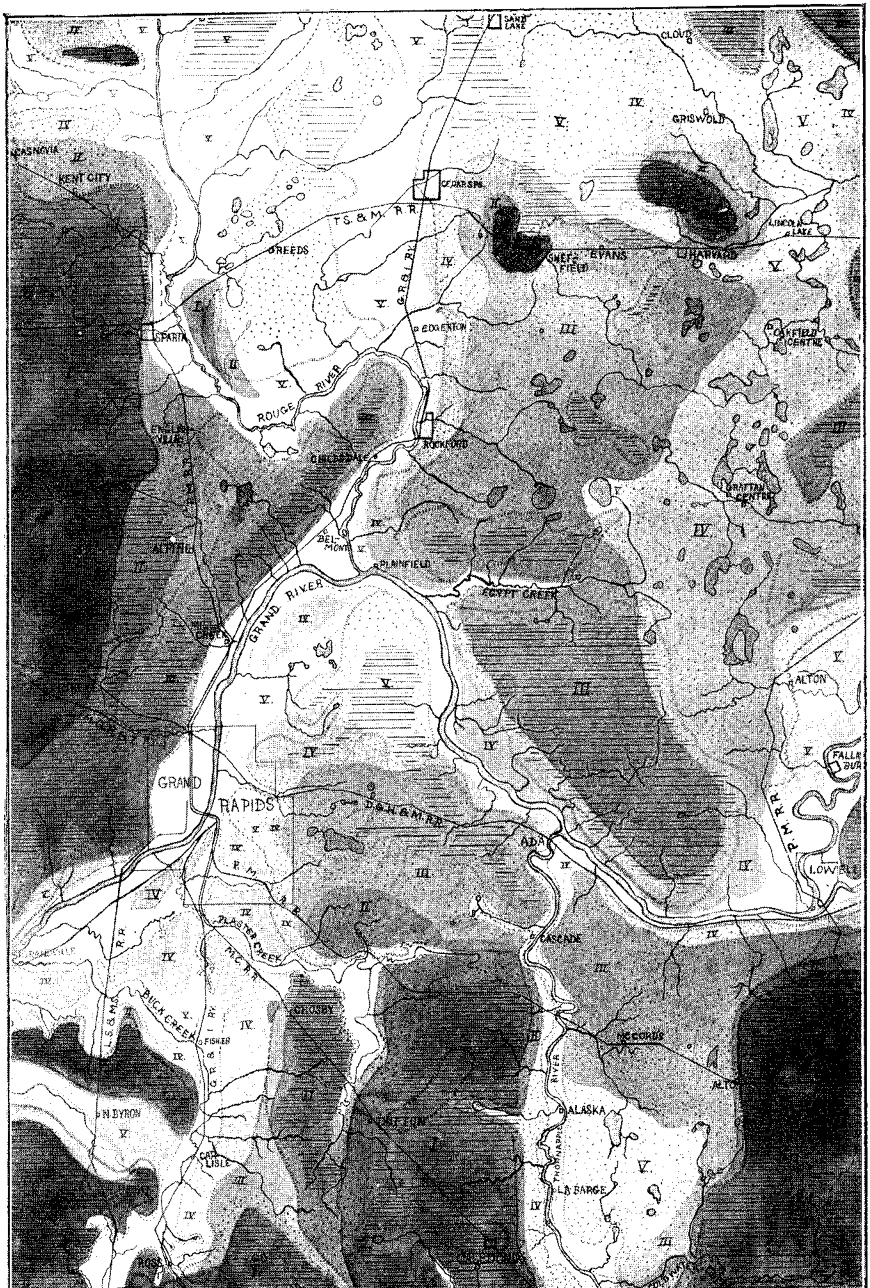
THE DISTRIBUTION OF THE PLANT SOCIETIES OF KENT COUNTY, MICHIGAN

BURTON EDWARD LIVINGSTON



UPLAND PLANT SOCIETIES KENT CO., MICHIGAN.

MORAINE MARGIN
TILL PLAIN MARGIN
CHANNEL MARGIN
CLAY AREA
LOAM AREA

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INTRODUCTION.

1. *A New Field for Research.*—It is a matter of common knowledge that the vegetation of any extensive area is made up of a greater or less number of plant species mingled and growing together. It is also generally known that these different species naturally fall into a number of somewhat distinct groups, giving to certain tracts of country an entirely different aspect from that of other tracts nearby. One who has traveled about the Southern Peninsula of Michigan can hardly have failed to notice, for instance, the differing vegetations of the pine plains, the oak forest, and the beech and maple forest. There is hardly a single plant found common to the first and last of these groups. They are as distinct as would be so many human commonwealths composed of different races of people. It is with the study of such plant groups that the present paper has to deal.

In some instances the study of these groups of plant forms has been undertaken by geologists, and their part in the work has been marked by the frequent use of the geological term *formation* to designate the groups. The word is still in use by many students of the subject, especially with reference to the larger and more comprehensive complexes. Among botanists the term *plant society* to mean the same thing has been suggested and quite largely used within the past few years. It seems somewhat more appropriate than the other word, on this account, at least, that it implies the idea of an organism and organic unity rather than that of a unity of mere juxtaposition in time and space. The latter word will be used throughout this paper.

A plant society, then, is a group of several or many species growing together over some more or less extensive area, and characterized by an apparent congeniality and community of interest, such that all thrive under the same general conditions. Since for any large area the ground will be occupied, not by a single society but by several, which will alternate with each other in some irregular manner, the next logical step after the determining of the societies themselves, will be to attempt the formulation of whatever principles may underly their arrangement or distribution over the surface of the region. How far success or failure has attended the attempt here made to determine some of the principles which underlie the distribution of the plant societies of Kent county, can be judged better at a later day, but it is hoped that this paper may stimulate and aid the prosecution of similar studies in related regions. Another more special reason for this research is this, that if the flora of these more thickly settled counties is ever to be studied and recorded, this work must be done soon; the present vestiges of the former primeval flora are fast disappearing.

Plant distribution has been a common subject for discussion among botanical authors for over a century, but (aside from the discovery of a few broad climatic factors which seem to determine the distribution of great vegetation types over world areas) little of a definite and satisfactory character has been attained. This is perhaps in great part due to the fact that *species* and not *societies* have usually been studied, thus causing general principles to be lost sight of in a mass of detail whose organization proved well-nigh impossible. It may also be due, in part, to the broad areas chosen for investigation, and the hasty and superficial study which of necessity resulted. Perhaps this general birds-eye viewing had to be done to prepare the way for more exact work, but it seems that enough of it has now been accomplished. What is needed now, if there is to be formed even an acceptable working hypothesis of the principles of plant distribution, is the careful and exhaustive study of areas of limited extent. Once having these studies at hand, comparisons between the different areas may be instituted, and thus, perhaps, some sort of a universe may be forthcoming from the present chaos.

2. *Literature.*—On account of the comparative newness of what may be termed the *society method* of study, as contrasted with the older species method, there is very little literature which can have any bearing on the present work. By far the most valuable paper which has come to my notice is that by Dr. T. C. Chamberlin,[1] of the University of Chicago, on the native vegetation of eastern Wisconsin. But the development of the society method of study for limited areas has, so far, been almost entirely due to the work of Dr. H. C. Cowles and his students. In his recently published account of the plant societies of the Chicago area[2] Dr. Cowles has given an excellent review of the most important articles upon the general subject of plant societies. It will therefore be unnecessary to enumerate them here, espcially since they have no direct bearing upon the flora of the region here studied. In this paper the author makes an attempt to classify the plant societies of the Chicago area according to the physiographic stage of the land which they occupy. For instance, the life history of the flora of a typical ravine in a clay moraine is here traced out in some detail, from its beginning as a small gully in the hillside, through all the physiographic changes accompanying the progress of erosion, to its temporary culmination in a broad flood plain. The thesis of the article is briefly this: that as the physiography of the land surface changes, so must the vegetation clothing it change also. Other papers having a very close bearing upon the historical aspects of our problem are another one by Dr. Cowles,[3] and the still more recent one by Mr. H. N. Whitford.[4] The bearing of these papers upon the conclusions here brought out will be introduced in connection with the development of the present work.

[1] Chamberlin, T. C.: Native Vegetation of Wisconsin. Geology of Eastern Wisconsin. 2:176. 1873—1877.

[2] Cowles, H. C.: The physiographic ecology of Chicago and vicinity; a study of the origin, development, and classification of plant societies. Bot. Gaz. 31: 73-182, 1901. *Idem:* The plant societies of Chicago and vicinity. Bull. Geog. Soc. of Chicago. 2:1-76. 1901.

[3] Cowles, H. C.: The physiographic ecology of Northern Michigan, Science 12: 708, 709, 1900.

[4] Whitford, H. N. The genetic development of the forests of Northern Michigan; a study in physiographic ecology. Bot. Gaz. 31: 289-325, 1901.

3. *Kent County, its Climatology.*—Kent county is so situated that it is traversed both by the southern boundary of the pine forest region and the eastern boundary of the so-called Michigan peach belt. It is also crossed by the Grand river valley, the line of one of the great main channels by which the melting ice of the glacial period reached the Mississippi system and the Gulf, and also the line marking the farthest northern extension within the peninsula of many typically southern plants. The county embraces a rectangular tract of land 24 miles by 36 miles in extent. Its western boundary is a meridian averaging about 23 miles east of Lake Michigan at its widest part. The lacustrine influence upon the climate is probably felt throughout the county. Owing to the comparatively small extent of area, differences in climate between its different parts could hardly be pronounced enough to cause any marked difference in its vegetation. Also on account of the great distance apart of the stations for meteorological observations, if there were lesser differences between the climates of different portions of the county, such would not be brought out by any records which have been made. Therefore a study of these meteorological data will give no clue to the principles underlying plant distribution within our area. The following tables are given here, not that they may be of any use in the present report, but that they may be on hand when this area is to be compared with another. They give the data by months for such stations as lie within or near the county:

AVERAGE TEMPERATURE BY MONTHS FOR THE KENT COUNTY REGION.[5]—DATA ARE IN DEGREES FAHRENHEIT.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
White Cloud	......	......	......	44.6	55.9	65.9	72.0	67.8	61.0	51.6	39.4	27.5
Stanton	23.6	22.6	25.9	......	54.9	65.6	69.7	65.8	60.5	47.0	33.9	19.3
Muskegon	24.2	21.7	30.2	44.7	55.2	65.5	69.8	67.9	62.1	49.9	36.9	28.2
Grand Haven	24.2	25.0	30.6	43.6	53.7	64.4	68.8	67.0	60.9	49.6	37.1	26.4
Ionia	......	......	32.0	46.0	......	68.2	72.0	69.4	61.2	50.8	37.4	26.1
Grand Rapids	24.8	24.9	31.2	47.2	59 0	68.2	72.3	69.2	62.3	49.0	37.4	30.9
Waverly	......	21.2	31.8	......	55.6	......	......	69.3	61.6	49.4	37.0	27.1
Hastings	23.4	25.0	31 6	46.0	57.7	67.7	71.2	68.7	61.6	49.4	37.4	29.6
Allegan	23.7	24.2	33.8	47.7	......	68.6	72.2	69.3	63.1	49.1	37.5	30.2

[5] These tables are compiled from the reports of the Michigan section of the U. S. climate and crop service.

AVERAGE PRECIPITATION BY MONTHS FOR THE KENT COUNTY REGION.[5]—DATA ARE IN INCHES.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
White Cloud	......	......	......	2.40	7.15	2.09	2.96	1.32	2.52	3.00	1.37	1.99
Stanton	......	......	......	1.98	......	......	......	1.93	3.34	2.36	2.47	2.05
Muskegon	4.36	2 32	1.85	1.61	2.59	1.48	2.55	1.30	3.27	2.32	2.20	1.76
Grand Haven	2.66	2.21	2.29	2.53	3.42	3.87	2.71	3.67	3.55	3.22	2.99	2.65
Ionia	......	......	......	1.67	......	2.02	1.94	1.17	2.84	1.97	1.99	2.36
Grand Rapids	2.87	2.76	2.18	2.74	3 34	4.53	2.82	2.56	3.12	2.91	3.15	3.09
Waverly	......	1.94	3.18	......	2.58	......	......	1.22	4.20	2.13	3.11	2.59
Hastings	2.60	2.03	2.12	2.68	4.02	4.06	2.26	2.74	3.12	2.62	3.11	2.98
Allegan	2.42	2.22	......	2.66	4.50	2.67	2.73	2.33	3.07	2.47	2.77	2.98

4. *Geology of the County.*—The bed rock of the area is almost entirely covered to a great depth by glacial drift, only a few small outcrops being found within its limits. A small portion at the northeast angle is underlain by the Jackson coal-bearing strata, a correspondingly small area in the extreme southwest is underlain by the Marshall sandstone, and all the intervening drift rests upon the formations of the Grand Rapids group.[6] The drift is so deep throughout the county that the underlying rock layers have apparently no influence upon the vegetation.

The drift itself presents some very interesting features[7] and, since these have an important bearing on the problem of vegetational distribution which confront us, it will be necessary to describe them in some detail.[8] The land consists, in general, of two great blocks of till upland lying on either side of a much lower gravel and sand plain of varying width, which extends in an irregular line from about the middle of the northern boundary (see map, Plate III) southward through Cedar Springs, Rockford, Plainfield, Grand Rapids, Fisher, Carlisle and Ross, and cutting the southern boundary about three miles east of the southwest angle of the county. This plain traces the path of the outflowing water as the Michigan ice sheet retreated northward at the end of the last glacial epoch. An indentation or embayment in the southern ice margin during this retreat marked the junction of the two lobes of the glacier, the eastern lobe coming from the region of Saginaw bay, the western from that of Lake Michigan. It was naturally into this embayment that much of the water was discharged during the melting process, and the line of sandy plains just traced marks, from Carlisle northward, the path of this gradually retreating notch in the edge of the ice. Southward of Carlisle the Green lake sand and gravel plain (in Allegan and Barry counties) originated in the same way.

[5] These tables are compiled from the reports of the Michigan section of the U. S. climate and crop service.

[6] See Geological Map of Lower Michigan, compiled by A. C. Lane, Mich. Geol. Sur. V, 1893.

[7] For aid in interpreting the glacial topography I am indebted to Mr. Frank Leverett, of the U. S. Geological Survey.

[8] A brief description of these features, by Dr. A. C. Lane, will be found in the introduction to Miss E. J. Cole's Grand Rapids Flora. Grand Rapids, 1901.

Three well marked terminal moraines lie partly within this area. The one earliest formed merely bends across the southern boundary, lying south of a line drawn from Ross to a point about two miles east of Carlisle, and thence out of the county in a southeasterly direction to Middleville and Hastings (Barry county). When this material was deposited, the embayment between the two glacial lobes had its head north of Green lake (Allegan county), and its outflowing water found its immediate outlet southward. It formed by its outwash the great triangular plain—which I have designated by the name *Green lake*—bounded on the north by a line drawn from Green lake to Irving (Barry county), and on the west by one from Green lake to Bradley (Allegan county). This plain and its margins being the only regions studied south of the Kent county line, it was thought unnecessary to include it on the map. The highest point of the moraine just mentioned is just east of Corinth. This is the junction point of the two moraines formed from the Saginaw lobe on the east and the Michigan lobe on the west. Thus the high land lying to the east of a line joining Green lake and Corinth is composed of materials from the region of Lake Huron and farther north, while that to the west is composed of drift from the Lake Michigan and Lake Superior region.

The second moraine passes through the middle of the county. Its southern edge is marked by the Grand river valley, its eastward termination being the margin of the plain of Flat river. The escaping water, at the time of its formation, found its way out to Lake Michigan apparently by two channels, one being the present valley of the Grand from Grand Rapids westward, the other extending directly southward to Ross, where it also began to bend toward Lake Michigan. The highest point, marking the junction of the two lobes, lies north of Plainfield.

The northernmost moraine has its highest point northeast of Cedar Springs. The sand plain formed by the outwash here extends from a point about three miles north of Cedar Springs south through Edgerton to Rockford. Its width north of Edgerton is from four to five miles, but near this village it begins to narrow rapidly and is joined by the Rouge valley. South of here the outflow of water cut a deep channel about one-half mile wide through the last moraine described, from a point about a mile and one-half north of Rockford to Childsdale. There the glacial stream entered the plain of the previous outwash. Following the old line of flow it cut a new channel in the already existing plain. Where the old plain divides, south of Grand Rapids, the newer channel is found to do the same. One of the branches follows the present Grand, being, of course, much wider than the flood plain of that stream and extending from the moraine margin about two miles farther to the southeast than the line of the Holland division of the Pere Marquette railroad. This railroad roughly traces the marginal line of the present flood plain. The other channel extends from the point where the Michigan Central railroad leaves the Grand Rapids & Indiana railroad, southward to Ross, thence southwest to Lake Michigan.

Besides the plains just described, there are very pronounced though narrower sand-gravel plains forming the valleys of the Rouge and Thornapple rivers, and a broader one through which the Flat river meanders.

Most of the surface soil throughout the country is predominantly sandy. There is so much sand in the till that almost every creek valley is a miniature sand-gravel plain. Especially is this true of Plaster creek, southeast of Grand Rapids, and of the larger creeks in the northern portion of the county. In classifying soils and designating them on the map, no attempt has been made to distinguish the different gradations between clay and sand. All which could not be termed either clay or sand have been bunched together as loam,—in the broadest sense of that word,—and denoted on the map by dots. More accurate records were made, but it was found that these minor differences of soil bore no apparent relation to the nature of the societies recorded, and it was thought best not to encumber the map with unnecessary details. Clay is denoted on the map by horizontal lines, sand by an absence of any marking. It will be noticed that moraine and till plain margins are not always the boundary lines of soil areas. This is explained by the fact that the sandy soil almost invariably borders and faces whatever escarpment there may be along a moraine or till plain edge; indeed, it often extends back from the edge for several miles on the higher level. This is true for even slight depressions. Anyone who has ridden a bicycle through Michigan must have noticed that where the road is on a higher level it may be hard clay, but where it descends to cross a creek the slopes and bottom of the valley are usually sandy. This illustrates the fact just stated. The process of erosion by which this condition of things is brought about is going on rapidly at present; the creek valleys are becoming more sandy rather than less so. On account of their small area, no attempt has been made to map these sand and gravel deposits. They are to be understood as existing along most of the creeks and about many of the lakes.

METHODS.

The studies here reported were begun at the suggestion of the State Geologist, Dr. A. C. Lane, in the autumn of 1900, and were completed in the summer of 1901. The author's previous botanical study in the vicinity of Grand Rapids, although not made definitely for this purpose, has been of value in the present work.

Owing to the large proportion of cultivated land in the county, and the correspondingly small proportion which is in an approximately natural state, a study of the natural plant societies is necessarily a difficult one. In the middle of a section, and hence farthest away from the roads, is usually quite a stretch of wooded land, and throughout much of the county these wood lots at the rear of the farms have been the field of observation. From these areas, taken here and there,—samples of the original vegetation, as it were,—an attempt has been made to reconstruct, as accurately as possible, the plant societies which occupied the region at the time of settlement. The effects of pasturing in these wood lots have been allowed for as far as possible. Information has been gathered from local residents as to the nature of the forest which was removed in making certain fields ready for the plow, and has been of great service in some instances.

The vegetation of the area falls naturally into two groups, that growing on what is commonly termed dry ground and that found in moist or swampy places. Each of these groups can be separated into several societies, which often merge gradually into one another so that in some localities it appears that we have a mixture of several of them. But in general the division is sufficiently well marked. In the following discussion the two primary groups will be taken up separately.

THE UPLAND SOCIETIES.

1. *The Societies Characterized.*—The range of altitude over the whole county is less than 400 feet, so that absolute altitude itself, with its concomitant variations in climatic conditions, is not a factor in the distribution of the flora. Differences in *relative* level, however, produce marked variations in the drainage, and hence in the water content of the soils. This is an important factor in plant distribution.

The vegetation of the upland falls into five societies, which may be characterized as follows:

I. Beech-maple Society, comprising as predominant and characteristic the following plants: Beech, sugar maple, enchanter's nightshade (Circæa), wild licorice (Galium lanceolatum), wood nettle (Laportea), catnip (Nepeta), pokeweed (Phytolacca), richweed (Pilea), nightshade (Solanum nigrum), and red-berried elder.

II. The Maple-elm-agrimony Society, comprising: sugar maple, American and rock elms, agrimony, spikenard (Aralia racemosa), honewort (Cryptotænia), spice-bush (Lindera), moonseed (Menispermum), black snake-root (Sanicula), and wild black cherry.

III. The Oak-hickory Society, comprising: white and red oak (*Quercus rubra-coccinea*), shag-bark and pig-nut hickory, false Solomon's seal (Smilacina racemosa), northern bedstraw (Galium boreale), Aster lævis, and panicled cornel. This society is much the same as the following, but with the addition of the two hickories. It also has many plants in common with the previous society, and may be regarded as an intermediate type between II and IV, both of which are much more distinct. Owing to the difficulty of distinguishing sharply between *Quercus coccinea* and *Q. rubra*, these two forms have been brought together under the name *Q. rubra-coccinea*.

IV. The Oak-hazel Society, comprising: the white and red oaks, Aster lævis, A. macrophyllus, New Jersey tea, hazel, spurge (Euphorbia), Helianthus occidentalis, Solidago cæsia, and hoary pea (Tephrosia). The spurge found in this society is the broad-leaved form. In the following society this plant is just as common and characteristic as here but there it has much narrower leaves. The individuals of the broad-leaved form appear stronger, greener, and more robust than the others.

V. The Oak-pine-sassafras Society, comprising the white and red oaks, white pine, sassafras, plantain-leaved everlasting (Antennaria), wormwood (Artemisia), sand bur, spurge (narrow-leaved form), huckleberry (Gaylussacia), lupine, sweet fern, braken, and Solidago nemoralis. This includes the dryest and most open form of "oak openings" together with the country which was once quite well covered with pine. They are put together here, because aside from the now partially extinct white pine the floras are practically the same.

To one who knows the woods it will be apparent that in these five societies we have a gradation from the close, compact formation of the beech and maple forest, where the sunshine seldom reaches the ground, to the very open and sunny oak openings and pine plains. It would naturally be supposed that the denser societies are living under more favorable conditions for growth than the more open. This, indeed, we shall find to be the case.

A more extensive list of plants is given in the following table, which shows almost graphically the distribution of the enumerated plants throughout the five societies. The nomenclature is that of the sixth edition of Gray's Manual.[9] The Roman numerals heading the five columns at the right of the names indicate the societies by number, the same method of indication being also adopted on the accompanying map. The letters opposite the plant names show in what societies the plant occurs, the relative abundance in that society being denoted by the letter itself. C denotes common; F, frequent, and R, rare. An asterisk accompanying the letter expresses the fact that the plant is one of those to be regarded as characteristic of that society. Our *rare* has not the meaning given the word by the systematist; plants which he would consider rare are not sufficiently abundant to be considered at all in such a list as the present.

A very complete list of the Pteridophytes and Spermatophytes of Grand Rapids and vicinity has been recently published by Miss Cole.[10]

TABLE OF THE UPLAND PLANT SOCIETIES.

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Acalypha Virginica	Three seeded mercury	F	F			
Acer rubrum	Red or swamp maple	R	F	R		
Acer saccharinum	Sugar or rock maple	C*	C	R		
Actæa alba	White baneberry	F*				
Adiantum pedatum	Maidenhair fern		F			
Agrimonia Eupatoria	Agrimony		C*	F		
Andropogon furcatus	Beard grass					C*
Antennaria plantaginifolia	Plantain-leaved everlasting					C*
Aralia racemosa	Spikenard		C*	F		
Artemisia caudata	Wormwood					C*
Aspidium acrostichoides	Christmas fern	F*				
Aster cordifolius		F	C	C		
Aster lævis				C	C*	
Aster macrophyllus				F	C*	
Bœhmeria cylindrica	False nettle	C*	F	R		
Carpinus Caroliniana	Blue or water beach		C*			
Carya Alba	Shag-bark hickory		F	C*	R	
Carya porcina	Pig-nut hickory		F	C*	R	
Ceanothus Americanus	New Jersey tea			R	C*	F
Cenchrus tribuloides	Sand bur					F*

[9] Gray, Asa: Manual of the botany of the Northern United States, 1889.
[10] Cole, E. J.: Grand Rapids Flora. Grand Rapids, Mich., 1901.

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Chimaphila umbellata	Prince's pine			R	R	F*
Circæa Lutetiana	Enchanter's nightshade	C*	R			
Cornus alternifolia	Alternate leaved cornel		C	C		
Cornus florida	Flowering dogwood		C	F		
Corylus Americana	Hazel			F	C*	F
Cryptotænia Canadensis	Honewort		C*	F		
Cynoglossum Virginicum	Hound's-tongue	F*	R			
Diervilla trifida	Bush honeysuckle				F	C*
Dracocephalum parviflorum	Dragon head	F*				
Echinospermum Virginicum	Beggars lice	C*	R			
Epigæa repens	Trailing arbutus					F*
Epiphegus Virginiana	Beech drops	C*				
Euphorbia corollata	Spurge			F[11]	C*[11]	C*[12]
Fagus ferruginea	American beech	C*	R			
Galium boreale	Northern bedstraw		F	C*		
Galium circæzans	Wild licorice	F*	R			
Galium lanceolatum	" "	C*	R			
Gaultheria procumbens	Wintergreen				F	C*
Gaylussacia resinosa	Black huckleberry				F	C*
Gerardia quercifolia	Smooth false foxglove			F	F	F
Geum album	Avens		C*	R		
Hedeoma pulegioides	American pennyroyal	F*				
Helianthus divaricatus	Sunflower		R	F	C	C*
Helianthus occidentalis	"			F	C*	F
Hepatica acutiloba	Liverleaf	C	C*	C		
Hepatica triloba	"			C	C*	
Hieracium scabrum	Hawkweed			F	F	C*
Juglans cinerea	Butternut		F	R		
Juglans nigra	Black walnut		F	R		
Laportea Canadensis	Woodnettle	C*	F			
Lechea minor	Pinweed					C*
Lespedeza polystachya	Bush clover				F	C*
Lespedeza Stuvei intermedia	" "					C*
Liatris cylindracea	Blazing star					C*
Liatris scariosa	" "					C*
Lindera Benzoin	Spice bush		C*			
Lobelia inflata	Indian tobacco	C*	R			
Lupinus perennis	Wild lupine				R	C*
Medeola Virginiana	Indian cucumber root	F*				
Melampyrum Americanum	Cow wheat				F	F*

[11] Broad-leaved form.
[12] Narrow-leaved form.

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Menispermum Canadense	Moonseed	......	C*	F		
Monarda fistulosa	Wild bergamot, horse mint, balm	......	......	F	F	C*
Monarda punctata	Horse mint	......	......	......	......	F*
Myrica asplenifolia	Sweet fern	......	......	......	......	C*
Nepeta Cataria	Catnip	C*				
Onoclea sensibilis	Sensitive fern	......	F*			
Ostrya Virginica	Ironwood	......	C	C		
Phlox subulata	Moss pink	......	......	......	......	F*
Phryma Leptostachya	Lopeed	......	F*	R		
Physalis Virginiana	Ground cherry	......	......	......	......	C*
Phytolacca decandra	Pokeweed	C*				
Pilea pumila	Richweed	C*				
Pinus Strobus	White pine	......	......	......	F	C*
Polygonatum giganteum	Solomon's seal	......	C	F		
Populus grandidentata	Large toothed aspen	......	......	......	......	C*
Prenanthes alba	Rattlesnake root	......	R	F	C*	
Prunus serotina	Wild black cherry	......	F*			
Prunus Virginiana	Choke cherry	......	......	F	C*	
Pteris aquilina	Braken	......	......	......	F	C*
Pyrola elliptica	Shinleaf	......	......	......	......	F*
Quercus alba	White oak	......	R	F	C*	C*
Quercus ilicifolia	Black scrub oak	......	......	......	......	F*
Quercus rubra-coccinea	Red or black oak	......	R	F	C*	C*
Rhus copallina	Dwarf sumack	......	......	......	R	F*
Ribes Cynosbati	Gooseberry	C*	F			
Rudbeckia hirta	Browneyed Susan	......	......	R	R	C*
Sambucus racemosa	Red berried elder	C*	R			
Sanicula Marylandica	Black snake-root	......	C*	F		
Sassafras officinale	Sassafras	......	......	R	R	C*
Smilacina racemosa	False Solomon's seal	......	C	C		
Smilax hispida	Greenbrier	......	F	R		
Solanum nigrum	Nightshade	C*				
Solidago bicolor concolor	Goldenrod	......	......	F	F	C*
Solidago caesia	"	......	......	F	C	C
Solidago nemoralis	"	......	......	......	......	C*
Solidago rugosa	"	......	C*	F		
Tephrosia Virginiana	Hoary pea	......	......	R	C*	C
Tilia Americana	Basswood	C	C	F		
Ulmus Americana	White or American elm	R	C*	F		
Ulmus racemosa	Rock elm	R	C*	F		

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Vaccinium Canadense	Blue berry			F	C	C
Vaccinium Pennsylvanicum	Dwarf blue berry			F	C	C
Vicia Caroliniana	Vetch		F	C*	C	
Vitis cordifolia	Frost grape		C	C		

2. *Distribution of the Upland Societies.*—This is shown by the map (Plate III). From the darkest to the lightest of the five shades used a gradation is shown corresponding to that in the societies from I to V. The sixth and lightest shade denotes deeply-eroded channels occupied chiefly by lowland societies. In these channels the areas occupied by the different societies are so limited that any satisfactory representation of them on the scale of the present map was deemed impossible. Therefore they are left unshaded. Also the lowland societies along the margins of smaller streams and lakes and in swamps among the hills are omitted entirely from the map. The reason for this is in part the same as the one given for the larger channels, and also in part this, that although some of the swamps are large enough to map well on the present scale, yet to trace their margins accurately would require more time than it would be worth, and to map them inaccurately would not be true to the instinct of the work.

Steep slopes where erosion is at present rapid, as along the margins of the many stream valleys and along old glacial channels, are occupied by societies III, IV and V. The character of the soil seems to make no difference here, the drainage being quite complete and the accumulation of humus impossible. It has also been found impracticable to indicate these very narrow areas upon the map.

In the southern tier of townships, all the heavy clay soil, whether it be rolling moraine or level till plain, was originally occupied by the beech-maple society (I). In the lighter loamy soils are usually found the oak-hickory society (III), with transition zones between it and (I) held by the maple-elm-agrimony society (II). The very sandy loam bordering the deep narrow valley of the Thornapple river and spreading eastward from Alaska and Labarge nearly to the Elmdale till plain, is occupied by the oak-hazel and the oak-pine-sassafras societies. This loam is in many places as sandy as the soil of the Grand river sand plain; it might almost have been denoted as sand.

Within the "big bend" of the Grand river is an area of decidedly clayey country occupied by the oak-pine-sassafras society (V), although here the pine is not at all prominent. It appears as though this area were well on the way toward society IV at the time of clearing. But the marked presence of sassafras, wormwood, sand bur, Solidago nemoralis and other forms of society V, make it impossible to classify it elsewhere.

The Grand Rapids sand plain (reaching from Rockford, through Plainfield and Grand Rapids to Grandville and Ross) is generally covered with societies IV and V. The foundation soil is apparently the same throughout, being a gravelly sand, but the areas of society IV have undoubtedly more surface humus, thus giving the soil a darker color and a more loamy texture. The higher parts of the plain, and hence the portions which have been out of water longest, are generally those to show this condition. The lower portions where violent water action probably continued after the main stream receded, and where, owing to the slope, erosion is even now well marked, bear little surface humus and are characterized by society V. Here, at the time of clearing, the pine was usually present. Transition areas between IV and V were covered with "oak openings," however. Of course much of these channel areas is swampy and hence thrown out of the present discussion.

North of Grand river it is only in the western column of townships that the heavy clay is characteristically covered with society I. In other portions of the region the clay is covered with society III, IV or V. It will be noticed that clay bearing the oak-pine-sassafras society is common in the extreme north and becomes less common southward. Societies III and IV approach each other in character as we pass northward. The hickories become less frequent and the general aspect of III becomes more that of IV. It needs to be remarked here also that the stretch of society III reaching from the Rouge river southward and lying west of Grand Rapids is a curious mixture of II and IV. Judging from the trees alone, the southern part of it would be placed in society II, but the presence of New Jersey tea, Solidago cæsia, etc., seem to place it in the oak-hazel group. Sassafras is present here to a remarkable extent and in many places, especially to the north, white pine also. The northern part of this stretch contains much pine. Altogether, the area can better be classified under III than elsewhere. In the general discussion to follow the possible reasons for the mixing will be considered.

In the bit of beech-maple society in the extreme northwestern part of the county is found the only marked instance of the presence of hemlock. This tree belongs typically with the hard wood group in northern Michigan.

In the northern part of the county white pine was almost universally present in the uplands at the time of settlement. This can be proven by stumps which are still in place or have been used in the construction of stump fences. There are pine stumps and a few trees still standing even in the beech-maple group upon areas north of an east and west line drawn through a point about midway between Cedar Springs and Rockford. South of this line the pine disappears in society I and becomes very rare in all but IV and V.

