GEOLOGY OF SCHOOLCRAFT COUNTY

by

O. F. Poindexter

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GEOLOGY OF SCHOOLCRAFT COUNTY

Rock Formations

The rock formations immediately underlying the surface materials in Schoolcraft County range in age from Niagaran to Ozarkian (?) inclusive. The Niagaran Series derives its name from the fact that the escarpment of Niagara Falls is formed from some of the more massive limestone and dolomite beds of this portion of the geological section. Rock strata of Niagaran age are at or very near the surface over most of the southern part of Schoolcraft County. There are no known rock outcrops north of a line drawn roughly from the north end of Indian Lake to Blaney, the northern four-fifths to five sixths of the county being rather heavily drift covered.

The Niagaran rocks consist of magnesian limestones and dolomites with generally thin beds of more or less pure limestones. Shale beds are so insignificant as to be practically negligible. Where present they do not amount to more than a few inches in thickness. The strata have a gentle lakeward dip or inclination amounting to from 40 to 60 feet per mile to the southeast. Locally, however, the dip becomes considerably steeper and may amount to as much as 750 feet per mile.

Below the Niagaran limestones and dolomites which have a thickness of about 375 to 400 feet in Schoolcraft County lie soft shales and shaly limestones of the Cataract formation and Cincinnatian Series. Owing to the southeasterly inclination of the strata the soft shaly beds underlying the Niagaran Series would normally outcrop immediately north of the thick limestones and dolomites. The soft character, however, of the Cincinnatian rocks, permitted them to be eroded by the pre-glacial streams with the result that valleys were developed where these rocks occurred and the harder Niagaran rocks being much more resistant to weathering were left to form steep cliffs or escarpments. Where not covered by glacial drift the Niagaran escarpment therefore is a prominent topographic feature in the eastern half of the Upper Peninsula. In Schoolcraft this escarpment has a height of 90 feet or more, but at Burnt Bluff in the Garden Peninsula, Delta County, it reaches its maximum expression in a bluff nearly 250 feet above Big Bay de Noc.

Nowhere in Schoolcraft County do rocks older than the Niagaran come to the surface. The Richmond formation and the Trenton and Black River limestones occupy broad belts crossing the central part of the county and north of these belts the Ozarkian (?) system of rocks underlies the glacial drift. The formations below the Niagaran are, however, more or less heavily covered by glacial drift.

Geologic Time Scale for Schoolcraft County

Quaternary System	Pleistocene Series	Glacial Deposits		
Silurian System	Niagaran Series	Lockport group - Engadine formation		
		Clinton Group	Manistique Formation	Cordell Member
				Schoolcraft Member
			Burnt Bluff Formation	Hendricks Member
				Byron Member
			Mayville Formation	
	Medinan or Alexandrian Series		Cataract Formation	Cabot Head Member
				Manitoulin Member

Ordovician System	Cincinnatian Group	Richmond Formation	Big Hill	
			Stonington	Ogontz
				Bay de Noc
			Bills Creek	
	Mohawkian Group	Trenton Formation	Prosser	
		Black River Formation	Decorah	
			Platteville	
		St.Peter Formation(?)		
Ozarkian (?) System		Hermansville Formation		
Cambrian System		Lake Superior Formation		

Algonquian - Archean Systems

Granites, gneisses, schists, and related rocks.

Explanation of Time Scale

The rocks outcropping or underlying the surface in southern Schoolcraft County belong to the Silurian system, which derives its name from a locality in Wales, British Isles, where the sediments of this portion of the earth's crust were first studied. A geologic system includes a succession of rock strata which were laid down during a transgression of the sea and which are characterized by a certain type of life. In point of time a system covers millions of years.

On the American continent the Lower Silurian rocks are best exposed in the gorge and falls of the Niagara River; hence the term Niagaran Series is applied to that portion of the geologic section. The larger divisions of the Michigan Silurian are therefore to be correlated with similar rocks in New York State. In the case of the smaller divisions, however, no such long range correlation is possible, but it is practical to correlate the Michigan beds with those of Wisconsin, Ontario, and other nearby states. For instance, the Engadine formation has been variously correlated with the Guelph of Ontario, Lockport of New York, and the Racine of Wisconsin, while the Mayville is found to be a continuation of the Mayville beds of Wisconsin. Prof. G. M. Ehlers of the Department of Geology, University of Michigan, has made an exhaustive study of the Upper Peninsula, covering a period of over ten years. The classification of the Niagaran Series as given in the above time scale is that proposed by Prof. Ehlers. Various state geologists, university professors, and outside geologists, have given more or less attention to the Silurian rocks and fossils of Northern Michigan. Due credit is given all of these investigators by Prof. Ehlers in his analysis and compilation of material from all available sources into a complete report on the "Stratigraphy of the Niagaran Series of the Northern Peninsula of Michigan." Dr. R. A. Smith, State Geologist of

Michigan, made a study of the economic aspects of the limestones of Michigan covering a period of two field seasons, and the results of this study are contained in Publication 21 of the Michigan Geological Survey. References in the present report are largely to the investigations of Prof. Ehlers and Dr. Smith.

The divisions of the Ordovician [redacted] are those proposed by Prof. R.C. Hussey of the University of Michigan, who has made these rocks the subject of a detailed study. The upper and middle portions of this system are generally correlated with rocks exposed in the Hudson River Valley of New York State. Some of the shale beds, however, are correlated with those occurring at Richmond, Indiana.

The lower divisions of the Ordovician and the Cambrian apparently are equivalent to formations occurring in Wisconsin, Minnesota, and other states. Lack of complete correlating data, however, makes it advisable to retain local names in some instances.

DESCRIPTIONS OF FORMATIONS

Engadine Formation

The name Engadine was proposed by R. A. Smith for the topmost formation of the Niagaran series in the Upper Peninsula, and these beds were provisionally correlated with the Guelph formation of Ontario. Dr. A. C. Lane, former State Geologist, has also held these beds to be of Guelph age. Ehlers, however, found paleontological evidence which suggested that while some of the beds in question might be Guelph, there were unquestionably older beds which correlated very well with Lockport strata of Cockburn and Manitoulin Islands, Ontario. Ehlers also found that the so-called Engadine was apparently continuous with the Racine beds of northeastern Wisconsin and originally correlated these beds. Later investigations, however, showed that neither the northern Michigan nor northeastern Wisconsin beds contained typical Guelph fauna. Lacking definite correlating data Ehlers therefore proposes to use the name Engadine as suggested by Smith for the highest Niagaran formation in the Upper Peninsula. The formation derives its local name from the village of Engadine in Mackinac County, where it is extensively exposed for one mile west of the village. The best exposure in the Upper Peninsula is probably at Ozark, also in Mackinac County, but this name could not be adopted by Dr. Smith in view of the fact that the Lower Ordovicion formations are grouped under the name Ozarkian.

The Engadine is not an important bed in Schoolcraft County. It is limited in occurrence chiefly to the area between Bull Dog Creek and the Millakokia River in the southeastern corner of the county, with small outliers on Seul Choix Point, near Whitedale, at Marblehead Quarry, and one mile east of the mouth of Marblehead Creek. The Engadine is ordinarily described as a white to bluish white or gray dolomite with bluish mottlings or streaks. The bluish white appearance is very characteristic of well cuttings from the upper part of the Niagaran series in the southern part of the Lower Peninsula. In all exposures noted in Schoolcraft County the color appears to be buff to light brown with bluish streaks and mottlings. The darker color may be due to the effects of weathering, but the Engadine beds of Schoolcraft County ~~are near the contact with the Manistique formation.~~ belong to the Lower ~~upper~~ part of the formation and may run to more of a buff color than the upper beds.

The Engadine is everywhere a very massive dolomite, devoid of apparent bedding planes except near the base of the formation. Because of ~~the~~ ' structure very large boulders are found in the drift overlying and j of the outcrop. Owing to their massive character, whiteness of the surface, and the presence of the bluish mottlings and solution ca these boulders are easy to recognize as derived from the Engadine the waves of Lake Michigan have acted upon the Engadine dolomite the surface of the rocks is pitted with innumerable spherical cavities about the size of marbles. These cavities are said to be the result of solution of shells of the brachiopod Pentamerous which is of common occurrence in the Engadine.

According to Ehlers the following fossils have been found in the upper two-thirds of the Engadine:

Amplexus sp.cf. A. Whitfieldi Miller

Pycnostylus guelphensis Whiteaves

Favosites sp. aff. F.occidens Whitfield

Trimerella sp. cf. T.accuminata Billings, and T.grandis Billings

Polenmita sp. cf. P.acamnata Clarke and Reudemann and cf. Pycnomphalus solarioides (Hall)

The above fossils are Guelph forms and Prof. Ehlers states that they indicate the possible correlation of the Engadine with the Guelph of Ontario and Wisconsin. The lower one-third of the Engadine produces abundant remains of Pentamerous oblongus Sowerby and poorly preserved species of Amplexus, Arachnophyllum, Favosites, Syringopora, and Halysites.

Thickness of the Engadine

In the southern part of the Lower Peninsula wells have penetrated up to 345 feet of white, blue white, and blue-gray dolomite, which is generally correlated with the Guelph of Ontario. At Cheboygan 320 feet of "white" dolomite were penetrated and at St.Ignace 278 feet. In these places, however, the Niagaran formations are deeply buried and have not been subject to erosion. In the Northern Peninsula where the Niagaran rocks are exposed there is ample evidence that considerable thicknesses of Engadine have been removed by the action of glaciers. Huge blocks of stone, some as large as a small cabin, are strewn over the surface at various places. Some of these large blocks of stone have been carried across the Straits and are found near Cheboygan.

According to Smith the maximum observed thickness of the Engadine dolomite is at a point about two miles north of Ozark, Mackinac County, where the stone is 64 feet thick. In Schoolcraft County it appears that the Engadine is at no place more than 50 feet in thickness.

Manistique Formation

The term "Manistique Series" is applied by Smith to the thick succession of cherty dolomites and magnesian limestones between the base of the Engadine and the top of the Fiborn limestone. Ehlers adopts the term "Manistique" for approximately the same thickness of of section, but points out that the section is not of sufficient magnitude to warrant the use of the term "series." He divides the Manistique into two members, Cordell and Schoolcraft. The type section of the Cordell member is at the old Scott Quarry at Cordell about 15 miles east of Trout Lake, Chippewa County, while the Schoolcraft beds are best exposed in the quarry at the east city limits of Manistique. The Cordell beds are also extensively exposed in Schoolcraft County from Seul Choix Point westward. They are at the surface over a large area just west of Whitedale and are also present in the Manistique quarry.

The Cordell beds are generally easy to recognize owing to their very cherty character and extremely fossiliferous nature. In color the Cordell beds are characterized by a general lack of uniformity in the same beds. The most typical color appears to be brown with bituminous streaks and delicate grayish streamers of chert, but much lighter colors also occur. Some portions are almost pure white. Cordell time appears to have been a period of extensive reef building for the beds of this formation are characterized by a profuseness of corals which have become generally silicified. Nodules and seams of chert are also abundant . Most of the Cordell is thin bedded but there are also some thick massive beds practically free from chert.

The Schoolcraft member differs from the Cordell in having much less chert and only occasional corals. The most characteristic type of rock is dense, slaty, blue, and hard, breaking with a sub-conchoidal fracture. This rock upon weathering becomes buff to light brown in color on the fresh fracture, but the exposed surfaces are very white. The beds also assume a very thin-bedded platy character. Smith refers to this rock as "ribbon stone," because of the banded structure brought out by weathering. A most striking occurrence of these beds is found about one mile northeast of Cooks where some peculiar ridges have been developed, either by folding or stream action. Other exposures are found in the vicinity of Marblehead and about 2½ miles northwest of Whitedale. Other beds of the Schoolcraft member are buff to brown in color and more thick bedded. Some of the beds contain considerable chert.

Thickness of the Manistique

Prof. Ehlers places the base of the Manistique formation "at a short distance below the base of a thick-bedded buff to buff-gray dolomite containing numerous remains of Pentamerous." This horizon is very important as a key bed for use in tracing and correlating the various beds of the

Niagaran in the Upper Peninsula. According to Smith's classification the Manistique includes all the beds between the base of the Engadine dolomite and the top of the Fiborn limestone. Ehlers, however, includes some of the beds above the Fiborn limestone in the Burnt Bluff formation. Ehlers assigns a maximum thickness of about 100 feet to the Cordell member of the Manistique formation, 67 feet being exposed in the type section at the old Scott quarry, Chippewa County. The thickness assigned to the Schoolcraft member is approximately 56 feet, all of which is exposed at the type locality in Manistique.

Life of the Manistique.(after Ehlers) (corals)

Streptelasma conulus Rominger

Streptelasma patula Rominger

Zaphrentis stokesi Edwards and Haime

Blothrophyelum caespitosum Rominger

Diphyphyllum huronicum Rominger

Omphyma verrucasa Rafinesque and Clifford

Ptychophyllum stokesi Edwards and Haime

Arachnophyllum pentagonum (Goldfuss)

Arachnophyllum striatum (D'Orbigny)

Cystiphyllum niagarense (Hall) var.

Lyellia papillata Rominger

Coenites crassus Rominger

Coenites laminatus Rominger

Favosites favosus (Goldfuss)

Halysites labyrinthiais (Goldfuss)

Syringopora verticillata Goldfuss

Other Fossils

<u>Pentamerus Oblongus</u> Sowerby

<u>Atrypa</u> new species or variety of A.reticularis

<u>Coelospira</u> new species

<u>Palaeocyclus</u> variety of P.rotuloides (?)

<u>Armenoceras gouldense</u> Foerste

<u>A. spheroidale</u> (Stokes)

<u>Huroniella ehlersi</u> Foerste

<u>H.bigsbyi</u> Stokes

<u>H.bigsbyi intermedia</u> Foerste

<u>H.engadinensis</u> Foerste

<u>H.Obliqua</u> Stokes

<u>H. Paulodilatata</u> Foerste

<u>H.vertebralis</u> Stokes

<u>Stokesoceras gracile</u> Foord

<u>Megadiscoserus remotus</u> (Foord)

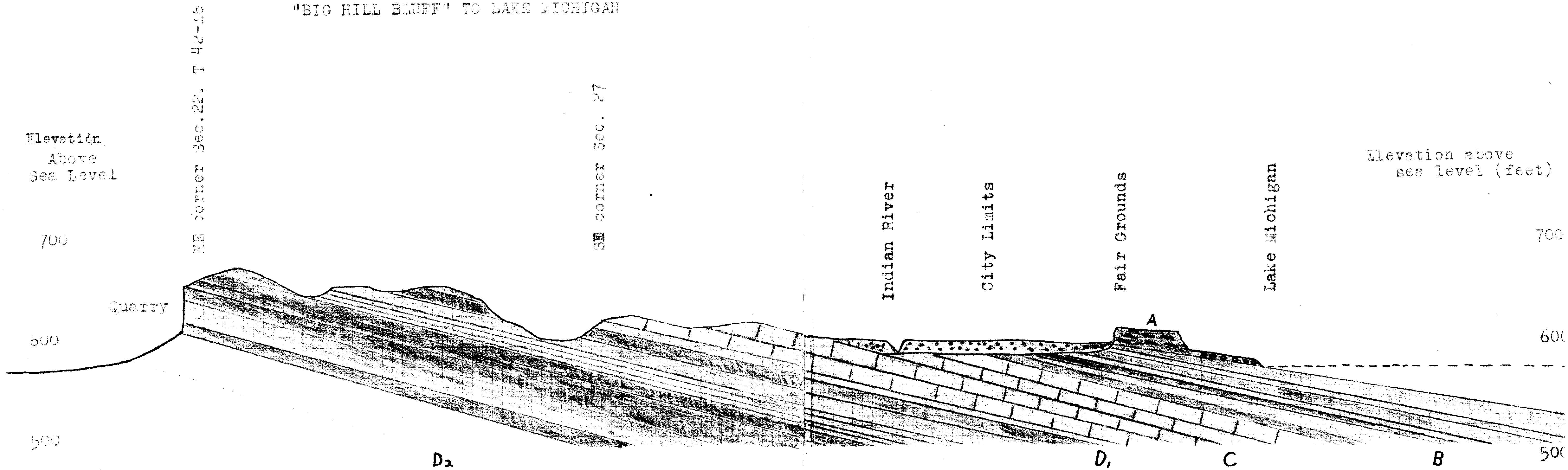
The above listed fossils are all found in the Cordell member. The chief form of the Schoolcraft member is <u>Pentamerous oblongus</u> Sowerby.

