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Analysis of Pleistocene Deposits from Kidder County and Stutsman County, North Dakota

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Report on

ANALYSIS OF PLEISTOCENE DEPOSITS OF KIDDER AND STUTSMAN COUNTIES, NORTH DAKOTA

Submitted to
Mr. Gillett

SENIOR THESIS REQUIREMENT

May 27, 1960

by?- Gary Saunders.

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ANALYSIS OF PLEISTOCENE DEPOSITS FROM KIDDER COUNTY AND STUTSMAN COUNTY, NORTH DAKOTA

I INTRODUCTION

A. Purpose of Report

¶The general purpose of this report is to differentiate Pleistocene (as used by Flint 1957, P. 10)* deposits in Kidder County and Stutsman County, North Dakota, utilizing various laboratory techniques of sedimentary lithologic studies. The value of this work is limited to some degree by the small number of samples and by the fact that these samples were randomly taken from the surface. The author received eight samples from various locations within Kidder County. These samples were furnished by the following University of North Dakota students: LeeClayton, James Chmelik, and Wallace Bakken. The two samples from the Cleveland Quadrangle in Stutsman County were furnished by Dr. Mark Rich.

¶The samples were first sieved, using 200 grams of each of the ten samples. Cumulative curves were drawn to show the distribution of grain sizes. Following this the author selected that fraction of the sample trapped between the Wentworth grade sizes

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* Pleistocene ~~which~~ includes all deposits laid down after the Pliocene.

0.125 and 0.250 mm. Where this size was in overabundance, a microsplitter was used to obtain a quantity weighting exactly 10 grams. A heavy mineral analysis was then conducted. The light minerals were separated from the heavier minerals in bromoform, a liquid having a specific gravity of 2.87. The heavy and the light minerals were collected in separate filter papers and weighed. The percentage of each, as compared to the original 10 grams, was calculated. The light minerals from this separation were split again until a very small quantity was obtained. These minerals were then mounted on slides and subjected for ten minutes to the fumes of hydrofluoric acid in a closed container. Then each slide was treated with a sodium cobaltnitrite solution and allowed to stand for two minutes, after which the slides were washed and permitted to dry. The slide was then treated with a solution of 0.5 percent eosine "B". This treatment was continued for 3 minutes before washing. It was then possible to distinguish the potash feldspars, the soda-lime feldspars and the quartz under a binocular microscope. The potash feldspars were stained an orange-yellow color, while the soda-lime feldspars were stained pink. Quartz appeared clear. Using a small grid under each slide, a count was made of the soda-lime feldspar grains, the potash feldspar grains, the quartz grains, and all other mineral grains. The percentage of each with regard to the (total number of grains) was calculated.

The heavy minerals, which were always less in quantity than the lighter minerals, were then subjected to a magnetic separation. An electromagnet was used, whereby only the extremely magnetic minerals were segregated. The ratio of magnetic to non-magnetic minerals was then formulated by volume, as the samples were too small to weigh accurately.

As a last step in further examining the samples, a pebble count was made of those fragments too large to pass through the 2 mm. Wentworth sieve. These fragments were split to a number which could be conveniently counted to determined general rock types. These rock types include: Carbonates (Limestone and dolomite), Igneous-metamorphic and Mudstone (including clay, silt, siltstone, claystone, shale and argillite).

All the data from each sample was then compared with other samples and conclusions were drawn as to differences. The author attempted to correlate the samples from Stutsman county and Kidder County, on the basis of these analysis.

B. Brief outline of the Glacial Geology of North Dakota

The two main workers on the Glacial geology of North Dakota to date have been Richard W. Lemke and Roger B. Colton of the United States Geological Survey. In the following discussion, the author will draw heavily from their published work (Lemke and Colton, 1958). Some mention of Flint's terminology (Flint, 1955) will also be mentioned. Classification of drift sheets in the midwest by others will be ignored as they confuse rather than clarify the situation in North Dakota.

According to Lemke and Colton (p. 45) there were seven distinct advances of glacier ice in North Dakota, as evidenced by the positions of prominent end moraines and ice marginal channels, by cross cutting relations of washboard moraines, drumlins, and eskers, and by the relative development of integrated drainage. The glacial drift of North Dakota has posed a problem in correlation with the surrounding states. The following is one of the classifications of the substages of the Wisconsin ice stage (from oldest to youngest) as used by Lemke and Colton (p. 46).

(1) Iowan (?) drift
(2) Tazewell (?) drift
(3) post - Tazewell - pre - Two Creeks drift
(4) post - Cary maximum drifts

The post - Cary drifts have been further subdivided according to glacial advances numbered from one to four or from oldest to youngest respectively, as evidenced by various topographic features. There is little evidence of pre-Wisconsin ice advances in North Dakota.

Iowan (?) drift

The Iowan (?) glaciers are thought to have advanced farthest, depositing a drift sheet which is exposed chiefly in the area south of the Missouri River (Fig. 2). This sheet generally ranges from 20 to 40 miles in width. The advance of the ice over much of the area can be attested to only by the presence of erratic boulders and scattered stratified ice-contact deposits. The till over most of this belt is thin and patchy owing to erosion and nondeposition. The orientation of the drift border and the position of the ice-marginal channels suggest that ice of this substage advanced from a northeasterly direction.

Tazewell (?) drift

Lemke and Colton interpreted the area lying mostly north and east of the Missouri River (Fig. 2) forming a belt 15 to 30 miles wide, as that of the Tazewell (?) drift sheet. The ice of this drift sheet seems to have advanced from the northeast except in the northwestern part of the state where the advance is indicated from the position of moraines to have been from the north and northwest. Most of this area of Tazewell (?) drift (thin to moderately thick) is characterized by well-developed integrated drainage. It has been argues that the Tazewell (?) and the Iowan (?) substages are one and the same, but Lemke and Colton believe that these are separate substages of the Wisconsin with the Krem moraine (Fig. 2) and other smaller moraines in the area being end moraines marking the greatest extent of the Tazewell substage.

Post Tazewell - pre - Two Creeks drifts

The Burnstad, Belden, White Earth, and Alamo moraines represent a series of prominent northwest-trending end moraines (Fig. 2), that extend from the south-central to the northwestern part of the state. These moraines mark the margin of a drift sheet whose youthful topography is in marked contrast to the Tazewell (?) drift to the southwest. There are many hummocky moraines and associated ground moraine deposits ~~associated with~~ in this drift and the drainage shows little integration in contrast to the well integrated drainage established on the Tazewell (?) drift. This drift appears lithologically to be the correlative of the Mankato drift, of Iowa as used by Leighton (1957, P. 1037-1038). Flint classifies this substage with the A-1 Mankato advance. If this correlation between the Mankato drift in Iowa and the post-Tazewell - pre - Two Creeks drifts exists, then the equivalent of the Cary drift in Iowa is not exposed in North Dakota, but is overlapped by the Burnstad moraine and associated drift.

¶ The outer margin of the drift associated with the Brunstad moraine lies in the southwestern corner of Kidder County and has been dated by C^{14} methods to be of Two Creeks interstadial age. The till underlying the dated material is believed to belong to the drift sheet associated with the Burnstad moraine which therefore, is thought to antedate the Two Creeks interstadial. Although the Cary drift is generally believed absent in North Dakota, there is good evidence what? that this drift is exposed in Kidder County.

Post - Cary Maximum drifts

¶ The Post - Cary Maximum drift is subdivided according to separate ice advances. Flint classifies the Post - Cary as being B-1 Mankato, but Lemke and Colton subdivided the Post - Cary into the following ice advances:

Advance No. 1

Although the Cary is not generally believed to be exposed on the surface in North Dakota, it is believed present in the subsurface~~s~~ and therefore that drift is considered to be deposited after the Cary is termed Post-Cary Maximum. The drift of advance number one is exposed in a northwesterly - trending belt 10 to 15 miles wide in the central and southeastern part of the state (Fig. 2). The Streeter moraine and associated moraines to the northwest mark the drift border of this advance. The positions of the associated end moraines and washboard moraines indicate that the ice advanced from a northeasterly direction but local lobations deviate considerably from this trend. Due to the present lack of knowledge it is difficult to ascertain whether this drift sheet antedates or postdates the Two Creeks interstadial. Because the Cary maximum drift is not believed to be exposed at the surface in North Dakota it can be assumed that the drift of the Streeter moraine is younger than the Cary maximum.

Advance No. 2

A major readvance of ice, after deposition of the Streeter moraine is indicated by the discordance in the trend of the Grace City, Kensal, and Oakes end moraines of this sheet with those of the previous advance. The drift of this advance extends in a belt, 15 to 40 miles wide, from the vicinity of Harvey to near the southeast corner of the state. The positions of the well-defined

Grace City and Kensal moraines and of numerous washboard moraines suggest that the ice advanced as two ~~lakes~~ lobes, one from the northeast and the other from the northwest. These two ~~lakes~~ appear to have been formed contemporaneously as no crosscutting relationships occur.

Advance No. 3

¶ Following the readvance number 2 of the ice and subsequent deposition, the ice retveated and advanced again to deposit the Martin, Heimdal, Cooperstown and Wahpeton moraines. The Martin moraine marks the terminus of the Souris River lobe, the Heimdal moraine the limits of the Leeds lobe, and the Cooperstown and Wahpeton moraines the border of the lobe that pushed down the lake Agassiz Basin into the southeastern part of the State. The Souris River lobe and the Leeds Lobe, which are believed to be essentially contemporaneous, apparently moved down from an ice source in Manitoba and Saskatchewan. This ice sheet advanced from the northwest and split into two lobes when it reached the north flank of the Turtle Mountains (Fig. 1, Fig. 2) just north of the International Boundary. The Souris River ice lobe moved southeastward as shown by the southeast - trending linear drumlins and grooves southeast of Velva, and formed the conspicuous Martin end moraine (Fig. 2). Washboard moraines trending northeast indicate a northwestward recession of the ice front. The other half of the ice sheet, the Leeds lobe, advanced around the east flank of the Turtle Mountains and then spread out radially. This ice lobe formed the prominent Heimdal end moraine. Due to a probable slight readvance of the generally receding front of this lobe, the North Viking moraine was formed. As the margin of the Souris River lobe receded into Canada, glacial Lake Souris, which then occupied only a small area in North Dakota, expanded into southwestern Manitoba. As deglaciation continued additional melt waters flowed down the Sheyenne River and into Lake Agassiz to the east.

