter, which consists of a hopper and a series of inclined chutes leading alternating to two pans placed on opposite sides of the apparatus. The sample was poured into the hopper using a rectangular pan, the width of which is equal to the width of the set of chutes. The sample is split to the desired size by resplitting the right and left hand halves alternately and the process repeated until the sufficently small split was obtained. (All sufficiently small splits were obtained by the same procedure). The sufficiently small split, which was used for the mechanical analysis weighed 101.57 grams. The representative sample (a sufficiently small split) weighing 101.57 grams was placed in the top sieve of a set of seives, however, before this was done, 1000 grams of the sample was used to test the seives to see which seive would allow the largest amount of the sample to pass through. This was done by picking a sieve which would not allow an appreciable amount of the sample to pass through it and then pouring the sample in the next sieve smaller all but a few grains to pass through it. This process was repeated until a sieve was found which would allow all but a few grains to pass through. The sieve which allowed the largest amount of the sample to pass through was placed under a sieve having a scree opening of .046 inches (1.168 mm.) was used as a top sieve in the set of sieves used in the mechanical analysis. Tyler sieves for closer sizing were used. The Tyler Standard Screen Scales Sieves having screen openings from .046 inches (1.168 mm.) to .0017 inches (.043 mm.) were used. Twenty one sieves were needed. The sieves were stacked in four sets, which consisted of one set of six and three sets of five. These seives were stacked with the largest sieve opening on the top and the remainder

of the sieves placed in decreasing order according to the sieves openings. Six sieves made up the first set, five sieves made up the second, third and fourth sets. The representative sample having a weight of 101.57 grams was placed in the top sieve having a screen opening of .046 inches (1.168 mm.) and the first set of sieves which consisted of six sieves was placed in the Ro-Tap Testing Sieve Shaker, and allowed to run for ten minutes. The sample portion in the pan which was on the bottom of the bottom sieve of the first set of sieves was poured into the top sieve of the second set of sieves having as its top sieve the next size smaller than the bottom sieve of the first set. This process was repeated until it became evident that no more sieves were needed. The portions of the representative sample retained in each sieve pan was weighed and this information used below. Two such representative samples were sieved and the remainder of the set of sieves placed in decreasing order according to the sieve openings.

HEAVY MINERAL ANALYSIS

Apparatus:

The only equipment needed for the heavy mineral separation was bromoform, a 100-110 $^{\circ}$ C thermometer, pinch clamp, filter paper, two glass funnels, ring stand, a buret clamp, two watch glasses, rubber tubing, and a Pasteur Chamberland filter.

Procedure:

Bromoform, having a specific gravity of 2.85, was poured into the upper funnel, after which a weighed amount of dry sediment was placed in it and thoroughly stirred; and the heavier minerals were then drawn off onto the filter paper in the lower funnel by opening the pinch clamp.

Several attempts were made to complete a heavy mineral analysis but they were unsuccessful. The sand flacculated in the fromoform which was in the top funnel and only a few of the heavier minerals sank to the bottom. When

an attempt was made to draw off the heavy minerals, the light and heavy minerals came down together. As foreign electrolytes was thought to be present, it was necessary to try to eliminate these electrolytes. Attempts were made to eliminate these electrolytes by using one normal and five normal solutions of sodium oxalate, however, these attempts were not successful.

Conclusion:

One of the simplest methods available for washing sediments is by means of Pasteur Chamberland filters according to Krumbein and Pettijohn (1938) Manuel of Sedimentary Petrography, p. 67. However, the equipment was not available, thus the probable soluble salts were not washed away and a heavy mineral analysis was not made. The soluble salts were suspected as the sediment is high in calcium carbonate and flocculation was apparent. These foreign electrolytes are believed by the author to have played an important role in the sorting of the sediment.

STANDARD METHOD OF TEST FOR
COAL AND LIGNITE IN SAND

Procedure:

This method of test covers a procedure for the approximate determination of coal and lignite in the routine laboratory examination of sands. This method separates along with the coal and lignite other particles of low specific gravity, such as small pieces of wood, vegetable matter, etc.

Apparatus:

(a) Balance-A balance having a capacity of at least 200 g. and sensitive to 0.01 g. A less sensitive blance may be used in wighing the wet sample.

(b) Container - A container suitable for drying the sand sample.

(c) Beakers - Two 400-ml. tall form, lipped beakers.

(d) Wire Gauze or Sieve - Wire gauze or a small sieve having about thirty openings per inch. A piece of wire gauze would probably be more suitable than a sieve.

(e) Hot Plate or Oven.

