

A STUDY OF THE EROSION
ACTION OF THE RED RIVER,
THE MATERIALS CARRIED IN
SOLUTION AND IN SUSPENSION,
WITH A CHAPTER ON THE STATE
OF SILICA IN NATURAL WATERS

by

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PRESENTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
MASTER SCIENCE DEGREE IN THE
UNIVERSITY OF MANITOBA .

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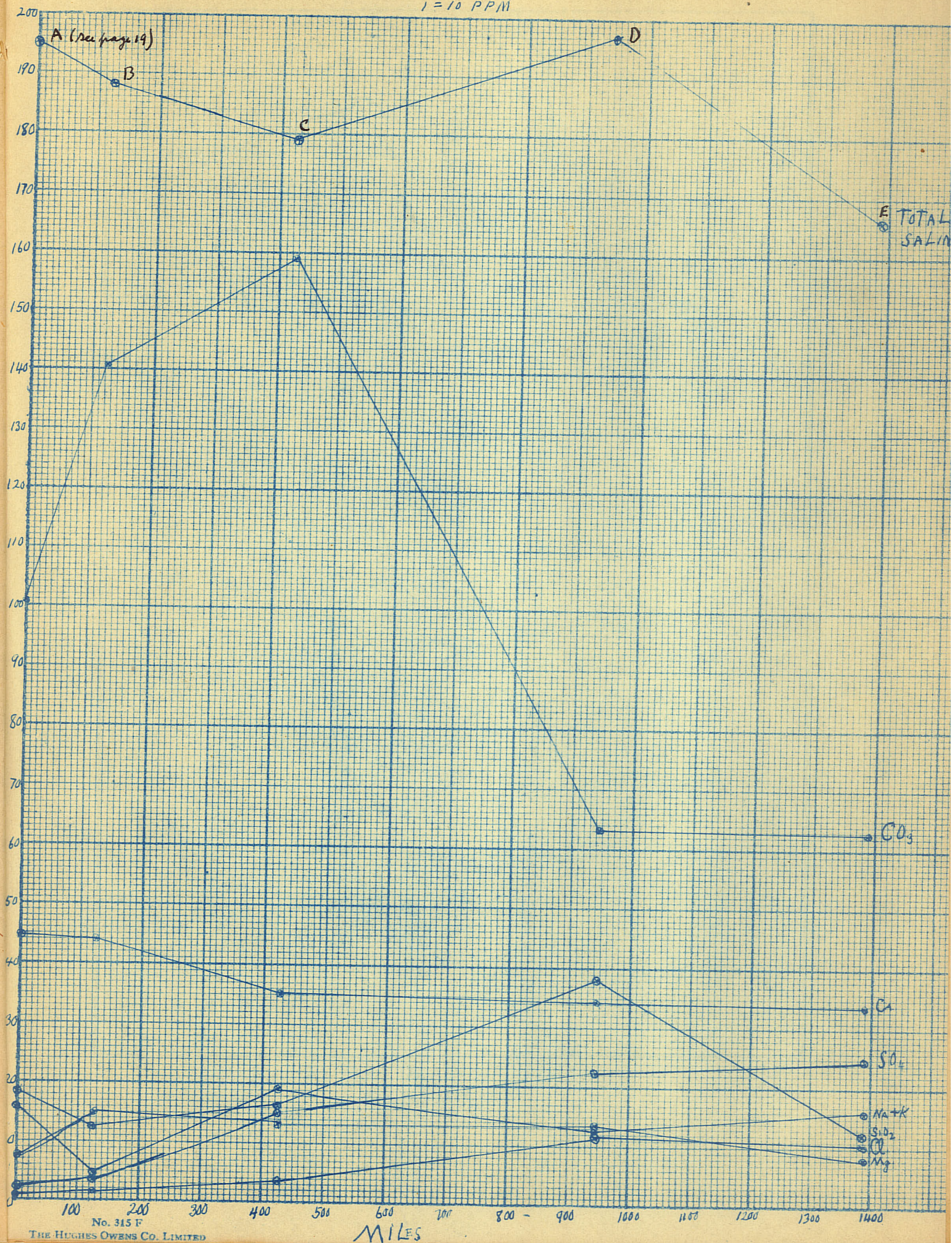
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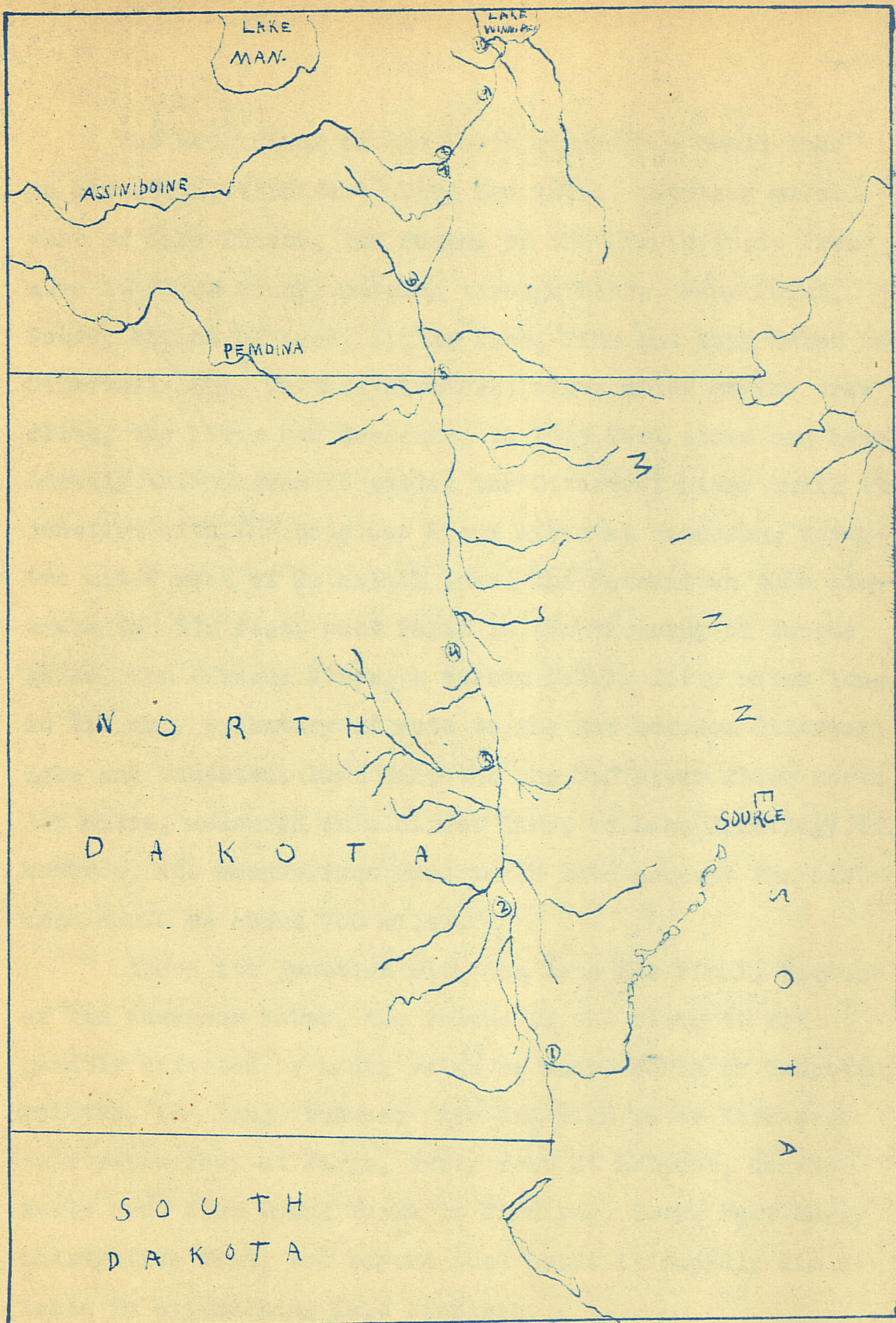
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MISSISSIPPI RIVER GRAPH B

1 = 100 MILES
1 = 10 PPM





(1)

The Red River of the North rises in a small lake in Minnesota, 1550 feet above sea level, thirteen miles west of Lake Itasca, the source of the Mississippi. From here it flows south, passing through Elbow, Many Point, Round, Height of Land, Little Pine, Pine and Rush Lakes to Ottertail Lake. In this distance, sixty miles as the crow flies, the river has descended to 1315 feet above sea level. Locally this stream is called the Ottertail River until its junction with the Bois des Sioux River at Wahpeton, forty-two miles west of Ottertail Lake. The descent in this distance is 372 feet, most rapid in the vicinity of Fergus Falls. The Pelican River, a stream nearly fifty miles long, is the only tributary of note to the Red between Ottertail Lake and Wahpeton. From Wahpeton the Red River flows north 285 miles, measured in a direct line, to Lake Winnipeg; if, however, its meanderings were taken into account the distance would be about 700 miles.

Above its junction with the Bois des Sioux, because of its numerous lakes, the volume of the river is not greatly affected by heavy rains or snow. North of Wahpeton, however, the range between low and high water increases thirty-two feet at Fargo, fifty feet at Belmont, nearly forty feet from Grand Forks to Winnipeg, Lower Fort Garry thirty-five feet, and beyond that point it rapidly diminishes in approaching Lake Winnipeg.