<u>Burnt Bluff Formation</u>

The Burnt Bluff formation(Ehlers) includes the Fiborn limestone of R.A. Smith, some dolomitic beds above the Fiborn, and beds of high calcium to high magnesian limestone below the Fiborn, provisionally designated by R.A.Smith as Hendricks series because of the occurrence in a test pit and in drill holes at Hendricks quarry, Mackinac County.

The Burnt Bluff is divided by Ehlers into an Upper or Hendricks member and a lower or Byron member. The type section for this formation is Burnt

COMPOSITE CROSS SECTION
From
"BIG HILL BLUFF" TO LAKE MICHIGAN



Bed "A" Cordell Member } Manistique Formation
Bed "B" Schoolcraft Member } Manistique Formation
Bed "C" "Fiborn Equivalent" } Burnt Bluff Formation
Beds "D-D" Hendricks Member } Burnt Bluff Formation

Scale

Horizontal 2 inches = 1 mile
Vertical 1 inch = 100 feet

——— NORTH

Figure 1.

Bluff, Garden Peninsula, Delta County, where some 250 feet of strata, (including covered materials) are present. The Burnt Bluff formation is probably the most interesting division of the Niagaran of the Upper Peninsula of Michigan. Unlike the Engadine and Manistique formations, the Burnt Bluff is not lithologically similar over great distances. The beds at Burnt Bluff and in western Schoolcraft County are strikingly different from those found in eastern Schoolcraft County and in Mackinac County. In these two latter areas there is a bed of high calcium limestone ranging from 18 to 60 feet in thickness. This bed was provisionally designated Fiborn by R. A. Smith. It is a grayish buff to brownish buff semi-lithographic stone containing disseminated calcite crystals and small geodes filled with calcite. The Fiborn is generally thick-bedded and breaks easily with a conchoidal fracture.

The Hendricks member of the Burnt Bluff formation is well exposed in Schoolcraft County, but the Byron beds are apparently not exposed. The Byron member is definitely correlated with the Byron beds of Wisconsin andthe distinction from the Hendricks member is based purely on paleontological evidence. Exposures of Hendricks strata in Schoolcraft County are found in the area from the old Calspar quarry to Green school and from Green school to Blaney Park. In three quarries located at these points about 65 feet of section is exposed, with no duplication of beds. There is also a covered interval between the Green School quarry and the Blaney Park quarry which may amount to a considerable thickness of strata owing to a rather steep dip of 200 feet per mile to the south and southeast observed at the latter quarry.

Other good exposures of Hendricks strata in southeastern Schoolcraft county are found in bluffs along the Manistique River and Bear creek in sections 8 and 9, T.42 N., R.14 W. (90-foot Bluff), and sections 33 and 34, T.43 N., R.14 W. In sections 8 amd 9, T.42 N., R.14 W., the cumulative height of two bluffs is about 150 feet and probably 60 to 65 feet of the ledge is exposed. Highway M-94 going from Manistique to Shingleton passes over the Niagara escarpment (Big Hill Bluff) about five miles north of the Manistique city limits. The total height of the bluff here is about 70 feet above the swamp to the north. The strata are well exposed in a small quarry opened for road material, and occupy the same position in the Hendricks member as the previously described exposures of Burnt Bluff strata. The beds exposed in the quarry and road cut aggregate about 33 feet and other beds alternating with covered intervals occur above these to the summit of the bluff. The lower 20 feet of the bluff is covered with talus. Rock is at the surface over most of the area between "Big Hill Bluff" and the Indian River, and since the strata dip to the southeast, higher and higher beds are encountered. Practically the complete section of the upper part of the Burnt Bluff formation can therefore be studied along M-94 and adjacent roads north of Manistique.

Beds occupying the upper portion of the Hendricks are exposed in a quarry two miles north of Cooks and at several places near Cooks School. Lower beds are exposed north and west of Cooks, but these beds are not as extensively exposed as in the area north of Manistique and in the southeastern part of the county.

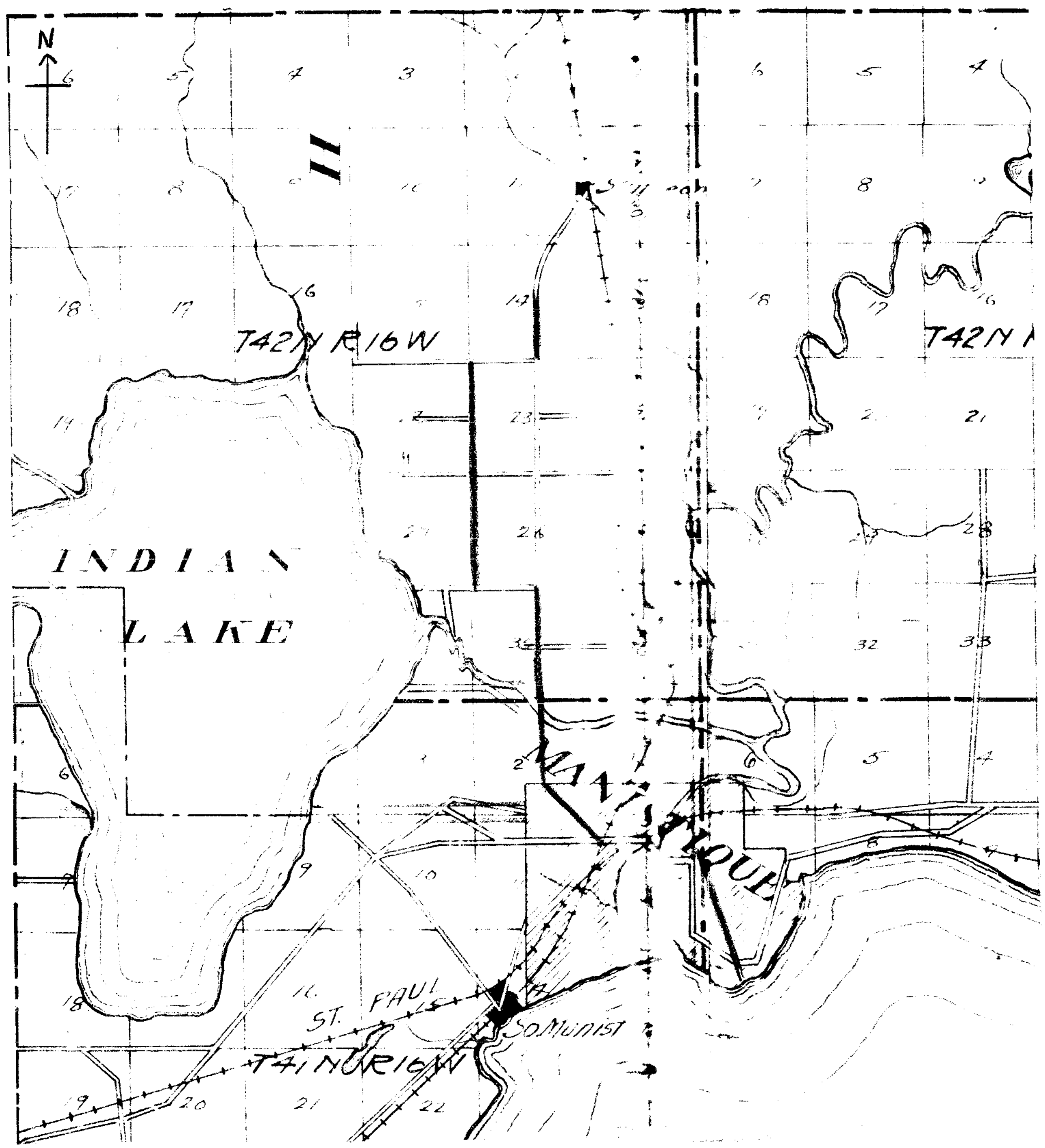
As indicated previously, the Burnt Bluff formation changes its lithologic character in passing from eastern to western Schoolcraft County. This change from pure limestone and magnesium limestones to beds generally dolomitic in character is noticeable in the upper part of the Hendricks member (Fiborn limestone), immediately west of the old Calspar quarry. Dolomitization in beds below the Fiborn is observed at "90 foot bluff" and more distinctly at "Big Hill Bluff" and in all outcrops between Big Hill Bluff and Burnt Bluff.

In spite of the westward change in composition of the Burnt Bluff there are several beds that possess characteristics which cause them to be unmistakably identifiable wherever encountered. In the small quarry on U S 2 at the western boundary of Blaney Park there is a 6-foot bed of brown limestone which seems to be formed from pebbles of lithographic limestone very similar to the Fiborn and cemented by a granular argillaceous limestone cement which gives a peculiar mottled appearance to the stone. The striking appearance of this bed therefore renders it valuable as a key bed should it be found persistent at other localities. Stone similar to this bed is, however, found at only one other locality, along Bear Creek in sections 33 and 34, T.43 N., R.14 W. The succession of beds there indicates that the nodular stone found at Bear Creek is higher than the 6-foot bed at the Blaney. The fact that this bed is repeated at least once in southeastern Schoolcraft County is proved by its recurrence at the very top of the Blaney Park quarry on the south side of the quarry only where about 1½ feet are present. Going south from this quarry to Green School this is the only kind of stone that can be found along the roadside except about one mile north of Green School where the stone exposed is more lithographic without any nodular character. The nodular bed forming the top of the bluff along Bear Creek in Section 34, T.43 N., R.14 W., was measured to be about 13 feet thick.

At "Big Hill Bluff" on M-94 one is impressed at the occurrence in the road cut of a bed of brown dolomite having a peculiar appearance reminding

MAP SHOWING

LOCATION OF COMPOSITE SECTION



SCALE $\frac{3}{4}$ IN. - ONE MILE

Figure 2

one of the nodular beds described above, but with the lithographic appearance lost and a granular porous texture substituted. The bed is approximately six feet thick and in view of the westward dolomitization of the Burnt Bluff formation one is led to suppose that this bed may be the dolomitized equivalent of the nodular limestone bed at BlaneyPark. This belief is strengthened by the presence above the brown bed of several feet of a wavy laminated light buff stone, some portions of which split readily into layers 1/8 inch in thickness. Some layers are delicately banded with purple. Ehlers notes at the base of this laminated bed 6 inches to 1½ feet of an "edgewise conglomerate."

This "edgewise conglomerate" was noted by Ehlers at Burnt Bluff, "Big Hill Bluff," "90-foot Bluff," and in the quarry at the west boundary of Blaney Park. At each of these locations the delicately banded purple streaked bed is found above the brown limestone or dolomite. The brown bed is remarkably uniform in thickness, being not less than five feet or more than six feet at any of the localities noted.

The similar conditions present in the brown bed and the bed immediately above indicate that the beds occupy the same stratigraphic position at all of the localities noted and may therefore be used to correlate the rocks of Schoolcraft County with the type section at Burnt Bluff. Since, however, the brown bed is repeated probably twice in the Burnt Bluff section, it is important to examine the beds immediately overlying in order to be sure that one is not dealing with a repetition of beds.

Below the brown key bed there are from 20 to 30 feet of Hendricks strata exposed in Schoolcraft County, the chief exposure being at "Big Hill Bluff."

Comparing the "Big Hill" section with Ehler's Burnt Bluff section one would therefore conclude that there are probably not more than from 10 to 20 feet of unexposed Hendricks in the county. The exposed strata below the key bed in western Schoolcraft County are chiefly rather thin bedded, hard, and dense, slaty gray weathering to brownish buff. Some beds, however, are brown and crystalline and more massive. All of these beds are dolomitic in character. In the southeastern part of the county the beds are light buff and light grayish buff, generally dense magnesian limestones. At least one thin bed of light brown lithographic limestone very similar to the Fiborn occurs four feet below the nodular key bed in the Blaney Park quarry. This bed is about 18 inches thick. The Fiborn limestone is apparently represented in the western part of the county by massive buff and buff-gray dolimites.

The Byron formation is correlated with the Byron beds of Wisconsin. The beds are exposed at Burnt Bluff and consist chiefly of buff to brownish thin-bedded platy dolomites. The Byron cannot be separated from the Hendricks lithologically, the division being based on paleontological evidence.

Ehlers assigns a thickness of 121 feet to the Hendricks member of the Burnt Bluff, and 117 feet to the Byron member. These thicknesses are based on the type section at Burnt Bluff.

Fossils of the Burnt Bluff

The most characteristic fossils of the Hendricks member are -

Clathrodictyon vesiculosum Nicholson and Murie var.

Camarotoechia winiskensis Whiteaves

Rhyehospira lowi Whiteaves

Stokesoceras romingeri Foerste

Leperditia fabulina Jones

Favosites N.sp. Nos. 1 & 2

Isochilina latimarginata (Jones)

Trimella sp.

> This last species (Trimerella) has been found of great value by Prof. Ehlers in correlating beds supposedly equivalent to the Fiborn limestone. Specimens of Trimerella were found by Prof. Ehlers 13½ feet below the base of the Fiborn limestone at Hendricks quarry, Mackinac County.

In view of the fact that Trimerella are found in Schoolcraft County in beds of massive dolomite which occupy a stratigraphic position very close to that of the Fiborn limestone and considering the fact that no outcrops of undoubted Fiborn have been found west of Green School, the theory has been advanced by Ehlers that the Fiborn limestone is represented by a massive crystalline dolomite throughout most of Schoolcraft County. A further discussion of the westward dolomitization of the Fiborn limestone will be found under "Economic Geology."

The Byron beds are practically barren of fossils.

Mayville Formation

This is the lowest division of the Michigan Niagaran. It does not outcrop in Schoolcraft County and exposures are of very limited extent in other counties. The formation consists of dolomites and magnesian limestones of varying character, but owing to the scarcity of outcrops no adequate description of the beds can be obtained. The nature of the Mayville in Schoolcraft County is best ascertained from the record of the well drilled at Seul Choix Point by the Schoolcraft Development Syndicate.

The Mayville beds have been correlated with the Mayville of Wisconsin because of the presence of a characteristic fossil, Virgiana mayvillensis Savage near the top of the formation.

Formations below the Niagaran

Since there are no known outcrops or strata lower than Niagaran in Schoolcraft County, no space will be given to a description of these rocks. A very good idea as to the character and thickness of these formations may however, be obtained from inspection of the record of the Schooldraft Development Syndicate Well #2 at Seul Choix Point. A copy of this record is reproduced here.

Seul Choix (Schoolcraft County)
Schoolcraft Development Syndicate Well No.2

Location: ½ mile north from well No.1 which was drilled at the SW corner of the NW¼ of section 31, T.41 N., R.31 W., Mueller township, (Southwest corner of section 21, T.41 N., R.13 W.).

Elevation: 625 feet (estimated) above sea level.

Samples furnished by Benjamin Gerow, Manistique.

