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PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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VOLUME XIX

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
—SENECA, *Naturales Quaestiones*

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INDIAN WATERWAYS OF THE SAGINAW DISTRICT, MICHIGAN

FRED DUSTIN

LESS than a hundred years ago, or, to be exact, on September 13, 1837, a party of three men, Dr. Douglass Houghton,[1] state geologist, and his assistants, Bela Hubbard and C. C. Douglass, left Detroit by wagon with Byron, Shiawassee County, as their immediate destination. This place, for which great things had been hoped and predicted, consisted of two houses and a mill at the junction of the north and south branches of the Shiawassee River. Here they procured a canoe and started on an exploration which took them to Saginaw, and from there up the Tittabawassee River to the site of the present village of Sanford and to Salt River, which enters the larger stream not far above. Returning from this point to Saginaw, they procured a larger craft, a dugout thirty feet long, but so narrow that a paddle could be used on either side by a person seated in the center. In this craft they made the river, bay, and lake trip to Fort Gratiot, about one hundred and fifty miles distant, where they took a steamboat for Detroit.

Hubbard's story of this trip, with its fine descriptions, is a partial picture of the old Indian waterways when Saginaw, the Kahbayshaywayning, "Gathering Place" of the red men, was, as it is now, a center of travel.

The drainage area of the Saginaw River comprises about 6,260 square miles. It is the largest in the state; the Grand is second, with 5,570 square miles.[2] It is formed by the junction of the Tittabawassee and Shiawassee rivers, which unite at the extreme southern boundary of the City of Saginaw, from which point to Saginaw Bay it is really a sluggish estuary of that body. With a northeast or north wind of some duration the current may be reversed or brought to a standstill. The early notices always referred to it as "Sagana Bay," or some other variation of the present "Saginaw."

The Tittabawassee, the source of which is in the springs of Ogemaw County, has as its principal branches the Tobacco, Salt, Chippewa, and Pine rivers, all entering on its western side.

The Shiawassee rises in Livingston and Genesee counties, with the Bad, Flint, and Cass rivers as its chief tributaries. In primitive days Swan Creek, which flows into the Shiawassee not far below the mouth of the Flint, was of some importance as a waterway.

The casual observer who sees the smaller streams in the droughts of August may question some of the statements which have been made concerning their navigation in former days; for instance, it has been related that in the early part of the last century one was able to get within thirty miles of Detroit by canoe by following up the Shiawassee River to its source in Genesee County. It is quite possible that this involved a short portage between streams, but even so there is much evidence to support the assertion.

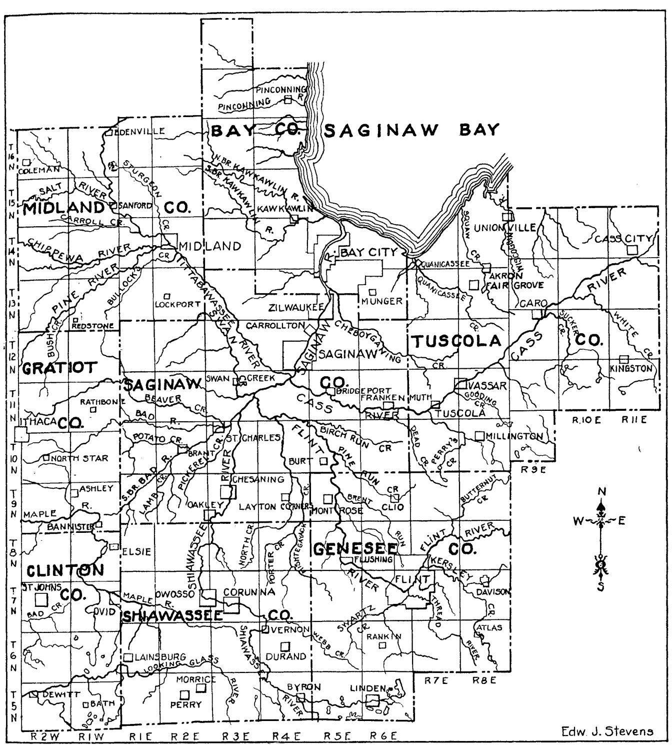
In this paper the designation "Saginaw District" covers not only the drainage basin, but also the bay of that name and some of the small rivers that empty into it. Since the travel of the Indians centered at one place, with subsidiary stations at convenient or strategic points, Saginaw has been made the starting place for the studies of the several waterways which have been named.

The locations of places and the courses of streams described in this paper can readily be found on the accompanying map (Map 1). For the preparation of the map I have to thank my friend, Mr. Edward J. Stevens, to whose kindness and technical skill I have been indebted on more than one occasion.

SAGINAW RIVER AND BAY

The first recorded notices of the Saginaw country indicate that it was in the possession of the Chippewas, a large and important branch of the Algonquian family. Their range was on both sides of Lake Huron to Sault Ste. Marie, along the north and south shores of Lake Superior and later into Minnesota. They were essentially a people of the woods and waters, and as a consequence of their environment the Great Lakes and streams flowing into them became their highways, and journeys of hundreds of miles by water were not uncommon.

Their birch-bark canoes were models of beauty and utility and were used largely in their voyages over the lakes, whereas the dug-outs, patiently worked from a solid log, were an ordinary means of conveyance on the streams in addition to the lighter craft.



MAP 1. Waterways of the Saginaw District, Michigan

The earliest white voyagers were familiar with the terrors of crossing Saginaw Bay, and today Harbor Beach, the great sheltered refuge, is not infrequently filled with vessels northbound, waiting for the choppy seas to go down before proceeding on their way. What, then, must it have been to the Indian in his frail craft? Schoolcraft says:[3] "In order to cross Saganaw Bay in safety in a canoe, it is necessary to pass up the eastern shore from Point aux Barques to Point aux Chenes [now called Oak Point], a distance of eighteen miles. Here, if the lake be calm, the voyageur crosses by a stretch of twenty miles to the opposite shore, with the advantage of landing on the island of Shawangunk [Charity], should a storm overtake him in the center of the Bay, which is frequently the case." He also mentions the fact that accidents caused by sudden squalls often happened at this crossing.

The course was almost due west, with the landing place at Gravelly Point, now called Point Lookout.[4] Saginaw Bay is, officially, that part of Lake Huron west and south of a line drawn from the Tawas Point Light to the Point Aux Barques Light; from here the distance to the mouth of the Au Sable River by a direct line is about forty miles. To gain this distance, an Indian in his canoe paddled nearly a hundred miles, for he crossed the bay, as noted, and followed the shore, keeping within easy reach of it.

Should he be on his way from the lower end of Lake Huron to the Saginaw River, he would not cross to Gravelly Point, but would coast along the eastern shore of the bay. If the Au Gras River, the Rifle, or the Kawkawlin was his objective, he would cross to Gravelly Point.

The Rifle is a cold swift stream having its sources in the infertile sand plains of Ogemaw County; it was difficult to canoe,[5] although carrying a good volume of water, whereas the Kawkawlin, a sluggish stream passing through a more arable territory, was a favored highway, as the numerous prehistoric remains attest.

Entering the Saginaw River, our primitive navigator passed the sand bluff at West Bay City's present site, finding little current and an unobstructed channel through the great marsh to the high ground where now is the city of Saginaw.

THE TITTABAWASSEE AND ITS TRIBUTARIES

Tittabawassee River has its sources in the pine lands of Ogemaw County. It flowed through wide belts of that timber, but along its lower course especially, through extensive forests of hardwood covering a very fertile soil. Game of all kinds, wild fruits, nuts, fish, and other edible products were in abundance, so that from the mouth of the Tobacco River to Saginaw the stream was dotted with Indian villages, and their remains not only have astonished the archaeologist by their number and extent, but have added richly to his stores of relics of the former inhabitants.[6]

The first branch of importance above the junction of the two rivers at Saginaw is the Chippewa, which empties into the Tittabawassee at Midland after receiving the Pine a mile or less above its mouth. The former has its sources in small lakes in Isabella and Mecosta counties. In Indian days canoes passed up its waters to Mount Pleasant or farther. A few years ago two young men canoed from that city to Saginaw. They reported a difficult passage in some places, but it is to be remembered that before the forests were cut off, the summer flow of the streams was much greater than at present.

The Pine River also had its beginnings in Isabella and Mecosta counties. It was an Indian waterway probably as far as Riverdale in Montcalm County.

The next tributary of importance is the Salt River, previously noted. It rises in Isabella County. In lumbering days much pine was floated down to the Tittabawassee, and on that river below the mouth of the Salt River experimental work in sinking a salt well was begun under the direction of Dr. Douglass Houghton in 1838.

The Salt River could be navigated by canoes for some miles above its mouth, and Indian artifacts have been collected along its course far up toward its headwaters.

In the days of the glory of the pine, "Sixteen" in Midland County (now called Edenville) was a noted place. The Tobacco River entered the Tittabawassee here, where active lumbering operations had their headquarters. From the relics since collected it seems evident that the red men found it a convenient camping ground as well as a more or less permanent residence. Canoes passed up the Tobacco as far as Clare, and quite probably to Farwell. I have collected chert chips on the river bank at the Clare dam, and others have found arrow points there. The Cedar River, which joins the Tobacco at Beaverton, was also navigable for several miles.

There is little doubt that the Tittabawassee was used as a waterway as far as Ogemaw County. The Mackinaw Trail touched its headwaters at several places and followed its lower course to Saginaw.

THE SHIAWASSEE AND ITS TRIBUTARIES

From its junction with the Tittabawassee the Shiawassee winds its way southward through a great marsh twenty miles long and six miles wide at its greatest breadth; through this marsh it receives all its tributaries, which were Indian waterways. Just below Chesaning quick water begins; from this point to Byron and above there were alternating rapids and stretches of dead water, but now the river is obstructed by several dams; the one farthest downstream is at Chesaning.

In the lower section of the great marsh the stream spreads out into a shallow sheet of water locally known as Shiawassee Lake, filled with rushes, water grass, and wild rice. In early days it swarmed with pike, large-mouth black bass, and multitudes of less esteemed fish, and was the nesting place of myriads of ducks and other waterfowl. On the driest portions of the marsh tall, coarse grass grew to a height of ten feet or more. One dry season forty years ago I was caught in this tangle of vegetation by a prairie fire. Only one who has had the experience can realize the difficulty of making his way through it with raging flames close at hand and the friendly river all too far away. In autumn it is no infrequent sight to see from Saginaw a brightly lighted sky southward, as of a burning city, but this has been lessened by the diking and cultivation of about eight thousand acres comprising what is known as "The Prairie Farm." On this marsh, covering approximately a hundred square miles, there is scarcely a change of contour line[7] aside from those created by the dikes. The interval on the topographic sheets of the Geological Survey of the district is only five feet.

As to the early navigation and its improvement by the white settlers, the following extract from a history of Shiawassee and Clinton counties[8] is of interest: "The company . . . commenced the work in 1837, and continued it during that and the following year, expending several thousand dollars on the river in removing obstructions (principally between Chesaning and the mouth of Bad River), erecting dams, and constructing tow-paths above Chesaning. The river was thus made navigable for flat-bottomed boats or scows, several of which were built with foot-boards on each side, on which men walked forward and aft in 'poling' the craft up the stream. This poling process was employed on that part of the river which is below Chesaning, but above that place horses were used. At some points the tow-path was made on the east side of the stream, and at others on the west. . . . Larger boats were afterwards used for floating products down the river from Owosso. One 'Durham' boat, built at that place . . . carried a cargo of two hundred barrels of flour from Owosso to Saginaw."

Later on a lock was constructed at Chesaning, and other improvements were made, but nothing now remains.

In 1887 a schooner fifty-one feet long of seventeen-foot beam and four-foot depth was built at Oakley near the south line of Saginaw County.[9] After the work was well under way and the planking on, an examination of the river below Chesaning revealed the fact that about four miles of the channel above the mouth of the Bad River was completely filled with flood wood, and that instead of a single navigable stream, there were three or four small creeks winding about through the obstructions. As a consequence, the little vessel was loaded on sleighs and hauled by four teams to St. Charles, where it was finished and launched. I have not been able to learn when the obstructions began, but they still remain.

The Shiawassee was a favorite Indian waterway. Along its course on rich bottom lands were numerous cornfields. On the bluffs and benches villages were located. At Owosso, Grand Traverse of the French canoeman, the Great Trail from Detroit to Saginaw Bay crossed the river and followed it down to Chesaning, "Great Rock," where a large limestone boulder lay in the river bed, and three quarters of a mile eastward another great rock mass of igneous origin stood in the woods, both objects of mild veneration.

Cass River enters the Shiawassee through the lower end of the great marsh about three quarters of a mile above where it unites with the Tittabawassee. Its sources are in Sanilac and Huron counties, the North and South branches joining in Tuscola County, a mile south of Cass City.

From its mouth to the Town Line Road in Saginaw County it is sluggish, with a fair depth of water; from this point to the Dixie Highway it becomes shallow, running over a sandy bottom with a few short rifts. Onward to Tuscola Village there are a number of rapids with gravel and boulders forming the river bed. From Tuscola to a point two or three miles below the Grand Trunk Railroad bridge near Cass City the river was a succession of rifts and still water; from here for about nine miles upstream the bed is sandstone. Near the lower end of this outcrop there is a stratum of argillaceous limestone, which the Indians used for making pipes.[10] Farther up near the Grand Trunk bridge I have seen blocks of similar rock, but did not observe whether there was an outcrop of it there.

The Cass is fed by several living streams entering on the south side, which have their sources in small lakes. At present boating is not feasible to where the rock bottom begins except in high water, although originally it was a waterway from the western edge of Sanilac County to its mouth.

A trail on each side of this river followed it from not far above its mouth to Indian Rapids in Sanilac County, with important crossings below the East Street bridge near Saginaw, at Bridgeport, Tuscola, and Caro.

The Flint River and Swan Creek enter the Shiawassee five or six miles above the mouth of the Cass from the east and west respectively, Swan Creek a few rods below the Flint.

Swan Creek has its beginnings in Saginaw and Midland counties, and although now insignificant in its summer flow, in the spring is often a torrent which spreads over its narrow valley to a depth of eight or ten feet. It parallels the Tittabawassee at an average distance of three miles. The lower half of its course is bordered by a narrow marsh on each side, which widens and merges in the great Shiawassee marsh three miles from its outlet.

Indian remains, beginning at the first high land above the great marsh and extending well up into Midland County, are numerous; no fewer than eight village sites have been located.[11]

There was no section of the whole district where game was more plentiful than in the immediate vicinity of Swan Creek, and during the canoeing season the aborigines living thereabouts whose affairs or inclinations took them up the Shiawassee found a nearer and more convenient route than the one down the Tittabawassee. A few years ago this creek was dredged to the Midland County line, with improvement in the boating. Forty years ago while hunting in the woods bordering the great marsh, I walked for many rods on logs that filled its bed near the edge of the timber and a long distance out on the open prairie. The season was unusually dry, and there did not seem to be a drop of water in the old channel, but above the woods there were several miles of deep water. The logs were the remnants of lumber days when much timber, especially pine and oak, was floated down its waters.

The lower six miles of the Flint River are through the great marsh, but it is not until Genesee County is entered that rapids begin. At Flushing it flows over a rock outcrop, and the rapids increase as it is ascended. At Flint the Detroit and Saginaw Trail crossed; a branch led north to Tuscola. Kearsley Creek and Thread River flowed into the larger stream at Flint, where it made a great bend to the north toward its sources in Lapeer County.

As a highway for pioneer settlers, the Flint River has perhaps figured more in the annals of Saginaw than any other. The first road opened from Detroit to Flint followed the Indian trail, but it was several years before it was made passable to Saginaw. As a result, many of the earliest comers to that place secured boats or canoes at Flint and made the two days' trip to the small village clustered around the stockade called Fort Saginaw.

Some of the historical sketches have been put into print and among them we find "A Trip from Detroit to the Saginaw Valley over Fifty Years Ago," by William R. McCormick.[12] At that particular time the trip took three days, since the water was very low and the "rafts" or "flood woods," as they were called, formed long and difficult obstructions. Later, when these rafts were opened, with a fair stage of water the time was shortened a day.

Quoting from McCormick's account, he says: "We had passed all the rapids and the river now became deeper, and we went on very well and soon arrived at the Driftwoods. These driftwoods had been accumulating for ages, having been brought down by the spring freshets. The river was so obstructed from the bottom to five or six feet above the water, and so tight was it jammed together, that a muskrat could scarcely find his way through it. The Indians had a portage around it where they drew their canoes. . . . These floodwoods were about forty rods long. We then started down the river, and had not proceeded over a mile when we came to the second floodwood. . . . This floodwood was about twenty rods long. We then proceeded down the river for about half a mile, when we came to the third and last floodwood . . . ten rods long. [This was near the present East Street bridge.] Close by was an Indian village where they had their cornfields. . . . The floodwoods . . . were removed by the lumbermen of the Saginaw valley in 1843."

These flood woods occurred also on the Cass and possibly on the Tittabawassee, although I have no record of them on the latter stream. They occasionally changed the courses of the rivers, a notable example of which can be seen about eighty rods west of the Dixie Highway on the Cass. Many years ago an aged Indian came to that locality on a visit, and remarked that the river was not where it should be. He indicated its course almost due west along the foot of a bluff on the south bank, whereas it now makes a sharp bend to the north until it strikes a clay bluff which forces it southwest to a point where it again touches the high ground on the south and meets its former bed. The part thus cut off is a clearly defined channel a mile long, usually with some water in it. The old Indian said when he was a boy the river ran through this ravine.