3. *Generalizations on the Upland Flora.*—Any sort of generalization upon a study of such a limited area as the present must necessarily be a hazardous undertaking. I shall venture to call attention to the following points, however, all of which must be looked upon as merely tentative suggestions:

a. *The Soil Factor.*—It appears that the general distribution of the upland societies is based primarily upon the nature of the superficial soil. This must be so since the roots of the smaller plants never penetrate very far into the soil, and since in the case of trees and shrubs, seed germination and the growth of seedlings is conditioned by these surface layers. If seedlings cannot develop it is clear that there can be no mature plants.

Surface soils may be classified either according to their chemical or according to their physical nature. The usual soil analyses show the relative amounts by weight of the different chemical constituents. Now it is very probable that the original till material covering Kent county was reasonably uniform in chemical constituents. That it was thoroughly mixed by the movement of the ice sheet is shown by the wealth of different minerals to be found in any small region. But the till has been more or less sorted by water action in many localities, so that in some few cases, almost pure silica is all that remains on the surface. However, in spite of this washing, the most sandy soils contain a considerable amount of other minerals.[13]

But the plant can make use of the soil constituents only after they are in aqueous solution. Now the great bulk of the soil is practically insoluble in water, and it makes no difference to the plant what may be the chemical nature of these undissolved substances. Thus it would be much more to the point to make analyses of the soil water, for it is this which effects the plant directly. Such analyses were not made in connection with the present work; the distribution of the vegetation seemed not to demand it. It is hoped that they may be made at some future time, either for this region or some similar one. It is very probable, however, that soil waters from the surface soil in different parts of this area will be found to be very nearly uniform in their salt content. We are led to this conclusion by two considerations: First, the chemical nature of the soluble part of the surface soil itself is probably very nearly uniform throughout the county. Secondly, the washed soils are usually comparatively shallow, and upward diffusion of dissolved substances probably takes place with comparative rapidity, especially when aided by the soil currents produced by changes of temperature, etc. The only localities where it is at all probable that a paucity in soluble salts would occur in the soil water, are the deep sand plains. There is some rather questionable evidence from the vegetation that such is the case in these localities. More work needs to be done before any definite decision can be made in this regard.

In classifying soils according to their physical nature, the only question which has any direct bearing upon plant growth is that of the ability of the soil to retain water by capillarity, so called. Primarily, this ability depends upon the size of the soil particles. Thus sand will retain less water than loam, and loam less than clay. The three grades of surface soil shown on the map have been indicated with this in view.

Sandy soil may be made to retain more water in two different ways, either by the addition of clay or by the addition of humus. The physical effect of the humus is very well marked. Of course the humus also adds some nitric acid and certain organic materials which are of benefit to the plant, and it also increases the amount of soluble salts at or near the surface; the humus is formed mainly from leaves, and in these organs

[13] Kedzie, R. C.: Analysis of soil of jack-pine plains near Grayling, Michigan. Annual report Mich. Board of Agriculture, 27, p. 211, 1888; also Bull. 99, 1893.

the mineral part of the plant body is concentrated. This is perhaps an important fact in the growth of hard wood upon deep sand which is well covered with humus. Where drainage is complete and rapid, as in sand, and oxidation is also rapid, humus does not readily accumulate; but where it does accumulate as a surface layer, the ability to retain water approaches that of clay.

From the present study it appears that the most important soil factor in the distribution of the flora of Kent county is this one of the relative ability of the superficial layers to retain water. In other words, the controlling soil condition is one of drainage.

Throughout the southern half of the county, soils which retain much water are covered with society I, II or III. The only exception to this is the small clay area within the bend of Grand river. The soil of this area is apparently as good as that farther south, but it is very dry in dry weather. There is no marked humus covering. Perhaps the proximity to the well drained valley on either hand has an influence through underground drainage, but this was not looked into and the question must be left for the present unanswered.

Within the sand plain area of the southern half of the county there are several small stretches of societies I and II. Owing to the fact that at one time a much larger stream than the present one flowed through the valley of the Thornapple river, that valley has a well marked terrace between the country level and the present flood plain. This old flood plain is sandy and corresponds in manner of formation to the Grand Rapids sand plain. But in very many places this terrace is covered with societies I or II. Some of the finest "sugar bushes" which I have seen are here. The sandy soil is thickly covered with a layer of humus. These strips of hardwood are so narrow that they could not well be shown upon the map. The same condition holds on the rather high part of the plain lying west of Crosby. This is indicated upon the map. Also at the base of the escarpment forming the margin of the deeper glacial channel in the Grand Rapids sand plain there are several instances of societies I and II upon humus-covered sand. Notably is this true near the southwest corner of Grand Rapids and on the margin of the Buck creek valley near the Lake Shore & Michigan Southern railroad. In this connection it is interesting to note that beech trees are found quite commonly upon the humus-covered established dunes along the east shore of Lake Michigan.[14]

In the northern half of the county west of the Rouge river we find the heavier soils still retaining societies I, II and III. East of the valley of this river we find the country is much cut up. The clay areas are small and pretty well drained. They may be occupied by any society from I to V. That they can support society I is well shown by its occurrence in several places. Its general absence from this region is perhaps due to another cause, to be mentioned later.

East of Sparta and northeast of Cedar Springs are perfectly typical examples of society I growing upon light soil, the former without trace of pine. In the western part of the Sheffield area I was told by a resident that the clay was at least twenty feet below the surface. But in these areas the soil is deeply covered with humus. What the conditions

[14] Dr. Cowles tells me that he has seen these beech covered dunes as far north as Frankfort, and Mr. Whitford has observed them on Manitou Island.

are which cause the accumulation of the humus in one place and not in another apparently similar place, I was unable to make out. This phenomenon most often occurs in a rather low region where the sand would normally remain moist longer than elsewhere. It has been suggested that the beech cannot grow to perfection in the absence of humus, because of the symbiotic relation of its roots with certain humus fungi. The maple-elm-agrimony society, however, grows to perfection on heavy soil with little or no true humus. It is also found on lighter soil which has a humus covering.

In the southern half of the county it seems fairly clear, then, that societies I and II will grow on rather deep sand if that be covered with humus, and that when society V is found on clay it is well drained and usually with little or no humus. Throughout the county there is an obvious difference in humus content between the areas occupied by societies IV and V, the sand of the former being mixed with vegetable debris. The intermediate society III is found on the loamy soils and on the dryer and better drained clay areas.

b. *The Historic Factor.*—Besides the factor of relative water content in the soils there is another which may be active in this region. I refer to what may be termed the historic factor.

As the ice sheet retreated slowly northward at the end of the last glacial period the portions of Kent county first uncovered were, of course, in the southern part. And the first parts of the sand plains to be uncovered lay also at the south, although these areas were probably under water long after the ice itself had disappeared. It is probable that the pine-heath[15] group which today reaches farthest north, reached well toward the glacier front during the ice age. And at the end of that age, the ice in its retreat was probably followed northward by vegetation, the pine-heath society leading the way. Near the ice margin the soils were probably raw, absolutely without humus, subject to great drought in summer and to extreme cold in winter. These are just the conditions in which we find the pine-heath group today in northern Michigan. It is probable that at one time they occupied all of Kent county, but the climate became warmer and more equable with the farther retreat of the ice, and the growth of the hardy pines, etc., produced a little humus. Their roots fixed the soil so that erosion was less rapid, and perhaps the sassafras and the white and red oaks and the whole of our society V gradually crept in, occupying the better part of the ground along with the pines and heaths. Then as the soil improved the oaks became more and more numerous and the pine seedlings could not develop on account of the shade.[16] The pines thus became fewer in the south and the oaks at last predominant. This would be the stage of our society IV. But the process of working over the soil continued,—though perhaps the ice-sheet had shrunken by this time nearly to its present size,—and humus continued to accumulate in favored places; the hickories, maples and beeches of Ohio and Indiana spread continually northward over every suitable stretch of soil, as fast as it was made fit for them. When the maples and beeches reached

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[15] This group comprises, besides several pines, two species of juniper, bearberry, hairbell, braken and several of the other forms found in our society, V. Cf. Whitford, H. N.: *loc. cit.* p. 298 *et seq.*

[16] It is known that pine seedlings fail to mature in the shade of healthy deciduous trees.

maturity in the richest parts of the oak and hickory forest the oaks and hickories probably ceased to mature. Seedlings of these trees fail to develop well under maples and beeches, possibly on account of the dense shade. Thus we have reached the stage of our society I.

In such a northward advance, the plant societies would not progress in uniform lines, like a marching army, regiment after regiment, as might be supposed at first thought; on the contrary, there would be many mixed areas, and the advance would often be almost imperceptible, like that of a ragged line of skirmishers. Here and there in a sterile, perhaps in a well drained portion, would be left a detachment of the advance guard, like the patches of societies V and IV in the southern townships of our county. And these would be surrounded by the later comers as they crowded on, occupying all soils in which they could come to maturity, and preventing the development of new generations of the forms previously in possession. With these thoughts in mind, a glance at the map will suggest much more than was seen before.

The beech and maple societies (considered by Cowles and Whitford[17] to be the climax society for temperate North America) extend northward along the lines of soil richest in water content, and reach farthest north in the western part of the county. This latter fact may be due to the lake influence. Chamberlin states[18] that in Wisconsin the beech is limited to regions near the lake. He believes its distribution to be determined by lacustrian climate. This is perhaps partly true here, at any rate the advance of society I has been much greater along the side of the county nearest the lake.[19]

Also the other societies,—II, III and IV,—are each a little in advance of the previous one, and each is apparently advancing into the area occupied by the next hardier one. In the extreme north we find almost the entire area occupied by societies IV and V.

According to this line of thought, the reason for the predominance of the pine groups in the north is simply that sufficient time has not yet elapsed since the glacial period for these areas to be reached by the societies found predominant farther south. Along a wavy east and west line passing through Rockford lies the "zone of tension" between societies I, II and III on the one hand and IV and V on the other. This line bends far northward at the west, following the western edge of the Rouge valley as far as Kent City and Casnovia. It also bends northward to Sheffield and Harvard on the other side of the Rouge valley. Perhaps a climatic factor is operative in producing this zone of tension, perhaps the beech-maple-hickory society cannot occupy large areas to the north of it. But it seems more probable that the climate,—somewhat colder as we pass northward,—has acted only as a retarding factor, assisted by the fact that a good portion of these northern townships have a light surface soil, which seems unsuited for the hard wood societies in the absence of humus.

The strongest point in favor of the idea just expressed is found in the fact that at the time of settlement practically all of societies I and II in the northern part of the county were well mixed with pine. In some

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[17] Whitford, H. N.: *loc. cit.* p. 302.
[18] Chamberlin, T. C.: *loc. cit.* p. 180.
[19] But Dr. Cowles tells me that in the neighborhood of Chicago beech is found almost exclusively on areas quite far removed from the lake.

places the pine stumps are so numerous as to raise the question whether the hard wood is not an entirely recent affair. It is probable, however, that scattered maples and beeches were mingled with the pine and that on the removal of the latter their seedlings simply took possession of the ground and shut out the pine seedlings.[20] Also in societies II and III, west of Rockford and as far south as Mill Creek the pine is still pronounced, and in many small spots society IV, or even V, still retains its hold. As has been noted before, this is a mixed group and is hard to classify. There are no traces of pine in the hard wood forests to the southward. It may well be, however, that a further extension of this study will show that this hypothesis of the historic factor is utterly untenable.

Another line of evidence seeming to throw some light upon the historical development of this flora, is that obtained from a comparison of the several sand plains of the region. As was stated in our introduction, there is a well marked sand plain just south of the boundary of Kent county, which we have termed the Green lake sand plain. The soil here is like that of the higher part of the Grand Rapids plain, shown on the map, very sandy, but with a good admixture and coating of humus so that at the surface it appears loamy. The vegetation is made up of all five of our societies. In general the type is that of society III, but there are many spots, especially on the margins of the numerous ponds and lakes where societies IV and V hold the ground. In slight depressions along the margin of the plain the humus is deep and society I is common. There are also many rather large areas of societies I and III well out in the plain. Usually these are in slight depressions, not low enough to be swampy, but well covered with humus. We may say, then, that in the most southern of the three sand plains which have been studied,—and therefore the one which has been out of water and fit for vegetation the longest,—the predominant society is III, but I and II are not uncommon, while IV and V occupy a relatively small portion of the area.

In the Grand Rapids sand plain we have seen that society IV is predominant, with a good part occupied by V and comparatively very little by I, II and III. And in the plain which extends from Rockford northward, the only upland society found is V. Of course the last plain has been out of the water a much shorter time than the other two. In fact, a great part of it is at present swamp and is occupied by lowland societies.

In these three plains we seem to see successive stages of vegetation occupying successive stages in the formation and accumulation of humus. Of course the extensive destruction of the natural vegetation which has taken place since settlement of this region began, will make it impossible for the natural course of events to continue here, even if the above hypothesis be the correct one. Often clearing and burning has reduced the soil from a condition suited to society II or III to one only fit for society V. This is probably also true on the moraines in the

[20] Beal has shown that oaks, maples, etc., can reach a considerable age in dense forests without any marked growth. An oak may thus be twenty-five years old and yet have a height of only a few inches. If the shade-producing plants are removed these dwarfed trees will set up a renewed growth. For figures of such dwarfed trees see Beal, W. J.: Observations on the succession of plants in Northern Michigan. Annual report Mich. State Board Agriculture, 27: 74-78, 1888.

northern part of the county. It will probably be impossible ever to trace the history much farther than it had gone at the time of settlement.

THE LOWLAND SOCIETIES.

Under this heading will be briefly considered three groups of societies, the pond-swamp group, the lake-river group, and the spring-brook group. In the first I shall include those aquatic societies which are found in small ponds together with those marsh societies whose habitat is undrained swamps either on the margins of such ponds or elsewhere in swampy depressions. The second group will consist of the aquatic societies of the large lakes and of flowing water,—whether in creeks or larger streams,—together with marsh societies which occupy the drained marginal swamps along these lakes and streams, and also the moist ground societies of the river and creek flood plains. The third group will comprise the societies of the spring-brook and its margins. I have been unable to observe any variation in these lowland societies corresponding to variations in the nature of the soil. It seems to make no difference whether the soil be sand or clay, if it contain sufficient water to cause it to be classified as lowland, it will always bear certain types of vegetation. These various types depend, apparently, upon the *amount* of water so retained and upon the *nature* of the water as a solution.

1. *Definition and Distribution of the Lowland Societies.*—In the following paragraphs the definition and the distribution of the several lowland societies will be presented together. My study of the lowland has not been as thorough as that of the uplands and the discussion will not be as complete. The societies will be numbered consecutively in the same series as those of the upland.

a. *The Pond-Swamp Group.*—Throughout the county, but especially in the northern and northwestern part, depressions which reach below the water line are numerous. They vary in diameter from a few hundred feet to several miles, and their margins are of course sinuous and very irregular. They may be found on almost any sort of topography, but especially in morainic areas and in sand plains. In the former situation these deep hollows among high clay hills are often almost impossible to drain, even artificially. The great accumulation here in the form of peat, of which we shall speak later, has led cultivators to drain these swamps wherever practicable. Sometimes ditches for this purpose have to be twenty or thirty feet deep and take a sinuous course for several miles, following the depressions in the topography. Thus in morainic regions these swamps are naturally undrained; there is no circulation of water through them, it is lost almost entirely by evaporation.

In the sand plains these depressions occur principally along the margins. The margin of the Grand Rapids plain is in some places almost a continuous line of such swamps and ponds. They also occur out in the middle of the plain, notably so in the Green lake plain, south of the county line. These sandy basins are apparently as poorly drained as those in the clay; it is probable that the deeper clay holds the water. The vegetation is the same whether the basin is in sand or clay.

VI. The Chara-Nymphæa (Aquatic) Society.—Where these undrained depressions are small, and at the same time deep enough to contain standing water throughout the year, we have a pond. The water is usually shallow and filled with aquatic growth. The presence of water prevents in some way,—perhaps by limiting the supply of oxygen, —the total decay of dead plant materials, and debris accumulates upon the bottom of such a pond, forming black peat. This may be intermixed with calcareous material from Chara[21] and from mollusc shells. The calcareous deposits may be quite pure, as sometimes in the larger ponds and lakes, so that they may be used for marl. Generally, however, an undrained swamp has a bottom of fine silt-like peat or muck, which,—being thoroughly saturated with water so as to furnish almost no support to a person or animal, and being of unknown depth,—gives to many ponds the name of bottomless. The vegetation of such a pond is characteristic. The white and yellow water lilies (Nymphæa and Nuphar), the alga Chara, which often forms great masses, the duck-weeds (Lemna, Wolffia, Spirodela) and the bladderworts (Utricularia), are the predominant types throughout the county.

VII. The Sedge-Sphagnum-Tamarack (Bog) Society.—It is obvious that as an undrained pond is filled up by peat deposit its margin will be built out into the water. This process has been going on since the close of the ice age, and thus many ponds are surrounded by a broad belt of characteristic *undrained swamp* or *bog*. In many cases the pond has been entirely obliterated by this encroachment of the marsh upon the standing water. These marshes, whether they have a true pond in the center or not, always show a zonal arrangement of plants. Thus several distinct societies might be made out of what is here brought under one head. An admirable discussion of these zones of plant life in the Chicago area is presented by Cowles (loc cit.). The facts are the same in Kent county as there. Along the margin, in shallow water, are found sedges (Carex), the bulrush (Scirpus lacustris), Scirpus atrovirens, S. polyphyllus, the buck bean (Menyanthes), and the swamp cinquefoil (Potentilla palustris). Farther back these give way to the true peat-bog flora, comprising cotton grass (Eryophorum), peat moss (Sphagnum), leather leaf (Cassandra), Calapogon, Pogonia, Cypripedium candidum, C. spectabile, the tall blue-berry (Vaccinium corymbosum), cranberry, poison sumac (Rhus veninata), pitcher plant, sundew, Elodes campanulata, Woodsia, shrubby cinquefoil (Potentilla fruticosa) and the tamarack tree. The black spruce, which is common in such localities northward,[22] is rare here. In one extensive swamp crossed by the right of way of the Detroit, Grand Haven & Milwaukee railroad about five miles east of Grand Rapids, and bearing the name of Saddlebag, there were originally many of these trees. They were first practically all killed by burning. Now the swamp has been artificially drained and I think no spruces remain. The margins of the undrained swamp are often occupied by a characteristic margin flora of which the winter berry (Ilex verticillata), hardhack (Spiræa salicifolia and S. tomentosa), and the Osmundas (O. cinnamomea, O. Claytoniana, and O. regalis) are perhaps the most typical. Or the margins may have a vegetation resembling

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[21] Davis has shown that Michigan marl is mainly from Chara. See Davis, C. A.: A contribution to the natural history of marl. Jour. Geol. 8: 485-497, 1900. Also: A second contribution to the natural history of marl. Jour. Geol. 9: 491, 1901.

[22] Whitford, H. N.: *loc. cit.* p. 314.

that of the dryer parts of the drained swamp, the elms, swamp oaks, asters, etc., forming a transition to the adjacent upland societies. Where the latter are of the type of IV and V, however, the transition zone is apt to be omitted. The margin flora just mentioned may be developed in such a case, or the swamp society may break off abruptly at the sandy slope which marks the original shore line of the pond from which the swamp has been formed.

b. *The Lake-River Group.*—The societies along the shores of the lakes and along the rivers and larger creeks are quite similar, no matter whether they be in sand or clay. Perhaps the wave currents of the large body of standing water and the better opportunity for saturation with oxygen and hence for oxidation, simulate the stream currents and prevent the existence of stagnant water conditions, whatever these may be. It is true also that most of the large lakes have outlets so that there is a constant, or at least intermittent changing of the water. In embayments and quiet places along the margins of such bodies of water the aquatics take on more or less the character of pond vegetation and the shores of such places are apt to develop the aspect of an undrained swamp. The vegetation here is often intermediate in character between that of the drained and of the undrained swamp.

VIII. The Potamogeton-Myriophyllum-Elodea (Aquatic) Society.—This occurs in lakes and the larger rivers. Besides species of the three genera mentioned it includes Vallisneria, Ceratophyllum, the water shield (Brasenia), water buttercup (Ranunculus aquatilis), and numerous green algæ, such as Cladophora, Spirogyra and Hydrodictyon.

IX. The Willow-Ash-Elm Society.—This occurs on the margins of lakes and rivers. The aquatic society (VIII) grades into the willow belt through a grass-arrowhead zone wherein wild rice is often predominant. In open places in the marginal willow thicket are often pickerel weed (Pontederia), cat-tail, Sparganium simplex and androcladum, and the like, or these may mingle farther out with the grasses and arrowheads. The sedge-bulrush zone is not nearly as pronounced here as in the case of the pond, though these plants occur often in great numbers. On the beach of Grand river, outside the willow zone, there is often a zone of rag weed (Ambrosia trifida) and other annuals.

But back of the willow margin, on the river and on the lake, we usually find a very characteristic drained swamp area. This is the richest in species of all our societies. It occurs along the margins of streams and lakes, but some of the finest examples of it are in the ancient channels of the glacial streams. The channel followed by the Grand Rapids & Indiana railroad from Grand Rapids to Ross was, at the time of settlement, almost one continuous stretch of drained swamp, although in some places there are patches of society VII marked by groups of tamarack. The same is true of the broad creek valleys in the northwestern part of the county. The vegetation here is a great complex of species, its *tout ensemble* remaining quite uniform but the component plants varying through a wide range. Only a few samples can be given. We may select the following: Black ash (Fraxinus Sambucifolia), elder (Sambucus Canadensis), Lobelia cardinalis, L. syphilitica, Polygonum lopathifolium, P. hydropiper, P. acre, P. dumetorm scandens, bittersweet (Solanum dulcamara), red osier (Cornus stolonifera), Epilibium coloratum, bugle-weed (Lycopus Virginicus), skull cap (Scutellaria), hedge nettle (Stachys), Solidago ulmifolia, panicled cornell (Cornus paniculata), sour-gum (Nyssa sylvatica), green brier (Smilax), arbor-vitæ, swamp oak (Quercus bicolor), red maple (Acer rubrum), slippery elm (Ulmus fulva), and alder (Alnus incana). The list might cover a page. Of course in any one place one will not find all of these plants, but they are pretty sure not to be far distant. Bugle weed is sure to be found everywhere. The Polygonums are the characteristic herb forms in the dryer parts of these swamps, and often in all parts, some ten or twelve species of this genus occurring there. Along the Rouge river, in the northern part of the county, the red maple is apt to be mingled with the willows in the margin zone.

X. *The Basswood-Hackberry-Phlox-Lungwort (Flood Plain) Society.*—This is the typical river flood-plain society. It contains many of the plants of society II. Here, as well as in society II, occur most of the spring flowering herbs, bloodroot (Sanguinaria), Trillium, Indian turnip (Arisæma), etc. The cork elm (Ulmus racemosa) is common, and the American elm frequent. Butternut and walnut (Juglans cinerea and J. nigra), the bur oak (Quercus macrocarpa), and the pig-nut hickory (Carya porcina), also occur here. Back from the lake or river this society merges gradually into the upland society which occupies the adjoining upland.

c. *The Spring-Brook Group.*—Here will be included a single society, that which forms ribbon-like stretches along the margins of the smaller brooks and broader patches on the springy hillsides, where the brooks have their sources. The little streams usually possess a well marked aquatic flora, which consists, however, of but few species. The algæ Vaucheria and Cladophora are found fastened to stones at the bottom, and the watercress (Nasturtium), together with water purslane (Ludwigia palustris), often forms great masses which well nigh stop the flow of water.

XI. *The Lobelia-Chelone Society.*—The trees of this society are either the same as of the upland through which the brook flows, or are like those of the drained swamp. But the herbs and shrubs which follow the brook are quite characteristic. Among these are the blue and red Lobelia (L. syphilitica and L. cardinalis), the turtle-head (Chelone glabra), the gentians (Gentiana Andrewsii and G. crinita), swamp milk-weed (Asclepias incarnata), beggar's tick (Bidens), tear-thumb (Polygonum arifolium and P. sagittatum), Aster puniceus, several Eupatoriums, alder (Alnus incana), and several low willows. Many of the plants found here also occur in the drained swamp society (IX), but they exhibit a better development here and are quite closely massed together in a narrow strip along the margin of the streams and in rather broad areas of springy ground at the stream's source, so that the society as a whole is quite distinct from IX.

2. *Generalizations on the Lowland Flora.*—From the possibility of such a classification of these lowland societies as the one just given, it seems probable that the main factor in determining their distribution is water. But the amount of water is practically the same in an undrained and in a drained swamp and on a brook margin; yet the floras are dissimilar, especially the first two. It has been suggested

that the great amount of organic materials in the solution of the undrained swamp may effect the plants physically or chemically and thus exclude those which occur in the drained swamp. If these substances effect the plants physically it must be through osmotic pressure. By this means a concentrated solution might withhold water from the plant. A few tests of the water from swamps whose flora was of the bog type seem to show that the osmotic pressure of the water is no greater than of that from a spring or river. Enough work along this line has not been done, however, to decide the question.

There remains the other suggestion, that the undrained swamp owes the peculiar character of its flora to the chemical nature of the soil solution. It may be lack of oxygen in the soil which shuts out the plants of the drained swamp. The question is to be solved by experiment, and not by observation. Perhaps, in the case of a brook, the more uniform flow of a solution of rather uniform constitution occasions the development in the margin of such a stream as different from that in a drained swamp. This question must also be attacked experimentally.

CONCLUSIONS.

From the present observations it appears that we are entitled to retain as a broad general hypothesis, the physiographic idea advanced by Cowles (loc. cit.), namely that physiography determines vegetation. But this hypothesis is not getting us very near to the ultimate factor upon which depends the distribution of the plant societies. The ultimate cause of all this varied vegetation must be something more particular, something which will affect the individual plant. For such a region as this, this *something* must exist in the nature of the soil; climatic factors cannot explain differences in such a small area; and the historical factor is broad and general like the physiographic one, and hence is not ultimate. That local differences in vegetation are due to soil factors has been as good as proved before this, and the proof is strengthened by the present study. The physiographic hypothesis explains how it is that various soils may be physically and chemically different. But after this is explained, the question with which we have to deal lies still untouched: What is it *in the nature of the soil which determines the distribution of our plant societies?*

Now, by "nature of the soil" we can denote two things, and only two, i. e., the *physical* nature and the *chemical* nature. But we have seen that neither of these can influence the plant *per se*. (See page 93). Either one of the features may, however, be effective through soil water. Water is the only feature of the soil which comes in direct connection with the vitality of the plant. The chemical nature of the soil may be effective through the nature of the dissolved substances which enter the plant, indirectly, through osmotic pressure. Its physical nature may be effective through the retention or non-retention in the soil of the water itself.

So far we may go *a priori*; beyond this tests must be made. The nature of the soil water from various soils in various positions must be carefully determined. From these determinations we shall know how much truth or falsity there is in the explanation here offered, that the nature of the soil water is not usually a decisive factor for such a region as this.

Also, by careful tests the ability of various soils to retain water must be determined, and these determinations recorded with the vegetation found growing where the tests were made. Thus, and thus only, can the hypothesis offered in the present paper be tested, i. e., the hypothesis that *the decisive factor in plant distribution over a small glaciated area is, in most cases, the moisture-retaining power of the soil.* Comparisons and observations can neither destroy this hypothesis nor establish it.

On the other hand, the present series of observations seems to show that the historic factor is a very important one in the distribution of the plant societies of Kent county, and the test of the hypothesis offered in this connection is to be obtained through observation and comparison, and through them alone; we cannot get the ice-sheet back and have the whole history worked out before our eyes.[23]

It may not come amiss to suggest some areas which it would be well to study for comparison with the present one. First, the study should be carried westward to Lake Michigan; along its shores we find much more primitive types of vegetation than anywhere in Kent county. Also, by this means the present area would be brought into better connection with that of Cowles' work. Secondly, an area should be studied in the center of the State and another bordering on Lake Huron or Lake St. Clair. With these at hand we might feel that we were free from the danger of drawing conclusions from a peculiar and exceptional area. Thirdly, there are needed studies and maps of several typical areas, scattered from the present one northward to Hudson's bay.

It is hoped that in the future such studies may be made and the results carefully mapped and published. Emphasis is here laid on the map, for by it alone can a satisfactory comparison be instituted. Photographs are apt to be too superficial to be of any accurate use, though they would undoubtedly be valuable in connection with the map.

I wish to thank Dr. H. C. Cowles, to whose writings I have had occasion to refer so often, for suggestions which have changed for me the whole aspect of the problem of plant distribution in this region, from that of a problem impossible—or at least hopeless—of solution, to that of one whose solution is apparently a question of time and of careful and accurate work.

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[23] Similar conclusions to the ones here expressed have just been published. The paper appeared too late to be referred to in the main text. Bruncken, E.: Studies in plant distribution. 1. On the succession of forest types in the vicinity of Milwaukee. Bull. Wis. Nat. Hist. Society, 2:17-28, 1902.

MUSKEGON COUNTY.

Prof. C. D. McLouth of the Muskegon high school has put in a little of his summer time very intelligently and industriously in collecting data as to the soils as well as to flowing wells, and the deep wells which have recently been drilled. His assistance in the latter matters I would gratefully acknowledge while incorporating his help into my notes on the prospects of oil in that region given on a later page. But he has also prepared a nearly complete series of township maps, showing the distribution of the soils, and has helped Mr. Leverett in his work. I append his general notes.

SOME GENERAL REMARKS ON THE TOPOGRAPHY, SOILS, WATER SOURCES, FLORA, ETC., OF MUSKEGON COUNTY.

C. D. MCLOUTH.

Surface.—A large portion of the surface is a sand sheet covering nearly the whole county, the principal exceptions being portions of the townships of White River, Whitehall, Montague, Casnovia, Ravenna, and perhaps the northern part of Holton. A belt of this sand area some 10 miles wide and having its middle line approximately along the course of Muskegon river has the general appearance of a plain, but slopes considerably from the point where the river passes the county line to the shore of Lake Michigan, also it becomes shallower and apparently lower northward and southward from the river, that is, the river seems to run nearly along its deepest part. In Cedar Creek and Blue Lake townships sand dunes are conspicuous but of undetermined extent. Similar but slighter hills, knolls and ridges of sand occur in various parts.

The northwestern part of White River township presents a surface of clay approximately 100 feet above Lake Michigan. Southward and eastward loam and finally sand become the dominant soils. Casnovia, eastern Moorland and northern and eastern Ravenna constitute a hilly region in which morainic ridges are prominent, loamy soil abundant and deposits of boulders and gravel frequent. A moraine traced by Mr. Leverett winds northward through Fruitland township from near Muskegon through Whitehall and Montague, thence northwestward to the limit of the county.

Coast.—Along the coast the land height, exclusive of dunes, falls from an elevation of probably more than 100 feet at the northern end to nearly the level of the lake at the southern end. Clay is visible on the beach only at and near the northern limit. Cobblestones and gravel are noticeable in the vicinity of White lake. Sand, with a slight sprinkling of pebbles, is the feature along the remainder of the line. Dunes are highest at the south and form an unbroken line about one-

PINE STUMP, WATER LEVEL DEEP.

PINE STUMP, WATER LEVEL NEAR SURFACE.

C. D. McLouth, Photo.

half the entire distance northward, beyond which there are considerable portions along which the level land surface extends to the slope of the bluff. A mile or so below the northern line of the county the sand dunes begin to diminish gradually but rapidly, lying against the face of the clay bluff instead of upon the bluff, and within two miles north of the boundary no traces of dunes are to be found. Black and reddish magnetic sands are conspicuous in many places along the beach and are sometimes separated by action of the waves into layers an inch or more in thickness.

Lakes and Lakelets.—The lakes along the coast are of course confined within slopes corresponding in height and abruptness with the general land elevation previously mentioned. Little Black lake in the extreme southwest drains into Lake Michigan by a shallow ditch. It is practically level with the receiving lake and has been lowered somewhat by the ditch. The land rises away from its borders with very slight ascent except where low sand ridges seem to indicate former confines gradually moving toward the coast.

Wolf lake, in the interior, lies in the high sand plain near Muskegon river. Its banks are steep, entirely of sand, somewhat more than 30 feet above the water level, which is 67 feet above Lake Michigan. Carr lake or Five lakes, a few miles south and westward, consists of a series of shallow, receding ponds lying in hollows on the north margin of an undulating tract of sand that seems to be an area of old dunes. Twin lake, in Dalton township, lies but little below the general land level. Some of the lakelets northward have deeper basins.

Speculations on the Geological History.—Evidently in successive stages of recent times less and more of this region has been covered by Lake Michigan than at present. White lake, Duck lake, Muskegon lake, Lake harbor, are infillings of the lower valleys of the several streams that formerly flowed farther out to reach the great lake; this is shown by the fact that the bluffs now confining these lakes are exactly continuous with the bluffs now lining the valleys of the streams for miles inland. Numerous sand ridges, dunes and swampy tracts indicate former presence of water of considerable depth.