Procedure:

A quantity in excess of 200 g. of sand (sampled wet) was dired to constant weight at a temperature of approximately 105 C. A 200-g. sample of the dired sand was weighed to the nearest 0.01 g. The sample was then poured slowly into about 250 ml. of a liquid having a specific gravity of 2.0 contained in one of the 400-ml. beakers. The liquid was then poured off into the second beaker passing it through the gauze or sieve. Care was taken that only the floating particles were poured off with the liquid and that none of the sand was decanted onto the gauze or sieve. The liquid collected in the second beaker was then returned to the beaker containing the sand, and, after further agitation of the sample by stirring, the decanting process just described was repeated until the sample was ffee of floating particles. The decanted particles contained on the gauze or sieve was washed in carbon tetrachloride, until the floatation liquid is removed, and then dired. The particles will dry very quickly, but may be placed in an oven at 105 C for a few minutes if desired. The decanted particles was then brushed from the gauze or sieve into the balance pan and the weight accurately determined to the nearest 0.01 g.

Calculation:

The approximate percentage of coal and lignite was calculated from the following formula:

Coal and lignite, per cent =

$$\frac{\text{Wt. of decanted particles}}{\text{Wt. of dry sample (200 g)}} \times 100 = \frac{.000021 \text{ gr.}}{200 \text{ grs.}} = .0000105 \text{ or } 1.05 \times 10^{-5}$$

Bromoform and acetone was used to obtain a mixture having a specific gravity of approximately 2.0 as described below:

100 ml. of acetone was weighted and its specific gravity determined as follows:

$$\text{specific gravity of acetone} = \frac{\text{weight of 100 ml. of acetone at } 20^\circ \text{ C}}{100} = \frac{78}{100} = .78$$

100 ml. of bromoform was weighed and its specific gravity determined as follows:

$$\text{specific gravity of bromoform} = \frac{\text{weight of 100 ml. of bromoform at } 20^\circ \text{ C}}{100} = \frac{285}{100} = 2.85$$

wt. of 100 ml. of bromoform = 285 gm.

wt. of 69.7 ml. of acetone = 54.366 gm.

wt. of 169.7 ml. of bromoform and acetone = 339.366 gms.

$$\text{Specific gravity of mixture} = \frac{339.366 \text{ gms.}}{169.7 \text{ mls.}} = 1.9997$$

Conclusion:

Pure bromoform has a specific gravity of 2.87 at ordinary laboratory temperature (20°C). 20° C = 68° F.

100 ml. of bromoform was weighed when the laboratory temperature was 68° F and the specific gravity of bromoform was determined to be 2.85. This low value of 2.85 can probably be attributed to the fact that the bromoform was used in other heavy mineral analysis and the bromoform probably reacted with one or more of the elements contained in the minerals analyzed causing the lowering of the specific gravity of the bromoform itself.

As there are lignite beds in the area, it was suspected small fragments of lignite would be transported by wind or water to the immediate area of the Wind Canyon sand and be deposited.

INSOLUBLE RESIDUE ANALYSIS

A representative sample of sand weighing 119 grams was placed in a beaker and digested in dilute hydrochloric acid, (3N.) until the carbonates were dissolved. The residure was washed, dried, and weighed.

$$\frac{\text{Weight retained}}{119 \text{ gms}} \times 100 = \text{percent insoluble residue} = \frac{89}{119} \times 100 = 74.79$$

Conclusion:

As insoluble residue occurs in typical associations or relative abundances their percentages can be used for correlation purposes.

STANDARD METHOD OF TEST FOR

ORGANIC IMPURITIES IN SANDS FOR CONCRETE

General Procedure:

This method of test covers the procedure for an approximate determination of the presence of injurious organic compounds in natural sands which are to be used in cement mortar or concrete. The principal value to the test is to furnish a warning that further tests of the sands are necessary before they are approved for use.

Sample:

A representative test sample of sand weighing about 1 -lb. was obtained by quartering.

Reference Standard Color Solution:

A reference standard color solution was prepared by adding 2.5 ml. of a 2 per cent solution of tannic acid in 10 per cent alcohol to 97.5 ml. of a 3 per cent sodium hydroxide [1] solution.

---

[1] Where chemically pure sodium hydroxide is not available, commerical soda lye may be used.

This was placed in a 12-oz. bottle, stoppered, shaken vigorously, and allowed to stand for 24 hr.

Procedure:

(a) A 12-oz. graduated clear glass bottle was filled to the $4\frac{1}{2}$ -oz. mark with the sample of the sand to be tested.

(b) A 3 per cent solution of sodium hydroxide [3] in water was added until the volume of the sand and liquid indicated after shaking was 7 liquid ounces.

