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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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Ann Arbor

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1930
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LOWER MACKENZIE REGION OF NORTHWESTERN CANADA

WILLIAM A. KELLY

THE following notes were made during the summer of 1923 on the region between the trading-posts of Ft. Resolution on Great Slave Lake and Ft. Good Hope on the Mackenzie River, a few miles south of the Arctic Circle. The account deals, therefore, with only a small portion of the 682,000 square miles in the Mackenzie River basin. (See Map 5, p. 213.)

Ft. Resolution is situated on a bay of the same name and near the mouth of one of the distributaries, or "snyes," as these channels are locally called, of the Slave River. Resolution is typical of the northern trading-post. It consists of a few white people, some hundred or so Indians, and literally hundreds of dogs.

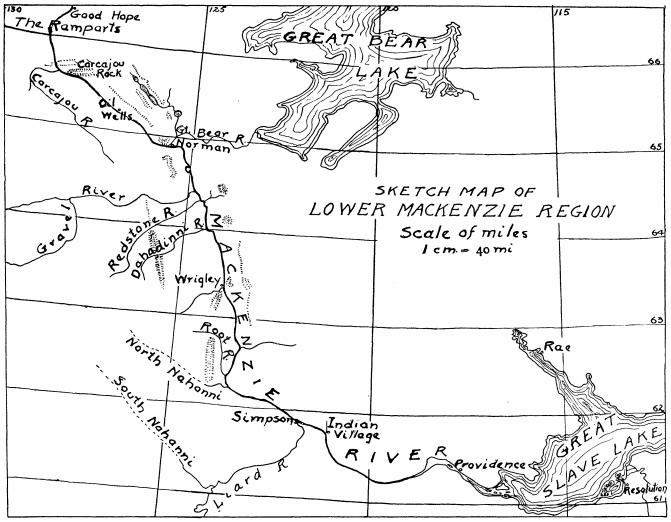
The northern lakes are ice-bound quite late in the season. Ice-floes were present on Great Slave Lake as late as June 22. The ice would move toward or away from the shores according to the direction of the wind. The passenger boats are forced to wait until the lake is free from ice, but canoes and other small craft are able to take advantage of temporary breaks in the ice-floes. Ice on the lake retards the growth of vegetation until late in June. Trees along the south shore are frequently not in leaf before the end of the month. On the other hand the vegetation is much farther advanced along the Slave River, which is free from ice earlier than the lake.

There is an appreciable current near the western end of Great Slave Lake where a drift toward the Mackenzie becomes noticeable. No marked dividing line exists between the lake and the upper part of the river, which is about seven miles in width. Several islands occur at this point, and illustrate a parallel to the Thousand Islands at the eastern end of Lake Ontario. One of these islands, named Brabant, was occupied during a period when the ice was leaving the lake in great streams. Individual icefloes were as much as 300 feet in length. The ice-floes pass steadily for several hours, and then there is an intermission during which the river is comparatively clear. While we were waiting for one of these periods, opportunity to examine the island was given. The flora of the eastern end of Brabant Island includes stunted spruce, small birch, Labrador tea, and Arctic moss, and differs considerably from that of the western end, where taller spruce, poplar and birch trees, without the tundra plants, are found. The deciduous trees here were all in bud, and farther advanced than those along the exposed shores of Great Slave Lake.

The Mackenzie had considerable drift ice as far down as Mills Lake. This lake is an expansion of the river about ten miles below Providence, a trading-post about 45 miles below Great Slave Lake. The sluggish and comparatively warm waters of Mills Lake are apparently sufficient to melt the ice which has drifted down stream to that point, for no floes were observed below it.

Although the Mackenzie forms the main highway of northern Canada, the unsettled character of the country on either bank gives few traffic problems. In the journey between Providence and Simpson, a distance of about 150 miles, we met only one canoe, and passed only one Indian encampment. With its conical tepees perched along a high bank above a row of birch-bark canoes, it appeared very picturesque from a distance.

Ft. Simpson is situated at the junction of the Mackenzie and Liard rivers. Both are large streams but markedly different in other characters. The water of the Mackenzie is still comparatively clear at Simpson because of the settling basin provided by Great Slave Lake. On the other hand the Liard does not flow from any lake, and its water is very turbid, and the volume subject to greater fluctuation during flood periods. At high water the Liard is said to have a greater volume than the Mackenzie. The waters of the two rivers do not mix readily, and there is a sharp contrast between the muddy water of the Liard and the clearer water of the Mackenzie. The difference in clearness of the water on opposite sides can be distinguished for about 75 miles below the junction of the two streams. Good drinking water is not obtainable on the west side of the Mackenzie, but despite this fact, most of the settlements are along that bank, because the settlers wish to make use of the large poplar trees which drift down the Liard, but are not found along the Mackenzie side. These large trees grow in the upper part of the Liard basin where the moderating influences of the Pacific upon the climate are effective.



MAP 5

Although Simpson is in a latitude somewhat north of Resolution, the plant growth is not retarded by a great body of cold water. By June 29, potatoes were up, hay was nearly ready to cut, and quickly growing vegetables such as radishes and lettuce were being served at the table.

From Simpson there is another stretch of about 150 miles before one reaches Ft. Wrigley. The Mackenzie Mountains are visible shortly after one leaves Simpson. The Root River Range belongs to this system and stands out as a bold escarpment when seen from near the mouth of the Root River. Its crest and eastern slopes were entirely free from snow. The fact appears to be an anomalous one, for a journey inland proves that the subsoils in this region are permanently frozen.

The Mackenzie River for part of its course flows obliquely across the trend of several mountain ranges. None of these is comparable in altitude or topographical aspect to the front range of the Rocky Mountains near the international border. Most of the ranges of the Mackenzie region have a relief of less than 2000 feet, and the tops of many of the mountains are rounded. Several streams flowing from the west into the Mackenzie have their sources in ranges which parallel the main stream. The Dahadinni River, some 35 miles below Wrigley, is an example of one of these tributaries. It rises nearly 40 miles west of the Mackenzie. The Dahadinni has a steep gradient, and numerous boulder rapids which make it unnavigable even for canoes. A trip inland up such a valley as this must be made by back-packing. No trails can be followed other than the slashings made by a prospector — in the winter, a trapper — along his winter trap line. In the summer of 1923 a large fire was burning in the country 20 miles back of the Mackenzie. Such fires are detrimental to trapping since they destroy the forests frequented by the fur-bearing animals. In place of the poplar, birch and spruce trees, small shrubs spring up. Such burnt-over land is known as "brule," and is good moose-hunting area. The fires are ordinarily attributed to the natives, who are hunters, rather than trappers.

Among small plants growing in the Dahadinni Valley the wild strawberry was noted. It was not observed north of the Dahadinni. Raspberries, gooseberries and red currants were found almost as far north as the Arctic Circle and are recorded even farther north.

The Redstone River, a somewhat larger stream than the Dahadinni, enters the Mackenzie 25 miles below the Dahadinni. There is a large delta at the mouth of the Redstone which has been sharply truncated by the swift current of the Mackenzie. Though the surface of the delta is several feet higher than the normal level of the Mackenzie, there is reason to believe that when the ice goes out of the main stream the water rises above the delta, because the trees here are snapped off at a height of three or four feet. This probably happened when the ice in the main stream backed up the tributary valley, because of an ice jam which had formed below the Redstone. These ice jams occur frequently on the Mackenzie, since the lower reaches remain frozen after the ice upstream is bulged up and broken. The ice first moves out of the Liard River, and the rising waters of this stream cause the progressive buckling up of the ice on the Mackenzie below Simpson.

The Mackenzie frequently broadens out to a stream several miles in width below its confluence with the Redstone. Gravel bars are common, and the mapping of a permanent channel is difficult because of the shifting

nature of the currents. The flat-bottomed stern wheelers and loaded scows frequently run aground. One of the Hudson Bay Company's boats was stranded on a gravel bar for several weeks.

Ft. Norman is a trading-post on one of these broad stretches. It is built at the mouth of the Great Bear River, about 300 miles below Simpson. Norman gained considerable notice in the years immediately following 1920 when there was a great deal of oil excitement in this region. By 1923 the excitement had died down and Norman's chief claim for fame at the time was the possession of a horse. It was the only horse north of Simpson, and to the Indians it was stranger than the aeroplanes which used to fly to the oil camp north of Norman. To them, the aeroplane was just a machine somewhat more wonderful than the steam- and motor-boats, but the horse was a creature akin to no animal they knew. When the horse was first brought to Norman the men wanted to shoot it; the Indian children feared it, or at least stood in awe of it. The horse adapted itself to the country, and was in excellent shape. As a means of transportation it will be second to the canoe and to the husky.

The oil field is 50 miles northwest of Norman. The Imperial Oil Company has drilled several wells in the region, the first of which has yielded a notable production. The presence of oil was known for over 100 years, since seepages occur along the river for many miles.

Portions of the Mackenzie between the wells and Good Hope are very impressive. Carcajou Rock, which is formed by a highly tilted limestone formation, rises abruptly from the water to a height of several hundred feet. An erosional remnant, high up the slope of the escarpment, resembles the form of a wolverine. This is the landmark for which the mountain is named.

About nine miles above the post of Good Hope the river suddenly contracts from a stream that is nearly two miles in width to one that is less than half a mile. The river enters a steep-walled canyon that is known as the Ramparts. This is comparable to Niagara Gorge. The walls of the canyon show the bedding-planes dipping gently upstream like those in the walls of the better known gorge, and like that gorge, the Ramparts were probably formed by a waterfall as it retreated upstream. We do not find any waterfalls at the head of the Ramparts today because the limestones exposed in the canyon are replaced there by softer rocks. The latter were deposited in hollows of the limestone which had been eroded long before the age of the Mackenzie by streams that had an east-west trend. Once the prehistoric Mackenzie waterfalls had retreated to the unconformable boundary between the hard limestone and the softer rock, the falls disappeared rapidly, and now only a small rapids formed by the lower beds of the limestone is in existence. If it were not for the unconformity, the ancient waterfalls would have persisted until the dip of the beds had carried the upper beds of the limestone below the level of the river, and waterfalls as great as those of Niagara would still be in existence.

Good Hope lies only two miles below the end of the Ramparts. It was reached late in August a few days before one of the steamboats was due to make its last trip of the season south. Canoes were disposed of at the post. Then followed a short wait until the boat arrived, and the homeward journey began.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

THE HIGHLAND RIM IN THE VICINITY OF MILL SPRINGS, KENTUCKY *

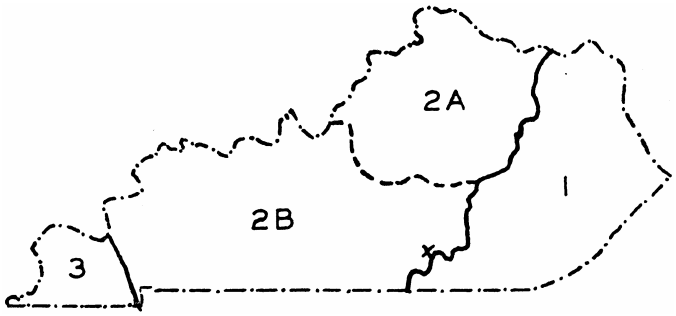
HENRY MADISON KENDALL

MILL SPRINGS, Kentucky (Map 6), and its immediate vicinity, on the Highland Rim within two miles of the outliers and slopes of the Cumberland Plateau, present a very distinct picture. A gently rolling surface (Map 7) dotted with sink holes gives way on the north to the dissected steep slopes of the Cumberland River Valley and to the south rise the slopes of the Cumberland Plateau. Cornfields and pasture land interrupted on the more rugged portions of this surface by patches of woodland dominate the landscape and the presence of houses and stores along the main road, the Monticello-Burnside Pike, seems to indicate the importance to the area of an improved route of communication.