We now come to our last river, the Bad. Geologists say that, long ago in geological time, Lake Huron, then much higher than now, emptied its waters into Lake Michigan by way of the Maple and Grand rivers.[13] The southwestern lobe of this ancient lake had its shore not far from the principal meridian which forms the boundary between Saginaw and Gratiot counties. On the headwaters of the Maple, northwest of Bannister in Gratiot County, we look across a broad, shallow valley, in places over a mile wide.

To one having some knowledge of the geological history of the region a wonderful page in Nature's Book lies open before him. In his mind's eye he sees to the east and northeast a vast lake; at his feet a mighty flood of water pours southwestward, but here the picture fades, and it remains for the specialist in Earth's history to complete the story. The great lake has receded to the present waters of Saginaw Bay and has its outlet northeastward to the sea through the St. Lawrence, and the little Maple River flowing along this great channel "is lost on the swampy floor throughout its whole course from two miles northwest of Bannister."

An examination of the Elsie sheet of the topographic survey of this vicinity[14] reveals some interesting facts. It is observed that the South Branch of the Bad River apparently ends its winding course on the line between Sections 23 and 24 in Elba Township, Gratiot County, less than two miles from a great bend in the Maple to the southwest. This bend has been cut off by dredging a straight new channel on the west side of the Ann Arbor Railroad. Where the crooked course of the Bad ends on the map, it has been straightened by dredging ditches west and south following section and quarter lines almost, if not to, the old channel of the Maple.

The divide between the two streams is hardly perceptible, and in driving across it we suddenly find water flowing west whereas but a few minutes before we saw it running east. Before the land was cleared and ditched, it was possible in very high water to pass from river to river in a canoe. Thus a continuous waterway existed in the early part of the last century arid before from Lake Huron to Lake Michigan.

The four rivers, Saginaw, Bad, Maple, and Grand, constituted an important waterway across Michigan. It was paralleled by the Saginaw Bay and Lake Michigan Trail, and an old map[15] has a distinctly marked portage between the Bad and the Maple, so that it is not to be understood that a continuous waterway existed at all times and seasons, but there were intermittent periods of complete navigation.

In his paper, "Indian Modes and Paths of Travel in Michigan: Waterways"[16] Dr. W. B. Hinsdale, of the University of Michigan, says: "Canoes could ascend the Grand to Lyons, Ionia County, take the Maple and approach within the breadth of a half-township the Shiawassee," whereby it was possible to ascend to its headwaters or to descend to Saginaw Bay.

The North Branch of the Bad rises in Gratiot County near Ithaca. In lumbering days great numbers of pine logs were floated down to St. Charles where they were sawed. Here the North and South branches unite, and Beaver Creek, another lumbering stream rising only two miles north of the headwaters of the North Branch, enters just below the forks. At one time a regular steamer service was maintained between St. Charles and Saginaw. The last time I was at the mouth of the Bad River, the rotting hulk of the Signet, which blew up there sixty or more years ago, was still visible.

There is an incident concerning the navigation of the Bad River, now almost forgotten, for it took place nearly a hundred years ago. During the 'thirties of the last century a wild craze for "internal improvements" afflicted the people of Michigan, corresponding to our recent craze for fabulously expensive highways. As a result, many projects for improving navigation were put forward. The state legislature approved of them all and undertook the construction of a number, one of the most ambitious being the Saginaw and Grand River Canal. Contracts were let and the work started speedily, but the bubble burst.

A historian of fifty years ago[17] says: "It was not to be expected that the contractor for this work . . . would be able or willing to prosecute it without prompt payment on the part of the State, which, failing to meet its engagements . . . was averred by the contractor as the cause of the work being abandoned. This occurred in June 1839. Most of the work required on one section of the canal . . . has been completed. . . . There is now on the line several thousand feet of plank and timber intended for the locks and dams. A great portion of the timber is framed, and will, from its exposed condition, decay very rapidly. The timbers mentioned . . . remained to rot on the ground, and the remnants of some of them have been visible in the town of Chapin, Saginaw County, in quite recent years."

Today as the traveler from St. Charles to Brant crosses the South Branch, he will note on his left a line of straight river about three quarters of a mile long with the retaining walls and old timbers. This is the portion of the

Saginaw and Grand River Canal that was completed, and stands as a monument of folly and fatuity.

As late as 1880 a small steamer operated on the Maple River between Maple Rapids in Clinton County to Bridgeville in Gratiot County, but was discontinued soon after, thus ending navigation on that stream.

It has been truly said that man or beast having a more or less distant objective will follow the lines of least resistance. This may be qualified at times, since occasionally it is more desirable to cross a hill directly than to go around it, time and distance being saved by such a course. Likewise a portage between streams or across great bends might save time if not labor. So far as is known, there were few portages in the Saginaw District and no cut-offs, but it was possible to pass readily from the waters of the Saginaw to the waters of the Muskegon,[18] or possibly from the Shiawassee to the Huron River.

SUPPLEMENT

DEFINITIONS OF INDIAN NAMES OF STREAMS OF THE SAGINAW DISTRICT

It seems fortunate that in the Saginaw District so many Indian names were bestowed on its streams and places, which, though corrupted and in some cases almost lost in bad spelling,[19] perpetuate the memory of the red man as well as give a significance and character that our meaningless names do not approach. It is believed that the names and definitions following illustrate the appropriateness of the aboriginal designations. In a few cases the authority for a definition is given. Some of the Indian names are no longer used, but English translations have been substituted.

Bad. — Maw-tchi Se-be, "bad river," was the Indian name for the South Branch; Mis-a-bos, "white rabbit," for the North Branch. Wau-po Se-be, "swan river," now called Potato Creek, flows into the South Branch a mile east of Brant Center. It appears on Farmer's map of Michigan.[20]

Bear. — The English rendering of the name of a small stream flowing into the Shiawassee in Section 14, St. Charles Township. The Indians called this creek, Maw-kwa Se-be, "bear river."

Cass. — Na-da-way, "I bring him in a canoe," referring to some event associated with the river. It was also called by the Indians "the river of the Hurons," owing to the fact that a band of Hurons lived for some period at its headwaters and about the forks near Cass City.

Cheboyganing. — "The place of the big pipe," according to Baraga's dictionary,[21] but an educated Ottawa Indian, F. S. Wakefield, of Grandville, Michigan, has informed me that "Cheboygan" means "a sound like the passing of a needle through fabric." Dr. Melvin R. Gilmore, of the University of Michigan, and Edward J. Stevens, of Kalamazoo, Michigan, also disagree with Baraga's translation. Mr. Stevens has made a study of Indian place names in this state, and Dr. Gilmore has secured considerable direct information from the Indians themselves. "Cheboygan" illustrates the differences occurring among those whom we may assume to be authorities.

Flint. —Pe-on-i-go Se-be, "flint river," or Pe-on-i-go-ing Se-be, "flint-place river." Authority: Daniel Wheaton, a full-blood, educated Indian of the Chippewa tribe, born in Saginaw County, where he lived all his life.

Kawkawlin. — A corruption of Kaw-kaw-ing, "crow place." According to William R. McCormick,[22] "Kawkawlin was called by the Indians O-kaw-waw-ning, the meaning of which is pickerel river." Andrew J. Blackbird[23] gives *o-gaw* as the name for pickerel. The *ing* means "place." George Wheaton, son of Daniel Wheaton, has informed me that Kawkawlin or, more accurately, Kawkawing, means "crow place."

Misteguay.— A corruption of Me-zhe-say, "wild turkey." This creek rises in Shiawassee County and enters the Flint River five miles above its mouth.

Pinconning. — A name commonly supposed to be a corruption of the Indian designation meaning "the place of the wild potato." This is not the potato of the market, but a small tuber which has been called by that name.

Dr. Melvin R. Gilmore says of this word:[24] "In the Chippewa language the word pin is a generic term signifying 'tuber,' and is applied to many tuberous growths." In this case it designates the *Apios tuberosa* Moench, commonly known as "rosary root," of which great quantities grew along the banks of Pinconning Creek and were harvested by the Indians. "For this reason," states Dr. Gilmore, "they called this locality *Pini-kaning*, which is to say, 'the place of the *pin*.'"

Rifle. — Me-sag-wisk, the name for Rifle River as used in the Treaty of Saginaw in 1819.[25] I have been unable to find its English equivalent.

Saginaw. — A corruption of the Chippewa phrase, Saug-ee an-te-nah ke0wat, "where the Sauks (Saugee) were." It was easily shortened to Saugeantenah or Saugenah. Authority: Daniel Wheaton.

Sebewaing. — A corruption of Se-be-wens, literally, "little river." *Sebe* means "river"; *wens* is a diminutive ending.

Shiawassee. — A corruption of O-zhaw-wask-kwaw Se-be, "green river," easily corrupted to Shawassee. Authority: Daniel Wheaton.

Swan. — An erroneous rendering of She-sheb Se-be (*e*'s pronounced as in *eat*), "duck creek."

Tittabawassee. — A corruption and shortening of an Indian phrase signifying "the river that follows the shore." Has been spelled in different ways, variations of the present rendering.

SAGINAW, MICHIGAN

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[18] See page 16 of article cited in note 15.

[19] The difficulties involved in defining Indian names will be readily observed in the following note from Schoolcraft, Henry R., *Information Respecting the History, Condition and Prospects of the Indians of the United States* (Philadelphia, 1854), Part II, p. 465:

"The crow was known among different bands of Chippewa by apparently unrelated names in some cases: for instance at Sault Ste. Marie it was On-daig; at Grand Traverse Bay, Kah-gah-ge; at Mackinaw, Aun-daig; at Saginaw, Kah-kah-ge."

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CLASSIFICATION OF LAND ON A GEOGRAPHIC BASIS*

JETHRO OTTO VEATCH

GEOGRAPHY is the science of areal differentiation. It is concerned with the earth as the differentiated home of man. The geographer must, therefore, have as a basis for his science a classification of natural environment. This is tantamount to stating that he must have a classification of the features of the earth's surface. The most obvious division of the earth's surface is the separation into water areas (seas) and land areas. For the further division of the land areas it would appear that climate might be the logical criterion, since climate determines in a broad way the kind of life, plant and animal, which can exist. However, the classification of climate has not been perfected to the degree that the equivalent climatic expression for the smaller units of land can be stated. The logical recourse is to classify the forms, or physiognomy, of the land. Man at some stage in his development must have dimly recognized the fact that some parts of the earth, were flat, others rough and broken, but later he learned that such a simple division was not sufficient, and gradually invented terms to designate differences in aspect, such as plains, plateaus, hills, mountains, valleys, basins, lakes, swamps, and streams. The grouping of forms of the earth's surface in an orderly fashion on the basis of their origin constitutes physiography. The physiographic divisions and topographic forms have served as a proper basis for the geographer's correlations, since the kind of surface has affected the numbers and movements of human beings. But two other factors enter which are not everywhere implied in the physiographic, or surface, divisions. These two factors are soil and vegetation. The soil, after all, is perhaps the most important environmental factor, since directly or indirectly it is the source of civilized man's food and clothing, whereas the amount of arable land and the kind and productivity of the soil determine the population, or if not everywhere the number of people, indirectly the kind of industry and commerce and to some extent the mental traits and type of social organization.

In effect, what is here proposed is to add the factor of soil to the physiographic, or surface, division, in the mapping of land types and to recognize associations of minor topographic forms as a basis of differentiation of minor land types. A combination of recognized physiographic divisions might have to be made for the broader land types, or those of the first and second order, but for the land types of the smaller orders the recognized physiographic divisions would have to be subdivided, although in a few cases it might happen that some recognized physiographic division is also a unit in soil and vegetation. To add the factor of soil is not so simple as it might appear, since there immediately arises the question of what characteristic or peculiarity of soil is to be selected as most important in the differentiation of land types. For the broader regions the family characteristics of soils would be selected; for the smaller physiographic or topographic divisions, the textural class would probably be selected as most important generally, but other soil classes might be selected according to their importance in relation to plant growth and use of land in the particular area being mapped, whether a physical condition, a chemical character, or a moisture condition. Where soils are quite variable, or where there are several kinds occurring in small separate bodies, peculiar associations of them would have to be recognized and contrasted with one another. To carry out the mapping of land to the smallest units of the taxonomic scheme, detailed maps of plant associations of natural vegetation would be desiderata.

In the land-classification scheme beginning with the broadest divisions the order would be: (1) zones, which are climatic; (2) divisions of these zones, which are units in soil and vegetation, as, for example, the grass land, dark-colored soil region, in contrast to the gray soils, forested land region of the North Temperate Zone; (3) divisions which are physiographic in nature; that is, the major physiographic divisions lying within the boundaries of (2); (4) the units of the separate relief features of (3) grouped according to sameness in soil and vegetation; (5) subdivision of the relief features of (4) on the basis of differences in soils and vegetation. At this point the "land divisions" would probably in a great many instances be practically equivalent to the "soil types" as at present differentiated in the detailed, or inch-to-the-mile mapping by the Soil Survey Division of the U. S. Bureau of Chemistry and Soils.

If land mapping were to be carried on in organized manner, the need for naming and correlating the divisions would at once arise. From the nature of things no rigid, mathematical rules of procedure for differentiation and correlation can be set down, any more than they can be set down for the classification of geological formations, physiographic divisions, or associations of natural vegetation. The principle to be followed is: All land areas having the same topographic expression together with the same associations of soil and natural vegetation should be given the same geographic name.

The Land Economic Survey Division of the Department of Conservation, State of Michigan, has been constructing maps of the "natural land divisions" in the separate counties of the state which it has mapped in detail. These divisions have a great deal of local geographic significance, but no attempt has been made to correlate the areas so that the state-wide geographic significance of any particular land division can be determined. The difficulties in the way of correlation are not insurmountable. The divisions are primarily physiographic or topographic and are related to the divisions of the geological map of the formations and features of glacial origin, such as moraines, till plains, and outwash plains. These separate glacial features and formations, however, are not sufficiently uniform in topography, vegetation, and soils to constitute within themselves a land entity from a geographic point of view, or to represent the same land types throughout the whole state. The problem in correlation is, then, to determine whether separate bodies of land possess sameness in associations of topographic forms, and associations of soils and vegetation.

The original native vegetation, of course, cannot everywhere be employed as one of the criteria, since there may be some localities where it has been completely destroyed or altered by man.

An illustration of the procedure in the recognition of land types and their correlation is given. A certain area in central Michigan is hilly and as a whole is a bold relief feature in contrast to the associated lower plains of sand and clay. Slopes are smooth and rounded, rather than steep and eroded, and generally are not in excess of 15 per cent. The included valleys, or basins, appear to be partly filled with sand, have nattish floors, and may not be occupied by streams; though present, streams, lakes, and swamps are not distinguishing features. The local differences in altitude do not exceed 100 or 150 feet. The soil is prevailingly a deep, dry sand, low in fertility, with an association of small patches of gravelly and clayey soil. The original forest cover was dominated by Norway (red) pine. The second growth is dominated by oaks. Wherever this same type of constructional topography, deep sand soil, and pine-oak cover occurs the same land-type name will be applied. But should there be any notable increase in the proportion of clay and loam soils, in the amount and distribution of swamps and lakes, or a replacement of pine by hardwoods, these things would be regarded as a sufficient basis for establishing a new land type, of the same order as the first, and for drawing a boundary line on the land map.

The pedographic land division constitutes a more logical unit for geographic studies than does the political unit, since the boundaries of the latter may be quite contrary to natural boundaries. But where it is not practicable to adopt the natural unit, statistics or other data are more understandable when the proportional area and location of different land types in the governmental unit are known. In a geographic study of a region the pedographic map and the economic map (divisions based primarily upon type of industry and upon population) are supplementary to each other.

A tentative key for Michigan is presented here for the purpose of illustrating further the idea of the geographic land classification.