After standing 24 hr., the color of the clear liquid above the sample was compared with the color of the reference standard color solution prepared at the same time and in accordance with the standard color solution reference or with a glass having a color similar to the color of the reference standard solution. Solutions darker in color than the reference standard color have a "color value" higher than 500 ppm. in terms of tannic acid. The test results were negative.

Conclusion:

The author conclused that more evidence is needed to imply that organixms did not occur at one time or another among the sand. However, the author suspects that the sand has a high salinity. The fact that most of the sediment is sand may account for a lower organic content not detectable by the method used, also, the light color of the sediment may suggest a sediment low in organic matter according to Pettijohn, F.J. (1949) Sedimentary Rocks, p. 118 and 175.

CHEMICAL COMPOSITION

A chemical analysis is being made and the results will be attached to this paper later.

TABLE I

Mineral-Stability Series in Weathering
(After Goldich)

Olivine	Calcic plagioclase
Augite	
Hornblende	Calcic-alkalic plagioclase
Biotite	Alkali-calcic plagioclase
Potash feldspar	Alkalic plagioclase
Quartz	

TABLE II

Minerals found in Wind Canyon sand.

3%	Olivine	4 pieces	Chlorite
traces	Augite	2%	Apatite
4%	Hornblende and pyroxene	traces	Limonite
8%	Biotite	4 pieces	Hematite
2%	Orthoclase	traces	Magnetite
traces	Muscovite	2 pieces	Schist
3 pieces	Talc	2 pieces	clear plagiclase (Oligoclase)

80% varieties of quartz: rose, smoky and clear
1 piece red quartzsite
7 pieces limestone: 4 pieces striated, 3 pieces not striated

Conclusion:

The minerals found above suggest that the Wind Canyon sand is a not mature sand and it probably has not been reworked to any great degree. However, about 3% of the sample was in the silt size and it is believed that the majority of the silt size material is reworked material. Also, there may have been slight tectonic movement in the source area of the feldspar as indicated by its presence. The striations on the four limestone grains suggest that transportation and deposition were inadequate to erase these features.

TABLE III

SAMPLE NO. A

Wentworth Scale	Screen No. Mesh	Screen Opening (mm.)	Weight Retained grams	*Percent	*Cumulative Percent
	14	1.168	0	0	0
1	16	.991	.058	.08	.08
	20	.833	.117	.136	.22
	24	.701	.095	.115	.33
	28	.589	.103	.122	.45
1/2	32	.495	.294	.310	.76
	35	.417	.287	.302	1.06
	42	.351	.415	.430	1.49
	48	.295	1.010	1.014	2.50
1/4	60	.246	2.524	2.5040	5.00
	65	.208	5.658	5.5800	10.58
	80	.175	10.250	10.1000	20.68
	100	.147	32.372	31.982	52.66
1/8	115	.124	19.109	18.831	71.49
	150	.104	15.306	15.091	86.58
	170	.088	5.646	5.572	92.15
	200	.074	1.916	1.908	94.06
1/16	250	.062	1.356	1.354	95.41
	270	.053	0.647	0.658	96.07
	325	.043	0.827	0.8361	96.81
	400	.038	3.149	3.120	100.03
		Total	101.139	100.0	

Weight original sieving sample 101.570 grams
(Subtract) Total wt. retained 101.139 grams
Sieve loss .431 grams
Sieve loss .424%

* Corrected values after weights were adjusted. All other figures are raw data.

TABLE IV

SAMPLE NO. B

Wentworth Scale (mm.)	Screen No. Mesh	Screen Opening (mm.)	Weight Retained Grams	Percent	*Cumulative Percent
	14	1.168	0	0	0
1	16	.991	0.041	.10	.10
	20	.833	0.056	.11	.21
	24	.701	0.060	.12	.33
	28	.589	0.067	.12	.45
1/2	32	.495	0.152	.24	.69
	35	.417	0.321	.37	1.06
	42	.351	0.400	.45	1.51
	48	.295	0.547	.59	2.10
1/4	60	.246	1.955	1.99	4.09
	65	.208	5.126	5.06	9.15
	80	.195	10.177	9.93	19.08
	100	.147	35.057	34.05	53.13
1/8	115	.124	17.472	17.04	70.17
	150	.104	15.711	15.25	85.42
	170	.088	6.023	5.92	91.34
	200	.074	2.408	2.39	93.73
1/16	250	.062	1.900	1.90	95.63
	270	.053	0.998	1.02	96.65
	325	.043	1.143	1.17	97.82
	400	.038	2.172	2.13	99.95
	Total		101.786	100.00	

Weight original sieving sample 103.201 grams
(Subtract) Total wt. retained 101.786 grams
Sieve Loss 1.415 grams

Sieve Loss 1.370%

* Corrected values after weights were adjusted. All other figures are raw data.