1. NATURAL SETTING

Surface

The Highland Rim in this section lies between 800 and 940 feet above sea-level. Early mature mantled karst expresses most aptly the features of surface and drainage which are encountered. The parent material in which the present surface has been etched is of the Saint Louis formation consisting of impure limestones. In that portion to the west of Mill Springs, erosion is well advanced, and the surface is somewhat more broken than is the land to the southeast of the village. To the east and northeast, there are remnants of outliers and the erosion of the valley edge has had a more noticeable effect upon that portion of the upland nearest to it. The largest stream, Meadow Creek, presents an example of an underground stream in part of its course. Most of the sink holes are filled with water, and there are no streams whose courses are on the surface throughout their lengths.

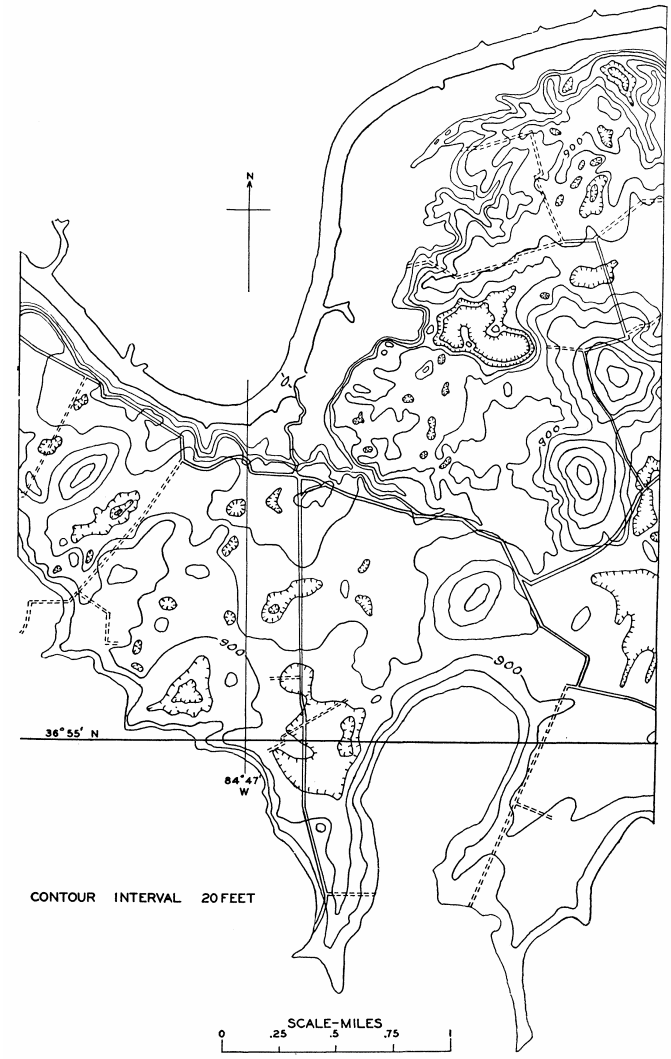


MAP 6. Diagram showing the physiographic regions of Kentucky and the location of the Mill Springs area
1. Appalachian (Cumberland) Plateau 2. Interior low plateaus: *a*, Lexington Plain; *b*, Highland Rim
3. Mississippian embayment; x = Mill Springs

Soil

The soil is, for the most part, a deep, residual one, with parent material of the Saint Louis formation. It may be divided into four main groups or types: clear loam; pebbly; rocky, or "nigger-head"; and fragmentary. By far the most common type areally is the "niggerhead." The clear loam occupies the next greatest area, and only small areas of pebbly and fragmentary soil are found. All these types have a reddish brown color at the surface, becoming lighter in color with depth. The "niggerhead," which is characteristically the soil of the area, is loamy in its upper horizon, apparently becoming less so with depth. Scattered unevenly throughout it are large pieces of limestone and chert, the latter being far more prevalent. These are of about the size and shape of a sheep's head, and are colloquially called "sheeps'-heads"; more often, however, they are called "niggerheads." In wet weather, these soils become very heavy and their clay content is well emphasized. The clear loam is very similar to the niggerhead, except that it does not contain rock fragments. The fragmentary soil is found chiefly in close proximity to the lower portion of the colluvial base of the Cumberland Plateau. The pebbly soil appears more or less scattered over the whole area, though no large individual patches are found. The pebbles are near the surface, and have the appearance of being water-worn. Their origin is not definitely known, but probably they were transported to the area by post-glacial streams from the Cumberland Plateau.

The area was probably originally covered with a light forest, small patches of which remain to the present. This forest was not so dense as was that of the Cumberland Plateau, and throughout it were patches of grassland. Back in the coves and on the slopes of the Cumberland River Valley, there still remain numerous cedar glades. In the patches of woodland that remain, chestnut and walnut are most prominent. Oak and poplar are found, but have largely been cut off, with, of course, no systematic attempt at reforestation.



MAP 7. Contour map of the Highland Rim in the vicinity of Mill Springs, Kentucky

Vegetation

2. MODIFICATION OF THE NATURAL SETTING

The original inhabitants of the area were Indians primarily engaged in hunting and fishing. With the coming of the whites, agriculture became the dominant pursuit and has continued so to the present. The first settlers found the area to be along the route from the coast to the Blue Grass region and to the Nashville Basin. With the westward expansion of the country, this route became little used. The apparent wealth of resources dwindled in comparison to the unknown resources of the west, and many settlers left the area for the new lands. Until the conclusion of the greatest period of western expansion, this area was isolated. Then began the improvement in communication which has left its impression on the present landscape.

Early Settlement

The white population is, for the most part, made up of descendants of the original pioneers who came through the Cumberland Gap from the Carolinas and Virginia. The stories of the present inhabitants encourage the belief that the original settlers were temporary in their occupation of the land. It is quite probable that some of the pioneers were hunters, but the record of permanent settlement at the base of the Cumberland Plateau, where the waters of Meadow Creek were available, leads to the conclusion that there were also among the first settlers those who were seeking permanent homes with brighter possibilities than had been found to the east. This area lay along the road from the Blue Grass to the Nashville Basin, and was a likely land in which to settle.

The first settlements were all in the timber or on its edge, not necessarily because of any distrust of the fertility of the grass-lands, but because a site in the forest country was more eligible for the frontiersman. For example, the oldest settlement in Wayne County, before 1790, was made on Meadow Creek, at the base of the Mountains, and in a cove extending back into the mountains. Here was good timber for the home and farm needs, walnut and chestnut that split easily into rails and could be hewn readily into timber; the soft, yellow poplar, a wood of all uses, and the giant white oak to be riven into shingles. Here were also great, cold springs, issuing at the base of the Mountains, stone for fire places and chimneys, and abundant mast for hogs. Immediately adjacent were the meadows of the limestone plateau, and level deep soil that could be cultivated without clearing.[1]

The settlers were at first occupied with the necessity of obtaining a permanent home and entrenching themselves in a self-sufficient position. They brought with them the corn and wheat which supplied their grain needs. The raising of a few cows and sheep, augmented by hunting, provided meat, leather and wool. By tradition, the people were primarily agriculturalists, and they remained so with some tendency toward cattle raising.

Later Settlement

Slaves were brought in and their descendants now make up a considerable part of the population. The increase in numbers of settlers led to an attempt to utilize the land across the river, and with this came the probable "raison d'être" of Mill Springs. The only fording place of the Cumberland River for many miles in either direction was in that part which is just below the clump of houses which make up the center of Mill Springs. Again, with the influx of settlers, there arose a need for a mill at which grain could be ground. The only surface stream in the area which could produce the power to turn a water-wheel of any size flowed down the dissected slope of the valley edge at the same place. A mill was built there, and probably accounts for the name of the village. With these two factors playing a very important part, there arose a distinct tendency for all roads to lead to Mill Springs.

The improvement of the pike, or, better perhaps, the establishment of the pike, was really only an emphasis of existing routes. It enters the area from the east, just to the south of an outlier of the plateau, and, turning rather sharply in a northwest direction, approaches the dissected edge of the upland. At Mill Springs, on the upland edge, it again changes direction, and continues almost due south into a cove between outliers of the plateau where there is a gap through which it finds an easy route to Monticello. Throughout its length, the pike follows the plateau edge, or the edge of the outliers, with the exception of its course through this one area where it definitely leaves its normal route to approach the river.

The Present

The pike provides an easy route of transportation and communication, and has had no little effect on the improvement of the area both economically and socially. The houses are distributed along it, and the establishment of stores at the intersections of other roads with it can be noted. The factor of isolation, with its power of forming small groups of people hostile to adjacent groups, and completely out of touch with the rest of the world, has been at least partially overcome. The establishment of stores has brought a common meeting place where news is gathered and dispatched, problems of general interest are discussed, and knowledge is disseminated by those who are recognized as the better or more prosperous of the farmers.

A few of the younger and more alert farmers are beginning to believe that probably the land cannot grow corn successfully for a hundred years or more without some care. They are beginning to try fertilization and rotation of crops. They realize that they must get all the benefits of life by their own devices, and these devices they are able to improve not only among themselves, but also by the cultivation of relations with the outside world.

The cross-roads store provides the people with their small needs by accepting poultry, eggs, corn and even hogs in exchange for the articles purchased. For machinery, farmers prefer to go to Monticello, where there are two well-stocked farm implement stores. Rarely purchases are made at Somerset and Burnside. There must be mentioned in addition the extensive patronage of mail-order houses for all articles ranging from coffee pots to suits and dresses. It appears that this source of human comfort is now less used than some fifteen years ago, before the improvement of the pike or the establishment of all but one of the stores.

Many of the houses along the pike have been painted, some for the first time. Some broken window panes have been replaced, though there are still many signs of the carelessness of the occupants. To the west of Mill Springs and away from the pike, the houses are in wretched condition. Sagging roofs, broken porch floors, and tottering joists appear to be quite in keeping with the energy of the inhabitants. Some of the rooms of the houses along the pike have been plastered and

papered, and the walls of every room have at least been covered by newspapers. Away from the pike, even the newspapers are missing. With the removal of the factor of isolation, more and more care is being taken of the appearance of all farm property. Of course, not all the poor farm buildings have been removed from their places along the road, nor are the more isolated sections completely devoid of any signs of improvement. In the midst of the clump of houses which forms the center of Mill Springs, there remain two very dilapidated barns; one is given over to storage, and the other combines the functions of store, garage and blacksmith shop. In one of the coves, one of the most modern of farms is found with its substantial house and barn and fences, and this is two miles away by the most practicable road from the pike. In general, all the houses of the area which are east of Mill Springs are in good repair, but those to the west are just about standing.