KEY TO LAND TYPES OF MICHIGAN

NORTH TEMPERATE LAND ZONE

Great Lakes Plains Region (physiographic-pedologic)

(Parent soil material unconsolidated glacial deposits)

I. Podsol-forest land divison (northern part of state)
  A. Dry, sandy-gravelly forested plains (major type)
    1. Pine plains type
      a) Norway pine — jack pine plains (Grayling subtype)
      b) White pine plains (more loamy and gravelly soil — Stambaugh subtype)
    2. Hardwood plains type
      a) Kalkaska subtype (more limy soils)
      b) Au Train subtype (less productive, acid hardpan soils)
  B. Diversified wet and dry, sandy, forested plains
    1. Sand and peat swamp type (mainly coniferous)
    2. Sand and peat swamp type (mixed hardwoods and conifers, more productive clay soils associated)
  C. Hilly sandy land (diversified topography, soils, and vegetation)
    1. Pine land, deep, dry sand (few lakes, streams, or swamps)
    2. Hardwood hills, deep sands, lakes, and swamps associated)
    3. Hardwood hills, heavier soils, and more stony land
  D. Sandy plateau upland and bench land
    1. Hardwood plateaus (intersected by deep valleys)
      a) Sandy table-land (steep escarpments and valley slopes)
      b) High stream-cut bench land (Munising subtype)
    2. Level and gently rolling sandy highland (lakes, swamps, shallow depressions)
  E. Lake bed clay plains (few or no lakes, generally not stony)
    1. Low-lying clay-swamp plains (Chippewa subtype)
    2. High, stream-cut clay plains (Ontonagon subtype)
  F. Rolling, stony, clay plains (lakes and swamps)
    1. Clay-ridge type (oval or parallel ridges, sandy and swampy valleys associated)
      a) Hardwood ridges (more limy soils)
      b) Hardwood and conifer ridges (high altitude, very stony, Iron County type)
    2. Rolling, clay plains (large proportion of wet land associated)
    3. Stony, clay land — swamp type
      a) Stony loam, hardwood-conifer land (rock outcrop, wet mineral soil and muskeg swamp associated — Gogebic subtype)
      b) Limy soils (Trenary-Onaway subtype)
  G. Stony, bedrock plains and plateaus
    1. Limestone bedrock type
    2. Sandstone bedrock type
    3. Crystalline bedrock type
  H. Superior highland, mountainous plateau and rock-knob land
    1. Huron Mountains type
    2. Copper Range rock-knob type
    3. Negaunee rock-knob type
  I. Swamp-plain type
    1. Spruce-cedar swamp, small bodies of wet and dry sands associated
    2. Swamp with islands of loam and clay soils associated
  J. Dune type
  K. Water (larger water-covered areas)

II. Brown forest-soil land division (southern part of state)
  A. Dry, sandy, gravelly plains (major type)
    1. Oak-hickory land (more clayey and more productive soils)
      a) Smooth plain subtype
      b) Deeply pitted, lake-swamp subtype
    2. Pine-oak land (deeper sands and less productive soils)
      a) Southern oak-hickory sandy land
      b) Northern pine-oak sandy land
      c) White pine-hardwood land (gravelly and more loamy soils)
    3. Prairie land (only a few areas of sufficient size to constitute separate land types)
  B. Diversified wet and dry sandy plains (few or no lakes and streams)
    1. Intermixed wet and dry sands (sandier and less fertile, soils)
    2. Intermixed wet and dry sands (large proportion of clay and the more fertile wet sandy soils of the Wauseon-Gilford types)
  C. Hilly sandy land (basins, knobs, lakes, swamps, few streams)
    1. Pine and mixed hardwood subtype (dominantly deeper sand)
    2. Oak-hickory and maple-beech subtype (higher proportion of sandy loam and loam soils)
    3. White pine-hardwood land (higher proportion of sandy loam)
  D. Level lake-bed clay plains land (more fertile soils, hardwood forest)
    1. Darker wet clay land (muck land associated, no lakes, few streams, not stony)
    2. High clay land (partly stony, more deeply trenched by streams)
  E. Rolling clay plains land
    1. More level land (few or no lakes and streams, swales and plats of dark-colored soil, small proportion of muck land)
    2. Rolling land (large proportion of muck and other swampy land in net form or in widely distributed shallow basins)
    3. More strongly sloping land (stream dissection, very small proportion of swamp)
  F. Dune land
  G. Muck swamp land (only a few areas of sufficient size to constitute a separate land type)

As an illustration of how the major land types of the state may be subdivided into a great number of smaller units, the dry, sandy, gravelly plains (II A) of the southern part of the state are selected:

DRY, SANDY, GRAVELLY PLAINS (MAJOR LAND TYPE)

Oak-hickory and other hardwood land (Fox type of soil comprises 50 per cent or more of the area)

I. Smooth highland (relatively few streams, lakes, and swamps)
  A. Heavier soils (maple, beech, oaks, walnut, elm, etc.)
  B. Sandy soils (oaks or oak-hickory)

II. Pitted and diversified plains (lakes and swamps numerous)

A. Heavier soils (mainly loams)
   1. Cobbly and gravelly soils
   2. Soils free from stones
B. Lighter soils (mainly sandy loams and sands)
   1. Level land
   2. Basin slopes
C. Dark soils (maple, beech, elm, walnut, oaks, etc.)

III. Valley plains

A. Chains of lakes and swamps
   1. Deep sand soils associated
   2. Wet clay soils associated
B. Terrace plains bordering rivers (few or no lakes)
   1. Loamy and darker soils
   2. Lighter and sandier soils

IV. Dissected terrace plains and escarpments (no lakes or swamps)

A. Slopes with moist and dark soils at the base
B. Slopes with dry sandy and gravelly wash at the base

Subdivision may be carried even farther than has been done here, although there may be no practicable need for such refinement. The particular unit selected for mapping will depend upon the scale of the base map used and the purpose in mind.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

* Authorized as Journal Article No. 155 (N. S.) from the Michigan Agricultural Experiment Station.

STRUCTURE AND PHYSIOGRAPHY OF THE SOUTHERN WASATCH MOUNTAINS, UTAH

ARMAND J. EARDLEY

CONTENTS

LOCATION

THE southern Wasatch Mountains are situated in central Utah and comprise the southern end of the Wasatch Range, which extends southward from a point near the Idaho line to the town of Nephi, a distance of 150 miles. The area mapped is 22 miles long in a north-south direction and 11 miles wide, and includes the southern Wasatch Mountains, part of the Wasatch Plateau to the east, part of the Gunnison Plateau to the south, and part of the Juab 377

and Utah valleys to the west, in which the towns of Santaquin and Nephi are situated.

STRUCTURE

There have been four major crustal disturbances in the region of the southern Wasatch Mountains, namely: the post-Archean revolution, the post-Algonkian revolution, the Laramide revolution, and the Basin and Range deformation. During the Paleozoic and Mesozoic eras minor disturbances occurred in the form of epeirogenic movements, and, preceding the Laramide revolution, in the form of normal faulting. The geologic history is summarized in Table I at the end of the paper.

PRE-LARAMIDE CRUSTAL DEFORMATION

The post-Archean revolution was probably more intense than any that occurred afterward. Sedimentary rocks were converted into schist and gneiss;[1] these were intruded by pegmatite dikes and granite; and all were later truncated by erosion. The Algonkian shale and quartzite now cover this old erosion surface. The unconformity thus created may actually be the result of a number of distinct disturbances, now all compounded into one great hiatus. The foliation of the schist and gneiss strikes roughly parallel with the axes of the much later Laramide folds, indicating that the structural lines of this ancient period of diastrophism may have exerted some control over the present Rocky Mountain trends of the region.

At the close of the Algonkian era of deposition a compressional orogeny occurred in which great folds were formed. The magnitude of these folds in the region around the southern Wasatch Mountains may be estimated by the amount of erosion that followed. The maximum observed thickness of the Algonkian strata in the Wasatch Mountains is about 11,000 feet. In Dry Mountain of the southern Wasatch Mountains a thickness of only 1,000 feet is found. It is, therefore, suggestive that folds having an amplitude of at least 10,000 feet were created in this post-Algonkian revolution.

During the Paleozoic and Mesozoic eras gentle epeirogenic warpings occurred, producing hiatuses in which most of Ordovician, Silurian, Devonian, and parts of Triassic and Jurassic times are not accounted for.[2] These hiatuses are marked only by disconformities not easily discernible and by low-angle unconformities.

Preceding the Laramide folding normal east-west faulting disturbed the region. A number of east-west faults are in the area mapped, and all have been classified as "pre-Laramide," although in only one instance can an exact age determination be made. On the north side of the mouth of Santaquin Canyon an east-west fault is cut by the Santaquin overthrust and is, therefore, older than the thrusting. The others are similar to this one inasmuch as they are all older than the Basin and Range block-faults, and none have topographic expression except that which is due to the relative resistance of the rocks on one side or the other.

LARAMIDE CRUSTAL DEFORMATION

The dominant structure built during the Laramide revolution in the southern Wasatch Mountains is a great overturned and over-thrust fold involving a series of strata in excess of 20,000 feet in thickness. With this as a key, all other features can be demonstrated to be incidental but interesting variations of the major structure. The block diagram of Figure 9 is an attempt to reproduce the position of the folded strata as they would have appeared if no erosion or block-faulting had subsequently occurred and if the earth's crust had remained rigid enough to support such an excess of weight as that imposed by this fold. The diagram is not complicated by any of the minor variations that exist.

The following points constitute a brief description of the Laramide structure.

Folding

The great anticlinal fold is practically isoclinal and overturned from Pole Canyon No. 2 south. Farther north in the Dry Mountain area it is broader and, so far as exposed, not overturned. In that part which is isoclinal only the post-Cambrian strata are involved, but in the open fold the entire rock section is engrossed. The range from North Canyon to Dry Mountain is sculptured out of the east limb of the open fold, whereas the beds in Mount Nebo are carved out of the lower limb of the overturned fold. The dip in Dry Mountain is about 30° E. and in Mount Nebo about 30° W. In Loafer Mountain, which is a continuation at deeper horizons of the Dry Mountain structure, now brought up by Basin and Range block-faulting, the dip is over 45° E. This may suggest that the fold continues at depth to an overturned position here also.

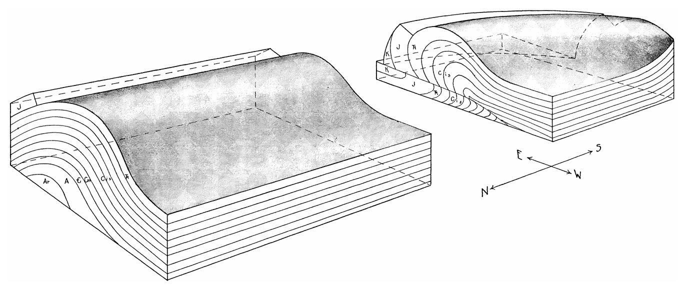


FIG. 9. Block diagram illustrating the author's conception of the structure produced during the Laramide revolution in the southern Wasatch Mountains. The area included in the diagram is approximately that of the geologic map (Map 11)

The axis of the fold trends slightly east of north, except at the southern end, where it veers decidedly to the west. This swing to the west is indicated by the present strike of the beds and by the exposure of the Paleozoic strata not to the south, but to the southwest, in the Canyon Range of the Great Basin.

The trace of the axial plane traverses the present erosion surface at approximately the junction of the piedmont with the steep slopes of the Wasatch front. At the north end of the mapped area the trace of the axial plane lies slightly west of the mountain front (Dry Mountain). From this point it continues about due south, crossing the ridge formed by the "Intercalated series" on the southwest side of the mouth of Santaquin Canyon. The axis of the fold is seen at the very mouth of Dry Canyon. In North Canyon the strata are arched, with a small western segment of the arch showing, indicating the axis here to be slightly to the east of the mountain base. In Pole Canyon No. 2 the axis is also decidedly within the mouth of the canyon, and continues so through Bear Canyon and Couch Canyon. The rocks at the mouth of Willow Creek show intense twisting and brecciation, with varying strikes and dips, which are thought to indicate the close proximity of the axial plane of the fold. From Willow Creek to Gardner's Canyon the axial plane follows in general the base of the mountain front, and then, from consideration of the strike of the axis, it is thought to swing off to the southwest.

Overthrusting[3]

The Nebo overthrust. — An overthrust fault is mapped skirting the southern base of Mount Nebo. It is recognized by the following evidence:

1. The Intercalated series of Pennsylvanian age rests on Jurassic shale (see geological map [Map 11]) in Gardner's Canyon.

2. Three Triassic formations, the Woodside, Thaynes, and Ankareh, are found in the North Fork of Salt Creek Canyon, but are absent in Gardner's Canyon. About 2,500 feet of strata are missing. The mapping of the Woodside, Thaynes, and Ankareh formations shows them all to disappear, one at a time, when followed around the High South Ridge of Mount Nebo, until finally the Intercalated series rests on the Jurassic shale.

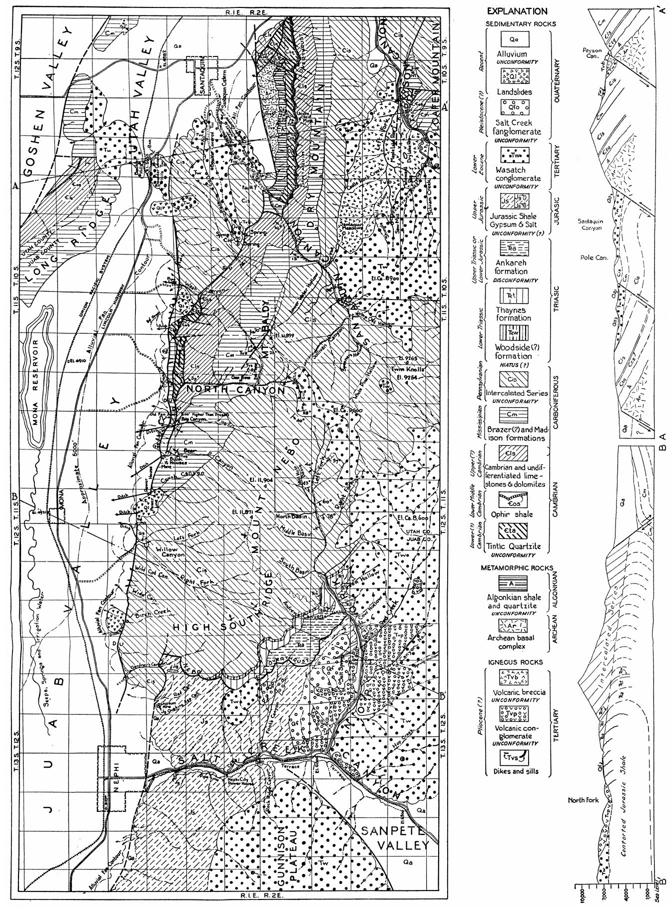
3. The fault plane is mapped as lying at the base of the overturned flank of the single great fold of which the southern Wasatch Mountains are composed. It is probable that under continued horizontal pressure the overturned fold would have ruptured at this position.

4. In the North Fork of Salt Creek Canyon the Ankareh and Jurassic shale contact is an angular one, and appears to be the result of overthrusting. There are two possible interpretations of this angular contact: first, an erosional unconformity; and, second, an overthrust fault. The writer believes the latter interpretation correct because:

(*a*) The upper beds of the Ankareh dip 45° NW. as they emerge from under the Tertiary cover in the North Fork of Salt Creek Canyon. The dip of the plane that truncated them is only 12° W. This plane falls in line with the plane of the overthrust, where it is more definitely located.

(*b*) There are no basal conglomerates or sediments of any kind to suggest an erosional unconformity. Where the contact is exposed, an oölitic limestone of rather pure calcium carbonate is the lowest bed of the Jurassic series.

(*c*) In the study, of the Triassic and Jurassic sections both north and south of Thistle Junction, a point about 15 to 20 miles to the northeast of Salt Creek Canyon, a cross-bedded sandstone, generally considered to be the Nugget formation, overlies the true Ankareh. Above this sandstone, probably disconformably, is a marine limestone, which is commonly referred to the Twin Creek horizon. But in the exposure on the east wall of the North Fork of Salt Creek Canyon, both of these formations are absent, and it is unlikely that an episode of erosion following the Twin Creek stage of deposition could have occurred so locally as to account for the absence of these two formations when a similar erosional break a short distance northeast in the Wasatch is not found.



GEOLOGIC MAP AND SECTIONS OF THE SOUTHERN WASATCH MOUNTAINS, UTAH
BY A. J. EARDLEY
1934

MAP 11

(*d*) Intense brecciation is noted in the immediately overlying Ankareh shale and sandstone.

In view of this evidence there is postulated in the sharply bent return of the overturned fold a fracture that produces the inception of an overthrust. The horizontal movement along this fault has been small and is thought to die out to the north and increase to the southwest, because the overturning of the fold dies out to the north and the stratigraphic break becomes greater to the southwest.

This fault will be referred to as the "Nebo overthrust." See Figures 9 and 11, and Plate LXXII, Fig. 1.

Santaquin overthrust. — In the Dry Mountain section of the great fold of the southern Wasatch Mountains the exposed strata dip east and are not in overturned position. Slipping of the beds over one another has occurred, and is chiefly concentrated in the Ophir shale, a noncompetent bed between two very competent beds, the Tintic quartzite and the Cambrian limestones. Slipping is inconspicuous where the normal sequence of the beds is unaffected, but with the occurrence of preexisting transverse normal faults, disarrangements of the normal sequence of the strata occur and produce structures to all appearances like major overthrusts. Such a fault is found in the lower part of Santaquin Canyon. See Map 11.

Here a prefolding fault has dropped Mississippian limestones opposite the Cambrian and Algonkian series of strata. When movement of considerable magnitude was concentrated along the Ophir shale this adjacent block of limestone was sheared off, leaving the overriding massive Cambrian limestones continuous above the quartzite and the limestone blocks alike. With subsequent Basin and Range faulting on the west, this limestone block is now bounded completely by faults. The plane of slipping in the Ophir shale and the actual overthrusting of the Cambrian limestones over the Mississippian limestone in Santaquin Canyon will be referred to as the "Santaquin overthrust," and it is so labeled on Map 11.

At the north end of Dry Mountain the Santaquin overthrust is well exposed where a prospect drift, known as the "Syndicate Tunnel," runs in, just under the Cambrian limestone. A large-scale corrugated and slickensided surface indicates the direction of the movement to be N. 75° W.

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An overturned fold has been recognized by Schneider[4] in the Wasatch Mountains in Rock Canyon east of Provo. This is much like the Nebo structure, but it has been studied only in cross-section and, therefore, its north and south projection is not well known.

Overthrusts have been described in the Park City district by Calkins,[5] Loughlin,[6] and Hintze.[7] In general, these thrusts are rudely parallel to the tilted sedimentary strata, though they locally cut the beds at all angles. They appear to have been affected by folding or tilting after the thrusting. They are older than the intrusive rocks and than most of the other faults.