TABLE V

Sample No. A

f= frequency
m= mid point
Ma = arithmetic mean
Qa = standard deviation
% = percent
wt = weight
mm = millimeters

Grade size mm.	wt. % frequency (f)	m	fm	m-Ma	$(m-Ma)^2$	$f(m-Ma)^2$
1.168 -.991	.078	1.028	.0803	.8613	.740	.0577
.991 -.833	.136	.912	.124	.7457	.553	.0753
.883 -.701	.114	.767	.0874	.6003	.360	.0412
.701 -.589	.122	.645	.0787	.4783	.228	.0278
.589 -.495	.310	.542	.168	.3753	.142	.0440
.495 -.417	.302	.456	.1378	.2893	.0834	.0252
.417 -.351	.430	.374	.162	.2073	.0428	.0185
.351 -.295	1.014	.323	.3278	.1563	.0244	.0248
.295 -.246	2.504	.270	.675	.1033	.0106	.0265
.246 -.208	5.580	.227	1.268	.0603	.0036	.0203
.208 -.175	10.100	.191	1.928	.0243	.0054	.0596
.175 -.147	31.982	.161	5.15	.0057	.0003	.0010
.147 -.124	18.831	.135	2.539	.0317	.0010	.0188
.124 -.104	15.091	.114	1.720	.0527	.0028	.0418
.104 -.088	5.572	.098	.546	.0687	.0047	.0262
.088 -.074	1.908	.081	.1546	.0857	.0073	.0140
.074 -.062	1.354	.068	.922	.0987	.0097	.0130
.062 -.053	0.658	.057	.0376	.1097	.0120	.0079
.053 -.043	0.836	.048	.0402	.1187	.0140	.0147
.043 -Pan	3.120	*.040	.1275	.1267	.0160	.0499
Totals	100.042		16.6738			.6050

* arbitary value assuming pan size to be .038 mm.

$Qa = \sqrt{\frac{.6050}{100}} = .0778$ mm $Ma = \frac{16.67}{100} = .1667$ mm approx.

TABLE VI

Sample No. A

Mean Deviation

Grade Size	f	m	(m-Ma)	f(m-Ma)
1.168 - .991	.078	1.028	.8613	.067
.991 - .833	.136	.912	.7453	.101
.833 - .701	.114	.767	.6003	.068
.701 - .589	.122	.645	.4783	.058
.589 - .495	.310	.542	.3753	.116
.495 - .417	.302	.456	.2893	.087
.417 - .351	.430	.374	.2073	.089
.351 - .295	1.014	.323	.1563	1.585
.295 - .246	2.504	.270	.1033	.259
.246 - .208	5.508	.227	.0603	.336
.208 - .175	10.100	.191	.0243	.245
.175 - .147	31.982	.161	-.0057	-.182
.147 - .124	18.831	.135	-.0317	-.597
.124 - .104	15.091	.114	-.0527	-.795
.104 - .088	5.572	.098	-.0687	-.383
.088 - .074	1.908	.081	-.0857	-.164
.074 - .062	1.354	.068	-.0987	-.134
.062 - .053	0.658	.057	-.1097	-.072
.053 - .043	0.836	.048	-.1187	-.099
.043 - Pan	3.120	*.040	*-.1267	-.395
Totals	100.042			-0.407

$$d_a = \frac{0.407}{100} = .0041 \text{ mm}$$

QUARTILE AND MOMENT MEASURES

Table 7

Arithmetic Mean (Ma)	= .1667 mm.
Sorting coefficient (So)	= 1.2 mm. well sorted
Standard Deviation (Qa)	= .0778 mm.
Modal diameter (Mo)	= .149 mm.
Median (Md)	= .147 mm.
Mean deviation (da)	= .0041 mm.
First quartile (Q_1)	= .173 mm.
Third quartile (Q_3)	= .120 mm.
90 percentile (P_{90})	= .094 mm.
10 percentile (P_{10})	= .213 mm.

The most significant values above are the sorting coefficient, the modal diameter, the median and the mean deviation. The modal diameter and the median have approximately the same values thus 50% of the sand is found above .147 mm and 50 % is found below.