Advance No. 4

The last lobe of ice to occupy North Dakota was apparently in the location outlined by a looping discontinuous end moraine in northwest Minnesota and northeast North Dakota with a continuation northwestward into Manitoba. In North Dakota this end moraine has been designated the Edinburg moraine by Lemke and Colton (p. 53). The position of the end moraine segments shows that a southward moving lobe pushed down the Lake Agassiz Basin to as far as Hillsboro, North Dakota in the far eastern portion of the state. The Edinburg moraine and the Holt moraine are said to have been submerged by Lake Agassiz (Leverett, 1932, p. 130-131). Several beaches are shown as crossing the Edinburg moraine in Grand Forks County but, in southern Walsh County it is shown as surrounded by but not completely covered by lake deposits (Leverett, p. 53). The Edinburg moraine definitely truncates a series of washboard moraines (concave to the northwest) in the vicinity of the Pembina delta. There are a number of postulations on whether the Edinburg moraine represents Advance no. 4 of the ice sheet or is possibly pre - Two Creeks in age, but the arguments pro and con will not be discussed in this paper.

C. Brief Outline of Glacial Geology in Kidder County, North Dakota

Two major drifts are believed present in Kidder County. The younger is believed to be post - Cary or Flint's South Dakota B-1 drift (Table 1). The older is post Tazewell - pre - Two Creeks or Flint's South Dakota A-1 drift of the Mankato substage (Table 1). The B-1 advance is represented along the eastern and northern margins of the county (Fig. 3). The A-1 drift, which has been designated as that outwash west and south of the B-1 borderline, has been questioned as being correctly named by Chmelik, Clayton, Bakken and Willaims, who did considerable work in the area during the summer of 1959. They agree that at least part of the area is of A-1 drift, but suggest other portions may be Cary in age due to slight lithologic differences in deposits and field relationships. Where two tills crop out in one exposure in the southern part of the county at the base of Long Lake group, one till is yellower, stickier, and harder than the other tills in the county and has small irregular joints coated with iron and manganese oxide. This till is thought to be possibly of Cary age. This example along with other slight lithologic differences in the outwash and stagnation moraine deposits in the northwestern portion of the state cause some controversy as to possible Cary exposures. It is one of the objects of this paper to see if any marked differences can be observed between the samples collected.

II SAMPLE ANALYSES

For convenience the samples will be referred to by numbers in this discussion. Location of the first eight are indicated on the index map (Fig. 3). Classification of sample and geographical location are indicated on the analys~~e~~s sheets (pp. 19-36)

A. Comparison of size Distribution

The outwash samples numbers 1 - 8 and number 10 show on the cumulative curves pages 37-46 the poor sorting typical of outwash. Sample numbers 1, 2, 4, 7, and 10 have the greatest percentage of the fragments in the Wentworth size range 2 mm. or greater. The other samples show more even distribution of grain sizes with the exception of sample 9 which has the majority of grains ranging between .25 and .062 Wentworth size class. This sample also shows a large amount of clay and silt in comparison to the other samples. Samples 3, 5, 6, 7, and 8 have an infinitely small percentage of grains in the silt and clay range .062 to 0 mm. The distribution of grain size in samples 5 and 6 is very similar. There is a marked difference in the median diameter between samples 1 - 7 and the samples 8 - 10. Those samples 1 - 7 have a median diameter greater than two while samples 8 - 10 have a median diameter less than two.

B. Fine Sand Count

As shown on pages 31-32 , the percentage of potash feldspar indicates approximate equivalency between various samples. Samples 9 and 10 have the lowest percentage (approximately 4.50 percent) of all the samples examined. Samples 3, 4, 5, 6, 7, and 8 have the highest percentage (between 17.86 and 26.79 percent). Samples 1 and 2 have intermediate percentages of 10.66 and 8.53 percent respectively.

The percentage of soda-lime feldspar is the lowest in samples 3, 5, and 9 (15.56 to 3.26 percent), while it is the highest in samples 1, 2, and 10 (39.34 to 62.86 percent). The remaining samples 4, 6, 7, and 8 have an intermediate percentage of soda-lime feldspar (20.54 to 25 percent).

The amount of quartz varies from 20 percent in sample 10 up to 84.53 percent in sample 9. Samples 3, 4, and 6 have approximately equal percentages of quartz (52.33 to 55.56 percent). Samples 1, 7, and 8 also show simalarities in the amount of quartz (32.92 to 44.64 percent). The quartz in samples 2 and 5 varies from 66.85 to 32.92 percent respectively.

The amount of other minerals varies from 3.49 percent in sample

3 to 12.85 percent in sample 10. The percentages of other minerals in the remaining samples range between these two extremes.

C. Magnetic and Non - Magnetic Ratio Comparison

¶ The ratio of magnetic to non-magnetic minerals in the heavy fraction varies from 1/5 in sample 8 to 1/60 in sample 9. (p. 36) Samples 2, 3, 4, 9, and 10 show low percentages of magnetic minerals in contrast to samples 1, 5, 6, and 7 which show very high percentages. Only those minerals which ~~have~~ are ~~fairly~~ highly magnetic ~~tendencies~~ were separated by the electromagnet.

D. Coarse Fraction (Coarser than sand) Counts

¶ The amount of carbonates (p. 33-35) in the coarse fraction is the largest in samples 1, 4, and 6 (greater than 50%) while in sample 10 they are completely absent (pp.33-35). It was impossible to analyze sample 9 by this method because the coarse fraction was too small. The carbonates in samples 3, 2, 7, 8, and 5 were all below 50 percent of the total.

¶ The amount of igneous and metamorphic fragments was low in all samples analyzed. Sample 8 had the largest percentage of igneous and metamorphic fragments (14 percent) while samples 1 and 6 were low with 6 and 8 percent respectively. The remaining samples had amounts between these relative highs and lows.

¶ The amount of mudstone fragments with respect to the total sample was definitely highest in sample 10 (85 percent) while it was lowest in sample 1 (22 percent). Samples 2, 3, 4, 5, 7, and 8 showed nearly equal percentages of mudstone (average of 42 percent). Sample 6 was intermediate between the above values (30 percent).

¶ The other minerals ? present in each sample were extremely low, the highest being in sample 8.

III Discussion of Sample Analys~~i~~es

¶ There are several possible reasons for the differences in size distribution among the samples analyzed. An individual sample may be very characteristic of a certain drift sheet provided it has not been winnowed and sorted by sheet wash or stream action. But outwash! This possibility however, is practically nonexistent as nearly all surface deposits are being acted upon by some erosional agents, such as, water and wind. The geographic and the topographic position of this drift will be the main determining factors in the amount of change this particular drift will undergo. In addition extreme care must be taken by the person sampling in order to get a very representative quantity ? of a particular drift. Thus these samples analyzed will show differences either because of some or all of the above factors or it will be characteristically different due to the type of deposit, ~~it happens to be~~. The outwash samples, as would be expected, were all poorly sorted while the sand dune deposit was fairly well sorted. This dune deposit represents all the finer material which has been separated mainly by wind from the coarser material. It is interesting to note that samples 1, 3, and 8, although shown on the map (Fig. 3) as being from stagnation moraine were classed as outwash when collected and proved indicative of outwash when sieved. Sample 2, although listed on the map (Fig. 3) as being from the Long Lake Loop end moraine, is also outwash and is also characteristically poorly sorted as indicated by the cumulative curve (p. 38). The question arises as to the reason this outwash is present in stagnation and end moraines. The reason is probably due to the intermixing of the drifts caused by the agencies listed previously. ? The small percentage of silt and clay size particles in samples 3, 5, 6, 7 and 8 is largely due to water carrying this size vertically downward into the soil thru time. X The similarity in grain size between samples 5 and 6 is understandable because they are from the same outwash area and have probably been subjected to equal erosional disturbances. The differences noticed in the median diameters of some of the samples can be attributed to the large percentage of fragments in the greater than two mm. fraction, thus causing the cumulative curve to bend accordingly. This is not the case in sample 9, however, where the sample is truly fine grained.

P Sample 9, listed as dune sand, shows a low percentage of potash feldspar and soda-lime feldspar. This is logical because it represents the end product in the erosional cycle whereby the feldspars are almost completely decomposed and the quartz, being very resistant, is preserved. Samples 3, 4, 5, 6, 7, and 8 show a high percentage of potash feldspar, due mainly to the incomplete weathering they have undergone. All are outwash samples from outwash area or stagnation moraine area (Fig. 3). The soda-lime feldspar will be destroyed before the potash feldspar since it is less resistant to decomposition. As is noted on pages 31-32 the same samples are fairly low or very low in soda-lime feldspar. Samples 1 and 2 have intermediate percentages of potash feldspar while are high in soda-lime feldspar and fairly high in quartz. These similarities between the two samples and their distant separation seems to indicate slightly that there may be correlation between the two, but in this case any correlation would be very questionable.

The similarities between the outwash sheet samples (Fig. 3) and the stagnation moraine samples from the northwestern portion of the county poses some questions in the mind of the author as to classifying the stagnation moraine as outwash area also. This, however, would probably be argued when seen in the field. ~~Being that~~ samples 1, 5, 8, 6, and 7 all show high magnetic ratios indicates a probability source area of plutonic rocks. While samples 1, 5, 6 and 7 give indication of a sedimentary source area with a low concentration of magnetic minerals.

¶ The high percentage of carbonates in samples 1, 4, and 6 gives evidence that possibely the source area for samples 1 and 6 besides plutonic may have been in a carbonate area also. The very high amount of mudstone in sample 10 definitely indicates a fine clastic source. The problem of locating the boundaries of the Cary within the presently termed Post - Tazewell pre-Two Creeks drift sheet still remains to be accomplished, however, since the analyses data based on relatively few samples is not sufficient to base definite boundary lines.

CONCLUSION

¶ It is the belief of the author that correlation between equivalent drift sheets and the locating of boundaries of the Cary drift sheet within Kidder County is inadvisable based on this data alone. ~~The reason being that~~ more data is definitely required to make any attempt at correlation. This data would have to be high in quantity and quality to be of usefulness. The samples would have to be obtained from below the surface where the effects of weathering have not been so violent and more samples would be needed to show definite trends. This type of analyses along with various dating devices, field evidence and various other tools will be the key to possible correlation in the future.

LITERATURE CITED

Lemke, R. W., and Colton, R. B. 1958, Summary of Pleistocene Geology of North Dakota: Guidebook 9th Ann. Field Conference; Midwestern Friends of the Pleistocene, N. Dak., N. Dak, Geol. Survey Misc. Series No. 10, p. 41-57

Flint, R. F., 1955, Pleistocene Geology of Eastern South Dakota: U.S. Geol. Survey Prof. Paper 262, 173 p.