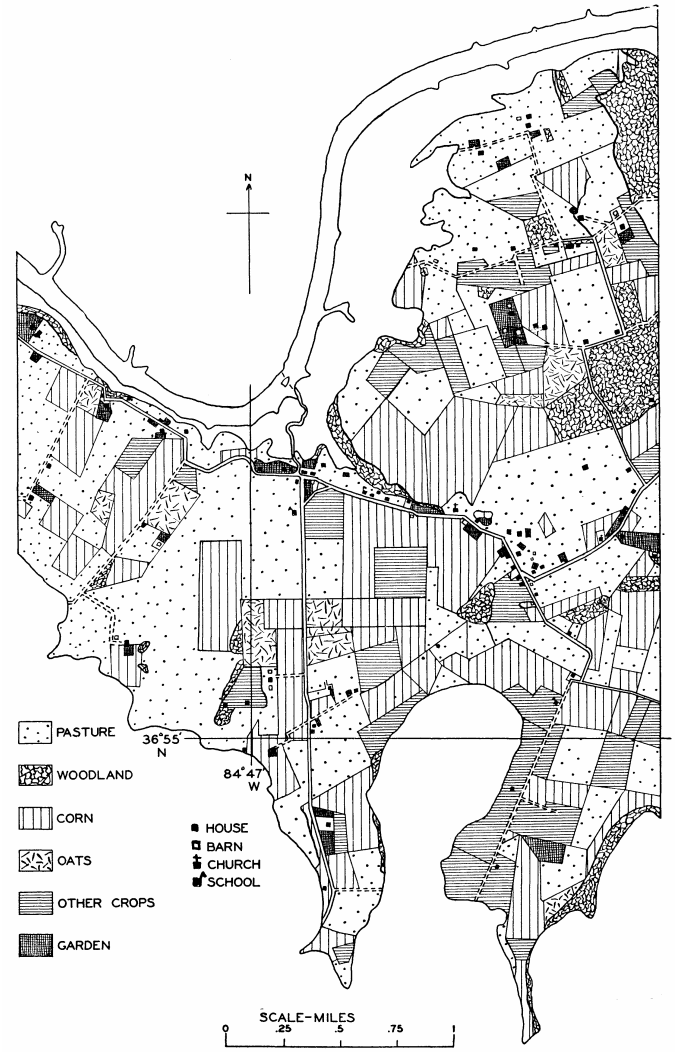
To the west of Mill Springs, the greater percentage of the land is in pasture. To the east and northeast, the outlier remnants are quite heavily wooded, and most of the remainder of the land is in pasture. In the area between the parts of the pike, most of the land is in crops. Yet there appears to be no striking difference between the farms in acreage of crops grown and the crops appear to bear no direct relation to the type of soil on which they are grown. It can be said, however, that corn is usually found on the loamy soil or on the niggerhead, and permanent pasture appears to be found in areas of fragmentary and pebbly soil. Corn is by far the most important crop on all farms, occupying nearly one third of all the land. The average farm has about fifty acres in corn, and about twenty in other crops, of which oats is at present the most important. Wheat often occupies a position of importance as a winter- or fall-sown crop,[2] but, during the year 1928, it had only a small acreage. The winter of 1927-28 was unusually severe, and the winter-killing of wheat necessitated replanting of the ground usually given over to it. Pasture, both cleared and brush, and woodland occupy somewhat over one half of the land. Less than one fifth of this can be classed as woodland, and the tree growth in any part of it is at best second rate. The stocking is mostly from three to six inches, and the patches of woods are crowded with underbrush. It might well be classed as waste land. Its function is almost non-existent, but it does occasionally supply firewood, and at times even timber for a temporary sawmill which at present is located beside the pike about a mile east of Mill Springs. There is a coffin factory, the work in which occupies most of the time of two individuals, but the sources of supply for this industry are the cedar glades which are found off the upland proper on the slopes of the Cumberland River Valley and on the slopes of the Cumberland Plateau.

An analysis of the cover map of the area (Map 8) supplies the following table:

	Percentage of the total land
Pasture (all kinds)	46.3
Corn	28.5
Woodland and waste land	6.2
Oats	3.6
Garden	1.9
Other cropped land [3]	9.9
Roads, houses, barns, etc.	3.5
	99.9

The percentage of the land in crops amounts to 43.9 per cent. The percentage of total cropped land in different crops is as follows:

	Percentage of the cropped land
Corn	64.8
Oats	8.0
Garden	4.5
Others	22.6
	99.9



MAP 8. Cover map of the Highland Rim in the vicinity of Mill Springs, Kentucky

Some two hundred head of cattle and two hundred and fifty hogs are kept on fifteen farms in the area. According to estimates made from statements of the

farmers, the number of hogs has been slowly decreasing in the past few years, while the number of head of cattle per farm has steadily increased. Many mules are kept as work animals, but the number of horses is very small. On the fifteen farms, there were forty-one mules and thirteen horses. Almost every farm has its quota of hens, or a few ducks and geese are kept. The poultry is of the scavenger type, and the products are mainly for family consumption, though some eggs, and, infrequently, chickens, are used in barter at the nearest store.

The dominance of corn in the crop land and the presence of a considerable number of livestock bring out more clearly the changing conditions. For many years, the people of the land were very nearly self-sufficient. They were isolated, and had to produce those things which gave them the greatest return for their energy expended. Corn for cereal was necessary. It grew well. The yield was high on the new and unused lands. It provided animal as well as human food. There was need, however, for variety of diet. Some meat was essential, and what could be more natural than the raising of the best converter? The hog became part and parcel of the life of the area. If corn was scarce, the hog could obtain food from the forest. A few cattle were kept, partially, at least, as a source of dairy products. Occasionally, the flesh of a cow gave a respite from the steady diet of "hog meat." Then, with the change in transportation facilities, which diminished the isolation, there came a realization of the possibility of producing for other parts of the country. It may not have been a conscious realization. The chance of buying goods manufactured outside the narrow sphere of existence of these people gave rise to the need for money. Their life before had been conducted without the use of currency. Barter had sufficed to purchase most of their needs. Now, a cash crop was necessary. The gradual change from the self-sufficient existence is still apparent. At the present time, about sixty-five per cent of the corn is fed to livestock, about fifteen per cent is used as human food, and the remainder is sold to the mill at Mill Springs. It would seem quite probable that there will be a continued increase in the practise of fattening cattle for the Cincinnati market.

The change in purpose of cattle raising and the relative decline in the raising of hogs has not as yet altered to any great extent the customary diet of the people. Corn in all forms (but more particularly as corn pone), "hog meat" and black coffee can be had at all times in all homes. Other things are still much of a luxury, though, of course, there are many vegetables during their growing months. With the establishment of many stores, there came the opportunity of a more varied diet by the consumption of canned goods. Peculiarly enough, the sale of these canned goods appears to be almost wholly in the line of fruits. The change is coming in the manner of life of the people, as well as in their ideas, but as yet it has made but slight progress.

3. CONCLUSION

In a natural setting, apparently, at least, well suited to the establishment of a fine agricultural community, a pioneering people settled and appeared for a while to have become isolated on the banks of the river of human life. They were isolated because of the development of other routes of travel to newer lands, which were discovered after the settlement of the earlier frontier. They had gone into the land with the desire to make a true home, and, of necessity, they had to make themselves self-sufficient for a time at least. They proceeded to do this effectively. Then, after their firm establishment, they turned about only to see the eyes of their nation fixed on newer and more distant lands — marvelous agricultural lands. Some of them went to the West. Many remained and continued their isolation. Their descendants have seen the growth of newer and better transportation routes and facilities. This growth has removed the factor of isolation and we see a people who are slowly changing their life. They have once again felt the sweep of the current, and are leaving the banks to enter again into the main stream of human activity.

UNIVERSITY OF MICHIGAN

* This study was made at the University of Michigan Geography Field Station, Mill Springs, Kentucky, during the summer of 1928, under the direction of Dr. R. Burnett Hall.

[1] Sauer, C. O., *Geography of the Pennyroyal*, Kentucky Geological Survey, Series VI (Frankfort, Ky.), 25 (1927): 134-135.

[2] The climate of the area is of the type Cfa. Though no weather station is located in the area rainfall and temperature are comparable with Eubank, Williamsburg and Burnside, as shown by the following statistics from *Bulletin W*, U. S. Weather Bureau.

RAINFALL

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Burnside (733)	4.7	4.3	5.3	4.3	4.2	4.2	4.9	4.1	3.5	2.9	3.3	4.2	49.9
Eubank (1177)	4.4	3.6	5.1	3.9	4.3	4.1	4.5	4.2	3.5	2.9	3.3	4.1	47.9
Williamsburg (939)	4.6	3.9	4.8	4.1	4.3	4.6	5.1	4.8	3.3	2.7	3.1	3.7	49.0

TEMPERATURE

	J	F	M	A	M	J	J	A	S	O	N	D	Year
E.	34.8	34.8	46.2	54.4	64.0	71.5	74.9	73.8	68.4	57.0	45.1	36.1	55.1
W.	38.2	38.2	49.0	55.8	66.1	73.8	76.5	75.8	70.6	59.8	47.3	38.9	57.5

[3] Other cropped land includes land in wheat, cow peas, hay, tobacco, sorghum cane and watermelons; wheat and cow peas, about one third each of the land so classed, while hay occupies about one sixth; tobacco, sorghum cane and watermelons the remaining one sixth.

THE OCCURRENCE OF GLAUCONITE IN THE HERMANSVILLE FORMATION OF ALGER COUNTY, MICHIGAN

STANARD G. BERGQUIST

GLAUCONITE is a dark green mineral with a dull luster and a lighter green streak. It is very soft and may readily be broken with the finger nail. Dana[1] gives the hardness of glauconite as 2 and the specific gravity as 2.29-2.39 and describes it as usually being amorphous. The chemical composition of glauconite is quite variable and indefinite, but it is essentially a hydrous metasilicate of iron and potassium with some aluminum. When pure, it probably has the composition represented by the formula Fe''' K Si_2O_6 aq.,[2] in which some of the iron may be replaced by aluminum, and other bases may replace potassium. With the composition thus given, glauconite should contain 13 per cent of potash.[3] The iron is present principally in the ferric form, but usually there is some ferrous iron in association with it. Leith[4] accounts for many of the observed variations in the composition of glauconite as being due to partial alteration of the mineral, resulting in the loss of alkali and the taking up of water. The other variations represent the replacement of the iron salt by its aluminum equivalent and of the potassium salt by corresponding compounds of sodium, magnesium and ferrous iron.

The origin of glauconite is not quite thoroughly understood, but it is thought to form inside shells, mainly Foraminifera, in marine sediments along the shores of the continents, usually at depths greater than 600 feet, but ranging from about 300 feet to somewhat more than two miles.[5] According to Murray and Renard,[6] organic matter inclosed in the shells and associated with the mud itself, through the action of sulphates contained in the sea water changes the iron of the mud into sulphide which may later be oxidized into ferric hydroxide. Sulphur, liberated in the process, becomes oxidized into sulphuric acid, which in turn decomposes the fine clay, causing the precipitation of colloidal silica and, at the same time, the removal of the aluminum by solution. The colloidal silica thus released reacts upon the ferric hydroxide in the presence of potash salts of the sea water and glauconite is formed.

Glauconite is widely distributed in the various oceans where it is now forming abundantly near the mud line just beyond the limits of wave and current action. Harder[7] states that glauconite is disseminated in marine sediments of all geologic ages and that in the Paleozoic rocks it occurs most abundantly in Cambrian and Ordovician strata. Cambrian greensand is common in the north central United States, where it is associated with siliceous limestone and calcareous sandstone beds.

In the geologic studies conducted in Alger County for the Land Economic Survey in the summer of 1928, it was noted that the surface drift in widely separated areas contained slabs and fragments of rock heavily impregnated with glauconite. Wherever these erratics had undergone weathering, patches of greenish clay, in many cases quite plastic, would result. Further investigations carried on to determine the probable source of the glauconitic rock resulted in the uncovering of highly concentrated zones in certain portions of the Hermansville formation.

Rock specimens were collected from two different exposures about ten miles apart in Alger County and these were studied individually for the purpose of finding out to what extent glauconite was present in the formation. The section at Au Train Falls on the Au Train River in NW. ¼, SE. ¼ Sec. 31, T. 46 N., R. 20 W., represents a thickness of about 90 feet made up essentially of dolomite with varying amounts of siliceous material. The section at Wagner Falls on Wagner Creek in NW. ¼, NE. ¼ Sec. 14, T. 46 N., R. 19 W., was sampled through a thickness of 61 feet. The upper 36 feet of this section is made up of siliceous dolomite which rests upon a lower, slightly calcareous ferruginous sandstone.