Various present conditions seem to indicate that the water is now or recently has been in quite rapid recession, considerably extending the land area. A large portion of Moorland with small portions of several adjacent townships is a recently reclaimed marsh (although considerably above Lake Michigan). Much of Sullivan township was a desolate swamp which extended into Fruitport and Norton townships, appearing to the eye as an unbroken plain and but a few feet above lake level at the coast.

In the southwestern corner of Fruitland township is a swampy tract extending back from the lake several miles. This swamp is bounded on the east by an irregular sand ridge reaching a height of 20 feet perhaps in places. Eastward from this ridge for something more than a mile extends a swamp that has been denuded of a fine growth of arbor vitæ and other trees. This second tract merges into higher land at the east, where it is more or less plainly demarked by low ridges and knolls of sand. This tract has been partially reclaimed and subjugated to the plow. Eastward still farther the land is mostly under cultivation, but distinct traces of a swampy character remain. Again, in the eastern row of sections in Dalton township and extending for some distance into Cedar Creek is a low, moist, loamy and sandy area. The north branch of Bear creek runs along the western limit of this tract, its bed but little depressed below the general land surface. Close to the creek on the west rises an irregular dune-like ridge of sand clearly determining the southward direction of the stream. This ridge (which has been viewed only at a distance of about half a mile) seems to be the dune line of an older border of the lake. It is quite evident then that these several areas extending some twelve miles from the lake into the central part of the county are successive reclamations from the lake.

The high sand plain along Muskegon river is thought to have been a delta formation when the lake extended far inland. This is suggested by the fact that it seems to be highest near the present course of the river, sloping very gradually southward, northward and towards the present shore.

Springs and Wells.—Springs are of course numerous along the streams and in the hilly regions of the east and northwest. Near the lake shore many streams have cut deeply into the underlying clay and springs gush out from the banks many feet above the streams. In the so called delta region there is very little water found at the surface, but so far as known wells are not very deep, 20 feet often being sufficient to find good water. In the low and level tracts previously mentioned water may usually be found by very shallow digging. Wells from 4 to 10 feet deep are the rule. In Casnovia many wells are more than 100 feet deep and often water is not found even at a greater depth.

Flowing wells are quite common near the shore, ranging in depth from 35 feet at Montague to some 250 feet at the south line of the county.

Soils and Minerals.—The character of the soils has been suggested in various ways by what has preceded. The high sand plain covering most of Muskegon township and more or less of Egelston, Cedar Creek, Laketon, Norton, Dalton and Fruitland is a particularly barren region. Away from the immediate vicinity of Muskegon the settlers are very scattering; few signs of prosperity are visible in their homes; frequent deserted buildings and clearings show where the struggle to get a living and establish a home has been abandoned. In traveling over the region along nearly the whole course of the river in the county no public road has been found except at the head of the lake from which the stream could be viewed. Blue Lake township is a most desolate region, supporting the least population of any township in the county. The low and level regions before described are mostly of a sandy soil more or less mingled with clay and having clay or "hardpan" (the latter a ferruginous sandstone approaching bog ore) lying but a few inches or feet below the surface. The low sands are more or less dark and may be finer than the high sands, and are always moist because of the impervious material underlying. These lands are said to have been easily cleared of stumps because of the horizontal direction of the roots. The rolling lands of Casnovia and parts of Ravenna and Moorland, with the similar lands in the northwestern part, are perhaps altogether the most valuable for general farming.

A large deposit of magnetic sand within a few miles of Muskegon is known to certain persons. At Twin lake the surveyor's compass is unreliable because of deflections. A deposit of diatomaceous earth lies somewhere in the northwestern part of Laketon township, probably not many chains distant from the coast.

Orchards and Other Crops.—Near the city considerable gardening and growing of small fruit is done even on the high sands. In Egelston township, between Wolf lake and Muskegon river, a man is surprisingly successful in raising melons on a high sand slope, using no fertilizer. Moorland has been famous for an immense production of peppermint oil, but low price has reduced the production to a small fraction of the former amount. Sugar beets are being grown with success on the swamp lands of Sullivan and Ravenna, the yield being high in tonnage and quite satisfactory in per cent of sugar. It is noticeable however that the acreage in beets yearly moves toward the loamy slopes bordering the swamp. Peach orchards in Casnovia township and in the vicinity of Whitehall village are thrifty and yield fine crops.

Native Flora.—Presumably the high sandy region was formerly occupied largely by pine and hemlock. The characteristic trees now are oaks, *Q. alba* and *Q. tinctoria*. These are usually of a scrubby character, but some good timber occurs. *Q. rubra* is scarce. *Pinus resinosa* is very scarce, only a few trees have been noted in Fruitland township. *Pinus Banksiana* is somewhat more common. *Pinus strobus* is seen everywhere, unless in the extreme east and northwest portions. Slocum's grove, occupying some half dozen sections adjacent in Casnovia, Moorland and Ravenna, is a splendid mixed forest containing perhaps 30 species of trees such as beech, maples, basswood, elms, oaks, hemlock, yellow birch.

On the moist low plains that have been recently cleared the characteristic tree growth seems to be the trembling aspen, *Populus tremuloides*. This seems to spring up quickly and profusely wherever such soil is left exposed.

The accompanying plate V shows the contrast between the roots of the pine in low places, where they have only a short way to go for water, and on the sand plains where they have to run down deep.

WASHTENAW COUNTY.

For some time the scientific departments of the State University have needed and asked for a topographic map of their neighborhood. Upon several occasions Prof. Russell has appeared before the legislature in behalf of such a topographic survey, not only of the neighborhood but of the State, and the following quotation from a letter from Prof. Spalding shows its importance in another department:

"I would like to reiterate and emphasize with all my power what you say regarding the necessity of a topographic map. This is so great a need with us in Ann Arbor that important work already begun will have to stop unless we can have the region mapped. I have already had some conversation with Prof. J. B. Davis, our professor of surveying, etc., in regard to a map of the Huron river at Ann Arbor. Some of my students have been constructing preliminary maps of some of the glacial lakes near here, and they serve for purposes of study to some extent, but they are not sufficiently accurate for a scientific piece of work and could not be published. Prof. Reighard feels the same need; so does Prof. Runel. We must, by one means or another get truthful maps of the State just as soon as may be. You may be sure of the hearty coöperation of all of us on that score, for it is a 'long felt want.' The right way, as you suggest, is for the State to do its share towards paying for it and then get the U. S. Survey as soon as possible to go ahead."

In consequence I entered into an arrangement with the United States Geological Survey, a copy of which is found in another place, for a topographic survey which will nearly cover Washtenaw county and also portions of adjacent counties on the north, east and south, and will, I trust, be of use in many ways to the large number of students that come to the State University and Normal College, particularly in illustrating to them the utility of such a map, as well as the residents of the region.

When this map is finished I hope to arrange for a careful geological survey of the county. Mr. F. Leverett, Prof. Sherzer and Prof. Russell already have many notes on the surface geology and two deep wells recently put down, that at Milan and at the university, help to give us more exact knowledge of its deeper structure and mineral waters.

The samples preserved at the university of the well were put up wet and have so cemented that I have been able only to give a cursory examination. An abstract of my examination and correlation, combined with newspaper items, may not be useless, pending further details or in case the samples should be in any way destroyed, and will be found in connection with my discussion of the prospects for oil and gas in a later paragraph.

It is to be regretted that the university has not made all that it might in addition to science from this boring. The rate of increase of temperature, the magnetism excited by the earth in the casing, and the character of the mineral waters and their gases, are as worthy of study as the mere succession of the strata. This well might be an important part of the equipment of a geological laboratory.

LAPEER COUNTY.

This is one of the counties the rocks beneath which are probably rather monotonous, the sandstones and shales of the Marshall and Coldwater series. It is, however, one where we are very uncertain of the dips and where anticlinals suitable for the concentration of oil and gas may occur, so that every item of information by wells is of exact value.

Mr. J. J. Mason informs us that he put down a well at Columbiaville 1500 feet deep, the last 90 feet thereof being a brine-bearing sandstone, presumably the Berea. The well was plugged at 700 feet in order to use fresh water, which comes in probably from the Marshall at 300 to 400 feet depth.

Mr. F. B. Taylor began to work up the surface geology of this county in the summer of 1900. But his work is not entirely finished, and I cannot tell how soon we may be able to finish a report uniform with those of Vol. VII. I prefer, therefore, to publish here his preliminary report, which has already been given to the residents of the county through the courtesy of the Lapeer County Clarion, March 8 and 15, 1901.

SURFACE GEOLOGY OF LAPEER COUNTY, MICHIGAN

SUMMARY OF REPORT OF PROGRESS.

BY F. B. TAYLOR.

SURFACE GEOLOGY OF LAPEER COUNTY, MICHIGAN.

SUMMARY OF REPORT OF PROGRESS.

BY F. B. TAYLOR.

The field work upon the surface geology of Lapeer county is still in an incomplete state. The month of May, 1900, was given to this work and the results so far attained are summarized below.

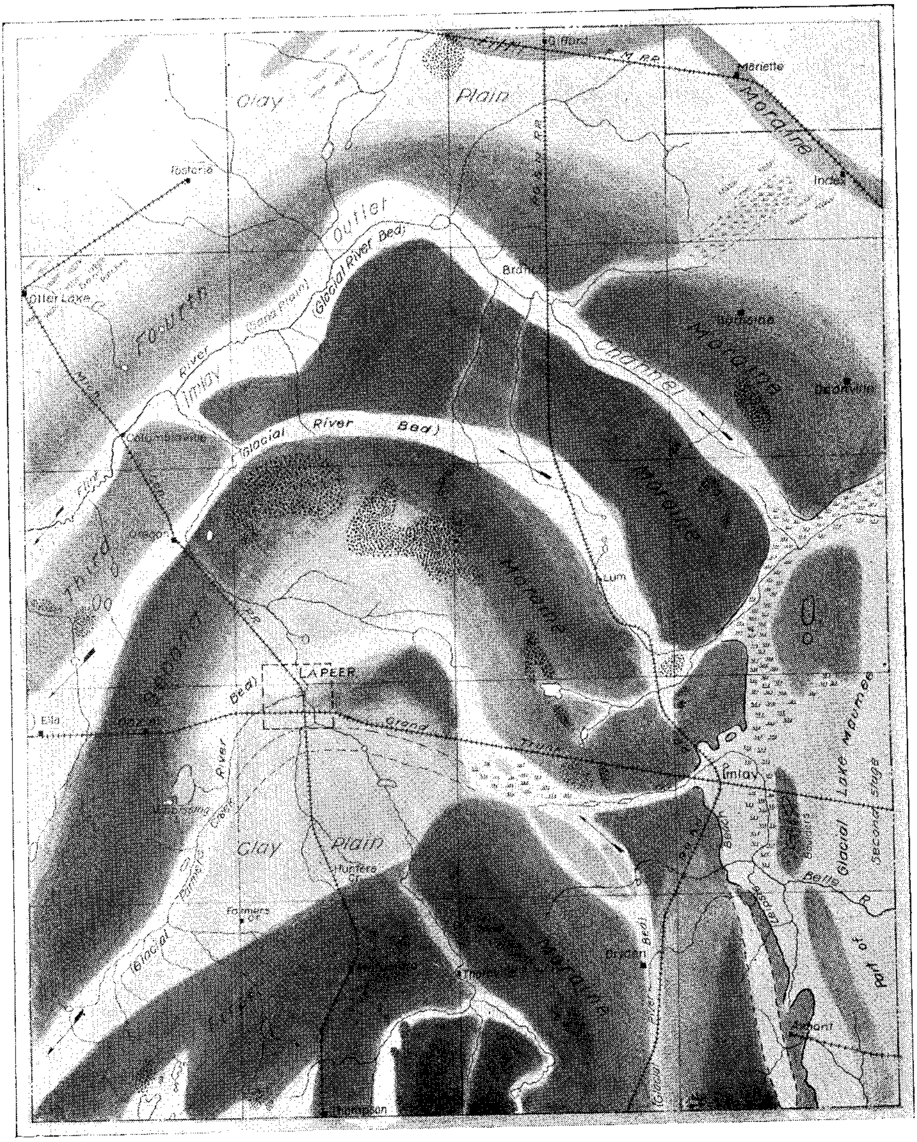
Work upon a topographic map with contour intervals of ten feet is well advanced and is nearly complete for the southern two-thirds of the county. The northern third will require some further barometric work. Some of the rougher parts in the central portion of the county will need some further study, especially in Arcadia, Mayfield, Deerfield and Oregon townships. The extremes of surface relief range from about 750 feet above sea level on Flint river in northwestern Oregon township to about 1275 feet above sea level in southern Dryden and Metamora. The highest point of the region is in section 6 of Addison township, Oakland county, about three-fourths of a mile south of the county line. This point is close to 1300 feet above sea level. Belle river in northeastern Almont is down to about 780 feet above sea level, that is 200 feet above Lake Huron. The central part of the county has several clusters of rugged, irregular, steep-sided gravel hills. Dryden, Metamora and Hadley are mostly high and hilly, while the eastern border and Burnside, Burlington and Rich townships are mostly flat and close to the level of 850 feet above sea level. On sections 21 and 28 of Burnside is a sharp isolated hill commonly called Burnside mountain, which rises about 300 feet above the plain to the east. The topography of the county is characterized by a series of ridges and valleys. In the eastern half they trend southeast and northwest, but in the western half they run northeast and southwest.

The bed rocks of Lapeer county are entirely covered by glacial drift, in most parts to a relatively great depth. So far as known they do not protrude at any point. The depth of the drift and the configuration of the buried rock surface beneath can be learned only as it is revealed in well borings and other excavations. Within the limits of Lapeer county there are so few such borings so far as learned which reach the rock surface that very little is known respecting it. In Dryden and Metamora townships, which comprise the highest parts of the county, the drift is known to be very thick, not less than 300 to 400 feet, and probably more. So far as learned, the drift does not appear to be much less than 100 feet deep in any part of the county.

The entire surface of the county is therefore composed of loose, unconsolidated sediments. By far the greater part of it is clay, but with a considerable admixture of sand, gravel and stones, large and small. With but few exceptions the clay has stones and boulders scattered promiscuously through it; clay of this sort is called "boulder clay" or "till," and by well-drillers "hardpan," and is well recognized as a characteristic glacial deposit. It is the normal deposit of slowly-moving massive bodies or streams of ice, and its heterogeneous character readily distinguishes it from sediments laid down in water, whether still or in motion. Almost the whole of the great mass of softer sediments which covers the bed rocks of Lapeer county is composed of this boulder clay or till. But here and there through it and upon its surface are occasional beds of sand and gravel and bouldery places and sometimes beds of clay horizontally bedded in fine layers free from all coarser sediments. These distinctly classified sediments are the deposits of water, the coarser ones in running water and the finer ones in quiet or still water. They are all comprehended under the general term of *modified drift*, that which was laid down by the glacier without the intervention of water action being designated as *unmodified drift*. The entire mass of the drift deposits is made up of an exceedingly complex mingling of these two classes of sediments. But while the main constituent of the drift is boulder clay or till, almost every well or other deep excavation shows more or less extensive and irregular masses of modified drift, usually sand or gravel, embedded in or lying under the till. These more porous layers often become great reservoirs for the accumulation of rainwater, and when they lie in an inclined position and are overlain by an impervious bed of till they are likely to become the reservoirs for artesian wells and perennial springs. There are a number of artesian wells and springs of this kind in Almont township. Before the completion of the work, it is desirable to make some further collection and study of well records with a view of learning as much as possible concerning the conditions of natural water storage and supply.

The study of the surface features and deposits of the county is also well advanced. Incidentally to the study of the topography and the distribution of the different kinds of soil, much has been learned concerning the history of the development of the surface. Inasmuch as the topography and soil distribution of the county as we find them are almost entirely results of the particular processes by which the drift was originally fashioned, it seems desirable to present a brief sketch of the history of that development. The data for this sketch and for the map of the surface features which should go with it are nearly complete. The accompanying map (Plate IV) presents a rough sketch of these features so far as made out, but is lacking in accuracy of detail in some parts, especially in the northern and northwestern parts of the county.

The general facts required for this historical sketch are at hand and may be briefly summarized. As its maximum the continental ice sheet of the glacial period overspread the whole of Michigan, and it reached far to the south over Ohio and Indiana. At that time a solid mass of ice filled the basins of Lakes Michigan, Huron and Erie and covered all the intervening and surrounding country. Southern Michigan was then deeply buried under the ice to a depth measured perhaps by thousands rather than hundreds of feet. As it retreated northward by gradual melting, its margin frequently halted, probably periodically, and at each



LAPEER COUNTY, SURFACE DEPOSITS.—F. B. Taylor.

halt a more or less well defined ridge of drift was formed at and under the edge of the ice. These ridges are known as moraines. A numerous and intricate series of them has been traced out and mapped in Ohio and Indiana and southern Michigan, and their distribution shows that when Lapeer county first began to be uncovered by the retreating ice the glacier was still occupying the Saginaw valley and the basins of Lakes Huron and Erie. The glacier moved forward most rapidly in the valleys and lagged behind on the higher ground, with the result that the higher parts of the country were uncovered first as the ice retreated. The thumb of Michigan forms a broad ridge projecting northward between the Saginaw valley on the west and the valley of the St. Clair and Detroit rivers on the east. Lapeer county may be said to lie upon the basal portion of the thumb. As the glacier retreated, its margin formed in two great lobes, one projecting southward in the Detroit valley and the other in the Saginaw valley. Between these projecting lobes was a sharp re-entrant angle running northward on the intervening high ground into Lapeer county. Thus, through all the time that the ice-front was retreating across this country, the apex of the re-entrant angle between the lobes was within its area. Strong drainage usually issues from such angles in the glacier, and its magnitude is roughly proportioned to the magnitude of the lobes that bound it. In Lapeer county the rivers that drained the glacier were large and they made a strong impress upon the surface deposits. Although some further investigation will be required on the relation of the moraines and the associated drainage in the central, northwestern and northern parts of the county, enough is known to show that in its retreat northward the ice-front halted five times, the moraine of the last halt barely touching the northern fringe of the county. In each position, except the last or most northerly one, a river of considerable size flowed along the edge of the ice and was fed by streams issuing from the ice itself.

Moraines are not merely dumps of detritus falling from the steep front edge of the glacier, but are also largely accumulated upon and under the ice near its margin. Such a moraine forms a belt varying usually from two to five miles wide, though sometimes much wider. The first moraine formed in Lapeer county covers the western half of Dryden township, the southwest corner of Attica, the southeast corner of Lapeer, nearly all of Metamora and the southeast half of Hadley townships. This is a very hilly district and forms the highest part of the county. The earliest glacial river bed in the county is associated with this moraine and lies in Dryden and Metamora townships. It turns an entire semicircle, starting north across the county line south of Whigville and turning gradually around to west and south and passing out of the county about a mile and a half east of Thomas.

This river bed has peculiarities which are hard to explain. There is some evidence that it did not flow along the ice-front, but under the solid ice-mass itself, and that it issued from under the ice at a point about two miles south of the county line. The ice-front at the time of this moraine appears to have been a little south of the county line, and the relation of this channel to it remains for the present somewhat problematical.

The next later moraine in Lapeer county passes north through the west half of Almont township, runs north-northwest through eastern Attica and central Arcadia, where it turns west across northern Mayfield and thence runs south-southwest through eastern Oregon, central Elba and northwestern Hadley townships. This moraine is quite irregular in character. It has a high rolling topography in southwestern Almont, is so weak as to be almost unrecognizable in southeastern Attica, but in northeastern Attica and in Arcadia and Mayfield it is very rugged and has many high, steep-sided knolls of gravel associated with it. In some parts it is chiefly made up of these.

The drainage at the time of this moraine went northward in eastern Dryden, northwest across Attica and, after crossing Lapeer in a course not yet clearly made out, it ran southwest up the course of Farmer's creek, across eastern Elba and central Hadley.

The next later or third moraine is a faint feature running north-northwest through central Almont and western Imlay and Goodland, becoming a strong feature in the latter township. Thence it passes northwest through North Branch to the northeast corner of Deerfield, where it turns southwest and, following the south side of Flint river, passes out of the county.

The drainage of this stage is not yet made out continuously. The long flat depression west of Almont suggests a line of drainage, but seems to lack specific characters of a river bed. It seems to fade away within three miles north and nothing representing a river bed appears until a point is reached about two miles northwest of Imlay City. Here a wide channel opens rather abruptly and runs northwest past Lum, King's Mills and north of Five Lakes. Beyond this its course is not yet made out, but there is a river course running across the center of Oregon township from northeast to southwest which is probably a part of the same. Between Almont and Imlay City it may be that a readvance of the ice filled up a channel that existed there and pinched it out.

The next and fourth moraine runs north-northwest through eastern Almont in very faint form and passes northward about a mile and a half east of Imlay City in broken fragments. In Goodland township it becomes a strong feature and turning northwest crosses southwestern Burnside, northeastern North Branch and southwestern Burlington townships. On the flat plains of Rich township it seems to have no representation. But in southwestern Rich and running southwest through central Marathon it is well developed along the north side of Flint river. This moraine and the two preceding ones are crowded together two or three miles south of Imlay City into a breadth of four or five miles.

At this stage the drainage took on a new relation. As the ice-front drew back to this position the water of Lake Maumee flowed in over a part of the ground uncovered and it found a free passage across a low divide in northern Goodland township and down Flint river. Thus an outlet for the lake was established instead of a river carrying only the drainage from the immediate ice-front. Lake Maumee was a lake which gathered in front of the receding margin of the continental glacier and it filled the valley of the Maumee river and had its principal outlet at Fort Wayne, Ind., and thence down the Wabash. One arm of this lake reached nearly to Cleveland in Ohio and another to Imlay City, Mich. But the new outlet through Lapeer county did not carry the whole discharge, for the Fort Wayne outlet continued to be active. A beach composed of gravel and sand was made by the waves of this lake where it dashed upon its shore. This beach, known as the Leipsic beach, has been traced northward through Almont and Imlay townships to the northern part of Goodland, where the outlet narrowed up and began to flow as a river in which wave action was not so powerful. At Imlay City this beach is about 850 feet above sea level, but it declines somewhat southward. From the center of Goodland the river ran directly northwest to the southern part of Rich township, where it turned southwest and followed the course of Flint river, passing out of the county in the northwest part of Oregon township.

The last and fifth halt of the ice-front in Lapeer county made a moraine which barely touches the northern edge of the county. A faint morainic ridge passes north of Silverwood and runs west-southwest into the northwest part of Rich township. Another runs east and west north of Clifford and another runs southeast a little south of Marlette in Sanilac county. The course of this last one probably carries it across the northeast corner of Burnside township. But the northern townships of the county have not yet been fully studied.

So far as known, this moraine does not appear to have had a river along its front. This moraine and the preceding one are both rather faint in the northern part of the county and there is no well marked valley between them, but an almost level plain. All these moraines have well developed courses of transverse drainage, that is, at right angles to the course of the moraine and the ice border. The streams that made these seem to have flowed out from under the ice. Belle river follows one of these in Attica and Imlay townships to where it joins the lake outlet north of Imlay City. Mill river follows others through the second, third and fourth moraines across Attica and Goodland townships. Another runs south-southwest from northern Burnside to the lake outlet in North Branch. Flint river passes through one at Thornville, and again in eastern Oregon and Marathon it follows two others. There is a good one also in western Oregon running northwest to Flint river. This one has an esker in it. It some instances these lines of drainage appear to be associated with large accumulations of gravel and sand, which were laid down by the streams as they came from under the ice. The greatest gravel accumulations, however, such as those in the northwest part of Arcadia and in northern Mayfield, do not appear to be associated with such transverse river courses. The transverse courses through the fourth moraine seem to have carried off the drainage of the firth directly away from its front.

There was, presumably, a soil covering the rock surface of Lapeer county before the advent of the continental glacier. That was a soil of disintegration, produced by the decay of the rock surface as it lay in place. Probably most of that soil was swept away by the first advance of the ice, but a considerable portion of it may have been mixed in with the other ingredients which make up the till. So far, however, there has been no certain recognition of the preglacial soil.

The character and distribution of the present soil of Lapeer county is very intimately related to its glacial history. The drift which the glacier left behind, with all its variety of topographic form and composition, has been the basis of soil formation. The weather, animal and vegetable life, and chemical action have all contributed to the final result. Mechanical forces of disintegration have resulted from frost and sunshine, from wind and running water, and from the action of both vegetable and animal life. Chemical decomposition results from oxidation and from the dissolving power of water aided by carbonic acid gas and the humic acid of decaying vegetation. The contribution of humus or decaying vegetation to the surface soil is perhaps the most efficient of natural agencies for its enrichment. Steep slopes and high ground generally are well drained and their principal sources of vegetable enrichment are derived from leaf mould and the decay of roots and fallen trees. But some part of these materials are always carried off in solution by surface streams to lower ground. Ponds and swamps, including especially in this county the old river beds, have poor drainage, and they receive a considerable contribution of enriching matter from the surrounding higher ground. A number of the ponds and swamps of Lapeer county contain deposits of marl and most of them contain more or less muck and peat, a few in considerable quantities.

The morainic areas of the county have for the greater part clay soils, and so have the flat till plains of the northern townships. There is, however, a considerable variety among these soils. They are heavier or lighter according to the proportion of clay they contain. The soil on the earliest or first moraine of the county comprising the high ground in the southern part, is in most parts rather more gravelly and sandy than the common run of the till in the other moraines and the soil is therefore a shade lighter. Some of this moraine, however, is purer clay and has a slightly heavier soil, notably in eastern Hadley and northwestern Dryden. The till plains of the northern and northeastern townships have in the main a still finer clay soil and are correspondingly heavier. Much of Rich and Burlington and Burnside, with the eastern parts of Goodland and Imlay, are of this heavier clay variety, sticky when wet and more or less inclined to harden on drying in the sun. There are sandy streaks, however, across Burnside township which contribute somewhat to ameliorate the toughness of the clay and turns it into sandy clay loam. Through the middle, southern and western parts of the county the clay soil is usually described locally as "clay loam."

There are a great number of knolls and scattering beds of glacial sands and gravels associated with the several moraines, and these of course have lighter soils. They are frequently devoted to fruit culture. Many gravel knolls are covered with orchards.

The old glacial river beds are mostly poorly drained. In consequence of this they are to a large extent swampy, although they all contain more or less sand and gravel in the form of bars formed by the currents of the glacial rivers. Some of these bars are flat and wide and furnish excellent light soil areas for small fruits.

The old lake outlet, or "Imlay Channel" as it is called, is mainly floored with muck and peat as far north as the north side of Goodland township. From that on it is partly occupied by sand bars to the bend in the south part of Rich township. Southwest from this there is an extensive sand plain bordering Flint river, narrowing at Columbiaville, but widening again below that and passing into Genesee county. This sand forms a very light, barren soil.

Dune sand is scarce, so far as seen, being found only in northwestern Mayfield and the adjacent part of Deerfield townships.

There are some large areas of muck (peat and celery) soil in Lapeer county, especially in the townships of the eastern and northern border. Some of these have been drained recently and are coming into use, notably those near Imlay City and along the course of Mill river in Goodland township. There are also many smaller areas in the central and western parts of the county.

Lapeer county has so far made but little progress in the development of industries based on its economic geological resources. These resources are, however, so far as now known, comparatively few. There is a considerable quantity of marl in the county and localities so far determined are shown upon the map. None of them, so far as learned, are of large enough extent to form a basis of cement works in the present stage of this industry. No beds have yet been found having an extent of over one hundred acres. Because of their present unavailability mainly, the marls found have not been tested thoroughly to determine their suitableness for cement. The largest swamps in the county, in the eastern and northeastern parts, appear not to yield marl. Marl was formerly burned for lime in several parts of the county, most notably in southwestern Hadley and southeastern North Branch townships.

Clay suitable for brick and tile manufacture may be found in several places, but so far as known none are now worked for these purposes. None, however, of the best quality and free from pebbles is known at present.

Gravel and sand are very generally scattered in patches over Lapeer county. For the greater part, however, it furnishes but indifferent road metal because it is too sandy. It remains loose and unpacked when put upon the roads. In many places the composition of the material is in large part too fine, and also in part too coarse. Such metal makes a road soft when new and rough after it has become settled or worn. The tendency of the sand to remain loose even where it does not appear to be too fine seems to be due chiefly to two causes: to the hardness of the pebbles and sand grains and to their roundness. Too few of the grains crush under the wheels to form any cementing material and the metal is generally very free from anything like clay as it comes from the pits. The grains are almost all of the hardest crystalline rock brought by the glacier from Canada, and their roundness and smoothness is such that they will not knit together and pack without the aid of some cementing material. Clay is sometimes put on sandy roads for this purpose, but this method, while it works well in many cases, is too commonly overdone. Too much clay is used to attain the best results. By a little judicious screening of the gravel and a proper use of clay for cementation, there is every reason to believe that the generally too sandy road metal of the county can be utilized to good advantage.

It may be remarked again in closing that this sketch of the surface geology of Lapeer county is prepared upon an incomplete basis of observation. Three or four weeks more ought to be given to field work before the final report is written.

ECONOMIC GEOLOGY.

ECONOMIC GEOLOGY.

The special subjects or heads under which geological research may best be grouped are of two kinds. Either they represent business interests, and the facts grouped under each head relate to the raw material or materials of some industry; an illustration are the papers on clay, coal and marl, all materials for the cement business, which are appearing in our volume VIII; or on the other hand it may be some more purely scientific question, upon which the facts grouped together throw light.

In regard to general relations of geology, especially of this State, to the business world I shall beg leave to submit a lecture given before the Field Columbian Museum* November 2, 1901, though the style is somewhat informal and I cannot well reproduce the accompanying lantern slides.

THE ECONOMIC GEOLOGY OF MICHIGAN IN ITS RELATION TO THE BUSINESS WORLD.

RAW MATERIAL.

It gives me great pleasure to represent the State from whose gypsum quarries comes one-third of the product of the United States, which not only furnishes most of your wall plaster, kalsomine, adamant and similar wall finishes, and magnificent slabs of oriental alabaster (Michigan is east of Chicago), but particularly the material of that White City which embodied in a beautiful dream the aspiration for beauty, the abounding liberality, the indomitable energy, the civic pride, and capacity for harmonious work which characterize this city of which you are proud to be citizens, in order to tell you something of its other treasures of raw materials which have supplied and will largely supply the matter for your work.

For economic geology is but the science of raw materials, the real or ultimate raw materials, upon which no work has been done. Such materials are always parts of the earth's crust. In common parlance, many things are called raw materials which are raw materials for one industry perhaps, but are the finished product of another. Iron ore may be a raw material from the point of view of the Pennsylvania blast furnace man, but it is the finished product of the Michigan miner, just as much so as the pigiron turned out by the furnace men, which goes on from hand to

* Reprinted in the Michigan Miner for Dec. 1901.

hand, or rather from machine to machine, issuing as the finished watch spring, only to become at once raw material for the watch manufacturer.

Now, the business world is concerned with material wealth, which is labor incarnate in matter. Energy, ability and wisdom become matters of business, objects of exchange as well as desire, only when they are employed upon and embodied in matter. Dirt has been said to be matter out of place. Raw material is matter out of use.

LOCATION.

Sometimes all that is required to bring the raw material into use is change of location. The strawberries which rot in Michigan beds would find a use fast enough in Chicago streets. Some of the sand piled high on Huron county beaches is worth over a dollar a ton placed at the bottom of a copper-smelting furnace. The waste sands from stamping the rock to get out copper are of no use in furnace bottoms, but, mixed with a little asphalt, make the best of paving blocks. A good gravel bed, such as that at Mecosta, well placed for road mending or railroad ballast may really be worth more per cubic yard than the golden gravels of the Yukon, the difference depending on the fact that the latter are hard to reach.

The value of an article in any market is then normally very closely dependent on the amount and quality of labor required to get to market the part of the supply needed that costs most.

The value of the raw material is proportionate to the advantage which it may have, in that it can be put into market and in shape for it with less labor.

Please note, for instance, how the copper mines of Michigan are chiefly grouped close to two great gaps in the range. Is this because the copper is bunched there exclusively? It is hardly likely. Is it accident? No, it is almost certainly due largely to the relative ease of transportation and discovery. The new railroad south from Houghton is partly the effect but partly the cause of the opening up of a new tract of copper-producing land.

These two processes just mentioned, putting the raw material where it is wanted and putting it in the shape it is wanted, correspond to the two great divisions of business, commerce and manufactures. The railroad and the commercial traveler are busy putting matter where it is wanted, —the mill and the manufacturer mold it into the required shape.

Let us then begin by looking at the advantage which Michigan has from a commercial point of view, in the ease in which transportation to market may be obtained. Studies of location are, as may be seen from what has been said, a very important part of the study of economic geology.