(1) Upham. Glacial Lake Agassiz. P 54.

On the east side of the Red River, the important tributaries, from south to north, are the Buffalo, Wild Rice, Marsh, Sand Hill, Red Lake, Snake, Tamarack, Two Rivers, Joe, Roseau, and Rat Rivers; and on the west the Bois des Sioux, Wild Rice, Sheyenne, Elm, Goose, Turtle, Forest, Park, Pembina, Marsiis, Boyne, La Salle and Assiniboine Rivers. Upham(1) states: "Excepting the Red Lake, the Sheyenne, the Pembina and the Assiniboine Rivers, all of these are small, the farthest point of their drainage being forty to seventy-five miles from the Red River. In summer droughts several of them, including the Bois des Sioux, are dried up along the greater part of their course"

Referring to the geological character of the areas drained by the Red and Assiniboine Rivers, Dr. G.M. Dawson (2) says: "The Red River, flowing from south to north, runs probably for its whole length over deposits of late date. These are, either the fine silty material laid down in the bed of the southward extension of Lake Winnipeg, which previously occupied the valley, or clays and sandy clays due to the glacial period. Long and important streams, however, join the Red River, both from the east and the west, and the character of the river water is doubtless due to the nature of the country occupied by the springs and the sources of these, rather than to the composition of the bed of the

(1) Glacial Lake Agassiz. P 56.

(2) G.S.C. 1879-80 H9.

main stream, with which the waters passing rapidly and in large volume cannot come very often or intimately in contact. Probably more than half of the water of this river is derived from the Rat, Roseau and Red Lake Rivers and other streams flowing from the wooded marshy country to the east.....This country is also covered with drift deposits of glacial and post glacial age, and the streams seldom or never flow over solid rock. The tributaries from the west, including the Sheyenne, the Pembina and numerous smaller rivers, are from a region which may be regarded as almost open prairie, and is subject to a rainfall considerably less in amount than in the east. These streams flow in part over glacial and post glacial deposits, but in part also over the underlying Cretaceous rocks, of which the clays and shales of the Fort Pierre group cover the most extensive area.....The Cretaceous shales contain a considerable portion of disseminated pyrites, which latter when exposed to atmospheric influences undergoes decomposition, ultimately giving rise, in the presence of the calcium carbonate contained in the rocks, to the formation of gypsum, with which mineral--generally in the form of selenite--many of the beds are, in consequence, charged. There are also on this side of the Red River, several springs impregnated with common salt; these resemble those of the Lake Manitoba district, and are probably, like them, derived from the underlying Devonian rocks. Springs of this character are known in the Salt River, south of the Pembina, and it was previously attempted to utilize them as a source of a salt supply.

Similar Springs are said to occur in the Scratching River.

The country drained by the Assiniboine resembles in most points that described as giving rise to the other western tributaries of the Red River. By some of the eastern of the upper part of the Assiniboine, from the Riding and Duck Mountains, a certain amount of woodland drainage is derived; but by far the greater part of its tributaries bring to it the drainage of the prairie land, with a comparatively small rainfall, and in which the saline matters would therefore be supposed to exist in a more concentrated form. Though a comparatively small portion of the total length of the streams can flow in actual contact with the underlying Cretaceous rocks, there is reason to believe that in the prairie region west of the valley of the Red River, a great part of the drainage of the country passes below the drift deposits along the surface of the underlying rocks, and thus being brought very intimately in contact with these rocks, would be likely to be influenced by their composition.

COLLECTION OF SAMPLES.

Two winchesters were sent to each of the points indicated on the map with the request that they be filled on October the ninth, 1924, or as close to that date as possible.

(1) Wahpeton, N.D. collected through the courtesy of L.H.

Dominick, Superintendent of Schools, on October the

ninth. Mr. Dominick writes: "The water was taken from the Ottertail River about one and a half miles above the point where it joins with the Bois des Sioux to form the Red River.....the effect of the Bois des Sioux at this time of year is negligible as there is hardly any water in the stream".

(2) Fargo, N.D. samples obtained through the kindness of C. B. Tigbe, Principal of Fargo High School, on October the ninth, 1924.

(3) Caledonia, N.D. the samples were collected by A.N. Solwold who says: "The samples were taken on Thursday morning, October the tenth, in place of Wednesday, because a heavy rain fell here that day"

(4) Grand Forks, N.D. The winchesters were filled at this point on October the eleventh, 1924, through the courtesy of A.G. Lenard, Professor of Geology, University of North Dakota, from the Red River just below its junction with the Red Lake River.

(5) Emerson, Man. The water was obtained on October the ninth through the kindness of Mr. G. White, Principal of the High School.

(6) Morris, Man.

(7) River Park, Winnipeg, Man.

(8) Kildonan Park, Winnipeg.

(9) Selkirk, Man.

(10) Mouth of River.

(11) Four miles out in Lake Winnipeg.

These three samples were collected by the author on October the ninth.

These samples were obtained through the courtesy of J.W. Simpson of the Northern Fish Company, Selkirk, between October the ninth and twelfth, 1924.

HEIGHT OF THE RIVER.

The following information concerning the height of the Red River for the last ten years was obtained from Mr. C.H. Atwood, District Chief Engineer, Dominion Water Power Branch, Winnipeg:

<u>Year.</u>	<u>Gauge Height for Month of September.</u>
1914	751.06
1915	751.96
1916	755.84
1917	749.15
1918	749.60
1919	751.37
1920	750.60
1921	749.78
1922	749.31
1923	749.18
1924	748.56

This table shows that, generally speaking, the Red has been getting lower and lower during the past few years, and, that in the autumn of 1924, when the above samples were collected, the River was lower than it had been for ten years.

METHODS OF ANALYSIS.

TOTAL DISSOLVED SOLIDS.

(1)

The total dissolved matter was determined with 500 c.c. of the carefully filtered sample, which was evaporated to dryness in the water bath in a tared platinum dish, dried

at 180° C. for one hour, cooled and weighed. The residue was computed to parts per million of the total dissolved solids.

The committee on standard methods of water analysis recommend that dissolved solids be dried at 103° C. for one-half hour, but R.B.Dole⁽¹⁾ found that the best results were obtained by heating to 180° C. for one hour. According to him, "Practically all the water of crystallization and that mechanically included by residues of ordinary amount from water of ordinary composition were driven off, and the organic matter was more or less carbonized and was greatly reduced in weight, though it was not completely destroyed."

SILICA.

The silica was determined, using the method outlined in Water Supply Paper 236.

IRON AND ALUMINIUM. CALCIUM AND MAGNESIUM.

The percentages of these minerals were determined, using the gravimetric method outlined by Leffman in his "Examination of Water for Sanitary and Technical Purposes".

SODIUM AND POTASSIUM; SULPHATE, CARBONATE AND BICARBONATE RADICLES.

The alkali metals and the sulphate, carbonate and bicarbonate radicles were determined, using the procedure given by Dole in U.S. Water Supply Paper 236.

CHLORIDE RADICLE.

The usual gravimetric method was employed for the determination of chlorides, i.e.-precipitating with silver nitrate as silver chloride in a nitric acid solution.

(1) Public Health Papers and Reports. Vol. 30. 1905.

ACCURACY OF ANALYSIS.

The accuracy of the analysis was checked by comparing the combining weights of the acidic and the basic radicles with each other, for, according to Dole,⁽¹⁾ the difference between the sum of the combining weights of the acidic radicles and the sum of the combining weights of the basic radicles is a good test of the accuracy of an analysis.

The combining values, or, as Palmer⁽²⁾ calls them, the reaction coefficients, are obtained by multiplying each radicle expressed in parts per million by the valence and dividing the product by the molecular weight of the radicle. The following table of reaction coefficients is given by Palmer:

Positive Radicles	Reaction Coefficients
calcium	.0499
magnesium	.0822
sodium	.0435
potassium	.0256
Negative Radicles	Reaction Coefficients
carbonate	.0333
bicarbonate	.0164
sulphate	.0208
chloride	.0282

(1) Dole. Water Supply Paper 236

(2) Palmer. U.S.G.S. 479.

(1)
It is generally assumed that the silica and the iron and aluminium oxides in natural waters are in the colloidal state, so they were not used in computing the error.

All the analyses were checked and those that did not comply with the limits of error allowed by the following table were rejected:
(2)

PARTS PER MILLION DISSOLVED SOLIDS.			
not less than	less than	maximum error of combining weights	
10	50	15	
50	100	8	
100	200	6	
200	500	5	
500	1000	3	
1000	2000	2	

As an example of the methods used the table below showing the combining values of "River Mouth, No. 10" water is given:

(1) Palmer, U.S.G.S. 479

(2) Idem (1)

Analytical Statement	PPM	Computation of Error			
		Bases, PPM.	Factor.	Combining value	
SiO ₂	13.9				
Fe ₂ O ₃ Al ₂ O ₃	2.1				
Ca	42.3	Ca	$42.3 \times .0499 =$	1.910	
Mg	24.7	Mg	$24.7 \times .0822 =$	2.030	
Na	27.9	Na	$27.9 \times .0435 =$	2.214	
K	5.8	K	$5.8 \times .0256 =$	1.484	
				<u>6.638</u>	
		<u>Acids.</u>			
CO ₃	....				
HCO ₃	199.2	HCO ₃	$199.2 \times .0164 =$	3.266	
Cl	36.0	Cl	$36.0 \times .0282 =$	1.015	
SO ₄	103.5	SO ₄	$103.5 \times .0208 =$	2.152	
				<u>6.434</u>	
Sum	<u>455.4</u>				
Total solids	454.0	error = $\frac{100(6.638 - 6.434)}{(6.638 + 6.434)} = 1.5\%$			
Diff.	<u>1.4</u>				

STATEMENT OF ANALYSES OF THE RED RIVER FROM WAHPETON TO
LAKE WINNIPEG, IN PARTS PER MILLION.