	Thickness feet	Depth feet	Thwaites Determination
Pleistocene:			
Lacking			
Silurian:*			
*Silurian subdivisions according to Prof.G.M.Ehlers of Ann Arbor.			
Manistique Formation:			
Buff mixed with gray and white dolomite	30	30	Manistique 30-40
Buff cherty dolomite	10	40	
Buff mixed with gray dolomite and white chert	110	150	
Burnt Bluff Formation:			
Buff dolomite	25	175	
Buff mixed with gray dolomite and white chert	25	200	
Buff mixed with gray dolomite	50	250	B.Bluff 150-155
Buff limestone	5	255	
Buff and gray limestone	5	260	
Gray dolomitic limestone	10	270	
Bluish gray calcareous shale	5	275	
Buff and gray shaly limestone	15	290	
Gray shaly dolomitic limestone	5	295	
Gray limestone	5	300	
Gray and dark gray shaly limestone	5	305	
Mayville Formation:			
Buff dolomite	35	340	
Cream dolomite	15	355	Mayville 155-375
Cream and light gray dolomite	5	360	
Dark bluish gray shaly dolomite	5	365	
Greenish gray plastic shale	5	370	
Gray shaly dolimite	5	375	
Cataract Formation: (Cabot Head Member)			
Reddish gray plastic shale	5	380	
Gray and buff mixed shale and shaly dolomite with gypsum; some purple shale	50	430	375-545 (9)
Greenish gray shale	5	435	
Greenish plastic shale	5	440	
Greenish gray shale	10	450	

Cataract Formation:			
(Manitoulin Member)			
Buff dolomite	15	465	
Light gray shaly dolomite	20	485	
Ordovician:			
Queenstown-Richmond Formation:			
Greenish gray shale	25	510	
Red and greenish gray shale with gypsum	15	525	
Greenish gray shale with gypsum	20	545	
Gray shaly dolomite	10	555	545-745(e.f)
Gray and brown shaly dolomite	30	585	
Gray and brown shaly dolomite	30	615	
Gray shaly dolomite	50	665	
(Loraine):			
Dark grey shaly dolomite	30	695	
Brown and gray shaly dolomite	50	745	
Lorraine Formation:			
Bluish grey shale (dolomitic)	90	835	745-890 (b.c.d
Dark gray dolomitic shale	155	990	
Collingwood Formation:			
Dark brown limy shale	15	1005	890-1005(a)
"Trenton" Formation (Black River):			
Brown to gray limestone	35	1040	
Brownish gray dolomite	10	1050	
Gray limestone	10	1060	Galena –
Brownish gray limestone	$2\frac{1}{2}$	$1062\frac{1}{2}$	Blk.River
Gray shaly limestone	10	$1072\frac{1}{2}$	
Gray shaly limestone	10	$1082\frac{1}{2}$	$1005-1202\frac{1}{2}$
Dark gray shaly lime	$22\frac{1}{2}$	1105	
Buff gray dolomite	20	1125	
Gray dolomite	20	1145	
Dark grey shaly dolomite	15	1160	
Gray dolomitic limestone	5	1165	
Dark gray shaly dolomite	5	1170	
Dark gray and brown mixed shaly limestone	25	1195	
Brown and gray limestone	$7\frac{1}{2}$	1202.5	Lower Mag.
Grey limestone	20	1228.5	$1202\frac{1}{2}-1292\frac{1}{2}$
Dark gray limestone	$2\frac{1}{2}$	1225	
Gray and brown limestone (fresh water)	5	1230	
Mixed gray and light gray limestone	$17\frac{1}{2}$	$1247\frac{1}{2}$	
Dark grey limestone	10	$1257\frac{1}{2}$	
Buff limestone	10	$1267\frac{1}{2}$	
Buff limestone becoming dolomitic	$7\frac{1}{2}$	1275	
Dark buff and gray dolomite	$12\frac{1}{2}$	$1287\frac{1}{2}$	
Dark gray dolomite and quartz sand	5	$1292\frac{1}{2}$	
(Sand from St.Peter see below)			

St. Peter Formation:			Jordan
Pure white large grained quartz sand	10	1302½	1292½–1325
Same with green and rust colored grains and slightly dolomitic	5	1307½	
Same with finer quartz grains	17½	1325	
Ordovician and Cambrian (Undivided):			
Beekmantown and Lake Superior Formations:			
Buff to reddish quartz and greenish slate particles slightly dolomitic	10	1335	Trempealeau or St. Lawrence 1325–1372½
Reddish quartz and greenish slate particles slightly dolomitic	2½	1337½	
Same	5	1342½	
Same but coarser grains	5	1347½	
Buff dolomite with rust colored grains and dark slaty grains	20	1367½	
Dark reddish brown and dark buff dolomite (Fresh water at 1370)	5	1372½	
White sandstone with buff and slate-colored grains	10	1382½	
White sandstone with dark shale particles; iron stains (from drill?)	7½	1390	
Coarse white sandstone slightly dolomitic	2½	1392½	Mazomanie 1372½–1500
Coarse white sandstone with dark shale and dolomite particles	5	1397½	
Medium grained white sandstone	2½	1400	
Coarse white sandstone with dark shale and dolomite particles	12½	1412½	
Medium grained white sandstone, slightly dolomitic	47½	1460	
Medium grained white sandstone with considerable gray dolomite	10	1470	
Medium grained white sandstone, slightly dolomitic	12½	1482½	
Medium grained white to gray sandstone; slightly dolomitic	17½	1500	Dresback 1500–1710
Coarse white sandstone	17½	1517½	
Pink dolomitic sandstone	2½	1520	
White sandstone	5	1525	
Pink dolomitic sandstone	2½	1527½	
Sandstone pink tinted	32½	1560	
Cream-colored sandstone, gradually shading to pink with depth; slightly dolomitic	52½	1612½	
Sandstone and gray dolomitic shale	12½	1625	
Fine grained gray sandstone, slightly dolomitic	85	1710	

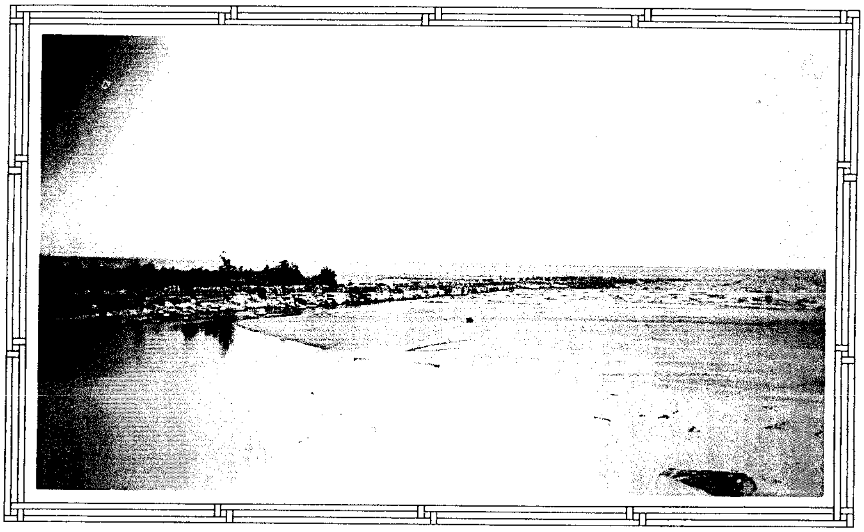


Plate I, ~~Figure 1.~~ A. — Outcrop of Engadine Dolomite at mouth of Bulldog River

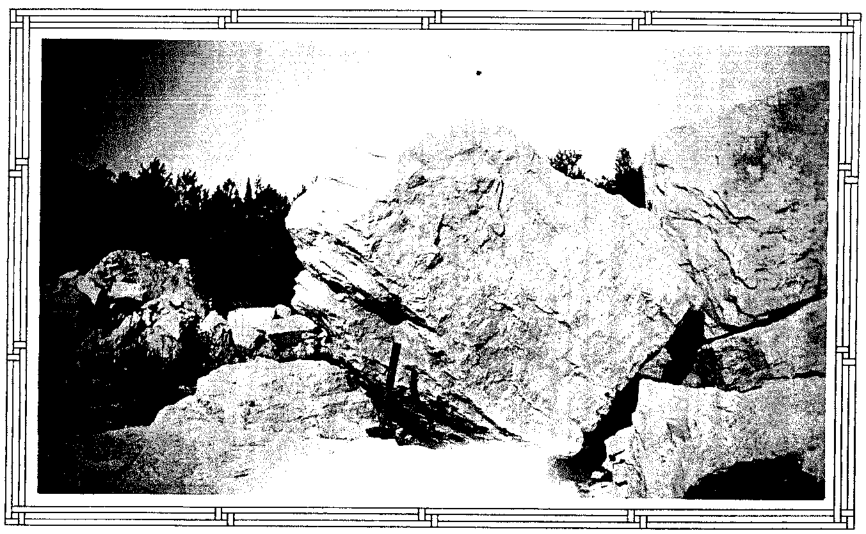
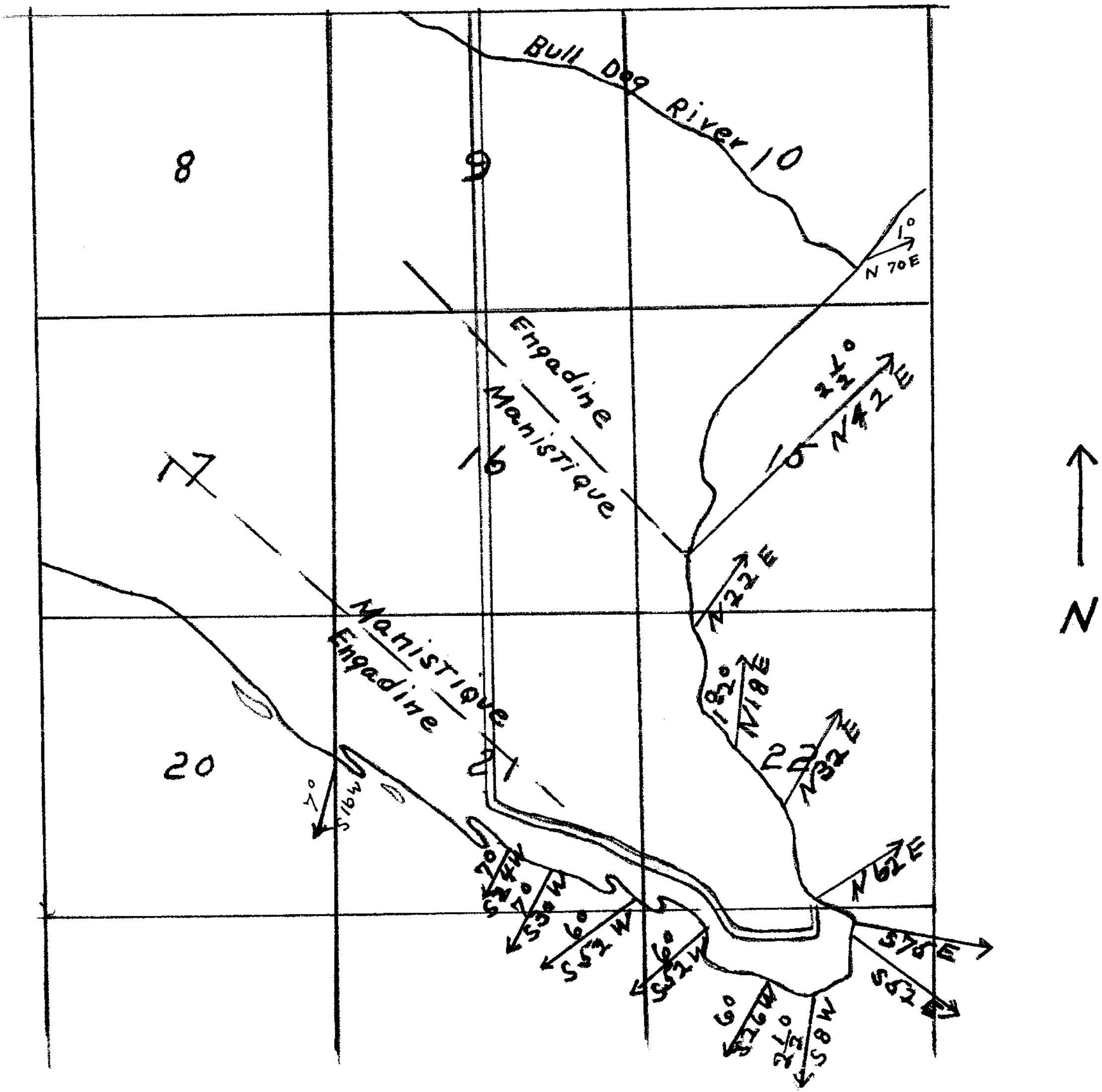


Plate I, ~~Figure 2.~~ B. — Engadine Dolomite, showing size of blocks obtainable.
(Quarry of Inland Lime and Stone Company)

SKETCH MAP OF SEUL CHOIX POINT

Geology and Structure of Beds

(After R.A. Smith)



Scale 1½ inch - one mile

Figure 3.

ECONOMIC GEOLOGY

Limestone and Dolomite

It has been stated that the Niagaran rocks of Schoolcraft County are divided into several formations based on lithologic character and type of fossils present. These formations are namely the Engadine, Manistique, Burnt Bluff, and Mayville. The Manistique is subdivided into the Cordell member, and the Schoolcraft member, while the Burnt Bluff is divided into the Hendricks member and the Byron member. Rocks lower than the Hendricks are apparently not exposed in Schoolcraft, owing to the heavy drift cover in the northern part of the county.

From the standpoint of economic units these divisions are satisfactory for reference except in the case of the Hendricks member of the Burnt Bluff formation where some qualifying terms must be used in order to adequately designate the economic importance of the member.

Engadine Formation

The Engadine formation is not of great commercial importance in Schoolcraft County, owing to the limited area which it covers. In Mackinac County this formation is extensively exposed at the surface and has a maximum exposed thickness of 54 feet near Ozark, according to R.A.Smith (Pub.21,page 152). In Schoolcraft County Engadine dolomite is found on Seul Choix Point from the mouth of Bull Dog creek east and north, north of the village of Whitedale, Marblehead Quarry, and about one mile east of the mouth of Marblehead Creek. With the exception of the Bulldog Creek occurrence the exposures are all very small and are only of local importance, as regards possible quarry sites. The Bull Dog Creek exposure covers an area of about two square miles in sections 10 and 11, 2 and 3, T.41 N., R.13 W., and sections 34 and 35, T.42 N., R.13 W. The outcrop begins as a ledge dipping into Lake Michigan on the east side of the creek. In the summer of 1932 this ledge formed a natural pier extending about 500 feet into the lake, owing to low water levels. At the shore about four feet of stone was exposed above the water. The ledge has a normal dip to the southeast of approximately 50 feet per mile, but there is a deeper dip at right angles (northeast) to the regional dip amounting to about 150 feet per mile.

From the mouth of the creek the escarpment can be followed for a distance of about one mile in a direction north about 25 degrees west. The ledge is cut through by M-99 in the northwest quarter of section 10 and is six feet in height at this point. North of this locality the ledge passes under sand dunes and is lost to view. Going north, however, on a road a little east of the center of section 10 and passing through the west one-half of section 3 the Engadine dolomite is at the surface, forming a flat pavement for a distance of more than a mile. This stone area is limited by swampy ground to the west at about the center line of section 3, and by sand ridges north of the Millikokia River. Engadine dolomite outcrops in the rapids of the Millikokia River in the southwest corner of section 35, and according to W.I.Robinson (1) there is an outcrop in the north portion of section 35.

The northern boundary of the main body of stone appears to be a hardwood ridge located near the small mud lake in the SW$\frac{1}{4}$ of section 34, T.42 N., R.13 W. In all it appears that not much more than one square mile of stone is near the surface in the Millikokia-Bull Dog area. About three-quarters of a mile south of the Bull Dog mouth the Engadine forms rugged bluffs rising about 10 feet above the water level and extending along the shore for about 1/8 mile. The area of stone under shallow cover here, however, is very small.

1. Oral Communication

[illegible]

The [illegible] Lime and Stone [illegible] Dolomite [illegible] in the [illegible]

[illegible]. This company [illegible] has been [illegible] depths of eight feet [illegible] about [illegible] acres. Practically [illegible] by the [illegible] Lime and Stone Company, [illegible] in the vicinity of the [illegible]. The company drilled several core tests in the vicinity of the quarry and near [illegible] Bull [illegible] creek. These [illegible] uniform conditions exist at these points. There is from [illegible] to [illegible] feet of [illegible] dolomite, [illegible] feet of [illegible] stone, [illegible] to a depth of [illegible] feet. [illegible] feet [illegible] dolomite. [illegible] dolomite [illegible] feet. [illegible] Bull [illegible] creek [illegible] south [illegible] the [illegible] McDonald [illegible] middle [illegible] of the [illegible]. On the [illegible] side of McDonald Lake there is [illegible] of the [illegible] formations [illegible] dolomite of the [illegible]. The [illegible] same direction as [illegible] Point [illegible] Sand [illegible] Point [illegible], however, [illegible] character.