Leverett, F., 1932, Quarternary Geology of Minnesota and Part of Adjacent States: U.S. Geol. Survey Prof. Paper 161, p. 1-149.

Flint, R. F., 1957, Glacial and Pleistocene Geology, John Wiley & Sons, Inc., p. ?

No order!

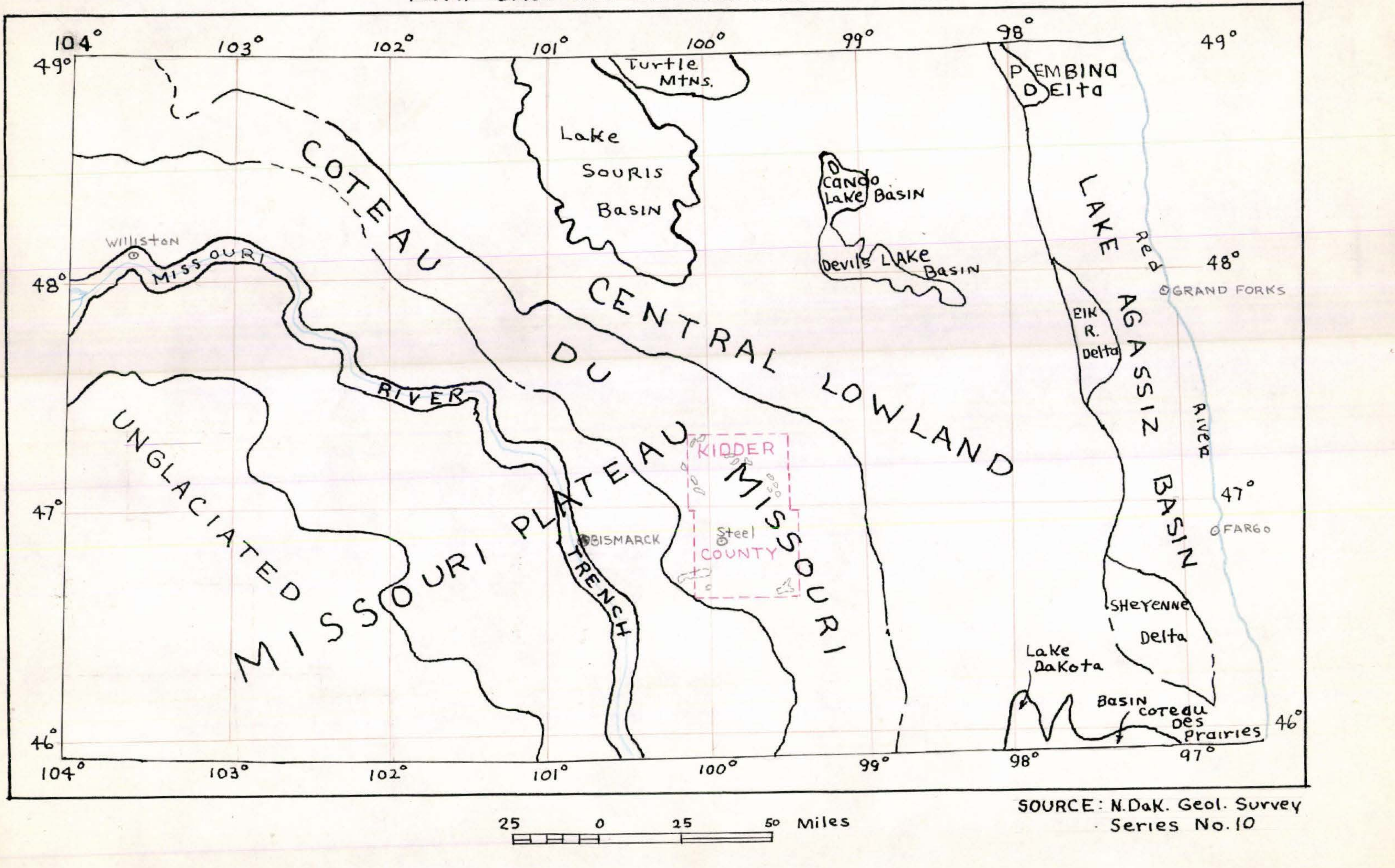
Table 1

VARIOUS CLASSIFICATIONS OF WISCONSIN STAGE

From Lemke and Colton (1958), table 1	From Lemke and Colton (1958), fig. 3)	Flints' usage in S. Dak. (Lemke and Colton 1958, fig. 3)	U.N.D. Students working in the Area - Bakken, Clayton, Williams, Schmelik
Valders substage			
Two Creeks interstadial			
Mankato substage	Post-Cary	B-1 and later Mankato advances	B-1 Mankato advance
	Post-Tazewell-pre-Two Creeks	A-1 Mankato advance	A-1 Mankato advance
Interstadial			
Tazewell substage	Tazewell(?)	Tazewell	Tazewell
Interstadial			
Iowan substage	Iowan (?)	Iowan	

FIG. 1

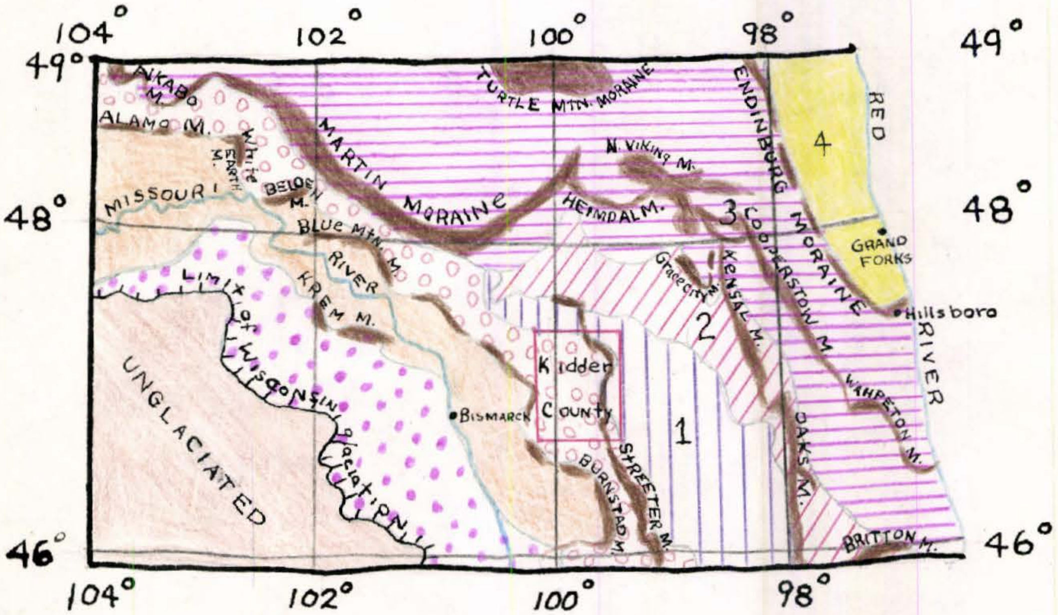
MAP SHOWING PHYSICAL SUBDIVIONS N.DAK



SOURCE: N.Dak. Geol. Survey
Series No. 10

FIG. 2

GENERALIZED MAP SHOWING APPROXIMATE BORDERS OF WISCONSIN DRIFT SHEETS IN N. DAK



LENGEND:

POST-CARY MAXIMUM DRIFTS
ADVANCE NO. 4 4
ADVANCE NO. 3 3
ADVANCE NO. 2 2
ADVANCE NO. 1 1

POST-TAZEWELL-PRE-TWO CREEKS DRIFTS

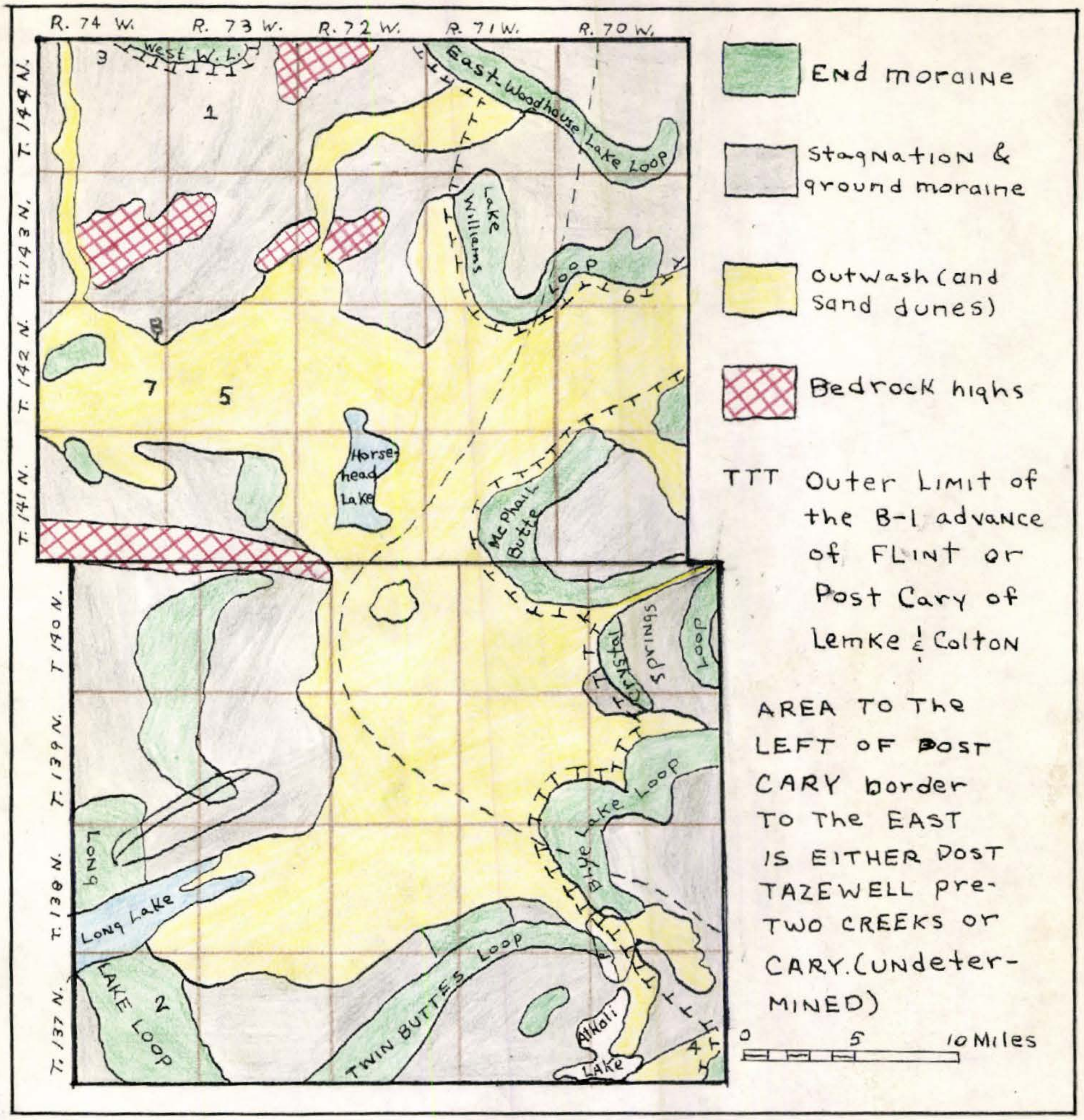
TAZEWELL(?) DRIFT

IOWAN(?) DRIFT

MORAINES

ADAPTED FROM LEMKE & COLTON, SUMMARY OF PLEISTOCENE GEOLOGY N. DAK., GUIDEBOOK MISC. SERIES NO. 10 P. 59

Fig. 3



AREA TO THE LEFT OF POST CARY border TO THE EAST IS EITHER POST TAZEWELL pre-TWO CREEKS or CARY. (UNDETERMINED)