One of the points of vantage is our nearness to Chicago, and a word as to the commanding position of Chicago itself may be allowed. The great cities of the world are generally found in geologic basins, and very frequently the basin takes its name from the city. Rome, Vienna, Paris and London, for examples, have geologic basins named after them. Such a disposition of the geologic strata makes some city near their center the natural meeting point for the later stages of manufacture and mart of trade for different materials. Now, Chicago may be treated as the center of a vaster basin than any of those mentioned, which extends from the coal mines of Pittsburg to the upturned strata of the Garden of the Gods in Colorado, and from the mines of Michigan to the Gulf of Mexico, the whole Mississippi valley, in fact. Michigan is also near to other great open markets, not only to Chicago and Detroit, but to Buffalo, Cleveland and Duluth as well.

WATER FACILITIES.

Not only is she near them, but she has cheap water transportation to them. Nowhere else in the world is there so great an extent of fresh water coast line (dotted with fisheries of value). Few states of the Union have so much water line of any kind. Not only is it cleft into two peninsulas (and outlying islands which amount to some 200,000 acres more), but by Saginaw bay and the so called Saginaw river the level of the Great Lakes reaches the center of the coal basin and the geologic center of the State. Moreover, the whole west shore of the State is lined with lakes, big and little, which the mere cutting of a sand-bar transforms into first-class harbors. The geological explanation of these lakes is full of interest. The land in which the basins filled by the Great Lakes lie is rising, but not equally. The farther north, the greater the rise, at the rate of about 0.4 foot per 100 years per 100 miles toward the north-northeast.

The result of this lift is evidently a tilting of the basin, so that while the water is leaving the northeastern part all the time it is backing up on the shore in the southwestern. This would naturally back the water of the lakes up the river valleys, and the Chicago outlet is but an anticipation of the course of nature. The Saginaw, the course of which is exactly against the direction of the uplift, is a good example of a backed-up stream, though the effect there has not been great. On the west shore the prevailing west winds and the lake current combine to throw sand-bars across the mouths of the drowned river valleys and convert them into lakes, and thus we have every stream of the west shore ending in a lake. This enables the direction of tilting and the line between the part where the water is retiring and that where it is gaining to be fixed quite nearly, for if we pass a line from the outlet at Port Huron to the northwest between Traverse City and Frankfort, then every stream to the south empties into a lake which is only the flooded part of its own lower valley. On the other hand, the streams to the northeast of this line come into the lake on the run, with water-powers close to their mouths, as at Alpena, Cheboygan, Elk Rapids, etc., thus showing that the lake has been getting away from them.

INTERRELATION OF RAW MATERIALS.

We have also to consider, in estimating the value of raw materials, not merely their location relative to great marts of consumption, but also relative to other raw materials, for there are but few finished products into which only raw material has gone. Take, for instance, the manufacture of beet sugar, of which Michigan will produce this year between one and two hundred million pounds. Those who are not specially interested perhaps think of the matter as one mainly of the climate and soil for sugar beets, but that is not the whole of the story. Besides sugar beets, water is needed, good water and plenty of it, without much organic matter and without salt. Only the other day I was consulted as to a supply of water for the Bad Axe beet sugar factory, and I have been informed that a doubt as to the quality of the water delayed the building of a beet sugar factory at Saginaw for years. Not only is water needed, but coal or other fuel to evaporate the water after it has soaked the sugar out from the beets; for instance, the presence at hand of slack as a cheap fuel is an important advantage of the Bay City factories, and the possibility of coal in the neighborhood, in fact right beneath the factory, may mean a good deal to the Lansing factory in the coming days of severe competition. Not only is the coal needed to boil down the juice, but limestone to clarify it, and that of a very high grade with less than two per cent of impurities if possible. Perhaps this one illustration will be enough to make clear to you the importance of the relation of locations in the study of raw materials. It is probably this principle that leads the center of a geologic basin to become a center of industry, because around it the various kinds of materials are arranged, and in it they meet for their mutual edification and improvement.

SAGINAW THE CENTER OF ATTRACTION.

Now, we find as a striking feature of the geology of lower Michigan a basin-like arrangement of the beds.*

A brilliant French writer, with that fondness for antithesis so characteristic of French style, has remarked that the rocks of France are arranged around two poles—the positive or attractive pole, toward which the rocks dip, toward which the streams of water flow, and, beside these material streams, streams of youth and intelligence, I need hardly name. To a Frenchman what can be the attractive pole of France but Paris? The other pole from which the rock strata dip is a rough mountainous region, repellant except to those who rejoice in wild scenery or who have been fascinated by architectural studies. This region of primitive rocks, where the original crust of the earth stands nakedly forth except as partially swathed in the debris of extinct volcanoes, is the rugged region of the Auvergne, culminating in Mont Doré and the Mont du Cantal. Around Paris and the Cantal curves in a great figure eight the band of Jurassic strata, while younger beds surround Paris and older ones are found in the Cantal curve.

This antithesis may without forcing be applied to the State of Michigan; but the geological center of attraction is neither Detroit nor Lansing, but Saginaw. This is geologically the center and attractive point of the State, and a geologist must prophecy a brilliant future for Saginaw and Bay City, which have the advantage of Chicago on a smaller scale. Toward it flow the rivers from all directions. Around it lies the coal basin, the youngest of the consolidated formations. The encircling strata of lower rocks all around dip toward it; and, turning to the most recent deposits, successively older and older beach lines encircle it, and then terminal moraines of the ice sheet.

The great figure eight made by the Jurassic strata in France must be replaced for Michigan by the Great Lakes, which unite and divide the two peninsulas.

* See Michigan Moderator, October, 1899. Also Plate IX.

The negative pole, the rugged protrusion of oldest rocks from which the strata dip and the streams flow, we find in the Huron mountains northwest of Marquette.

There are a number of other ways in which these two poles may be contrasted. The one is the highest land of the State, the other the Saginaw valley, the lowest large area. The one is surrounded by mines of iron and copper and is relatively devoid of farms. The other has mines of coal and is a fertile valley. The one pole is and will be comparatively unpopulated, the other is or will be densely populated.

Michigan may also very handily be compared to two hands. The right hand is the Lower Peninsula, fat with fertility. The Saginaw valley is the hollow palm upturned, receiving blessings from the skies. The likeness is so plain that the district of Huron, Sanilac and Tuscola counties has long been known as the Thumb. The overhanging and projecting cliffs of the Point Aux Barques may pass for the Thumb-nail. Leelanau county we may then call the little finger.

The Upper Peninsula may then be taken as the left hand, which will be leaner, with bones and sinews of rock far more prominent, and of this hand Keweenaw Point may be taken as the thumb.

The two hands taken together contain almost all the resources necessary for man, and mutually complement each other.

UNION OF INDUSTRIES.

One striking instance of correlation in industries and in raw material has been of the greatest importance in Michigan. I refer to the union of lumber and salt. In the manufacture of lumber there was a vast amount of waste wood and saw-dust which had to be burned to be got rid of, which indeed is burned today in some places. But fortunately almost anywhere in the Lower Peninsula of Michigan one can by drilling find either rock salt or a strong brine for salt manufacture. In the former case they pump down water to dissolve the rock salt so that in both cases they have to evaporate the brine, and for this the waste heat from burning the saw mill refuse was used. When the pine was cut and the saw mills of the Saginaw river began to move or burn up without rebuilding, it was thought that time had struck the knell of the salt industry. But instead of that the hour had struck to awake the black giant coal, which all this time had been lying low and saying nothing, to take up the task. And now in the Saginaw valley, whenever they have a little waste heat or coal, at the power plant of the electric road, at the glass works or at the dump of the mines, they can always turn it to use in making salt.

Of all the raw materials, those which supply power to do a man's work for him are of the most value, not only in themselves, but in their correlative raising the value of almost every other adjacent material. Two of them we have just mentioned—wood and coal. Others are water-power, wind, peat, oil and gas. These materials do not have the generation of power as their sole use; but if, as we have said, wealth is labor incarnate in matter, it is obvious that anything which can replace or multiply labor is of the widest economic importance.

WATER-POWER.

Of all these sources of power, water-power is probably the most permanent, though if we sacrifice our wood too recklessly we may also injure our water-power resources.

It is not possible to go into details regarding the water power of the State, for which I must refer to the writings of Robert E. Horton,* but one or two salient facts may be noted. One of these, the location of water-powers near the mouths of streams northeast of the tilting axis, has been mentioned. Another is the abundance of lakes upon the highlands of the Lower Peninsula, which serve to steady the flow of the streams. The Great Lakes formerly stood 100 to 200 feet higher than today. As they retired they left the old lake bottoms, around Detroit and Saginaw, for instance, as nearly smooth plains, while above their former extent we have a region which was the dumping ground of three glacier arms, one of which came down Lake Michigan, one through Lakes Huron and Erie into Ohio, and a relatively shorter one followed the Saginaw bay. This higher region is studded with lakes and swamps, and near the boundary of the two regions there is an especially well-marked water-power belt, on which Adrian, Tecumseh, Ypsilanti, Rochester, Owosso, Alma, Mt. Pleasant, and a host of other thriving little manufacturing towns are springing up.

This line is not only one of river water-power, but also one where we are especially likely to find flowing wells. Though one does not often think of them as sources of power, they are, for they save the work employed in pumping or the cost of a windmill, and when they will run a hydraulic ram, or without it throw water all over the house, they are a commercial asset of value.

The flowing wells just referred to come from the drift, and are from strata of gravel, etc., having their sources toward the highland region and following the slope of the country down to the lake. But, beside these wells, there are many from the rock.

The structure of the State being that of a synclinal or basin, wherever a boring can tap a porous bed which takes in water at some higher level we are likely to have flowing wells. This was the case over most of the Saginaw valley and in the valleys nearly all the way back to Hillsdale, as at Lansing. Along the shore of the Lower Peninsula, too, with but few exceptions, flowing wells may be obtained. In the Upper Peninsula, along the whole of Lake Michigan from Menominee to Drummond's Island, wells with a strong head may be obtained. The Lake Superior shore from Keweenaw Point west should also yield artesian wells.

The temptation to digress and discuss the water supplies of farms and cities, the great advantage which the Upper Peninsula has in its soft waters, the cost of the hard water in laundry bills and soap, and the distribution of hard and soft waters through the State, must be resisted, for power is the subject in hand just now. I will merely remark that manufacturers and promoters have made trips from Chicago and Detroit to Lansing just to talk over this one matter with me.

Returning to water-power proper, I would remind you that in connection with electricity water-power is to be of increasing importance. A

* U. S. G. S., Water Supply papers No. 30, 48, 49 and the Michigan Engineer for 1901.

great dam at Allegan has just been put in from which it is planned to realize 3,000 horse-power. Another is in preparation. Thunder Bay river furnishes several hundred and could furnish perhaps 2,000 or 3,000 horse-power at several different points. But the greatest water-powers of the State are yet undeveloped. The Au Sable, Au Gres and Rifle have numerous lakes and considerable flow all the year and magnificent water-powers untouched. In the Upper Peninsula there are still more. Lake Gogebic sends fine power past the Victoria mine, and the Ontonagon river has a large valley to the south of the Copper Range, through which it forces itself with a rapid flow.

The Dead river near Marquette furnishes light to all the town at a nominal cost, but it has 850 feet of fall in 10 miles and could do every stitch of work done in the town. The Sturgeon falls help run the mines of Iron Mountain, and, though I shall not pretend to list the Michigamme, Tahquamenon and all the other powers, yet I could not be pardoned if I forgot the "Soo" with its 18 feet of fall and all Lake Superior behind, where the carbide for your bicycle light is manufactured.

In air power Michigan has no special advantage.

WEALTH IN WOOD.

The wealth of Michigan in wood is well known, and, though the forests of pine that were thought inexhaustible are well nigh exhausted, there is yet a great deal of hardwood left, the raw material of the furniture manufacturer and also of the charcoal man; 160,000 tons of charcoal iron are made in the State.

The great wealth in wood in kind and quantity is due to the range of climate and range of soil. The hardwood belts are characteristic of the glacial moraines. The use of waste wood as fuel has been already mentioned. The next source of fuel (peat) may be considered a mixture of the two previous (wood and water). We have used our own peat bogs to grow peppermint and celery, and the peat itself for nursery packing, etc., but until recently no serious attempt has been made to use it as fuel.

It is so largely water that it cannot be an economical fuel unless we can arrange to have it handled, compressed and dried by machinery, and make the peat itself do the work. If that can be arranged there are millions of tons awaiting development, for there are vast peat bogs in both peninsulas and a company has been formed to experiment.

If wood is the father and water the mother of peat, coal is its child, and there has been no more important raw material than this. The coal basin of Michigan covers at least 7,000 square miles, and I have estimated that 8,000,000,000 tons await development, but it has been backward in developing and has lain dormant under a sheet of glacial deposits and a blanket of lake deposits while the fields further south and better exposed were opening up.

As late as 1895, when I first visited Saginaw and urged the development of the coal deposits, there were but a few thousand tons produced in the whole State, which today is producing a million tons a year of frequently excellent bituminous coal. It has spread to Nebraska and the Dakotas, and is one of the factors to be reckoned with in the future development of every material in the State.

OIL AND GAS.

Oil and gas we cannot count a Michigan resource. There is a small refinery at Port Huron, but thousands of dollars are spent almost every year in boring with no commercial results. We have several oil and gas-bearing strata underlying the State,—the Berea Grit, which is a famous Pennsylvania sand; the lower Devonian beds, which have yielded such rich results in western Ontario; the Trenton, which is the famous Ohio oil rock,—but the basin-like structure does not seem to be favorable to concentration into gushers. And yet I live in hopes that some day some subordinate pucker of value will be found.*

IRON.

Not only does man want power to do his work for him, but he wants tools to do it with, and that means iron, the framework of our whole industrial system. I do not need to tell you that Michigan is one of the greatest iron producers in the world, that the tonnage which pours through the canal at the "Soo," making it surpass the Suez of the old world, is largely iron ore. In 1900 3,457,522 tons from the Marquette range, 2,875,295 tons from the Gogebic range, 1,665,820 tons from the Vermillion range, 7,809,535 tons from the Mesabi range, besides 3,261,221 from the Menominee range which does not go through that portal, or nearly 10,000,000 tons of iron, are produced in Michigan.

These facts are familiar, but the course of the iron ore trade in the past 10 years illustrates some principles of wider application to raw materials, so that I will go into some detail.

Early in the nineties iron ore from a new range appeared in the Cleveland market, and caused consternation in the heart of Michigan ore producers. It was the Mesabi range of Minnesota. Here iron ore could be mined under conditions than which nothing better could be desired, except as to climate. It was 13 below zero when I visited the range in March, 1895. The ore bodies were soft so that they often could be scooped up with a steam shovel and put on to the cars directly. They were generally quite flat, and covered with only a light covering of soil or unconsolidated glacial deposits. Under such circumstances the cost of ore was hardly more than of railroad ballast, and the miners of Michigan, mining in hard ore bodies, mainly standing vertically and with the cream already from the top, hardly saw where they were coming out. (The iron ore of Michigan I may say comes from a process of leaching and is gathered in lenticular irregular pockets in the oldest stratified formations of which we have any certain knowledge.) Indeed, as I was traveling in the rigors of a northern winter in the hard times of 1893, one-third only of the chimneys of Iron Mountain and Ishpeming were smoking. However, it was found gradually that the soft friable ores of the Mesabi needed some old range hard ore to make them work well in the furnace. Another thing had happened also. The hard times had taken the heart entirely out of the Duluth boomers, and left them an easy prey to the octopus.

Some years before the spare dollars of some of the Standard Oil men had been invested on the Gogebic range. As usual in people who go

* See article on prospects for oil and gas, below.

outside their business, in some cases they got pretty badly bitten, but they are stayers, and once in they did not let go, but added property until they had a strong interest in the Gogebic range, though how much they paid for it I do not know.

Through their interest there they were led on to other iron ranges, especially the new Mesabi, and, to make a long story short, by 1895 it came to be recognized that there were two great interests in the Mesabi range, each of these controlling a railroad to the lake ports—the Duluth & Iron Range and the Duluth, Mesabi & Northern. Each of these interests had properties on the other ranges which it would not pay them to let go to rack and ruin, and it was soon discovered that the two new Minnesota ranges, the Mesabi and Vermillion, were not destined to deal death and destruction to Michigan iron interests, for it was also discovered to their sorrow by the independent ore producers of these ranges that these two great interests did not care a nickel whether they made their profits in the railroad corporation or the mining corporation, and they accordingly fixed the rates for ore so that only just so much ore should be mined as suited them. If that left a very small margin of profit for outsiders, and it generally did, they were usually allowed to sell out when they got tired.

A fight followed for new railroads, and for state regulation of the ore rates in the Minnesota legislature, which is outside the scope of my paper. It did not break the grasp of the larger interests on the situation materially, and the next step in a great industrial evolution followed in the acquisition by the Rockefeller interests of an ore-carrying fleet. This brought all the work from the ore in the ground to the open ore market at Cleveland under one control. Up to this time the transportation of the ore had been a matter of bargain and sale, and close competition with widely fluctuating rates, depending not merely on the activity of the iron trade and the demand for iron ore, but also the movement of corn and wheat from Duluth, etc. But now from the mine to Cleveland came under one control. Simultaneously from the other end consolidation had gone or went on, rolling mill with blast furnace and steel plant and blast furnace with railroad, until the complete consolidation was only a question of time. This has just followed, and whereas we had seven independent interests and three open markets on the way from the raw material in the ground to the finished rail ready for the track, (towit:

Miner,
Railroad,
Boat.
Cleveland open market for ore—
Railroad,
Blast furnace.
Pittsburg and Ohio market for pig iron—
Rolling mill.
Open market for rails—
Railroad.)

Now we have but one—the United States Steel Company, or if, as is commonly reported, the Pennsylvania railroad controls the Republic Steel

Company, in that case the consumer owns practically the raw material and there is no open market. I do not mean that these two concerns control the steel industries. There are a number of other plants, but more and more each interest in self-protection is found to own or control its own iron mines and intermediate links. It is easy to see the advantages of the system. The great corporation can take the ore more easily mined first. It does not feel the anxiety of the small private owner, that he shall see the reward of his piece of ore in his lifetime, that often gluts the market. Whereas in the old days, the mines mined all they could to reduce expenses and production, and fought the ore carriers for low freights, and one year made lots of money and the next were in the hole, and the same thing was true of the blast furnace man in his field, now, given the amount of rails needed, the ore to be mined can be adjusted accordingly. In other words, the speculative element is eliminated from business and concentrated in Wall street fluctuations in prices of steel stocks. Moreover, the great corporation can afford to do what a small one cannot. It can, for instance, and does execute private geological surveys that put those of the State to shame. A small owner could not do that,—it would not pay him. It can study and experiment on minor economies which may be worth while on account of the large scale of its operations as a private individual cannot. A very important item of saving in the Rockefeller system is the building of huge ore carriers of 5,000 tons and over. The fitting together of the various links is also better, until, as Dr. Hulst tells me, the ore is raised and handled but twice from the mine in the far north to the pig-iron of Pittsburg. Machinery and gravity do the rest.

Sometimes it is said that but one profit is required instead of seven, but that depends upon whether the combination is capitalized at less than the units.

Now, I wish to call your particular attention to the difficulty of entering into competition with such an anaconda of industries except along the whole line.

Suppose I find and start an iron mine. What chance do I stand if the railroad belongs to my rivals? Even suppose that my mine is right by the lake, still I must trust to shipping and be dependent on the shipowner for reasonable rates,—and then whither am I to ship it? I must find an independent ironmaster to smelt my iron and turn it into rails. And at the other end, if I want to go into the iron business, there is no use in erecting a blast furnace unless somebody at hand will buy my pig iron, or starting a rolling mill unless some one will use my iron plates. Moreover, I must be sure that I can get pig iron as reasonably as any one, and the blast furnace that makes the pig iron must be able to see its way clear to a supply of ore. And just here is the reason why Michigan, producing 8,400,000 tons of iron ore, produces 163,712 tons (less than one-half per cent as much) iron, and this charcoal iron for which our forests are furnishing the fuel at tremendous cost. For why should not iron be made in the State, say at Bay City? Coal is handy, the best of limestone is handy, the ore is nearer and a good deal of iron is used, and more will be, in shipbuilding, etc., boilers, etc., right in the district, and I know of capitalists who pine for the chance to put in the money. There is just one reason. We are too late. A modern plant for the manufacture of iron and steel costs hundreds of thousands of dollars, and no people are going to put in their money unless they can be sure of suitable supplies of ores, and most of the available known ore is controlled by the United States Steel Company or other manufacturing plants. It must not be forgotten that with the growth of industries into large units the scrutiny of the quality of the raw materials becomes ever more severe. If you need a few sacks of cement for your cellar floor you do not test it, for it would not pay, but depend upon the reputation of the brand, nor do you have your coal analyzed before placing your winter order, though very likely it might pay, but if you were to have a $10,000 order of the one or the other you would not be wise if you did not. A difference of 1 or 2 per cent in ash would pay for a gross of coal analyses. So, for instance, in iron the percentage of phosphorus is studied with the greatest care. If it runs over one-tenth of 1 per cent it ceases to be Bessemer ore suited for steel production and it makes a great difference in the price of the ore, and the hundredths of a per cent are watched with jealous care. Now, one great advantage of our better Michigan iron mines is their low per cent of phosphorus, though analyses are going on all the time, for even these minute percentages are not distributed at random, but show that their distribution is affected by a leaching action. This scrutiny is felt all over the line, and the strain upon the chemist and the economic geologist is ever greater. It is not merely where is iron ore, where is limestone, where is coal, but where is the biggest and the best (not over 2 per cent of impurities) and the handiest deposit. But the last factor, that of accessibility, becomes day by day less important as roads and railroads multiply, especially in this State, where, as we have said, every part is equally accessible to large operations.

Before leaving the iron business let me say that while the consolidations which led up to the organization of the United States Steel Company seem to me to be distinct steps of progress in the orderly conduct of business, in such a combination, as in the combination of molecules in a crystal of alum, it is possible that a great deal of water is taken into the arrangement, and the heat of adversity is likely to drive off this water of consolidation, respectively crystallization, even if the whole arrangement does not deliquesce.

COPPER.

Leaving now iron, the sinew of Industry, we turn to copper, which furnishes her nerves. Up to 1876 the Michigan mines often furnished nearly 90 per cent of the total output of the United States. Of late years, however, the growth of Michigan's output has not kept pace with that of the western, until now our production of about 150,000,000 pounds (155,845,786 in 1899, 144,227,340 in 1900) is but a quarter of that of the United States. Yet the copper of Michigan occupies a unique position in regard to its toughness and conductivity for electricity. It occurs associated with a series of very old, dark, heavy lavas, which we find around the edges of the Lake Superior basin and dipping toward it. One of the minerals of these lavas is known as chrysolite, which has been used as a gem, but although hard it is easily attacked by the weather. It generally contains small amounts of copper and nickel. It has almost always been decomposed in these rocks, which are among the oldest sedimentaries known, so old that no trace of life has been found in them. The chrysolite has, I believe, lost its copper, which has been reduced and deposited from aqueous solution in the opener, more porous parts of the rocks, to wit: the upper parts of the lava flows, originally full of bubbles, known as amygdaloids, or sometimes in old gravel beds, known as conglomerates, or sometimes in fissures in the rocks. The two former classes of lodes run parallel with the formation, that is, in a general way, parallel to the lake shore. The last class runs frequently at right angles to the course of the formation, i. e., toward the lake.

But not every conglomerate, amygdaloid or fissure bears copper, and no one conglomerate, amygdaloid or fissure bears copper equally everywhere throughout its length. The law of distribution is very complicated, though it is safe to say that near the crossing of a fissure and an amygdaloid or conglomerate lode both are likely to be richer than elsewhere, for their intersection will make a sort of trough to guide the waters which undoubtedly have collected and deposited the copper. If, as suggested, they are laid down by percolating waters, the circulation might be more active beneath high land which is close to low land, i. e., gaps in the range.

In economic geology as in other things it is vastly easier to tell where a thing isn't than where it is, and the geologist could be of full as much service, if people would let him, in saving them from crazy schemes of exploration, boring for coal around Detroit, for instance, as in telling them where to find things. Still, we can usually be of considerable assistance in finding a copper-bearing lode. How rich it will prove remains for providence to determine; for instance, my friend and predecessor, Dr. Hubbard, now manager of the Copper Range Company, located the Baltic lode very readily on their property. I quote his account.*

"On May 10, 1898, immediately after the disappearance of snow, I began examination of the southeastern portion of the land held by the company under option from the St. Mary's Canal Mineral Land Company, where the beds of the Keweenaw copper-bearing series were known to outcrop, near what is supposed to be the line of contact between the copper-bearing rocks and the eastern sandstone. On that day I found a conglomerate in the northeast quarter of Sec. 31, T. 54, R. 34, which from its position, strike (about north 26 degrees), and dip (northwest about 71 degrees) seemed likely to be the equivalent of a belt of conglomerate about 110 feet horizontally southeasterly of the amygdaloid bed mined by the Baltic Mining Company. On the following day I found immediately under the conglomerate, a four-foot bed of amygdaloid that carries a good deal of copper.

"On May 14 a force of laborers, under charge of Capt. John Broan, began to uncover both beds, preliminary to trenching northwesterly across the series; and on the 17th, Capt. Broan, while examining with a pick the rocks toward the west, found copper in a bed about 190 feet from the conglomerate. Three trenches were dug across this bed, one of which, the so called 'discovery pit' near the present D shaft, found the 'lode' to be 37 feet wide and richly impregnated with copper.

"On May 23 trenching was begun in a valley about 1100 feet south-

* Report of company for 1900.

westerly of the discovery pit, and the lode was located there in June, and also at a point 1800 feet northeast of the discovery pit (about 100 paces southwestly of the present B shaft)."

It will be noticed that he worked from its position relative to an easily recognized bed. I may remark that the supervisors of Houghton county in assessing land values took the strike at the Baltic property and got over a mile out at the same distance.

The copper found in our Michigan mines is not usually any ore, but the pure metal, unalloyed, although a little silver is often intimately mixed. Now, just as in iron, a hundredth of a per cent of phosphorus may make the difference between Bessemer and non-Bessemer ore; so it is with copper, but more so. A ten-thousandth part of a per cent admixture of arsenic will noticeably affect its power to transmit electricity. Thus, since our mines are not only the largest of the world, but can furnish the purest copper, it commands half a cent to a cent more than the next grade electrolytic, that is a premium of 5 per cent for Lake copper over every other brand. While pure copper is typical of the lake regions, near the surface carbonates and oxides are found, and rarely in fissures the sulphides and arsenides. I mentioned that nickel and copper were generally found together in chrysolite. Recently for the first time in such a fissure (in the Mohawk mine) nickel has been found with the copper. It is not wonderful that it should be found. The queer thing is its absence hitherto.*

It was not unnatural that the same interests so largely interested in iron should become interested in copper; in fact, they were invited in—I may even say let in—in more senses than one, for I presume I am not telling tales out of school in saying that the Arcadian, Isle Royale and other so called Standard Oil properties are not the cream of the lake copper mines. But once let in they have a remarkable capacity for staying until they now control a good proportion of the United States copper output and some important Michigan mines. It has been supposed that they are about to repeat the story of the Mesabi range, but circumstances alter cases. Leaving out of the question the difficulty of getting control of a mine by any kind of stock market manipulation while its chief owners are dredging crinoids in tropic seas, or enjoying the sights of Europe, and have left no orders to sell, for this is not properly a matter of economic geology, we have to consider the following facts:

The amount of copper per ton is not generally very great—3 or 4 per cent in the Calumet & Hecla to 0.61 per cent in the Atlantic. The number and area of lodes containing copper, in percentage greater than that of the Atlantic at any rate, is probably very large, but (and this is characteristic of Michigan generally, not only in copper but also the iron and coal countries) there is a heavy mantle of drift which renders their discovery and exploitation difficult and expensive. The development of the mine and the concentration are expensive processes. The new mines that have amounted to anything have started with a fund of from $200,000 to $500,000 for exploration, and, if enough is found to warrant it, the erection of a stamp mill to crush the rock, and then by a sys-

* Transactions of Lake Superior Mining Institute, Vol. VII, pp. 62-64.

tematic process of washing extract the copper, and of a permanent plant, can easily absorb $200,000 to $500,000 more.

Thus there is no chance for a poor man or group of men to come into the copper country and unaided make their fortunes as they can in the Yukon; and, on the other hand, the various mines have strong financial backing and cannot readily be coerced. They all own their stamp mills, as I have said. Smelting the concentrates is not an elaborate process, and is performed right in the district. A number of the more powerful mines practically control their own smelters now. In fact, in the copper district not only are the copper ingots produced, but the copper wire ready for the electrician or trolley man, so that, with water transportation close at hand, it is not easy to compel men to come into a combination, and it is easy for capitalists to start another independent mine.

Thus there are geological reasons in the mode of occurrence and location of the Michigan copper mines why it will be much harder for one interest to get the grip on the copper situation than upon the iron, since there is not the same economy in it, and competition will be much easier.

SANDSTONE.

The copper-bearing series is inclined, but toward the upper part of the series the inclination becomes less and less as the younger rocks are less and less disturbed, and the formation passes without any great break into that of the Lake Superior sandstone, whose beauty in the red and white cliffs of the Pictured Rocks contrasted with green foliage of the matted cedars above and the blue waves beneath is so well known. But it also makes one of the most pleasing building stones, and the Portage redstone and Marquette brownstone are known throughout the territory tributary to the Great Lakes. In regard to the building stones, the ease of the water transportation is a most important item, yet it must be confessed that in that respect the State is far behind our neighbor state of Wisconsin and behind what we might expect. We have not a single granite quarry, though plenty of granite in the old Archean "negative pole" is not far from lake transportation.

There are a few sandstone quarries here and there in the Lower Peninsula, and yet perhaps the most interesting are not far from building stone at all. The Cleveland Stone Company is working away at the Thumb-nail* of lower Michigan, and making it into scythe and grindstones. For this purpose a combination of qualities must exist in the sandstone. It must be fine grained and even grained with a firm, tough cement, and not so hard as to glaze, to hold together the angular grains of quartz and feldspar, which are so small that under the microscope we see that their edges are sharp, and that they have been floated along in the water rather than rolled into place and rounded.

Down in the southeast corner of the State there is another sandstone, white as the driven snow and almost absolutely pure SiO_2, which is an admirable material for glass manufacture, is also used in sanding paint and matchboxes, but not for sugar.†

* Vol. VII, Part I.
† Vol. VII, Part II.

LIMESTONE.

Just as building stone is but one of the uses of sandstone, so it is but the least of the uses of limestone. Few people realize the variety of uses of the limestone, with which this State is well provided. For building stone, for macadam, for quicklime, for Portland cement, in making bromine, and in making from our own salt deposits the soda-ash which is the basis of our baking powders, washing powders, seidlitz powders, to reduce our iron and copper ores, to line steel converters, and to clarify beet sugar syrup, limestone is used.

Each one of these uses makes different demands. For macadam it must be tough; for Portland cement it must be tender, and either argillaceous itself or near clay or shale as well as fuel; for converter linings it should be magnesian, but most of the chemical industries require it as pure as possible, protesting more or less if over a fiftieth part of impurities occur, and each industry has its own pet aversion among impurities.

SALT.

This list of industries in which limestone is an important raw material suggests an almost endless vista for consideration. Without touching on all, we cannot omit alkali manufacture. You know that salt manufacture is one of the great industries, and one of the necessities of life, upon which oppressive governments fasten their taxes, for they know that people must pay. Eighty million barrels of salt has Michigan produced, and is still producing at the rate of five million per year,* over a fourth of the product of the United States, and the ease of obtaining it and making it ready for the market is so great that no monopoly can exist that will raise the average price for more than a year over a tenth of a cent a pound. Think what it means to the packers of Chicago to have this storehouse of salt at their very doors! The salt is obtained either from the evaporation of strong brines contained in four or five different sandstones, or from beds of rock salt many feet thick. The waters of the St. Clair and Detroit rivers are pumped down upon them to dissolve them, for there is no mining as yet.

While we all realize the importance of salt, few realize the fact that soda is largely made from it, nor how important soda is in the framework of modern society. The soda-ash business is one of the foundation stones of chemical industries. Thus I have prophesied that Michigan will be the home of the chemical industries for the Mississippi valley.

These same brines and salt beds which yield the salt and soda are not only fountains for the "healing of the nations," as at Mt. Clemens and St. Clair, but will yield potash and bromine, the manufacture of which latter source of soothing for Americanitis and base of best photograph paper is controlled by Michigan.

By-products of the soda-ash business are calcium chloride and bleaching powder, and, though this latter has a number of uses in refrigerating and in making artificial stone, it piled up faster than they could dispose

* 96,993,584 through 1901, 5,580,101 that year, *not* counting that which is used in making soda.

of it, so the Michigan Alkali Co. at Wyandotte have taken to mixing it with the mud of Detroit river and making Portland cement of it. At Alpena Portland cement is made of limestone and shale. But, as you doubtless know, most of the factories of the State are making it out of the calcareous mud at the bottom of our lakes and clay.