	(1)	(2)	(3)	(4)	(5)
	<u>Wahpeton.</u>	<u>Largo.</u>	<u>Caledonia.</u>	<u>Grand Forks.</u>	<u>Emerson.</u>
SiO ₂	10.1	8.2	6.01	7.9	8.6
Fe ₂ O ₃ Al ₂ O ₃	4.0	2.7	10.2	2.5	6.0
Ca	46.4	41.9	47.08	53.9	50.5
Mg	25.2	19.3	22.3	28.0	17.2
Na	5.6	6.6	9.5	4.3	126.0
K	3.5	2.6	5.3	3.2	15.0
CO ₃	14.2	4.6	3.8	1.7	4.0
HCO ₃	129.8	131.5	145.5	166.3	205.4
Cl	1.3	4.9	16.2	5.3	150.0
SO ₄	<u>77.4</u>	<u>52.1</u>	<u>86.</u>	<u>84.7</u>	<u>137.8</u>
Total	317.5	273.5	351.9	357.8	720.5
salinity	316	276	354	359	718

	(6)	(7)	(8)	(9)	(10)	(11)
	<u>Morris River</u>	<u>Park.</u>	<u>Kildonan</u>	<u>Selkirk</u>	<u>River</u>	<u>Lake</u>
	<u>Park.</u>	<u>Park.</u>	<u>Park.</u>	<u>Park.</u>	<u>Mouth.</u>	<u>Winnipeg.</u>
SiO ₂	9.0	11.4	12.4	11.3	13.9	6.7
Fe ₂ O ₃ Al ₂ O ₃	6.2	11.3	4.5	4.0	2.1	...
Ca	48.7	77.2	68.4	66.3	42.3	20.6
Mg	18.1	17.3	15.0	16.4	24.7	6.8
Na	79.3	74.3	84.4	82.2	27.9	9.2
K	10.2	8.8	10.0	6.5	5.8	1.8
CO ₃	7.0	7.1	10.5	4.3	.....	.....
HCO ₃	181.9	178.5	172.6	171.2	199.2	49.1
Cl	105.4	107.1	88.8	84.1	36.0	10.4
SO ₄	<u>106.0</u>	<u>102.0</u>	<u>101.0</u>	<u>104.6</u>	<u>103.5</u>	<u>49.5</u>
Total	570.8	595.0	567.7	550.9	454.0	154.0
salinity	567	595	566	549	450	154

THE COMPOSITION OF THE RED RIVER FROM WAHPETON TO WINNIPEG.

As mentioned in the introduction the Red River has many important tributaries. Analyses were obtained of only four of these, the La Salle, the Assiniboine, the Rat, and the Roseau, winter analyses in all cases. These were recalculated to approximately the autumn concentration by comparison with analyses of the Red at River Park made in October and in January.

A. La Salle at St. Norbert, Man.

B. Assiniboine at the foot of Kennedy St., Winnipeg.

C. Rat. C.P.R. analysis.

D. Roseau. C.P.R. analysis.

	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
SiO ₂	16.9	16.6	23.0	14.5
Fe ₂ O ₃ Al ₂ O ₃	14.6	1.8	6.0	1.5
Ca	87.6	63.1	68.0	92.3
Mg	44.6	29.6	20.4	39.0
Na	201.5	59.8	17.0	42.0
K	35.4	8.9		
CO ₃	249.5	141.0	193.0	277.0
Cl	254.8	68.1	17.0	24.0
SO ₄	124.3	131.5	12.6	20.7
	1029.2	520.0	357.0	441.0

The La Salle River as seen from the above analysis has a very high concentration, nearly one half is due to sodium and chlorine, derived, no doubt, from the salt springs that flow into the La Salle higher up.

From graph A ^(Baker Pass) it will be noticed that generally speaking the Red River increases in concentration from Wahpeton to Winnipeg. The discrepancies of the graph may be explained, it seems, in most cases by local conditions. At Fargo, for example, the total salinity is found to have dropped, but this may be due to dilution by the Wild Rice River which joins the Red a few miles above Fargo. From Fargo to Winnipeg, if Emerson be disregarded, the increase is fairly regular. The high concentration at Emerson is due mainly to sodium and chlorine. The Pembina River unites with the Red just above Emerson, and it has an important tributary, the Tongue River, which is fed by salt springs. The Pembina it-

self, flowing from the prairies in which the rainfall is rather limited, will likely have a fairly high concentration. The waters become more dilute between Emerson and Morris which may be caused by fresher water flowing in from the few small tributaries between these points, or to the fact that where the sample was collected at Emerson the waters of the Pembina and the Red had not been thoroughly mixed. From Morris to River Park (above the Assiniboine) the concentration is again increased, probably due to some extent to a few small tributaries, the Ia Salle being one of them. The Assiniboine flows into the Red between River Park and Kildonan Park and dilutes the river water noticeably. Between Kildonan Park and Selkirk there is a small drop in total salinity, but from Selkirk to the mouth the drop is rapid. This last, however, cannot be accepted for the water at the mouth of the river is bound to be affected by the more dilute lake water. The water in Lake Winnipeg itself, in common with that of the Great Lakes, has a low salinity, it being fed by many springs and rivers flowing through solid rock.

Silica occurs in the Red River water from Wahpeton to its mouth in relatively small and fairly uniform amounts.

(1)
Gruner says: "It was formerly believed that silica was carried in solution as alkaline silicate and that on separation from the alkali, the silica was precipitated, but it is now held that silicates are hydrolyzed and the silica is carried as a colloid in dilute natural solutions". The author in work carried on during the past few months has been attempting to establish

(1) Economic Geology Journal. P 442.

the above assumption by super-centrifuging the river waters.

Silica is only slightly soluble but once in solution it is quite stable due to the protective organic colloids in the river water. From Wahpeton to Caledonia there is a slight decrease in silica but it seems that this is more likely due to dilution by waters poor in silica than to precipitation. From Caledonia to the Mouth the increase in silica is quite gradual, as would be expected, and is not influenced to any great extent by tributary waters.

The Red River also contains small amounts of iron and aluminium oxides. Gruner ⁽¹⁾ states that the average river water contains a very small amount of iron, but water high in organic content, such as tropical rivers and swamps, may contain as much as sixty parts per million. The Red River at River Park carries only eleven parts per million of iron and aluminium oxides and above and below this point the quantity varies from two to only a trace.

Calcium occurs in the Red River Water in quantities ranging from 64.48 PPM at Kildonan Park to 20.6 PPM four miles out in the Lake. Generally speaking, the calcium curve conforms fairly well with the bicarbonate curve, as would be expected. The calcium--magnesium ratio at Wahpeton is about 2:1, and this remains fairly constant with a slight decrease in magnesium between Winnipeg and Selkirk. The decided jump in calcium between Morris and Winnipeg may

(1) Economic Geology Journal. P 442. 1922

be in part due to the high calcium water of the La Salle River. The Assiniboine is poorer in calcium than the Red at River Park, and this will explain the lower calcium content at Kildonan Park. There is a decided increase both in calcium and magnesium between Kildonan Park and Selkirk. Between these points there are no important tributaries to cause such an enrichment and it seems improbable that such an increase could be caused by leaching of the clay banks, even by a water with so high a carbonate content as the Red.

The sodium and the chlorine curves follow in general the curve of total salinity; as has been mentioned previously, the high concentration at Emerson and at River Park is due largely to sodium and chlorine. From Wahpeton to Grand Forks the sodium and chlorine show very little change. Between Grand Forks and Emerson, however, there is a large increase in concentration of both, no doubt due to salt springs. At Morris, evidently, there has been some dilution but there is another jump between Morris and River Park, perhaps due to the high sodium and chlorine content of the La Salle River. From River Park to the Lake the chlorine content gradually diminishes, aided somewhat by the lower chlorine waters of the Assiniboine. The sodium, however, between River and Kildonan Parks shows a slight enrichment in spite of the fact that the Assiniboine is lower in sodium than the Red at River Park. Sewage may in some way account for this increase.

Potassium is found in the waters of the Red in quite small and very uniform amounts.

The clays through which the river flows are much richer in potassium than in sodium and it would seem that if the composition of the water depended entirely upon the leaching of the material through which the river passes, that the potassium in solution would be greater.