SURFACE GEOLOGY OF KIDDER COUNTY

ADAPTED FROM: CLAYTON, Lee;
PLEISTOCENE GEOLOGY OF
KIDDER COUNTY, N. DAK; 1959
UNPUBLISHED

SIEVE ANALYSIS DATA SHEET

Sample No. 1 Analyst G.R.S. Date 4-15-60

Median 1.70 So. 2.40 Sk. .627

Sand 53.58 % Silt & Clay 2.38 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	88.44g.	.4414	44.14	44.14	
SAND	1.000 to 2.000	23.43g.	.1169	11.69	55.83	
	0.500 to 1.000	29.24g.	.1453	14.53	70.36	
	0.250 to 0.500	33.76g.	.1683	16.83	87.19	
	0.125 to 0.250	17.25g.	.0862	8.62	95.81	
	0.062 to 0.125	3.62g.	.0181	1.81	97.62	
Silt & Clay	0.062	4.63g.	.0238	2.38	100.00	

Location: Wood Lake Loop
NE 1/4, NW1/4, Sec. 16
TwP. 144
RGE. 73

Totals

Difference between original wt. of whole sample and total of wts. retained .37g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 2 Analyst G.R.S. Date 4-15-60

Median 2.30 So. 2.41 Sk. .412

Sand 44.37 % Silt & Clay 2.19 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	107.04g.	.5344	53.44	53.44	
SAND	1.000 to 2.000	24.48	.1222	12.22	65.66	
	0.500 to 1.000	26.33	.1315	13.15	78.81	
	0.250 to 0.500	24.12	.1264	12.04	90.85	
	0.125 to 0.250	10.24	.0512	5.12	95.97	
	0.062 to 0.125	3.69	.0184	1.84	97.81	
Silt & Clay	0.062	4.39	.0219	2.19	100.00	

Location NE Corner of Sec 15
TWP 137
RGE 74

Totals

Difference between original wt. of whole sample and total of wts. retained +.29

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 3 Analyst G.R.S. Date 4-15-60

Median .88 So. 2.62 Sk. 1.45

Sand 69.98 % Silt & Clay .84 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to <4.000	58.42	.2918	29.18	29.18	
SAND	1.000 to 2.000	28.88	.1443	14.43	43.61	
	0.500 to 1.000	41.15	.2056	20.56	64.17	
	0.250 to 0.500	60.79	.3038	30.38	94.55	
	0.125 to 0.250	8.05	.0402	4.02	98.57	
	0.062 to 0.125	1.20	.0059	.59	99.16	
Silt & Clay	0.062	1.78	.0084	.84	100.00	

Location NNE 1/4, Sec.44
TWP. 144
RGE. 74

Totals

Difference between original wt. of whole sample and total of wts. retained +.07g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 4 Analyst G.R.S Date 4-14-60

Median 2.62 So. 2.83 Sk. .63

Sand 40.01 % Silt & Clay 2.14 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	116.04	.5785	57.85	57.85	
SAND	1.000 to 2.000	14.54	.0725	7.25	65.10	
	0.500 to 1.000	14.15	.0705	7.05	72.15	
	0.250 to 0.500	22.00	.1097	10.97	83.12	
	0.125 to 0.250	23.75	.1184	11.84	94.96	
	0.062 to 0.125	5.81	.0290	2.90	97.86	
Silt & Clay	0.062	4.30	.0214	2.14	100.00	

Location SE 1/4, SE 1/4
TWP. 137 N
RGE. 70 W

Totals

Difference between original wt. of whole sample and total of wts. retained +.59 g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 5 Analyst G.R.S. Date 4-14-60

Median .963 So. 2.34 Sk. 1.05

Sand 71.18 % Silt & Clay .78 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	56.10	.2804	28.04	28.04	
SAND	1.000 to 2.000	41.20	.2060	20.60	48.64	
	0.500 to 1.000	38.28	.1914	19.14	67.78	
	0.250 to 0.500	40.05	.2003	20.03	87.81	
	0.125 to 0.250	19.73	.0986	9.86	97.67	
	0.062 to 0.125	3.11	.0155	1.55	99.22	
Silt & Clay	0.062	1.57	.0078	.78	100.00	

Location SW 1/4, SW 1/4
Sec. 22
TWP. 142N.
RGE. 73W.

Totals

Difference between original wt. of whole sample and total of wts. retained +.04 g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 6 Analyst G.R.S. Date 4-22-60

Median 1.38 So. 2.27 Sk. .77

Sand 61.16 % Silt & Clay 1.86 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	74.22	.3698	36.98	36.98	
SAND	1.000 to 2.000	38.24	.1905	19.05	56.03	
	0.500 to 1.000	39.88	.1987	19.87	75.90	
	0.250 to 0.500	30.19	.1504	15.04	90.94	
	0.125 to 0.250	11.34	.0564	5.64	96.58	
	0.062 to 0.125	3.13	.0156	1.56	98.14	
Silt & Clay	0.062	3.73	.0186	1.86	100.00	

Location: Williams Lake Loop
SW 1/4, SW 1/4 Sec. 35
TWP. 143N, R. 70W

Totals

Difference between original wt. of whole sample and total of wts. retained +.73g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 7 Analyst G.R.S. Date 4-22-60

Median 1.46 So. 2.11 Sk. 1

Sand 57.20 % Silt & Clay 1.24 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	83.04	.4156	41.56	41.56	
SAND	1.000 to 2.000	26.39	.1321	13.21	54.77	
	0.500 to 1.000	42.58	.2131	21.31	86.07	
	0.250 to 0.500	33.84	.1694	16.94	93.01	
	0.125 to 0.250	8.91	.0446	4.46	97.47	
	0.062 to 0.125	2.57	.0129	1.29	98.76	
Silt & Clay	0.062	2.47	.0124	1.24	100.00	

Location NE¼, NE¼, Sec. 24
TWP. 142N, R.74W

Totals

Difference between original wt. of whole sample and total of wts. retained -.20

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 9 Analyst G.R.S. Date 4-22-60

Median .17 So. 1.56 Sk. 1.03

Sand 92.28 % Silt & Clay 7.35 % Classification Dune Sand

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	.73g.	.0037	.37	.37	
SAND	1.000 to 2.000	3.02	.0151	1.51	1.88	
	0.500 to 1.000	10.86	.0544	5.44	7.32	
	0.250 to 0.500	38.23	.1911	19.11	26.43	
	0.125 to 0.250	80.26	.4014	40.14	66.57	
	0.062 to 0.125	52.14	.2608	26.08	92.65	
Silt & Clay	0.062	14.69	.0735	7.35	100.00	

Location SW 1/4, SW 1/4, Sec. 23
TWP. 139 N., RGE. 68W
Cleveland SW Quad., N. Dak.
Stutsman County

Totals

Difference between original wt. of whole sample and total of wts. retained .07g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 10 Analyst 1.83 Date 4-25-60

Median 48.55 So. 3.95 Sk. Glacial Outwash 1.03

Sand 48.55 % Silt & Clay 3.95 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	95.04g.	.4750	47.50	47.50	
SAND	1.000 to 2.000	54.11	.2703	27.03	74.53	
	0.500 to 1.000	23.02	.1151	11.51	86.04	
	0.250 to 0.500	10.40	.0520	5.20	91.24	
	0.125 to 0.250	5.98	.0297	2.97	94.21	
	0.062 to 0.125	3.68	.0184	1.84	96.05	
Silt & Clay	0.062	7.93	.0395	3.95	100.00	

Location SW 1/4, SW 1/4, Sec. 11
TWP. 139 N, R. 68 W
Cleveland SW Quad.,
Stutsman County, N. Dak.

Totals

Difference between original wt. of whole sample and total of wts. retained .16g.

Percent error = difference X 100/ original wt. 0 %

SIEVE ANALYSIS DATA SHEET

Sample No. 8 Analyst G.R.S. Date 4-25-60

Median 3.00 So. 1.32 Sk. 1,29

Sand 13,77 % Silt & Clay 1.64 % Classification Glacial Outwash

Weight of whole sample 200 g.

	Diam. in mm.	Weight Retained	Weight of Fraction	%	Cumul. %	Remarks
	2.000 to >4.000	150.06	.7499	74.99	74.99	
SAND	1.000 to 2.000	22.74	.1136	11.36	86.35	
	0.500 to 1.000	14.69	.0735	7.35	93.70	
	0.250 to 0.500	6.07	.0303	3.03	96.73	
	0.125 to 0.250	2.04	.0101	1.01	97.74	
	0.062 to 0.125	1.23	.0062	.62	98,36	
Silt & Clay	0.062	3.29	.0164	1.64	100.00	

Location: NW1/4, NW1/4, Sec. 12
T. 142N., R. 74W

Totals

Difference between original wt. of whole sample and total of wts. retained +.12g.

Percent error = difference X 100/ original wt. 0 %

SAMPLE NUMBER 1

Wt. of total sample 10g.

Wt. of light fraction 9.80g.
% of total weight 98.0%.

Wt. of heavy fraction .20g.
% of total weight 2.0

SAMPLE NUMBER 2

Wt. of total sample 10g.