Our limestone supplies are beginning to be appreciated, but in clays and shales as in building stones we are behind out neighbors on the south, though we have glazing clays, paving brick clays, clays suitable for Portland cement, and others which are or will be the source of livelihood to many. Most of our surface clays, however, have too much lime for many uses.

GOLD, PEARLS, DIAMONDS, ETC.

It will be noticed that most of the things I have mentioned are what might be called common things and cheap things, and I might have gone on and discussed the adaptability of our soils for some of the crops for which Michigan is famous, such as sugar beets, peppermint, celery and fruit. But I have said nothing about gold, though a production of $632,444 in the last 13 years shows that it will become a settled industry, have barely mentioned silver, which is merely a by-product of copper, have said nothing about pearls or diamonds, though once in a while a Unio yields a pearl, and an occasional diamond found in the gravel of Michigan or Wisconsin may perhaps have been derived from some of our Upper Peninsula serpentines. I have not even mentioned chlorastrolite, peculiar to the beaches of Isle Royale, for I have not tried to give an illustrated catalogue of products,—time, my breath, and your patience would fail,—but rather to select for description certain raw materials whose occurrence, exploitation, and use illustrate certain principles applicable not merely in Michigan but everywhere, which may be summed up thus:

CONCLUSION.

The ultimate raw materials are a part of the earth's crust. Their value depends on the relative ease with which they may be turned into the finished product, which in turn depends on their accessibility to other raw material and to market.

The modern tendency to consolidation takes place:

First, by the union of similar and parallel plants into enormous establishments. This results in the consumption of large amounts of raw material by individual owners, and this in turn justifies a scrutiny ever growing more severe to see that the raw material is the best both in quality and location. In spite of this, the tendency has ever been to use ore deposits, lower in grade, but whose quantity and circumstances enable them to be handled cheaply in large quantities at a profit.

Second, consolidation takes place by union of successive industrial links in the line from the ultimate raw material to the consumer. This tends to eliminate competition by making it impossible to compete except all along the line. When the sources of any necessary raw material are controlled, competition in the whole industry becomes impossible.

Finally, the raw materials of greatest value to the State and civilization are not the rare and costly things, but those things common as dirt, whose value depends largely upon their location mutually and relatively to their market, which are needful to sustain a varied and hence vigorous and intelligent industry.

Of the various subjects mentioned above, the following have received especial study this year:

A report on coal* is entirely in the hands of the printers and should certainly be issued before this annual report. It is based on the report printed in the first volume of the Michigan Miner, but a very slight inspection will show a large amount of new work and new material, especially as to the chemical quality of the different seams.

A report on marl and the Portland cement industry will form Part III of Volume VIII. It contains Mr. David J. Hale's studies on the use of marl or bog-lime, Mr. C. A. Davis' studies on the origin of marl, and especially the important contribution that vegetation has made thereto, and the studies of Mr. B. Walker upon the species of shells that are found therein, and also a review of some of the economically important bog-lime deposits. It is hardly possible to make this exhaustive, for there are 5000 lakes and over in the State, and I should think one-third have more or less of these bog-lime deposits, which also occur in many marshes which are not connected at present with lakes.

It will appear from this report how abundant marl or bog-lime is, though the full working thickness of the deposits is rarely as pure calcium carbonate as published analyses would indicate, how it usually lies in a shelf around the lake, and under the bordering marsh, or has filled in the lake completely, and how largely it is deposited by the lake weed of the genus Chara, and is of recent origin and now being deposited. Mr. Walker also finds but little sign of change of life in the marl. The following letter summarizes some of his results:

Detroit, Michigan, Nov. 25, 1901.

A. C. Lane, Esq., Lansing, Michigan:

My Dear Sir.—I enclose my report on the mollusks found in the seventeen lots of marl material received from yourself and Prof. Davis during the last two years. I have not included the recent species of which several lots were received from Prof. Davis as this determination was not pertinent to the marl fauna particularly. I can send you a list of them if you desire. There is however nothing of special interest in them and the list of Saginaw valley shells which you made use of in your former report will include them all.

Taken as a whole the fauna of the marl deposits does not differ from the present fauna of that portion of the State from which they come. Nor have I found in the specimens from any particular locality any special peculiarities which would indicate peculiar local conditions of environment. Individual variations occur, more or less frequently, but no more than is often found in similar collections of recent species. The inference is therefore that the marl fauna lived under substantially the same environmental conditions as the present fauna does, or at least not sufficiently different to produce any special or characteristic variations.

The one species peculiar to the marl deposits of this State is *Pisidium contortum* Prime. It was originally described from the post-pleiocene formation at Pittsfield, Mass. It occurs abundantly in the marl deposits both in Michigan and Maine. It has recently been found living in one locality in the latter state and it is quite possible that it may yet be found alive in this State. But so far as our present knowledge extends it is extinct in Michigan. Why this one species out of the fifteen, included in our list, to say nothing of the other genera represented in the marl, should have failed to survive, while all the others are still abundantly represented in our present fauna is very curious. I have been entirely unable to imagine any adequate explanation.

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* Vol. VIII, Part II.

The characteristic feature of the marl fauna is the great relative abundance of certain of the smaller species. This is especially noticeable in *Planorbis parvus* Say, *Valvata tricarinata* Say and *Amnicola limosa* Say and *lustrica* Pill. The larger *Planorbis bicarinatus* Say and *campanulatus* Say occur in nearly every lot of material, but the number of individuals is comparatively small. *Pisidium* both in the number of species and individuals is also a characteristic feature of the marl as it is indeed of our present fauna. There is probably no district in the United States in which this genus abounds to a greater extent, both in species and individuals than in the inland waters of this State.

The terrestrial species represented in the marl are few both in number and individuals. This is what would naturally be expected as those that do occur are the occasional examples that have been washed into the water from the adjacent land. Such as have been found present no peculiarities as compared with recent specimens from the same region.

The almost complete absence of the *Unionidæ* from the collections is also noticeable.

The peculiar variations noted in *Valvata tricarinata* Say from Cement City are of considerable interest. A similar tendency to unusual variation, although in another direction, has been noticed in the same species from a post-glacial deposit near Niles in this State (Nautilus XI, p. 121). In both instances however the variation was not common to the whole colony but was limited to a very few individuals. It cannot therefore be attributed to any peculiar conditions in the environment, for in that case it would undoubtedly be more general in effect.

Please do not forget to give Dr. V. Sterki the credit for identifying the Pupidae and Pisidia.

Yours very truly,

(Signed.) BRYANT WALKER.

LIMESTONES.

LIMESTONES.

Upon the uses of limestone we have already touched. A good deal of material as to their physical character will be found in previous reports, especially Part I of volume VII and Part III of volume I, by Dr. Carl Rominger. But it may be well to run over them briefly, particularly referring to their chemical character, which is of especial importance in their new uses, in sugar, soda and bromine manufacture, since these reports are out of print and scarce.

I may say to begin with, that in using the term "limestone" for the heading of this article, I include not merely carbonate of lime, but limestone as we find it, a mixture mainly of carbonates either of lime or magnesia, and more or less iron, strontium, etc., with clay or sand, and the uses for which limestone serves as raw material vary greatly according to its composition. For instance, there is a very great demand for anything like pure carbonate of lime, and as soon as it gets near 98 per cent it can be used in the manufacture of calcium acetate in connection with charcoal kilns, the clarification of beet sugar syrup, and generation of carbon dioxide for soda water and for making soda carbonate out of soda chloride, as well as for burning lime or making Portland cement by admixture with clay.

In the Midland process for the manufacture of bromine it is also used. As I understand it, chlorine water decomposes the bromine which is blown out by an air current and collected by quicklime.

The demand rapidly drops as the per cent of $Ca\ CO_3$ falls, and by the time it has sunk only 4 or 8 per cent, to 94 per cent of calcium carbonate, the chemical industries have ceased to demand it. It still may be burned into a hot lime which will stand much sand and it will serve very well for blast-furnace flux. Generally as the per cent of magnesia increases, the lime becomes milder and slower setting and quality poorer, until by and by, at about 20 per cent MgO, it ceases to slake, becomes hydraulic and becomes a dolomitic limestone which, if properly massive, makes a good building stone, but is not good for much else. Then as the per cent of magnesia increases it becomes a refractory material suitable for basic furnace linings. Finally, pure magnesia carbonate comes into demand once again by chemical manufacturers to produce carbonic acid gas* and the salts of magnesia. This is but a rough outline sketch of the uses of one series of calcium and magnesium compounds, and the relative percentages of the various impurities which are tolerable vary according to the special use. I am told that not over 3 per cent of MgO is allowable in the manufacture of cement, whereas there is much greater latitude in percentages of alumina, silica and iron.

* The presence of lime when the stone is dissolved in sulphuric acid produces plaster of Paris and clogs the working.

For use in beet sugar the limestone should make a lime which is not lumpy, but slakes readily to a milk. The magnesium saccharate is more soluble and makes more ash in the sugar, and hence should be avoided.

It will be of interest to take up the limestones of Michigan geologically and geographically, pointing out where they are conveniently accessible, what their composition is likely to be, and what uses have been or may be made of them. Their general distribution is indicated on the map given herewith. Plate IX.

Beginning with the oldest rocks, we find down in the Archean,* associated with the iron-bearing or Huronian rocks, beds of dolomite which have been so hardened and re-crystallized that we may safely call them marble, a term which has been applied to many other of our limestones with less justification. The amount of the various carbonates contained probably varies, but they are generally truly dolomitic. One formation is known by the United States Geological Survey, around Marquette, as the Kona dolomite. Farther south they call it the Randville and Antoine dolomite. These beds have been used at times as a flux in iron smelting and might be used more if the reduction of iron ore were carried on very much in the Upper Peninsula. But they are extremely hard and their silicious character makes them rather unsuitable for use with ores which are already too silicious. Analysis No. 1, given by Rominger, is from one of them. Other analyses made for H. L. Smyth show a considerable though variable percentage of carbonate of magnesia, from 16 per cent to 42 per cent and are given just below.

Sometimes they present a handsome porphyroid appearance. I have seen large, deep red crystals sprinkled in a pink ground, which made a very handsome and attractive ornamental stone. I suspect, however, that there would be a good deal of jointing and waste. Crystals of tremolite also occur. These dolomites are not close to the water and the rigor of the climate would have to be considered in planning to quarry them.

Analyses of Randville dolomite by G. B. Richardson:

	I.	II.	III.
Insoluble in HCl	2.0	9.7	29.1
Fe_2O_3	1.2	2.1	2.2
$CaCO_3$	53.2	48.9	39.3
$MgCO_3$	42.3	38.0	27.7
Total	98.7	98.7	98.3

Analyses of dolomites from Michigamme mountain area by R. J. Forsyth:

	I.	II.	III.
Residue insol. in HCl	14.25	9.34	......
$Al_2(Fe_2)O_3$	11.15	12.57	5.38
$CaCO_3$	47.18	45.98	36.60
$MgCO_3$	18.48	19.22	16.38

We cite from Bulletin 168, a number of analyses and of them "A" of the series made in the United States Geological Survey laboratory may belong to the same formation.

* I use Archean, as used by Dana its sponsor, to include all Precambrain rocks.

Analyses of Archean dolomites and kindred rocks, from the United States Geological Survey laboratory:

	A.	C.	E.	F.	G.	H.	I.	P.
SiO_2	3.07	7.05	3.16	28.86	46.47	46.01	36.73	42.37
Al_2O_3	......	.48	.08	1.29	.70	.83	.38	......
Fe_2O_3	.09	1.33	.93	1.01	.86	1.35	.98	1.09
FeO	.86	Undet	15.18	37.37	28.57	26.07	34.81	31.41
MnO	.15	.19	1.15	.97	.40	2.09	.52	......
CaO	29.72	50.08	26.65	.74	.49	.63	.48	.50
MgO	19.95	.57	11.01	3.64	2.30	2.86	2.74	2.48
H_2O at 105°	.30	.25	.54	.68	.60	1.71	.12	......
H_2O ignition							1.40	......
P_2O_5	......	.27	.06	Trace	Trace	.07	.01	......
CO_2	45.31	39.68	41.10	25.21	19 24	17.72	22.44	21.80
SO_3	......	.21	......	......	......	.15	.16	......
Cl	Trace	......	Trace	......	?	......	......	......
FeS_2	......	......	.34	......	......	......	......	......
TiO_2	......	......	......	.20	.10	.12	.19	......

A. Dolomite. Near Sunday lake, Gogebic district, Michigan. Analysis by W. F. Hillebrand, record No. 767.

C. Limestone. Bed of Slate creek, Huron Bay slate quarries, Michigan. Analysis by T.M. Chatard, record No. 894. From laboratory records.

E. Iron carbonate, from S. E. 1/4 Sec. 20, T. 47 N., R. 43 W., Michigan.

F. Iron carbonate. South side of Sunday lake, Michigan.

G. Iron carbonate. Palms mine, Gogebic district, Michigan. Analyses E, F, G by W. T. Hillebrand, records Nos. 769, 770, 771.

H. Iron carbonate. Miner and Wells option, Sec. 13, T. 47 N., R. 46 W., Michigan. Analysis by T. M. Chatard, record No. 893.

I. Iron carbonate. N. W. 1/4 Sec. 18, T. 47 N., R. 45 W., Michigan. Analysis by Chatard, No. 895.

P. Ferrodolomite. Marquette district, Michigan. Analysis by George Steiger, record No. 1473.

	Q.	R.	S.
SiO_2	26.97	26.67	.30
Al_2O_3	1.30	.12	1.18
Fe_2O_3	2.31	.16	2.15
FeO	39.77	......	39.77
MnO	.29	......	.29
CaO	.66	......	.66
MgO	1.94	.10	1.84
Alkalies	.09	......	.09
H_2O at 100°	.10	......	......
H_2O above 100°	.51	......	......
P_2O_5	.03	......	.03
CO_2	26.20	......	26.20

Q. Ferrodolomite. Marquette district, Michigan.

R. Portions of Q, insoluble by hydrochloric acid.

S. Soluble portion of Q. Analyses of Q, R, S by George Steigner, record No. 1442.

Associated with the iron ores in certain cases are ferrodolomites E, F, G, H, I and P, which Irving imagined to have been an early form of the iron ore.

The Archean marbles are exploited by the North Michigan Marble Company in Dickinson county, on Sec. 26, T. 48 N., R. 28 W. The Commissioner of Mineral Statistics reports as follows: "Some of it is pure white, some variegated, shading from white to pink, green, gray and purple, making beautiful slabs for wainscoting and interior work. It is somewhat granitic in nature, sufficiently so that the tests given foreign and New England marbles will not furnish the highest polish. It is susceptible of a polish almost equal to onyx. There is pressing demand for the stone beyond anything that they can supply, even the chips and small spalls being disposed of. One concern in Chicago has used several carloads of small chips. The price received is from $3 to $4 per ton for the rough rock that is produced in opening the quarry, and from $2.50 to $5 per cubic foot for sound, square-channeled rock."

Before leaving the subject of Archean marble, a word should be said garding the verde antique marble. This is really a decomposed product of peridotite and is strictly to be classed under the serpentines, although it frequently, as Rominger's analysis (2) shows, becomes a carbonate rock. The beauty of the serpentine and verde antique for interior finish needs no statement, and the Michigan outcrops prove to be quite as good as any. Mr. Julian N. Case of Ishpeming took the trouble to have a certain amount worked up, and I have heard it very highly praised by such architects as Mr. Patton of Patton & Fisher. The death of Mr. Case interfered with its exploitations and I do not know that it has yet been commercially developed. Serpentine occurs in a number of places mentioned in the 1892 report of the Michigan Geological Survey (p. 134). The principal area lies north of Marquette and Ishpeming, being exposed from Presque Isle to north of Ishpeming, beginning in the eastern port of Sec. 27, T. 48, R. 27, and extending in a southwesterly direction to Sec. 2, T. 47, R. 28. It is also to be seen in T. 44 N., R. 32 W., and in Secs. 22 and 28, T. 42 N., R. 31 W. An analysis of such a dolomite serpentine product is given by Rominger (No. 2).

The Keweenawan series contains some large veins of calcite, and associated with the copper are sometimes crystals of calcite as pure and clear as Iceland spar. I do not know of any vein, however, which could be an economic producer of lime in a large way.

It is not until we begin to get above the Potsdam sandstone toward the Trenton that we begin to get calcareous beds again in a large way. The Calciferous strata may be taken as a group of beds which form a transition from the sandstone to the almost purely calcareous Trenton. Analyses seem to indicate† not over 54 per cent carbonate of lime and not less than 32 per cent nor more than 42 per cent of carbonate of magnesia. There is generally considerable sand. Analyses by Rominger (3 to 14) suggest that basic furnace linings might be obtained from the formation, and its outcrops along St. Mary's river would be readily accessible. It appears also to be a durable building stone and in some cases has a tendency to oölitic structure.

It is well exposed and could be easily quarried near Chatham, the Upper Peninsula agricultural experiment station. An analysis gave the chemist:*

Insoluble sand (SiO_2)	35
($FeAl_2$) O_3	5
$CaCO_3$	32
$MgCO_3$	22
Difference (water and organic)	6
	100.00

The ratio of lime to magnesia is similar to that in Rominger's analyses.

* Bulletin 186, Dec., 1900.
† See page 70, part I, Vol. 3, Michigan Geological Survey Reports.

I see no reason why this would not make converter linings.

The Trenton formation, generally speaking, is less silicious, and while in a general way there is a great deal of dolomite in it, not infrequently we find streaks which are a high grade of limestone like Rominger's analysis (20) from the Escanaba river. I have heard of even purer material. The Trenton forms the northwest shore of Green bay, where it could easily be obtained, as well as on St. Mary's river.

The next group of beds, the Cincinnati and Hudson river group, are usually spoken of as shales or shaly limestone. As a matter of fact, however, the only part where they are shown in our State, where they run from the point which splits the upper end of Green bay, they are quite calcareous, as shown by Rominger's analysis 24 as well as Keonig's tests below.

For lime burning or for building, however, the beds are too argillaceous. There is a great deal of variation from bed to bed, and even along the beds. The argillaceous character of the beds suggests that they might be suitable for the manufacture of hydraulic cement. But the following series of tests shown me by Prof. G. A. Koenig of the Michigan College of Mines makes it probable that they are too irregular in composition for that purpose:

ANALYSES, BLUFF OPPOSITE GLADSTONE, MICH., OCTOBER 7, 1899.

No. of sample.	Per cent. $CaCO_3$.	Thickness of beds in inches.
1	42.4	....
2	50.4	....
3	63.3	30
4	52.8	....
5	48.0	19
6	50.8	....
7a	57.3	4
7b	46.0	....
8a	49.6	6
8b	49.6	....
8c	51.6	5 spotted.
9	66.4	5 spotted.
10	42.4	3
11	45.2	6
12a	50.4	10
12b	43.2	....
13	44.0	6
14	54.0	8
15a	42.0	13
15b	44.0	....
16a	42.0	....
16b	43.6	30
16c	40.0	....
16d	40.0	....
17	34.00	7
18	36	30
18	32	....

Samples with the same number but a different letter are from the same level or horizon, but taken at different points. The residue is very largely insoluble, argillaceous.

The Niagara limestones are a very well defined belt and in their best estate, shown in Rominger's analysis (No. 30), fairly free from anything but carbonates. They are characteristically very light colored, and the drillers have often referred to them as snow-white marble. We know from the records that they lie beneath the whole State, but their outcrop is confined to the well marked ridge which separates Green bay from the rest of Lake Michigan and is frequently exposed clear to Drummond's Island. Some idea of their chemical character is given by Rominger's analyses Nos. 26 to 36, from which it will appear that usually they are dolomite, though analyses Nos. 30 and 31 indicate a limestone very low in magnesia, and he says that the white lenticular-like masses, between the beds of the Burnt Bluff section, are almost pure carbonate of lime. Other reports have come to me which show that there is doubtless quite high grade limestone in the series.

On Sec. 16, T. 44 N., R. 7 E., on land belonging to Chase S. Osborn, is an interesting group of caves in this limestone, which here appears to be exceptionally free from magnesia. Perhaps this has something to do with the origin of the caves. I visited them August 3, 1901. As they are approached from Lewis Station to the south there is little or no relief, occasional sandy rises in the midst of swamps, until not far from the southeast corner of the section the trail passes between some small sinks, which are the entrance to several hundred feet of cave, low and flat, in general not over two or three feet high, but with a channel six to eight feet deep cut in beautiful meanders which slightly increase the size of loop as they cut down, and are barely wide enough for a man to walk in them.

The stream finally falls by a cascade into a larger and picturesque sink hole about 30 feet deep, in which no outlet could be found. It was probably concealed by broken rock.

About one-third mile north and one-fourth mile west the trail passes over a couple of sinks, the one to the west being much larger and showing under the road a fine portal to a larger cave, which was, however, at the time of our visit much fuller of water, though from what I learned I judged that it may have been a temporary choking up.

Continuing north the country soon drops off more rapidly.

This limestone is said to be very pure and suitable for the manufacture of calcium carbide. There must be a considerable area, with little stripping and easily drained.

The Niagara limestone is also extensively exposed and has been burned for lime along the D., S. S. & A. railroad, not far off, from about one-half mile north of Ozark at frequent intervals on hills rising up to 40 feet above the track, which passes through a limestone a little more than a mile southeast of Ozark. It is white irregular crystalline, with corals such as Favosites, Cystiphyllum and Monticulipora.

Then again at Palms, and Jere. Taylor's, one-half mile east, were quarries. The kilns supplied the Newberry charcoal iron furnaces, and stopped when they stopped, but the lime is highly spoken of locally.

The White Marble Lime Company of Manistique, Mich., is also making lime from the Niagara, and furnishes the following analysis:

	Unslacked lime.	Limestone.
Silica	1.80	1.50
Iron and aluminum	.90	.....
Lime	52.40	52.77
Magnesia	44.65	45.75
Balance	2.05	.....
	100.00	100.02

The freedom from insoluble matter is noteworthy. There are, however, cherty and silicious layers in the Niagara.

The amount of iron and alumina is in general the lowest of any formation. The most constant impurity, probably, is a certain per cent of pure quartz sand, so pure that by itself it would make glass sand. The Niagara could be easily quarried at many points and readily handled by water. A curious bed of this limestone and all those below it is caught and held in a very sharp fold a few miles from the head of Keweenaw bay on Secs. 13, 14, 23, 24, T. 51 N., R. 35 W., and a hill near by. The Niagara is characterized by many well defined fossils, of which the "chain coral" is as familiar and easy to recognize as any.

Above the beds of the Niagara come the beds of the Salina and Lower Helderberg series or, as I have called them all, the Monroe beds. At several points of this series dolomites and dolomitic marls occur. Around St. Ignace the series appears, and on Mackinac Island also, but it has mainly been developed in the extreme southeast part of the State, where it has been carefully studied by Prof. W. H. Sherzer in the Monroe county report.*

This region lies so close to the large cities of Detroit and Buffalo that it has been very extensively developed for building stone and for road matter, and to some extent for lime. The rock is in general silicious dolomite and seems to have more or less sand, and is sometimes marketed as sandstone, and indeed passes into it by degrees, as is shown by the following analyses from the Woolmith quarry, the third of which is distinctively sandstone. Frequently large blocks have been quarried.

Woolmith quarry analyses cited by Sherzer:

	I 4 ft. down.	II 18 ft. down.	III 24 ft. down.
Silica	6.19	3.05	97.76
Iron oxide and alumina	.45	.31	.55
Magnesia carbonate	43.53	44.59	1.43
Calcium carbonate	50.12	52.72	1.14
Difference	.29	.67	.88
	100.00	100 00	100.00

Other analyses of dolomite along the line of the Pere Marquette are, according to General Manager S. T. Crapo:

	I	II
Silica and insoluble	2.33	5.92
Iron and alumina	.48	.52
Carbonate of lime	55.03	53.16
Carbonate of magnesia	42.17	40.36
	100 00	100.00

An analysis by J. D. Pennock of dolomite from a Raisinville quarry, claim 516, is as follows:

Silica	3.45
Iron oxide and alumina	.20
Calcium carbonate	51.69
Calcium sulphate	.43
Magnesium carbonate	45.01
Difference	.78
	100.00

* Vol. VII, Part I. Analyses cited are on pp. 82, 83, 95.

The Monroe Stone Company have a quarry about two miles north of the city of Monroe which has given K. J. Sundstrom the following results:

	2 ft. down.	7 ft. down.	10 ft. down.
Silica	.70	.98	.58
Iron oxide and alumina	.01	.22	.31
Calcium carbonate	54.54	54.47	54.94
Magnesium carbonate	42.75	43.59	42.84
Difference	......	......	......
	100.00	100.00	100.00

An interesting feature of the dolomites of Monroe county is the presence of considerable quantities of strontium, both the carbonate strontianite and the sulphate celestite. These are also found on the islands of Lake Erie. Aside from their value as a source for red fire, they could replace lime to great advantage in the manufacture of beet sugar. No analyses for strontium are known to me, so that I have assisted Mr. W. K. Wonders of the Agricultural College in collecting material for a thesis on this subject.

The places in Monroe county where the dolomites of the Helderberg series are mainly worked are around Monroe (near which are a number of quarries), Brest, La Salle, near Samaria on the Ann Arbor line, and around and near Whiteford. The only one of these places where the industry is carried on on a large scale is Monroe, where there are lime kilns and rock crushers. The Monroe rock is a dolomite which shows by analysis for H. H. Dow by A. W. Smith:

	I.
Calcium carbonate	54.47
Insoluble	1.12
Iron and alumina	.16
Magnesium carbonate	43.47

It yields a limestone which slakes slowly, does not develop much heat, and cannot take much sand. From Monroe county in 1899 some 55,706 tons were shipped. The usefulness of some beds is greatly impaired by a brecciated character. They are real limestone conglomerates. The brecciated and conglomerate character is even more conspicuous in the northern part of the State around Mackinac Island, and renders much of the rock useless for any purpose. Rominger's analyses 37 to 41 show that the rock here also is a typical dolomite.

Next above these beds come beds which contain more calcium carbonate; in fact I have drawn the line between the Dundee and Monroe, so as to make it coincide with the division between the limestones of the upper Helderberg or Corniferous and the dolomite of the lower Helderberg or Waterlime (Manlius). This difference in chemical character appears quite uniform throughout the State, as is shown by very numerous qualitative tests on drill borings as well as the quantitative analyses given. The purer Dundee limestones are one of the important horizons of the State, which I think will be even more developed in the future. The most extensive quarry is that of the Sibley Quarry Company of Detroit river, in the south part of Wayne county.

All through this region we find this general distinction between the Dundee or Corniferous, running high in calcium carbonate, and lower Helderberg or Monroe beds, with low per cent. I may state that at

Monroe there is about 50 per cent of calcium carbonate, at Gibraltar and Grosse Isle 62 per cent, at Newport and Brest somewhat higher, about 80 to 84 per cent, and at Amherstburg 92 per cent, while the Sibley quarry probably runs best of all with 94 to 98 per cent of calcium carbonate. The 9-foot blue bed, it is said, can be so picked as to give 98 per cent, guaranteed at each shipment. Below are given some of the analyses from some of the beds of the Sibley Quarry Company. It will be noticed that not all are high in calcium carbonates, but are useful for macadam, lime, building stone and other purposes, while the beds high in calcium carbonate are reserved for chemical purposes.

The region along the Detroit river is very well suited for such industries, for it is on the water, has ample railroad facilities, has the high grade limestone of the Sibley quarry, and by boring 800 or more feet down an indefinite supply of rock salt can be obtained. Some of the beds are of great thickness as is shown by the record of the well at Royal Oak, given in Vol. V of our reports, and records elsewhere printed in these reports. The only well of which we have an accurate record, which has passed clear through the salt, is that at Wyandotte, which is reported in the same volume and reached Trenton rock at 2610 feet. Suffice it to say that from 800 to 1500 feet down there is a very large supply of rock salt. The use of carbonic oxide for the making of soda is so extensive that the calcium chloride becomes a product which is manufactured faster than it can be used. The Solvay Process people, who are manufacturing soda at the old exposition grounds, are using the chloride of calcium to make land and redeem a marsh, known as Zug Island, good property. Calcium chloride is used as the basis of a number of artificial stones. It is also employed in refrigeration, as calcium chloride can be circulated through pipes at a very low temperature with no danger of freezing. But this is not the only use for the Sibley limestone. Michigan has within two or three years leaped into prominence as a producer of beet sugar. It has just the right climate, many of the hard lake-clay soils with a light coating of sand on top, have just the right character for the growth of sugar beets. And there is a good German population who are not afraid to work and make good growers of the beets. Consequently we have a number of factories established at Kalamazoo, Rochester, Alma, Lansing and elsewhere, which largely depend upon the Sibley quarry for their supply of calcium carbonate.

The soda ash men, who originally planned to manufacture soda ash here, have probably got a better thing in their limestone quarry than in the manufacture of soda. The drillings here show clearly and sharply by the sudden rises in magnesia the line between the Dundee and Monroe (Corniferous and Waterlime), and the very best beds run over 98 per cent of lime. A section of the quarry will be as follows:

A. 6-foot bed of limestone, thin layered, very fossiliferous and a high grade limestone.

B. 7-foot bed, 2 to 11 inches thick, more coarsely crystalline, somewhat pyritic, not so conspicuously fossiliferous.

C. 2 feet limestone with much cystiphyllum.

D. 5 feet limestone with a deposit of black carbonaceous material full of crinoids and bryozoa.

E. 6 feet limestone, almost solid mass of crinoid joints, bryozoa, corals, and brachiopods. Between D and E there is also a carbonaceous deposit.

F. 14-inch bed, mainly of chert, which contains only 3 per cent or so of $CaCO_3$.

G. 6 feet limestone, light gray and full of crinoids, etc.

H. 2-foot bed of chert about 30 inches thick, very friable, of a hard, ringing, impure matrix, when sent to the crushers.

I. 9 feet pure limestone, supposed to be the best bed of the quarry and frequently runs over 98 per cent of calcium carbonate.

J. 6-foot magnesian bed. It is magnesian only, however, in comparison with I, for it is really a fairly pure limestone but not so pure as I.

K. 8-foot bed of limestone full of the usual fossils. A thin bed as exposed and good for lime or building purposes. Prospect holes sunk from bed I show limestone for 83 feet and for 40 feet down calcium carbonate from 81 to 93 per cent, magnesia from 2½ to 16 per cent, and silica from 0.73 to 7.24 per cent.

Below this we find a sudden drop in calcium carbonate, which runs from 54.27 to 70.54, while the magnesia carbonate runs from 23.49 to 43 per cent.

Analyses of limestone from the Sibley Quarry Company, K. J. Sundstrom, chemist:

	$Ca CO_3$	MgC_3.	$Fe_2 O_3$-$Al_2 O_3$.	$Si O_2$.	Diff.	Rem.
A 6 ft. top bed	91.75	2.52	0.34	1.82	1.57	......
B 6 ft. gray and blue bed	92.00	4.62	0.28	1.92	1.18	......
C 2 ft. blue bed	94.50	3.36	Trace	1.04	1.10	......
D 5 ft. blue bed	93.50	4.20	"	1.08	1.22	......
E F } 6 ft. blue bed upper	87.00	9.45	0.58	2.24	0.73	......
G 6 ft. blue bed lower	85.75	10.29	0.20	2.56	1.20	......
H 2 ft. flinty bed and all flint beds	53.50	12.18	3.45	30.87	0.87	......
I 9 ft. blue bed	93.50	2.73	1.12	0.64	2.01	......
J Magnesia bed	74.00	20.58	0.74	3.74	0.94	......
K 8 ft. blue and gray bed	87.00	9.66	0.16	1.62	1.56	......
10 ft. blue bed	94.00	2.10	1.86	0.91	1.13	......
Flinty layer top of 8 ft. bed and top of 10 ft. bed	43.50	9.66	2.03	43.76	1.05	.....
6 ft. lower bed	92.60	5.40	......	......	0.72	......

Analysis of different beds in the Sibley quarry:

Kiln bed: 6 ft. blue bed.

$Ca\ CO_3$	94.404
$Mg\ CO_3$	2.180
$Al_2\ O_3$	Traces.
$Si\ O_2$	2.960
Diff	0.456
	100.000

Five foot upper bed, dried.

$Ca\ CO_3$	91.15
$Mg\ CO_3$	4.87
$Al_2\ O_3$	....
$Fe_2\ O_3$	2.90
$Si\ O_2$	1.08
	100.000

	$Ca\ CO_3$.	$MgCO_3$	$Al_2\ O_3$.	$Si\ O_2$.	Diff.
Bed No. 2 W. bank	89.7	4.8	2.85	1.06	1.59
Bed No. 1 W. bank	86.79	6.8	2.50	2.00	1.91
Lower 6 ft. bed west side	80.36	14.05	2.71	2.88	....
" " " south side	81.95	7.20	6.60	2.29	1.96
Middle bed building stone	83.87	6.29	6.82	3.02	Dried
Very top bed	78.58	14.26	4.75	2.41	"

Very much the same limestone beds as those of the Sibley quarry are exposed on Macon river and have been quite fully described by Rominger (analyses 46 to 47) and Sherzer, who quotes, p. 76, the following analyses, the first four by G. A. Kirschmeier, the two latter by K. J. Sundstrom:

	Bed A.	Bed B.	Bed C.	Bed D.
Calcium carbonate	90.80%	86.80%	77.60%	95.00%
Magnesium carbonate	6.87	11.60	17.41	3.86
Silica	.48	1.10	2.78	.81
Iron	.16	.12	.56	.41
Organic matter	1.69	....	1.63	....
Difference	.00	.38	.02	.08

Calcium carbonate	98.10%	86.96%
Magnesium carbonate	.63	10.08
Silica	.70	1.86
Iron oxide and alumina	....	.62
Sulphur	.055	.123
Difference	.515	... .