In the exposure at Au Train Falls, glauconite was found to be disseminated through most of the 90 feet of the section. Of the sixty specimens examined, only three were entirely devoid of the mineral; the others contained it in greater or lesser amounts.

The glauconite is not uniformly distributed through the mass of the rock. It seems to be most heavily concentrated at the base and forms into a series of thinly laminated bands in the lower 10 feet of the section. The bands in which the glauconite is so abundant as to impart to the rock a distinctly greenish color are relatively thin, ranging from merely a few inches to 14 inches in thickness. In these areas glauconite forms as much as 25 to 35 per cent of the total mineral composition of the rock. In the remaining upper portion of the section, glauconite is widely distributed through the rock mass, occasionally developing finely laminated areas, but more generally occurring as interstitial grains. No glauconite was detected in the specimens representing the upper 5 feet of the formation.

Pyrite is a common associate of the glauconite and occurs in minute grains which are disseminated through most of the formation. The mineral seems to be present in very small amounts in the lower 10 feet of the section where the glauconite is most abundant. At 50 feet above the base of the formation the pyrite is concentrated into a small system of veins and lenses ranging from one sixteenth to one quarter of an inch in thickness. In this pyritic zone, glauconite is entirely lacking, but just above, it comes in again as pyrite disappears. The pyrite occurs essentially as small grains diffused rather widely through the rock, except where it is concentrated into lenses and nodules. In places it is intimately associated with the glauconite as minute inclusions or forms border granules completely surrounding it.

Ferric hydroxide in the form of brownish grains, crusts and stains is distributed generally through the rock of the section. It seems to occur with the pyrite to a large extent, but is most abundant in the areas where pyrite and glauconite are relatively sparse or entirely lacking and especially near the surface in the oxidized zone. In the areas where the limonite is most highly concentrated, it forms distinct laminations in the rock in much the same way that glauconite forms thin layers where it is most pure. Where the pyrite nodules have undergone alteration, they are frequently coated with a brownish layer of limonite.

It is quite obvious from the nature and the distribution of the limonite in the rock that it has resulted, at least in part, from the decomposition of the pyrite.

Clay, in the form of fine dust and powder, is scattered through the rock, generally as a coating around the quartz and calcite grains in the mass, but occasionally also as distinct lenses and layers in shale. It is usually present in quantity sufficient to give to the rock a distinct argillaceous odor.

In the exposure at Wagner Falls forty-eight specimens, representing a total thickness of 61 feet, were studied. Glauconite was found to be present in the upper 36 feet of the section covered by twenty-eight specimens. This portion of the section is made up of rock which ranges from siliceous dolomite to calcareous sandstone. Below the upper 36 feet, the rock changes to a sandstone composed largely of silica and containing some calcareous cement.

At the contact between the lower sandstone and the upper more calcareous rock, glauconite is concentrated into a series of thin lenses which are interlaminated with the quartz and calcite. These lenses form a banded zone of distinctly greenish rock about 14 inches thick. For a distance of 15 feet above this contact, the glauconite is quite widely scattered through the rock with some limonite and pyrite associations. In places where the limonite is concentrated and definitely laminated, glauconite is present in occasional grains only. In the upper 21 feet of the section, glauconite is profusely disseminated through the rock mainly as interstitial grains, but forming also definite laminations and bands ranging from a few inches to 14 inches in thickness.

Pyrite occurs as scattered grains and occasionally in small knots in certain portions of the rock, but it is not widely disseminated through the section. It seems to be confined to a few narrow belts in the rock and especially in the areas where glauconite is rare or lacking altogether.

Limonite, in the form of small grains, dust and stains, is diffused in varying amounts through the rock. At intervals in the section it is concentrated into definite thin laminations giving to the rock a banded appearance. The glauconite appears to be present in very limited amounts in the areas where the limonite is most prevalent.

In places, the glauconite is interlaminated with thin lenses and seams of shale. Many of the quartz and calcite grains are coated with a fine dust or powder of clay which seems to be present as a part of the cement in the rock.

The glauconite, as it occurs in the rock specimens studied, is mainly in the form of small rounded grains. These range in size from very minute particles to fragments with diameters slightly over 2 mm. The majority of the grains are less than 1 mm. in diameter while comparatively few exceed 2 mm. The average glauconite grains run as large as, and larger than, the quartz grains found associated with them in the rock. Most of the grains of glauconite are worn smooth and bear evidence of having been transported before redeposition. The weathered surfaces of the mineral are usually coated with a darker green and appear quite dull in luster, some of the grains assuming a semi-enamaloid appearance. When broken open, however, these particles are light green in color and somewhat earthy in luster.

Except where the mineral is concentrated into thin laminae and bands, the grains are quite widely separated in the rock matrix and occupy the interstices between the quartz and calcite particles in the rock. In the large number of glauconite grains examined under the microscope, no evidence was found to bear out the theory that foraminiferal shells were involved in the formation of the glauconite. Neither was there any indication that the grains of glauconite consist of cores which are apparently nearly pure silica, as suggested by Hart.[8]

Because of the close association of the glauconite with the matrix of the rock, it is quite impossible to separate the mineral out in sufficient amounts to run a chemical analysis on the pure material. Attempts were made to concentrate the mineral by magnetic separation in the method described by Mansfield,[9] but with no success. Either the magnetic field was too weak or the glauconite had lost its property of magnetism.

Analyses were made on two of the more highly concentrated glauconitic rock samples taken from the Wagner Falls section. Sample 1 represents a twelve-inch layer of the rock taken out at a depth of eleven feet below the surface. Sample 2 is from an eight-inch layer 8 feet lower than 1, or about 19 feet from the surface. The glauconite in both these samples is sufficiently abundant to give to the rock a distinctly greenish color. It is associated with a large number of subangular grains of quartz.

ANALYSES OF THE GLAUCONITIC ROCK

	Percentages in sample 1 *	Percentages in sample 2 †
SiO_2	53.80	49.90
Al_2O_3	1.75	10.30
Fe_2O_3	2.96	
FeO	1.07	——
MgO	7.98	7.83
CaO	11.40	12.93
Na_2O	1.00	——
K_2O	1.52	1.90
Mn_3O_4	——	0.15
P_2O_5	——	0.40
CO_2	not det.	16.28
SO_3	——	1.02
H_2O	——	——

* Analyses of sample 1 by E. Leininger and F. B. Leedy
† Analyses of sample 2 by O. B. Winter

The following table giving the approximate composition of glauconite as compiled from a series of analyses of greensand deposits in the eastern United States will serve to give comparisons:[10]

	Percentages
Silica	50.0
Ferrous iron	4.0
Ferric iron	19.0
Alumina	7.5
Magnesia	3.0
Potash	7.5
Water	8.5
Soda and Lime	0.5

From the observations made in the two sections studied it seems probable that the presence of glauconite may find some value as a horizon marker and be of assistance in working out more definite correlations.

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[1] Dana, E. S., *System of Mineralogy*, 6th ed., p. 683. 1914.

[2] Clarke, F. W., *The Data of Geochemistry*, 5th ed., U. S. Geol. Surv. Bull. 770, p. 521. 1924.

[3] Ashley, G. H., "Notes on the Greensand Deposits of the Eastern United States," *U. S. Geol Surv. Bull. 660*, p. 34. 1917.

[4] Leith, C. K., "The Mesabi Iron Bearing District of Minnesota," *U. S. Geol. Surv. Mon.* 43, p. 245. 1903.

[5] Mansfield, G. R., "Potash in the Greensands of New Jersey," *New Jersey Geol. Surv. Bull. 23*, p. 138. 1923.

[6] Murray, John, and Renard, A. F., "Deep-sea Deposits," *Challenger Report*, p. 389. 1891.

[7] Harder, E. C., "Iron Depositing Bacteria and Their Geologic Relations," *U. S. Geol Surv. Prof. Paper 113*, p. 59. 1919.

[8] Hart, Edward, "Glauconite or Greensand," *Journ. Am. Chem. Soc.*, 39:1919. September, 1917.

[9] Mansfield, G. R., *op. cit.*, p. 118.

[10] Ashley, p. 33, as cited in note 3.

INTERPRETATION OF RECENT DISCOVERIES IN THE SALT-BEARING ROCKS OF MICHIGAN

ROBERT B. NEWCOMBE

THE areas of rock salt deposition have always been referred to as basins. The most important deposits of bedded salt in the northeastern states occur in western New York, northeastern Ohio, western Ontario and the southern peninsula of Michigan. Up to the present time all these beds have been considered Silurian and referred to Lower Cayugan or Salina age. Lane[1] thought that the New York and Michigan salt basins were not entirely separated and were joined across some part of Ontario that was as yet unexplored, probably between Goderich and Petrolia. To judge from his writings in 1913 Cook[2] was inclined to be of the same opinion, but he tended to be non-committal on the certain existence of a physical connection between the New York and Michigan basins. Alling,[3] in his recent work on the Silurian salt of New York state, expressed the belief that the Ohio-New York basins were continuous, but that the Michigan-Ontario and Ohio-New York basins should be considered as separate. In his correlation table, however, he compared the Salina salt of Michigan directly with the Camillus salt-bearing beds of New York.

The discoveries of recent deep wells in Michigan show that the Michigan basin has a distinct problem of similar nature within its own borders. A correlation of salt-bearing beds in well records demonstrates that more than one important age of rock salt deposition existed within the state. Cross-sections bring out the fact that salt was deposited not only in the Silurian, but, if our present correlation of Detroit River is correct, in the Devonian as well.

This conclusion was first suggested when salt was encountered in a well drilled near Roscommon at a depth of only 275 feet below the base of the Dundee limestone. Later, in a drilling near Walhalla, Mason County, an important sandstone member with characteristics resembling Sylvania was struck at 280 feet below the last salt bed. This sandstone was first correlated as a member of the Guelph because of its unusual position below the salt and the association with a few thin streaks of white cherty dolomite. In the summer of 1928 the deep test at Manistee revealed further supporting evidence which cannot be related because the information is held as confidential.

A well completed in the fall of 1928 near Fowlerville, Livingston County, exhibited an abnormally large thickness of Detroit River formation which led to mistaken correlations by nearly every geologist working in the state. A similar thick Detroit River section has just recently been penetrated by a deep test at Saginaw. This well also showed some free salt at a depth in the

Detroit River which directly compares with the upper salt in the western part of the state.

Four sections which demonstrate these relationships have been drawn across the state in different directions, as shown in Figure 2. In constructing these sections a stratigraphic datum has been used for the purpose of more directly comparing formations and eliminating the contortion involved by a basin ward dip. For sections A-A' and C-C' the base of the Devonian or the Sylvania sandstone has been used as a datum plane and for sections B-B' and D-D' the base of the Mississippian or the Antrim shale has been used as a datum plane.

Section A-A' (Fig. 3) brings out the similar thickness of the Salina salt-bearing sections in the eastern and central part of the state. It shows a progressive thickening of the Detroit River to the northwest and an increasing amount of dolomite and anhydrite in all the Devonian sediments. The position of the salt beds above the Sylvania is demonstrated on the western side of the state. The close correspondence of intervals and lithologic comparisons evidence the Detroit River age of the upper salt-bearing beds.