Structure of Beds on Seul Choix point

The Engadine dolomite forms a fringe on the southwest side of Seul Choix Point and the beds dip in that direction at angles of from $2\frac{1}{2}$ to 16 degrees (R.A.Smith) from the horizontal. The central portion of the point and the northeast shore to about the middle of section 15 are occupied by the Cordell cherty beds, but Engadine dolomite again occurs in section 15, three-quarters of a mile south of Bull Dog Creek. Here the beds dip to the northeast at lower angles of from 1 to $2\frac{1}{2}^{o}$. (See sketch map by R.A. Smith)

The relatively steep dip to the beds on the southwest side of Seul Choix Point has resulted in the formation of fairly deep coves back of the tilted edges of the dolomite beds. These coves are extensively utilized as harbors for fishing boats.

Other Areas of Engadine Dolomite

In addition to the exposures of Engadine dolomite in the Bull Dog-Millakokia area, Seul Choix Point and McDonald Lake, there are small exposures north and east of Whitedale, at Marblehead quarry and one mile east of the mouth of Marblehead creek. At Marblehead quarry there is a capping of Engadine dolomite eight feet in thickness which has been quarried over an area of about 40 acres for magnesian lime. This quarry was abandoned about 6 years ago. The exposures at Whitedale and at the mouth of Marblehead creek are small and of no importance except for very small local uses.

Properties and Uses of Engadine Dolomite

Dolomite is a mineral crystallizing in the hexagonal system and having a chemical composition as follows:

Calcium Carbonate 54.35% Magnesium carbonate 45.65%

It occurs in extensive bedded deposits and is generally known as limestone or simply "lime rock." Limestone from the mineralogical standpoint is a rock containing only very small percentages of magnesium carbonate, but there are all gradations from a relatively pure limestone to dolomite. The intermediate varities are known as magnesium limestones or dolomitic limestones. The exact mechanics involved in the formation of the vast deposits of dolomite are not thoroughly understood. It is generally accepted, however, that dolomites are formed by some manner of replacement of the calcium carbonate of limestone by magnesium carbonate.

That the Engadine is a normal dolomite is shown by analyses of the stone at Marblehead and Millakokia River. For comparison analyses from the type localities at Engadine and Ozark, Mackinac County, are also given.

	1	2	3	4	5	6	7	8	9	10
SiO_2	0.26	.56	.87	1.03	.56	1.50	1.83	.86	.70	1.26
Fe_2O_3)) Al_2O_3)	.11	1.65	.32	.28	.26	.40	0.84	.25	.24	.38
$CaCO_3$	54.02	53.70	56.35	54.38	55.00	55.24	54,76	55.60	55.82	55.39
$MgCO_3$	42.83	42.68	44.85	46.66	44.31	41.02	45.74	44.79	45.31	44.79

1 & 2 Ozark quarry; 3 & 4 one mi.W.of Engadine; 5, 6, & 7 Marblehead quarry; 8,9,& 10 Millakokia River quarry (upper 10 ft.). Analyses 1-7 incl. from Pub.21, Mich.Geol.Survey, 8, 9, & 10 core analyses, courtesy of Inland Lime and Stone Company (Indiana Harbor laboratory).

The above analyses show the high purity of the Engadine dolomite which especially adapts the stone for use as a basic lining in open hearth furnaces and for the manufacture of paper by the sulphite process. Unfortunately, however, the demand for dolomite for these purposes is comparatively small. In recent years metallic magnesium has been coming to the front as the important constituent of light weight alloys. In the past magnesium metal has been derived from magnesite, which is the pure magnesium carbonate mined in the Western states, and from natural brines containing magnesium sulphate and calcium-magnesium chloride. At the present time the brines constitute the sole source of this metal, the entire domestic output being supplied by the Dow Chemical Company at Midland, Michigan. Owing, however, to the rather localized areas of domestic magnesite and the enormous quantity of brine required, in contrast to the almost universal occurrence of large deposits of high grade dolomite, there is a tendency to inquire into the possibilities for producing magnesium from dolomite. If it is found that this can be accomplished satisfactorily and economically this will open up a large and profitable field for these large deposits of stone, the magnesium content of which was formerly considered a detriment to their development.

While the area of Engadine dolomite in southeastern Schoolcraft County would undoubtedly be of considerable importance as a source of magnesium, the reserves are small in comparison to those of Mackinac County.

The Engadine dolomite varies in color from light buff to buff, brownish buff, and light brown. Where unweathered the freshly fractured stone is mottled and streaked with blue. These bluish colorations, however, are not permanent but disappear upon long exposure. In the quarry of the Inland Lime and Stone Company near the mouth of the Millikokia River the stone is uniformly mottled with blue except at the surface and adjacent to cracks, where the stone is of a light brown color.

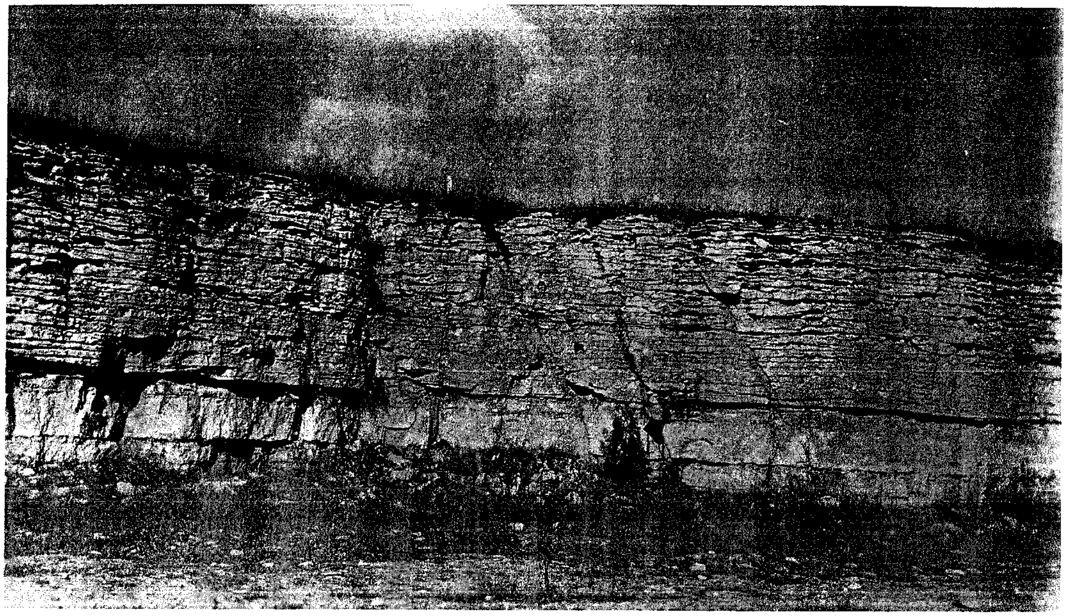
The stone is crystalline and without well-defined bedding planes in the massive portion of the formation. Upon long exposure the stone develops a pitted surface due to solution of shells and casts of the brachiopod Pentamerous. Owing to the massive character of the stone it is well suited for the production of riprap for harbor construction. Some blocks of quarried stone about six feet in diameter were noted in the quarry.

Manistique Formation

The Manistique formation, as previously stated, is divided into two parts; namely the Cordell member and the Schoolcraft member. The Cordell consists of very cherty and siliceous magnesium limestones and dolomites, while the Schoolcraft member is characterized by the thin-bedded bluish dense stone with more massive beds of buff to brown crystalline stone and much less chert than the Cordell beds.

The Manistique formation constitutes the most extensively exposed stone areas in Schoolcraft County. Cordell beds are most conspicuously at the surface in an area extending about 2½ miles west of Whitedale. There is a large area north of Whitedale where the Cordell and underlying Schoolcraft beds are very near to the surface. The Manistique formation is also exposed on Seul Choix Point, in the vicinity of Manistique, south of Thompson, and near Cooks. Small quarries have been operated for road metal two miles west of Whitedale, in the SE¼ of section 2, T.41 N., R.15 W., and in the NE¼ NW¼ of section 34, T.42 N., R.15 W. A large quarry was operated in the city of Manistique for many years, the stone being burned for magnesian lime.

The Cordell beds, because of their uniformly high chert and silica content have no apparent commercial value at the present time. The Schoolcraft beds where free from chert, may be of some limited potential importance for their magnesian content. The more important exposures are, however, rather remote from water transportation. Schoolcraft beds are most prominently exposed about one mile north of Cooks and in the NW¼ of section 28, T.42 N., R.14 W., where a small quarry was at one time operated for stone for foundations and other local uses.



(Courtesy Prof. G. M. Ehlers)

Plate II, Figure 1. - Cordell Strata at Manistique.
(White spots are chert nodules)

Plate II, Figure 2. - Old quarry of Inland Lime and Stone Company at Manistique, showing Schoolcraft beds.
(Courtesy Prof. G. M. Ehlers)

Analyses of Schoolcraft Member*

* From Pub.21, Mich. Geol. Survey (Manistique Quarry)

	1	2	3	4
SiO_2	1.14	2.10	1.92	.93
Fe_2O_3) (Al_2O_3)	.54	.40	.30	.51
$CaCO_3$	57.00	64.72	54.04	54.83
$MgCO_3$	39.87	33.75	43.81	45.45

The above analyses show that the Schoolcraft beds vary in composition from magnesian limestone to normal dolomite

Burnt Bluff Formation

The Burnt Bluff formation has been divided by Ehlers into the Hendricks member and the Byron member. From an economic standpoint,however, the Byron beds can be eliminated from consideration as they are apparently not exposed in Schoolcraft County. The Hendricks member is therefore the last group of rock strata to consider under the discussion of Economic Geology. There are two obvious divisions of the Hendricks from the standpoint of utilization. The most important is the Fiborn bed and its dolomite equivalent. The second division may be designated simply as "Beds Below the Fiborn." Above the Fiborn there are a few beds of magnesian limestone which are of no importance commercially.

Fiborn Limestone

The Fiborn limestone was so designated by R.A.Smith from its occurrence at Fiborn quarry in Mackinac County. By far the most important exposures of Fiborn limestone are found in Mackinac County and the reserves of high calcium stone are very large. In fact the Fiborn bed appears to be simply a lens of pure limestone which is almost limited in commercial extent to the western one-half of Mackinac County in the Upper Peninsula. The equivalent of the Fiborn has not been found in the many wells which have penetrated the Niagaran series in the Lower Peninsula of Michigan. Outcrops of undoubted Fiborn were found by Smith just west of Trout Lake in Chippewa County but eastward it cannot be traced because of heavy drift cover

Fragments resembling the Fiborn were found by Smith on Lime Island, St.Marys River, and a 3-foot bed of high calcium limestone on Drummond Island, reported by Rominger, was considered by Smith as being possibly the much reduced equivalent of the Fiborn. Ehlers, however, is of the opinion that this is one of the thin high calcium beds found below the Fiborn.

In Schoolcraft County the true Fiborn is limited to the eastern part of the county where it is well exposed over an area of about three square miles. The chief exposures are in section 3, T.42 N., R.13 W., where a quarry was operated for many years at Calspar, section 2 of the same township, and sections 34 and 35 of T.43 N., R.13 W. Owing to the lack of soil and forest cover in much of this area, and the white appearance of the weathered rock slabs, the extent of the stone in these sections is rather easy to determine from aerial survey maps. In section 1, T.42 N., R.13 W., and in section 36, T.43 N.,R.13 W., the Fiborn has a sandy drift and swamp cover, which amounts to from 6 or 7 feet or more. At the Nicholson farm in the southeast corner of section 1, it is 7 feet to rock in a well at the house, and one-fourth mile east of this corner it is about an equal distance to rock in a railroad ditch.

Undoubted outcrops of the Fiborn limestone have not been found west of a point about one-quarter mile west of Green School. At this point Smith noted an outcropping of typical Fiborn limestone a few paces south of the road. Several paces farther crystalline magnesian limestone was noted. Similar conditions are to be observed along the road leading south from Green school where fairly typical Fiborn limestone is found adjacent to crystalline stone. In the basement of the house just west of Green School a grayish to brownish buff crystalline magnesian limestone forms the floor at a depth of 4 feet. Going east from Green School typical Fiborn stone is encountered in a low ridge crossing the road one-quarter mile east of the school. Along the side of the road, however, there are ledges of crystalline magnesian limestone. About one-third mile east along the railroad from the camp of the Buckeye Lumber Company in section 8, the tracks cross a low ridge of brownish buff porous crystalline dolomite, very similar to the stone found in the quarry in the NW$\frac{1}{4}$ of section 13, T.42 N., R.14 W. Drill holes of the Inland Lime and Stone Company in the area between Green school and Calspar show a decided trend toward dolomitization of the Fiborn.

The Fiborn bed in the Calspar quarry, according to Smith, has a maximum thickness of 26 feet. In the new quarry opened just across the line in Mackinac County about 4$\frac{1}{2}$ miles east of the old Calspar quarry about 60 feet of high calcium stone are present, but in the Fiborn and Hendricks quarries the bed thins to 30 and 18 feet respectively. It is possible that the greater thickness of stone available at the new location may be due to a locally higher purity of the beds of the Hendricks formation immediately below the Fiborn. This situation is suggested by the high calcium character of the beds outcropping along U S 2 from a point one mile north of Green school to a point about 2$\frac{1}{2}$ miles north of the school. The decided increase in width of the Fiborn outcrop east of the old Calspar quarry may, however, be significant.

Physical and Chemical Properties of Fiborn Limestone

The Fiborn limestone is easily recognized in the field because of its smooth lithographic texture and conchoidal fracture, together with calcite geodes and disseminated crystals and grains of calcite. The color is generally grayish buff to brownish buff and light brown and the stone is usually thick-bedded and irregularly jointed. It is soft and brittle and calcines easily.

The stone is of high purity, ranging generally from 95 to 98 percent calcium carbonate, which especially adapts it for blast furnace flux and other uses demanding a very pure limestone.

The following analyses of Fiborn limestone in Schoolcraft County are taken from Publication 21, Michigan Geological Survey:

	SiO_2	Fe_2O_3 Al_2O_3	$CaCO_3$	$MgCO_3$
1	.77	.91	95.87	3.76
2	.60	.61	95.98	2.70
3	1.40	Trace	97.50	1.00
4	.25	.36	97.93	.38
5	.56	.26	94.73	3.82
6	1.30	.28	93.00	5.14
7	1.23	.69	94.38	3.74
8	1.66	.29	97.28	1.61
9	.86	.70	97.92	1.36
10	1.64	.37	97.07	1.88
11	.40	.26	97.92	1.12

Nos. 1-7 incl. Calspar quarry, Sec.3, T.42 N., R.13 W.

Nos. 8-11 incl. Section 1, T.42 N., R.13 W.

As p reviously indicated, no positive identification of the Fiborn bed has been made west of the outcrop near Green school. Smith collected a sample of high calcium limestone (CaO 98.76, MgO 2.59) from a small exposure about 40 rods west of the southeast corner of section 2, T.42 N., R.14 W. The writer obtained samples of light brown lithographic limestone from the bottom of a small gravel pit worked to bed rock on the farm of J. W. Nefziger in the NW corner of section 12, T.42 N., R.14 W. This is very near to the Smith locality mentioned above and possibly is the same bed, The stone from the gravel pit contains small geodes, some of which are filled with dolomite crystals. About one-quarter mile southeast of the gravel pit grayish to brownish buff crystalline dolomite outcrops.

In the NW¼ of section 13, T.42 N., R.14 W., there is a small quarry with about six feet of stone exposed. The stone is grayish to brownish buff crystalline and characterized throughout by numerous small cavities. The outcrop forms a low ridge trending east-west and having a width of about 1/8 mile where crossed by U.S.2. Ehlers considers this stone as the dolomitized equivalent of the Fiborn limestone, basing this conclusion not only on the stratigraphic position of the bed but on the presence of the species <u>Trimerella</u> which he found in beds below the Fiborn at Hendricks quarry, Mackinac County. The cavities, Ehlers believes, are due to solution of calcite crystals present in the Fiborn stone. As indicated in the discussion of the outcrop near Green school there is considerable evidence in favor of this theory. It is not probable that a quarry could be opened at this location for other than local purposes as it is quite likely that alternating ~~beds of~~ low and high magnesian beds will be found; thus rendering the quality of the stone quite uncertain. Distance from water or rail transportation would also be a detriment.

Stone similar to that in the northwest of section 13 is found near the center of section 15 and on the section line between sections 15 and 16. The outcrop here has not sufficient width to warrant development. Apparently much of the stone is overlain by swamp in the north part of sections 15 and 16.