The drainage and transportation facilities of these quarries are not as good as at the Sibley quarry.

When we pass to the northern part of the State we find indications of the same contrast of limestone and dolomite between the Dundee and Monroe (Corniferous and Waterlime). The Dundee or Corniferous extends from the Straits of Mackinac and the islands west of Presque Isle north of Grand lake in Alpena county. But in this northern part a group of rocks not conspicuous in Wayne and Monroe counties are important—the Traverse group, full of fossils, of considerable economic value, corresponding more or less closely to the Hamilton and Marcellus (Erian) of New York. Mr. A. W. Grabau has recently begun to work them up in some detail for us and his preliminary report follows.

We leave to him these limestones, and above there are no more limestones of commercial importance for quite a long distance. There are, to be sure, nodules of lime in the Devonian black shales* which are quite pure carbonates of lime, with some organic matter, and in the shales of the Carboniferous likewise, we find nodules and bands of carbonate that are in most cases mainly carbonates of iron. They have been used from time to time for iron manufacture, but it is very doubtful if there is anything commercial. When we get up higher to the beds in which the famous Grand Rapids gypsum beds occur, at the horizon of the Burlington and Keokuk of the Mississippi valley, we find limestone again. This time it appears very much like the cement rock of Milwaukee and, although it has never been developed for this purpose, a fair quality of rock cement could doubtless be made from it. Portland cement will probably replace rock cement in this neighborhood, however. The most promising place to investigate this limestone would be in the neighborhood of the gypsum quarries of Grand Rapids and along Saginaw bay, in Iosco and Arenac counties,† in Huron county near Soule and Oak Point, and also in the valley of the Cass near Cass City.

Above the Michigan series we come to a much more important limestone horizon, which has been extensively quarried at Grand Rapids and is now quarried at Bellevue, Bayport and Arenac county. It corresponds in part to the St. Louis limestone and the Maxville limestone of Ohio, and contains some layers which are nearly pure limestone. There is some dolomite and other layers are more or less argillaceous, and it tends, however, to be rather silicious and often pyritic. Some of the layers are very massive and hard, with practically no porosity, as shown by tests which I have made myself as well as by those made by Prof. Johnson. Below we give three analyses of the Bayport limestone, two of calcareous beds and one of dolomite, and among Rominger's analyses (52, 53) will be found some analyses of the Bellevue quarry of limestone and dolomite. The Bellevue quarry is said to cover 300 acres and to run 90 per cent of lime. Over 200 men are employed in the quarry with two trains a day, and about 700 tons of rock are shipped to Wyandotte, for this quarry is owned by the Michigan Alkali Company (the Fords). The plant is said to have a capacity for crushing 2,000 tons daily. The main building is 44x68 feet, 50 feet to plate, with a power house 30x60 feet. It has its own electrical plant, owns 200 railroad cars of its own and ships about 25 carloads daily to Wyandotte. This stone is there used in the manufacture of soda ash, including baking powder. The soda ash is used in making plate glass. The supply is practically inexhaustible, or at least will give constant employment to a force as large as the present for a long time, it is said. The rock lies only about two feet below the surface and is from 10 to 20 feet thick. Underneath this

* See Rominger's analysis No. 50, below, also article by R. A. Daly in the Journal of Geology Vol. VIII, No. 2, p. 137.
† See Gregory's report.

is a blue rock which, with the refuse from the limestone, is used for macadam pavement. It is said to be rather soft and very dusty for use on city streets.

The limestone is also combined with mud from Detroit river and burned to make Portland cement.

The largest quarry next to the Bellevue quarry, probably larger in fact, one certainly which has been worked vigorously for over a decade, is that at Bayport. The main quarry is on Sec. 5, T. 16 N., R. 10 E., but the limestone upon which it stands extends from section 22 to the lake shore and is also found on North Island of Wild Fowl bay, where a small quarry was opened some years ago. The Bayport stone seems to be, if anything, harder and more massive than at Bellevue. We find the range from limestones which have 90 per cent and over of carbonate of lime to those which are dolomite, as shown in the analyses below.

ANALYSES FROM THE BAYPORT QUARRY.

	I.	II.	III.
Carbonate of lime	91.538	91.32	61.52
Carbonate of magnesia	.944	2.48	14.50
Sand	3.330	4.46	20.85
Clay	......	......	2.04
Phosphate of lime	Traces	......	.09
Bisulphate of iron	1.334	.78	.15
Water	2.854	.95	.85
	100.00	100.00	100.00

The crushing strength as determined at the Watertown arsenal was 26,000 pounds per square inch, the weight 170 pounds per cubic foot and the specific gravity 2.72. I am inclined to think that there is generally less sulphur than at the Bellevue quarry. The material has so far been mainly used for quicklime, macadam and building stone, and I see no reason why it should not make a good blast furnace material, and it must be remembered that it is only a few miles from coal mines.

On the other side of the bay we have extensive exposures of limestone in Au Gres township, and thus northwest. There are a number of half-opened quarries on the line of the Detroit & Mackinac R. R., about three miles southeast of Omer.* Just south of Omer, near Arenac postoffice, an extension of this limestone gave the Dow Chemical Company the following analysis:

Calcium carbonate	94.8
Magnesium "	1.1
Iron, alumina	.9
Insoluble	1.7
Organic matter by difference	1.5
	100.0%

It would seem quite possible that in this region the limestone quarry business might be largely developed since it is convenient to water and not very far from railroads nor from coal, sugar and alkali works. The same limestone occurs in the neighborhood of Grand Rapids, and in fact the ledge makes the rapids from which the city takes its name. The beds have been worked for building stone both on the river and at other points. Many of the older quarries are built over so

* More fully described already by N. M. Gregory. pp. 12-18. Mr. Griffin's quarry is the most extensively opened.

as not to be accessible. As usual a certain amount of sulphide of iron is found. Some of the older quarries are on Davis street, Taylor street and Myrtle street.* Three or four miles south, the limestone is near the surface and contains about 93 per cent of calcium carbonate.

The limestones above this in the coal measures are little known. There are not infrequently bands and nodules of carbonate of iron, but nothing of commercial value has been developed. In fact no practical investigations have ever been made, but if the manufacture of iron were once fairly undertaken in the Saginaw valley, which would be an excellent place for it, I think some attention might be given to these black band ores.

Beside the limestone already described there is one very important form of lime which is generally and rather improperly called marl. The marl of Michigan, which has been eagerly sought for in the manufacture of Portland cement, has more properly been called "bog lime," and might well be called lake lime. It is not at all what is ordinarily known as marl, for there is very little clay in it, and in fact the quality that is sought has practically no clay, but it is a nearly pure carbonate of lime found in the shape of an ooze at the bottom of a great many Michigan lakes. It is nearly white, sticky and slimy, and in that respect differs from calcareous tufa but is quite as pure as tufa. There is usually a small amount of silica, introduced by diatoms or as sand, and a smaller amount of insoluble iron and alumina. There is always considerable organic matter which may be combined directly with the lime. The amount of magnesia varies. The following analysis by Lathbury and Spackman fairly represents the composition of the marl after the water and organic matter are driven off:

Carbonate of lime	95.00
" " magnesia	1.00
Silica	.10
Iron and alumina	.32
Sulphuric acid	.52

The analyses of marl are rather hard to compare on account of the uncertain amount of water and organic matter which will appear in the samples and the different way in which they are treated by different chemists. A certain amount of organic matter appears to be inherent to the marl, and indeed combined with the lime, but another part may be introduced from the layer of peat and muck overlying in the process of taking the sample. The main use of this marl has been in the manufacture of Portland cement, an industry now well established in Michigan which indeed bids fair to be overdone in time. Deposits of marl are very abundant and many of them very extensive and of good quality. It looks as though those plants would survive in the long run which are well situated in regard to market and a suitable coal as well as a marl, and are properly managed. The coal for the manufacture of Portland cement should be of uniform quality and as free as possible from sulphur, and few if any of the surface coals fulfil this condition.

The following groups of marl analyses are furnished by W. M. Courtis, M. E., of Detroit. Many more will be found in Mr. Hale's report on marl:

* See pp. 62 and 65 of the First Report of the Michigan Acad. of Science, C. A. Whittemore.

MARLS.—FROM LAKE SHORE WEST OF GRAND RAPIDS.

(The sample loses 6.376 per cent of water and volatile hydrocarbon when dried at 100 C.)

THE DRIED MARL CONTAINS:

Organic matter	0.790 per cent.
Combined water less org. matter as above	0.235 " "
Silica (no sand)	2.528 " "
Tricalcic phosphate	0.150 " "
Chlorine as sodium chloride	0.119 " "
Alumina and a little iron	0.432 " "
Carbonate of magnesia	1.250 " "
Carbonate of lime to balance	94.496 " "
Sulphur	none " "
	100.000

FROM ALPENA COUNTY, MICHIGAN.

	Per cent.
Carb. of lime	74.48
" " magnesia	0.50
Silica	7.20
Alumina	0.54
Ferric oxide	2.36
Sulphuric acid	0.89
Organic matter	12.88
Water	1.25
	100.00

NEAR GRAYLING, MICHIGAN.*

(Average sample.)

Water lost at 100 degrees	61.
Dried marl	49.

	Per cent.
Moisture	0.60
Organic matter	9.80
Insoluble silica	0.78
Soluble silica	0.13
Ferric oxide	1.13
Alumina	0.07
Calcium carbonate	87.00
Magnesium "	0.91
Sulphuric acid	0.27
	100.69

(Same sample figured without the organic matter is:)

	Per cent.
Calcium carb	97.00
Silica	1.01
Ferric oxide	1.26
Alumina	0.08
Magnesium carb	1.01
Sulphuric acid	0.30
	100.66

CASS CITY, MICHIGAN.

Lime carb	82.1420
Magnesia	4.6200
Iron and alumina	0.9775
Silica	1.1510
Phosphoric acid	0.0370
Sulphuric acid	none
Organic matter	11.1730
Loss on ignition	16.2700

CASS CITY, MICHIGAN.

Lime	89.965
Magnesia	1.672
Iron	0.999
Alumina	0.158
Silica	1.222
Phosphoric acid	¾ lbs. to the ton.
Sulphuric acid	none
Organic matter	5.984
Loss on ignition	9.750

* Another analysis of marl from Grayling is given in the Agricultural College Bulletin, No. 99, p. 11.

ANALYSES BY C. ROMINGER.

		Carbonate of lime—Per cent.	Carbonate of magnesia—Per cent.	Iron, Alumina Hydrate—Per cent.	Residue—Per cent.
Archean dolomite, Vol. I, page 101	1	61	34	1	0.25
Secondary, Vol. I, page 92	2	55	35	5	5
	3	47	38	3	12
	4	54	42	1	2
	5	42	33.6	1	23
	6	45	35	2	18
	7	50	33	2	14
Calciferous, Vol. I, page 79	8	49	32	2.5	15
	9	47	37	0.8	15
	10	47	36	2	15
	11	42	34	0.7	23
	12	52	40	2	6
	13	49	40	5	6
	14	53	39	4	3.7
	15	52	38.5	3	5.5
	16	88	4	1	6.4
	17	55.8	21	2.4	20.8
	18	90	3	1	4.6
Trenton, Vol. I, page 78	19	92	2	1	5
	20	51	38	2.5	7
	21	89	2	1.5	8
	22	82	3	1.5	13
	23	47.3	2.5	1.6	48.6
Cincinnati, Vol. I, page 78	24	36	18	4	42
	25	56	40	1	1.5
	26	56	43	traces	1
	27	62	33	2	3
	28	54	39	4*	2
	29	58	32	2	7
Niagara, Vol. I, page 48	30	95	1	2	2
	31	94	2	1	2
	32	52	35	2	9
	33	52	38	3	6
	34	60	32	1	3
	35	59	38	1	1
	36	56.6	39	1	2.5
Salina, Vol. I, page 31	37	53	44	1	2
	38	41	22	7	30

* Almost all alumina.

ANALYSES BY C. ROMINGER—Concluded.

			Carbonate of lime—Per cent.	Carbonate of magnesia—Per cent.	Iron, Alumina Hydrate—Per cent.	Residue—Per cent.
Monroe or Waterlime	Vol. I, page 29	39	46	14	10	30
Monroe or Waterlime	Vol. I, page 29	40	55	41	4	…
Monroe or Waterlime	…	41	51	37	…	…
Monroe or Waterlime	Vol. III, page 28	42	54	42	…	4
Monroe or Waterlime	Vol. III, page 28	43	46	…	…	54
Monroe or Waterlime	Vol. III, page 35	44	59	39	…	…
Dundee or Corniferous	Vol. I, page 29	45	68	22	2	8
Dundee or Corniferous	Vol. III, page 26	46	87.5	10.1	…	2
Dundee or Corniferous	Vol. III, page 27	47	84	13	0.4	2.2
Traverse	Vol. III, page 59	48	58	38	1.5	0.5
Traverse	Vol. III, page 60	49	56	39	2.8	0.4
Antrim (Genesee), Vol. III, page 66		50	89	2	…	7.5
Michigan	Vol. III, page 109	51	48	27	4	18
Michigan	Vol. III, page 113	51	96	1.0	0.5	1.5
Michigan	Vol. III, page 113	53	56	23	5.5	9.0
Michigan	Vol. III, page 115	54	63.7	11.4	18.4	2.9
Michigan	Vol. III, page 116	55	94	1	1	4
Michigan	Vol. III, page 117	56	96.9	1	0.7	1.4

LOCATION OF SPECIMENS.

1. Specimen of Archean dolomite from Sturgeon river, near the Breen mine, of flesh color and free from silicious seams.
2. Specimen of the more compact kind of dolomite formed from decomposed peridotite, of flesh-red color.
3. Dolomites forming the top stratum of Sulphur Island.
4. Calciferous formations, Grand Rapids of Menominee river, lowest strata above the sand rock of oölitic structure.
5. Variegated limestone, stratum No. 3 of the Grand Rapids section.
6. Upper strata at Grand Rapids of Menominee river.
7. Arenaceous limestone, with *Lingula antiqua,* from Escanaba river.
8. Lowest brecciated limestone, near the forks of the Escanaba river.
9. Dolomite from the forks of the Escanaba river.
10. Falls of Au Train river, calciferous sand rock.
11. Mud lake, three miles south of Au Train river falls, calciferous sand rock.
12. West Anebish Rapids, calciferous dolomite.
13. Calciferous strata on top of the ravine near Munising furnace, Grand Island bay.
14. Calciferous strata from coaling station No. 3 of Munising furnace, pure dolomite stratum.

15. Dolomites forming the upper beds of the Trenton group, at the mouth of the Escanaba river.
16. Wedge-shaped limestone of the Escanaba river, next following the former dolomites.
17. Fossiliferous, shaly and arenaceous limestone, next below the wedge-shaped limestone of the Escanaba river.
18. Limestone containing *Orthoceras proteiforme* of the Escanaba river.
19. Lowest beds of the Trenton group on the Escanaba river, containing Cyrtodonta.
20. Dolomite of the Trenton group on Whitefish river, two miles above the saw mill.
21. Upper limestone of Encampment b'Ours, with *Orthoceras proteiforme.*
22. Blue limestone with smooth conchoidal fractures, forming the middle strata of the Trenton group on St. Joseph's Island.
23. Lowest sandy beds on St. Josephs, containing Cyrtodonta shells.
24. Argillaceous limestone from the Hudson river group of Bay de Noquette.
25. White crystalline dolomite from the middle division of the Niagara group from the Lake Huron shore, one mile east of Pine river. This is typical Guelph dolomite.
26. Light gray colored dolomite from the middle division at Point Detour on St. Mary's river.
27. Dolomite forming the top stratum at Marblehead, Drummond's Island.
28. Upper part of Marblehead quarry of laminated structure with absorbent earthy structure.
29. Lower beds of Marblehead quarry, Drummond Island.
30. Limestone from the section of Marblehead with acicular cavities (vide description below).
31. Limestone from the Marblehead section, 30 feet below the acicular limestone, described as nodular bituminous limestone containing fossils.
32. Lowest beds in the Marblehead section.
33. Loose slab on the west side of Sitgreaves' bay, immediately above the Hudson river group strata, Drummond's Island.
34. Quarry Point on the west side of Drummond's Island, quarry stone of laminated structure.
35. Sole bed of the same quarry of more crystalline structure than specimen No. 10.
36. Lowest strata of Burnt Bluff of Big Bay de Noquette. The white marble-like masses embedded between them are almost chemically pure $Ca\ CO_3$.
37. Dolomite in the bed of Carp river.
38. Variegated marl of St. Martin's Island.
39. Dolomite from gypsum quarries of Point aux Chênes.
40. Exposure on the east side of Mackinac, close to water level.
41. Oölitic dolomite from Plum creek.
42. Compact dolomite rock mottled with light and dark blue cloudy specks. Sec. 16, Ida township, Monroe county.
43. Calcareous sandstone, same quarry two miles west of Ida.

44. Dolomite with acicular crystals.
45. Blanchart's farm, Mackinaw.
46. Principal quarry stone of the Helderberg group, Macon river, Christiancy quarry.
47. Better quarry stone of the Helderberg group, Macon river, Christiancy quarries.
48. Khagashewung Point dolomite.
49. Norwood dolomite.
50. Concretions of granular limestone structure, from the shales of Norwood.
51. Non-fossiliferous portions of rock at the Grandville quarries.
52. Bellevue limestone.
53. Brown dolomite rock of the Bellevue quarries.
54. Brown cellulose dolomite rock, a short distance northeast of Parma village.
55. On Mr. Shoemaker's land, in Summit township, three miles south of Jackson.
56. Limestone of Portage river.

STRATIGRAPHY OF THE TRAVERSE GROUP OF MICHIGAN.

BY AMADEUS W. GRABAU.

STRATIGRAPHY OF THE TRAVERSE GROUP OF MICHIGAN.

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INTRODUCTORY.

The field work on which the following account of the Traverse group of Michigan is based, was done in the late summer of 1900 and during a part of the field season of 1901. Ten days were spent in 1900 in the Alpena region in company with Mr. W. F. Cooper of the Michigan Geological Survey, and four weeks in 1901 (July 20 to August 21) in the Alpena and Petoskey regions in company with Mr. H. W. Shimer, assistant in Palæontology in Columbia University, New York city. The field investigations during the first season were carried on under the auspices of the Geological Survey of Michigan and with the cooperation of the State Geologist, Dr. A. C. Lane; those of the second season, under the same auspices, with additional cooperation of the Geological Department of Columbia University, this department defraying Mr. Shimer's field expenses. The work in the Alpena region during both field seasons was greatly facilitated by the active interest of several prominent Alpena citizens. Foremost among these is Mr. W. H. Johnson, who almost daily assisted us in our work, and whose intimate knowledge of the region enabled him to either personally conduct us, or direct us to the important outcrops of fossiliferous beds. It is but fitting that we should express our personal thanks to Mr. Johnson, for the many courtesies he showed us, in addition to calling attention to the efficient manner in which he has aided the prosecution of the work carried on for the State. Mr. Monaghan of the Alpena Portland Cement Company and Messrs. F. M. Haldeman, superintendent, and L. H. Ludlow, chemist, of the cement company, also put us under obligation by furnishing us with analyses of the various limestones and clays. Mr. Ludlow's lively interest in our investigations, and his constant readiness to aid us, is one of the pleasant recollections of our field experiences. Capt. John D. Persons of the Thunder Bay Island life saving department showed us numerous courtesies during our examination of that and the neighboring Sugar Island, during which time we were his guests. To all these gentlemen our sincere thanks are herewith tendered.

PREVIOUS WORK.

The work of only a few investigators in this region need be noted in this connection.[1] In his report of 1860, Professor Alexander Winchell

[1] In 1823 Dr. J. J. Bigsby read notes on the Geography and Geology of Lake Huron before the London Geological Society, in which the Presque Isle and Middle Island limestone is described, p. 201, as well as that about Mackinac, p. 194, and those on the north side of the lake.

devoted three pages to the Hamilton group of Michigan. In 1866 he issued his report on the Grand Traverse region, in which he devoted less than ten pages to the Hamilton group. On the accompanying map he gives eight localities where typical exposures may be seen. Frequent reference to this report will be made in the discussion of the Petoskey region. Later, in the same year, appeared an appendix to the report on the Grand Traverse region, by the same author. In this pamphlet of fifteen pages he gives a correlation of the various beds described previously, and a table showing the vertical distribution of the various species. He furthermore gives brief descriptions without illustrations of sixty-two species of fossils not before recognized. The illustrations prepared to accompany this report were never published.

In 1875, Professor N. H. Winchell[2] published a brief account of the region of Cheboygan and Old Mackinac. He gives a succession of the beds of this region, with incidental mention of the Alpena region. In 1876 (Proc. Am. Ass. Adv. Sci., II, 57-59) the same author gave a brief account of the parallelism of Devonian outcrops in Michigan and Ohio. In both these papers the Dundee and Lower Traverse beds were referred to the waterlime, on account of the lithologic similarity.

In the Report on the Geology of the Lower Peninsula of Michigan, Dr. Carl Rominger[3] gives the most complete account of the Hamilton or Traverse group of Michigan theretofore published. Twenty-six pages of the report are devoted to the Hamilton group, all the most important outcrops on both sides of the Peninsula being described. Notes are also given on prominent intermediate localities. In the second part of the volume, which is devoted to the description of fossil corals, Rominger describes a large number of species, many of them new, from the Traverse beds of Michigan.

Dr. Lane, in 1895 (Geol. Surv. Mich., Vol. 5, pt. II, the Geology of Lower Michigan with Reference to Deep Borings, p. 24), gives a brief account of the Traverse group, in which he proposes to change the name Little Traverse, employed by Winchell, to Traverse group. The numerous sections given at the end of the volume give the thickness and relative position below the surface of these beds in various parts of the State. A brief record of the Churchill well in Alpena was published by Lane in 1899.[4]

My own studies of this region began in 1900, when I made a brief examination of the Alpena region, the result of which is embodied in a report published in the American Geologist, Vol. 28, pp. 177-189, for September, 1901, under the title of "A Preliminary Geologic Section in Alpena and Presque Isle Counties, Michigan." The second season's work consisted in examining certain of the 19 localities of 1900 and of the study of 32 additional ones, making a total of 51. While a considerable number of localities still remain unexamined, it is nevertheless believed that enough has been done to permit of a preliminary analysis of the Traverse group of Michigan. The complete analysis must, of course, be preceded by a careful study of additional localities and of the fossils

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[2] Twelfth Annual Report of the State Board of Agriculture, Mich., for 1873, pp. 103-107. The report is dated 1871.

[3] 1876. Geol. Surv. Mich., Vol. 3.

[4] Engineering and Mining Journal, Nov. 4, 1899, p. 548 after a visit the previous winter, in which I visited the quarries and collected some of the records herein contained. See also my U. S. G. S. water supply papers Nos. 30 and 31.—L.

collected, a work which will require some considerable time. The list of species given in this report for the various beds in each locality include only the common or more readily recognized types. In general these may be considered the type fossils of the beds described, although it will be observed that many of these species have a wide vertical range. The preparation of an exhaustive report on the Palaeontology of the Traverse group of Michigan has been begun, and it is hoped that the vertical range of at least the majority of species may be determined. The conclusions herein given, in so far as they depend upon palaeontologic research, must be considered as tentative and subject to modification, should the final studies of the fauna demand it.

DESCRIPTION OF LOCALITIES.

A. Alpena (Thunder Bay to Presque Isle) Region.

During the first season's field work a north and south section was prepared extending northward from Alpena. An account of this was published with brief descriptions of 19 localities along the section,[5] and this account, together with additional notes, is here included.

As no topographical map was available, the profile of the country along the section had to be prepared in the field, at the time the geological data were collected. Distances were measured by means of a cyclometer attached to the bicycle, which was the only conveyance employed in the field. To eliminate errors due to unevenness of the country and to other causes, the cyclometer readings were checked by special readings on the section lines. Elevations were obtained by reading the aneroid barometer at all the stations, as often as these stations were passed, and correcting these readings by the barograph record obtained from a stationary instrument at Alpena. Owing to the length of the section, the barograph corrections did not always prove satisfactory, especially as several severe atmospheric disturbances affected the aneroid in the northern part of the section, which were felt to a less degree at Alpena, where their record was obtained by the barograph.

LOCATION AND EXTENT OF THE SECTION.

The section is located in Alpena and Presque Isle counties, Michigan. It runs north from the city of Alpena along the meridian of 83° 25′ longitude west of Greenwich, and forms the western boundary of the eastern third of range 8 E. It extends through the whole of township 32 and 33 north and parts of townships 31 and 34 north. The total length of the section is nearly eighteen miles, but the distance covered in its preparation was nearly double that.

The section is interrupted near the middle by Long lake, and it passes by the eastern end of Grand lake. It strikes the shore of Lake Huron about four miles southeast of Presque Isle light. About one half of the line of the section is along a north-south road.

[5] Loc. cit. for these localities consult the map Pl. VII.

TOPOGRAPHY OF THE SECTION.

In the following table the distances between stations as calculated from the cyclometer readings are given. The elevations given are calculated from the aneroid readings and corrected by the barograph readings. The resulting elevations are those of the various stations above the mean level of Lake Huron, which is taken as 580 feet above the sea.

Station, number and location.	Distance between points. mi.—yds.	Elevation above Lake Huron. (580 ft. A.T.)
1. Thunder Bay	....	00.0
2. Round House	2.2 — 66	27.7
3. Sec. 15, N. E. Cor	.2 —110	40.7
4. Sec. 10, E. line base of terrace	.8 — 66	44.4
5. Sec. line top of terrace	.0 —110	56.4
6. Sec. 10, N. E. Cor	.1 — 22	59.4
7. Sec. 3, E. line, base of terrace	.2 —110	52.1
8. Section line top of terrace	.1 — 88	62.1
9. Sec. 3, end road running west	1 —	67.1
9a. Offset on same, top of terrace	.1 —	79.1
10. Sec. 3, E. line, base of terrace	.1 — 66	62.5
11. Section line top of terrace.	.1 —	72.8
12. Sec. 3, E. line top terrace	.6 — 88	85.8
13. Sec. 3, N. E. corner, road running west	.19—132	92.8
14. Sec. 34, E. line	.7 — 44	93.5
15. Sec. 35, W. line	.1 —132	103.5
16. Sec. 34, N. E. corner	.0 —154	119.9
17. Sec. 27, E. line top of terrace	.0 — 88	128.9
17a. Sec. 27, outcrop	.0 — 88	128 9
18. Sec. 27, E. line, base of terrace	.1 —154	120.2
19. Section line, outcrop	.1 —110	124.2
20. Sec. 26, W. line	.1 —132	134.2
21. Sec. 27, E. line, base of terrace	.2 — 44	124.2
22. Section line outcrops	.4 —132	119.2
23. Sec. 22, fork roads	.2 — 88	125.2
24. Sec. 22, centre north line	.7 — 88	117.9
25. Long Lake	.8 —110	110.6
24a. Hell creek bridge	.2 — 22	100.6
25a. Sec. 23, north line, center	.5 —132	106.4
26. Road east of Long Lake	1.2 —154	121.4
27. Sec. 3, E. line	1.1 — 66	125.2
28. Sec. 3, end road running west	.4 — 00	113.0
29. Sec. 3, E. line	.0 — 88	126.0
30. Sec. 3, E. line, top of ridge	.6 — 44	136.8

Station, number and location.	Distance between points. mi. — yds.	Elevation above Lake Huron. (580 ft. A.T.)
31. Town and county line	.0 — 88	136.8
32. Sec. 34, E. line, top of moraine	.6 — 00	134.8
33. Sec. 35, W. line, Rabiteau's farm	.2 —110	112.6
34. Sec. 27, E. line, base of terrace	.3 — 00	81.6
35. Sec. 22, E. line, road running west	1.3 — 22	63.4
36. Fork of roads	.1 — 88	76 4
37. Lake Huron at Bell	.1 —132	32.4
38. Grand lake at Lumber mill, Sec. 15, N. E. corner	1.4 —154	56.2
39. Top moraine, Grand Lake	3.8 — 00	41.7
40. Grand Lake isthmus	.2 — 44	11.7
41. Top gravel ridge, Club house	.1 —132	25.1
42. Kaufman's	.2 — 88	31.1
43. Lake Huron at Presque Isle Light	5.22— 00	33.6

Of the stations here recorded, Nos. 1 to 23, and Nos. 27 to 35, are on the section line; the others are either to the east or the west of the section line. From these data, the accompanying profile of the section (Plate VII) has been constructed.

From a careful plotting, it appears that Long lake and Grand lake lie along the outcrops of shale beds of considerable thickness. The valleys of these two lakes, therefore, which extend along the strike of the strata, represent longitudinal lowlands, carved by streams of the subsequent type out of the softer strata.

From an inspection of the section it will be seen that it crosses a number of terraces of gentle southward and steep northward descent, separated by lowlands of greater or less extent. The greatest of these lowlands is occupied by Long lake and Grand lake, while others are occupied by streamlets. The terraces and accompanying lowlands may be traced northwestward and southeastward along the strike of the strata, the former marking the outcrops of the resistant strata, while the latter mark the softer beds. In a number of cases the northeastern face of the terrace is an abrupt cliff, a good example of which is shown on the south shore of Grand lake. The topographic elements thus produced are a series of minor cuestas (W. M. Davis) and lowlands, such as are normally developed in regions made up of nearly horizontal strata of alternating hardness. From the soundings of the Lake Survey Charts it becomes evident that a cuesta of considerable magnitude, formed by the lower strata of this region, can be traced across Lake Huron from a little east of Presque Isle to the Canadian shore above Goderich.[6]

Similar alternations of terrace and lowland are found south of Alpena, though they are in general less pronounced. One or more of the lowlands is followed by Thunder Bay river in portions of its course.[7]

[6] See Grabau, Bull. N. Y. State Mus. No. 45, p. 54.

[7] It may be noted that the direction of general ice advance is such that the shock and lee sides would nearly harmonize with preglacial structural forms.—L.

TOPOGRAPHY OF THE SHORE LINE.

The shore line in this portion of the peninsula is generally low and not infrequently swampy. This is especially true of the Thunder bay region south of Alpena as far as Partridge Point, at which place bluffs about 12 feet in height front the lake. At only one locality between Alpena and Partridge Point are rocks exposed along the shore. This is at Stony Point, immediately south of Alpena, where low ledges, generally submerged, appear on the lake shore. No rock exposures have been observed along the north shore of Thunder bay except in the easternmost portion. Here Thunder Bay Island and Sugar Island show ledges, though the relief is very slight. Rock cliffs are found at the head of Misery or Little Thunder bay, forming the walls of a large sink hole. Other ledges occur at intervals along the shore; most of these, however, are low, or even submerged. The northeast shore of Presque Isle and False Presque Isle extend along the strike of a resistant limestone bed (Dundee), which, however, does not rise into cliffs. The same bed probably forms the eastern shore of Middle Island.

The strike of the strata of this region is approximately northwest and southeast. The dip is 42 feet to the mile toward the southwest. This is equivalent to 30 feet to the mile along the line of the section.

STRATIGRAPHY OF THE EASTERN (ALPENA) REGION.