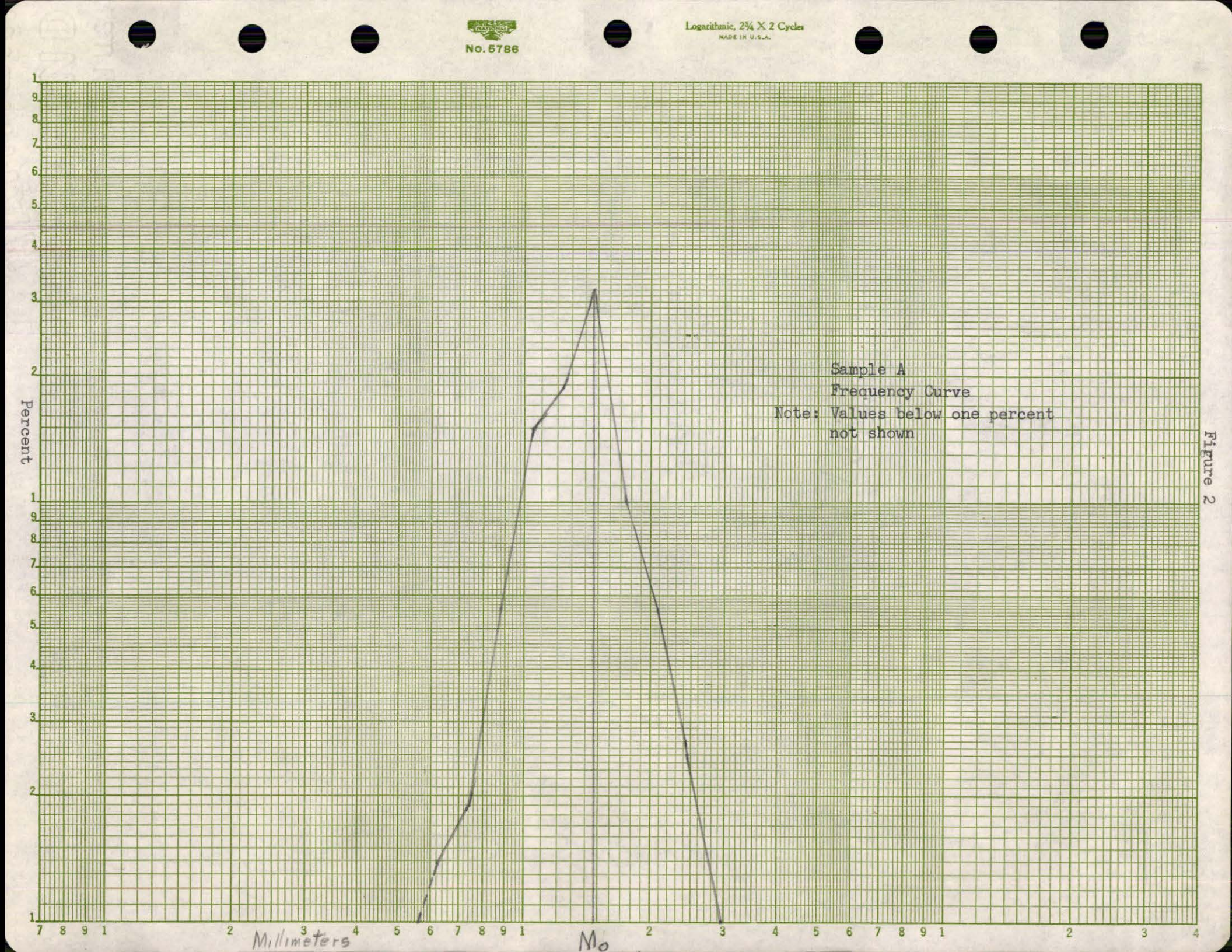
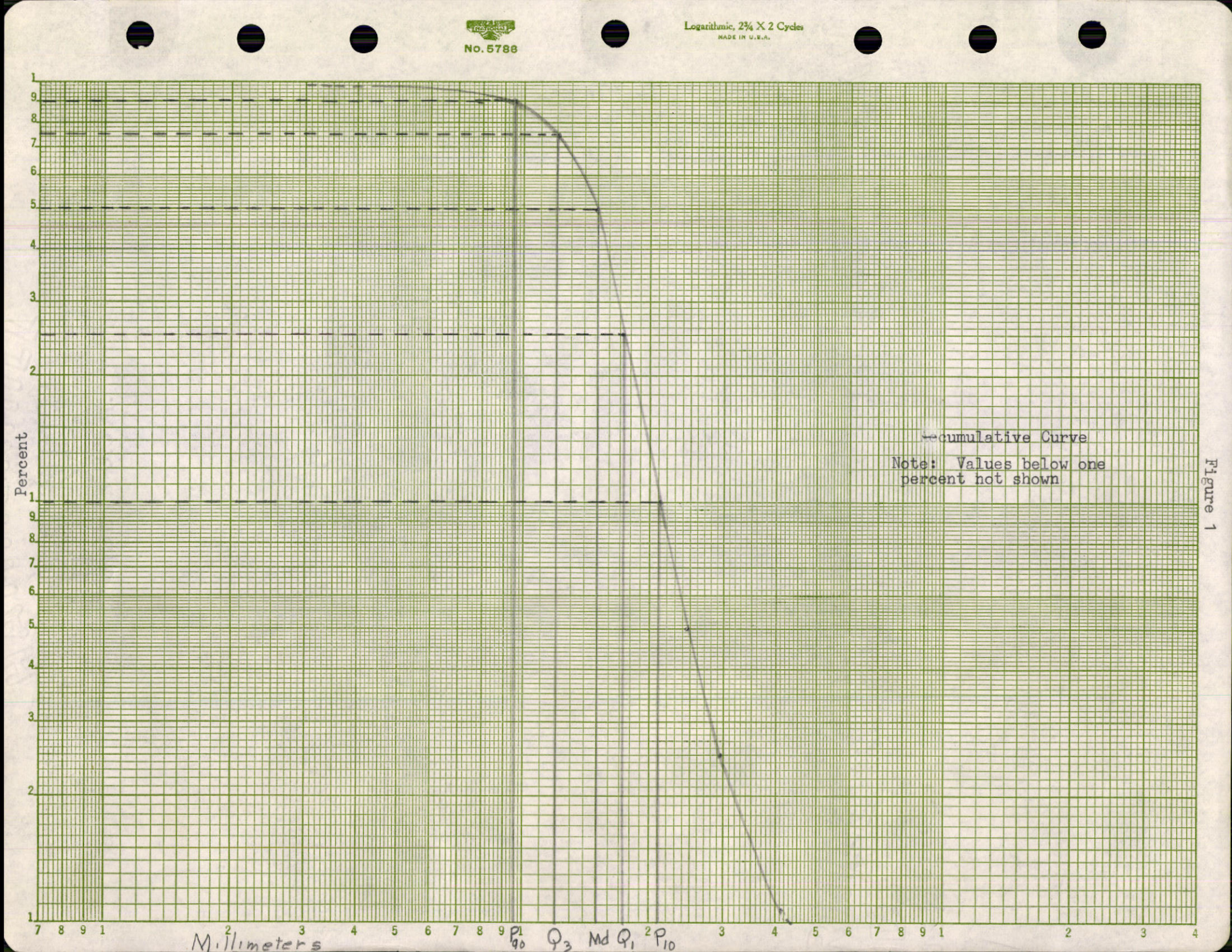