The most important exposure of the supposedly Fiborn equivalent in the eastern part of the county is found along the River Road from the center of the west half of section 17, T.42 N., R.14 W., thence one mile north to Wood school near the center of the section line between sections 8 and 9. West of the road the stone generally forms a rather flat pavement and as shown at "90 foot bluff" in the SW¼ of section 8, the stone is thin on that side of the road, the crystalline dolomite being present only at the very top of the bluff. Just south of the Wood school, however, the stone form bluff 50 feet in height, the beds dipping to the southeast and generally becoming lower. Ehlers suggests that the topography here represents an elevated river terrace.

The total area of stone exposed in this area approximates one square mile. Owing, however, to the thinness of the stone west of the road it is probable that quarrying operations should be restricted to the east side of the road.

The stone is brownish and grayish buff to light grayish brown, very hard, and extensively crystalline, thick bedded, and containing some cavities, but not decidedly porous. Analyses of samples collected by R.A.Smith show that the stone approximates a dolomite in composition; hence if transportation facilities are available this area might be of value for magnesium or magnesian lime.

Analyses

	SiO_2	Al_2O_3 Fe_2O_3	$CaCO_3$	$MgCO_3$
1	.45	.62	58.35	21.10
2	1.54	1.33	54.05	20.62
3	1.13	1.31	54.79	21.82

1. "60 foot bluff" Top 12 feet
2. " " " 20 feet from top
3. " " " 30 feet from top

At "90 foot bluff" (SW$\frac{1}{4}$ section 8, T.42 N., R.14 W.) the Niagaran escarpment is cut through by the Manistique River and a broad drift-filled valley developed. The Fiborn equivalent is next encountered in going north from Manistique on the Shingleton-Munising road. Beginning at a very small quarry just north of the Indian River thick-bedded buff gray crystalline dolomite extends northward along the road for a distance of about 3/4 of a mile. In the southeast quarter of section 35 and near the center of section 35 the stone is brownish buff and porous, very similar to the exposures east of Manistique. Just north of the center of section 35 the thick-bedded stone overlaps thinner bedded dense brownish buff dolomite which is well exposed to a depth of 7 feet in a small quarry in the SW corner of section 26, T.42 N., R.16 W. It is probable that a quarry for magnesium or magnesian lime could be worked to the base of the stone exposed in this quarry, which would make available an area about one mile square in this portion of the county. The southern boundary of the stone is only about 3 miles from the lake and the Manistique and Lake Superior railroad passes very close to the eastern boundary of the deposit. Analyses of the stone is not availableas yet but it is believed that it will run fairly close to normal dolomite. It would appear that this is the most promising dolomite area in the county aside from the exposures of Engadine dolomite in the Bull Dog creek-Millikokia River area. If the crystalline dolomites north

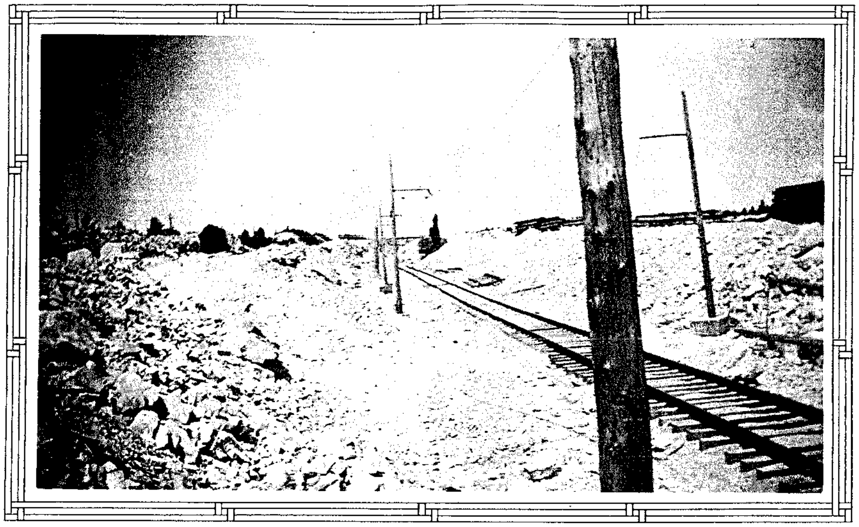


Plate III, Figure 1. New Quarry of Inland Lime and Stone Company (Mackinac County) (Fiborn Limestone)

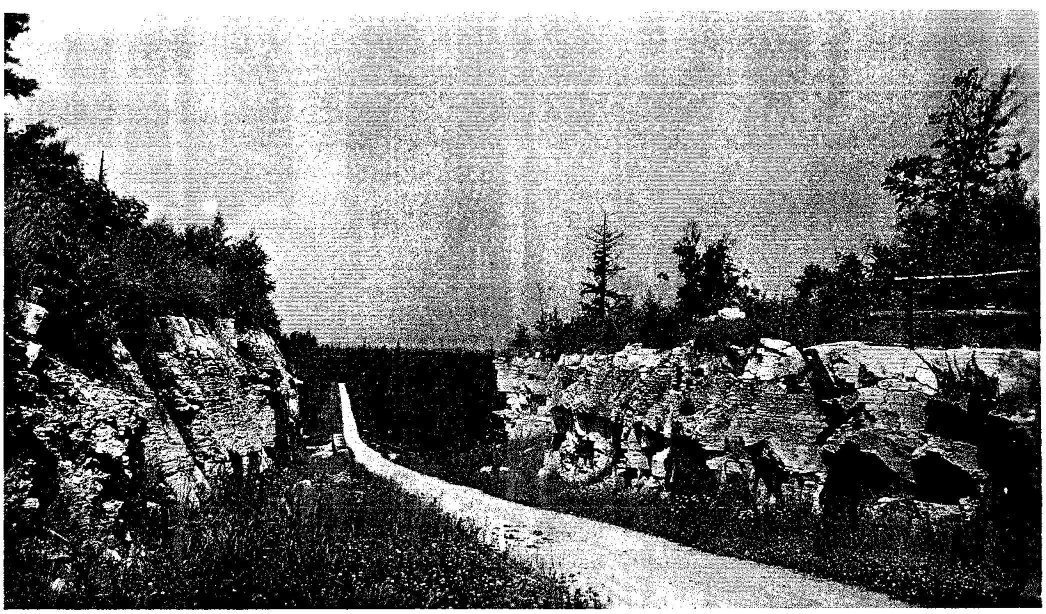


Plate III, Figure 2. "Big Hill Bluff" M-94 5 miles north of Manistique, showing Burnt Bluff strata (Hendricks Member) (Courtesy Prof. G. M. Ehlers) of Indian River are as thick as those at "90 foot Bluff" a total of 50 feet of stone may be available. However the Fiborn equivalent apparently thins to the west and somewhat less than this thickness may be present. It is possible that for magnesium content a quarry might be worked deeper to include beds of the Lower Hendricks which are generally dolimitized on the west side of the county.

West of Manistique the rock strata are rather heavily drift covered (103 feet at Parkers) for a distance of several miles. The Fiborn equivalent is well exposed to a depth of 15 feet in a small quarry in the southeast corner of section 9, T.41 N., R.17 W., in the vicinity of Cooks School, and in a quarry in the SW corner of section 17. In this latter quarry from 12 to 14 feet of thick-bedded dolomites are exposed in the upper portion of the quarry. Below this the beds are thinner and variable for a distance of 10 or 11 feet, and a buff to buff gray weathered crystalline porous dolomite is encountered in the bottom of the quarry. Since the outcrop of the massive dolomite does not generally appear to be more than ¼ mile in width in this part of the county it is possible that the 12 to 14 feet of stone in the top of the quarry in section 17 and the 15 feet exposed in section 9 may represent the total thickness of the Fiborn equivalent in the western part of the county. At Burnt Bluff this bed if present is apparently of considerably less thickness.

It is not probable that any commercial developments are practical in the Fiborn equivalent in the western part of the county. Highway U S 2 is located on the strike of the outcrop which appears to make a right angle swing to the south at the northwest corner of section 17. It is at about this range where all the Niagaran and lower strata change the trend of their strike from a generally east-west direction to southwesterly.

Beds Below the Fiborn

Under the discussion of the Fiborn limestone it was indicated that the lower beds of high calcium stone found in the new quarry of the Inland Lime and Stone Company might possibly correspond to the beds exposed along U.S.2 north of Green School. A 6-foot bed of high calcium nodular limestone and a 1-foot 6-inch bed of lithographic limestone very similar to the Fiborn are exposed in the quarry at the center of section 29, T.43 N

R.13 W. Other beds in this quarry are magnesian limestones and dolomites. There is an area of stone in the vicinity of this quarry probably one-half mile in diameter, but owing to the alternating beds of high calcium and high magnesian stone it is not probable that the area would be of value for either high calcium or high magnesian stone.

The only other area where the beds below the Fiborn might be of some economic importance is the area southward from "Big Hill Bluff" on the Manistique Shingleton road. Here beds comprising the middle and lower portions of the Hendricks are near the surface over an area of about two square miles. As previously indicated, a quarry operated in the thick bedded dolomites of the Fiborn equivalent over-lapping farther south might be worked deep enough to include some of these beds which have become pretty well dolomitized in this part of the county. Just north of Maple Grove school, however, an outcrop of the brown nodular stone retains its lithographic character; hence it is probable that locally the beds may run fairly high in calcium carbonate.

SUMMARY OF STONE RESERVES IN SCHOOLCRAFT COUNTY

Anyone riding through Schoolcraft County on U.S.2 might gain the impression from the numerous outcrops of bed rock that the limestone resources of the county are very large. A detailed study of the county, however, shows that only the southern one-fifth of the county is immediately underlain by limestone or dolomite, and furthermore that only relatively small areas of stone are suitable for commercial development. There is only one area of high calcium limestone in the county, but the reserves in this body of stone are fairly large. This area may be located by starting with a point exactly 3½ miles directly south of the village of Blaney, thence east three miles to pass over the approximate center of the deposit. It appears that a conservative estimate would indicate at least two square miles of available stone which should average 25 feet in depth. This would amount to 100,000,000 tons of stone or enough to last 100 years at a rate of quarrying to supply a fairly large demand.

With the exception of the high calcium stone in the Blaney area, the rock formations of Schoolcraft County are generally of a magnesian or dolomitic character. The most extensive of the formations, which occupies a belt several miles wide, is extremely cherty and does not appear to be of commercial grade at the present time.

There are two areas of dolomite which have commercial possibilities from the standpoint of quality of the stone, - location and transportation facilities. One of these is the Engadine dolomite in the area between Bull Dog creek and Millikokia River, where a quarry has been opened for obtaining riprap; and the other is in Hiawatha township about one mile north of the Manistique city limits. A third area near Wood school in T.42 N., R.14 W. might be of commercial importance were transportation facilities available. On none of these areas are the reserves of stone in sight extremely large. A total of 50,000,000 tons for each area would probably be a fair estimate.

ROAD MATERIALS

A number of small quarries were opened in Schoolcraft County years ago for road-building purposes. Most of these were for surfacing the main road (now U.S.2) and are right at the roadside or only a short distance from the road. Entering Schoolcraft County on U.S.2 from the east the first of these quarries is observed on the south side of the road at the western boundary of Blaney Park. Continuing south for about 3 miles a second quarry is found on the north side of the road about ½ mile west of Green School. The next quarry is 2 miles west and one mile south of the east side of the road, but not visible, and the next is 2½ miles west of Whitedale. The Marblehead quarry may be seen on the top of the hill about ¼ mile west of Marblehead creek. There is a small quarry not visible from the road on the line between sections 2 and 11, T.41 N., R,15 W. U.S.2 passes directly by the old Manistique quarry in the east part of the city.

West of Manistique there is a small quarry one mile east of Cooks school on the north side of the road and a larger quarry 1½ miles north of Cooks on the east side of the road.

About 10 years ago a quarry was opened in Big Hill Bluff 5 miles north of Manistique for building M-94. Other quarries are located in the SW¼ section 26,T.42 N., R.16 W., NE¼ section 2, T,41 N., R.16 W., NE of the NW section 34, T.42 N., R.15 W., NW of the NE section 35, T.42 N., R.15 W. At several places on the river road where stone is exposed crushers were set up and material taken out for surfacing.

None of the above quarries, however, produced very satisfactory material for road-making purposes. The cherty and thin-bedded dolomites of the Manistique formation have no value for use in concrete aggregates and very small value for macadam roads, owing to low cementing power. The stone from "Big Hill Bluff" used for M-94 is also said to be poor road material and the quarry near Cooks was said to produce stone low in cementing power and difficult to roll down on the road. These two latter quarries are located in the Burnt Bluff formation.

It is possible that the Engadine dolomite and the massive beds of the Burnt Bluff formation may be suitable for concrete aggregate if sufficiently free from cavities. A large percentage of pore space, however, causes absorption of water with a resultant decrease in strength of the concrete.

With the exception of the concrete pavement just east of Manistique Schoolcraft roads are of asphaltic macadam or gravel. The tar bound roads make use of either crushed stone or gravel. The crushed rock was formerly obtained from the Calspar quarry and more recently from the new quarry near Millakokia Lake in Mackinac County. For a job of resurfacing on U S 2 in the vicinity of Cooks, crushed stone was shipped from Port Inland to Manistique by boat, and truck-hauled to the job.

The Calspar stone is excellent for macadam roads, owing to its high cementing power and ease of rolling. Its suitability for use in concrete aggregates depends upon proper screening and washing. The pavement east of Manistique was built from this stone.

Sand and Gravel

Schoolcraft County does not possess large reserves of sand and gravel suitable for building purposes and road construction. Unlimited quantities of sand for foundry purposes and other uses to which a rather fine high silica sand is adapted are available in the dune area from Manistique to the east county line. Only a few gravel deposits of commercial importance were observed in the entire county. It is possible, however, that an intensive survey of certain areas may disclose others. A very large deposit of what appears to be the best concrete gravel in the county occurs in an esker two miles north of Blaney. Here a gravel pit was opened by the State Highway Department in 1924 for surfacing of M-77.

The ridge is about three-quarters of a mile long on the west side of the road and from 20 to 40 feet in height. The gravel is of good quality, containing a normal percentage of igneous rock with few soft or otherwise objectionable particles. Washing, however, is essential, and crushing is advisable, as there is considerable oversize in the pit. The ridge continues on the east side of the road and a small pit has been worked about 100 yards from the road. However, the ridge is much lower and the gravel becomes sandy and generally of poorer grade than that on the west side of the road. North of the Blaney deposit there are several small pits in the heavy moraine extending through Germfask township. One of these is located about $\frac{1}{4}$ mile east of South school, but this pit appears to have been pretty well worked out as only clay is visible in the bank. Poorly assorted, angular gravel, however, shows in the roadside ditch. The deposit apparently represents a concentration of gravel in the moraine and the surrounding area does not look promising for gravel. Other pits are located in the SW$\frac{1}{4}$ section 2, SE$\frac{1}{4}$ section 11, and NE$\frac{1}{4}$ section 12, T.44 N., R.13 W. These deposits are, however, comparatively small and the material is of inferior quality, being suitable chiefly for township roads.

The new Blaney fire tower is located ona gravel knoll several acres in extent and a small pit has been worked to a depth of 8 feet in one side.of the knoll. The gravel is of good quality for surfacing and a considerable quantity might be obtained by working around to the north of the tower. A small pit is also located in the knoll on which the old Blaney tower is situated. The gravel here is very coarse and cobbly, containing soft stone and shingle. It is probable that other material of this type is present in Blaney Park and environs.

There is a prominent gravel bar in the area between Gulliver and McDonald lakes in which pits have been operated for a number of years. The deposit lies in section 1,T.41 N., R.14 W., and section 36, T.42 N., R.14 W., and crosses several properties. A portion of the deposit is owned by the county and the remainder by private owners. The bar was thoroughly tested by D.C.McLachlar of the 1930 gravel survey in connection with the construction of M-99 and was estimated to contain about 10,000 yards of sandy pockety gravel. Since 1930 considerable material was taken out for the west end of M-99, but a fairly large quantity is yet available. The material appears, however, to be generally too find for use in concrete aggregate.

Very small gravel deposits only a few feet deep to bed rock are located in the SE corner of section 26, NW$\frac{1}{4}$ of section 34, NW$\frac{1}{4}$ of section 12, SE of NE of section 29, all in T.42 N., R.14 W.