The Red is very rich in sulphates. From Wahpeton to Emerson there is a gradual increase, with the exception of Fargo, seeming to prove that the Wild Rice River, which flows into the Red above Fargo is poor in sulphates. There is a dilution of sulphate between Emerson and Morris, while between Morris and River Park there is a decided concentration of the sulphate ion, due in part, no doubt, to the high sulphate waters of the La Salle. The Assiniboine, deriving its waters from country covered by Cretaceous shale, rich in pyrite, is naturally rich in sulphate; but it does not seem to affect the waters of the Red below it as much as would be expected.

The bicarbonate and the carbonate ions are found in the waters of the Red, the former being the more abundant. According to Clark⁽²⁾ the bicarbonate ion is derived from the river water and from the carbon dioxide of the atmosphere and from the decay of vegetable substances and their further oxidation. Also he says: "The relatively insoluble carbonates of calcium and magnesium are held in solution by the excess of carbonic acid, which is always present...."

(1) Wallace and Maynard. Clays of Lake Agassiz. P 15.

(2) Clark's Data of Geochemistry.

without this solvent much of the load would be deposited. The carbonate ion throughout the whole course of the river remains fairly small and fairly uniform. The bicarbonate ion, however, shows a gradual increase from Wahpeton to Emerson, then a considerable decrease at Morris and at River Park. The Assiniboine is low in bicarbonate and influences somewhat the drop from River Park to Kildonan Park.

River waters may be divided into two classes, sulphate and carbonate, accordingly as the sulphate or carbonate ions predominate. The Red River is a carbonate water although the sulphates are also quite high. It could perhaps be safely said that, if the Red River was shut off from all its tributaries, and its composition dependent throughout its entire length upon the leaching of Pleistocene clays, at Winnipeg the carbonic ions would be much more in excess of the sulphate than they are now.

It must be remembered in studying the above graph that it was made from a series of analyses of samples collected on or about October the ninth, 1924, at various points along the Red River, and as the composition of a river is always changing, due to rains, etc., the graph can only be said to show accurately the relationship between the various constituents at that time. It is no doubt fairly representative of the river taken as a whole for October. A similar graph made from, say, ten analyses at each of the above points, would very likely be less irregular than graph A.

THE MISSISSIPPI AND ITS TRIBUTARIES.

The following information gathered principally from Clark and various Water Supply Papers gives a fairly complete summary of the composition of the waters of the Mississippi and four of its most important tributaries.

A. Brainerd, Minnesota, near source (Clark).

B. Above Minneapolis.

C. Moline, Illinois. (Water Supply Paper 239)

D. Memphis, Tennessee. (Clark)

E. Above New Orleans. (Clark)

The following analyses were not made from samples collected about the same time, but were averages of a series of samples collected daily over long periods, and may be taken as representative of the composition of the water at the point where taken. They have been recalculated into parts per million.

	A	B	C	D	E
CO ₃	100.6	140.5	159.0	63.0	62.5
SO ₄	2.0	3.3	15.0	22.2	24.7
Cl	1.0	1.7	3.7	11.2	10.4
Ca	44.6	44.0	35.0	33.4	38.8
Mg	7.9	15.4	13.0	13.2	8.6
K Na	15.3	4.5	10.0	12.2	15.7
SiO ₂	18.3	12.3	16.0	38.2	11.1
Al ₂ O ₃	3.9	...	...	...	1.09
Fe ₂ O ₃	3.1	.7	.39	1.5	.25
	195	188	179	197	166

The above analyses were plotted on a graph (B), parts per million against miles from Brainerd.

The Missouri and the Ohio Rivers flow into the Mississippi between Moline and Memphis; and the Arkansas and the Red River (of the south) are the main tributaries between Memphis and New Orleans. The following analyses of these streams were obtained from Clark's Data of Geochemistry and the U.S. Water Supply Paper 239, and were recalculated to parts per million.

- A. Missouri at its mouth.
- B. Ohio--no complete analysis of the Ohio could be found, so a mean of four of its tributaries (Monongahela, Wabash, Kentucky, and Cumberland Rivers) was taken.
- C. Arkansas at Little Rock.
- D. Red River of the South at Shreveport, Louisiana.

	A	B	C	D
CO ₃	30.1	55.9	66.8	54.7
SO ₄	28.2	26.2	76.1	77.6
Cl	8.1	10.1	189.6	46.6
Ca	11.0	34.8	49.7	44.2
Mg	6.1	7.1	12.8	18.4
Na K	19.3	11.7	128.0	38.5
SiO ₂	10.2	13.9	33.4	33.4
Al ₂ O ₃	.....	4.3	.....	4.6
Fe ₂ O ₃	.....	.....	2.6	.....
	113	164	559	318

As seen from graph B, between points C and D there is a decided increase in the sulphate radicle. The Missouri and the Ohio, especially the former, are high in sulphates. W.D. Collins (1) says: "On account of the large proportion of sulphate in the Missouri River water, the Mississippi River water below the mouth of the Missouri is much less satisfactory

(1) Water Supply Paper 239

for industrial purposes, even after purification.

The increase in concentration of the Mississippi between C and D does not seem to be due to the Missouri or the Ohio, for they are both much more dilute than the Mississippi at Moline and would tend to decrease, not increase, the concentration.

Also, between Moline and Memphis, there is a decided drop in the carbonate radicle while the two main tributaries between these points are both high in carbonate. These tributaries are also high in silica but not high enough to account for the jump from 16 to 38.2 FPM as shown on the graph.

The calcium and the magnesium ions show little change although the Missouri is quite low in both, and the Ohio low in magnesium.

The two tributaries are both similar to the Mississippi in alkali metal content, but are higher in chlorine, perhaps partially accounting for the increase from 3.7 to 11.2 FPM between C and D.

Between Memphis and New Orleans, the Arkansas and the Red are the two chief tributaries. The decrease in total salinity as shown on the graph is not, as would be expected, for both the Arkansas and the Red are more concentrated than the Mississippi at Memphis. Also they are both quite high in the carbonate radicle, which does not seem to affect the main river greatly. The chloride radicle takes a slight drop which is again contrary to expectations, for the tributaries, especially the Arkansas, are rich in chlorine. Of

course, sewage and other local conditions may explain this.

The most noteworthy change between D and E is the large decrease in silica, dropping from 38.2 to 11.2 PPM. The tributaries are quite rich in silica, so it seems possible that as the river slows down and becomes more sluggish, as it flows through the mud flats above New Orleans, by some means a part of the silica is deposited. (Are tides a possible explanation?).

From the above it appears that in the Mississippi, at any rate, the average composition is not affected to any great extent by the tributaries taken into account; had a more complete comparison been possible the results may have been different.

THE ST. LAWRENCE RIVER AND ITS TRIBUTARIES.

A very complete series of analyses are found in Clark's Data of Geochemistry of the St. Lawrence and its tributaries. It was thought that the mean of all the tributaries would bear a close relation to the analysis of the St. Lawrence at Montreal.

- A. Pigeon River, Minnesota.
- B. Grand River at Grand Rapids, Michigan.
- C. Kalamazoo River near Kalamazoo, Michigan.
- D. Maumee River at Toledo, Ohio.
- E. Genesee River at Rochester, New York.
- F. Oswegatchie River at Ogdensburg, New York.
- G. Ottawa River at Ottawa.
- H. Lake Champlain.
- I. Mean of the above eight tributaries.
- J. St. Lawrence at Montreal.

	A	B	C	D	E
CO3	21.4	114.3	114.4	87.6	64.4
SO4	2.4	33.4	22.9	48.2	44.0
Cl	3.0	7.7	3.4	40.2	2.3
NO3	....	2.4	2.2	4.5	....
Ca	9.4	56.2	55.1	55.5	39.6
Mg	2.9	19.4	17.9	16.1	10.0
Na	2.6	8.2	6.9	22.3	4.4
K	1.2	2.4	1.7	5.2	2.2
SiO2	7.4	13.9	16.9	16.3	1.5
Fe2O3 Al2O3	.7	.1	.6	2.1	1.6
PPM	51	256	242	298	170

	F	G	H	I	J
CO3	30.1	15.9	30.6	59.5	65.7
SO4	9.4	3.8	7.3	21.4	16.6
Cl	.04	.63	1.2	7.3	3.5
NO3	.04	....	....	1.1	....
Ca	16.1	7.4	15.2	31.8	30.6
Mg	4.02	2.1	2.1	9.3	9.4
Na	4.9	2.07	5.9	11.2	7.1
K	1.4	.7	3.7	9.9	14.8
SiO2	10.7	9.0	3.7	9.9	14.8
Fe2O3 Al2O3	.3	3.4	1.0	1.2	....
PPM	77	45	67	152.7	147.7

A study of I and J shows that they do resemble one another noticeably. The fact that there is only a difference of 5 PPM between the actual analysis of the St. Lawrence and the analysis I is itself significant. Generally speaking, the eight tributaries dealt with have a very marked effect on the composition of the St. Lawrence at Montreal.

THE RED RIVER AND SOME OF ITS TRIBUTARIES.

Analyses of four tributaries between Emerson and Winnipeg were obtained, the Rat, the Roseau, the La Salle and the Assiniboine. The Red at Emerson was also

considered as a tributary, and the mean of the five tributaries was taken to see what relation they bore to an analysis of the Red below Winnipeg.