Blackwelder's paper[8] on the Wasatch Mountains, in which he recognizes the Willard and other overthrusts in the northern Wasatch, is well known. The fault planes there dip to the east, and would at first suggest overriding from the east. This idea has been incorporated in Flint's paper,[9] in which he attempts to apply the wedge theory of diastrophism to the Rocky Mountains. It may be a fallacious deduction because of the evidence to the contrary furnished in the central and the southern Wasatch Mountains, where the direction of thrust as manifest in the Rock Canyon and Nebo overturned folds is from west to east. From recent field work in the Beartooth-Bighorn region[10] of Wyoming and Montana, however, it has been demonstrated that the thrust in the central part of the range is toward the east, whereas in the wing sections it is toward the west. Such a reverse relationship may exist in the Wasatch Mountains. The problem must remain unsettled for the present.

Throughout the whole length of the Wasatch Mountains thrusting and overturning may be postulated as an integral part of the structure, with the possible exception of the central portion, where the Uinta arch meets the Wasatch Range. It has been found in the Nebo district that intense brecciation indicates proximity not only to faults, but also to the axis of isoclinal folds.

Crustal shortening

In order to arrive at an approximate figure of the amount of crustal shortening localized in the southern Wasatch Mountains a bed about in the center of the exposed sedimentary rock series was selected for measurement. A bed higher up in the series would yield a greater figure and one lower in the series a smaller. A reconstruction of the fold as it affected this bed was drafted to scale, and the amount of shortening was found to be approximately twelve miles. An additional mile of shortening may have occurred in the thrust, especially in the vicinity of Gardner's Canyon, where the Intercalated series rests on Jurassic shale. The total shortening in the southern Wasatch may be roughly estimated as thirteen miles.

Age of Laramide deformation in the southern Wasatch Mountains

The youngest beds affected by the disturbance in the area mapped are Upper Jurassic in age. In areas not far distant, however, younger beds have been upturned and eroded. In Lake Fork, a tributary to Soldiers' Creek near Thistle Junction, Schneider has recognized Colorado beds standing nearly vertical. In Six Mile Canyon, near Manti, Wasatch beds rest unconformably upon beveled edges of vertical Montana and Colorado strata;[11] in a more detailed discussion of the problem in the Wasatch Plateau Spieker and Reeside[12] state that "in this disturbance the rocks up to and including the Price River formation were folded by intense compression." The Price River formation is the uppermost of four formations included in the Mesaverde group. Spieker and Reeside suggest that it agrees closely in age with the Fruitland and Kirtland formations of the San Juan Basin and the Laramie formation of the Denver Basin.

The folded and truncated beds are overlain by the Wasatch conglomerate, which has been determined as Lower Eocene.[13]

The date of the Laramide revolution in the southern Wasatch Mountains may thus be limited to that period of time intervening between early Paleocene and Lower Eocene. Whether the revolution, as it affected the southern Wasatch Mountains, was recurrent throughout the greater part of Paleocene time, or whether it was confined to some definite part of the Paleocene, is not discernible from the evidence at hand.

BASIN AND RANGE CRUSTAL DEFORMATION

Nature of faulting

The block-faulting of the Basin and Range disturbance is exceptionally well exposed in the southern Wasatch Mountains. Here recent movements along the major fault planes and remnants of the downthrown blocks still unburied by alluvium have revealed with unusual clearness the detail of the fault system. The dominant structure of the region mapped is a normal fault zone running slightly east of north, with the east block raised and tilted, forming a bold escarpment 4,000 to 7,000 feet high. Figure 10 is a stereogram representing the writer's conception of the block-faulting of the area, on the assumption that no erosion took place during faulting and that the surface broken by the faults was a peneplane. Neither of these assumptions is warranted except, possibly, for purposes of illustration. A comparison of this stereogram with the geologic map (Map 11) will serve to identify the various faults. The numerous east-west normal faults are considered to be older than the block-faults of the Basin and Range disturbance, as previously stated, and are not represented on the diagram.

A small part of Long Ridge is included in the map of this report. The block-faulting of this ridge has been studied by several geologists, the most recent of whom is Eaton.[14] His conclusions coincide with those of the writer in respect to the fault on the northwest side of the Long Ridge and, therefore, this particular part of the work is not original. It will be seen by comparison of the cross-sections in Baton's paper with those in this report that the general ideas are the same, but that detailed study has added to, and somewhat altered, the conceptions as expressed in the diagrams by Eaton.

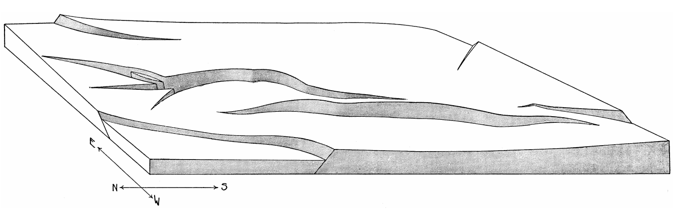

FIG. 10. Block diagram of the Basin and Range faulting in the southern Wasatch Mountains. Compare with geologic map (Map 11). The region was not peneplained before the inception of faulting, as the diagram indicates, and erosion reduced the fault scarps as faulting progressed. In these respects the drawing is not correct, but for illustrative purposes the restoration is, perhaps, justified.

Throw of fault

On the north side of the mouth of Santaquin Canyon the upper part of the Mississippian has been faulted down to the bottom of the Algonkian, making a displacement of about 5,500 feet.

On the south side of the same canyon the bottom beds of the Intercalated series have been dropped about 2,000 feet below the base of the Cambrian limestones. This displacement amounts to about 5,900 feet.

The fault which extends up Payson Canyon has a much smaller displacement than the two just mentioned. It is the southern end of the major Wasatch fault of the Utah Valley arc.15 An east-west fault of earlier date than the Payson Canyon fault, which it intersects, has placed Cambrian quartzite at the same elevation as Mississippian limestone. The later Payson Canyon fault has dropped beds of the Intercalated series opposite the Mississippian limestone on one side of the east-west fault and the Cambrian quartzite on the other side. The total displacement of the Payson Canyon fault must, therefore, not include the throw of the earlier fault, but is to be measured by the relationship of the Mississippian limestone to the beds of the Intercalated series. This measurement amounts to approximately 2,000 feet. The Payson Canyon fault is believed to decrease in throw rapidly southward, where it disappears in a volcanic breccia.

The vertical displacement of the mountain block above the valley block in the Santaquin-Nebo district, on the basis of these measurements, is thought to be throughout most of its length at least 5,000 feet and not more than 6,000 feet. The relief of Mount Nebo in excess of this figure is explained by the theory of strong relief before block-faulting.[16]

Dip of fault plane

Two parallel faults of the Basin and Range orogeny cross the mouth of North Canyon. An old prospect hole follows down along a silica gouge zone on the eastern of these two faults just north of the canyon. The footwall is the fault plane. The dip, definitely defined, is 50° W.

At the mouth of Santaquin Canyon the trace of the main fault is seen on the south wall and, if the writer's interpretation of the structure is correct, measures about 50° W.

A study of the geologic map (Map 11) will indicate that the fault planes have a considerable inclination to the west.

These data correspond with those gathered by Gilluly in the Oquirrh Mountains[17] to the northwest. He recorded an average dip of 54° for faults of Basin and Range age. He also discusses the figures of lower dips as published by Davis and Gilbert, and the higher dips as published by Pack. It will not be necessary, therefore, to review this argument. Suffice it to say that the writer's observations in the southern Wasatch concur with those of Gilluly's in the Oquirrh Range, which fact adds additional weight to the conclusion that the major faults of the Basin and Range orogeny in the vicinity of the Wasatch Mountains dip about 50°-55°.

Laramide structural control

The stereogram, Figure 11, shows the relation of the axial plane of the large Laramide anticlinal fold to the normal fault system of the later Basin and Range deformation. It will be noted that the main line of faulting closely follows the trace of the axial plane of the fold. It is thought that the axial plane of the fold represents the zone of greatest fracturing of the rocks deformed during the Laramide revolution and, therefore, the locus of the subsequent normal faulting of the southern Wasatch Mountains.

Age of Basin and Range faulting

Since its initiation the block-faulting of the southern Wasatch Mountains has continued intermittently to the present. There have been movements along the fault planes which have left very fresh escarpments in the valley alluvium, and hence must not far antedate the arrival of the early settlers in the valley.

The time of commencement of the faulting postdated the Wasatch conglomerate (Lower Eocene) and also the extrusive igneous rocks which overlie the Wasatch conglomerate, because the faults cut them both. There are no younger sedimentary rocks in the region, and hence no accurate conclusion regarding the age of the faulting can be reached on the basis of stratigraphy. There is, however, a certain amount of physiographical evidence which can be brought to bear on the subject. It will be presented later.

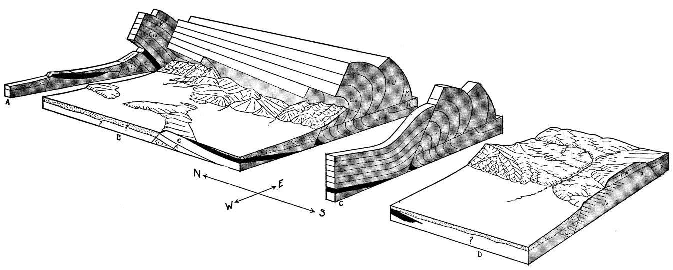

FIG. 11. Block diagram of the southern Wasatch Mountains representing the Laramide and Basin and Range structures combined with partial restoration of the strata. Block *A* shows section through Dry Mountain; Block *B*, the development of the nearly symmetrical fold at Dry Mountain to the overturned fold at Mount Nebo; Block *C*, complete restoration of strata as effected by both orogenies; Block *D*, the Salt Creek Canyon area as it is today. The four blocks should be imagined as pushed together for a composite picture.

PHYSIOGRAPHY

Since the Laramide Rockies were formed in the region of the southern Wasatch Mountains four distinct, if only partial, cycles of erosion have occurred. The evidence for this conclusion comes from a study of two buried surfaces now exposed by deep dissection, and of the existing surface, which reveals an interruption of a third cycle and an inauguration of a fourth.

PRE-WASATCH CONGLOMERATE TOPOGRAPHY

The rise of the Laramide Mountains resulted in the dissection and then partial burial of a surface having a relief of at least 10,500 feet. This figure is ascertained by the study of the surface upon which the Wasatch conglomerate of Lower Eocene age rests. Figure 12 is a cross-section of Mount Nebo, showing the present remnants of the conglomerate and the surface upon which they lie. If to the relief of this latter surface the amount of erosion it suffered previous to the deposition of the conglomerate may be added, the total height of the Laramide Mountains in this vicinity may be approximately determined.

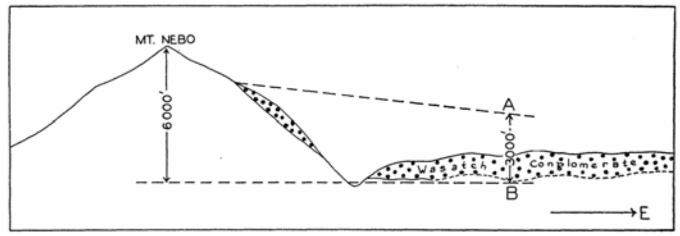

FIG. 12. Section through Mount Nebo, showing pre-Wasatch conglomerate surface

The relief represented between the base of the conglomerate and the top of Mount Nebo is 5,600 feet. It is estimated that the thickness of the conglomerate is about equal to the reduction by erosion which the land area suffered in supplying the conglomerate material. Mount Nebo was part of the area eroded.[18] The original thickness of the conglomerate may be conservatively estimated to be 3,000 feet. See Figure 12, A-B.

To this must be added the amount of erosion that Mount Nebo has suffered since the Wasatch conglomerate itself has been undergoing erosion, which process dates back to early Eocene time. This may be crudely estimated as 2,000 feet by assuming that one foot of rock is removed each 10,000 years and that the Eocene is 20,000,000 years old.[19]

If the three figures, 5,600, 3,000, and 2,000, be added together, the total relief at the close of the Laramide revolution just prior to the deposition of the Wasatch conglomerate may be obtained; it is found to be, roughly, 10,500 feet.

PRE-VOLCANIC TOPOGRAPHY

The Wasatch conglomerate, after being deposited at the base of the mountains created during the Laramide revolution, was itself attacked by erosion which, by Miocene (?) time, had left a topography with considerable relief. This surface was partly preserved under a cover of volcanic ejectamenta.

In order to measure the relief just prior to the volcanism the same method will be used as in the preceding paragraphs on the pre-Wasatch conglomerate topography. Mount Nebo rises about 6,000 feet above the lower limit of the volcanic deposits. To this figure must be added the amount of reduction in elevation that Mount Nebo has suffered by erosion since the Miocene (?). This must necessarily be less than the estimate of 2,000 feet of erosion since Eocene time, and by the same method of calculation must be about 1,000 feet. By adding, then, the present relief of the old surface, 6,000 feet, and the amount reduced by erosion since, 1,000 feet, a total relief of about 7,000 feet must have existed just prior to the middle or late Tertiary volcanic activity.

Post-volcanic erosion resulted in the reëxcavation of the major drainage channels that existed before the volcanism. Remnants of the pyroclastics may be seen along the present valley walls of Salt Creek Canyon[20] and its North Fork, which were filled in by torrential streams disposing of an excess load imposed by the eruption of large amounts of fragmental material. This cycle of erosion continued, it is thought, without interruption until the block-faulting of the Basin and Range orogeny began.

PRE-BASIN AND RANGE FAULTING TOPOGRAPHY

By this time the mountains had been materially subdued, so that a submature surface with relief of about 3,500 feet existed. The evidence bearing upon this problem has been treated in a separate publication[21] and, therefore, will not be repeated here. However, the physiography of Salt Creek Canyon deserves special mention.

A reference to photographs, Plate LXXI, will reveal the fact that the present Salt Creek Canyon is but a recent and narrow incision into the floor of a much wider and older valley. The latter is four miles wide and, although remnants of a flood plain are lacking, probably displayed characteristics of maturity.[22] This older valley is by far the largest of any transecting the Wasatch Mountains. It is postulated, like the others, to have existed before the block-faulting began and to have drained a large area to the east of the range. The great size of the valley suggests the possibility that it was the course of a master stream draining a considerable area to the east and carrying the waters to the present Great Basin region, through which they might have flowed even to the Pacific. In order that this point may receive convincing support the study must be made regional, which has not yet been done.

Block-faulting transverse to the course of Salt Creek interrupted the cycle of erosion by tilting the Wasatch Mountain block eastward and dropping the valley block, thereby rejuvenating the stream. Incision was greatest at the fault scarp and died out gradually upstream. See Figure 11 and Plate LXXI, Figures 1-2.

A very recent episode of faulting is responsible for fresh scarps in the alluvium from Wash Canyon to Nephi. They occur at the junction of the steep mountain front with the piedmont. The displacement of these recent slippings is not more than 100 feet. Plate LXXII shows two photographs of that portion of the recent fault scarp of which Davis speaks:[23] "An excellent example of repeated faulting is seen in a fan about three miles northeast of Nephi. The earlier fault has a displacement of about 100 feet [corrected by the writer to 65 feet]; then a valley several hundred feet wide was opened in the uplifted part of the fan; after this a smaller displacement of about 20 feet [corrected to 30 feet] occurred, making a very light colored band along the base of the earlier scarp and continuing for a mile or more southward through the piedmont waste slope."

AGE OF BASIN AND RANGE FAULTING

The time of the initiating of the block-faulting of the eastern part of the Great Basin has been variously determined as middle Miocene;[24] close of the Miocene;[25] close of the Miocene or possibly "well into the Pliocene";[26] post-Eocene, and also later than the pyroclastic and lava rocks which in the High Plateaus of Utah overlie the Eocene sediments;[27] middle and late Tertiary;[28] and late Tertiary.[29]

In harmony with Westgate's determination in the Pioche district (last reference) the following conclusions regarding the age of the faulting in the western part of the Great Basin may be cited; Ferguson believes that the block-faulting in western Nevada is late Tertiary and Pleistocene;[30] Louderback concludes, from stratigraphic and physiographic evidence in eastern California, that the faulting began in "late Pliocene or post-Pliocene time. The greater part of the deformation was completed before the late Pleistocene, and while movements have taken place at intervals up to within a few years, the Recent displacements are only a small fraction of the total."[31]

The faulting may not have begun at all points in the Great Basin at the same time and, therefore, it is probably not safe to rely entirely on the preceding type of diastrophic correlation. The conclusions reached by this method may be strengthened, however, by a comparison of Pleistocene erosion of a number of different ranges in the Rocky Mountains with that of the Wasatch. If no greater denudation or gorge cutting has occurred in the Wasatch than in other ranges under somewhat comparable conditions where the present erosion cycle is known to date only from late Tertiary or early Pleistocene time, then the faulting of the Wasatch, which inaugurated the present cycle of erosion there, must have begun also at this late geologic time.