There is an interesting gravel pit at the approximate center of section 4, T.42 N., R.14 W., said to be the most important source of material in that part of the county. At the time of inspection this pit was being operated by the county for bridge material. The material is very coarse cobbly limestone gravel with slabs of limestone on the surface and through the gravel. Were it not for the evidence presented by the pit one would be led to believe that bedrock is very near the surface at this point. The pit has been worked to a depth of about 20 feet without definite evidence of bedrock. The ridge in which the pit is located appears to continue in a southeasterly direction to the SE$\frac{1}{4}$ of section 4 where a small pit is located at the roadside. The material in this part of the ridge is somewhat different from that in the pit operated by the county. The gravel is considerably smaller in pebble size and no large slabs of limestone are present. The pebbles also have a decided angularity. The ridge located in this section may have been formed in part as a bar resulting from river action before the uplift of the area above the present valley of the Manistique River.

In the SW$\frac{1}{4}$ of section 1,T.41 N., R.15 W., about $\frac{1}{2}$ mile north of Marblehead Junction, a pit has been worked at the edge of the bluff to a depth of 15 or 20 feet. The gravel is somewhat angular and poorly graded and contains large blocks of limestone. The gravel is not suitable for concrete paving but considerable material for surfacing may be available at this point. At the base of this bluff shallow pits have been worked in bars formed when the waves of Lake Michigan acted upon the stony and gravelly bluff forming the shore.

Cooks Pit

The Cooks pit is generally considered to be the best gravel in the county for road surfacing. The material is fairly well assorted and roughly stratified, with very little large stone present. The pebbles are generally angular and have a clay binder which renders it excellent for gravel roads. The pit has been worked to a depth of about 20 feet and the best material appears to lie in a northwesterly direction. A 4-foot ledge of rock outcrops on the east side of the pit below six feet of surface. Owing to the increasing thickness of drift to the east and northeast a considerable quantity of material may yet be available in this pit.

Gravel in Northern Schoolcraft County

North of Indian Lake and the Manistique River there is a vast area in Schoolcraft County consisting of mostly sand and swamp which is lacking in sufficient roads to permit of an adequate reconnaissance survey. No gravel is known in Seney township and very little in Hiawatha township, although the county has done considerable prospecting in this latter township. Gravel for M-28 and the north portion of M-94 was taken from a pit at Star Siding in Alger County. The portion of the county included in Hiawatha National Forest appears to have better possibilities for gravel than Seney or Hiawatha townships. No large deposits are known but several small deposits have been opened and there are indications that thorough prospecting may develop more deposits of this type for local needs. A small pit was at one time operated in the top of a high knoll one mile north of Steuben, and the railroad has a pit in an adjacent knoll. The railroad pit has a face 100 feet long and 30 feet in height. The material is very fine and sandy with a few cobbles at the top. The other pit is very similar in character with the best material limited to the upper 5 or 6 feet.

Sandy gravel is exposed at several points between Kentucky (Delta County) and the Little Indian bridge. The material appears to be sandy and of shallow depth , but owing to the fact that this portion of the county is quite hilly it may be of value to prospect at some of the more likely points.

Garden Peninsula

There appears to be an outwash area of considerable magnitude embracing the settlement in sections 3,4,9, and 10, T.40 N., R.17 W., along the old state road to Garden. Several small pits were noted and in view of the cobbly and loamy nature of the soil, which has made it suitable for farming, particularly along the line between sections 4 and 9, it is possible that commercial deposits of gravel may occur in this area.

Bog Ore

In the northern part of Schoolcraft County the sandy plains contain considerable quantities of iron in the form of hydrated oxide. The presence of iron is detected in well and stream waters and in many places the soil is cemented into a kind of hardpan. At favorable places where there are collecting or settling basins a thickness of several feet of bog ore may accumulate. According to the postulated mechanics of deposition the iron is generally taken into solution at its primary source as a carbonate and deposited as hydrated oxide due to the action of organic matter and other agencies. Since iron is commonly present in the sandy plains of northern Schoolcraft County as the hydrated oxide derived from primary sources and deposited through glacial agencies, it is quite probable that the concentrations of bog iron which are of small diameter as far as observed, have resulted largely from the secondary transportation and deposition of finely divided and colloidal iron oxide. The deposits generally occur in small depressions between the sandy knolls, but often due to a lowering of the water table by means of drainage ditches the bog ore occurs as a capping of small knolls resulting from surface wash and the differential resistance of the bog iron and the surrounding sand.

The probable mechanics in the formation of the bog deposits may be observed in drainage ditches along the highways after heavy rains, where the sand in the bottom of the ditch may be observed to be coated with a film of iron oxide when the water has drained away.

Bog ore is used for road material on some of the secondary roads in the northern part of the county. About 8 miles west of Hiawatha bog ore has been dug from shallow deposits in T.43 N., R.16 W., and used on M-94 for a distance of several miles. Oxidation and dehydration give a bright red color to the road at this point. In the vicinity of the intersection of the "Big Ditch" with M-94 the deposits where excavated show a few inches to one foot of soft ore. In some instances there are several inches of fibrous peat below the iron oxide, with sand below the peat.

Bog ore may also be observed in the vicinity of Seney. A good exposure is found about ½ mile south of Seney on M-77. Here the ore is hard and contains considerable manganese oxide. The maximum observed thickness is about 2 feet and a thin layer of fibrous peat is sometimes found below the iron ore. Shallow deposits of one foot or less may be observed along M-28 west of Seney.

Marl (Bog Lime)

Schoolcraft Count apparently does not possess any significant deposits of marl. The lakes in the southern part of the county lie in rock basins but contain no marl deposits. This may be due to the relatively insoluble character of the surrounding rocks which are chiefly dolomite and magnesian limestone.

The lakes in the northern and western parts of the county lie for the most part in deep depressions in the sandy plains. While soundings for marl have not been conducted in any of these lakes, no marl has been observed in shallow water near the shores and it does not appear that the conditions favorable for the deposition of relatively large quantities of marl exist in these sandy plains. As may be inferred from the discussion of "bog iron" the vast areas of sand are characterized by the presence of iron oxide rather than lime carbonate. Hence it is considered probable that conditions of bog deposition in the northern part of the county are much more favorable for the accumulation of iron oxide than for the accumulation of appreciable quantities of marl.

Peat

Small areas of fibrous peat not over one foot in thickness may be noted along M-28 west of Seney. As a result of roadside ditching these deposits are now several feet above the water table. Just east of Seney there is a large Cassandra (leather-leaf) bog and farther east tamarack spruce bog. Soundings made by the State Highway Department show that there is an average depth of 10 feet of peat in this area.

The great swamp of the Manistique River (Seney Swamp) contains many bogs of this type. The Marquette Land Company has surveys covering 180,000 acres of their holdings in Schoolcraft County. Systematic soundings of the depth of peat are included in this survey, the maximum depth of the soundings being about 4½ feet. In many places, however, the total depth of peat is believed by the Survey engineers to amount to as

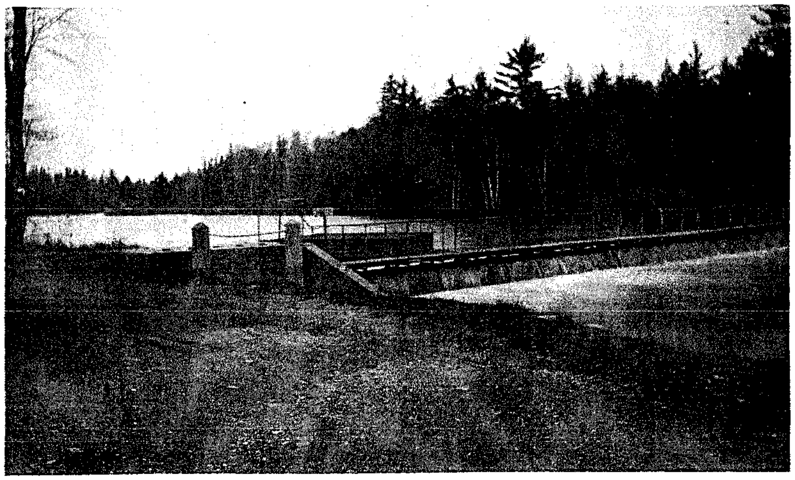


Plate IV, Figure 1. City of Manistique
Intake Park (Indian River)

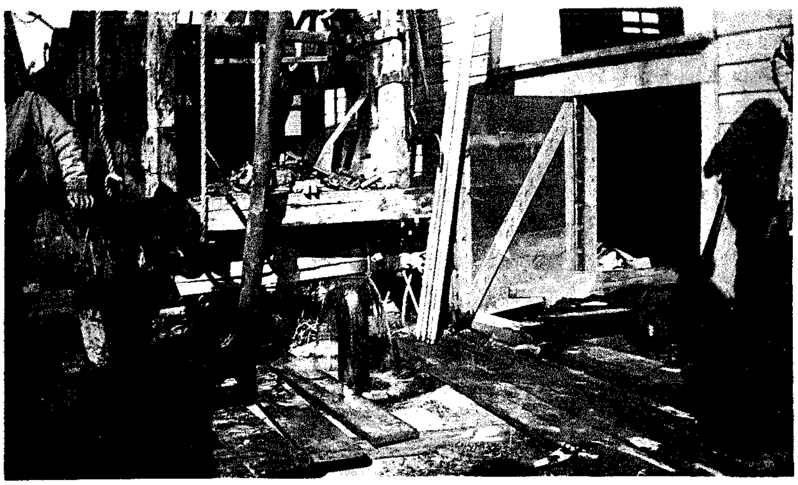


Plate IV, Figure 2. Flowing Well. Manistique much as 8 or 10 feet. The Marquette lands covered by this Survey lie in T.46 N., R.15 W., 45 N., 15 W.; 44 N., 16 W.; 45 N., 16 W.; 46 N., 16 W.; and 46 N., 17 W. Inspection of the soil and forest cover maps of the Michigan Land Economic Survey indicate, however, that conditions typical of the Seney Swamp are found in these townships. A correlation of information obtained through soundings of the State Highway Department and Marquette Land Company and by consultation with soil and forest mappers of the Land Economic Survey would indicate that the most important deposits of commercial importance in the county lie in the large spruce tamarack swamp east of Seney and possibly in a similar area north of Cusino in the extreme northwest part of the county. The peat in these swamps is probably of the woody type underlain by fibrous peat.

For delination of the areas mentioned above, the maps of the Michigan Land Economic Survey should be consulted.

WATER SUPPLIES

Water supplies in Schoolcraft County are drawn from both surface and underground sources. Surface waters are obtained from rivers and lakes, while the underground supplies are derived from the glacial drift and Niagaran limestones by means of wells.

Surface Supplies

Surface supplies of water are developed only at Manistique as a municipal source. The Great North Woods Club pipes water from Big Murphy Lake to a plumbing system in a large resort hotel, but the water is not used for drinking purposes.

At Manistique the city water supply is obtained from the outlet of Indian Lake at a point approximately one mile due north of the new pumping station. A head of about 9 feet is obtained at the dam and the water after passing over a 10-foot filter bed of gravel and crushed stone, feeds by gravity to a reservoir near the pumping station. The gravity main is 24 inches in diameter and of wood construction covered with tar paper and bound with steel hoops placed four inches apart. The first city mains were laid in 1905 and the original pressure tank was located in the eastern part of the city. This tank has a capacity of 140,000 gallons, and while not in regular use at the present time, is available for use in case of an emergency. The present system installed in 1922 has a tank capacity of 200,000 gallons and is served by two electric pumps with a capacity of 1400 gallons per minute each. The pumps are started automatically when the pressure falls below a set amount. A gasoline pump of like capacity is held in reserve for emergencies. Chlorine gas is automatically mixed with water in the proper proportions and fed into the mains.

The following table gives water consumption in the city of Manistique for the months of minimum consumption as compared with the months of maximum usage in 1931-1932:

Month	Gallons per day
December	600,287
January	611,387
February	656,965
June	773,600
July	708,258
August	713,193

Analysis of Water from Indian River near Intake

	Total Solids	SiO_2	Fe_2O_3	Ca	Mg	Na+K	Cl.	SO_4	HCO_3	CO_3	Hardness
Parts per Million	162	7.2	.31	41.0	8.2	Tr.	4.0	43.2	107.0	None	135

Manistique has an ideal location for a perfect water supply and sewage system, the water supply being taken from the relatively inexhaustible reservoir of Indian Lake to the north and the sewage discharged at a lower elevation to the

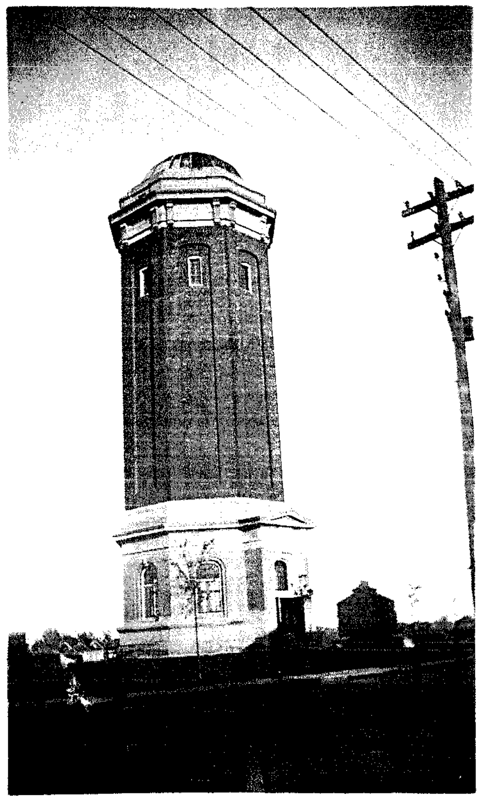


Plate V. City of Manistique - Water Works

the drift waters are obtained act as a filtering unit by means of which harmful impurities are removed. In the case of wells in limestone the water must circulate by means of crevices, bedding planes, and solution channels. Obviously little or no filtration occurs in such openings. A second advantage of drift wells lies in the fact that the water, especially in the case of the deeper drift wells, is apt to be considerably softer than that occurring in limestone. This is due to the fact that constant circulation of water through openings in limestone results in the solution of large quantities of calcium carbonate. A third advantage of drift wells is economic in character. A shallow well in the glacial drift can be constructed at very small cost. In the vast sandy plains of the northern part of the county adequate supplies of satisfactory water may invariably be obtained at depths of from 15 to 30 feet by simply driving a pipe with a well point. In more consolidated materials the well may be dug by hand or sand pumped. A deep well in the drift, however, costs as much as a rock drilled well. Shallow drift wells have one disadvantage over rock wells in that they sometimes contain considerable iron. This is the case in several localities in the northern part of the county and the water is rendered unfit for any use whatsoever. Deeper drilling, however, eliminates this undesirable feature.

Origin and Occurrence of underground Waters

In general underground waters have accumulated in one of two ways. A large percentage of the water falling as rain sinks into the earth through openings in the surface material and joint cracks in the rocks and penetrates to such depths that it is affected but little by evaporation. Waters of deep formations which contain quantities of sodium and calcium chloride, bromides, iodides, and other heavy constituents are believed to represent original sea water which was retained in the rocks during the process of sedimentation. These deep waters or brines are, however, not suitable for use as domestic or municipal water supplies. They are widely used, however, as mineral waters for therapeutic purposes. From the standpoint of general usage the underground waters of Schoolcraft County may therefore be considered to be of meteoric origin, that is resulting from rainfall. The point at which underground water is first encountered below the surface is known as the water table. Dug and driven wells ordinarily penetrate to a depth but slightly below the water table; hence the yield of such wells is affected by the seasonal variation of this level. Drilled wells seek more stable supplies at greater depth which have the added advantage of the protection from contamination owing to distance from surface sources.

Underground waters occurring in sand and gravel beds are of course contained in the pore spaces between the grains. Sand has more pore space than gravel; hence will contain a greater supply of water. Owing, however, to the small size of the openings, movement is not so rapid as in the case of a water-bearing formation in which gravel predominates. Very fine sand is also difficult to screen out of the water upon pumping. An ideal mixture of sand and gravel permits the gravel and coarse sand to pack around the screen and prevent the finer sand from passing into the pipe, the finer particles immediately adjacent to the screen being first removed by heavy pumping.