- A. Roseau River. C.P.R. analysis, recalculated to PPM.
- B. Rat River, C.P.R. analysis, recalculated to PPM.
- C. La Salle River at St. Norbert, Manitoba.
- D. Assiniboine River at the foot of Kennedy St., Winnipeg.
- E. Red River at Emerson, Manitoba.
- F. Red River at Kildonan Park, Winnipeg.
- G. Mean of the above tributaries.

	A	B	C	D	E	F	G
CO ₃	277.0	193.0	249.5	141.0	209.4	183.1	202.0
SO ₄	20.7	12.6	124.8	131.5	137.8	101.0	94.0
Cl	24.0	17.0	254.3	68.1	150.0	88.8	104.0
Ca	92.3	68.0	87.6	63.1	50.5	68.5	68.0
Mg	39.0	20.4	44.6	29.6	17.2	15.0	27.0
Na and K	42.0	17.0	236.9	68.7	141.0	94.4	102.0
Fe ₂ O ₃ Al ₂ O ₃	1.5	6.0	14.6	1.8	6.0	4.5	4.0
SiO ₂	14.5	23.0	16.9	16.6	8.6	12.4	15.0
	441	357	1017	520	718	567	616

As the tributaries vary greatly in size, in calculating the mean, two volumes of the Red at Emerson, and two of the Assiniboine for one volume of each of the other three was taken.

If it was assumed that the composition of the Red at Kildonan Park depended upon the five tributaries mentioned, then F and G should be the same. Such is not the case, but they are somewhat similar. The differences may be due to the fact that several minor streams were not taken into account, and also that the run-off directly into the main Red as well as the leaching action of the Red upon its banks from Emerson to Winnipeg were disregarded.

It was this latter fact that led to the experiments on leaching which are given later in the paper.

LAKE WINNIPEG.

The Red River empties into Lake Winnipeg, one of the great fresh water lakes of North America.

The following analyses, taken from Grabau's Principles of Stratigraphy and recalculated to parts per million, give the average composition of some of the Canadian lake waters.

- A. Lake Superior at Sault Ste. Marie, Michigan.
- B. Lake Michigan at St. Ignace, Michigan.
- C. Lake Huron at Port Huron.
- D. Lake Erie at Buffalo, New York.
- E. Lake Champlain.
- F. Lake Winnipeg--analysis by the author from a sample taken four miles out from the mouth of the river (Red).

	A	B	C	D	E	F
CO ₃	23.6	56.7	51.3	61.1	30.6	49.1
SO ₄	2.3	6.5	5.8	12.5	7.3	49.4
Cl	.83	2.4	2.3	7.2	1.1	10.4
Ca	13.4	27.3	24.2	31.8	14.2	20.6
Mg	2.6	8.0	6.8	8.5	2.8	68.0
Na and K	2.6	4.1	3.4	6.4	5.8	11.0
SiO ₂	6.5	10.7	10.7	6.9	3.7	6.7
Fe ₂ O ₃ Al ₂ O ₃	.06	.06	.09	.1	1.7	trace
Total						
salinity 52.		116	105	134	67	154

From the above it is apparent that the water of Lake Winnipeg is quite similar in composition to that of the waters of Lake Champlain and the Great Lakes. It is much higher in the sulphate radicle than

the other lakes, but as the sample was taken only four miles from the mouth of the Red River, which is quite high in sulphates, it may be that the river water still influences it somewhat.

The water of Lake Winnipeg is much more dilute than that of the Red River as it has only 154 PPM, while the Red at Selkirk has 550 PPM.

The river water is diluted on reaching the lake but is dilution the only change that takes place? To compare the waters of the lake with those of the river the lake water analysis was expressed as if the lake had the same concentration as the river at Selkirk. The sample collected from the mouth was disregarded in this comparison, for it would no doubt be contaminated by the lake water, especially after a high wind from the north.

A. Lake Winnipeg Water expressed as if its total concentration was the same as that of the Red at Selkirk.

B. The Red River at Selkirk.

C. Loss or gain of lake water in PPMs

	A	B	C	
			Gain.	Loss.
SiO ₂	23.8	11.3	12.5	
Fe ₂ O ₃ Al ₂ O ₃	....	4.0	....	4.0
Ca	73.9	66.3	7.6	....
Mg	24.4	16.3	8.1	....
Na	32.7	82.2	....	49.5
K	6.4	6.5	....	.1
Cl	38.1	84.1	....	46.0
CO ₃	....	4.3	....	4.3
HCO ₃	174.9	171.2	3.7	....
SO ₄	175.8	104.6	71.2	....
	550	550.8	103.1	103.8

As can be seen from the table above, Lake Winnipeg, if of the same concentration as the river, would be richer in

silica, calcium, magnesium, bicarbonate and sulphate; and poorer in iron and aluminium oxides, the alkali metals, chlorine and carbonate than the river.

COMPARISON OF RIVERS IN SOLID ROCK WITH THE RED RIVER.

The Red River flows throughout its course entirely through Pleistocene clays. ⁽¹⁾ Hannamann gives a number of interesting analyses of Bohemian waters showing the composition of the waters as related to the rocks through which they flow.

- A. From Phyllite. 5 analyses.
- B. From granite. 6 analyses
- C. From mica schist. 6 analyses.
- D. From basalt. 4 analyses
- E. From the Cretaceous. 4 analyses.
- F. Analyses made by the author of the Red River at Winnipeg. (mean of 3 analyses).

	A	B	C	D	E	F
CO ₃	35.94	30.49	32.14	46.85	33.01	33.20
SO ₄	6.46	14.12	12.86	7.94	27.69	20.40
Cl	10.15	6.39	7.24	1.66	2.87	12.30
Ca	11.91	11.89	12.61	20.07	22.12	12.00
Mg	5.02	3.58	5.08	5.76	5.29	5.20
Na	11.20	10.57	10.85	6.22	3.43	11.50
K	4.30	5.63	4.22	3.20	2.72	1.50
SiO ₂	14.94	17.33	15.00	7.67	2.87	3.10
Fe ₂ O ₃ Al ₂ O ₃	.....	.....	.....	.63	.....	.80
percentage	100.00	100.00	100.00	100.00	100.00	100.00
total salinity	48	65	74	343	603	583

(1) Clark's Data of Geochemistry, P 79

LEACHING.

(1)

Hilgard in his book on soils, gives a series of analyses of drain waters from unmanured fields, and compares them with the waters of some of the world's largest rivers. The drain water was made up of materials removed by leaching by the carbonated waters of the atmosphere and soil of certain easily soluble compounds formed in the process of chemical decomposition of rocks. He stated: "It will be noticed that in all the drain waters, lime is the ingredient most abundantly leached out, and as a reference to the acids show, mainly in the form of carbonate, also in that of sulphate. Magnesia is next in amount among the bases, next is soda, largely in the form of sodium chloride. Potash is present in small but rather uniform amounts. Of the acids the carbonic is the most abundant, sulphuric next; chlorine and silicic acid come next, in about equal amounts."

A comparison of the drain waters with river waters showed a general qualitative agreement but a marked diminution in salinity, especially of lime and carbonic acid, which Hilgard considered as indicating a deposition of lime carbonate in the river deposits or alluvial lands.

The Red River flows throughout its entire course through Pleistocene clays; but the waters of its tributaries are influenced by soil, boulder clay and Cretaceous shale as well. In order to determine to what extent these agencies influence the composition of the river water the following experimental work was carried out:

(1) Hilgard. "Soils" P22.

One sample of each of the above materials was obtained.

- A. Pleistocene clay from Kildonan Park, Winnipeg.
- B. Boulder clay from the Moraine between Morden and Thornhill, Manitoba.
- C. Typical soil from the experimental farm at Morden.
- D. Cretaceous shale from an outcrop in the Pierre horizon near Crystal City, Manitoba.

About 50 grams of each sample were ground to a very fine powder, then mixed with approximately 500 cc. of distilled water and shaken for several hours. The solution was carefully filtered off, evaporated to dryness, and analyzed.

	A	B	C	D	E	F
S102	7.1	8.0	15.4	6.7	9.3	3.1
Al ₂ O ₃ Fe ₂ O ₃	1.2	4.5	2.4	5.0	3.3	.8
Ca	22.0	20.2	18.7	25.0	21.5	12.0
Mg	4.2	6.7	4.6	5.4	5.2	5.2
Na	8.1	5.6	9.7	5.1	7.1	11.5
K	.9	1.2	1.5	2.0	1.4	1.5
CO ₃	17.2	18.2	17.9	17.1	17.6	33.2
Cl	6.1	10.4	6.9	7.1	7.6	12.3
SO ₄	33.1	24.9	21.7	26.8	26.6	20.4
Percentage	99.9	99.7	99.8	100.2	99.6	100.0

E was an average of A, B, C and D, while F was an average of four analyses of the Red River below Winnipeg. F represented a water that has been influenced to a greater or less extent by all four factors. If it was assumed that these factors, clay, soil, etc., modify the river water to the same extent, then there should be a similarity between E and F.

That these two analyses were similar was apparent

when the agencies, atmospheric and otherwise, that would change the composition of the river water and would not affect the water used in the artificial leaching, were taken into account.