In the case of the Sierra Nevada, where Blackwelder has recognized a fourth stage of glaciation, which he thinks may represent the Nebraskan stage of the Mississippi Valley, erosion has occurred to such an extent that the drift of this earliest epoch is now found only on high divides and isolated mountains. He concludes that it must antedate the present eastern front of the range with its deep canyons.[32] These canyons are even greater in size than the post-faulting gorges of the Wasatch, such as Provo Canyon, American Fork Canyon, Ogden Canyon, and Spanish Fork Canyon and, inasmuch as faulting in the Wasatch has provided steep gradients conducive of rapid erosion, it appears probable that the canyons in the Wasatch are as young as those of the Sierra Nevada.

The San Juan Mountains of southwestern Colorado provide another good example with which to compare the post-faulting erosion of the Wasatch. Atwood and

Mather[33] have ably demonstrated that there have been two main cycles of erosion in this range since the beginning of Pleistocene time. The earlier of these progressed in general to the condition of late maturity when the first of the three glacial stages occurred, namely, the Cerro, which the authors have tentatively correlated with the Illinoian, but which Blackwelder,[34] Leverett,[35] and McClintock[36] believe to be of Kansan age. The depth of these mature valleys ranged from 600 to 2,500 feet. Domal uplift then occurred, causing in some places the youthful incision of canyons into the bottoms of the mature valleys to a depth of 1,500 feet. It is evident, therefore, that Pleistocene erosion in the San Juan Mountains (ca. 4,000 feet) has been commensurate with or even greater than that of the Wasatch Mountains (ca. 3,000 feet), since the Basin and Range block-faulting inaugurated the gorge cycle of erosion.

The Grand Canyon of the Yellowstone has been eroded, partly filled, and reëxcavated to a depth of 1,100 feet since the deposition of an early (?) Pleistocene drift on the plateau surface.[37]

There are other ranges in the Rocky Mountains where an old glacial drift has been observed, but where erosion has not been so vigorous as in the three instances cited above. It is believed that uplift with consequent rejuvenation has been less intense in these cases than in the Sierra Nevada, San Juan, and Wasatch Mountains and that, therefore, a comparison with them would not be justified. On the basis, then, of a correlation of magnitude of erosion in the Sierra Nevada, San Juan Mountains, and Yellowstone Plateau the writer concludes that time has been ample for the erosion of the large cross-canyons of the Wasatch during Pleistocene time. If this is true, then the block-faulting which initiated the gorge cycle of erosion must date from the close of Tertiary time or the beginning of Pleistocene time.

A comparison of the geologic history of the Wasatch region with that of southeastern Idaho shows a close accord of events up to and including the deposition of the Pliocene Salt Lake formation.[38] Block-faulting of the Basin and Range orogeny divides the sequence .of events at this point, since it occurred in the Wasatch Mountains but not in southeastern Idaho. This fact lends support to the theory that the time of initiation of the block-faulting was late Tertiary, post-dating the deposition of the Salt Lake formation in Pliocene time.

It is noteworthy that the greater part of the faulting occurred before the Iowan (?) stage of glaciation.

Atwood[39] and Gilbert[40] both observe the association of the terminal moraines of Little Cottonwood Canyon, Bell Canyon, South Dry Creek Canyon, Bear Creek Canyon, and Alpine Canyon with the sediments of Lake Bonneville. These moraines are thought to belong to the "earlier glaciation" of Atwood and have been determined as Iowan (?) by Blackwelder.[41] They post-date any considerable fault displacement, and, therefore, it may be concluded that the greater part of the faulting occurred before Iowan (?) time.

In spite of the lack of stratigraphic evidence later than Lower Eocene time in the Wasatch Mountains, it may be concluded with a fair degree of assurance that the block-faulting of the Basin and Range orogeny commenced either at the close of the Tertiary or the beginning of the Pleistocene and continued intermittently until the present, with most of the displacement occurring before the Iowan (?) stage of glaciation.

GLACIATION

The only evidence of glaciation that the writer has observed in the southern Wasatch Mountains is in the form of cirques on either side of the high peaks of Mount Nebo. Those on the west slopes are particularly well developed, but at present are partly filled with much talus material. It is assumed that the ice did not extend far below the mouth of the cirques, since no morainal material was noticed. The glaciation was much more intense farther north in the central Wasatch and in the Uintas.

It is thought that no previous glaciations, such as are recognized in the Sierra Nevada, occurred, either because the Wasatch Mountains did not reach sufficient height as a result of block-faulting until the Iowan (?) stage of the Pleistocene or because the snow fields were too limited.

TABLE I

OUTLINE OF THE GEOLOGIC HISTORY OF THE SOUTHERN WASATCH MOUNTAINS

ERA	PERIOD	EPOCH	STAGE	GEOLOGIC EVENT
Cenozoic	Quaternary	Recent		Inhabitation of region by early settlers Faulting of alluvial fans built across block-faults Amelioration of climate with increasing aridity. Shrinkage of Lake Bonneville to Great Salt Lake
		Pleistocene	Wisconsin	Lake Bonneville. Maximum size at maximum extent of glaciation. Rose to overflowing of basin rim. Cut down outlet rapidly and fell 300 feet Glaciation. Mountains had become high enough to catch increased precipitation of Wisconsin Stage and were glaciated for the first (?) time. An older glaciation (Iowan ?) is recognized in the central Wasatch Mountains
			Iowan Illinoian Kansan Nebraskan	Outlet of drainage to Pacific cut off Silting up of down-faulted areas and back valleys Erosion of gorges 3,000 feet deep through uptilted mountain block Formation of fresh-water lakes in down-faulted areas Continuation of block-faulting. Most of 6,000 feet displacement completed before Wisconsin Stage (before Iowan (?) Stage in central Wasatch)
	Tertiary	Pliocene ?		Crustal disturbance. Initiation of block-faulting of Basin and Range orogeny Erosion, leaving surface with relief of 3,500 feet. Drainage now from east to west
		Miocene ?		Mineralization. Emplacement of lead-zinc ore deposits Vulcanism. Sill and dike intrusions and extrusion of andesite breccia and pyroclastics Erosion, leaving surface with relief of 7,000 feet
		?		Hiatus ?
		?		Erosion. Disappearance of Lower Eocene lake and erosion of conglomerate and highlands
		Lower Eocene		Sedimentation. Torrential streams from highlands deposit 3,000 ± feet of coarse conglomerate (Wasatch conglomerate) at base; finer material to east
Mesozoic	Cretaceous	Post-Price River and pre-Wasatch		Erosion, leaving relief of 10,000 feet or more. Highlands to west, fresh-water lake to east Crustal disturbance. Great compressional orogeny (Laramide revolution) Formation of overturned fold and thrust fault. Thirteen miles of shortening
		Montana		Sedimentation. Shore line shifted eastward, with deposition of fresh-water sediments over marine Colorado
		Colorado		Sedimentation. Coarse influx of boulders, pebbles, and sand from west into sea of Colorado age Crustal disturbance. Normal east-west faulting Crustal disturbance. Uplift of land to the west, probably beginning of Laramide revolution
		L. Cretaceous		Hiatus. Lower Cretaceous time not represented
Mesozoic	Jurassic			Sedimentation. Thick marine series of buff shale and thin-bedded limestone and sandstone. Upper Jurassic fossils Crustal disturbance. Vertical movements and erosion occurred during all or part of Lower Jurassic time
	Triassic			Sedimentation. 1,400 feet of deep red, arkosic sandstone, possibly fresh-water (Ankareh) Crustal disturbance. Epeirogenic warpings and erosion Sedimentation. 1,000 feet of marine, buff, fine-grained sandstone and arkose (Thaynes) Sedimentation. 500 feet of limestone and red shale (Woodside ?)
	?			Hiatus. No Permian fossils found and no apparent unconformity
Paleozoic	Pennsylvanian			Sedimentation in slowly subsiding geosyncline of 10,000 ± feet of interbedded sandstones and limestones. Pottsville and post-Pottsville fossils (Intercalated series) Submergence
	Mississippian			Erosion. Black shale and Brazer limestone removed locally Crustal disturbance. Epeirogenic warpings Sedimentation. Black shale Sedimentation. Limestone with Brazer fossils Sedimentation. Limestone and dolomite with Madison fossils Sedimentation. Thin wind-blown sandstone. Near shore deposit Submergence of older limestones
	?			Crustal disturbance. Very gentle crustal movement resulting in hiatus Sedimentation. Undifferentiated limestones; no fossils found. There are probably hiatuses
	Cambrian			Sedimentation. Ribbon and oölitic limestone and dolomite Sedimentation. Shale and thin-bedded sandstone with lower Middle Cambrian fossils. (Ophir shale) Sedimentation. Sandstone, later turned to quartzite (Tintic quartzite) Submergence of Algonkian erosion surface
Algonkian				Erosion of Algonkian beds. Reduced to thickness of 500 feet Crustal disturbance. Folding Sedimentation. 10,000 feet of red sandstone and variegated shale of fresh-water (?) origin. Red sandstone later changed to quartzite Submergence of Archean erosion surface
Archean				Truncation by erosion of schist, gneiss, granite, and pegmatite Crustal disturbance. Profound orogeny Intrusion of granite and pegmatite into schist and gneiss Metamorphism of granite (?) and shale (?) into gneiss and schist Intrusion (?) of granite ? Sedimentation (?) of shale ?

OUTLINE OF GEOLOGIC HISTORY

The outline on pages 398 and 399 of the geologic history is confined to the events as they occurred in the southern Wasatch Mountains. For certain age determinations the writer has sought evidence outside the immediate region in consideration. The outline is to be read from bottom to top.

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[3] In order to avoid the question of "overthrusting" or "underthrusting" some authors have used the term "thrust fault" or simply "thrust." In general the term "overthrust" has been used in the Rocky Mountains, and for this reason it is retained here. For the same reason, where direction of thrust is stated, it always has reference to the overriding block. The writer desires to remain noncommittal on the subject of overthrusting vs. underthrusting in this article.

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[15] Gilbert, G. K., *Studies of Basin-Range Structure, U. S. Geol. Surv., Prof. Paper 153*, p. 20, Fig. 12. 1928.

[16] Eardley, A. J., "Strong Relief before Block-Faulting in the Vicinity of the Wasatch Mountains," *Journ. Geol*., 41: 243-267. 1933.

[17] Gilluly, James, "Basin Range Faulting along the Oquirrh Range, Utah," *Bull. Geol. Soc. Am*., 39: 1123-1124. 1928.

[18] Eardley, as cited in note 13, p. 406, Fig. 14.

[19] Pirsson, L. V., and Schuchert, C., *A Text-Book of Geology*, Part II, Second edition, p. 105. 1924; Fenner, C. N., "The Analytical Determination of Uranium, Thorium, and Lead as a Basis for Age Calculations," *Am. Journ. Sci*., Fifth Ser., 16 : 369-381. 1928.

[20] Eardley, *op. cit*., pp. 339-342.

[21] Eardley, as cited in note 15.

[22] The Salt Creek conglomerate was deposited as a veneer on a pediment developed from the High South Ridge out to the valley floor.

[23] Davis, W. M., "The Wasatch, Canyon, and House Ranges," *Harvard Coll. Mus. Comp. Zoöl*, Bull. 49: 3. 1905.

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[34] Blackwelder, as cited in note 32, p. 918.

[35] Oral communication.

[36] Oral communication.

[37] Holmes, W. H., "Glacial Phenomena in the Yellowstone Park," *Am. Naturalist*, 15 : 203-208. 1881; Jones, O. T., and Field, R. M., "The Resurrection of the Grand Canyon of the Yellowstone," *Am. Journ. Sci*., 27: 260-278. 1929.

[38] Marsell, R. E., Geology of the Jordan Narrows Region, Traverse Mountains, Utah (*in manuscript*).

[39] Atwood, W. W., *Glaciation of the Uinta and Wasatch Mountains, U. S. Geol. Surv., Prof. Paper 61*, pp. 78-83. 1909.

[40] Gilbert, G. K., *Lake Bonneville, U. S. Geol. Surv., Monograph 1*, pp. 306-315. 1890.

[41] Blackwelder, Eliot, "Correlation of Glacial Epochs in Western United States," *Bull. Geol. Soc. Am*., 41: 91-92. 1930. *Idem*, as cited in note 32, p. 918.

PLATE LXXI

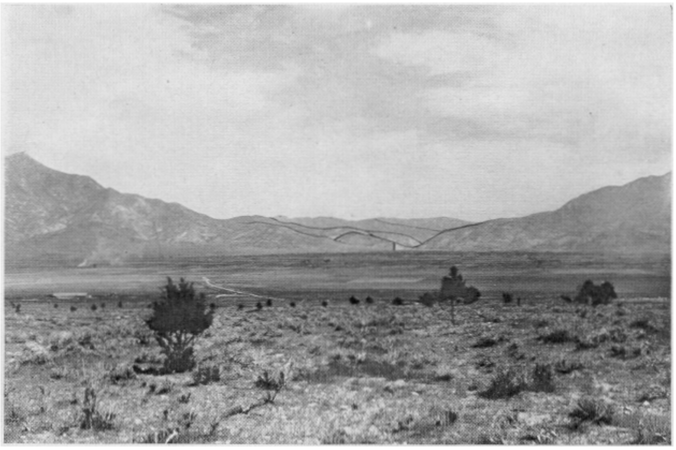


FIG. 1. Photograph of Salt Creek Canyon, looking east. The mountains rise abruptly from the alluvial flats of the valley along the Wasatch fault. The dark lines indicate the sharp incision of the present Salt Creek Canyon into an older and much broader valley. The High South Ridge is on the left and the Gunnison Plateau is on the right

FIG. 2. Photograph of upper Salt Creek Canyon, looking east; taken at the junction with the North Fork. The entrenchment of the stream here is is not so great as at the mouth of the canyon, as shown in Figure 1, and gradually dies out upstream

PLATE LXXII

FIG. 1. Mount Nebo from the east. The strata forming the upper part of the mountain are all overturned. The line of dashes indicates the approximate trace of the Nebo overthrust

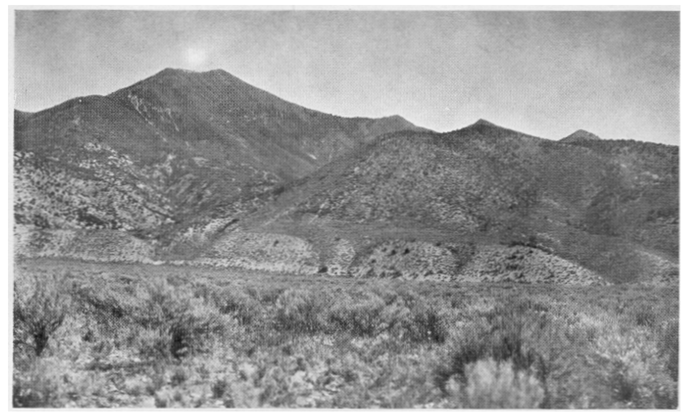


FIG. 2. Scarp formed by two recent movements on the Wasatch fault plane at the mouth of Gardner's Canyon. The scarp is about one hundred feet high. The High South Ridge is in the background

PLEISTOCENE POTHOLES IN THE CLOCHE MOUNTAINS OF ONTARIO

GEORGE M. STANLEY

INTRODUCTION

THE presence of some gigantic potholes near the north shore of Lake Huron was made known to the writer by Professor William Sargent, of Detroit. Since these potholes were in close proximity to shore formations being studied by the writer's party at the time, late in August, 1932, and since they were unusual in both their great size and topographic position, two days were devoted to making a detailed survey of them.

The location of the potholes is shown in Maps 12-13, and it may be more accurately described as follows. Along the eastern extent of the Cloche Mountains, which border the North Channel and face Great Cloche Island, and due north of tiny Carpmichael Island there is an unusual accumulation of terraced shore deposits, quite conspicuous from the water, as is also "the Sugarloaf," a rocky knob rising a hundred feet or so above them. It is in this vicinity, only a few hundred feet north of the Sugarloaf, that the 56 potholes were found. A total of 49 are described, of which 17 are fractional, i.e. with a portion of the circle absent.

DESCRIPTIONS OF POTHOLES

The surveying (by hand level) to the adjacent beach formations rendered it convenient to ascertain the elevations of the various potholes above the lake. All were floored with loose debris, mostly of a fine sort, and floor elevations were taken to the surface of this debris. The rock bottoms of most potholes lie at unknown depths below the so-called floor, and in only one was excavation attempted.

The main group of potholes, numbering 25 and including the most magnificent, is on the south slope of the quartzite knoll (encircled in Pl. LXXIII, Figs. 1-2) just north of the Sugarloaf. To the east a few hundred feet two adjacent quartzite outcrops have 8 and 12 potholes each. These are surrounded by surface deposits which perhaps conceal other potholes. A few more are to be found, however, on occasional outcrops still farther east and beyond the trail.

Pothole *A* is the most striking of all, though it is not the largest. It is about 12 feet in diameter and almost circular. Its walls rise above the floor of alluvium to a height of about 7 feet; they show distinctly the rounding effect of the water action, with traces of undercutting, resulting in an increased diameter below the top. The floor is covered with low shrubbery, and two jack pines 5 and 8 inches in diameter are growing in it. Pothole *A* is one of the highest of the group; its floor has an elevation of 342.5 feet. Formerly, when water cascaded over the hillside, this hole was at the head of a series by which the water passed. The minimum elevation of its wall on the upstream side, its threshold, is 348.8 feet. The most distinguishing feature of pothole *A* is its outlet trough or spout (see Pl. LXXIV, Fig. 1; Pl. LXXV, Fig. 1); there is no previous record of such a spout in the literature. At its brink this trough is slightly over a foot wide and 344.0 feet in elevation, and leads directly down to pothole *B*. One's first impression is that it was made by the overflow of water from pothole *A* to pothole *B*; but a little reflection leads one to consider that such a small stream as would fill this trough would scarcely have the power to carve such gigantic potholes; and that one should regard this trough as formed by a train of debris borne in the bottom of a torrent, which did not just flow through this spout, but completely submerged it. Certainly this small spout does not measure the stream of water that eroded the potholes.