It is impossible to develop any kind of well in clay owing to the fact that any water present is too firmly held in the minute pores to permit other than a capillary movement. Wells of large diameter can be developed in glacial till which is a mixture of clay, sand, gravel, and boulders, owing to the fact that water is able to migrate slowly because of the porosity induced by the presence of sand and pebbles. There are often very thin sandy layers which permit passage of water. Dug wells are the most satisfactory type for use where water must be obtained from glacial till, owing to the fact that their large diameter constitutes a storage basin to preserve the yield of the well during heavy withdrawals. It is generally impractical to attempt development of a well of small diameter owing to the fact that the supply cannot be replenished as fast as it is drawn off. If some water is encountered in drilling a well in till, conditions may sometimes be such that by heavy pumping enough of the finer particles may be removed to create an area containing only the coarse material packed about the screen; thus forming a sort of collecting basin. Wells of this type when developed by competent drillers often yield an abundant supply of water and prove otherwise satisfactory.

Water occurs in limestones and dolomites along bedding planes, in joint cracks, and in solution cavities and channels. To make a well in limestone regions it is therefore necessary that the drill hole intersect some of these water bearing features. An illustration of the free circulation of water in limestone channels was encountered in T.42 N., R.14 W., where a farmer drilled a well which caused his neighbor's well to go dry. The neighbor drilled a second well at another location which promptly drained the original offending well. Flowing wells in the city of Manistique are all more or less affected by the heavy pumping of a well or by the drilling of a new well. It is said that practically all wells in the city increased their flow when pumping of the well at the blast furnace was discontinued. Some wells became flowing wells which previously had not flowed since before the pumping operations. Because of the free movement of water in the open channels and passages it may therefore be surmised that polluting of one or all wells may occur if the water drawn upon is subject to some source of contamination. It is reported that at one time all wells in the city of Manistique were condemned.

Types of Wells

Water wells in Schoolcraft County are of two general types, namely standard drilled wells and driven well points. Drilled wells are adapted to the limestone ridge traversing the southern part of the county and to the several areas which have a heavy type of drift cover such as from Blaney north to Germfask, and in the vicinity of Hiawatha. Driven wells are resorted to almost exclusively in the sand drift-covered areas of the northern part of the county and have a limited application in the high sandy plain several miles east of Manistique. In this area the wells are generally dug to depths of from 4 to 15 feet and points driven from 8 to 25 feet. Alternating layers of sand, gravel, clay, or hardpan are encountered in this high plain.

The hand-dug well is uncommon in Schoolcraft County as conditions are not favorable to this type of well. There are a few in the heavy morainic country south of Germfask ranging in depth from 14 to 25 feet, and several in T.42 N., R.14 W. Two of these latter, however, are little more than open holes on the edge of a swamp, utilized by backward farmers.

DIAMETER AND CASING OF WELLS

For drilled wells 5- and 6-inch casing is used almost exclusively and the casing is set a short distance below the top of the solid rock in order to exclude surface waters from the well. In drift wells the casing must of course be run to the bottom of the well to prevent caving. It is probable that in formations more or less free from prominent joint cracks, as for instance the Cordell beds of the Manistique formation, that the practice of extending the casing to beds slightly below the top of the rock may prove satisfactory. However, for rocks that are prominently jointed or contain solution channels, casing should be run to a greater depth to exclude surface waters. Lack of adequate casing also greatly reduces the efficiency of the well by permitting the bottom water to escape through crevices in the rocks. This is well illustrated in the farming area along M-94 north of Manistique which is underlain by rocks of the Burnt Bluff formation. These rocks are generally thin-bedded and fractured,and probably contain enlarged passages and solution channels due to the presence of beds of stone of higher calcium content than those of the Manistique formation. In this area due to escaping water along crevices and bedding planes, because of inadequate casing it is necessary to raise the water from 60 to 100 feet and a gasoline engine or windmill must often be employed. Some trouble from surface water is also encountered because of the seamy character of the rock. It is said that some of the wells in this area would probably flow if cased to the bottom or below the point of lateral escape of the water. Considerable difficulty was encountered in a well drilled recently at Manistique because of a crevice which existed at a depth of about 100 feet. This difficulty was overcome by setting a packer just below the crevice with a pipe of small diameter attached to the packer.

Driven wells utilize the regular $1\frac{1}{4}$-inch pipe and the dug wells where properly constructed are generally four feet in diameter and boarded up. Flat limerock or cobblestones are used in a few instances. The dug wells practically all have a wooden platform and pump installed. Only one open dug well with pail lift was noted in the entire county.

Flowing Wells

A flowing well is one in which the water rises naturally in the casing and overflows at the surface. Wells of this type were originally known as artesian wells, the name being derived from the village of Artesium (now

Artios) in France, where the first well of this type was drilled. Later, however, the term "artesian" became used rather loosely to designate any deep drilled well, whether the water over-flowed at the surface or not. Another usage designated as artesian, wells in which the water was under a head of pressure, that is rose some distance in the casing but not necessarily over-flowing at the surface.

The geologic conditions requisite for a flowing well call for a formation through which water can circulate freely, overlain and underlain by relatively impervious beds to confine the water to the strata permitting of free movement. Furthermore the beds must be inclined or dipping at such an angle that the elevation of the water-bearing bed at its outcrop is higher than the mouth of the well.

There is a belt of flowing wells in Schoolcraft County extending from Hunt Spur (Mackinac County) to Thompson in the southwest part of the county. It appears that this flowing well belt coincides fairly closely with the outcrop of the Manistique formation. It does not appear, however, that this formation is the source of the water obtained, unless the water is found very close to the base of the Schoolcraft member. It seems more likely that the flows come from the soluble limestones and thin-bedded dolomites of the upper portion of the Burnt Bluff formation. The wells at Manistique undoubtedly penetrate these beds, while the wells at Seul Choix Point and east of Whitedale are of sufficient depth to reach the lower beds of the Schoolcraft member, if not the upper beds of the Burnt Bluff formation. These conditions suggest that the cherty and dense platy dolomites of the Manistique formation form the capping layer which confines the water to the pervious beds below. This theory is strengthened by the fact that flowing wells are not obtained north and west of Manistique, although ample water occurs in the porous beds of the Burnt Bluff.

At Blaney a large flowing well taps a water-bearing bed below the Niagaran Series. Since a bed of shale is penetrated in the well it is probable that the flow comes from the Cataract formation which underlies the Niagaran rocks. The composition of the water is very different from that of the flowing wells south to Seul Choix Point (see analysis #24).

Flowing wells in the glacial drift are not numerous owing to the lack of development in the heavily drift-covered areas. Flows have been obtained at Blaney, Germfask, and Walsh.

In drilling for oil at Seul Choix Point a heavy flow of fresh water was encountered at a depth of 1370(?) feet. The water over-flowed at the top of the casing which was pulled to the top of the derrick, a height of 80 feet. This water comes from the Lake Superior sandstone. A head of 80 feet could easily be developed in this formation since the Lake Superior sandstone outcrops in Alger County at elevations of 300 feet above the level of Lake Superior. The dip is from Lake Superior southeastward to Lake Michigan at the rate of about 50 feet per mile.

Temperature of Flowing Wells

The temperature of flowing wells is affected by latitude, depth, volume of flow, and local conditions of the well as regards protection from the direct rays of the sun, and in regard to moisture conditions of the soil and sub-soil.

Leverett has shown (United States Water Supply Paper #182) that the temperatures of flowing wells in the Lower Peninsula of Michigan show a range corresponding to the range in average annual air temperature from the southern part of the State to the Straits of Mackinac. Air temperatures in the Southern Peninsula range from an annual mean of about $48\frac{1}{2}^{\circ}$ in the southern tier of counties to 42° in the extreme northeastern part of the Lower Peninsula. Flowing well temperatures, according to Leverett , show an almost identical range but average almost 4° higher than the air temperatures. Temperatures of wells should, therefore, average from approximately 52° in the southern part of the State to 46° in the extreme northern part of the Lower Peninsula. Local conditions will, of course, vary these figures.

The average annual air temperature of the Northern Peninsula is about 40°F, and the lowest observed temperature of flowing wells in Schoolcraft County is 43½°F. The highest observed is 49°F and the average for 20 wells is approximately 45°F. The wells tested in the city of Manistique all run remarkably uniform in temperature, ranging from 45½ to 46½°. Wells closely spaced in other areas and of approximately the same depth also show a uniformity in temperature.

The effect of depth on temperature is negligible within 200 feet of the surface. For the deeper wells an increase in temperature with depth can generally be observed Volume of flow is, however, very important. In a well of very small flow the time element involved permits the water to absorb more heat than if it issues from the pipe very rapidly. Since the upper layers of the ground are warmer than those below, the temperature of the water will be raised if the pipe is carried horizontally through the soil for any distance.

Tabulation of Flowing Wells in Schoolcraft County

Owner	Location	Date Drilled	Depth Ft.	Head	Temp °F.	Gal. per Min.	Driller	Remarks
Inland Lime & Stone Company	Sec.1 43N,13W	1928	173	+22 (In'l)	46	12-15	Wm. Bowman	Piped to fountains in office & plant
" "	Sec.1 43-13	1928	165	+1	45½	3	"	
Nicholson farm	Sec.1 42-13		30-40?		49	~~49~~ 2		
M.St.P.& SSM RR	Sec.22 42-13	About 1902		+1	43½	2		
" " "	Sec.22 42-13	"			43½	1-3/4		
Dave Lancour	Sec.30 42-13	1928	86½	(Est) +6	45	4	"	
Wm.Vertz	Sec.20 42-13	About 1922	75	#3	44	7½	"	
Israel Fornea	Sec.36 42-14	About 1922	88	+10 (In'l)	44	6½	"	Water has sli sulphur odor
Andrew Michaelson	Sec.25 42-14	About 1922	125		46	3/4	"	

Owner	Location	Date Drilled	Depth Ft.	Head	Temp. °F	Gal. Per Min.	Driller	Remarks
Wm.Bowman	Sec.23 42-14	About 1922	35		43½	1¼	Wm.Bowman	
Blaney Park	Sec.16 43-13		117		43½	15-20	Salter	
" "	Sec.16 43-13		17	0				Driven well On lake shore (in drift)
Gas Station Manistique East ~~City~~ Limits	41-15	1932	188	+2	45	2	Walt Bowman	
Furnace	City				46½	3		Flowing below surface in basement
Furnace #2	"				45½	5		
Park Hotel	"				46	8		Tapped at surface and led to drain. Pump installed.
Hiawatha Hotel	"				46	2		
Gas Sta.M-94 US-2	"				45½	6		Piped to fountain
M-94 2 blocks N. of US-2	"					25-30		
Cheese Factory	"	1935	241	+3	45	8	Walt Bowman	Packer set below crevice at 100 ft.
John Olson	Sec.32 41-17	About 1888	180	+3	45½	3/4		
Stearns Lbr.Co.	Sec.34 46-15	1927	184	+2	47	4		Water is slightly sulphuretted. Drift well.

Quality and Composition of Water Supplies In Schoolcraft County

Schoolcraft County is fortunate in having adequate supplies of pure water. The municipal supply of Manistique drawn from Indian Lake is filtered and chlorinated, while the supplies of all the communities are drawn from wells deep enough or otherwise protected to render them fairly safe for drinking. As previously indicated, open dug wells are very rare in the county; thus eliminating the type of well which has the greatest chance for contamination. The deep drilled wells in limestone run a chance of being polluted if the rocks are full of cracks or if channels of rather large diameter have open connections with the surface. If the rocks over-lying the water-bearing strata, however, are relatively impervious or if adequate casing is used in the more seamy rocks, there is a good chance that the water will not be seriously contaminated.

A few of the driven wells in the sandy drift deposits of the northern part of the county were found to be polluted or containing so much iron as to render them unfit for use. Pollution in even the very shallow driven wells can be avoided if the well is properly located with respect to distance from all possible sources of pollution. If such precautions are taken the water obtained by means of the shallow driven wells in the sandy drift is generally as good as, or better than, water from other sources. When local conditions are such that the water contains large quantities of iron the use of the shallow water should be discontinued and deeper drilled wells resorted to.

A comparison of the analyses of river and lake water with those from wells show that the average composition of lake and stream waters is not greatly different from water obtained from the glacial drift. Well waters from the drift, however, vary greatly among themselves, while river and lake waters do not diverge nearly so widely among themselves. This is probably due to the thorough mingling of all water brought in to the main stream by tributaries and from underground sources. In the case of well waters local conditions of the soil or sub strata may cause wide variation in chemical composition of the water obtained.

Waters from rock wells vary greatly not only among the individual wells but in comparison with drift and surface waters. The rock wells contain much larger percentages of calcium and magnesium carbonates and many of the deeper wells have a high sulphate content.

The average hardness of 14 samples of lake and stream waters from Schoolcraft County is approximately 90. Nine samples of water from wells in the glacial drift average 110 in hardness, and ten samplesof waters from rock wells have an average hardness of 520. This latter figure, however, is perhaps misleading as it includes several wells from deeper formations in which the hardness of the water is from 1000 to 1500. The waters from the more shallow formations will average from 200 to 250 in hardness.

Analyses of River, Lake, and Spring Waters in Schoolcraft County*

(Samples collected by S. G. Bergquist, Michigan State College)

	SiO_2	Fe_2O_3	Ca	Mg	Na+K	Cl.	SO_4	HCO_3	Total Solids	Hardness as $CaCO_3$
Gulliver Lake	8.8	----	30.0	13.8	3.2	4.0	10.5	149.5	154	130
McDonald Lake	4.8	.23	29.0	11.9	Tr.	4.0	15.8	123.0	132	120
Lake Michigan	5.6	---	33.5	11.2	8.0	5.0	15.1	135.0	154	130
Indian River M-94	8.8	Tr.	45.0	9.3	4.1	3.5	56.0	118.0	188	150
Intake Park	7.2	.31	41.0	8.2	Tr.	4.0	43.2	107.0	162	135
Indian Lake South End	15.2	Tr.	47.0	10.0	2.3	3.0	56.8	122.0	214	168
Driggs Lake	2.4	.23	24.0	5.6	Tr.	4.0	4.9	89.5	88	80
Ross Lake	4.0	.45	18.5	5.2	Tr.	4.0	4.0	72.5	76	68
Smith Lake	4.0	.34	5.0	1.5	4.3	4.0	6.5	20.0	36	18
Thunder Lake	4.0	---	21.5	7.3	7.6	4.0	8.8	99.0	106	82
Murphy River	7.2	---	27.0	8.2	2.7	3.0	14.8	107.5	116	100
Manistique River Sec.24,T45N, R13W	8.0	.34	28.0	6.6	8.9	4.0	25.0	93.5	134	100
Fox River-Seney West Branch	6.4	1.02	16.5	4.5	4.3	4.0	7.2	72.0	78	60
Driggs River	5.6	.74	19.5	5.0	5.0	4.0	4.9	85.0	82	70
Thompson Spring	6.4	---	21.5	13.8	9.6	4.0	5.9	125.5	133	110
Big Spring	17.6	----	230.5	21.0	3.4	6.5	532.0	130.0	878	700
Indian River Sec.34 T44N, R17W	12.8	----	27.0	7.1	5.7	4.0	6.5	113.5	124	95

*Analyses by Miss Alice Exworthy of the Michigan Department of Health

Analyses of Well Waters from Schoolcraft County*
Parts per Million

	SiO_2	Fe_2O_3	Ca.	Mg.	Na+K	Cl.	SO_4	HCO_3	Total Solids	Hardness as $CaCO_3$
Drift Waters										
1	3.2	None	31.5	8.8	Tr.	4.0	21.0	108.5	128	112
2	29.6	19.4	32.5	7.5	12.2	3.0	4.9	157.0	186	110
3	12.0	1.3	64.0	15.7	16.9	20.0	54.0	215.0	304	220
4	2.4	Tr.	4.5	2.2	Tr.	4.0	8.9	5.5	28	25
5	9.6	.34	15.5	7.2	31.7	11.0	1.3	113.5	156	68
6	4.8	None	52.5	16.8	Tr.	4.0	12.8	224.5	204	200
7.	4.8	.34	16.0	11.2	3.0	20.5	25.7	14.5	270	98
8	7.2	Tr	14.0	10.5	25.3	5.0	3.6	148.5	142	78
9	4.8	.63	21.5	8.4	Tr.	3.5	7.5	95.0	98	90
10	15.2	1.83	366	100	14	11	1180.0	134.0	1752	1300
11										
12. Limestone waters										
13.	4.0	.74	54.0	30.0	Tr.	4.0	9.9	293.0	268	258
14	5.6	Tr.	45.5	21.2	2.9	5.0	5.2	234.5	184	200
15	7.2	.63	42.5	21.6	Tr.	4.0	9.9	219.0	194	195
16	8.0	.51	45.5	22.0	1.4	3.5	6.6	239.0	208	204
17	11.2	1.2	173.0	62.0	46.8	100.0	425.6	249.0	960	680
18	6.4	None	40.0	20.0	9.2	3.0	4.6	235.0	194	182
19	7.2	None	43.0	20.4	3.9	3.0	5.3	232.0	198	190
20	9.6	Tr.	340.0	44.8	Tr.	5.0	870.0	157.0	1346	1050
21	6.4		126.5	54.8	20.2	6.0	440.0	144.5	726	540
22	8.8	.17	170.5	59.6	43.8	75.0	480.0	192.0	928	668
23	5.6	.34	45.5	19.9	9.6	10.0	17.0	204.5	232	195
24	8.8	.51	560.5	43.2	5.5	16.5	1368.0	172.5	2160	1580

*Analyses by Miss Alice Exworthy of the Michigan Department of Health

Underground Water Supplies of Schoolcraft County

City of Manistique

About 1890 the Chicago Lumber Company, which owned most of Manistique at that time, drilled wells at convenient intervals over the city to secure water for drinking and household purposes. The exact number of these wells is not known, but 18 pumps have been installed by the city and many residents prefer the well water to the municipal supply for drinking purposes. The wells are said to vary from 160 to 250 feet in depth, but the chemical analyses of the water from several of these wells indicate that the water in the wells must come from one of the deeper formations.