Although the percentage of organic matter was not determined it must have been quite high, especially in C, and waters rich in organic matter will carry much more colloidal silica and colloidal iron and aluminium hydroxides than water poor in organic matter. Therefore it is quite possible that part of the load of silica and iron and aluminium hydroxides was deposited on reaching the main river, which was no doubt poorer in organic matter than the drain water.

The magnesium, sodium and potassium ions showed very little difference in the two analyses.

In the leaching experiments the samples and the distilled water were in stoppered flasks and the action of the air was negligible so, quite naturally, the percentage of the carbonates was lower than in river water which is exposed to air.

The decrease in percentages of calcium and sulphate may be due to precipitation of calcium sulphate but it seems more likely that the quantity does not change but the influx of carbonate ions lowered the percentages.

The chlorine ion showed an increase in the river water, but this had, likely, little, if any, significance, for F was an analysis of waters taken below Winnipeg which were somewhat polluted by sewers.

From the above it seems that the composition of the

waters of the Red River below Winnipeg was influenced by the Pleistocene clay through which the river flowed, by boulder clay, soils and Cretaceous shale through which its tributaries passed. No doubt some of these substances influenced the water more than others, but before the relative value of each could be determined, much more quantitative work would have to be done and information garnered concerning the amounts of the different materials found in the drainage basin.

SEDIMENT

Besides the dissolved matter the Red River carries a certain amount of suspended matter, the quantity depending upon the nature of the river bed and the velocity of the current. Two analyses of this sediment were made.

A. Kildonan Park, Winnipeg.

B. Four miles out in Lake Winnipeg.

	A	B.
SiO ₂	44.7	44.0
Fe ₂ O ₃ Al ₂ O ₃	22.3	21.9
CaO	7.9	7.3
MgO	4.8	5.9
Na ₂ O	1.8	2.5
K ₂ O	.7	1.2
loss on igniti-		
on	17.4	16.2
percentage	99.6	99.8
PPM	62	23

The Lake sediments were characterized by their extreme fineness, while the Kildonan Park sediments were quite coarse.

There is a striking similarity between the two

chemical analyses, for although the total quantity had diminished greatly, it seems that while some of the sediment was precipitated on reaching the Lake, that no one salt was precipitated in greater quantity than another.

CHEMICAL DENUDATION.

It has been seen from the preceding analyses that the Red River carries a ^{fairly} ~~fairly~~ large quantity of dissolved matter.

It was assumed that analysis number eight of the first table of analyses in the paper was a fair average of the composition of the blending Red and Assiniboine Rivers for October.

(1)

The mean flow for the united rivers was found to be 2200 second feet for October. This was calculated as cubic feet for 31 days and from that to pounds, and it was found that 368,280 million pounds of water flow into Lake Winnipeg in that month. As every million pounds of water contain, from analysis eight, 12.4 pounds of silica, etc., the total weight of each ion was determined for the month:

	SiO ₂	4,566,672
Fe ₂ O ₃	Al ₂ O ₃	1,657,260
	Ca	25,227,180
	Mg	5,524,200
	Na	31,082,832
	K	3,682,800
	CO ₃	3,866,940
	HCO ₃	63,605,128
	Cl	32,703,264
	SO ₄	37,196,280

209,112,556 pounds

(1) Dominion Water Power Branch, Winnipeg.

From the sediment analyses given above it was found that the Red below Winnipeg carried 62 PPM of suspended matter. Assuming this to be an average for the month of October, then the total weight of sediments carried into Lake Winnipeg in that month was 22,821,360 pounds.

In order to obtain an approximate estimation of the erosion of the Red and Assiniboine Rivers it was assumed that the load carried during the month of October was typical, and represented about one-twelfth of the total load for the year. Accordingly it was found that the total suspended and dissolved matter for one year was 2,783,000,000 pounds. It was estimated from figures given in the U.S.W.S.P., 274, page 164, that 107 pounds of the load represented one cubic foot of rock and soil. There was, therefore, about 25,580,000 cubic feet of material eroded from the river basin in one year. As mentioned above, the united drainage basins occupy 116,000 square miles, and it was found that this would be lowered one inch by erosion in 900 years, or one foot in 10,800 years.

THE STATE OF SILICA IN NATURAL WATERS.

It is generally accepted that silica is carried colloiddally in natural waters. Dole said: "Kaklenberg and Lincoln conclude from their experiments that it seems perfectly safe to say that in natural waters, silica always occurs in the colloidal state, and other investigators make practically the same statement". Now, if the above is assumed to be correct, it should be possible to separate this colloidal silica from the surrounding ionic and molecular material.

Red River water which had been filtered with extreme care was used in the following work.

Naturally, the first attempt at separation was by dialysis, but owing to the many mechanical difficulties met with, the experiments were not successful. It was found impossible to pass enough material through a semi-permeable membrane to effect an appreciable separation.

Ultra-filtration was next tried. A piece of parchment paper was cut to fit a suction funnel attached to the water tap. It was hoped that after a few litres of filtered water had passed through that a noticeable amount of colloidal matter would be held by the paper, and that its quantity might be determined by subsequent ignition and weighing. It was found, however, that the water passed through the paper so slowly, even with the greatest pressure possible

(1) Clark's Data of Geochemistry.

(2) Dole. W.S.P. 236.

(3) Kaklenberg and Lincoln. J.P.C. 1898. Vol.2.
P.77.

at the tap, that no results could be obtained.

The above experiments being unsuccessful, attention was next turned to centrifuging. Bancroft⁽¹⁾ states: "Since the existence of a colloidal solution depends on the brownian movements counteracting the force, it follows that, if one increases the force of gravity, a colloidal solution will become less stable and may precipitate. This can be realized experimentally by centrifuging."

The centrifuge available had a maximum speed of 3000 RPM. It was thought that with this, although the colloidal solution would not be precipitated, it would be concentrated somewhat at the bottom of the tubes after a few hours centrifuging.

About two litres of Red River water (Grand Forks) were carefully filtered to remove all the suspended matter, and poured into a flask which was tightly corked to prevent evaporation. 50 cc. of this water were evaporated in a tared platinum dish and the weight of the dissolved salts noted. Now two 100 cc. centrifuge tubes were filled with the water, and carefully sealed. After running the machine for a time 25 cc. were pipetted from the bottom of each tube and this evaporated in a platinum dish and weighed.

	Time.	Approximate Speed.	Increase in Weight.	Percentage Increase.
1	4 hrs.	2000 RPM	.0008 g	4.8
2	5 hrs.	2500 RPM	.0010 g	6.02
3	6 hrs.	2500 RPM	.0020 g	12.04

(1) Bancroft. "Colloidal Chemistry" P 186.

A quantity of water (Kildonan Bridge) was next prepared as before, and centrifuged. In the first instance, instead of drawing the water from the bottom of the tube, it was removed from the top, for the top layer should show a decrease in concentration if the colloidal material was collecting at the bottom. A like quantity of the same sample of water was used, and 25 cc. fractions drawn from the bottom to check the former.

	Time.	Approximate Speed.	Change in Weight.	Percentage.
1	4 hrs.	2500 RPM	.0032 decrease	10% decrease
2	4 hrs.	2500 RPM	.0036 increase	11% increase

These two experiments show a change in concentration surely too great to be due entirely to experimental error. Of course one is not as yet justified in saying that this is due to a concentration of silicic acid in the bottom of the tube, but it seems quite likely that such is the case.

It was highly improbable that this increase was due to either molecular or ionic species. The salinity of the water used was, Grand Forks-- 392 PPM, and Kildonan Park - 622 PPM, (1923 samples). From this it was apparent, that with such dilute solutions, the quantity of the solute in molecular form would not be appreciable. Now with the solute all in the ionic state, moving at a high rate of speed, it did not seem possible that the force developed by a centrifuge revolving at about 2500 RPM would be sufficient to cause these ions to separate into layers of varying concentrations as seemed to be the case. With a low speed

centrifuge only capable of handling tubes containing 100 cc., it was not possible to pass through enough material to make a more accurate analysis.

A Sharpless Super Centrifuge capable of running at 40,000 RPM having been obtained, the work was carried on with it and the following results obtained:

1. Approximately ten litres of river water were filtered through three papers and then passed through the centrifuge. Rate 40,000 RPM; flow 40 cc. PM. After the water had passed through the machine the inside of the bowl was rinsed with distilled water into a platinum dish and the washings evaporated to dryness, heated to 180° C. for one hour and then weighed.

Platinum dish and washings	40.4654 grams.
Platinum dish	40.4614 "
Difference	.0040 "

This small amount was analyzed as carefully as possible and found to contain about 55% silica. This quantity, however, was considered too small for satisfactory work, and it was concluded that, even if the silica in the water was colloidal, the centrifuge was not powerful enough to cause it to be precipitated on the inside of the bowl in appreciable amounts.

2. To determine whether or not it was possible to effect a precipitation or a concentration of colloidal silica by the Super Centrifuge a very dilute solution of water-glass was

used, 2000 cc. of this (.2% solution) were centrifuged at 30,000 RPM and a flow of 40 cc. PM. The solution (about 250 cc.) remaining in the cylinder at the close of the experiment was taken and evaporated to dryness and it was found that a silica gel formed on the bottom of the dish, proving that a separation was effected, for the amount of the gel was much greater than the amount of silica in each 250 cc. of the solution before centrifuging.