The largest entire pothole is *B*, with a diameter of 15 feet. Its walls, somewhat undercut, are only from 2 to 5 feet high; its floor elevation is 335 feet. A pine 8 inches thick grows in it. As has been said before, pothole A was tributary to *B*; also tributary to *B* were potholes *X* (floor 351.5 feet) and *Y* (floor 349.0), and, in order, *T* (floor 350.4) and *S* (floor 345.6).

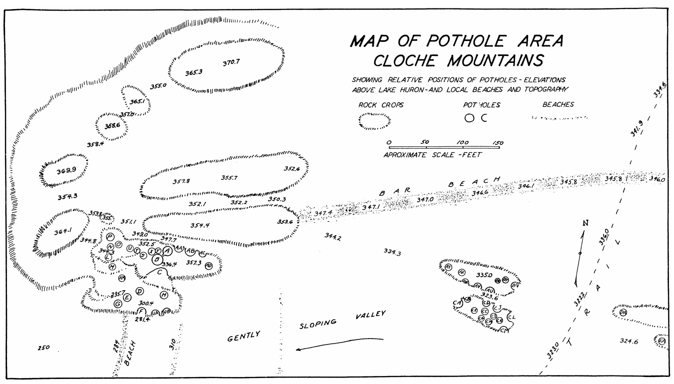
After passing pothole *B* (see Map 12), the water cascaded from a shelf of rock (336.4 feet) and plunged straight down into pothole *C* (floor 317.3), which has a wall height of 19 feet. Although this is the largest (see Pl. LXXV, Fig. 2), with a diameter of some 20 feet, it is not entire, but consists of a semicircular scallop cut into the quartzite, and is open to the south. It is not perfectly semicircular, but somewhat parabolic, the flatter edge being to the west. The walls of pothole *C* are clearly water-worn, although there has been some subsequent weathering; it is evidence of powerful erosive action.

The water from pothole *C*, merging with that from *D* (floor 309.7 feet), made a similar fall over another ledge (300.4) into pothole *F* (floor 281.4), thus dropping 19 feet or more here. Pothole *F*, only 7 feet in diameter, is open to the south and faces the Sugarloaf across a little westward-sloping valley full of shore deposits. As to the course and erosion of the water below here one cannot tell, because of concealment of the bedrock by the lake alluvium.

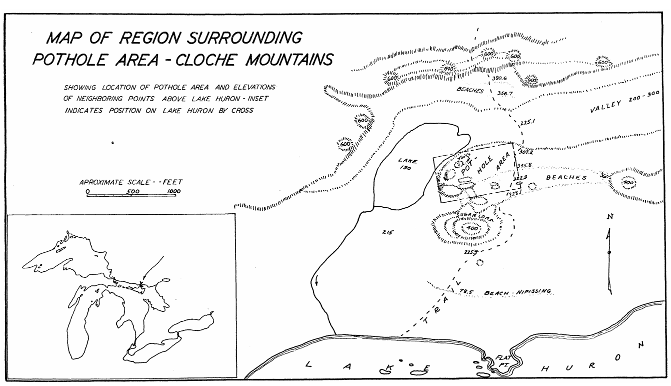
Excavation of one of the smaller potholes, *AD*, was tried. A heterogeneous mixture of sand, gravel, and stones as large as apples was removed slowly, the latter with considerable difficulty, owing to their being tightly wedged in. This pothole is 1.5 feet in diameter at the mouth, but somewhat larger below. At a depth of 2 feet excavation was abandoned; it could have been continued only with a crowbar (see Pl. LXXVI, Fig. 1). In two very small potholes, *X* and *F*, the rock bottom was visible after the removal of small clumps of humus and grass, but the majority are filled or floored with much alluvial débris, including certainly the former tools, and are somewhat grown over. Water and marsh grass were observed in one or two, for example, in pothole *AX* (see Pl. LXXVI, Fig. 2).

There seem to be three types of potholes represented here, although not always distinct from one another: (1) those formed possibly by a sheet or current of water passing over the almost horizontal surface into which they were drilled, as shown by potholes *AD* (Pl. LXXVI, Fig. 1), *AX* (Pl. LXXVI, Fig. 2), *L, M, E, G, AY, BX, BY, CK, CI, DA*, and others; (2) those fashioned by plunging of water, such as *F* and *C* (Pl. LXXV, Fig. 2), and, in some measure, *A* and *B*; (3) fractional ones cut in a vertical wall, with the energy coming probably from a stream of water passing at the side, such as *AA, AB, AC, UA, UB, BV, AU, AV, CJ*, and others. This grouping is not by way of general classification, but only for analysis of the local problem.

The surfaces of the smaller potholes are smooth and polished, apparently just as when formed. Weathering has somewhat marred the larger, pothole *C*, and to a lesser degree *A* and *F*. Adjacent to *AD* (Pl. LXXVI, Fig. 1) may be seen angular corners of the quartzite ledge, as though weathering had taken place on these surfaces since the pothole was formed. In no case could the effects of glacial abrasion be seen; indeed the hard quartzite in which the holes occur seems nowhere in the vicinity to have been striated. Whether they were ever overridden by the glacier after their formation cannot be answered by this test. Besides the potholes there are many obviously water-rounded and scoured surfaces close by, suggestive also of strong water action.



MAP 12
(See Map 13 for general location)



MAP 13. Sketch map of the pothole area of the Cloche Mountains. The rectangle north of the Sugarloaf indicates the area shown in Map 12

Detailed descriptions of all the potholes would be lengthy, and also incomplete without excavation, which would be a laborious task. The accompanying table gives the most significant data concerning them: (1) the estimated maximum diameter, although the diameter does not vary much in any of these potholes, which are generally fairly round; (2) the greatest height of the wall above the floor of debris which fills a pothole, or above the rock bottom noted in a few instances, although such height varies considerably for some potholes and in fractional ones, not entirely circular, becomes 0 on one side; (3) the elevation of the floor above Lake Huron; (4) the elevation, where determined, of the threshold or top of wall, over which water had to flow to enter the potholes. The letters represent potholes as indicated on the sketch map (Map 12). Elevations given to decimals are determinations by hand level and rod; those without decimals are by aneroid. The elevation of one of the peaks to the north was measured (640 feet); the others were estimated.

TABLE I

TABLE OF POTHOLES

Elevations to decimals, by hand level; others by aneroid

Pothole	Diameter in feet	Observed depth or height of wall in feet	Floor elevations above Lake Huron (not rock bottom) in feet	Threshold on top of wall
A	12	7	342.5	348.8 (outlet spout 344.0
B	15	5	335	344.0
C*	10	19	317.3	336.4
D	4	4	309.7	313.0
E	4	3	303.2	306.0
F*	7	19	281.4	300.4
G	3	3.5	292.1	295.7
H	5	3	314.9	.....
X	1.5	1	351.5	352.5
Y	1.5	1	349.0	.....
U	3	....	351.9	.....
T	4	2	350.4	.....
S	6	4.5	345.6	350.1
P	4	1	350 ±	.....
N	1.5	1.5	347.4	.....
O	1.5	1.5	347.0	.....
L	3	3	341.2	344.3
M	3	2	337.5	.....
AM	4	3	327.9	330.9
AA*	6	....	347.2	.....
AB*	10	....	344.3	.....
AC*	3	....	342.0	.....
AD	1.3	2	329.4	331.4
UA*	12	12	315	.....
UB*	8	6	312	.....
AY	2	1.5	328.9	.....
AX	4	3	331.9	.....
AW*	....	....	331.3	.....
AV*	10	....	326.9	.....
AU*	10	5	324.1	.....
BV*	6	1	331.0	.....
BX	1.5	1	327.8	.....
BY	1.5	1	327.8	.....
CA*	6	3	321.7	.....
CB*	3	2	323.4	.....
CC	5	3	325.3	.....
CD*	6	4	325.2	.....
CE	1	1	324.8	.....
CG	1.5	1	325.1	.....
CH	3	1.3	325.3	.....
CI	1.5	1	324.9	.....
CJ*	8	5	323.0	.....
CK	2.5	....	323.7	.....
CL*	6	2.5	321.6	.....
CM*	16	....	320 ±	.....
DA	1.5	1	324.0	.....
EA	2	1	321.7	.....
FA†	1.5	1	322.8	.....
GA†	1	1	335 ±	.....

* Fractional pothole.
† Not shown on map.

TOPOGRAPHIC RELATIONS AND COURSE OF THE MELT WATER

It is probably more than a coincidence that near these potholes is found the largest accumulation of glacial debris along this face of the Cloche Mountains, namely, the terraced lake deposits adjoining the Sugarloaf. A great bar terrace at about 345-350 feet ties the Sugarloaf to more easterly hills, and beaches have been formed in this at lower levels. The present beach at Flat Point is a great alluvial flat. The Cloche Mountains form a barrier along the shore here, and some 400 to 700 feet above it, with a broad lowland to the north occupied by the Spanish River and numerous lakes. About one mile to the northeast of the Sugarloaf, however, there is a cleft in this barrier, a valley about 200 to 300 feet in elevation above Lake Huron. This valley may have offered a convenient passage southward for glacial or subglacial melt water. The drift accumulation in the shore deposits was perhaps brought by the same glacial stream which sculptured the potholes. A stream coming through this valley today would empty directly into the little lake which lies northwest of the Sugarloaf at an elevation of 190 feet (aneroid), and thence by its outlet to Lake Huron, as may be seen from Map 13. But the potholes are 90-160 feet above this inland lake (281-351 feet above Lake Huron).

It seemed at first that if the lake basin and valley northwest of the Sugarloaf had been filled with ice, stagnant perhaps, a lake might be impounded by this ice and by the beach bar at 345.8-347.0 feet, so as to have its outlet threshold over the hill near the groups of potholes at and around *A*. But a close examination, with determination of the elevations in Map 12, showed that this was impossible; the bar beach is scarcely high enough; nor would the potholes to the south of this beach be accounted for, i.e. *BX, AX, CC, DA, EA,FA, GA,* and others. (Potholes *FA* and *GA* are not shown on the map, but are a few hundred feet east of *DA* and *EA*.)

The potholes must have been formed when the ice which covered the region directed a rapidly moving stream to the brow of the hill near pothole *A*, around which hill the ground is lower in all directions.

One course of the water down the hillside is detailed on pages 402-403. A similar course existed some 50 feet to the west, going successively to potholes *P*, *N* (floor 347.4 feet), *O* (floor 347.0), *L* (floor 341.2), *M* (floor 337.5), *AM* (floor 327.9), *E* (floor 303.2), and *O* (floor 292.1). (See Map 12.) Moreover, it is evident from the local topography and the relations of the rims or thresholds of the potholes to the adjacent rock slopes (the rims are frequently higher than the slopes on either side) that there were not just these two distinct cascades, but that the whole intervening area was covered by a moving cataract, and that a column of water some 10 feet deep moved through the passageway (threshold 344.8 feet) west of *P* and down to the southwest; that another moved southeastward down the little channel (threshold 347.7) north of *A*, eroding on its way potholes *AA, AB*, and *AC*. Scouring action all over the hillside is conspicuous. One must here picture a great stream running underneath the ice. It may have fallen much of its time through a crevasse directly upon the area between potholes *A* and *P*, spreading out laterally and running off southward down the rock basement, or it may have approached the same area with a more horizontal motion from the northeast. From the general appearance of the bed of this torrent down the hill, as compared with the sites of numerous waterfalls seen in streams entering the upper lakes, the writer would estimate a normal discharge here to be perhaps 10,000 cubic feet per second, probably as large as any stream today entering the Great Lakes, except their connecting rivers.

The general course of the water near potholes *A, P, C,* etc., seems to have been as a cascade over the hill from north to south. In considering the potholes on the quartzite outcrops just west of the trail, one would prefer to imagine the active stream as moving more nearly horizontal over the surface. A like condition would seem to explain those potholes to the east of the trail, *EA, FA*, and *GA*. A stream active on the groups just west and east of the trail would certainly not at the same time be active on the group about pothole *A*, as may be gathered from the elevation data. The possibility that the potholes of the east-west course (*CL, BV, AX, EA, FA*, and those near by) might have been formed at the base of moulins occupying successively new positions instead of by a more horizontally moving stream should not be overlooked, but seems less likely.

Thus there appear to have been two distinct local courses of the water, whether active at one time or not. One course cascaded southward down the steep hill, where are *A* to *F*. The other led westward down the more gradual slope which runs across the trail to the south of the beach at 346 and through the valley immediately north of the Sugarloaf and past the foot of the cascade first mentioned. Here the courses join and continue west through the same valley (see Map 12 and Pl. LXXIV, Fig. 2) and toward the basin of the small lake below.

SHORE LINES AND THEIR RELATIONS TO THE POTHOLES

It is quite apparent that the erosion of the potholes took place prior to the formation of the adjoining beaches. From a glance at Map 12 it is clear that the cascade from potholes *G* and *F* and others would have destroyed the beach at 284, had it then been present; also the stream from potholes *AX, CC*, etc., would have swept away the beaches to the west. Moreover, the floors of potholes *F, UA,* and *UB* are continuous with and a part of the shore deposits of the valley floor. That the potholes were a result of shore or lake action is not to be considered; their depths, shapes, magnitudes, and vertical range all distinguish them unmistakably from potholes of this origin.

There are strong bar beaches at 346 and 328 adjacent to the pothole area and incidentally reaching about the same elevation as the highest of them. At the east end of the beach at 346, however, is a succession of short beaches up to 360; still higher, where the trail climbs the slope of the ridge north of the potholes, it crosses a strong set of rubble beaches ranging from 356.7 to 390.6 feet.

Beaches of the upper Algonquin group are strongly developed at 360 to 433 feet above lake level along the brow of the escarpment behind Little Current in the northern part of Manitoulin Island.[1] Correlatives of these must exist along the Cloche Mountains, eleven miles to the north, even though absence of the very highest of the series might be explained by the position of the ice border. If one makes allowance for northward rise, the highest Algonquin beaches should be expected in the pothole region about 480 feet above Lake Huron. Considering the terrain there, the writer was not in the least surprised at failing to find them, but they would surely be discovered by a prolonged and intensive search.

The ice border was receding northward across this area about the time of the three-outlet phase or Port Huron-Chicago stage of Lake Algonquin.[2] Regardless of the exact time of this recession in lake history, the glacial lake was then at least 40 feet (as indicated by the writer's beach at 390.6), and more probably 130 feet (as indicated by highest Algonquin), higher than the highest potholes, and some 200 feet above the lowest of the pots (*F*); it could not have been lower. If the potholes were then in process of formation, the sculpturing stream, which entered this lake, was under hydrostatic pressure where it passed over the potholes, probably by as much as 130-200 feet head of water. A precisely similar relation can be seen by analysis to hold for the great potholes observed by McKellar[3] on the north shore of Lake Superior. The writer can see no sound way of avoiding the conclusion that, if these potholes were in process of formation toward the close of the last glacial period, they were formed by streams under hydrostatic pressure.

ORIGIN OF THE POTHOLES

Discussion of giant potholes formed by glacial moulins has been presented by many writers, especially Upham.[4] He sees difficulty in the theory that the moulin remained stationary for a period long enough to erode potholes, unless at an early or late date in the glacial period, when ice motion was negligible. Manning[5] notes the view of Agassiz that, owing to reforming of crevasses in the same locality, the moulin might remain stationary though the ice advanced. The writer wishes to point out that the majority of such potholes are on the tops or high slopes of hills.[6] Upham reviews numerous instances. Would it not be natural for hills to cause the formation of crevasses?

The potholes of the Cloche Mountains do not seem to be necessarily of moulin origin. From what the writer has seen of potholes in existing streams, he would consider that no great moulins were necessary for production of the ones in question. Some of them, such as *B*, *C*, and *F*, and a few others, are of the plunge type described by Elston,[7] and involve considerable descent of the water; but this would have been natural on the hillside where they occur.

It is questionable whether potholes of the moulin or plunge type could be formed by water under hydrostatic pressure. Water freely falling would seem more natural for their production, but no definite data to decide this are available.

If the Cloche potholes were not formed under hydrostatic pressure, they must have originated at an early time in the glacial period, when, for some reason, glacial lakes did not surround the ice to great depths, as at the close of the Pleistocene. And in this case they might be considered remarkably intact.

Similar reasons have led to the belief that potholes along the coasts of Maine and Norway were formed early in the glacial period.[8] Elsewhere some have been found with glacial markings on them.[9] The exact time relations and hydraulic conditions of formation of the potholes described must remain at present a problem.

SUMMARY AND CONCLUSIONS

1. A group of 56 potholes, drilled in quartzite, from 1 to 20 feet in diameter, within an area 200 by 800 feet, on the summit and slopes of a hill, 281 to 352 feet above Lake Huron, were found north of Manitoulin Island.

2. The potholes were formed by a glacial stream previous to the making of the beaches in the region, and when ice covered the surrounding lowlands. The stream was probably responsible also for great drift accumulations in the vicinity, and was perhaps attracted here by a marked rift in the east-west Cloche Mountain barrier to the north.