Wt. of light fraction 9.92g.
% of total weight 99.2%

Wt. of heavy fraction .08g.
% of total weight .8%

SAMPLE NUMBER 3

Wt. of total sample 10g.

Wt of light fraction 9.36g.
% of total weight 93.6g.

Wt. of heavy fraction .64g.
% of total weight 6.4g.

SAMPLE NUMBER 4

Wt. of total sample 10g.

Wt. of light fraction 9.82g.
% of total weight 98.2%

Wt. of heavy fraction .18g.
% of total weight 1.8%

SAMPLE NUMBER 5

Wt. of total sample 10g.

Wt. of light fraction 9.56g.
% of total weight 95.6%

Wt. of heavy fraction .44g.
% of total weight 4.4%

SAMPLE NUMBER 6

Wt. of total sample 10g.

Wt. of light fraction 9.58g.
% of total weight 95.8%

Wt. of heavy fraction .42g.
% of total weight 4.2%

SAMPLE NUMBER 7

Wt. of total sample 10g.

Wt. of light fraction 9.36g.
% of total weight 93.6g.

Wt. of heavy fraction .64g.
% of total weight 6.4%

SAMPLE NUMBER 8

Wt. of total sample 10g.

Wt of light fraction 9.65g.
% of total weight 96.5%

Wt. of heavy fraction .35g.
% of total weight 3.5%

SAMPLE NUMBER 9

Wt. of total sample 10g.

Wt. of light fraction 9.89g.
% of total weight 98.9%

Wt. of heavy fraction .11g.
% of total weight 1.10%

SAMPLE NUMBER 10

Wt. of total sample 10g.

Wt. of light fraction 9.75g.
% of total weight 97.5%

Wt. of heavy fraction .25g.
% of total weight 2.5%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
1	Potash Feldspar	13	10.66%
	Soda-lime Feldspar	48	39.34%
	Quartz	49	40.16%
	Others	12	9.84%
	TOTAL	122	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
2	Potash Feldspar	7	8.53%
	Soda-lime Feldspar	42	51.23%
	Quartz	27	32.92%
	Others	6	7.32%
	TOTAL	82	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
3	Potash Feldspar	30	22.22%
	Soda - Lime Feldspar	21	15.56%
	Quartz	75	55.56%
	Others	9	6.66%
	TOTAL	135	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
4	Potash Feldspar	17	19.76%
	Soda-lime Feldspar	21	24.42%
	Quartz	45	52.33%
	Others	3	3.49%
	TOTAL	86	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
5	Potash Feldspar	43	23.37%
	Soda-lime Feldspar	6	3.26%
	Quartz	123	66.85%
	Others	12	6.52%
	TOTAL	184	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
6	Potash Feldspar	20	17.86%
	Soda-lime Feldspar	23	20.54%
	Quartz	60	53.57%
	Others	9	8.03%
	TOTAL	112	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
7	Potash Feldspar	15	26.79%
	Soda - Lime Feldspar	14	25.00%
	Quartz	25	44.64%
	Others	2	3.57%
	TOTAL	56	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
8	Potash Feldspar	18	22.50%
	Soda-lime Feldspar	20	25.00%
	Quartz	32	40.00%
	Others	10	12.50%
	TOTAL	80	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
9	Potash Feldspar	11	4.60%
	Soda-lime Feldspar	16	6.69%
	Quartz	202	84.53%
	Others	10	4.18%
	TOTAL	239	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
10	Potash Feldspar	3	4.29%
	Soda-lime Feldspar	44	62.86%
	Quartz	14	20.00%
	Others	9	12.85%
	TOTAL	70	100.00%

Sample Number	Mineral	# Grains	Per Cent of Total Grains
—	Potash Feldspar		
	Soda - Lime Feldspar		
	Quartz		
	Others		
	TOTAL		

Sample Number	Mineral	# Grains	Per Cent of Total Grains
—	Potash Feldspar		
	Soda-lime Feldspar		
	Quartz		
	Others		
	TOTAL		

PEBBLE ANALYSIS CLASSED ACCORDING TO GENERAL ROCK TYPE

Sample Number	Total Grains	Number of Particular grains	Composition
1	36	23	Carbonates
		2	Igneous & Metamorphic
		8	Mudstone
		3	Others

NOTE: Caliche present on all of the larger fragments.

Sample Number	Total Grains	Number of Particular Grains	Composition
2	39	16	Carbonates
		4	Igneous & Metamorphic
		15	Mudstone
		4	Others

NOTE: Entire sample coated with calcareous dust,
Caliche also present on large fragments.

Sample Number	Total Grains	Number of Particular Grains	Composition
3	35	14	Carbonates
		4	Igneous & Metamorphic
		14	Mudstone
		3	Others

NOTE: Dark shales very prominent, maybe Pierre.
Caliche on larger fragments.

PEBBLE ANALYSIS CLASSED ACCORDING TO GENERAL ROCK TYPE

Sample Number	Total Grains	Number of Particular grains	Composition
4	37	24	Carbonates
		3	Igneous & Metamorphic
		8	Mudstone
		2	Others

NOTE: Shell fragments observed. Generally lower in shale. Caliche prominent

Sample Number	Total Grains	Number of Particular Grains	Composition
5	48	18	Carbonates
		4	Igneous & Metamorphic
		20	Mudstone
		6	Others

NOTE: Shale very Abundant (black and gray). Caliche prominent.

Sample Number	Total Grains	Number of Particular Grains	Composition
6	60	38	Carbonates
		2	Igneous & Metamorphic
		17	Mudstone
		3	Others

NOTE: CARbonates abundant, shale abundant CALiche prominent.

PEBBLE ANALYSIS CLASSED ACCORDING TO GENERAL ROCK TYPE

Sample Number	Total Grains	Number of Particular grains	Composition
7	60	24	Carbonates
		5	Igneous & Metamorphic
		25	Mudstone
		6	Others

NOTE: Shale high. Carbonates high.

Sample Number	Total Grains	Number of Particular Grains	Composition
8	42	16	Carbonates
		6	Igneous & Metamorphic
		12	Mudstone
		8	Others

NOTE: Chert quite common, shale abondant, caliche prominent.

Sample Number	Total Grains	Number of Particular Grains	Composition
10	46	0	Carbonates
		5	Igneous & Metamorphic
		39	Mudstone
		2	Others

NOTE: chiefly poorly cemented calcareous mudstones. Limonitic stains present on many fragments. Differs significantly from other samples. No caliche present.

Plot on Δ diagrams

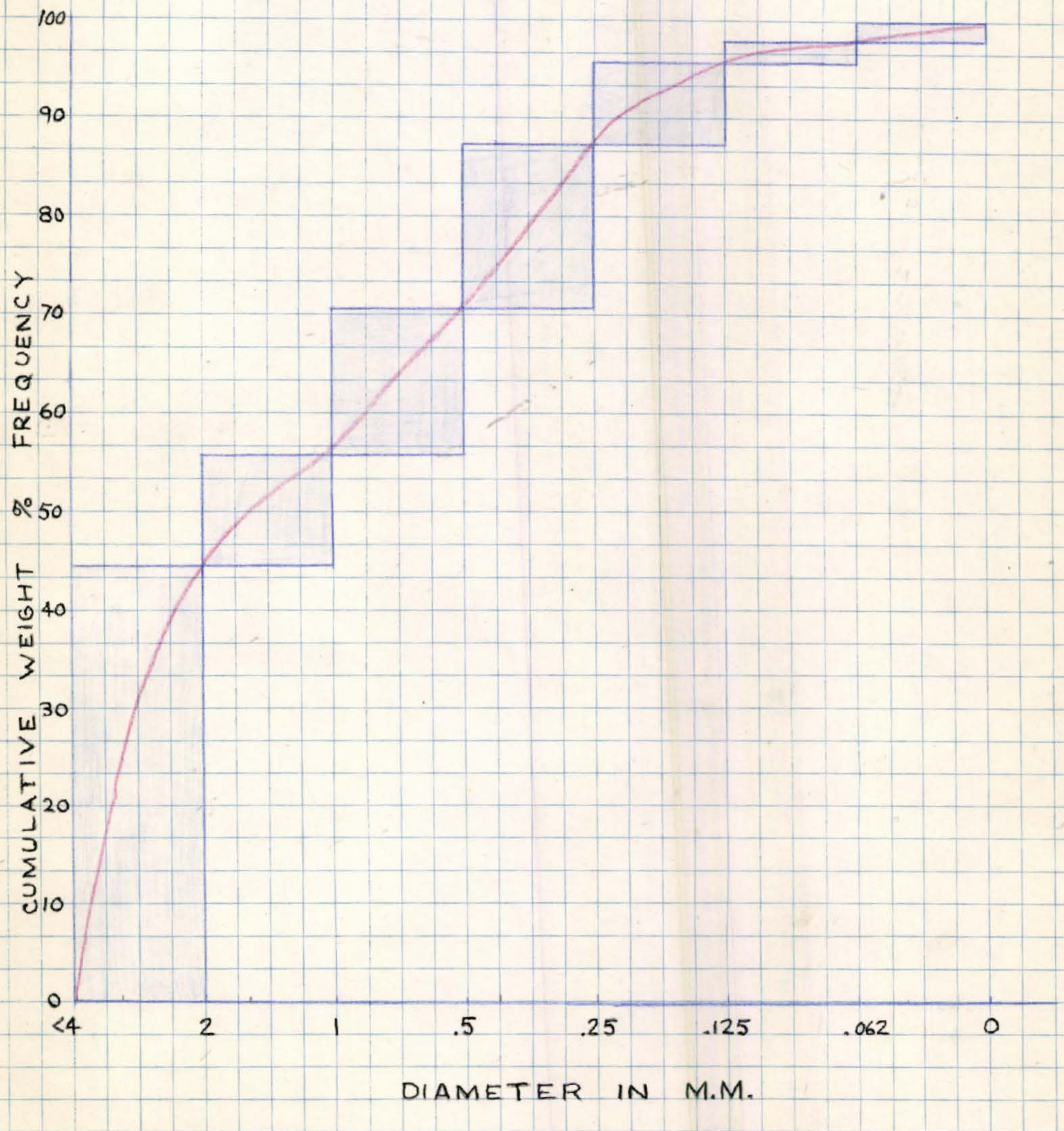
HEAVY MINERAL RATIOS BY VOLUME

Sample Number	Magnetic/Non-magnetic minerals -- Ratio
1	1/8
2	1/40
3	1/30
4	1/20
5	1/6
6	1/10
7	1/8
8	1/5
9	1/60
10	1/50