3. To confirm the results of 2, another solution of water-glass was prepared, this time of only .01% concentration, and 2000 cc. of this were centrifuged as before. The last 250 cc. in the bowl were evaporated to dryness and analyzed for silica.

Platinum dish and residue from 250 cc.	40.5122 g.
Platinum dish.	40.4600 g.
	.0522 g.

Therefore there was .0320 grams of silica in 250 cc. of the solution remaining in the centrifuge. Now 250 cc. of the original solution only contained .025 grams of water-glass, and as not quite one half of the water-glass was silica, it could readily be seen that a considerable concentration had been effected.

4. The above method was next applied to river waters. Two litres of carefully filtered water were centrifuged at 40,000 RPM and 35 cc. PM. The water remaining in the bowl was evaporated and analyzed for silica.

Silica present	4.5%
Silica present before centrifuging	2.2%
Increase	2.3%

This experiment shows that the silica of the river water has been concentrated by centrifuging and must, therefore, be colloidal.

Three attempts were made to confirm the above, but owing to the leakage of the cylinder no results were obtained. It seemed that the concentrated solution leaked out, for analyses of solutions in the cylinder showed no change from that of the solution before centrifuging. In one case an increase of .1% silica was noted but it was too small to be of value.

5. New washers being obtained for the cylinder, the experiments were repeated using similar quantities of water but the speed this time was only 30,000 RPM, due to low air pressure. The contents of the cylinder were treated as before, and the silica extracted.

Silica present.	3.3%
Silica present before centrifuging	2.2%
Increase	<u>1.1%</u>

This result confirmed 4; the smaller percentage of concentrated silica being due to the fact that the machine was running 10,000 RPM slower than in 4.

This experiment was done twice more at 40,000 RPM and the results were as follows:

Increase of silica	2.7%
Increase of silica	2.4%

Now in three experiments an increase in concentration of silica varying from 2.3 to 2.7% had been accomplished, and in another an increase of 1.1% was noticed. These results seem to prove that the silica of the river water was concentrated by centrifuging, and was therefore

colloidal, but as the quantities dealt with were small further work was done in order to make the proof absolute.

6. Four litres of the water were carefully filtered and then divided into Two equal parts A and B. A was centrifuged as before and the water remaining in the bowl was put away in a corked flask; B was treated similarly. Now the supposedly concentrated solutions from A and B were put together and passed through the machine. The solution remaining in the bowl was evaporated and analyzed for silica. ~~The~~

Silica present	5.8%
Silica present before centrifuging	2.2%
Increase	<u>3.6%</u>

This work was repeated using three 2 litre quantities instead of two.

Silica present	8.3%
Silica present before centrifuging	2.2%
Increase	<u>6.1%</u>

The weight of silica in the last 250 cc. in the bowl was .0101 grams. The six litres of water contained .0618 grams of silica so it was evident that although a concentration had been brought about, only about one-sixth of the total amount of silica had been obtained.

Two more experiments were conducted as before, using, however four 2 litre quantities.

1. Increase of silica	8.9%
2. Increase of silica	8.8%

In these the mean weight of the silica in the solution remaining in the cylinder was .0140 grams. The total weight

of silica in eight litres was .0824 grams, so as before, only approximately one sixth of the silica had been obtained.

7. Experiments were next conducted using dilute solutions of common salt, in order to learn whether or not ions and molecules were concentrated by the Super Centrifuge. Three solutions of sodium chloride in distilled water were used, .1N, .2N and .3N respectively. These were centrifuged as in 4 and the solutions remaining in the bowl evaporated to dryness and weighed and in no case was a concentration noticed.

From the above work it can be seen that while, in the attempt to establish the theory that silica was colloidal in natural waters dialysis and ultra-filtration were of no avail, the centrifuge was of great value. Even with the low speed machine, although the quantities dealt with were minute, it was significant that the results were all positive.

Dilute water-glass solutions were first used with the Super Centrifuge and it was proven that a concentration of the colloidal silica of the water-glass was effected in the bowl of the machine. Red River water was next used in carefully filtered two-litre quantities, and increases in concentration of silica varying from 1.1% to 2.8% were obtained. A method of centrifuging and fractionation and subsequent centrifuging of the fractions was devised as outlined in experiment 5 and very conclusive results were obtained. Increases of concentration of silica ranging from 3.6% to 8.9% were obtained depending upon the number fractions treated. In this work, however, it was shown that only about one-sixth of the total silica was separated by the machine. It was also proven that sodium chloride ions and

and molecules were not concentrated by the machine, and therefore it seemed safe to say that the centrifuge was only powerful enough to effect a concentration of particles of colloidal size and that the silica separated by the machine was in the colloidal state. That is, the silica in the water of the Red River was colloidal to the extent that one-sixth of it could be separated by the Super Centrifuge.

SUMMARY.

The Red River of the North rises in Minnesota and flows into Lake Winnipeg, Manitoba. Eleven samples were obtained on October the ninth, 1924, or thereabouts, from points on the river between Wahpeton and Lake Winnipeg. These were analyzed and the results plotted on a graph to show the relationship between the various constituents and the changes in composition as the river advanced northwards. Generally speaking, the total salinity increased from Wahpeton to River Park and then fell sharply towards Lake Winnipeg. An attempt was made in the discussion to explain the various irregularities in the graph as far as possible.

A study of the Mississippi, the St. Lawrence and the Red Rivers, and their tributaries showed that the chemical composition of the tributaries had a profound influence on the composition of the main streams. An analysis of the St. Lawrence at Montreal, for example, was found to be practically the mean of the analyses of eight of its tributaries.

An analysis of Lake Winnipeg water was compared with analyses of other Canadian fresh-water lakes and was found to be quite similar in composition although somewhat richer in sulphates. This enrichment was no doubt caused by the high sulphate content of the Red.

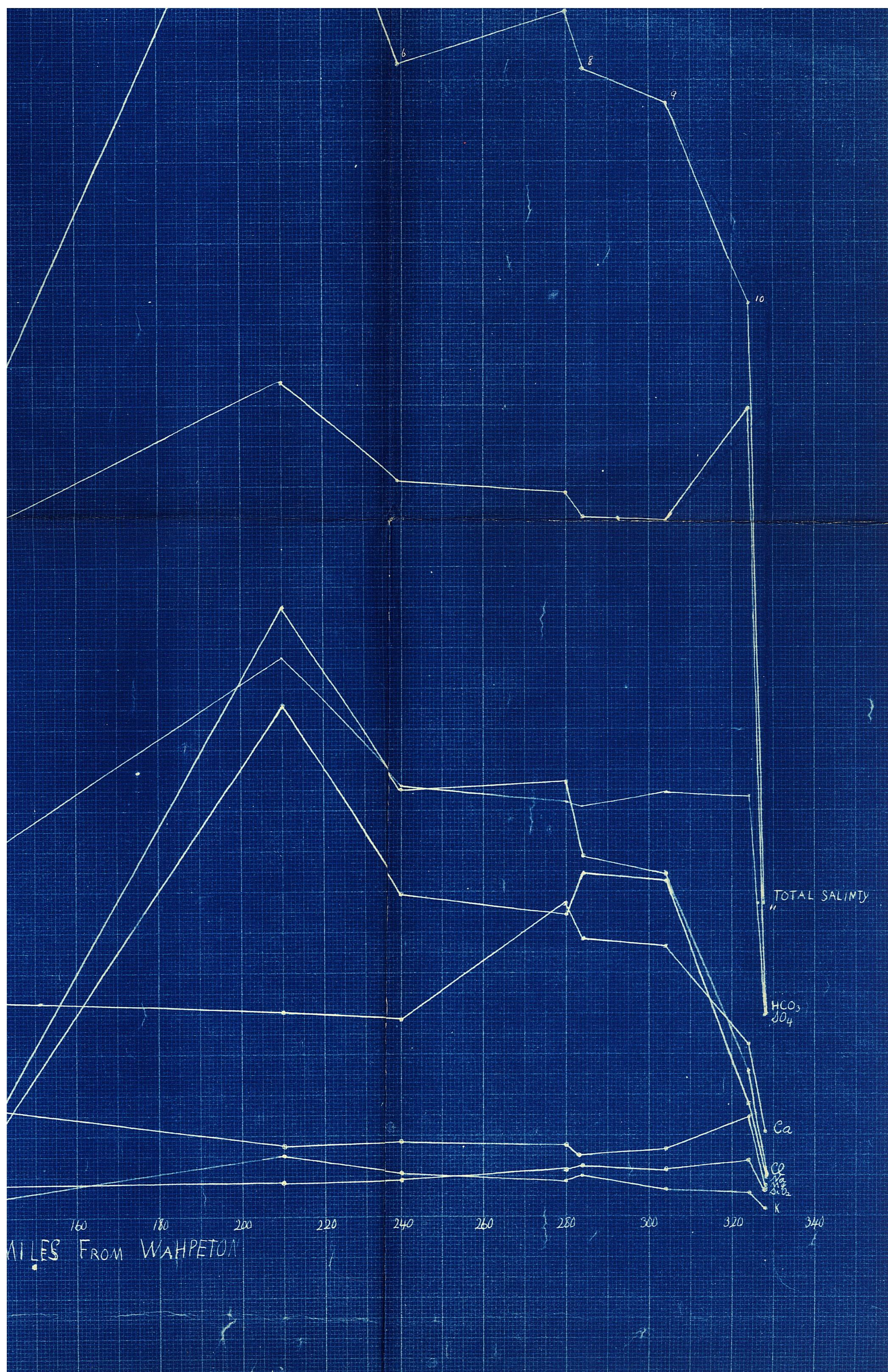
A series of experiments on leaching, in an attempt to discover the effect of soil, clays, etc., on the composition of the river water, were made.