3. They were formed perhaps by moulins, but not necessarily by the great tumble of water through deep crevasses, which is suggested by this word. If the ice could have supported the stream of water and directed it to the hilltop around which the potholes occur and there freed it, its part would have been sufficient.

4. The potholes either (*a*) were formed by a stream under great hydrostatic pressure or (*b*) were made previous to the recession of the last ice sheet.[10]

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[1] Writer's unpublished notes and data.

[2] Leverett, F. L., and Taylor, F. B., *U. S. Geol Surv., Mon. 53*, pp. 438-439. 1915.

[3] McKellar, Peter, "Pot Holes North of Lake Superior Unconnected with Existing Streams," *Bull. Geol Soc. Am*., 1: 568-570. 1890.

[4] Upham, Warren, "Giant Kettles Eroded by Moulin Torrents," *Bull. Geol. Soc. Am*., 12 : 25-44. 1900.

[5] Manning, P. C., "Glacial Pot Holes in Maine," *Proc. Portland Soc. Nat. Hist*., 2 : 185-200. 1901.

[6] Upham, *op. cit.;* McKellar, *op. cit.;* Manning, *op. cit.;* Barker, E. E., "Glacial Pot Holes at Crown Point, New York," *Journ. Geol.* 21: 459-464. 1913.

[7] Elston, E. D., "Pot Holes, Their Variety, Origin and Significance," *Scientific Monthly*, 5: 554-567. 1917; 6:37-51. 1918.

[8] Upham, *op. cit*.

[9] McKellar, *op. cit*.

[10] After this paper had gone to press the writer saw a few long-abandoned potholes near Whitefish Falls, Ontario, about nine miles east by north of the group described. Though much inferior in development and fewer, they appear likewise to have been produced by Pleistocene stream action, for they are far out of reach of ordinary river floods. They are about 50 feet above and 400 feet west of the Whitefish River, just below the logging chute and the bridge of the Algoma Eastern Railway.

PLATE LXXIII

FIG. 1. Looking north from the Sugarloaf. The hill on which the potholes are developed is encircled. Pothole *C*, twenty feet in diameter with a nineteen-foot wall in back, is in the smaller circle. In the distance is Cloche Mountain Ridge

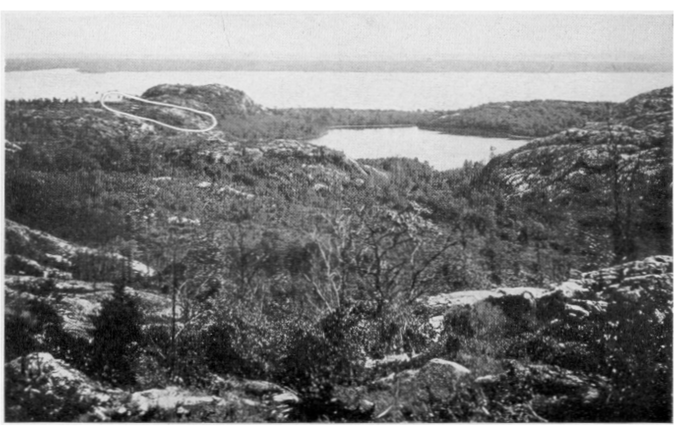

FIG. 2. Looking south from the Cloche Mountains toward the Sugarloaf and the North Channel of Lake Huron. The hill with the potholes is encircled. The Sugarloaf is beyond and higher

PLATE LXXIV

FIG. 1. Pothole *A*, twelve feet in diameter. The spout in the lower left corner is a unique feature, eroded by the train of departing debris. Undercutting may be observed on the far wall

FIG. 2. Looking northwest from the north slope of the Sugarloaf across the small valley toward the neighboring lake. In the upper right corner is the steep slope down which formerly cascaded a large volume of water

PLATE LXXV

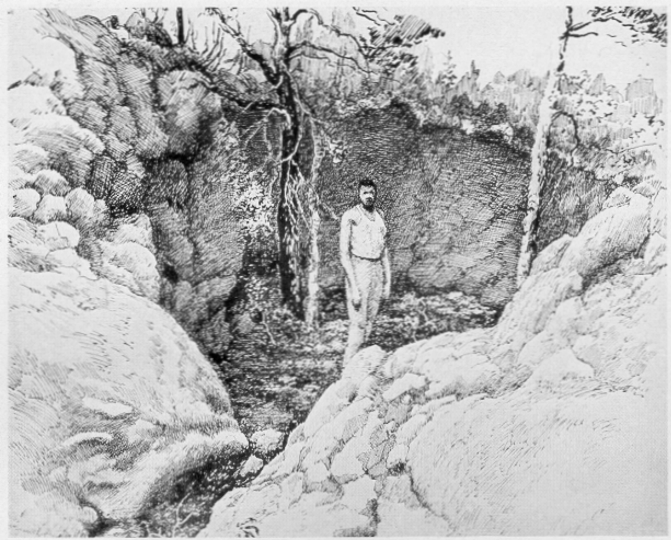

FIG. 1. Pothole *A*. See Plate LXXIV, Fig. 1

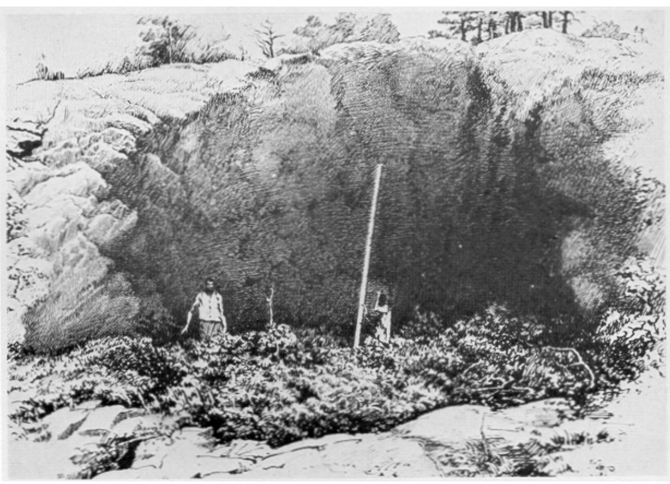

FIG. 2. Pothole *C*. This is the largest of the potholes. It is twenty feet in diameter. See Plate LXXIII, Fig. 1

PLATE LXXVI

FIG. 1. This small pot (*AD*) was excavated with great difficulty to a depth of two feet, where the bottom was not evident. The stones were tightly wedged in

FIG. 2. One of the few potholes found full of water, grass, and algae. This pot (*AX*) is four feet in diameter; the depth is not known

WELL LOGS IN THE NORTHERN PENINSULA OF MICHIGAN SHOWING THE CAMBRIAN SECTION

FREDRIK T. THWAITES

INTRODUCTION

IN 1910 the writer was assigned the problem of the age and stratigraphic relations of the Lake Superior sandstone of Wisconsin. His conclusions were published in 1912 as Bulletin 25 of the Wisconsin Geological and Natural History Survey, entitled *Sandstones of the Wisconsin Coast of Lake Superior*. It was found that the solution of this problem, namely, the upper limit of the pre-Cambrian of the Lake Superior district, does not lie in Wisconsin but in the adjacent states. To the west in Minnesota the drift cover is heavy. To the east in Michigan there is lack of areal continuity, for the ridge of Keweenawan traps intervenes between Irving's "Western Sandstone" and the sandstones east of Keweenaw Point at the bottom of the Paleozoic sequence. Lack of financial support prevented further investigation on the problem, but in the meantime work was undertaken in northeastern Wisconsin, and extensive studies were made of well logs, including several in the Northern Peninsula of Michigan. The present paper does not attempt to settle the problem of the true relation of the marine Paleozoic formations to the older red non-marine sandstones which are involved in the Keweenawan folding and faulting, but only to present some data which bear upon the correlation of the Cambrian section of northern Michigan with the better known formations in Wisconsin.

PREVIOUS INVESTIGATIONS

There is very little recent published information on the lower part of the Paleozoic section of northern Michigan, and the work of Rominger[1] is still the most detailed account. He applied the name "Lake Superior sandstone" to all the sandstones between the base of the "Calciferous" (now Beekmantown) and the underlying traps of the Middle Keweenawan. Some sandstone of later age seems to have been included under the same name. A division into an upper light-colored member and a lower red member is clearly given.[2] The following section was measured on Laughing Whitefish River near Laughing Fish Point (formerly Whitefish Point) in Alger County. The description has been changed to conform to current terminology.

	Thickness Feet
7. Sandstone, dolomitic, casts of "*Pleurotomaria*" ("Calciferous")....	—
6. Sandstone, massive, soft, white, makes cliffs....................	50
5. Sandstone, soft, thin-bedded; thin seams of blue shale...........	75–100
4. Sandstone, rather soft, thick-bedded, light gray; layers of quartz pebbles; a few feet of dark red coarse conglomerate at the top...	?
3. Sandstone, coarse, hard, red and speckled, heavily bedded, cross-bedded, layers of conglomerate, makes cliffs..................	15–20
2. Sandstone, fine, shaly, red; seams of red shale..................	12
1. Sandstone, thin-bedded, red and white, blotched and spotted......	25

Irving[3] regarded this section as proving "that in the Eastern Sandstone we have to do with the same formation, or with its downward continuation, as the fossiliferous Cambrian sandstone. . . . There appears to be but one way in which this conclusion can be avoided, and that is by supposing that where, east of Marquette, the red sandstone is overlain by the lighter-colored, there is a discordance of greater or less extent, the red sandstone having been thus separated by a relatively large time-gap from that which overlies it. This view was, indeed, held as long ago as 1841, by Houghton, who, however, so completely altered his opinion in the next few years. . . ."

In 1907 Lane and Seaman[4] proposed to name Irving's Eastern Sandstone "Jacobsville" "while the term *Munising* sandstone is to apply to the upper 250 feet of Lake Superior sandstone which crosses the bluffs back of Munising, dips southerly, and is white or light colored." These authors also quoted the early statement by Houghton and listed a few fossils which had been discovered in the upper sandstones.

The foregoing nomenclature was followed on the geological map published by the Geological Survey of Michigan in 1916.

In 1923 the writer[5] published an account of the results of his study of logs of deep wells based on samples. In 1931 he was one of the collaborators for the Geological Cross-Section of the Central United States for the Fifth Annual Field Conference of the Kansas Geological Society of Wichita, Kansas. This section was published as a blue-line print and was accompanied by a mimeographed explanation in the guide book. The route of the section is much the same as that here given, but it was drawn to sea-level datum.

In the last few years E. O. Ulrich of the United States National Museum has collected fossils from the Cambrian of northern Michigan.[6]

ACKNOWLEDGMENTS

The writer is indebted to R. B. Newcombe of the Michigan Geological Survey for unpublished information and for permission to prepare the following paper.

COMPARATIVE STRATIGRAPHIC SECTION

Although the purpose of this paper is to present data on the probable correlation of the Cambrian of Wisconsin with that of northern Michigan, it seems necessary to include a discussion of all formations below the easily recognized Trenton (Black River of Wisconsin) dolomite because there seems to have been much confusion in the several interpretations of the underlying Ordovician formations. Efforts to recognize the St. Peter and Jordan sandstones in well logs have led to ascribing widely different lines of division and therefore to deducing rapidly varying thicknesses for the underlying formations.

With the purpose of testing the validity of the several assumptions the writer has prepared the accompanying comparative stratigraphic section (Fig. 13), in which the top of the Munising sandstone is shown as a straight line. This horizon seems to be the best marked key, for it is a contact between firm dolomite, for the most part red, and underlying sandstone. Thus it can be identified even in logs not based upon sample examination by a geologist.

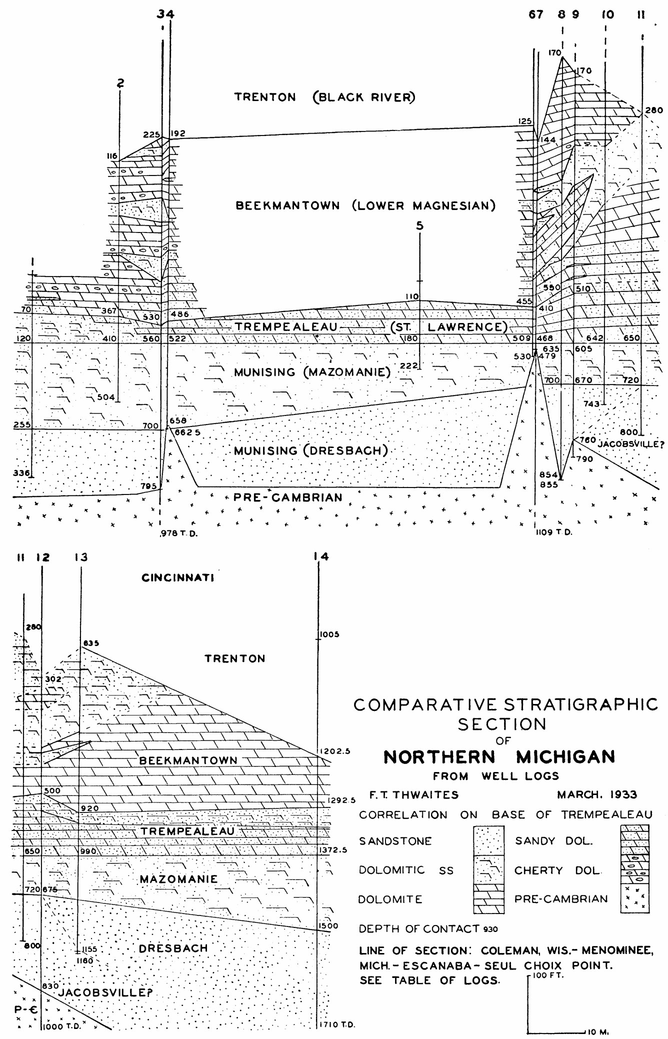

FIGURE 13

WELL LOGS USED IN PREPARATION OF FIGURE 13

No. of location	*Owner*	*Remarks* *
1 Coleman, Wisconsin	Coleman Canning Company	Samples examined by F. T. Thwaites, University of Wisconsin, Nos. 76444–76514
2 Peshtigo	Peshtigo Pulp and Paper Company	Samples examined by F. T. Thwaites, U. W., Nos. 54155–54255, 54303–54310
3 Marinette	City well, No. 2	Samples examined by R. A. Smith, Publ. 24, pp. 238–239
4 Menominee, Michigan	Menominee and Marinette Light and Traction Company	Samples examined by F. T. Thwaites, U. W., Nos. 86432–86558A
5 Powers	Delta-Menominee Sanitorium, Sec. 16, T. 38, R. 26	Samples
6 Pine Ridge	Schemmel exploration, Sec. 28, T. 39, R. 23, Nos. 1 and 2	Samples examined by R. A. Smith and L. P. Barrett, Publ. 24, pp. 216–218
7 Same	Same, No. 1 (No. 3 ?)	Diamond drill hole
8 Escanaba	Chicago and Northwestern Railroad shops, Sec. 29, T. 39, R. 22	Samples examined by R. A. Smith, Publ. 24, pp. 214–215, and by F. T. Thwaites, U. W., Nos. 50416–50452
9 Wells	Escanaba and Lake Superior Railroad, Sec. 18, T. 39, R. 22 Escanaba Oil Company, No. 1 Stephenson	Samples examined by F. T. Thwaites, U. W., Nos. 84846–84791A Samples examined by F. T. Thwaites and by W. Osgood, Publ. 37, p. 282
10 Gladstone	Minneapolis, St. Paul, and Sault Ste. Marie Railroad, Sec. 21, T. 40, R. 22	Drillers' log, possibly with a few samples, Publ. 14, p. 237
11 Rapid River	Oil test, Sec. 34, T. 42, R. 21	Drillers' log and a few samples, Publ. 14, pp. 237–238. (May have reached pre-Cambrian)
12 Masonville	Neff well, Sec. 31, T. 42, R. 20	Few samples; Publ. 14, p. 239
13 Nahma	Oil test, Bay de Noc, Sec. 20, T. 42, R. 19, No. 1	Drillers' log
14 Seul Choix Point	Schoolcraft Development Syndicate, Sec. 21, T. 41, R. 13, No. 2	Samples; recorrelated by writer

* The abbreviation "Publ." in this column refers to the publications of the Michigan Geological and Biological Survey.

TRENTON (BLACK RIVER)

In northern Michigan, where the Trenton (Black River of the Wisconsin Survey) is not underlain by St. Peter sandstone, discrimination of the base of the formation is dependent on other means. So far as the experience of the writer goes, the Trenton dolomite is free of chert. On solution in hydrochloric acid a considerable residue of shale is obtained. In many places the base of the formation contains large sand grains, greenish gray shale, much pyrite or marcasite, and a peculiar very light gray dolomite.