CUMULATIVE CURVE

SIEVE ANALYSIS

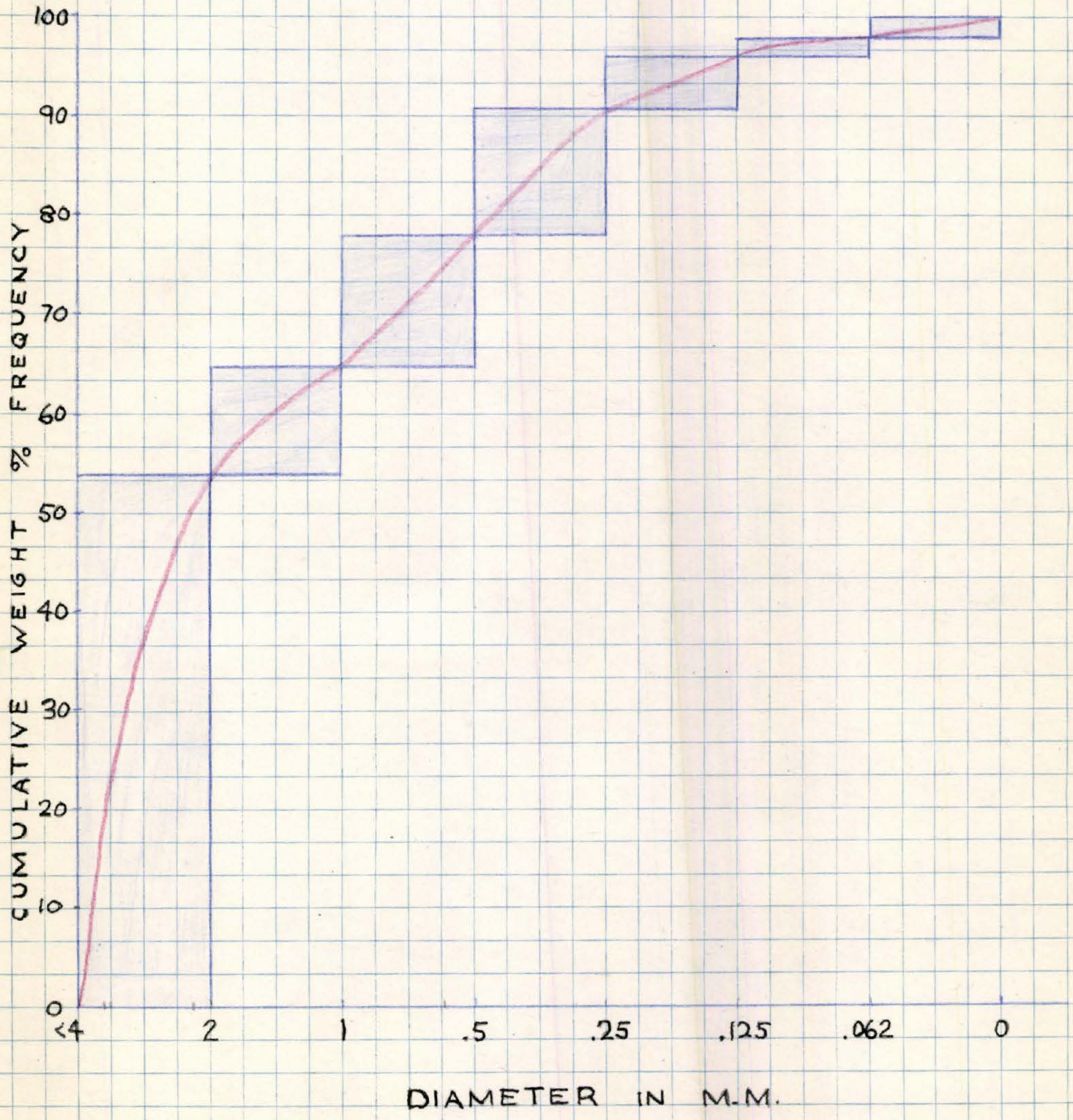
SAMPLE 1



CUMULATIVE CURVE

SIEVE ANALYSIS

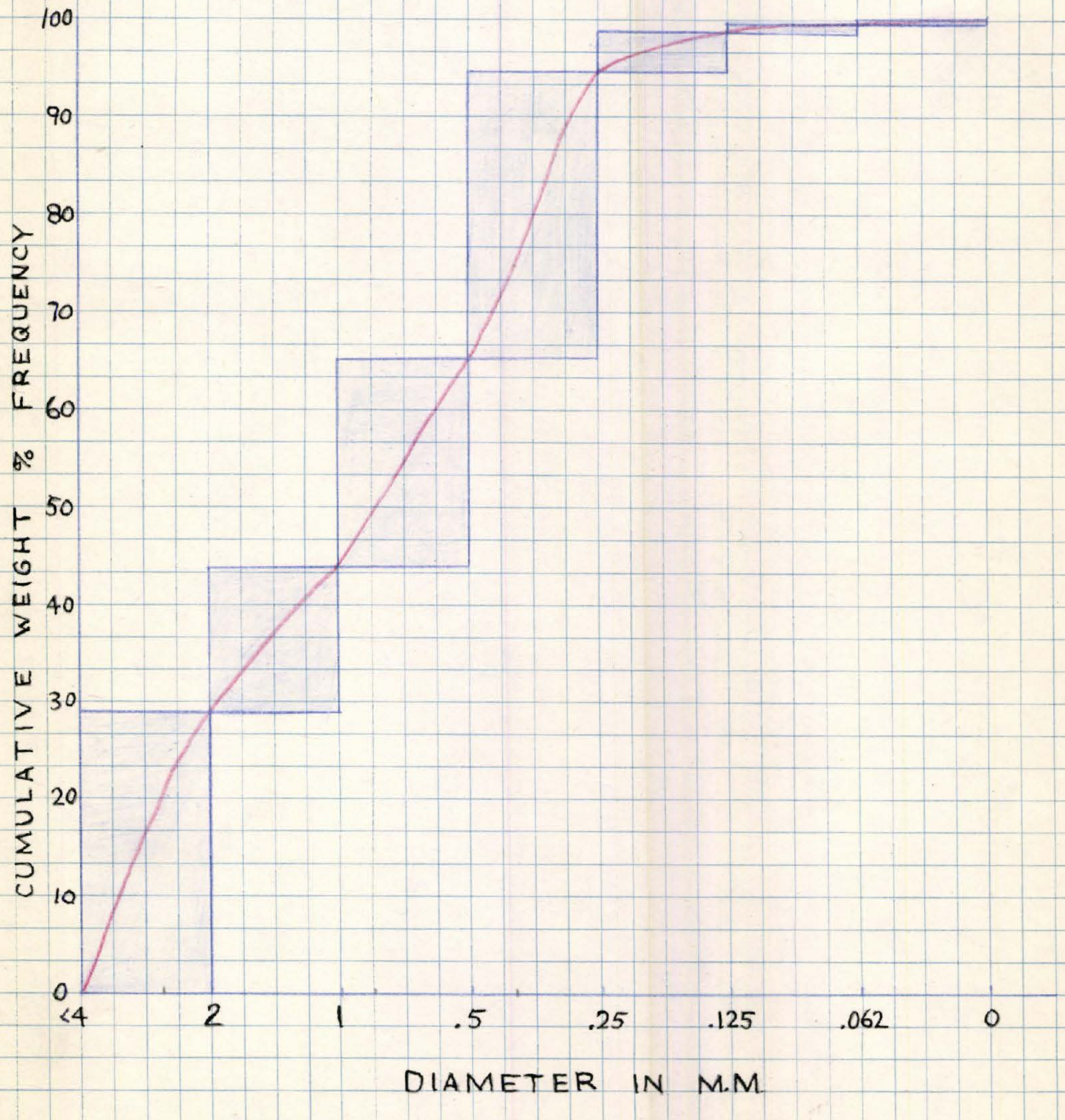
Sample 2



CUMULATIVE CURVE

SIEVE ANALYSIS

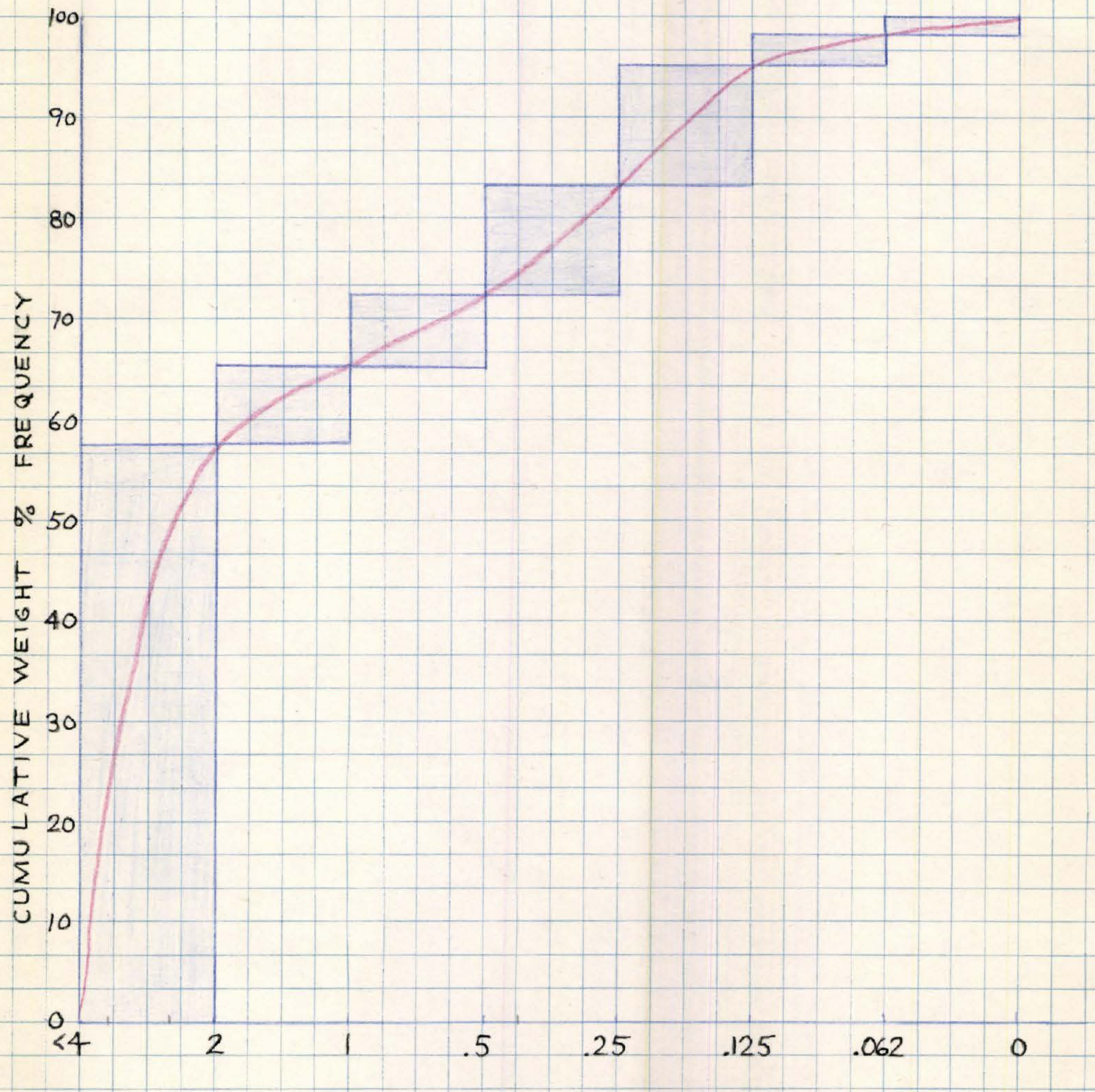
SAMple 3