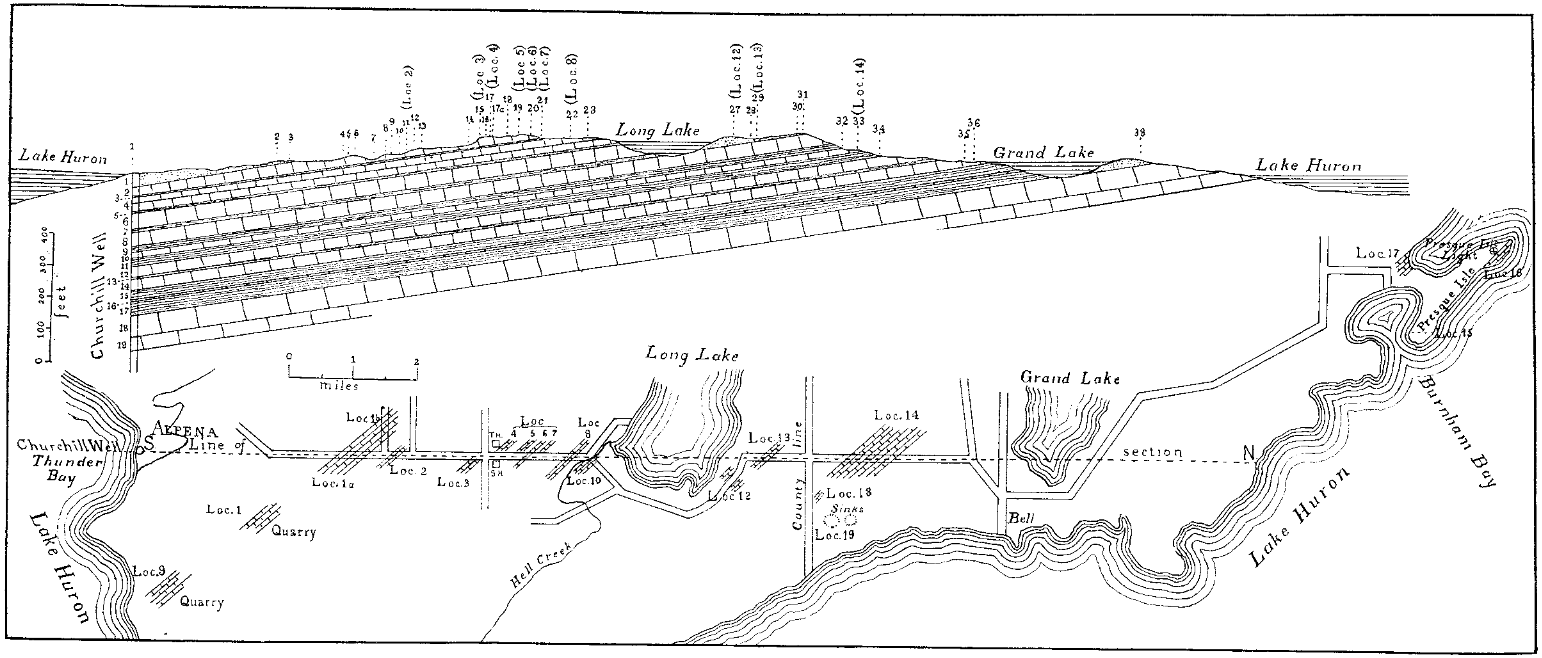
A. Well records.

Owing to the extensive drift coverings of this region, rock exposures are comparatively rare, and are confined to roadside cuttings, quarries and the few natural exposures, which are found along the tops of the terraces and on the shore. From well records, however, we gain a knowledge of the succession of beds, and of the thickness of the various members. Taking this as the foundation of the stratigraphic work for this region, we may attempt a correlation of those beds which crop out on the surface, with those recorded in the well. Lithic characteristics will have to be relied upon in such a correlation, and for the area covered by this section, these may be considered reliable. This is especially the case, since all the strata entering into the section are off-shore deposits, with a minimum of coarse detritus, and hence of a character which remains uniform over a large area.

The following succession of strata in this region has been derived from the records of the Churchill well, the location of which is near the southern end of the section in Alpena.[8]

The mouth of the well is near the level of Lake Huron, and above the coral limestone of Alpena. This rock, which will be called the Alpena limestone, is the middle member of the Traverse (Hamilton) group of Michigan, and hence the entire upper portion of this group is unrepresented in the well record. At a depth of 1267 to 1278 feet, the well ends in the salt beds of the Salina group, having penetrated the entire lower Devonic and part of the upper Siluric rocks of the region.

[8] Geol. Surv. Mich., Vol. V, p. 87. See also p. 68.



Bed 1 = sand and gravel.
Bed 3 = thin shale bed.
Bed 5 = " " "
Bed 13 = " " "
Bed 16 = thin limestone bed.

GEOLOGIC SECTION IN ALPENA AND PRESQUE ISLE COUNTIES, MICH.

(I.) Succession of strata in the Churchill well at Alpena, Mich.:

		Feet.	Depth.
1.	Sand and boulders	41.0	41.0
2.	Hard white (light colored) limestone	25.0	66.0
3.	Shale	9.0	75.0
4.	Very hard white limestone	49.5	124.5
5.	Shale	2.5	127.0
6.	Extra hard gray limestone	40.0	167.0
7.	Blue shale	20.0	187.0
8.	Hard white limestone	34.0	221.0
9.	Shale, 7 feet white and slimy, possibly gypsum (?)	18.0	239.0
10.	Hard white limestone	23.0	262.0
11.	Very sticky blue shale	27.0	289.0
12.	Hard white limestone	32.0	321.0
13.	Shale	3.0	324.0
14.	Hard white limestone, upper two-thirds extra hard	39.0	363.0
15.	Shale	24.0	387.0
16.	Hard white limestone	5.0	392.0
17.	Shale, mostly blue	52.0	444.0
18.	Hard white and gray limestone, mostly extra hard	60.0	504.0
19.	Extremely hard (flinty) limestone	39.0	543.0
20.	Shale	25.0	568.0
21.	Hard gray and white limestone	103.0	671.0
22.	Shale	20.0	691.0
23.	Hard white limestone	86.0	777.0
24.	Sandy lime and shale	10.0	787.0
25.	Hard white limestone	480.0	1267.0

This carried the drill down to the rock salt of the Salina group.

Strata 15 to 17 are provisionally considered the equivalent of the New York Marcellus, though there is no evidence at present to indicate that the faunal characteristics, on which the separation of the Marcellus beds alone rests, are found in this region. For this reason it is perhaps better to speak of these beds as the lowest Traverse shales, regarding the five-foot stratum of limestone (No. 16) as an integral part of the series. The total thickness of this lowest shale series, which are below referred to as the Bell shales, is therefore 81 feet.

Strata 18 and 19 are provisionally referred to the Dundee[9] limestone, which is considered the equivalent (approximately) of the Onondaga limestone series of New York. The combined thickness of the two strata referred to this formation is 99 feet.

Stratum 21 probably represents the Mackinac limestone, a formation which is believed to be the time equivalent of the Manlius limestone of New York. It undoubtedly is of upper Siluric age, but the determination of its exact equivalency must be deferred until paleontologic investigations are made. The beds below it, belong, in part at least, to the same horizon.

Whether the shale of stratum 20 belongs to the overlying or underlying formation is likewise an unanswered question.

If the above correlations are correct, the Churchill well record gives us the following thicknesses of Devonic formations:

Traverse upper shales	Not represented
Traverse middle limestone (Alpena limestone)	25
Traverse lower shales and limestones	378
Total middle and lower Traverse	403
Dundee limestones	99
Total	502

[9] They yield freely water charged with H_2S.

(II.) Well of Alpena Portland Cement Company:

On the land of the Alpena Portland Cement Company (Loc. 9) a well was put down in search of water, within the last year. I had the opportunity to examine the samples of this well through the courtesy of the officers of the cement works. The following record was obtained from samples taken at two-foot intervals:

Character of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Pure white limestone of very uniform character	Alpena limestone	34	34
Gray shale appears and increases in amount down to 50 feet, then it decreases again	Long Lake limestone & shales	20	54
Gray and black shales predominate, often bituminous	"	22	76
White limestone again abundant	"	02	78
Black and gray shales abundant, then decrease to 82 feet	"	04	82
White limestone predominates. Shale in small quantity	"	02	84
Missing	"	04	88
Gray calcareous shale in small quantity with white limestone	"	02	90
Gray calcareous shale and gray limestone	"	02	92
Missing	"	20	112
Gray shales abundant with white limestone	"	04	116
Nearly pure grayish limestone	"	02	118
Gray shale increases	"	04	122
Mostly gray calcareous shale	"	04	126
White limestone with small quantity of gray shale	"	02	128
Gray shale somewhat more abundant, mostly white and gray limestone	"	02	130
Gray shale increasing to about equal quantity with limestone	"	06	136
Mostly gray calcareous shale, very little white limestone	"	02	138
Limestone more abundant	"	02	140
About equal amounts of gray shale and white limestone	"	02	142
Acervularia	"	02	144
Gray crystalline limestone	"	02	146
Gray limestone with some gray shale	"	02	148
Gray shale with gray and white limestone	"	02	150

This record does not seem to correlate at first very readily with that of the Churchill well. The Alpena limestone here has a thickness of 34 feet, and since this rock on Dock street is overlain by shales (Dock street clay), the total thickness of the Alpena limestone is probably in the neighborhood of 35 feet, instead of 25, as shown in the Churchill well. After this follows 20 feet of calcareous beds in which there is a considerable quantity of gray shale, probably in the form of thin intercalated beds. A part of this at least is to be correlated with the shale bed (No. 3) nine feet in thickness recorded in the Churchill well. The rest, with the 22 feet in which gray and black shales predominate, correspond to what in the Churchill well record has been called limestone. The shale is probably in thin layers and so would not attract the attention of the drillers, who would regard all the strata as limestone.

(III.) Wells of Alpena Business Men's Association, Frank J. Jahncke, driller:

No. 1. On north line of Sec. 22, T. 30 N., R. 8 E., close to the shore and not eight feet above it.[10]

The section is south of the western end of Partridge Point and gives the following succession:

Description of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Black shale	Neo-Devonian black shale (Antrim)	50	27–29
" "	"		47–49
" "	"		49–57
" " and greenish argillaceous limestone	"		67–69
Buff dolomite?	Upper Traverse shale and limestone.	48	77–79
" "	"		85–89
Dark bluish shale or limestone	"		97–99
Buff limestone	"		104–109
Coarse varicolored limestone	"		123–125

No. 2. This is half a mile south of No. 1, near the center of Sec. 22. The record is as follows:

Description of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Black shale	Antrim black shale	75–80	76
Gray shale	Upper Traverse shales	-	83

[10] The Survey has alternate bottles of samples, the others being retained by Mr. Monaghan of Alpena.

(IV.) Well of C. Moench & Sons Company, T. 31 N., R. 8 E., Sec. 28: This is in the southwestern portion of Alpena, a mile or more southwest from the line of strike of the rocks exposed in the Churchill well. The following brief record is preserved. The drilling occurred in February, 1899:

Description of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Quicksand		80	80
Shale and rock	Traverse group	360	440
Balance rock	Traverse&Dundee gr.	210	650

Although the record does not state so, the drilling probably commenced at the summit of the middle limestone bed (Alpena limestone). The 80 feet of drift in this well, taken in connection with the 41 feet of drift in the Churchill well, suggests that Alpena is underlain by a preglacial valley—that of the Lower Thunder Bay river—which is of the normal consequent type, and opened out in a bed of soft shale, similar to Long and Grand lakes. This old valley appears to have had as its floor the resistant Alpena limestone, which gradually rises to the northeast and comes to the surface a mile or more northeast, i. e., across the strike of the strata, from the Churchill well. The position of this limestone is thus obtained at three points: at the Churchill well, a mile or more northeast of this, and a mile or more southwest of the well. At the northeasternmost point, i. e., Loc. 1, the limestone comes to the surface. At the Churchill well it is 41 feet below the surface. In Sec. 28 it is apparently 80 feet below the surface, while the surface of the well is probably but little above the level of the lake. This gives approximately 40 feet to the mile as the dip of the limestone, which is nearly the ascertained dip of the rocks in this region.

At Stony Point rock appears on the surface, where the point is formed of resistant limestone layers. Other outcrops are found at Warner's brickyard (Loc. 25), which lies northwest from Stony Point. It thus appears that these beds are at least 80 feet above the Alpena limestone, and that the Stony Point beds form the edge of an ancient escarpment (inface of a cuesta) the valley in front of which is drift-filled to a level with the top of the cliff.

(V.) Tannery well:

In Sec. 22, T. 31 N., R. 8 E., a well was put down in November, 1892, to a depth of 625 (?) feet, by the Northern Extract Company. This struck water in good quantity at a depth of about 400 feet, where a soft shale rock was found, which greatly impeded the drilling. This well is essentially along the strike of the rocks from the Churchill well, and it is probable that the bed of shale here referred to is the Bell Shale (see beyond), out of which the valley of Grand lake is carved. This shale at the Churchill well lies about 360 feet below the surface.

(VI.) Well No. 6.[11] Put down to salt at 1164 feet, before 1866, near the electric light works.

[11] Geol. Surv. Mich., Vol.V, p. 47.

(VII.) Rominger[12] speaks of a similar well put down in 1872 close to the bed of Thunder Bay river. The borings commenced in limestones and continued without much interruption by other beds to a depth of 400 feet, where blue shales 80 feet in thickness were struck, and a powerful stream of water, for which this formed the impervious bed, rose to the surface, carrying with it many of the characteristic fossils of the lower beds. These Rominger supposed to have come from the shales, but since they abound in the overlying beds it is more probable that they were derived from these.

(VIII.) Fletcher well. Paper mill on Fletcher street, Alpena, Mich. A. J. Scott, driller. March, 1901. Fifteen feet above lake, 595 A. T.:

	Description of rock.	Thickness, feet.	Depth, feet.
1.	Surface sand	32.0	32.0
	Drive pipe (end of Pleistocene)	....	32.8
2.	Gray limestone	20.0	52.0
3.	Limestone and shale	28.0	80.0
4.	Gray limestone	40.0	120.0
5.	Dark limestone	40.0	160.0
6.	Brown shale	5.0	165.0
7.	Light and dark limestone with streaks of shale	85.0	250.0
8.	Soft shale (soapstone)	80.0	330.0
9.	Limestone with shale streaks	20.0	350.0
10.	Gray limestone	10.0	360.0
11.	Slate (soapstone)	82.0	442.0
	Casing 6¼ inches to	....	450.0
12.	Gray limestone	43.0	485.0
	First flow at	....	490.0
13.	Brown sandy limestone	55.0	540.0
14.	Very hard brown limestone which cuts bits badly, but is said all to dissolve in muriatic acid	15.0	555.0
	Second flow at		615.0
	Slightly sulphureted head to 40 feet above lake level, flow 600 gallons per minute.		
14a.	Same as 14	80.0	635.0
	End of Corniferous or Upper Helderberg.		
15.	Gypsiferous limestone	7.0	642.0

In this well the Alpena limestone appears to be only 20 feet thick, though it is probable that the record is not as accurate as preceding ones. Stratum 8 of this well probably corresponds to stratum 11 of the Churchill well, but the thickness in the Fletcher well (80 feet) is probably given as too great. Stratum 11 of the Fletcher well corresponds to strata 15 to 17 inclusive in the Churchill well, and represents the basal shale series, i. e., the Bell Shale.

It is not improbable that the "coarse, varicolored limestone" met with at a depth of 123 feet in the Business Men's Association well No. 1 (III-1), south of Partridge Point, is the stratum cropping out at Stony Point. If this is the case, the total thickness of the shales between this stratum and the base of the Black Shale is, according to the interpretation of the well record, 46 feet. This is not inconsistent with the dip of the strata. Adding to this thickness the 80 feet of strata between the Alpena limestone and the Stony Point beds, we have a total thickness of 126 feet, or, in round numbers, 130 feet for the upper shales and limestones of the Traverse group of Thunder bay. If this is correct, the Traverse group of this region admits of the following subdivision:

[12] Geol. Surv. Mich. Vol. III, Part I, 1876, p 40.

3.	Traverse upper shales and limestones, or Thunder Bay series (minimum estimate)	130 feet
2.	Traverse middle limestone or Alpena limestone	35 "
1.	Traverse lower limestone and shale—	
	B. Long Lake series	298 "
	A. Bell Shale	80 "
	Total	543 feet

Rominger estimates the total thickness of the Hamilton group of Thunder bay to be about 580 feet (p. 40). The total thickness of the upper or Thunder bay series is probably somewhat more than 130 feet, and may even reach 170 feet, in which case Rominger's estimate of the total thickness is the true one. The distance measured in a straight line across the strike from the point of outcrops of the top of the middle limestone at lake level to the first appearance of the Black shale at the lake level, would give about 200 feet for the thickness of the shales overlying the Alpena limestone, assuming that the dip of the strata remains a constant one, i. e., 42 feet to the mile. Rominger's estimate may, therefore, be regarded as probably a close approach to the truth. Still his division of 100 feet for the upper beds and 480 feet for the lower is not borne out by the more accurate records of the recent well borings.

B. Records from outcrops.

For the detailed description of the strata of this region the Alpena limestone makes the most convenient reference stratum, and as it is also the most important member of the group from an economic standpoint, it will be described first. Following it will be given descriptions of the lower members of the group, in their stratigraphic order, from the highest to the lowest beds. The upper Traverse or Thunder bay series will be described last, as least exposed. It will be observed that the field localities do not regularly succeed one another, since it was most convenient to study the localities without direct reference to succession. The localities of the Alpena region are here given in succession:

Loc. 1.	Quarries N. E. of Alpena. (Owen Fox and Richard Collins)	Alpena limestone.
2.	Outcrop two miles N. of Alpena, Long Lake Road (Sec. line sta. 11)	" "
3.	Long Lake Road (Sec. line sta. 15)	" "
4.	Section line sta. 17a	" "
5.	Section line sta. 19	Long Lake series.
6.	" " " 20	" " "
7.	" " " 21	" " "
8.	" " " 22. Forks of road south of Long Lake	" " "
9.	Quarry Alpena Portland Cement company	Alpena limestone.
10.	Hell Creek Fall (sta. 24)	Long Lake series.
11.	Bell Road (sta. 26)	" " "

Loc. 12.	Bell Road (sta. 27)	Long Lake series.
13	Bell Road (section line sta. 29)	" " "
14.	Rabiteau's farm (section line sta. 33)	" " "
15.	Burnham Bay	Dundee limestone.
16.	Presque Isle Light	" "
17.	Mainland south of Presque Isle	" "
18.	Presque Isle county, S. E. of Loc. 14	Long Lake series.
19.	Sink holes sec. 36 R. 8 E., T. 33 N	Bell shales at base of 19.
20.	Misery Bay	Long Lake series.
21.	Fletcher Dam	Upper Traverse beds or Thunder Bay series.
22.	Stony Point	"
23.	Partridge Point	"
24.	Boom Company Dam	"
25.	Warner Brickyard	"
26.	Thunder Bay Island	Lower Alpena limestone.
27.	Roadside sec. 27 R. 8 E., T. 32 N	Long Lake series.
28.	¼ mile N. E. of preceding	" " "
29.	Wiesey's well	" " "
30.	2 miles S. of Clay Pits	" " "
31.	Clay Pit Alpena Portland Cement company	" " "
32.	Same as Loc. 8	" " "
33.	Long Lake Road North of preceding	" " "
33a.	N. E. of 32	" " "
34.	Long Lake road near lake	" " "
35.	Under root of tree near sink holes (Loc. 19)	" " "
36.	False Presque Isle	Dundee limestone.
37.	Grand Lake Ledges	Lowest Long Lake beds.

ALPENA LIMESTONE.

This limestone underlies a considerable area to the north and northeast of Alpena. It appears on the surface in the northeastern portion of the town where several quarries are opened in it (Loc. 1). It is also quarried in the cement-works quarry less than a mile east of the town, near the lake shore, or approximately southeast of the preceding locality. This is designated Loc. 9.

The rock first appears on the section line, about a mile north of the town (Sta. 4). It appears at intervals to the north of this, and is prominently exposed in the terrace which crosses the section line in a direct northeast line from the quarries. (Sta. 8).

This terrace continues northwestward and furnished another good exposure of the limestone about a tenth of a mile west of the section along the first west road. (Sta. 9a, Loc. 1b.)

Loc. 1. Quarries northeast of Alpena. The limestone is here almost wholly composed of corals and hydro-corallines, though brachiopods and other organisms are not wanting. The corals are Favosites and Acervularia, the former probably represented by a number of species. Large masses of the rock are entirely made up of these corals, which appear to be still in the place where they grew. Other large masses of the rock are composed of the hydro-coralline Stromatopora and allied genera, which also appear to be represented by several species. Among the smaller corals, species of Zaphrentis, Aulopora, and Ceratopora predominate, while the Bryozoa are chiefly represented by fenestelloids, and Lichenalia-like types. The chief brachiopods are: *Atrypa reticularis* (an extremely convex form), *Spirifer* cf. *S. mucronatus*, Stropheodonta, several species, *Cyrtina umbonata* var *alpenensis*, *Gypidula romingeri*, etc.

The central mass of limestone of this region has all the characteristics of an ancient coral reef in which the chief reef-builders were the Favosites, Acervularias, and Stromatoporas. These formed the main mass of the reef, while between them grew the smaller species, and the other organisms which go to make up the *ensemble* of the reef population. A careful examination of sections in the quarries shows that there is an absence of stratification and regularity of structure in general, within the reef portion of this limestone. This is to be expected, since this portion of the mass is entirely of organic origin. In form, this portion is dome-like, and the stratified beds of limestone which flank it, dip away from it in all directions at an angle exceeding that of the normal dip of the strata of this region as shown by the following figure:

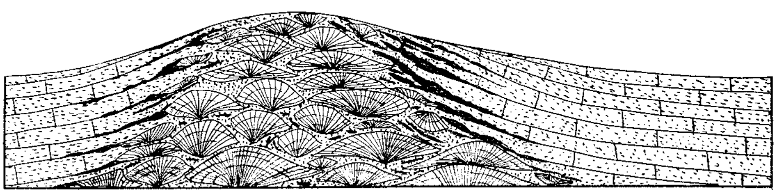


Fig. 2. Cross section of the coral reef in Collins' Quarry, Alpena, showing the reef portion, the flanking layers of coral sand limestone and the interfingering of the two. The dips are actually observed.

a. Owen Fox's Quarry:

In this quarry the general dip of the strata is 4 degrees to the southwest. In the eastern end of the quarry the dip increases, according to the following observations: 8 degrees, 10 degrees, 18 degrees; the steepest dip is in the easternmost portion, where the abundance of corals indicates the neighborhood of the reef.

On the southwest, dark shaly limestones and bituminous shales overlie the limestone, and carry a rich coral and brachiopod fauna. (For analyses of the limestones of this quarry, see beyond.)

b. Richard Collins' Quarry:

This quarry, across the road from the previous one, shows the central reef with the flanking lime-sandstone strata dipping away from it. This quarry was formerly known as Phelps' lime kiln quarry, and Rominger, on page 43 of his report, mentions the central reef as a bubble-like protrusion. The relation of the fragmental strata and the reef mass is shown in the accompanying figure. The strata dip away from the reef in all directions. At first the angle is 28 degrees, then it falls to 14 degrees, then to 4 degrees, and finally to 2 degrees, the normal dip of the strata in the quarry. In the reef portion, the coral masses (heads of *Favosites alpen-*

ensis, various species of Stromatopora, and large heads of *Acervularia davidsoni*) are surrounded by the crystalline coral sand which filled in all the interstices between the coral heads as shown in the preceding figure, Fig. 2.

These interstitial limestone masses in the reef are generally made up of coarse fragments in which large crinoid joints predominate. Brachiopods and Bryozoa also occur here, for this was a favorite habitat of these animals. These interstitial masses are often re-crystallized, and crystals of dogtooth spar are often abundant.

The coral heads are generally of large size. Sometimes they are overturned, but most of them appear to lie in their normal position. In some places the crystalline coral sand forms most of the rock exposed, the large coral heads being scattered through the sand. This latter shows no stratification, which is found only on the flanks of the reef and beyond it. The sand in the cavities of the reef is generally much coarser than that on its flanks or farther away, a feature indicating normal sedimentation.

In places at some distance from the center of the reef the rock consists of an organic breccia, made of brachiopods, bryozoa, and the small branching corals plentifully interspersed with crinoid joints.

Away from the reef the limestone is bedded, wholly of fragmental origin, and made up directly of comminuted coral and crinoid remains. The stem joints of the latter stand out in relief on the weathered surfaces. Crinoid heads (Dolatocrinus) and small corals (Favosites, etc.) are found in the limestone, but such fossils are generally most abundant in the somewhat shaly films which separate the successive limestone strata.

The origin of these limestone masses and the accompanying beds of stratified limestone may be explained as follows:

In the Devonic sea of this region, the luxuriant growth of corals and other lime-secreting organisms produced isolated reefs, which rose to within the sphere of wave activity. Being subject to the continued attack of the waves, these reefs were destroyed wherever the vitality of the polyps was insufficient to resist the wave attack. Wherever exposed, the dead coral rock was ground into a coral sand, this being accomplished in part by the direct activity of the waves, in part by the aid of tools chiefly in the form of loose blocks which were rolled about, and served to grind up the coral rock, and in part by the many reef-destroying organisms, which in every reef are actively breaking up the dead coral masses. The resulting coral sand was carried away by the waves and currents and deposited on the flanks of the reefs, and in the quieter water beyond.

Stratification is well marked in such a fragmental limestone, or lime-sandstone, and it not infrequently happens that cross-bedding structure, ripplemarks, and other shallow water characteristics are shown in such a limestone. In fact, we may consider that there is no essential difference in structure between such lime-sandstones and ordinary quartz-sandstones, the mineralogical character of the component grains being the only distinction. In such a lime-sandstone fossils need not be abundant, in fact we could understand their total absence. Near the growing reef, which is the source of the coral sand, the minor reef organisms may be expected to occur, but their number would decrease in proportion as we pass away from the reef. In the immediate vicinity of the reef, an interlocking of the organically and the mechanically formed limestones occurs, for at times the coral sand encroaches upon the reef, and again the reef organisms extend outward, growing on the foundation of sedimentary coral sand. This inter-locking of the two types of limestone is well shown in the quarries opened in the reefs in question, and on either side the stratified limestone, consisting wholly of consolidated coral sand, is seen dipping away from the reef. This stratified limestone is strikingly barren of organic remains; only a few brachiopods or small corals are found at intervals. In texture it is very uniform, and in composition very pure, yielding from 96 per cent to 99 per cent $CaCO_3$. (See analyses given beyond and under Loc. 9.)

The purity of these limestones is readily accounted for when we remember that the reef-building organisms flourish only in water free from terrigenous matter. Since the stratified limestone beds which always accompany the reef are derived from the organically formed limestone, and since there is an absence of terrigenous matter within the area of their deposition, it follows that these limestones must be very pure, within a radius of some magnitude from the central coral reef, the source of supply of the lime sand. It furthermore follows that the thickness of the coral reef, and the thickness of the flanking fragmental limestones, may agree and that beds of great thickness may accumulate, depending on the length of time during which the reef remains in an actively growing condition.

It thus appears that the reefs are the most trustworthy guides to the purity of the limestones. Close to the reefs from which they were formed, these limestones will generally be free from foreign material, while this may increase in amount progressively with the distance from the reef.

Loc. 1a. The rock exposed here shows essentially the same characteristics as that of the preceding two localities. *Favosites* appear to be the most common fossil. Other fossils are *Atrypa reticularis, Spirifer granulosus, Zaphrentis* sp., and several species of *Stropheodonta.*

Loc. 1b. The limestone has here less the character of a reef, but appears to have accumulated in the immediate neighborhood of a reef. It is highly fossiliferous, Favosites and Stromatopora being very common, though apparently not forming very large masses as in the reef portions of the preceding localities. Stropheodonta is a well-represented genus, though the species are generally small. *Gypidula romingeri* and *Atrypa reticularis* are among the other common brachiopods.

The limestone of the quarries is exposed in the fields at numerous localities north and east of the prospecting holes. Many small prospecting holes have been opened in it, but no extensive quarrying operations are carried on except in the two quarries mentioned and in that of the cement company.

To the south and southwest the limestone of Loc. 1 is overlain by a blue clay, which is exposed in a test well on Dock street, where it is six or seven feet thick. This clay will be mentioned again below.

The following analysis of the limestone of Collins' quarry was furnished by Mr. S. H. Ludlow, chemist of the Alpena Portland Cement Company, under No. 23:

SiO_2	.62
Al_2O_3	.60
Fe_2O_3	.33
$CaCO_3$	97.39
$MgCO_3$	1.09
	100.03

The following analyses of the rocks of Loc. 1 and of the limestones of the lower series were made for the Survey by Mr. F. Brady, chief chemist of the Illinois Steel Company from samples Mr. Grabau collected, received July 27, 1901:[13]

Marked.	Silica.	Ferric oxide.	Alumina.	Calcium. carbonate.	Magnesia carb.	Sul-phur.	Phos.
1. Alpena Loc. 1	.42	.19	.45	98.04	.88	.014	.007
2. " " 1	.24	.16	.26	98.88	.45	.006	.003
3. " " 1	.32	.29	.33	94.83	4.20	.020	.012
4. " " 1	1.18	.31	1.79	95.29	1.33	.089	.017
5. " " 1	.24	.16	.32	98.84	.43	.007	.004
6. N. of Alpena, Loc. 2	4.62	.45	1.15	92.38	1.36	.029	.013
7. N. of Long Lake, Loc. 5	4.54	.50	1.36	91.82	1.67	.084	.031
8. Cement Quarry, Loc. 9	.70	.30	.76	96.90	1.30	.022	.020
9. " " " 9	.38	.19	.21	98.69	.52	.009	.004

[13] The following partial analyses were made for A. C. Lane.

1. From the Collins quarry: Limestone dipping away from a reef on which the kiln stands. The upper layer is rather blue and shaly, with *Phacops rana, A. reticularis, S. mucronatus*, etc. The analysis of the sample made by A. N. Clark:

$CaCO_3$	95.40
$MgCO_3$	1.76
Insoluble } SiO_2, etc. }	1.10
Organic and loss	1.74
	100.00

2. From the same neighborhood samples yielded the Dow Chemical Co.

	1	2	3
SiO_2	3.18	4.01	2.51
Iron and alumina	1.43	2.20	1.81

DESCRIPTIONS OF SAMPLES ANALYZED.

No. 1. Fragmental semi-porous limestone consisting of ground-up organic remains. Loc. 1, Collins quarry, Alpena.
No. 2. Fragment of unweathered and unfilled Acervularia. Fox's quarry, Loc. 1, Alpena.
No. 3. Compact light crystalline limestone, forming the lower beds in Fox's quarry, Loc. 1, Alpena.
No. 4. Dark crystalline limestone forming the upper beds in Fox's quarry, Loc. 1, Alpena.
No. 5. Fragment of Stromatopora, unaltered. Fox's quarry, Loc. 1, Alpena.
No. 6. Porous fragmental limestone from roadside about a mile north of Alpena at Loc. 2. Somewhat oxidized. Surface specimen.
No. 7. Compact gray limestone from Loc. 5, Alpena, just overlying the Stropheodonta shales. Long lake.
No. 8. Compact lime sandstone from quarry opposite cement works, Loc. 9 (Alpena Cement Co.'s quarry).
No. 9. Fragment of Favosites with cavities filled by infiltration. Cement quarry, Loc. 9, Alpena.

Nos. 2, 5 and 9 represent the chief corals which make up the coral reef in the Alpena limestone, and from the destruction of which the flanking beds of limestone or fragmental limestone were formed. It will be observed that they are very low in silica, and approach 99 per cent of $CaCO_3$. They are furthermore low in $MgCO_3$, showing that these corals are practically pure lime structures. The silica is probably a secondary introduction, being highest in the Favosites, where the intertabular spaces were filled by infiltration.

The only other sample high in lime is No. 1, which represents the comminuted coral and shells which made up the old reef. The sample came from the flanks of the old reef and shows the purity of the rock derived from the reef.

The light colored lime-sandstone, forming the chief fragmental beds, resting upon the old reef exposed in Fox's quarry (No. 3), is lower in its percentage of lime than the dark limestone overlying it (No. 4). This is due to the high percentage of magnesium carbonate (4.20), which is most likely of later origin, having replaced the original calcium carbonate. The percentage of silica and alumina is not much higher in this rock than in the corals from which it was derived, and a tenth of a per cent lower than in the fragmental lime rock from the reef in Collins' quarry (No. 1), which is high in lime and comparatively low in magnesia. The upper beds in this region, as represented by the analysis of sample 4, are comparatively high in silica and alumina owing to the presence of diminutive clay particles, which give this rock its relatively dark tint. These beds grade upward into calcareous shales.

Nos. 6 and 7 are high in silica, not so much from the presence of clay, for there is a smaller amount of alumina than occurs in sample 4, but rather from a certain amount of silicification of the contained organic remains. This has not been carried very far, however, the percentage of silica not rising much above 4.5.

The analysis of the limestone from the cement quarry (No. 8) represents the average of this rock in its percentage of lime, though 98 per cent, and even 99 per cent and over, have been recorded. The presence of a considerable per cent of $MgCO_3$ in sample 8 accounts in part for its lower per cent of $CaCO_3$.

The following analyses were given in the last annual report:

LIMESTONES FROM QUARRIES OF ALPENA PORTLAND CEMENT COMPANY.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Calcium carbonate	95.91	89.10	98.37	98.03	96.35	96.50	96.92	98.14	98.03
Magnesia carbonate	3.63	8.67	.92	1.36	.94	1.26	.98	.98	1.05
Silica	.36	1.77	.33	.38	1.38	1.64	1.46	.42	.68
Iron oxide / Alumina	.13	.35	.18	.19	1.21	.27	.54	.18	.26
Total	100.03	99.89	99.80	99.96	99.88	99.67	99.90	99.72	100.04

No. 1. Quarry C. Shell to be removed in stripping. One to two feet thick.
No. 2. Quarry C. Top strata. Two feet thick.
No. 3. Quarry C. Second strata. Two feet thick.
No. 4. Quarry C. Third strata. Four feet thick.
No. 5. Quarry C. Fourth strata. Two feet thick.
No. 6. Quarry F. First strata. Two feet thick.
No. 7. Quarry F. Second strata. One foot thick.
No. 8. Quarry F. Third strata. Two feet thick.
No. 9. Quarry F. Fourth strata. Floor of quarry.
All samples show traces of sulphates and phosphates.