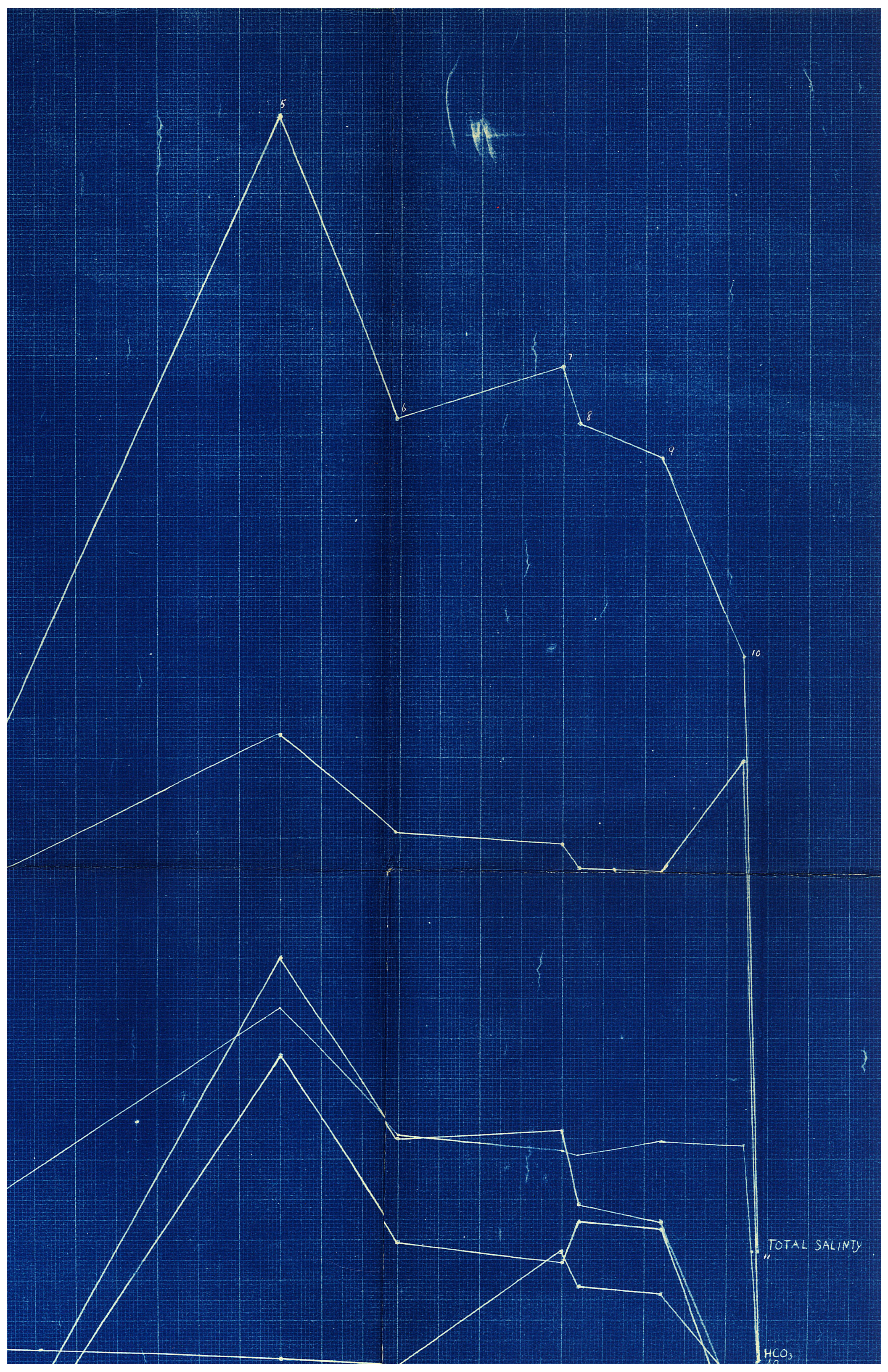
An analysis of the suspended matter in Lake Winnipeg was compared with that in the River below Winnipeg and was found to agree closely in percentage composition although

the Lake had only 23 PPM to the River's 62 PPM.

An estimation was made of the total eroding effect of the Red and Assiniboine Rivers and it was found that approximately one foot of the whole drainage basin would be eroded in 10,800 years.

It was also shown by a series of experiments that the silica in the Red River water was colloidal to the extent that one-sixth of it could be separated by the Super Centrifuge.



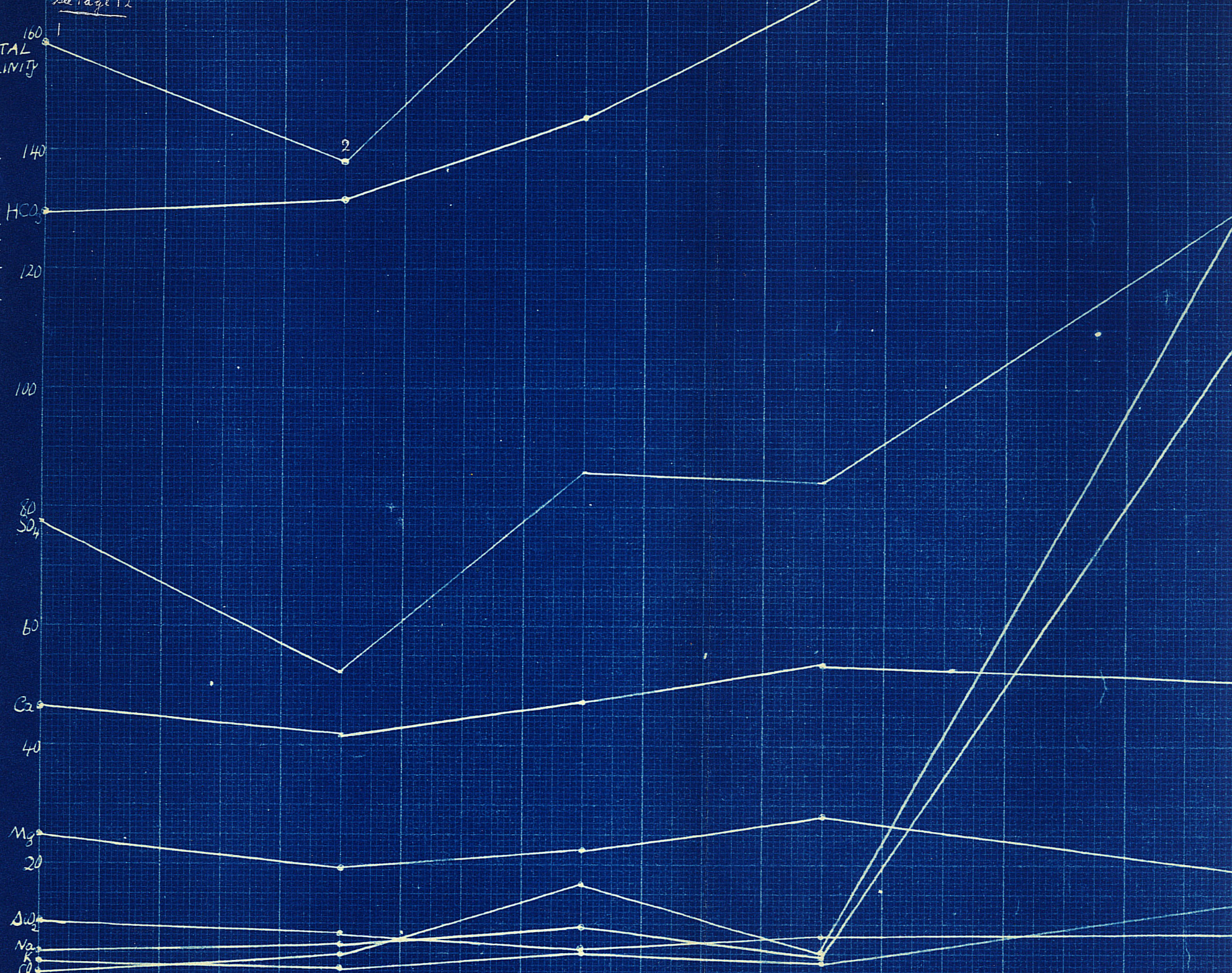


PARTS PER MILLION

TOTAL SALINITY

280
260
240
220
200
180
160
140
120
100
80
60
40
20
0

See Page 12



Scale 1 in = 20 PPM
1 in = 20 Miles For Totals 1 in = 40 PPM

MILES FROM WAHPETON

PARTS PER MILLION

TOTAL SALINITY

See Page 12

160

1

140

2

120

100

80

60

40

20

0

1

2

3

4

5

6

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