About one-half dozen of these wells are flowing open at the present time, and several others have been tapped below the street level and led off to the drain. A number of the wells are still flowing a large stream in spite of the fact that they were drilled 40 or more years ago. The well at the Park Hotel is said to behave in a peculiar manner; when a south wind is blowing the well flows much heavier than when the wind is blowing from the north. In the latter instance the flow is aaid to sometimes stop altogether. It is possible that this phenomenon is due to barometric pressure. With a north wind blowing it is likely that the barometer is high and the result is to depress the well. With a south wind the barometer is apt to be low and the effect on the flow will be the reverse of that in the case of high atmospheric pressure.

Village of Blaney and Blaney Park

All water supplies for Bear Creek Lodge, Celibeth Tavern, the store and cottages are derived from two five-inch wells located about 10 feet apart between the store and Bear Creek Lodge. The wells are about 48 feet in depth and the water is drawn from a stony gravel. The supply, which is ample to meet all demands, is pumped by windmill to a pressure tank for the purpose of furnishing tap water to the hotels and cottages. In addition to the hotel supplies there are rock wells at the gas station, tourist camp, farm, and at the foreman's house. These wells are all grouped about the junction of U.S.2 and M-77, where the glacial drift is thin, the depth to rock varying from 6 to 14 feet, and the total depth of the wells ranging from 62 to 200 feet. There is a strong flowing well at "Beaver Bills" 117 feet in depth, 72 feet of which is in rock. The water from the well is extremely hard, containing large quantities of calcium sulphate. The other rock wells clustered about the road corners have a normal hardness of about 200. The main supply at the hotel is fairly soft, having a hardness of only 112 (analysis #1).

Other wells at Blaney Park consist of three driven wells from 18 to 26 feet in depth at Tee and Ford lakes. There is a shallow driven well 17 feet deep at Lake Anne Louise, which flows a small stream. The driven wells are said to yield much better water than the deeper wells in limestone.

Whitedale (Gulliver) and Vicinity

Water supplies of this area are all obtained from drilled wells in the Niagaran limestones and dolomites, varying in depth from 35 to 240 feet. Many of the wells east of Whitedale along the Soo Line and South to Seul Choix Point are flowing wells. These apparently draw their water from the lower part of the Manistique or the upper part of the Burnt Bluff formation. Some of the shallow wells may get water from the Cordell beds of the Upper Manistique member. The water from wells less than 200 feet in depth is of average hardness, running about 200 parts per million, but deeper wells may carry larger quantities of calcium sulphate. (See analysis #17). The wells are all six inches in diameter and casing is set below the weathered surface rock. Generally, however, it is not necessary to set over one length of pipe. The water is generally under considerable head of pressure and rises to some height in the pipe. In some instances, however, there is no perceptible head.

Village of Germfask

Most of the residents obtain water from four drilled wells. Two of these are located on the main thoroughfare of the village and belong to the township. A third well is located at the school and there is a flowing well near the bridge on M-98. The well near the hotel is 65 feet deep and the water comes from a bed of gravel overlying the solid rock, and rises to within five feet of the surface. This is apparently the same vein of water which produces the flowing well on the river banks about 18 feet lower than the well at the hotel. The other wells in the village are about the same depth with bed rock at 60 to 65 feet. The hardness of the water at the hotel is 220. (Analysis #3).

Water is also obtained at Germfask by means of shallow driven wells 12 to 20 feet in depth. The water obtained from these wells, In the farming country north of Cooks it is usually necessary to drill 100 feet or more for water. None of the wells are flowing and it is said that the water rarely rises more than 20 feet in the hole. Drift generally runs from 10 to 40 feet in thickness, but at one place 63 feet of drift are reported.

Hiawatha and Vicinity

The region about Hiawatha is an elevated tract consisting of a heavier type of soil and glacial drift than the areas to the north and south. Water is generally obtained at depths of from 35 to 50 feet, although several wells are deeper than this. Two wells 45 feet in depth in section 11, T.43 N., R.16 W. were dug by hand to a depth of about 20 feet, and a point was driven to 48 feet. A thin seam of clay was encountered in one of these wells, but otherwise driving was said to be not difficult.

The resorts on Island and Dodge lakes have dug and driven wells ranging in depth from 15 to 30 feet. The presence of clay here hampers the construction of wells by driving a point from the surface, and water is not obtained at nearly so shallow depths as would be suggested by proximity to the lake shore. One well on Island Lake is dug 16 feet and a point driven six feet. The presence of a thick bed of clay above the water-bearing strata should provide excellent protection for the water supplies obtained below.

Village of Seney

The chief water supplies are obtained from six deep wells drilled on the township water fund. The wells range from 100 to 115 feet in depth and 4-inch casing is used. The water comes from a bed of gravel and is pure and very soft. (Analysis #5). The structure of the drift at Seney is unusually favorable for obtaining large supplies of pure water by deep drilling. The upper 60 feet of the drift is reported as yellow sand, with hard blue clay, requiring water for drilling from 60 to 100 feet, and below this a bed of gravel is encountered. The water from the gravel bed is under a considerable head of pressure and rises almost to the surface. The well at the school flowed when first drilled, about 40 years ago.

Shallow water supplies are also obtained at Seney by means of driven wells in the sandy drift at depths of from 15 to 25 feet. One of these wells was sampled and found to be contaminated, but this condition is undoubtedly due to improper location and gross negligence in protection of the well. The water was analyzed and found to be extensively low in mineral matter (analysis #4). It is very probable that if shallow driven wells in the vicinity of Seney are correctly located with reference to sources of pollution and are properly protected, that these wells may be made to yield satisfactory water. Several residents along the Fox River road west of Seney report water from the shallow driven wells to be of excellent quality.

Water from the West Branch of the Fox River is used for locomotive boilers. Analysis of this water shows that it has a very low content of incrusting solids and corrosive elements; hence should be excellent for boiler use.

Steuben

The community water supplies are obtained from 8 or 10 driven wells from 24 to 28 feet in depth. The water is said to be good but rather hard. Bacterological tests of samples from the well at the hotel showed the water to be free from contamination.

Great North Woods Club

Water for drinking purposes is obtained from six driven wells averaging about 20 feet in depth. The water is said to be very good and it has been approved by the Michigan Department of Health, according to club officials. All cottages operated in connection with the hotel have chemical toilets, and the hotel has a plumbing system, so that there are few apparent sources for contamination of the drinking supply. Water for the plumbing system is piped from Big Murphy Lake and pumped to a pressure tank for supplying the hotel.

Dishneau's Resort

Water for drinking is obtained from a shallow driven well twelve feet in depth, located on the shore of Thunder Lake at an elevation 127 feet below the cottage sites. In view of the inconvenience of hauling water up a very steep hill and the possibilities for contamination of a shallow well located at the base of the hill and adjacent to picnic grounds, it is suggested that a deep drilled well in the center of the group of cottages would furnish a much more convenient and satisfactory source of water.

Other Localities

Driven wells from 20 to 30 feet in depth are utilized at Lilly-Boot Resort, Jack Pine Lodge, Lavender Corners, Stearns Lumber Company (Section 27, T.47 N., R.15 W.), The Pines, Juneau & Fortier lumber camp (Sec.23, T.42 N., R.17 W.), and other places in the northern and western parts of the county. The water obtained is generally satisfactory and safe for drinking.

Indian Lake Resorts

"Harrison Beach" , "Copenhagen", "Ossi Beach", "Rowe's Beach", "Reilly's Beach"

At Harrison Beach there is one deep well 127 feet deep which is the source of supply for most of the resorters. There are a few driven wells 10 to 15 feet in depth, but the water is said to be generally unsatisfactory for drinking. It is 27 feet to bedrock at this beach. At Ossi Beach C.S.Hovey has two wells drilled into the bedrock. One of these is 125 feet in depth and water is encountered at 76 and 96 feet. The water at the 96 foot level rose in the pipe to within 16 feet of the surface and stands at that level. The other well is 107 feet deep and is said to have a sulphur taste. A third well on this beach is located at the Nicholson cottage and is 111 feet in depth.

At Copenhagen Beach water is carried from a spring and at Arrowhead Inn water is drawn from a spring on the lake shore, by means of an electric pump. At Rowe's Beach water is obtained from a driven well 27 feet deep, and at Reillys there is a drilled well 128 feet in depth. It is 70 feet to bedrock at this latter place.

Springs

There are a number of very interesting large springs in the vicinity of Indian Lake. Several of these are of considerable economic importance for water supplies and one of these, the "Big Spring," is a scenic wonder. The utilization of springs for water supplies at Indian Lake and at Thompson has been mentioned. At the new Thompson fish hatchery a large spring furnishes the water for operating the station. This spring issues at the base of a big bluff and has formed a pool four feet deep and 25 feet across. The water boils up strongly at several points in the bottom of the pool. The outflow of the spring is 1500 gallons per minute, which is in excess of the normal requirements of the hatchery. The water has a temperature of 45° in the troughs.

There is a strong spring arising in DuFour creek about 100 yards upstream from the bridge on the Thompson road. Here the collecting area is in the side of the bank and is about 10 feet across and five feet deep. The spring boils up strongly in the bottom and forms the source of supply for an adjacent farmhouse.

It is said that Silver Creek on the west side of Indian Lake also arises from a big spring.

The "Big Spring" is about 175 feet across and 40 feet deep. A sizeable stream issues from the pool formed by the spring. The collecting area of the water which issues at the "Big Spring" undoubtedly lies somewhere to the north or northeast of Indian Lake where there is ample altitude to furnish any amount of pressure head. Wells which have been drilled in the vicinity of "Big Spring" and Indian Lake give some clue to the conditions possibly causing the flow. In the well at the spring 29 feet of soft clay was encountered at the surface; below this 8 feet of fine, hard sand and clay; then 8 feet of hard gravel, sand, and clay; and $10\frac{1}{2}$ feet of quicksand and hard strata, with fine sand and gravel at 55 feet 8 inches, yielding ample water which rises 48 feet in the pipe. It is probable that the well taps the same stream of water which forms the spring. At Reilly's on the west side of Indian Lake 70 feet of clay overlies the bedrock. Near the new Thompson fish hatchery there is a bed of clay 8 to 10 feet thick underlain by sand. At Parker's Resort just south of Indian Lake 105 feet of sand above bed rock is encountered. Records of these wells indicate that the water-bearing bed is confined by a heavy bed of clay and that the gravel bed which carries the water may pinch out in clay or else the perviousness of the gravel bed greatly decreased by the presence of fine sand and clay as indicated by the lower part of the record of the well at the State Park. A strong back-pressure would be developed by these conditions.

Chemical analyses of water from the "Big Spring" and from the well about 100 feet to the northwest support the geologic evidence that the water arising from the "Big Spring" and that obtained from the well are derived from the same source. According to the evidence obtained from inspection of the soil samples and driller's log of the well, the water from both of these sources is derived from a bed of sand and gravel at a depth of about 55 feet.

Analyses of water from the spring and from the well are entirely inconsistent with the results obtained from analyses of 25 other samples of water from lakes, rivers, springs, and drift wells, taken at various places in the county. The water from the "Big Spring" has a content of SO_4 amounting to 55[illegible] parts per million, and a total hardness of 700; while the water from the well has an even greater sulphate content amounting to 1180 parts per million with a total hardness of 1300. Practically all of the sulphate determined in these analyses is present as calcium sulphate.

The maximum sulphate content of **sixteen** samples of water from lakes, streams, and springs in Schoolcraft County is only 56.8 parts per million at the south end of Indian Lake, 53 parts per million in Indian River at the M-94 bridge, and 43.[illegible] parts at the municipal intake about one mile below the bridge. The Manistique River a few miles northeast of Germfask has a sulphate content of [illegible]5 parts per million, and the average of 12 other samples from various parts of the county is only 8.7 parts of SO_4 per million. The spring at Thompson which arises under hydrostatic pressure and which is a miniature of the "Big Spring," shows a sulphate content of only 5.8 parts per million.

Similarly wells obtaining their supply from the glacial drift show a maximum sulphate content of 54 parts per million and an average content of 16.5 parts per million for nine samples from various parts of the county.

In the case of wells drilled into the underlying limestone and dolomite, three wells out of twelve samples show sulphate content ranging from 425 to 480 parts per million (see anal. 17, 21, 22). One well contains 870 parts per million and one contains 1368 parts per million (analysis #24). The remaining seven average only 8.3 parts per million. These latter are also located in the county and of such depths that they do not penetrate the lower members of the Niagaran. Analyses 20, 21, and 22 are from wells in the city of Manistique which appear to draw their supplies from the lower beds of the Niagaran series. Although no free gypsum can be observed in samples from one well on Garden Avenue, or in samples of the Niagaran from the well at Seul Choix Point, the fact that no shale is encountered to a depth of 240 feet indicates that the water comes from the Lower Niagaran. Analyses No.24 was made on water from a well which penetrates below the Niagaran beds and obtains a strong flow of water extremely high in sulphates underneath a bed of shale 25 feet in thickness. This shale bed appears to constitute the top of the Cataract formation as recorded in the log of the well at Seul Choix Point. Abundant calcium sulphate in the form of brown anhydrite with lesser amounts of gypsum is present in the samples of the upper part of the Cataract formation. Reddish gypsum and anhydrite are also abundant at the top of the Cincinnatian group about 100 feet below the top of the Cataract formation.

In view, therefore, of the great difference in chemical composition of the water from the big spring and the adjacent well as compared to glacial drift and surface waters, and its similarity to certain waters from the lower rock formations, it seems logical that the immediate source of the water forming the "Big Spring" is to be found in the Lower Silurian or Upper Ordovician rocks, the water finding its way to the surface through enlarged joint cracks, fissures, or solution channels.

Assuming the immediate source of the "Big Spring" to be the above mentioned formations, it appears that we may look for the ultimate source of the water in the glacial drift, swamps, and lakes to the north, the water from these sources entering the rock beds which outcrop immediately below the drift and passing southeastward along the dip build up a sufficient head of pressure to produce flowing wells or springs wherever a point of issue may be naturally or artificially formed.

It is possible that some of the other springs in the vicinity of Indian Lake may have an origin similar to that of the "Big Spring" but analyses are not available to make comparisons as to the character of the water. An analysis of the Thompson spring shows the water to be of an entirely different character, probably of drift origin.