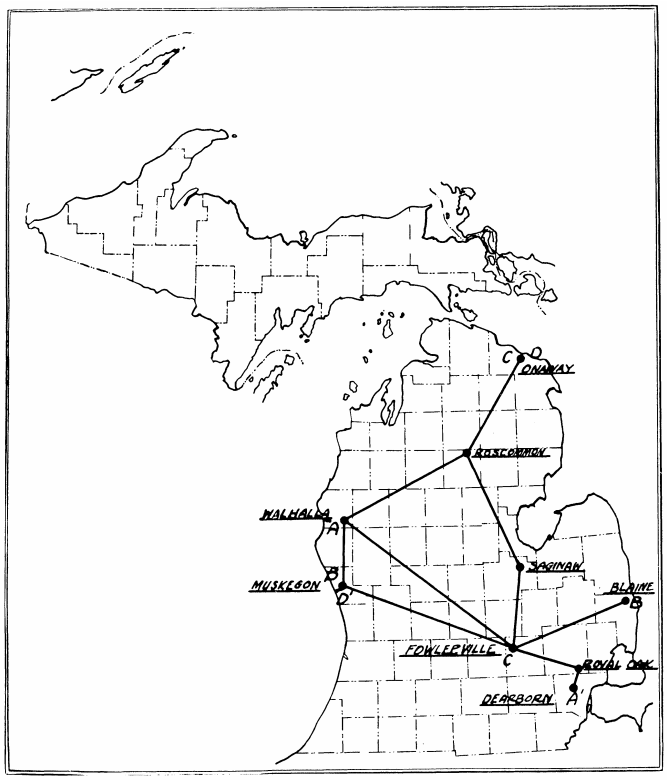

FIG. 2. Map showing location of wells in sections A, B, C and D

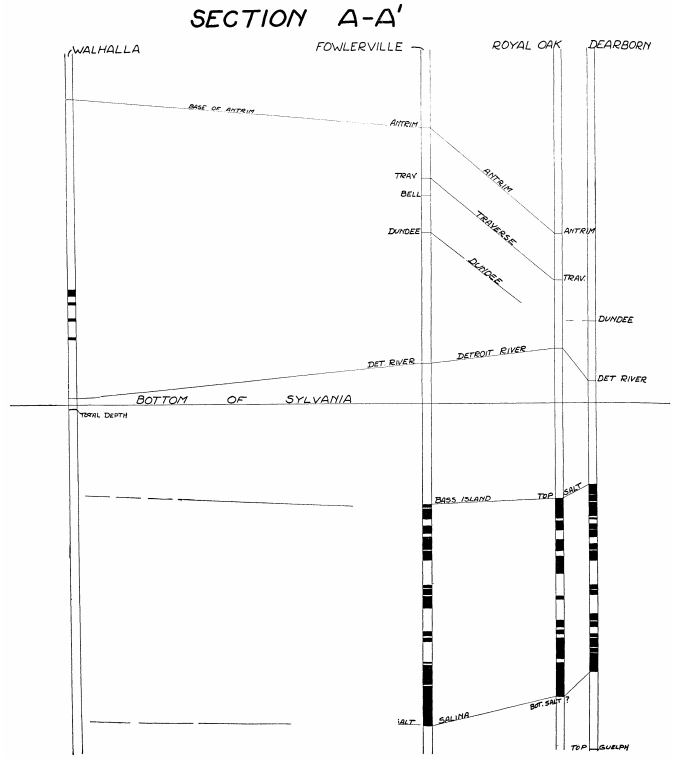

FIG. 3

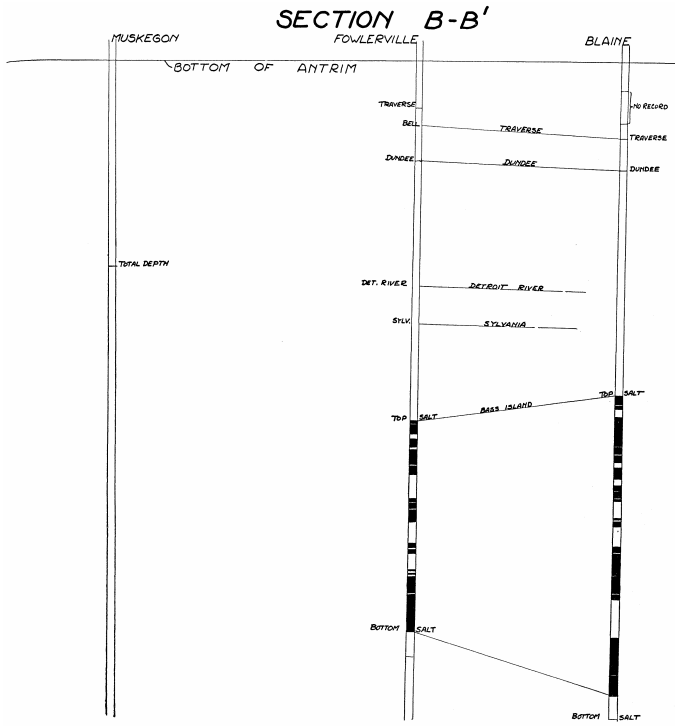

FIG. 4

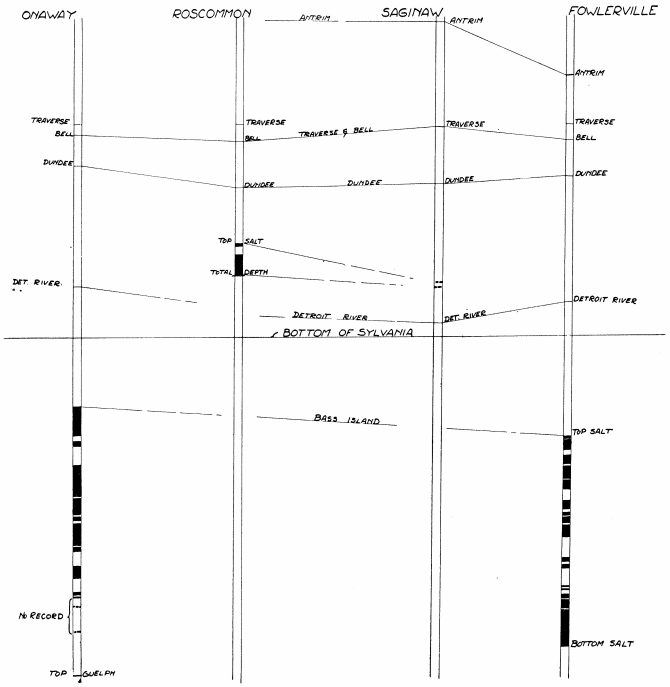

FIG. 5

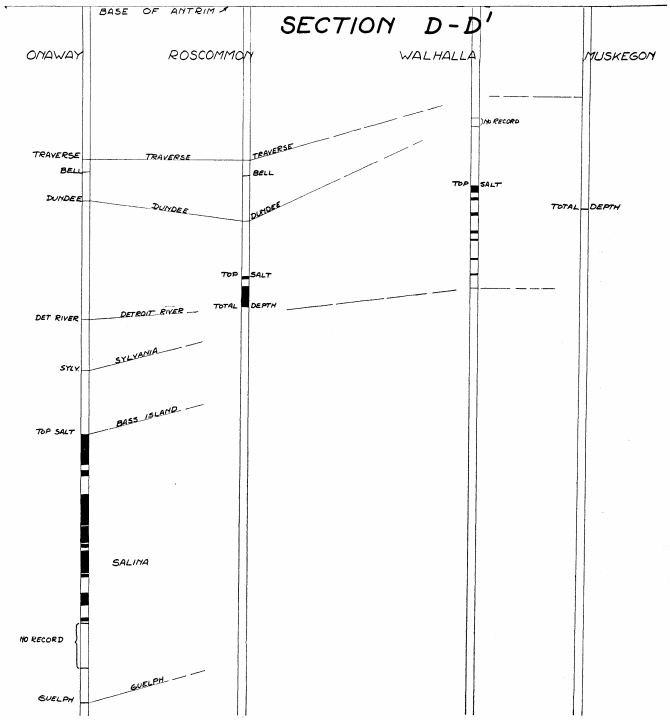

FIG. 6

Section B-B' (Fig. 4) is not quite so significant. It would suggest, however, that the deeper part of the Salina salt basin existed to the north of Livingston County. Prior to 1928 the well at Blaine, St. Clair County, has shown the greatest thickness of salt of any well in the state. Another possibility exhibited by this section is that the salt-bearing Salina rocks have not yet been penetrated at Muskegon and the anhydrite beds should be correlated with the Detroit River salt-bearing rocks in Mason and Manistee counties.

Section C-C' (Fig. 5) illustrates the similarity in thickness of the Salina salt-bearing beds on the north and south sides of the Michigan basin. The salt at Roscommon seems to correspond rather closely in stratigraphic position to the salty beds at Saginaw. The northern and southern limits of the Detroit River salt series are roughly defined by this section. A corresponding thick section of Detroit River rocks is found at both Saginaw and Fowlerville.

Section D-D' (Fig. 6) exhibits the southwestward change from limestones to dolomites in the Devonian section. Dolomites appear higher and higher in the series as one progresses to the southwest. The southwestern limits of the Detroit River salt-bearing beds seem to be outlined as being in the vicinity of Muskegon.

Many will question a correlation by strictly lithologic methods with no supporting paleontologic evidence. The use of well sections necessitates frequent discrepancies of measurement and interpretation which enter into their construction. In numerous cases samples are not furnished and only the record of formations as logged by a driller can be used. The inaccuracies resulting can be eliminated only by referring to a large number of wells and by comparing them from every possible angle. In this way many significant facts may be indicated and later interpretations of importance in stratigraphic correlation may result.

The Silurian-Devonian contact was for a long time a battle ground in the correlation of Michigan rocks. The present classification of the Monroe was reached by Lane, Prosser and Sherzer,[4] and Grabau and Carman[5] added further reasons for placing the Detroit River and Sylvania in the Devonian. At the present time the classification of Detroit River and Sylvania as Devonian is accepted by most geologists, although the distinct Silurian affinities of the Lucas fauna seem not to be refuted. Apparently the paleontologic and the stratigraphic evidence is in conflict.

Years ago Lane[6] recognized the existence of those conditions in the Upper Monroe which might lead to salt formation. He speaks of three distinct periods of desiccation which would be referred to our Salina, Bass Island and Detroit River beds. Cook[7] stated that some of the rock salt deposit might be of Monroe age and suggested the origin of the Monroe brines from lakes which did not entirely disappear after the deposition of the Salina salt.

The Detroit River age of the upper salt beds of the western and the north central parts of the southern peninsula seems to be fairly well established by the correlation of well sections. If the Devonian equivalency of the Detroit River is to be maintained, we must offer some sort of explanation for the occurrence of conditions causing the formation of rock salt. The arid climate of the Salina no doubt existed through much of the early

Devonian. Lane[8] accounted for the cessation of salt making in the Lower Monroe by either a change of climate or crustal shifting opening an outlet. Present evidence makes the latter alternative seem the more plausible. He also stated[9] that the Upper Monroe seemed to have been deposited in a narrow trough. We know now from the abnormal thickness of Detroit River at Saginaw and Fowlerville that this trough probably had a northeast extension which permitted the entrance of Devonian fauna. Detroit River time in Michigan apparently had two phases, a seaward dolomite-producing phase on the borders and a landward salt-producing phase in the central part of the state. Devonian life probably did not migrate far into the center of the state; when the outlet to the trough was temporarily closed the remnants of the Silurian facies were brought back from the salt-producing basin. This would account for the Silurian aspect of the Lucas fauna.

To fulfill the requirements of this explanation, the most recent theory of salt deposition postulated by Alling[10] would be applicable. His final statement is "that the salt must have originated by *evaporation* under *desert* conditions behind a *bar* or *barrier* separating the basin or basins from the sea." He believes that nearly all salt was deposited in desert basin lakes analogous to our playa lakes of today. The source of evaporating brines may have been either rivers carrying salt in solution or incursions of sea water dammed back by some sort of bar or barrier.