CUMULATIVE CURVE

SIEVE ANALYSIS

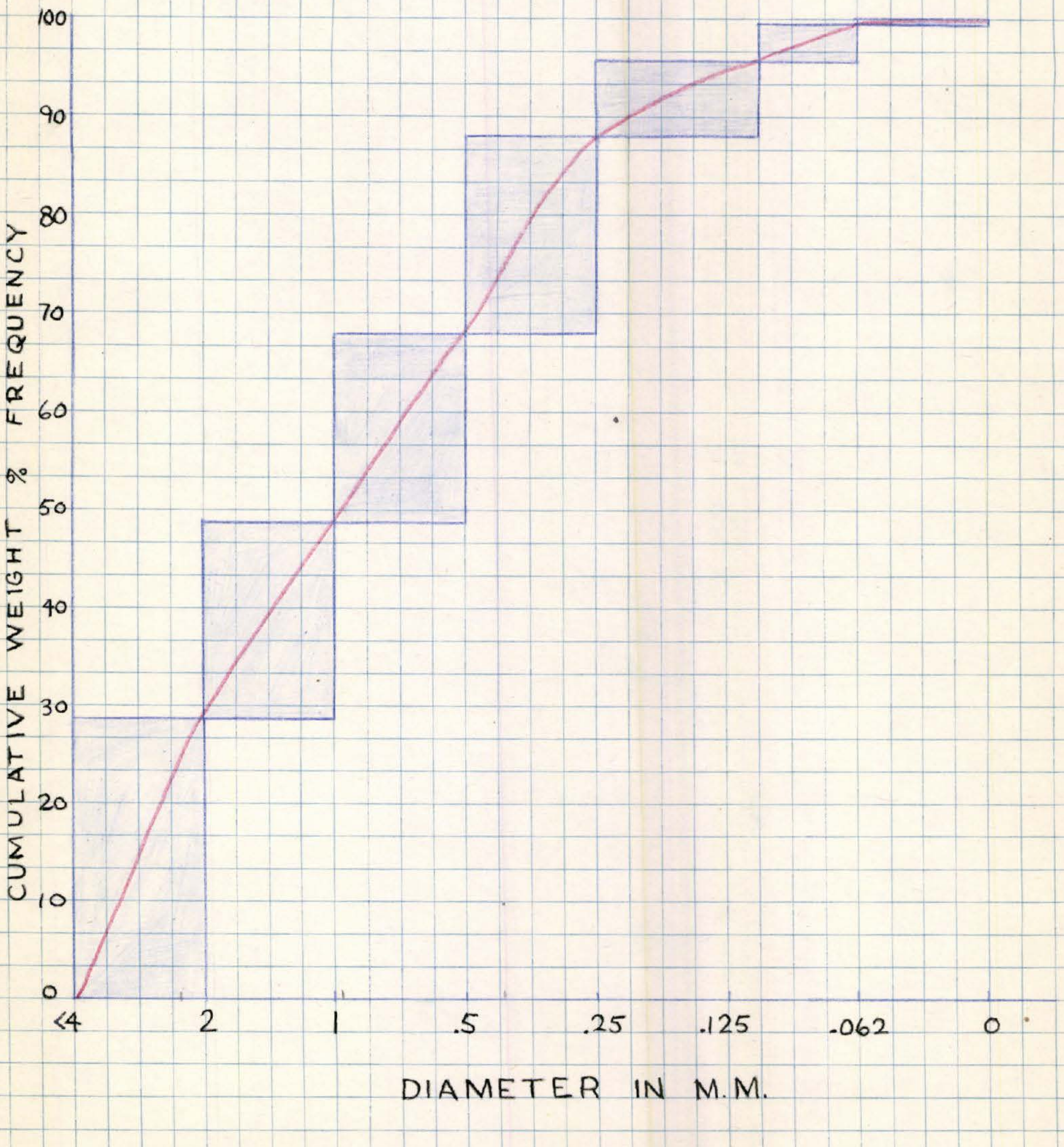
SAMPLE 4



CUMULATIVE CURVE

SIEVE ANALYSIS

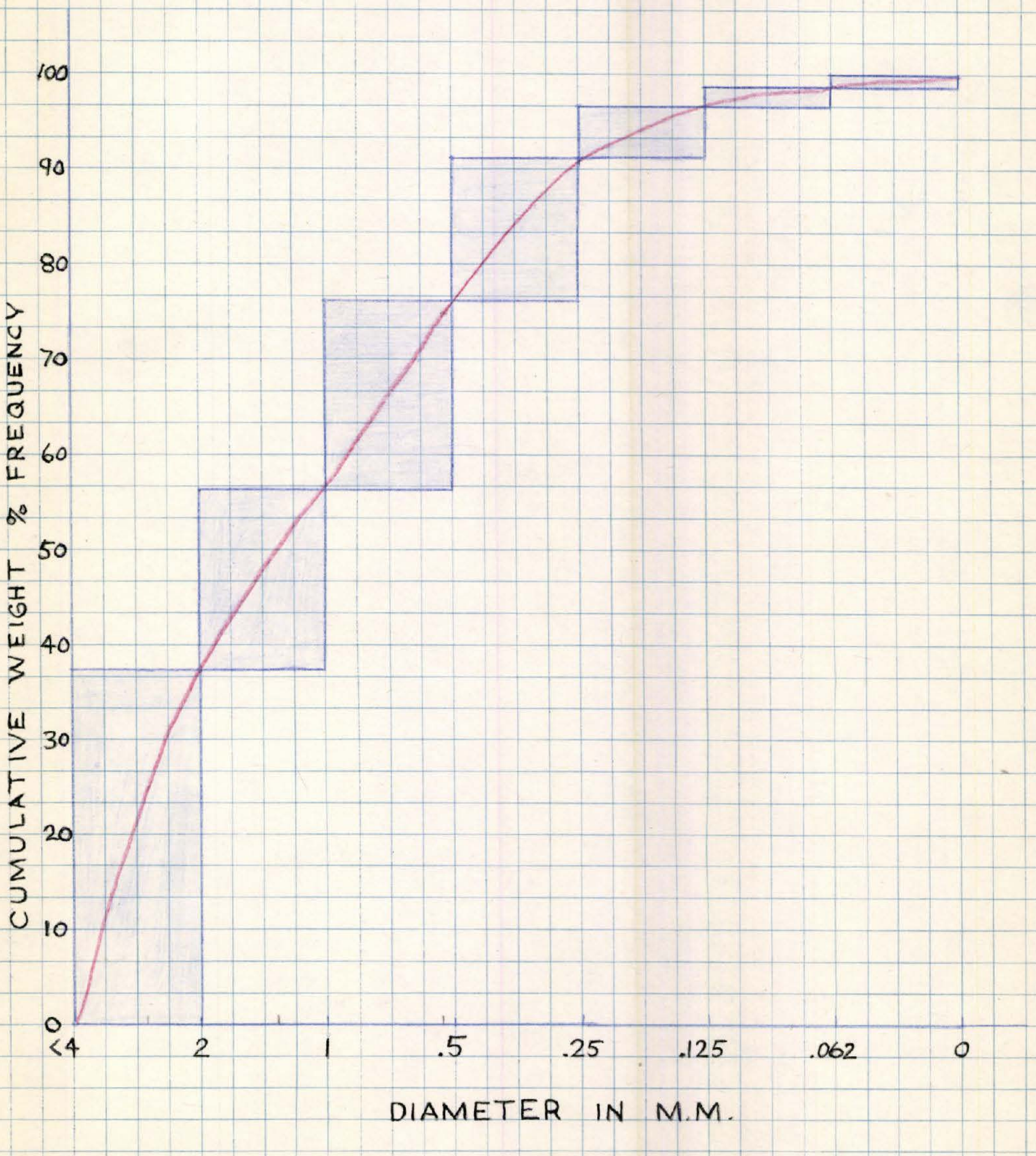
SAMPle 5



CUMULATIVE CURVE

SIEVE ANALYSIS

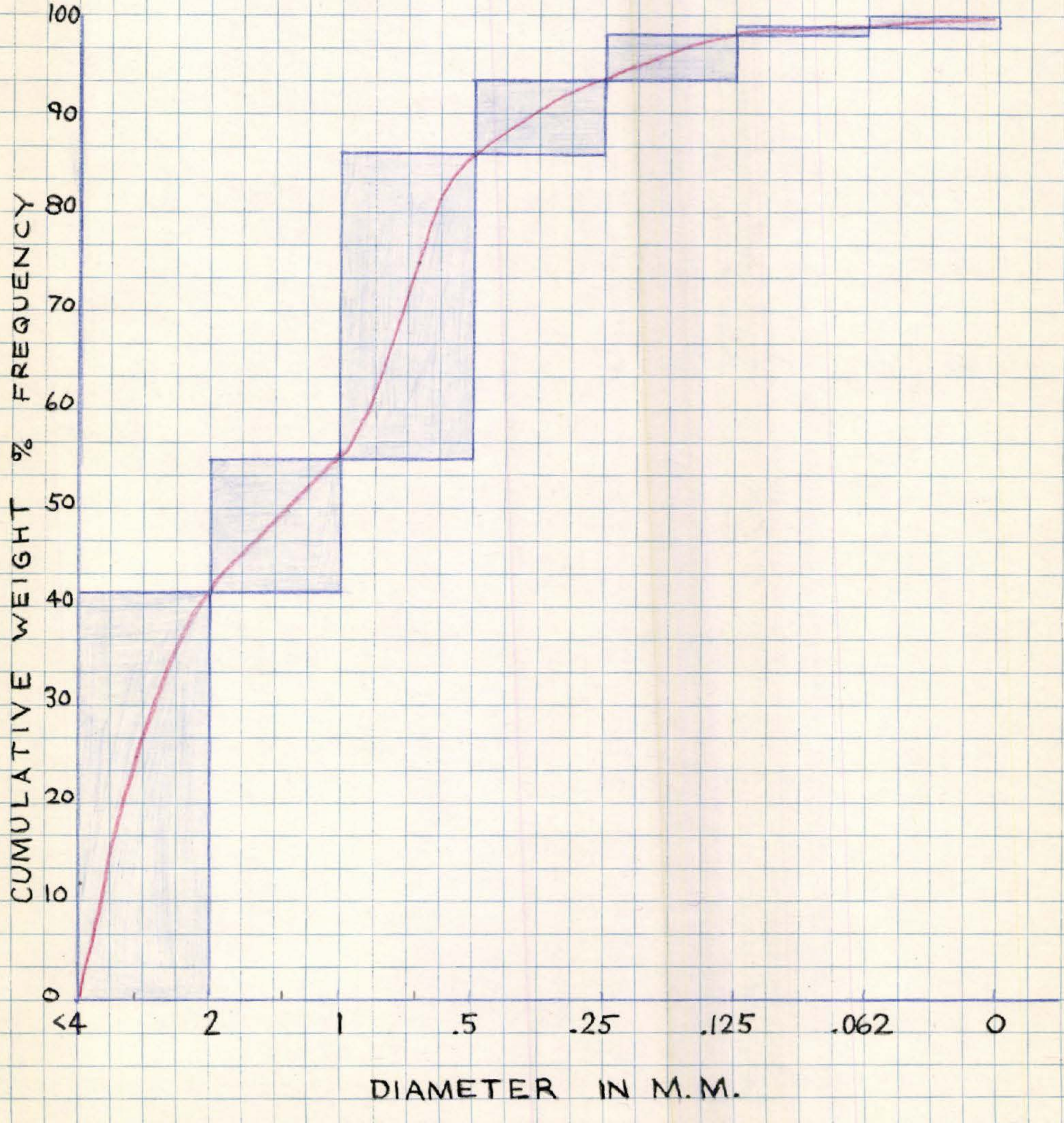
SAMPle 6



CUMULATIVE CURVE