PARTIAL LOG OF WELL OF ESCANABA AND LAKE SUPERIOR RAILROAD, WELLS, MICHIGAN

	Thickness Feet	Depth Feet
Dolomite, light gray to gray	30	95
Dolomite, light gray, in part pyritic	20	115
Dolomite, blue and light to dark gray	30	145
Dolomite, gray, bottom pyritic	25	170
Total	105	

Note — top eroded

PARTIAL LOG OF WELL OF PESHTIGO PULP AND PAPER COMPANY, PESHTIGO, WISCONSIN

	Thickness Feet	Depth Feet
Dolomite, bluish gray	47	60
Dolomite, light gray	25	85
Dolomite, light bluish gray, part mottled blue and gray	25	110
Dolomite, blue and gray, floating sand; sandstone, fine, gray, dolomitic	6	116
Total	103	

Note — top eroded

ST. PETER SANDSTONE

To date, the writer has not been able to distinguish the St. Peter sandstone as far north as the south end of the section here given. At Menominee there is a thin sandstone at the horizon at which the St. Peter should occur, but it is far from certain that this is really the St. Peter. Where it is present in Wisconsin the St. Peter invariably lies on the underlying formations, with a marked erosional unconformity. Red non-dolomitic shale, locally bleached to a green-gray color, as well as chert conglomerate, tells positively of emergence. Despite the fact that no such strata have yet been found in Michigan the irregularity of the inferred contact of the Trenton with the underlying formation strongly suggests a marked break. The drawing of the line on the section is, however, subject to revision in the light of more refined studies of the insoluble residues.

BEEKMANTOWN (LOWER MAGNESIAN) DOLOMITE

The Beekmantown formation of Michigan is for the most part equivalent to the Lower Magnesian dolomite of Wisconsin, which is believed to embrace the Oneota and overlying Shakopee dolomites of Minnesota. It consists of dolomite which is mainly gray, but which has some red zones, and contains much chert and sand. The chert is gray and yellowish gray and occurs in three varieties: dense, oölitic, and dolocastic. The oölitic chert is a positive marker of the formation. Lenses of medium-grained dolomitic sandstone, some of them many feet thick, are abundant throughout the formation. Thin laminae of greenish gray shale are abundant. The attempts at correlation of the sandstone lenses in Figure 13 should not be regarded too seriously, and the vertical exaggeration of 528 times must also be taken into account. The thickness of the Beekmantown as here defined varies from 90 to 380 feet.

PARTIAL LOG OF WELL OF MENOMINEE AND MARINETTE LIGHT AND TRACTION CO., MENOMINEE, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, medium, gray, very dolomitic; shale, greenish gray	11	203
Dolomite, dark blue-gray, very shaly	10	213
Dolomite, gray; shale, greenish gray	12	225
Dolomite, light gray; shale, greenish gray	7	232
Dolomite, gray, floating sand near bottom	23	255
Sandstone, fine, light gray, dolomitic; shale, blue; chert, gray	5	260
Dolomite, light gray; shale, greenish gray	60	320
Dolomite, light gray, very sandy; shale, greenish gray	5	325
Dolomite, light gray, very fine sand	35	360
Dolomite, gray, pink, sandy; chert, pink and gray	10	370
Sandstone, fine, light gray, dolomitic	15	385
Dolomite, light gray, some fine white sand	50	435
Dolomite, white, thin layers	10	445
Dolomite, light gray, very fine sand	10	455
Dolomite, light gray, fine sand	31	486
Total	294	

PARTIAL LOG OF WELL OF ESCANABA AND LAKE SUPERIOR RAILROAD, WELLS, MICHIGAN

	Thickness Feet	Depth Feet
Dolomite, light gray, some dark spots passing below to dark blue and dark gray	40	210
Dolomite, light gray	35	245
Dolomite, light gray and dark brownish gray	5	250
Dolomite, light gray	20	270
Dolomite, light gray and greenish gray, pyritic	5	275
Dolomite, light gray; chert, white	10	285
Sandstone, medium, gray, very dolomitic, frosted grains	48	333
Sandstone, medium to fine, white	17	350
Dolomite, light gray, very sandy	10	360
Sandstone, medium to fine, light gray, dolomitic	5	365
Dolomite, light gray, sandy	10	375
Dolomite, light gray	51	426
Sandstone, medium to fine, light gray, very dolomitic	19	445
Dolomite, light gray	30	475
Sandstone, fine, light gray, very dolomitic	5	480
Dolomite, light gray	15	495
Dolomite, light gray, very sandy	5	500
Dolomite, gray to dark gray	10	510
Total	340	

TREMPEALEAU FORMATION

The term "Trempealeau" was proposed by Ulrich[7] to replace the name "St. Lawrence," which had been very loosely used. The former name has never been approved by the Board of Geologic Names of the United States Geological Survey. Present custom in Wisconsin is to include as Trempealeau all strata from the base of the cherty Lower Magnesian through the lowest firm dolomite layers, which are in most places underlain by a few feet of very glauconitic sandstone conglomerate. In part of northeastern Wisconsin the top of the Trempealeau as thus defined is a clean sandstone, which must be equivalent to the original "Jordan" of Minnesota. The Jordan sandstone (now regarded as a member of the Trempealeau) is believed by Ulrich and Resser[8] to be the "emergent closing stage of the Cambrian." In much of both northeastern Wisconsin and northern Michigan no sandstone can be distinguished at this horizon, and the contact is fixed only with difficulty in well logs. Heretofore strata of Trempealeau age have undoubtedly been included in the Beekmantown. The writer has fixed the upper limit of the Trempealeau at the contact between prevailingly gray, more or less cherty dolomite above and prevailingly red or pink, non-cherty sandy dolomite below. Closer determination of this horizon by use of insoluble residues is desirable. Glauconite is abundant in the lower part of the Trempealeau and may extend through it and even up into the base of the Lower Magnesian. It can be found easily by dissolving the samples in hydrochloric acid. The bottom of the Trempealeau is more easily fixed than its top, for it is marked by an abrupt lithologic change to the underlying sandstone. The thickness of the Trempealeau along the section here considered seems to vary from 30 to 130 feet. This variation may be due in part to inaccurate determination of the top, but it is quite probable that, as the sandstone at the top gives out to the southwest, there is a disconformity between the Beekmantown and the Trempealeau marking the Ordovician-Cambrian boundary.

PARTIAL LOG OF WELL OF ESCANABA AND LAKE SUPERIOR RAILROAD, WELLS, MICHIGAN

	Thickness Feet	Depth Feet
Dolomite, pink, much fine sand	20	530
Dolomite, light gray and pink	40	570
Dolomite, gray and pink, sandy, glauconitic	5	575
Dolomite, light gray, some pink, sandy, part pyritic	30	605
Total	95	

PARTIAL LOG OF WELL OF MENOMINEE AND MARINETTE LIGHT AND TRACTION CO., MENOMINEE, MICHIGAN

	Thickness Feet	Depth Feet
Dolomite, light pink, sandy, glauconitic	9	495
Dolomite, gray, dark blue spots, sandy	5	500
Dolomite, gray, very sandy, pyritic	22	522
Total	36	

PARTIAL LOG OF WELL NO. 2 OF SCHOOLCRAFT DEVELOPMENT SYNDICATE, SEUL CHOIX POINT, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, coarse, white	10	1302.5
Sandstone, coarse, white, some green grains, slightly dolomitic	5	1307.5
Sandstone, medium, white	17.5	1325
Sandstone, fine, buff and pink, dolomitic; shale, greenish gray	10	1335
Sandstone, fine, red, dolomitic; shale, greenish gray	12.5	1347.5
Dolomite, buff, sandy, shaly	20	1367.5
Dolomite, dark red to dark buff	5	1372.5
Total	80	

MAZOMANIE SANDSTONE

The strata underlying the Trempealeau formation in eastern Wisconsin are commonly termed "Mazomanie." In Michigan these strata are part of the Munising sandstone. The questions of the proper application of the term "Mazomanie" in respect to priority and the relation of the Mazomanie sandstone to the Franconia sandstone farther west need not here be entered upon. Suffice it to say that the writer has for some years used the name to cover all the dolomitic sandstone between the base of the Trempealeau and the top of the underlying clean sandstone of the Dresbach. The Mazomanie, as thus defined, is characteristically glauconitic, although that mineral is much less abundant in Michigan than it is farther south. The thickness of the Mazomanie in the section here described varies from 65 to 140 feet. It is not unlikely that certain beds ascribed by Ulrich to his "Devils Lake" formation lie within or at the top of the Mazomanie, or possibly within what is here termed Trempealeau.

PARTIAL LOG OF WELL OF MENOMINEE AND MARINETTE LIGHT AND TRACTION CO., MENOMINEE, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, medium to fine, gray, very dolomitic	23	545
Sandstone, very fine, greenish gray, very dolomitic, glauconitic	30	575
Sandstone, medium to coarse, gray, very dolomitic	38	613
Sandstone, medium to coarse, white, clean	4	617
Sandstone, medium, gray, dolomitic	33	650
Sandstone, very fine, gray, very dolomitic	5	655
Sandstone, coarse to medium, gray, dolomitic	3	658
Total to pre-Cambrian	136	

PARTIAL LOG OF WELL OF ESCANABA AND LAKE SUPERIOR RAILROAD, WELLS, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, medium to coarse, light gray, dolomitic	30	635
Sandstone, medium, light gray, dolomitic	35	670
Total	65	

PARTIAL LOG OF WELL NO. 2 OF SCHOOLCRAFT DEVELOPMENT SYNDICATE, SEUL CHOIX POINT, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, white, some dark gray grains	10	1382.5
Sandstone, white, some dark gray shale	7.5	1390
Sandstone, coarse, white, slightly dolomitic	2.5	1392.5
Sandstone, coarse, white, dolomitic; shale, dark gray	5	1397.5
Sandstone, medium, white	2.5	1400
Sandstone, coarse, white, dolomitic; shale, dark gray	12.5	1412.5
Sandstone, medium, white, slightly dolomitic	47.5	1460
Sandstone, medium, white, considerable gray dolomite	10	1470
Sandstone, medium, white, slightly dolomitic	12.5	1482.5
Sandstone, medium, white to gray, slightly dolomitic	17.5	1500
Total	127.5	

DRESBACH SANDSTONE

For some years the writer has used the term "Dresbach" to include all the strata of northeastern Wisconsin which intervene between the highest clean white sandstone and the underlying pre-Cambrian. Farther west and south it is possible to separate the top of this sequence as the Dresbach and to call the remainder "Eau Claire" and "Mt. Simon." In that region a division is possible because the Eau Claire is shaly and contains many red strata. The Mt. Simon, which lies next to the pre-Cambrian, is much coarser grained than the Eau Claire. In the region under discussion the entire interval is sandstone, and subdivision is impracticable. The questions of priority and original application of these names cannot be here considered. The thickness of the Dresbach of this section reaches a known maximum of 210 feet. This formation is locally absent in northern Michigan.

PARTIAL LOG OF WELL OF COLEMAN CANNING CO., COLEMAN, WISCONSIN

	Thickness Feet	Depth Feet
Sandstone, coarse, gray (base of Mazomanie?)	5	260
Sandstone, fine to medium, light gray	55	315
Sandstone, medium to coarse, white	5	320
Sandstone, fine to medium, light gray	16	336
Total penetrated	81	

PARTIAL LOG OF WELL OF ESCANABA AND LAKE SUPERIOR RAILROAD, WELLS, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, medium, white	75	745
Sandstone, very coarse to medium, white and pink	11	756
Conglomerate, pebbles of schist in medium, gray sandstone	4	760
Total to pre-Cambrian	90	

PARTIAL LOG OF WELL NO. 2 OF SCHOOLCRAFT DEVELOPMENT SYNDICATE, SEUL CHOIX POINT, MICHIGAN

	Thickness Feet	Depth Feet
Sandstone, coarse, white	17.5	1517.5
Sandstone, pink, dolomitic	2.5	1520
Sandstone, medium, white	5	1525
Sandstone, medium, pink, dolomitic	2.5	1527.5
Sandstone, medium, pink	32.5	1560
Sandstone, medium, cream to pink, slightly dolomitic	52.5	1612.5
Sandstone, medium, gray; shale, gray, dolomitic	12.5	1625
Sandstone, fine, gray, slightly dolomitic	85	1710
Total penetrated	210	

JACOBSVILLE SANDSTONE

The term "Jacobsville" as applied to sandstone includes all of living's "Eastern Sandstone" shown on his map as Division I of the Paleozoic formations.[9] It is predominantly a red sandstone, for the most part quite arkosic, and filled with layers both of conglomerate and of red micaceous sandy shale. Stratification is extremely irregular. It is probably equivalent in age to the upper part of Irving's "Western Sandstone" of Wisconsin, a group which the writer termed "Bayfield." In 1912 the writer decided that the Bayfield sandstones are non-marine, a conclusion which has stood the test of over twenty years. Irving believed — and his conclusion has been accepted by most geologists down to the present day — that the red Jacobsville sandstones are the conformable downward extension of the light-colored Munising sandstone. It must be realized that this conclusion was reached long before the dawn of modern knowledge of sedimentation and that disconformities between horizontal beds were then unrecognized. In the light of present-day science a restudy of the question in the vicinity of Munising, where the contact is exposed, might disclose a vast hiatus involving the great pre-Cambrian peneplain. Unfortunately, the available well logs are not sufficient to add much to the solution of this important question. Two very poor logs in the present section indicate red feldspathic sandstone of a type foreign to the recognized Upper Cambrian. If the correlation of these beds which is suggested on the section as Jacobsville is correct, it would serve to strengthen the hypothesis of a disconformity. In this connection it is necessary to note that at Limestone Mountain[10] the red sandstones are overlain not by Munising sandstone, but by Black River dolomite. The same condition is also true near Sault Sainte Marie.[11] These facts suggest a profound hiatus, although it might be urged that it may not be the base of the Cambrian, but rather the sub-St. Peter unconformity.

CONCLUSIONS

In the present state of knowledge the following facts have been established:

1. No St. Peter sandstone can be recognized in northern Michigan.

2. The Beekmantown formation includes several sandstone members which should not be confused with either the St. Peter or the Jordan sandstones.

3. The Trenton (Black River) formation is disconformable on the Beekmantown, and study of insoluble residues is needed to fix the plane of division more accurately than has been done heretofore.

4. The Trempealeau formation, as defined at present in Wisconsin, extends into Michigan and has formerly been included with the Beekmantown; it can be discriminated by use of insoluble residues and by its red colors.

5. The Trempealeau is probably disconformable below the redefined Beekmantown (Lower Magnesian), for the Jordan sandstone is missing throughout much of northern Michigan.

6. The Mazomanie and Dresbach sandstones as now defined in northeastern Wisconsin extend into northern Michigan and form the Munising sandstone.

7. It seems probable that the Jacobsville non-marine sandstone is separated from the marine Munising sandstone by a profound disconformity which marks the top of the pre-Cambrian, but final conclusions on this point await further field studies. If this suggestion proves correct we would have to return to the interpretation of Houghton,[12] made in 1841, that this sandstone [Munising] rests unconformably upon the red sandstone [Jacobsville], the former dipping gently to the south or southeast, while the latter dips very considerably to the north or north west."[13]

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[1] Rominger, C., "Palaeozoic Rocks [Upper Peninsula]," *Geol. Surv. Mich*., Vol. 1, Part III. 1873.

[2] *Ibid*., p. 81.

[3] Irving, R. D., "The Copper-bearing Rocks of Lake Superior," *U. S. Geol. Surv., Mon. 5*, pp. 351-352. 1883.

[4] Lane, A. C., and Seaman, A. E., "Notes on the Geological Section of Michigan: Part I, The Pre-Ordovician," *Journ. Geol*., 15: 680-695. 1907; *Geol Surv. Mich., Ann. Rep. for 1908*, pp. 23-42. 1909.

[5] Thwaites, F. T., "The Paleozoic Rocks Found in Deep Wells in Wisconsin and Northern Illinois," *Journ. Geol*., 31: 529-555. 1923.

[6] Ulrich, E. O., and Resser, C. E., "The Cambrian of the Upper Mississippi Valley, Part II: Trilobita; Saukiinae," *Bulletin of the Public Museum of the City of Milwaukee*, 12: 217. 1933.

[7] Ulrich, E. O., "Notes on New Names in Table of Formations and on Physical Evidence of Breaks between Paleozoic Systems in Wisconsin," *Trans. Wis. Acad. Sci*., 21: 72-90. 1924.

[8] Ulrich, E. O., and Resser, C. E., "The Cambrian of the Upper Mississippi Valley, Part I: Trilobita, Dikelocepalinae and Osceolinae," *Bulletin of the Public Museum of the City of Milwaukee*, 12 : 11. 1930.

[9] Irving, *op. cit*., Plate XXVIII, after p. 410.

[10] Case, E. C., and Robinson, W. I., "The Geology of Limestone Mountain and Sherman Hill in Houghton County, Michigan," *Mich. Geol. and Biol. Surv*. Publ. 18, Geol. Ser. 15, pp. 165-181. 1915.

[11] Lane and Seaman, *op. cit*., p. 39.

[12] Houghton, Douglass, *Geological Reports of Douglass Houghton, First State Geologist of Michigan*, 1837-1845, (Michigan Historical Commission, Lansing), p. 499. 1928.

[13] "A short distance northwest from Munising and on Grand Island are excellent exposures of conglomerate, up to 10 feet thick, composed of well rounded quartz pebbles principally. On Grand Island the exposure in the cliffs shows that this conglomerate lies between an upper cream to buff sandstone and a lower red and white mottled sandstone. The beds below the conglomerate dip gently in a northward direction and close above it the conglomerate dips gently in a southward direction, so that at the south end of Grand Island the conglomerate is at water level, while at the northern end it is 125 feet or more above water level. There is no basis for an assured correlation of the lower series, but my belief from its lithologic character is that it is the same as the Jacobsville. The upper sandstone grades upward into fossil-bearing beds, so that we know they are Paleozoic." — W. O. Hotchkiss, personal communication, March 27, 1933.