In applying this theory to the Michigan basin it would be possible for the salines forming the Detroit River salt series to be derived either from stream erosion of earlier rocks or from incursions of sea water from the deeper dolomite-depositing troughs. The limits of the basin in which the Devonian rock salt beds were deposited are roughly outlined by the Onaway, Saginaw and Muskegon wells. Figure 7 shows by inclined lines the approximate extent of this basin as determined from present wells, and future drilling will more or less modify the shape of its outline. The approximate center seems to correspond rather closely with the center of the Salina basin as sketched by Robinson.[11] The limits of the Salina salt basin are indicated by the contrasting inclined lines in Figure 7.

As a final conclusion, it is evident that two important salt-depositing periods are represented in the Michigan basin. The earliest of these can be referred to Salina age and is equivalent to the Camillus of the New York section. The later less important salt-producing period is represented by a smaller basin within the same general area. The age of this upper salt is more or less conjectural, but by stratigraphic sequence and lithologic correlation it compares very closely with the Detroit River formation or Upper Monroe. This would indicate that salt-forming conditions prevailed not only in the Silurian, but also during Devonian times in the central part of the southern peninsula of Michigan.

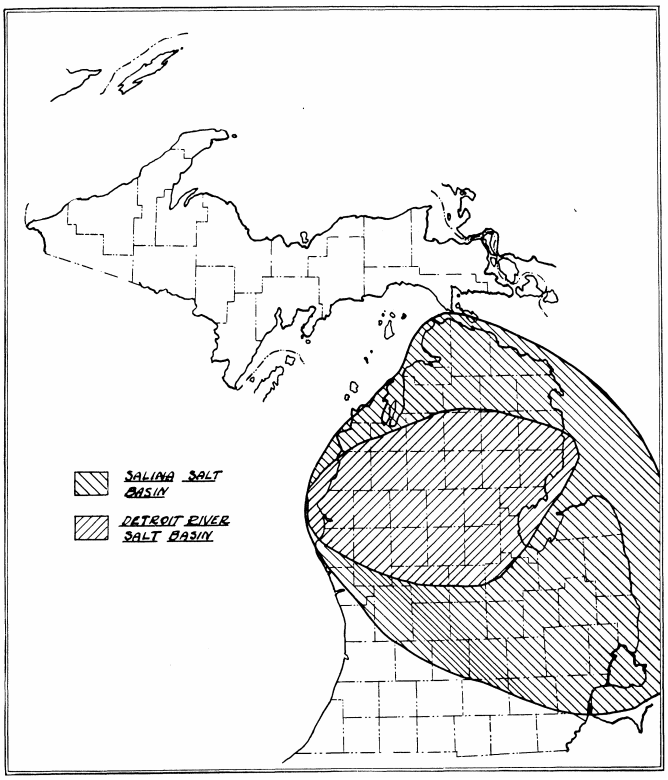

FIG. 7. Approximate areas of the Detroit River and Salina salt basins

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LANSING, MICHIGAN

[1] Lane, A. C., *Tenth Annual Report, Mich. Geol. Surv*., 1908, p. 61.

[2] Cook, C. W., "Brine and Salt Deposits of Michigan, their Origin, Distribution and Exploitation," *Publ. 15, Geol. Ser. 12, Mich. Geol. and Biol. Surv*., 1913, p. 82.

[3] Alling, H. L., *Geology and Origin of the Silurian Salt of New York State Publ. 275, Bull. New York State Mus*., 1928, pp. 8, 10.

[4] *Bull Geol. Soc. America*, 19: 553-556.

[5] Carman, J. E., "The Monroe Division of Rocks in Ohio," *Journ. Geol*., 35 (1927): 481-506.

[6] Lane, A. C., *Geological Survey of Michigan*, 5: 28.

[7] Cook, C. W., *op. cit*., p. 81.

[8] Lane, A. C., p. 62 of work cited in note 1.

[9] *Ibid*., p. 67.

[10] Alling, H. L., *op. cit*., p. 125.

[11] Robinson, W. I., *Publ. 35, Geol. Ser. 29, Mich. Geol and Biol. Surv*., p. 36.

NEW FACTS ON THE NIAGARA GORGE

FRANK BURSLEY TAYLOR

IN THE study of so great a problem as the recession of the Falls of Niagara and the making of the gorge, one should not be surprised if new facts and interpretations are brought forth after a lapse of sixteen years. It is only in this way that science and knowledge make progress.

In a recent paper entitled "The Age of the Upper Great Gorge of Niagara River," W. A. Johnston, of the Canadian Geological Survey, presents some new and important facts,[1] and suggests new interpretations of gorge history. The new facts relate mainly to the gorge in the vicinity of the two railroad bridges, comprising the upper part of the gorge of the Whirlpool rapids and the lower part of the Upper Great gorge. Johnston calls attention to exploratory borings made by the Michigan Central Railroad Company at the Cantilever bridge over the upper end of the gorge of the Whirlpool rapids. Johnston's sketch map showing the location of the borings is here reproduced as Figure 8. The sketch shows nineteen borings, eight on the west side of the river and eleven on the east side, and it shows the depths and the structures penetrated, and also the depth of the river under the bridge.

As compared with the Upper Great gorge, which extends from a point a little above the railroad bridges to the Horseshoe Fall, the gorge of the Whirlpool rapids is narrow and shallow. Much difference of opinion has been expressed in the past concerning the origin of this section of the gorge. The basin of the Whirlpool is universally recognized as part of an older gorge not made by the modern, postglacial river, but by a great river which did its work *before* the advent of the last or Wisconsin ice-sheet. The result was that this older gorge was completely filled and obliterated mainly with glacial drift swept into it by the ice-sheet, but also in part by stratified sand and clay deposited in lake waters which invaded the gorge, when the advancing ice-sheet obstructed northeastward and eastward drainage in the St. Lawrence and Mohawk valleys. The buried valley, commonly known as the St. David gorge, extends more than two miles northwest from the Whirlpool to a well-marked reëntrant in the great escarpment south of the hamlet of St. David. For about a mile in this reentrant the rock wall of the escarpment is absent and the only filling is glacial drift. This is at the mouth of the St. David gorge.[2]

Several of the earlier writers held that the St. David gorge was made in preglacial time, but there is evidence that it was made in the last interglacial epoch. It was claimed that it was made by a relatively small river, and that its valley was widened toward the north by weathering. On this view, the gorge of the Whirlpool rapids is the upper part of this valley which had not been measurably widened. From the Whirlpool north, there is no widening, excepting at the mouth, and this is strikingly characteristic of glacial action, for the salient on the west side received the full force of the oncoming ice, and its upper layers were torn away. The lower layers (Whirlpool sandstone, and others) were not measurably modified; neither was the eastern salient, even its upper layers, for it stood in a protected position. In fact, the main characteristics of the St. David gorge are precisely those of the present Upper Great gorge — wide and deep — and indicate the work of a great vertical cataract, with volume as great as that of the present river.

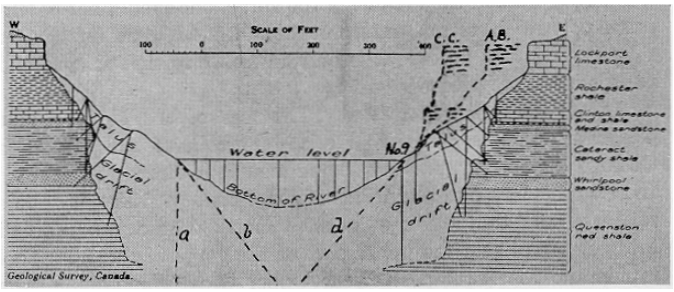

Fig. 8. Cross-section of Niagara gorge at Michigan Central (Cantilever) Railway bridge. After A. W. Johnston, with a few additions. *A B*, approximate place and profile of cliff at Arch bridge; *C C*, approximate place and profile of cliff at steepest place, 300 feet north of Arch bridge (about at *c c* in Fig. 10). Profile under river is unknown, but certainly shallower and narrower than that shown by Johnston at Cantilever bridge, *a, b, d*, places where additional borings would add greatly to knowledge of Cantilever gorge

This history of the St. David gorge was fully recognized in the *Niagara Folio*,[3] but it was then thought that the interglacial gorge ended at the south side of the Whirlpool, except, perhaps, for a small, narrow gorge or ravine of slightly later date, extending a few hundred feet toward the southeast. The walls of the Whirlpool are broken through where the river comes in, and again where it goes out, and in both places the gorge is narrower both at the top and at the water surface, and reefs obstruct both openings, causing short rapids. The reef-rock is mainly the Whirlpool sandstone, which is here just at the surface of the water.

When the *Niagara Folio* was published, the best interpretation which then seemed available pictured the present or postglacial river as cutting its gorge from the escarpment south of Lewiston to the Whirlpool, where, purely by accident, it uncovered and cut into the upper end of the buried St. David gorge. The great river cleared the glacial deposits out of the Whirlpool basin very quickly, and then was supposed to have resumed gorge-making at the southeast side of the Whirlpool. It was believed that the contracted width and the reef between the Whirlpool and the Eddy basin showed that, when the great cataract of the present river resumed gorge-making, it did not begin just where the older, interglacial cataract of the St. David gorge left off. Instead, it plunged either from an unbroken older ledge a few hundred feet to the southeast, near what is now the

center of the Eddy basin, or else into a short section of older narrow gorge (*Niagara Folio*, Figure 7), and for this reason failed to remove the reef. But the great cataract had only fairly begun work in the making of the relatively wide, deep Eddy basin, when a sharp halt was called, and 85 per cent of the water of the falls was taken away. This was due to the retreat of the ice-front in the far north. During the making of the Lower Great gorge, extending from the bend at Niagara University up to the south side of the Eddy basin, the front of the ice-sheet had continued its slow northward retreat, until it lay in the Mattawa and Ottawa valleys east of North Bay, Ontario. Finally, the water of the upper lakes broke through past this dam, establishing a new outlet then lower than that at Port Huron, and escaped down these valleys to the sea, leaving the falls at the Eddy basin with only the discharge of Lake Erie or about 15 per cent of the river at normal full volume. With this largely reduced volume, the falls were believed to have made the gorge of the Whirlpool rapids to the point of expansion and increased depth close above the railroad bridges. This is in substance the account of the origin of the Whirlpool, the Eddy basin and the gorge of the Whirlpool rapids as given in the *Niagara Folio* in 1913. See Figure 9.

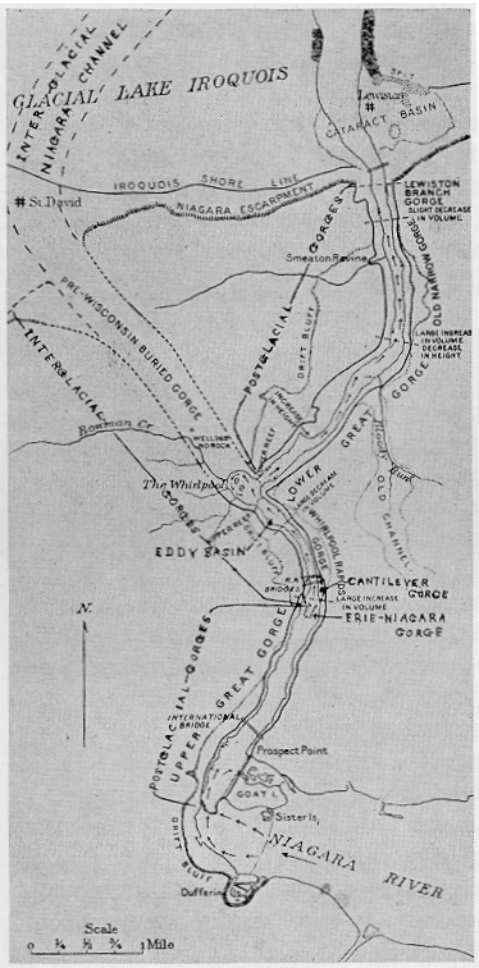

FIG. 9. Sketch plan of Niagara gorge (from the Niagara Folio, p. 21, with certain modifications). Shows places of Cantilever and Erie-Niagara gorge sections, and also the distribution of the interglacial and post-glacial sections.