SIEVE ANALYSIS

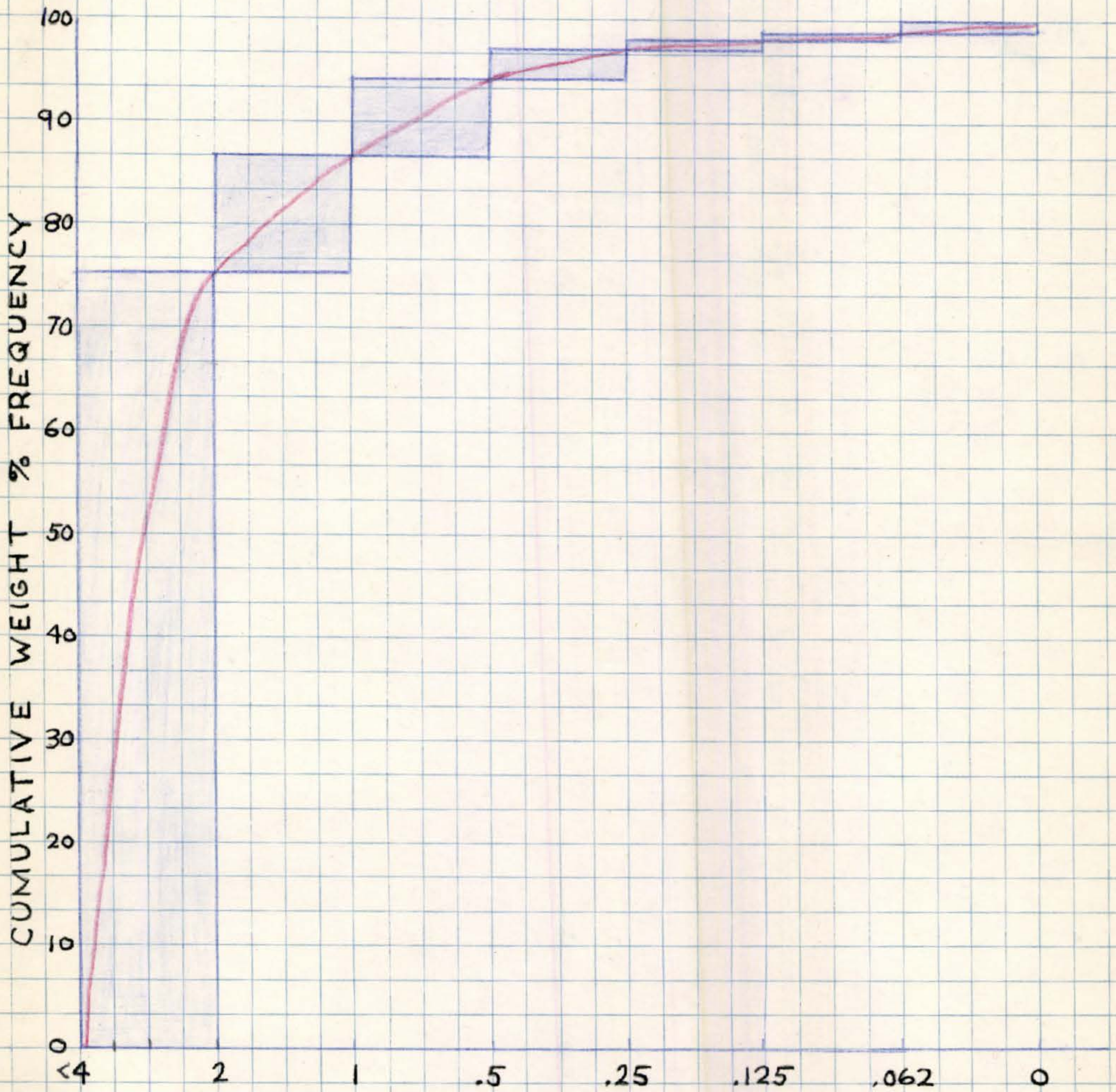
SAMple 7



CUMULATIVE CURVE

SIEVE ANALYSIS

SAMPle 8

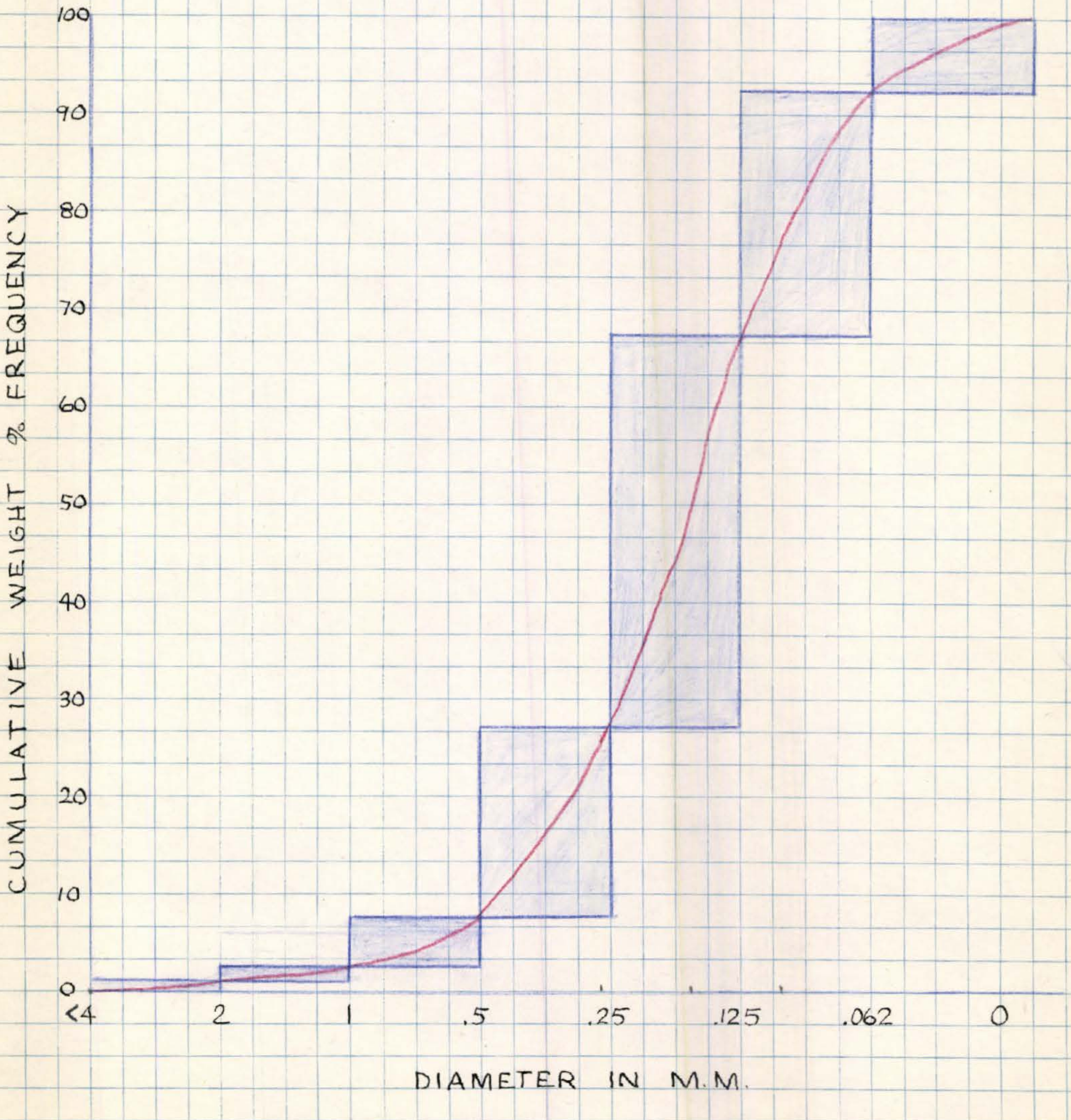


DIAMETER IN M.M.

CUMULATE CURVE

SIEVE ANALYSIS

SAMple 9



CUMULATIVE CURVE

SIEVE ANALYSIS

SAMple 10