No. 5786
Logarithmic, 2¾ X 2 Cycles
MADE IN U.S.A.
Percent
Millimeters
Mo
Sample A
Frequency Curve
Note: Values below one percent
not shown

Figure 2


No. 5788
Logarithmic, 2¾ X 2 Cycles
MADE IN U.S.A.
Percent
Millimeters
P_{90}
Q_3
Md
Q_1
P_{10}
—cumulative Curve
Note: Values below one percent not shown
Figure 1

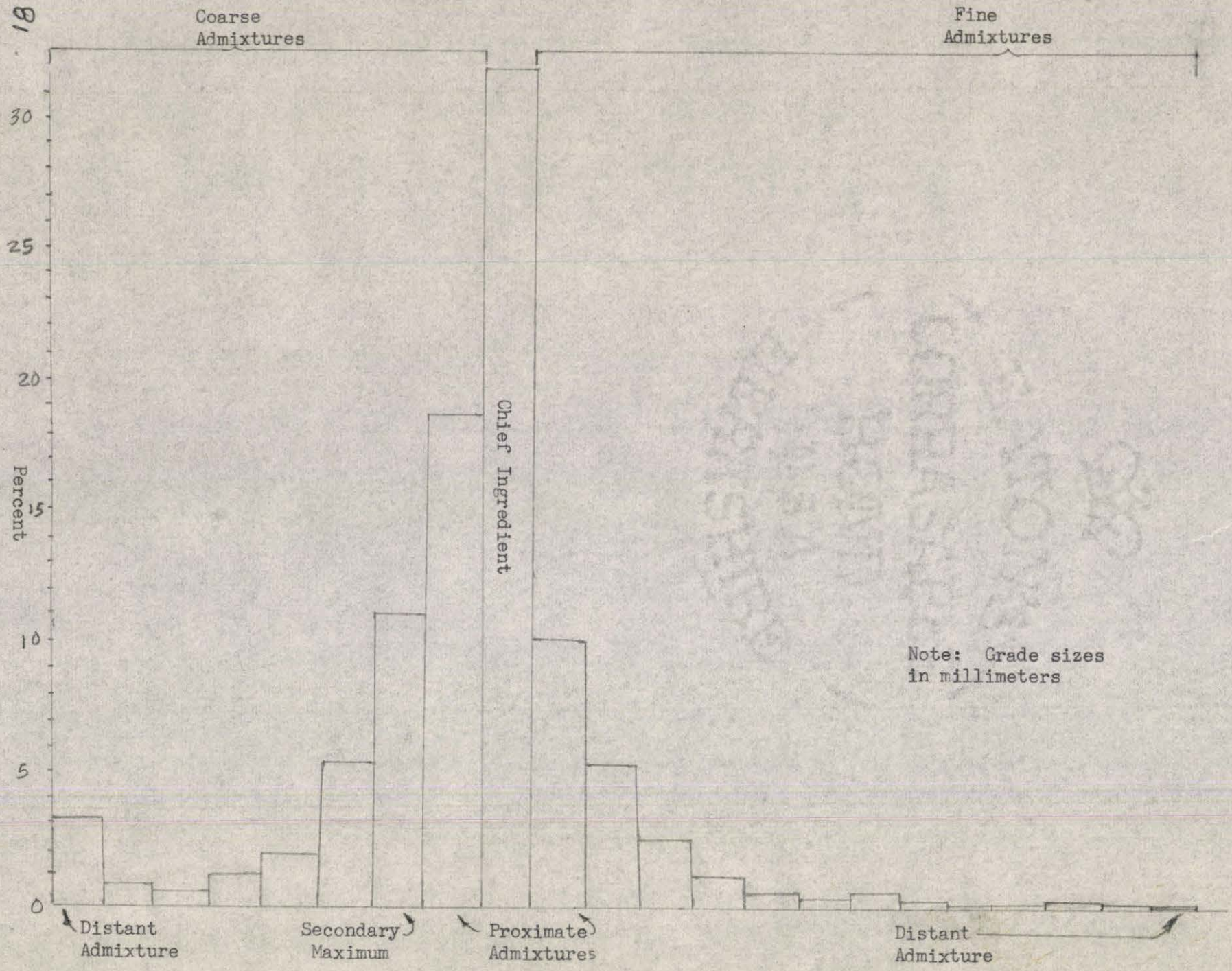

Coarse
Admixtures
Fine
Admixtures
30
25
20
15
10
5
0
Percent
Chief Ingredient
Note: Grade sizes
in millimeters
Distant
Admixture
Secondary
Maximum
Proximate
Admixtures
Distant
Admixture

Figure 3

DESCRIPTION OF CUMULATIVE CURVES

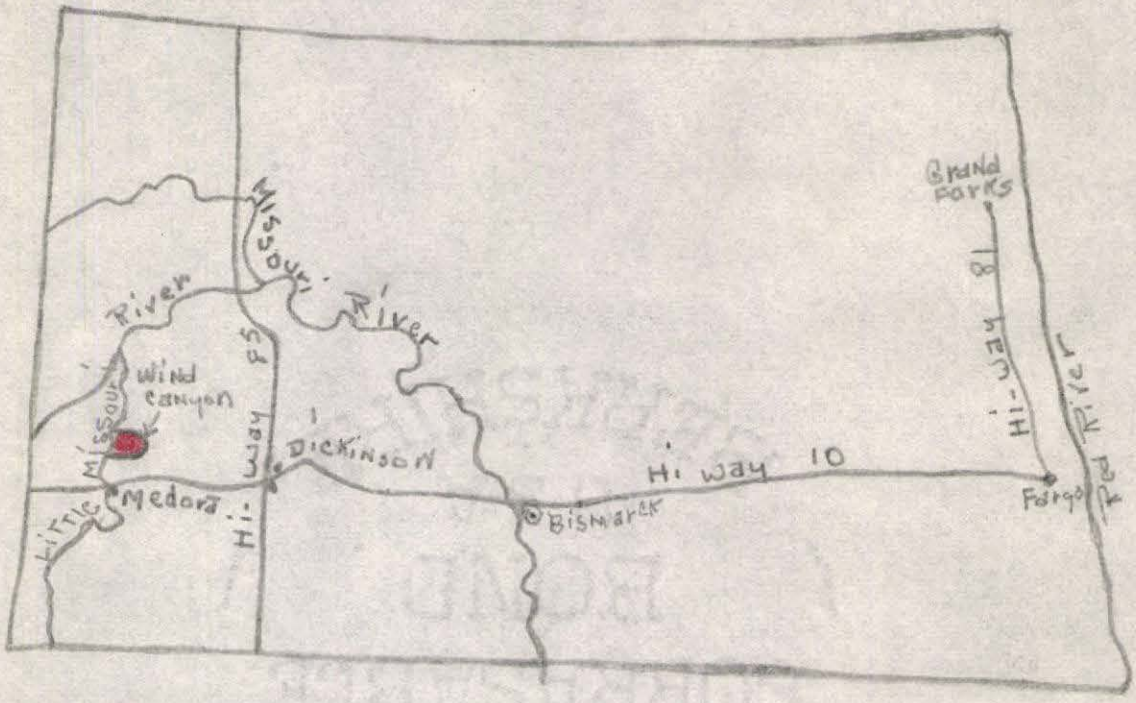
The curve is essentially a straight line between 1 and 50%. The screen openings are plotted to the logarithm of the diameter of the opening (the ratio between the sizes being a constant), thus horizontal scale of screen opening are one of equal spaces and do not increase or deminish in the same ratio as that of screen openings. From the 50% point up to 100 % point the line is curved. This is caused by consecutively decreasing amounts of sand retained in each grade size and the fact that the median (.149 mm.) and the modal diameter (.147 mm) have almost the same value, thus allowing them to maintain the same position with essentially the same pattern above and below the median.