The facts presented by Johnston evidently reveal a different history, and necessitate a revision of these conclusions, but not altogether on the lines suggested by him, for there are a number of other important facts which have a strong bearing on problems relating to the history of this part of the gorge.

The record of borings shows clearly that a deep and wide gorge was made in the bed rock under the Cantilever bridge, and that this gorge was afterwards filled with glacial drift, including many boulders and also toward the bottom a few layers of sand and gravel partly stratified. All of this was later covered over and masked by talus from the cliffs. The present width of the water surface under the bridge is about 400 feet, but if all the talus and drift at the sides were removed the width would be about 700 feet. This shows that the buried gorge seen in Johnston's cross-section is the work of a great cataract, not a small one.

Another significant fact, which was noticed by Spencer many years ago, is the steepness of the buried rock wall on the east side as compared with the weathered cliffs in most other parts of the gorge.[4] But Spencer was drawing all of his inferences from one boring, No. 9, the first hole on the east side. Nine later borings on that side show that the rock wall is considerably steeper than he supposed. These facts seem to show that a short section of gorge lying under the Cantilever bridge, and extending about 300 feet north of it, and at least 500 or 600 feet south of it, was made by a large-volume cataract just before the oncoming of the last or Wisconsin ice-sheet. For a brief time, lake waters entered in advance of the ice and deposited stratified sand and clay, but the ice-sheet soon arrived and buried the whole district under its drift. For convenience, this short section may be called the Cantilever gorge.

Thus, the amended gorge history seems to show that in the interglacial epoch preceding the Wisconsin ice-sheet, a great cataract — in fact, a real interglacial Niagara — made the St. David gorge and the Eddy basin, and then, when the great interglacial cataract was working at the south side of the Eddy basin, the volume of the river was suddenly greatly reduced, and a much smaller cataract was left to make the narrow, shallow gorge of the Whirlpool rapids. When the small cataract had worked back about to the Cantilever bridge, the full volume of the interglacial Niagara came back and began the making of the deeper, wider Cantilever section. This new section appears to be the exact interglacial counterpart of the present postglacial Upper Great gorge. But the work of the great interglacial cataract in this section was soon stopped by the arrival of the advancing Wisconsin ice-sheet. Then, probably, for 50,000 or 60,000 years, the whole Niagara region lay deeply buried under the ice. But when the front of this ice-sheet had retreated so far that it began to uncover the Niagara region north of Buffalo, the whole drama of lake, river and cataract interplay began to be reenacted. The postglacial Niagara was able to appropriate only a

part of the buried interglacial gorge, because the escarpment moraine on the top of the escarpment south of St. David stood nearly 60 feet higher than the passage from the Whirlpool to the escarpment south of Lewiston. Thus, the modern river had to cut its gorge out of the solid rock from the cliff south of Lewiston to the Whirlpool, but from the Whirlpool to the south side of the Cantilever section it had only to remove the filling of glacial drift.[5] (See Fig. 10.) The modern river seems to have worked with full volume from the bend at Niagara University to the Whirlpool, and it would seem to have continued with the same volume in clearing the glacial drift at least out of the Whirlpool, the Eddy basin and perhaps part of the gorge of the Whirlpool rapids, but when it came to the buried Cantilever section, with its much greater depth and width, it cleared only a relatively narrow passage, leaving a large part of the filling unmoved, as is shown in Johnston's cross-section.

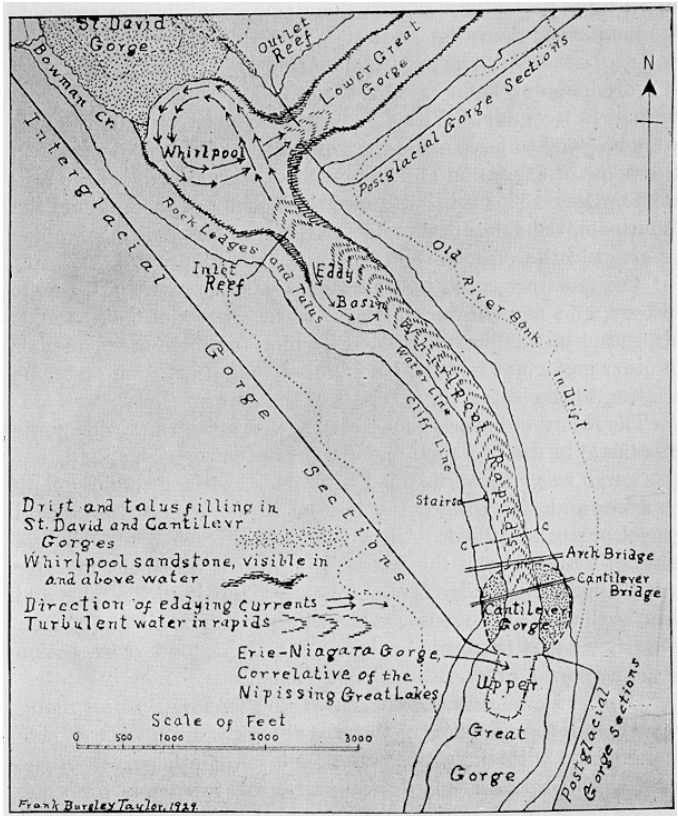

FIG. 10. Sketch of gorge sections between the Lower and Upper Great gorges shows m more detail places and approximate dimensions of Cantilever and Erie-Niagara gorges; outcroppings of Whirlpool sandstone, with reefs at inlet and outlet; underturned loop of the river in the Whirlpool-return current in Eddy basin, and parts of interglacial and postglacial gorge sections

The last contact of the Wisconsin ice-sheet with the Great Lakes was when its front rested in the Mattawa Valley east of North Bay, Ontario, and in the Ottawa Valley below the town of Mattawa. When this dam broke, the discharge of the upper three Great Lakes rushed through to the east past North Bay and down the Mattawa and Ottawa valleys to the sea, thus establishing the last or non-glacial stage of the postglacial lakes, known as the Nipissing Great Lakes.[6] The isobase of North Bay runs north about 68 degrees west, and the Nipissing beach on and near this line on the northern shore of Lake Superior is probably the most strongly developed old shore-line in the Great Lakes region, being even stronger than the Algonquin beach on the isobase of Kirkfield. Naturally, its great strength was taken to indicate a relatively long duration for this lake stage, and it was thought to be the correlative of the gorge of the Whirlpool rapids, made by the Erie-Niagara or small-volume falls. But since the making of this section of the gorge is now relegated to the interglacial epoch, we must look for the gorge correlative of this postglacial lake stage somewhere else. If the outlet at North Bay had opened when the river began to clear the drift out of the Cantilever section, then we should have a small-volume postglacial cataract resuming gorge-making at the place where a larger-volume interglacial cataract had left off, and this would probably be at least 500 or 600 feet south of the Cantilever bridge.

Much light on the rate of recession of a small-volume cataract under conditions like those of the Niagara region may be had by studying the American Fall. It is about 1000 feet wide, and falls from a remarkably level ledge of dolomite. Before the larger diversions, the water near the crest averaged less than two feet in depth, and the deepest place was reported to be about three and one-half feet. According to United States engineers, the American Fall carries 4.83 per cent of the whole volume of the river.[7] The discharge of Lake Erie being about 15 per cent of the whole volume, is roughly about three times the volume of the American Fall. If the mean rate of recession of the Horseshoe Fall be taken as 4.5 feet per year, as stated in the *Niagara Folio*, it is estimated that it is about 1600 years since the Horseshoe and American Falls were united in one curved crest-line. If the rate be taken as 3.8 feet per year, as given by Johnston and Boyd, the time since the united crest would be nearer 1800 years. The record of surveys since Hall's first in 1841, nearly 90 years, reveals no measurable recession of the American Fall since that date. Indeed, a comparison of the crest-line of the American Fall with the cliff-line of Goat Island and of the gorge north of the fall shows that this cataract has not receded by a measurable amount beyond normal cliff recession due to weathering in the whole period since the two falls parted company. The sharp 40-foot reentrant 120 feet north of Luna Island is a superficial feature. The American Fall is too feeble to do gorge-making at a rate that is certainly measurable in 90 years or even in 1600 or 1800 years. On the other hand, if the American Fall, with its present crest-line, had had three times its present volume, it seems quite probable that it would have accomplished something — at least a small amount — in gorge-making. Three times its present volume would be about equal to the discharge of Lake Erie alone, which constituted the small-volume Niagara during the time of the Nipissing Great Lakes. If with the

same volume the crest-line were narrower, the water on it would be deeper and would tend to cause more rapid gorge-making. So far as known, the geological conditions in the Niagara district have always tended to produce wide, flat crest-lines for the falls, to this extent favoring slow gorge-making, especially at times when the volume of the river was relatively small.

Before the greater diversions, the upper three lakes contributed about 6.6 times as much water to Niagara River as did Lake Erie, and considering the influence of a wide, flat crest in thinning the water of the fall, especially where a small-volume cataract immediately succeeds a large-volume cataract, it would seem certain that the rate of gorge-making would diminish in a higher ratio than the difference of volume. Heretofore, the writer has assumed tentatively that the small-volume or Erie-Niagara River would tend to make a gorge at a rate somewhere near one tenth of the rate of the full-volume river. Spencer had earlier adopted the same rate. At 4.5 feet per year, as stated in the *Niagara Folio* for the Horseshoe Fall, the rate for the Erie-Niagara or small-volume cataract would be about 0.45 foot per year or 800 or 900 feet of gorge in about 2000 years. If the rate were less, the time for making a given length of gorge would be proportionally longer.

If a large-volume Niagara made the Cantilever gorge section in the last interglacial epoch, there is no place for a gorge correlative of the Nipissing Great Lakes, except immediately south of the Cantilever section. A gorge section of this description, but only a short one, must have been made, and the only place for it is between the interglacial Cantilever gorge and the present or postglacial Upper Great gorge. It seems probable that the opening of the postglacial North Bay outlet occurred when the falls were at or near the Whirlpool, and that it was the Erie-Niagara small-volume cataract which resumed gorge-making at the south side of the Cantilever section. If it made 600 or 800 feet of narrow, shallow gorge in a period of 2000 or 2500 years before the North Bay outlet was closed, this record would seem to agree with the evidence now in hand.

Theoretically, when a small-volume cataract makes a gorge which is naturally narrow and shallow as compared with the gorge of a cataract with more than six times its volume, and then is followed by a large-volume cataract of the proportions named, the larger river literally overwhelms the small gorge. It not only falls into it at the end, where the smaller river was last working, but advances over the flat floor and runs far forward on both sides so as to fall in mainly at the sides, thus forming a U-shaped cataract. If the small gorge be not too long, the greater river will widen it and eventually obliterate it entirely. So it was, as the writer conceives, with the small gorge extending south from the Cantilever section. It was not so long but that it was completely wiped out by the succeeding great cataract, when it began to make the Upper Great gorge. Thus, a gorge correlative of the Nipissing Great Lakes was probably made and later destroyed.

All this, of course, makes a considerable difference in the estimate of time since the modern or postglacial cataract began to make the gorge at the cliff south of Lewiston. Space forbids a detailed discussion of this phase of the problem, but it is evident that the former estimate given in the *Niagara Folio* of 20,000 to 30,000 years (mean of 25,000) must be somewhat reduced, because that estimate was based on the idea that the Eddy basin and the gorge of the Whirlpool rapids were made by the postglacial river, whereas we now see, thanks to the Michigan Central Railroad and to Dr. Johnston, that the postglacial river had only to clear out glacial drift and other loose material from the Whirlpool to the south side of the Cantilever section. The writer formerly allowed 6000 or 7000 years for the making of the Eddy basin and the gorge of the Whirlpool rapids, but now 2000 or 2500 years seems enough; and this takes at least 1000 feet from the previous measure of the length of the Upper Great gorge. On this basis the time for the making of the postglacial gorge seems nearer to 18,000 or 20,000 years than the former estimate of 25,000 years. These estimates are based on the former determination of rate, 4.5 feet per year, rather than on the slower rate, 3.8 feet per year, as found by Johnston and Boyd.[8] The phototopographic method of survey used by Boyd in 1927 has many advantages, but his computation of the rate of recession seems unsatisfactory. The method of perpendiculars to the crest-lines yields results that are interesting, but, unless the arbitrary "apex zone" is severely restricted, does not give the true rate of recession. With increasing departure from parallelism with the main axis of recession, more and more of the *widening* component enters in and yields a misleading result. For example, in Plate VIII of his paper, Boyd shows lines on the east crest which are perpendicular not only to the crest-line, but also to the central axis of recession. Such lines show cliff recession, but not true cataract recession. It seems doubtful whether the rate of 3.8 feet per year is nearer the truth than 4.5 feet. The writer is not disposed to accept the arguments made by Johnston and Boyd for the slower rate.

A valuable check on the age of the Upper Great gorge is found in the determination of the rate of the tilting of the land by uplift in the north in the central part of the lake region. Dr. Gilbert studied the gage readings at stations on Lakes Michigan and Huron for the period 1875 to 1895, and Mr. Moore carried the same study to 1925. The place of the hinge-line or zero isobase for recent and present tilting of the land had not been fully determined when Gilbert wrote, and was not considered by him. But after correction for this omission, his results and Moore's are remarkably accordant, and when extended to North Bay, Ontario, and applied to the present elevation of the outlet at that place, show that that outlet was closed by uplift about 3000 years ago, being now about 104 feet higher in altitude than the

outlet at Port Huron. The same rate of tilting applied to Lake Erie and to the outlet at Buffalo proves to be in very close accord with the result obtained for Lakes Michigan and Huron, and is strongly supported by well-marked evidences of recent drowning on the middle and western shores of Lake Erie.[9]

The buried Catitilever gorge shown in Johnston's cross-section is a truly remarkable feature. That it is restricted to a relatively small distance both north and south from the bridge seems clear. Its limit to the south is not definitely known and is probably not determinable, but to the north it seems well defined. Except for some of the top layers on the east side, the Cantilever gorge certainly does not extend northward beyond the Steel Arch bridge of the Grand Trunk Railroad, a distance of about 300 feet. The top layers are broken for about 300 feet farther, but lower down in the wall of the gorge the Clinton limestone, coming from the north, reaches to the piers of the Arch bridge. This is shown in photographs more clearly on the east side, but it reaches about to the same point on the west side also (Pl. XXXVIII, Fig. 1). From a point about 300 feet north of the Arch bridge, east side, the gorge wall for 1200 or 1300 feet to the north is almost vertical above the tracks of the electric railroad. As stated by Spencer and Johnston, this wall has evidently been undercut by the modern river and cliff recession has been active in recent centuries. Figure 2 of Plate XXXVIII is a picture of a great rock-fall from this cliff at a point 500 or 600 feet north of the Arch bridge. The profile of this cliff is sketched in on Johnston's cross-section. As Johnston says, the Whirlpool sandstone is evidently cut through in the lower part of the gorge of the Whirlpool rapids. But it does not follow from this that it is cut through in the upper part at or north of the Arch bridge. The river falls about 50 feet in the rapids, and the strata dip about 31 feet to the mile toward the south, the Whirlpool sandstone being last seen above water in the northern part of the Eddy basin. These two slants diverge southward; hence it must be something like 70 or 75 feet from the water surface under the Arch bridge down to this sandstone. It seems quite probable, therefore, that the Whirlpool sandstone is not broken through under the Arch bridge, nor for several hundred feet to the north. Spencer and Johnston are quite right, however, in emphasizing the part played by the huge boulders and blocks which choke the upper part of the rapids.

In the next to the last paragraph of his paper, Johnston questions the value of the earlier interpretations of the whole gorge between the Cantilever bridge and Lewiston. He says (p. 29):

The age of Niagara gorge as a whole cannot be determined, for there is no way of telling the rate of formation of the Whirlpool rapids gorge nor of the lower gorge reaching from the Whirlpool to the escarpment at Queenston. It seems probable that a large part of the flow of the river was diverted during the formation of the Whirlpool rapids gorge and probably at other times during the formation of the lower gorge, but the size of these diversions and the effect the reduced flow of water would have on the rate of formation of the gorge are not known.

Of course, the age of the gorge as a whole cannot be accurately determined, but this should not deter us from making the best possible tentative determinations. It seems to the writer that Dr. Johnston fails to see clearly the elements involved and the extreme simplicity of their relations. Throughout all of postglacial Niagara history, the element of river volume at the falls was always determined mainly by the interplay of two units, the upper three lakes constituting one unit, and Lake Erie the other. When these units were united, the falls always had full or 100 per cent volume, but when they were separated, the falls had only the discharge of Lake Erie or about 15 per cent, the other unit of about 85 per cent going somewhere else. At first, five streams fell over the escarpment from Lake Tonawanda. From a study of the now abandoned gorges and stream beds of the other four, it was estimated that the Lewiston branch carried about 25 per cent of the river. This, of course, was nothing more than a fairly well directed guess. At another time there was a discharge at Chicago, but it was small and short-lived. All the large changes of volume since Lake Tonawanda have been produced by the combination or separation of the two simple units mentioned above; and the conditions are thought to have been much the same in the inter-glacial epoch.

With Dr. Johnston's contribution of the Cantilever gorge, and with the linking of this section with the Whirlpool, the Eddy basin and the gorge of the Whirlpool rapids as being all of inter-glacial age, the status of these parts of the gorge seems cleared for better estimates of rate and time. The most obscure section now remaining is the Old Narrow gorge, extending from the south end of the Lewiston branch gorge up to the bend at Niagara University. But the relations in this part seem simple enough, for there is Kirkfield, Ontario, with its outlet carrying off the discharge of the larger unit, leaving only that of the smaller one for Niagara Falls. Of course, geological relations enter largely into the problem, but the structure is simple and nearly uniform throughout the whole gorge; only the capping hard layer is thinner toward Lewiston, and all the strata stand at slightly higher levels at the north.

It is fully realized that the effect of the amended history on the estimation of the time factor is not adequately discussed in this paper, but that can wait.

FORT WAYNE, INDIANA

[1] *Transactions of the Royal Society of Canada*, Section IV, 1928, pp. 13-29.

[2] See Figure 9. A buried river channel extends north and northeast across the lower Ontario plain from the mouth of the St. David to the west bank of Niagara River about two miles south of Niagara-on-the-Lake. This was first described by Josiah T. Scovell, "Another Old Channel of Niagara River," *American Geologist*, Vol. 3, 1889; also in *Proc. Am. Assn. Adv. Sci.*, Vol. 39, 1891. Described later (1907) by J. W. Spencer in work referred to in footnote 4; more recently by Glenn C. Forrester, *The Falls of Niagara* (New York, 1928, 154 pages).

[3] *U. S. Geological Survey, Niagara Folio*, Folio No. 190, p. 17, including Figure 7. 1913.

[4] Spencer, J. W., *Evolution of the Falls of Niagara*, Department of Mines, Geological Survey Branch (Ottawa, 1907), 470 pages. For buried old river channel in plain north of St. David, see Chapter XI, pages 137-139; for borings at Cantilever bridge, see Chapter XII, especially pages 147 ff.

[5] In an earlier paper, the writer has discussed certain evidences which seem to indicate a remarkable recurrence of Great-Lake and Niagrara conditions and history in three successive deglaciation or warm-period epochs, two of them interglacial and the last one postglacial. See " Evidence of Recurrent Depression and Resilience in the Region of the Great Lakes," *Pap. Mich. Acad. Sci., Arts and Letters*, 7 (1926): 135-143.

[6] *U.S. Geological Survey, Monograph 53*, 1915, Chapter XXII, pp. 447-463.

[7] "The Preservation of Niagara Falls," *Senate Document No. 105*, Washington, 1911, p. 13.

[8] Boyd, W. H., "A New Method of Determining the Rate of Recession of Niagara Falls," *Transactions of the Royal Society of Canada*, Section IV, March, 1928, pp. 1-12.

[9] Taylor, F. B., "The Present and Recent Rate of Land-Tilting in the Region of the Great Lakes," *Pap. Mich. Acad. Sci., Arts and Letters*, 7 (1926): 145-157, with references. Also, by the same author, "The Status of Lake Erie in Recent and Present Land-Tilting," *ibid*., 10 (1928): 251-260, with references.

PLATE XXXVIII

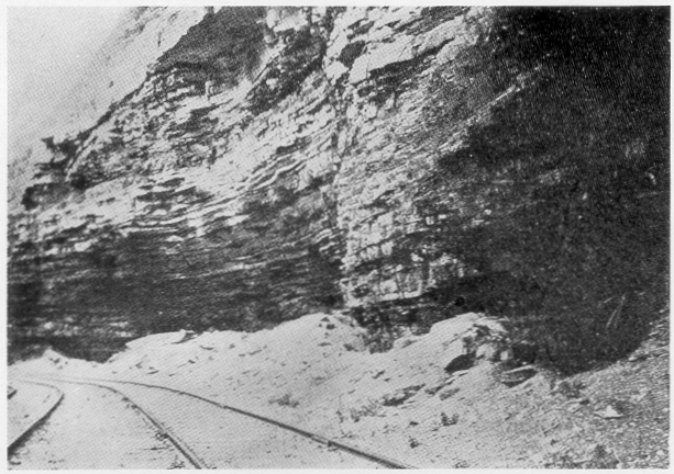

FIG. 1

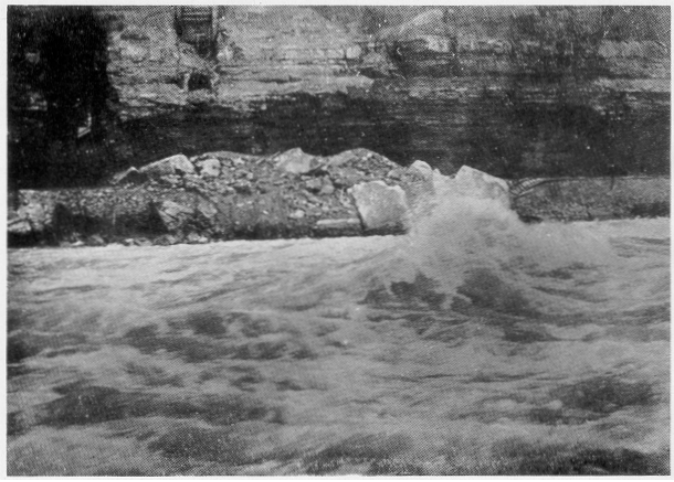

FIG. 2

EXPLANATION OF PLATE XXXVIII

FIG. 1. View of rock wall under Arch bridge. Note absence of talus and glacial drift in contrast to Johnston's cross-section at Cantilever bridge. Shows outcrops of Medina sandstone and red shale, with Clinton limestone above. (From J. W. Spencer, *Evolution of Falls of Niagara*, p. 157. 1907.)

FIG. 2. View of great rock-fall from east wall of gorge of Whirlpool rapids 500 or 600 feet north of Arch bridge. Note at right of center electric railroad track displaced by the fallen rock masses. View taken by the writer April 26, 1899.