The three percent of the sand which is below .043 mm. is grouped together in one size. This can be attributed to the fact that no smaller sieves were available.

DESCRIPTION OF FREQUENCY CURVE

It can be seen by the frequency curve the most aboundant grains are associated with the inflection point. The inflection point of a curve is according to Krumbein and Pettijohn, (1938), Manuel of Sedimentary Petrography, p. 192, the point of maximum slope of the tangent. It is the point where the tangent to the curve changes its direction of rotation. It may accordingly be located by moving a ruler along the curve so that is is always tangent to it, until the point is reached where the directions of rotation of the ruler reverses itself.

Fig. 4



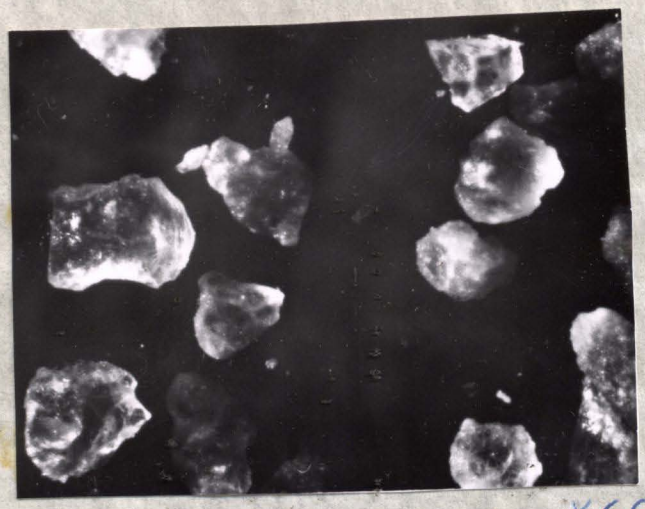
Wind Canyon

Index Map of North Dokata Showing Outline of Wind Canyon, Theodore Roosevelt National Park.

Wind Canyon is approximately 2.3 miles down stream (north) from the point where the Little Missouri River passes under Highway 10 in Medora, North Dakota, and 1.15 miles down stream from the park headquarters. Also, it is located on the east bank of the Little Missouri River.

MODAL SIZE of SAND

Figure 5



X60

The grain sizes of the sand shown above varies between .147 and .175 millimeters and the magification of these grains are 60. It can be seen in the photo above that the sphericity is low and the roundness varies from angular to sub rounded and there are numerous sharp corners of several of the grains. These sharp corners along with the composition suggest that the sand is an immature sand.

SUMMARY

The Wind Canyon Sand has twenty one grade sizes ranging from approximately .038 millimeters to 1 millimeter as determined by mechanical analysis using the fourth root of two scale ($\sqrt[4]{2}$). The sand is well sorted and the mode and the median have approximately the same values. The mineral composition showed essentially immature minerals according to Goldlick's Mineral Stability Chart and these same minerals have high angularity and some of the mineral grains are fractured, others are frosted and a few are striated.

The sandstone is well indurated in Wind Canyon, yet weathering has effected this lenticular sandstone body and has considerably weathered away a large portion of it. Calcium carbonate and gysum are just two of the cementing materials in the sand. The apparent high permeability and high porosity played an important role in weathering as did the agents of chemical and mechanical weathering.

CONCLUSION

The information in this paper is not adequate to give the origin of the Wind Canyon Sandstone. However, the data obtained can be used as tools when a more detailed field and laboratory research is made.

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