Chemist, F. M. HALDEMAN.

Alpena, Mich., Feb. 12, 1900.

The analysis of a limestone near Rogers City, given Mr. Lane by J. G. Dean, may be inserted here for comparison:

Calcium carbonate	98.34
Magnesium carbonate	0.45
Alumina and iron	0.20
Silica	0.62
Sulphates	traces
Organic matter	0.09
Difference	0.30
	100.00

A yellow clay shale near by (weathered Bell shale?) gave:

Silica	66.39
Alumina	13.60
Iron oxide	5.87
Lime	.99
Magnesia	.50
Sulphuric anhydride	1.00
Organic matter and water	10.32
Difference	1.33
	100.00

A specimen of the Alpena stone gave W. M. Courtis, M. E.:

Calcium carbonate	95.231
Magnesium carbonate	0.946
Ferric oxide	0.536
Alumina	0.159
Silica { insoluble 1.205, soluble 0.113 }	1.318
Organic matter	1.510
Water	0.300
Phosphoric acid	traces
Sulphuric acid	Slight traces
Chlorine	Slight traces
Alkalies	traces
	100.00 per cent.

The following analyses of limestone from the quaries of M. J. Griffin in the Alpena limestone at Bolton[14] which were made by E. J. Schneider, chemist, yielded, calculated from limestone:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
SiO_2	1.81	.16	1.67	1.39	2.85	1.39
Fe_2O_3 & Al_2O_3	1.54	1.32	1.42	2.56	1.10	1.49
CaO	93.44	95.89	96.96	94.48	93.51	95.53
MgO	2.99	.53	.49	.14	1.69	1.81
Loss	99.58	97.90	100.54	98.57	99.15	100.22
Corresponding Limestone.						
SiO_2	1.2	.2	1.0	.8	1.54	1.8
$(Fe_2\ Al_2)O_3$	.9	.8	.8	1.5	.63	.9
$CaCO_3$	94.4	95.5	97.6	97.5	95.7	97.9
$MgCO_3$	3.5	.6	.6	.2	2.13	3.20
	100.00	100.00	100.00	100.00	100.00	100.00

Location of sample taken.
No. 1. Railroad cut on surface.
No. 2. First quarry on surface of subterranean passage.
No. 3. " " top layer 5 feet from surface.
No. 4. " " " " 8 " "
No. 5. New " " layer from surface to 3 feet down.
No. 6. Top layer on surface ¼ mile back from quarry.
Top layer at subterranean passage 8 feet in thickness, while that at new quarry is 5 feet.

The following analyses of the limestones of the cement quarry were furnished by Mr. S. H. Ludlow:

Sample No.	SiO_2.	Al_2O_3. and Fe_2O_3.	$CaCO_3$.	$MgCO_3$.
1	.32	.55	98.23	.98
4	*	.73	95.16	3.91
6	*	.34	98.62	1.04
22B	.....	....	98.03	....
22C	.....	....	98.58	....
24B	.....	....	98.32	....
25	.....	....	99.19	....

* Included in next column.

No. 4, the lowest in $CaCO_3$, is the richest in $MgCO_3$, containing nearly 4 per cent. Large areas here and there in the quarry are relatively rich in magnesia, and these do not effervesce with dilute HCl. In general the rocks here have a porous texture and are commonly more oxidized than the rest of the rock, sometimes having a deep ochre color.

No. 25 yielded the highest per cent of lime obtained in the quarry at that time.

No. 6 is a bluish coralline limestone of a flinty texture, and probably represents a part of the reef. No. 24b is known as sugar stone.

A sample taken at a depth of 32 feet in the well of the cement company,

[14] There is, however, at Bolton also a layer of dolomite with 56 per cent Ca CO_3.

and therefore representing the lower portion of the Alpena limestone, has given the following analysis:

SiO_2	.40
$CaCO_3$	97.16
Al_2O_3 and Fe_2O_3	1.00
$MgCO_3$	1.06
	99.62

This, therefore, compares well with the average of the limestones of this bed.

The following analyses of a recent large blast of coral limestone from the reef in the cement quarry was also furnished by Mr. Ludlow:

SiO_2	.21
Al_2O_3	.33
Fe_2O_3	......
$CaCO_3$	99.33
$MgCO_3$	.21
	100.08

A later blast gave 99.63 per cent of $CaCO_3$.

An analysis of the limestone from some distance northeast of the cement works (Isaacson stone), and two feet from the surface, gave the following results:

$CaCO_3$	96.75
Al_2O_3 and Fe_2O_3	1.06
SiO_2	.79
MgO	.35
	98.95

The Portland cement made by the cement company from this rock gives the following results, from 26 to 27 per cent of the clay of Loc. 31 being added to the limestone:

SiO_2	20.26
Al_2O_3	8.62
Fe_2O_3	2.71
CaO	63.22
MgO	2.34
K_2O and Na_2O	1.34
SiO_3	.76
H_2O and CO_2	.75
	100.00

Loc. 2. About two miles north of Alpena, at Sta. 11 on the section line, a highly fossiliferous limestone is exposed along the roadside and in the adjoining farm lands. This rock consists mainly of the stems and joints of crinoids, and of various Bryozoa, among which the fenestelloids are the most common. In the exposed portions the fossils appear to form a loosely agglomerate mass, without the interstitial filling of calcareous sand. Brachiopods are very common, and the space between the valves is generally unfilled, except for subsequently infiltrated calcite. The brachidium of these brachiopods is generally well preserved, indicating a freedom from disturbances. *Gypidula romingeri* and *Atrypa reticularis* are both abundant. Stropheodonta cf. *S. demissa* and *S. nacrea* are also common. *Chonetes coronatus* is a conspicuous species, while *Spirifer mucronatus* and *S. granulosus* are among the other characteristics brachiopods.

Fenestella, Loculipora, and the other frondose Bryozoa are also well preserved, frequently still showing the original funnel-like form of the frond.

Crinoid stems and joints make up the greater portion of the mass. These are mostly enlarged, and changed to cleavable calcite. Dog-tooth spar is common in the cavities, which latter are very numerous, since all the remains are loosely joined, forming a porous or loose-textured rock.

No Favosites or other corals have been observed. The condition of preservation of these fossils is such as to point to quiet and rather deep water wherein they accumulated, in a depth apparently beyond that of wave activity. This limestone was therefore of great purity, since it consists wholly of the calcareous remains of organisms, but it has since been somewhat silicified as shown by No. 6, of Brady's analyses on page 179. The position of the limestone appears to be near the base of the middle Traverse limestone (stratum 2), but its characters are probably not traceable over a very large area.

Loc. 3. About a mile north of this outcrop, at Sta. 15, is another outcrop of limestone along the west line of Sec. 35. Here the limestone has again the coral-reef character, with Acervularia and Favosites predominating. This exposure belongs near the base of the limestone series. Besides the fossils mentioned, Zaphrentis, fenestelloids, *Atrypa reticularis* and crinoid stems may be mentioned.

Loc. 4. This is two-tenths of a mile north of the last locality, at Sta. 17a, along the east line of Sec. 27. The limestone here is similar to the preceding, and belongs to the same series. It contains numerous crinoid remains, and Stropheodonta is the commonest genus of brachiopods.

THE LOWER TRAVERSE SERIES.

a. Long lake shales and limestones:

These beds are a succession of thin-bedded limestones and shales, exposed both north and south of Long lake. This occupies a depression underlain by one of the prominent beds of blue clay shale occurring in this series.

Loc. 5. About a third of a mile north of Loc. 4, at Sta. 19, on the section line, is an outcrop of impure but highly fossiliferous limestone, which weathers to a yellowish-brown color, and leaves an earthy residuum. The reef corals are rare, but other types, such as Zaphrentis, Aulopora, and the like, are met with. Brachiopods are common and among these a robust variety of *Atrypa reticularis* is the most abundant. Other common species are: *Spirifer mucronatus, Chonetes coronatus, Stropheodonta demissa, S. concava,* and *S. erratica* (?).

From the thin bedded character of this rock, it might well be mistaken for a shale in the drill record. At any rate, this rock underlies the crystalline limestone, and with the beds next below it probably forms the nine-foot stratum of "shale" (stratum No. 3) in the Churchill well record.

Loc. 6. Less than two-tenths of a mile to the north, at Sta. 20, is an outcrop of black shale, highly bituminous, and characterized by the extreme abundance of a small species of Stropheodonta. This is a species closely related to *S. plicata* of the Iowa Hamilton. The plications are angular near the beak, but become rounded and less pronounced toward the front. The exterior of the shell is striate, the interior pustulose. When worn, the shell appears punctate. A few fenestelloids occur, but other fossils are very rare.

Loc. 7. This is at Sta. 21, on the section line, something more than two-tenths of a mile north of the preceding locality. The rock is a dark-colored, somewhat shaly, fine-grained bituminous limestone, and lies just below the shales of Loc. 6. It is exposed at the base of a terrace, on the west side of the road, and fossils are very rare in the exposed portion.

Loc. 26. Thunder Bay Island. This island is the easternmost point of land north of Thunder Bay. It consists of flat ledges of limestone rising but slightly above the water level. During high storms the water sweeps the ledges bare. The limestone is composed of crinoid fragments, brachiopods, and corals, with a predominance of fine coral sand. Stromatopora is the most abundant fossil, large heads from one to two feet in diameter being very frequent, and some even up to five feet in diameter having been noted. Wherever they occur, the surface presents a hummocky appearance, the Stromatopora heads rising in dome-like masses, over which the strata arch. On the eastern end of the island the limestone layers are separated by shaly beds often several inches in thickness. These shaly beds are highly bituminous, black, easily soiling the fingers, and with a petroleum odor. The surface of the layers is covered by black, glistening, carbonaceous deposits. The limestone is dark and generally of a shaly character. Favosites of several species and Acervularia are common, though the latter has not been seen in large heads. The shale often has the appearance of being sun cracked. The black shale contains brachiopods (*Stropheodonta costata,* Owen (?) and others) and branching Favosites. It varies in thickness up to half a foot and contains numerous pyrite concretions, which on oxidizing stain the rock and leave cavities.

In the limestone and associate shales the following fossils have been found, among others, in the beds of Thunder Bay Island: Stromatopora, *Acervularia davidsoni,* Proetus sp., *Spirifer mucronatus, Atrypa reticularis, Stropheodonta erratica, S.* cf. *costata, S. nacrea, Chonetes,* cf. *coronatus, Meristella* cf. *nasuta, Gypidula romingeri.* Rominger also mentions *Proetus crassimarginatus, Phacops bufo* (?*rana*), Gomphoceras, Orthoceras, *Eunella lincklaeni,* and *Spirifer consobrinus* as other common species.

These limestones and shales apparently represent the beds found 20 to 40 feet below the Alpena limestone in the cement company's well (No.2). Here black shales are common. The black shales of Loc. 6 are doubtless the same as those of Thunder Bay Island, though in these latter the small angularly plicated Stropheodonta appears to be less abundant.

Rock of the same type and carrying the same fossils as on Thunder Bay Island is found on Sugar Island, but the ledges are mostly submerged.

Along the eastern shore of Thunder Bay Island the ledges extend out under the water for some distance, submerged from two to three feet. Then they suddenly break off and a submerged cliff carries the lake bottom down six fathoms. This cliff is probably the wall of a sink hole similar to that found at the head of Misery bay.

Loc. 27. This is an exposure along the road side (section line) forming the western border of the southwestern quarter of the northwestern quarter of Sec. 25, R. 8 E., T. 32 N. Here the road is crossed by a terrace of compact gray limestone containing Acervularia, Favosites, Stromatopora, and occasionally crinoid joints. Lower down, some beds are filled with a robust variety of *Athyris fultonensis* (?), which often becomes large, and then has the aspect of a Seminula, or of *Meristella nasuta* without the anterior strong protrusion. *Crytina umbonata alpenensis* is extremely abundant, as is also *Stropheodonta* cf. *costata*. Other common species are *Productella spinulicosta* and *Spirifer mucronatus* with characteristic features; also, less common, *Stropheodonta nacrea*, *Spirorbis*, etc. These beds appear to lie above those of Loc. 8 *et seq.*, as is indicated by the strongly plicated *Stropheodonta* cf. *costata*, which scarcely occurs in or below the beds of Loc. 8, also abundant in the lower beds.

Loc. 28. This is another outcrop a quarter of a mile or less northeast of the preceding locality. On the road between Secs. 24 and 25, near the western end of the sections, are exposures of coralline limestone that show *Acervularia davidsoni*, *Favosites alpenensis*, *Atrypa reticularis*, Cyathophyllum, etc. This may be the continuation of the beds exposed in Loc. 8. (See below.)

Loc. 8. This is at Sta. 22, on the section line near the forks of the road south of Long lake. The rock is thin-bedded, gray, weathering to buff, and highly fossiliferous. Favosites and Acervularia occur, but not in very large masses. *Atrypa reticularis*, represented by an extremely convex variety, is the most abundant brachiopod. Several species of Stropheodonta occur, among which a variety of *S. demissa*, and *S. erratica*, and *S. inequistriata* should be mentioned. *Cyrtina hamiltonensis* also occurs. These limestones are probably a part of the stratum 4 series of the Churchill well.

Loc. 32. The same beds in the second season's fieldwork were designated Loc. 32. In addition to the species mentioned, the following should be noted among others: *Spirifer mucronatus*, *S. audaculus*, *Productella spinulicosta*, *Orthis (Schizophoria) propinqua*, a large species, rather common, *Gypidula romingeri*, *Athyris fultonensis*, Favosites, Aulopora, *Acervularia davidsoni*, and numerous cup corals, among which Zaphrentis, Heliophyllum, and Cyathophyllum predominate. Bryozoa are also common.

Loc. 33. This is along the Long lake road, half a mile or more northwest of the point where the Bell road branches off from the Long lake road. The rock here is a dark, easily split lime shale, having very uneven surfaces, and weathering into red clay. These beds are but slightly below those of Loc. 8, the two localities being nearly along the strike of the beds. They are rich in crinoid joints and corals are extremely abundant. These are mainly silicified and comprise *Acervularia davidsoni*, several species of Zaphrentis, Cyathophyllum, and others. *Atrypa reticularis* is common and of the robust type found in the beds above. With it occurs the large *Orthis propinqua, Gypidula romingeri, Spirifer granulosus, Sp. mucronatus, Sp.* cf. *varicosus*, and several species of Stropheodonta, including *S. erratica, S. demissa,* and *S. nacrea,* the last three being rare; also *Productella* cf. *productoides, Crytina hamiltonensis, Athyris fultonensis, Gypidula romingeri, Pentamerella dubia, Phacops rana, etc.* Bryozoa are also common.

Loc. 33a. A quarter of a mile southeast of Loc. 33, or halfway between Locs. 32 and 33, and in beds of about the same level, the following species have been found: *Atrypa reticularis, Spirifer mucronatus, Sp. granulosus, Sp.* cf. *varicosus, Athyris fultonensis, Gypidula romingeri, Orthis propinqua* of large size, *Productella spinulicosta, Cyrtina hamiltonensis, Stropheodonta erratica,* and, more rarely, *S.* cf. *costata* and *Crania hamiltoniae.* Of corals, *Acervularia davidsoni,* Zaphrentis, and Favosites occur.

Loc. 34. This is on Long lake road, north of the preceding localities, and on the slope of the terrace leading down to the lake. The chief fossils found here are Acervularia, Craspedophyllum, and Zaphrentis, the rock consisting mostly of coral masses. *Heliophyllum coalitum* also occurs, as well as Favosites. *Atrypa reticularis* is less robust and common in these beds, which are below those of the preceding localities.

Loc. 10. This exposure is at Sta. 24, where Hell creek, the outlet of Long lake, cascades over some limestone ledges. This locality is off the section, and the rock here exposed appears to be the correlative of the limestone series No. 6 of the Churchill well. Acervularia and Favosites occur here, and with these *Spirifer granulosus, Sp. mucronatus, Atrypa reticularis,* and *Orthis* cf. *propinqua.* This same rock probably crops out close to the lake.

Loc. 30. This is on top of the terrace fronting Hell creek, and on the line of the railroad of the Alpena Portland Cement Company, about two miles south of the clay pits. It is the continuation of the terrace fronting Long lake, and along the strike of the beds of the terrace. The beds of this locality are therefore of the same horizon as those near Long lake. Outcrops of this rock occur all along the front of the terrace and over the top, and weathered-out specimens may be picked up everywhere in the fields. The fossils are generally silicified, especially the corals. *Acervularia davidsoni* is very common in places, occurring in thin, explanate heads. Stromatopora and other corals found at Long lake occur likewise. Among the characteristics brachiopods are: *Orthis propinqua*, large form; *Gypidula romingeri; Atrypa reticularis,* very robust and extremely abundant; *Athyris fultonensis; Cyrtina hamiltonensis; Spirifer mucronatus,* abundant and characteristic; *Sp. granulosus; Stropheodonta nacrea; Str. sp.,* and *Productella spinulicosta.* The faunal correspondence is obvious.

Loc. 20. Misery bay. At the head of the inlet known as Misery bay or Little Thunder bay, a large sink hole, known as "the bottomless hole," has formed, from the bottom of which strong springs arise. The western wall of this sink hole remains as a vertical cliff composed of thin-bedded limestones separated by shale partings. Large masses are continually separating along joint planes and falling into the bay. The beds are strongly iron-stained, and rich in brachiopods, among which the robust *Atrypa reticularis* of the Long lake localities predominates. These limestones are found on the surface for a considerable distance eastward of the bay. Their equivalency to the beds of localities 32 and 33 is probable.

Loc. 29. Wiesey's Well. A short distance northeast of the terrace described under Loc. 30, and between it and Hell creek, a well was sunk on the farm of Mr. Wiesey, which revealed twenty feet of bluish clay with some calcareous beds intercalated, the whole underlying the calcareous beds of Loc. 30. This is the shale which in part underlies Long lake, and probably is bed No. 7 of the Churchill well record. The calcareous beds are very fossiliferous, and especially rich in typical specimens of *Spirifer mucronatus.* Other fossils are *Stropheodonta demissa,* typical form, *Stropheodonta perplana; Chonetes coronatus; Chonetes sp.; Athyris fultonensis;* Modiomorpha, etc.

An analysis of the shale from Mr. Wiesey's well was furnished by Mr. Monaghan, as follows:

SiO_2	55.68
Al_2O_3 and Fe_2O_3	20.68
CaO	9.69
Mg O	2.35
Alkalies	3.60

Locs. 11-13. These are small outcrops of limestone along the roadside at Stas. 26, 27 and 29 respectively. They appear to belong to the limestone bed (No. 8 of the Churchill record) which underlies the blue shale of Long lake (7), and contain Acervularia, Gypidula, and other fossils characteristic of the massive limestones.

These beds are again seen in the high ridge of limestone north of Loc. 31. This ridge extends northwest and southeast, and can be traced almost to the shore, opposite Middle Island. Its average height is about 35 feet above the plain of the clay pits (Loc. 31).

Loc. 31. Clay Pits. The clay pits of the Alpena Portland Cement Company are situated in the N. E. ¼ of S. E. ¼, Sec. 18, T. 32 N., R. 9 E. They are begun on a stripped level, about twenty feet above the surface of Lake Huron.

The clay at present mined represents the upper beds of the series, about six feet in depth, which are thoroughly delithified and very homogeneous. Fossils are rare in this mass, but typical *Spirifer mucronatus, Stropheodonta demissa,* and *Phacops rana* are found in it, besides other species. At the base of this mass in a compact bluish clay shale, with calcareous layers full of typical *Spirifer mucronatus, Chonetes* cf. *deflecta, Stropheodonta demissa, Athyris fultonensis, Dielasma romingeri,* and other species. Lower down (31a), and exposed in the drain ditch, are calcareous beds containing *Cyrtina hamiltonensis, Stropheodonta demissa, Athyris fultonensis, Dielasma romingeri, Atrypa reticularis, Meristella* cf. *meta, Orthis iowensis* cf. *propinqua, Spirifer granulosus,* and *Sp. mucronatus,* besides Favosites, Zaphrentis, Cystiphyllum, and *Acervularia davidsoni.*

Loc. 31c. Overlying the clay beds is a thin-bedded limestone, rich in *Atrypa reticularis, Chonetes coronatus, Spirifer mucronatus, Sp. auda-*

culus, Sp. granulosus, Stropheodonta nacrea, Str. demissa, variety, *Str. erratica,* and numerous corals, including *Acervularia davidsoni, Cystiphyllum vesiculosum,* Zaphrentis, etc.

Loc. 31d. From a test hole in the woods, the following species have been obtained from the top beds of the clay, and the calcareous beds immediately above: *Cladopora alpenensis, Aulopora serpens, Cyathophyllum houghtoni, Zaphrentis* cf. *nodulosa,* Favosites, *Stropheodonta demissa, Stropheodonta* sp., *Spirifer mucronatus, Atrypa reticularis,* Chonetes, etc.

The following analysis of the upper clays (those used in the cement works) was furnished by Mr. Ludlow. (See also analysis in Ries's report on clays and shales, Vol. VIII, Part I, page 48.):

SiO_2	57.96
Al_2O_3	20.44
Fe_2O_3	3.03
$Ca\ CO_3$	9.12
CaO	.28
$MgCO_3$	5.02
SO_3	.72
	96.57
Alkalies	3.43
	100.00

The following analysis of the calcareous beds below the clay of the clay pit was furnished by Mr. Monaghan:

SiO_2	28.38
$Ca\ CO_3$	59.00
$MgCO_3$	1.93
Fe_2O_3	1.59
Al_2O_3	7.23
	98.13

Loc. 14. This is at Sta. 33, half way between Long and Grand lakes. The best outcrops are along the roadside and on the farm of Mr. Rabiteau. The rock is thin-bedded and extremely fossiliferous, the fossils weathering out in relief. The limestone is not very pure, an earthy residuum remaining on the solution of the lime. This is by far the most fossiliferous of the lower series of beds in the region, a large number of species having been obtained from the outcrops of this rock. Brachiopods predominate, with the large and robust *Atrypa reticularis* at the head. *Gypidula romingeri* Hall and Clarke is also extremely abundant, while the Stropheodontas and Spirifers are common, and represented by all the common and some rare species. Chonetes, Productella, and other characteristic Hamiltonian brachiopods occur abundantly. Among corals the smaller types predominate, i. e., Aulopora, Ceratopora, etc. In the lower beds, however, the reef-building types occur, notably Acervularia. Stromatoporoids are also, though more rarely, met with.

Loc. 18. This is on the farm land north of the county line and east of the line of the section. The outcrop is in line with those of Loc. 14, and of the same type, containing also the same species of fossils.

Loc. 35. This is an exposure of the upper beds along the strike of the beds from Loc. 14, in the southwestern quarter of Sec. 36, and near the sink holes of Loc. 19. The fossils were collected under the root of an upturned tree. Zaphrentis and Ceratopora are most abundant. The following is a partial list: *Heliophyllum juvene,* Cyathophyllum, Zaphrentis, *Acervularia davidsoni,* Favosites, Ceratopora, *Atrypa reticularis, Athyris fultonensis, Stropheodonta erratica, S. demissa, Athyris spiriferoides* (?), *Pentamerella dubia* (?), *Cyrtina umbonata alpenensis,* etc. These beds may be considered identical with those found on Rabiteau's farm (Loc. 14).

Loc. 37. Grand lake ledges. These ledges are exposed on the southwest shore of Grand lake, opposite Kaufman's hotel. The cliff rises perhaps 40 feet above the level of the lake; the lower half is obscured by a talus slope. The beds are the northwest continuation of the lowest beds, seen near the base of the terrace north of Loc. 14. The upper layers are full of a species of Ceratopora, which in places constitutes almost the only fossil seen, with the exception of crinoid joints and stems. Below this are about 10 feet of a compact, fine-grained limestone, with occasional large heads of Acervularia. Below this the beds become somewhat shaly and contain large specimens of Zaphrentis, Cyathophyllum, etc.

These ledges are again exposed in T. 32 N., R. 9 E., Sec. 6, directly west of Middle Island. Here they form a chain of bluffs 16 feet high, which commence about half a mile from the shore. "Nearly the entire rock is made up of specimens of Stromatopora mingled with Favosites, *Cyathophyllum profundum, Diphyphyllum archiaci,* and other corals, which by exposure easily become disintegrated" (Rominger, loc. cit. p. 50). I have not seen this exposure, but it is well described by Rominger and its relation to the Grand lake ledges appears clear.

Loc. 19. Sink holes. The sink holes are situated in the southwest quarter of Sec. 36, T. 33 N., R. 8 E. There are at least a dozen of them extending in a northwest and southeast line through Sec. 36 and into Sec. 35. They are generally at the bottom of a ravine or longitudinal depression. The great "bottomless" sink has vertical sides of overhanging cliffs on all sides, and has a depth to the water surface of about 50 feet (estimated). The water in the bottom has a similar or greater depth. The upper 20 feet or more of the wall consist of limestones, the basal beds of the Long lake series, which form a vertical cliff. Below these are the blue Bell shales, which weather back, leaving the limestone cliffs overhangnig.

In the majority of sink holes the greater part of the cliff is talus covered. Where the upper beds are exposed they are seen to be fine grained, very homogeneous limestones, with a smooth, somewhat conchoidal fracture, and spotted by scattered masses of calcite. These are granular, and appear to have replaced minute organisms. The rock is singularly barren of organic remains; only occasionally a coral or fragment of a brachiopod is found. It is for the most part composed of a fine lime mud, in which even stratification is not well marked. The rock is heavy bedded and broken by frost into large cubical blocks. The thickness of the stratum is about 10 or 12 feet.

Below this are six feet or more of shales, frequently bituminous, and covered with alum efflorescence. They contain numerous small branching Favosites and a few other fossils. Below this, limestones occur again, which, together with the bituminous beds and the compact limestone on top form the upper part of the beds seen in the walls of the great sink hole.

B.—THE BELL SHALES.

These shales are for the most part inaccessible, since they are either deeply eroded or covered by drift deposits along their line of outcrop. From the well records we know their thickness to be about 80 feet, which thickness is pretty nearly constant over the northern part of the state. For some years the clay was dug north of Bell and manufactured into bricks. The works have, however, been abandoned for many years and the pits are full of water. Grand lake is undoubtedly underlain by these shales, or carved out of them, but no exposures are found. The only place where the shales may actually be seen is in the cliff of the great sink hole before mentioned, of which they constitute the lower portion. They are, however, quite inaccessible. In color they are blue, like those of the Cement company's clay pit, and it is very probable that they contain the typical lower Hamilton faunas. The black Marcellus shales are absent in this region, and hence we must not expect to find a typical Marcellus fauna. Rominger (p. 50) mentions an exposure of blue shales at the base of the bluff in Sec. 6, T. 32 N., R. 8 E., and gives a long list of typical Hamilton fossils from these. These beds apparently represent the upper portion of the Bell shale.

THE DUNDEE LIMESTONE.

This limestone, which underlies the Bell shale, was struck in the Churchill well at a depth of 444 feet. Its occurrence on Middle Island is noted by Rominger, who, however, refers it to the basal Hamilton. The following localities have been examined:

Loc. 15. This is along the shore of Burnham bay, southwest of Presque Isle. No outcrops are found here, but the beach is composed of rounded and subangular dark to light gray limestone pebbles. Chert is a common constituent of this rock, which probably belongs to this formation (representing the Corniferous limestone).

Loc. 16. This is in front of Presque Isle light, along the shore of Lake Huron. A dark, somewhat shaly, apparently non-fossiliferous limestone crops out at the water's edge. This undoubtedly is the lower Dundee limestone (stratum 19), which probably forms the shore for a considerable portion of the county.

Loc. 17. This is on the mainland, north of Presque Isle. The rock, though locally disturbed, chiefly by shore ice, is undoubtedly in place, and represents the stratum overlying that which crops out in front of Presque Isle light. The rock is a very compact and uniform grained limestone, of a drab color, and sparingly fossiliferous. Almost the only fossil found in it was a large and rather smooth Paracyclas *(P. elliptica)*.

Loc. 36. False Presque Isle. Along the outer shore of this peninsula a compact limestone is exposed in low, flat slabs at the water's edge. Behind this are high beaches of limestone pebbles. The rock is sparingly fossiliferous, and the following species have so far been recognized among those collected: *Atrypa reticularis, Strophcodonta* cf. *demissa,* Zaphrentis, Cystiphyllum, *Euomphalus* cf. *decewi, Euomphalus* cf. *clymenioides, Paracyclas elliptica.* The last three species mentioned are characteristic of the Onondaga formation of New York and Ontario. They may be regarded as indicative of the Onondaga (Dundee) age of the beds in question. The same species are recorded by Rominger from Middle Island, and again from Crawford's marble quarry along the north shore.

(THUNDER BAY SERIES) TRAVERSE UPPER SHALES AND LIMESTONES.

There are fewer and less satisfactory exposures of the Thunder Bay or Upper Traverse series than of the lower series, owing chiefly to the less calcareous character of the strata of the upper series, which allowed deeper erosion. Fewer localities have been examined so far, hence the present report on the upper series will be less complete. The following localities are arranged in the ascending order of the strata:

Loc. 1c. Dock street clay. This is the remnant of a clay or shale bed overlying the limestone of Loc. 1. In a test well on Dock street it was found to be about six feet deep. The following analysis of this clay was furnished by Mr. Monaghan, and represents a sample taken five feet below the surface:

ANALYSIS OF DOCK STREET CLAY.

SiO_2	55.80	(or calculating Mg and Ca as Carbonates)	SiO_2	55.80
Fe_2O_3	5.11		Fe_2O_3	5.11
Al_2O_3	20.93		Al_2O_3	20.93
CaO	1.98		$CaCO_3$	3.53
MgO	1.23		$MgCO_3$	2.57
Alkalies	5.55		Alkalies	5.55
Loss by ignition	7.78		Loss by ignition	7.78
Total	98.38		Total	101.27

Overlying this clay shale is a thin bed of limestone from two to three inches in thickness, of which fragments are scattered about on the fields southwest of the quarries. This limestone in places is filled with a small variety of *Cyrtina umbonata,* which resembles in most respects the typical form of the species from Iowa.[15] It is smaller, less robust, and with the beak less arched than is the case in the variety *alpenensis,* which is the most characteristic form of the higher strata.

Loc. 21. Fletcher dam. This locality, formerly known as Broadwell's saw mill and mentioned by Rominger under that name (loc. cit. p. 44), is on Thunder Bay river, in Sec. 7, R. 8 E., T. 31 N. At the Fletcher pulp and paper mill, a reef of the type found in Loc. 1, but less extensive, appears in the river bottom, and formerly caused a fall of several feet. The dam was built over this reef, and thus the strata at this point are not accessible. Large heads of Favosites and large specimens of Cystiphyllum occur among the debris at the base of the fall. On the right bank below the dam, the strata dip about eight degrees down stream. On the left bank of the race below the mill, about six feet of rock are exposed. The upper half of this is an earthy, gray, thin-bedded fossiliferous limestone, with beds perhaps three-fourths feet thick, and less. The

[15] See Pal. Iowa, pl. 5, fig. 2, 1858.

lower half is a bluish gray, calcareous shale, with a sandy feel, and the appearance of a natural cement rock. This is full of what appear to be sun-cracks, and only occasionally contains fossils. *Atrypa reticularis, Spirifer granulosus, S. mucronatus,* and Ceratopora have been observed in it, besides fenestelloids. This shale is exposed for about 20 feet down stream, when the dip carries it below the water. The dip at the upper end of the race is five degrees east of south, which abnormal direction and large angle is probably due to the buried reef.

In the race below the mill the lower strata have been uncovered, and the fragments thrown upon the bank have weathered and readily yield their fossils. This rock has the appearance of a limestone breccia in which the spaces between the limestone fragments are filled by masses of bluish gray clay. Both clay and limestone effervesce freely with dilute hydrochloric acid. It is essentially an old reef of Bryozoa and branching corals, among which *Craspedophyllum archiaci* and a small species of Ceratopora (?) predominate. Branching species of Favosites, and the large spreading masses of *F. placenta* and large heads of *Favosites alpenensis,* var *billingsi,* are common, and with them occur *Strombodes alpenensis, Acervularia davidsoni,* and occasionally *Cystiphyllum vesiculosum.* Bryozoa of various types are abundant, but brachiopods are comparatively rare. Among those found are *Spirifer asper, Sp. audaculus, Cyclorhina nobilis,* and *Atrypa reticularis.* Crinoid stems are abundant, and heads also occur. Those noted are *Dolatocrinus triadactylus* and *Dolatocrinus sp.*

The following analysis of the blue shale at Fletcher's dam (second bed from the top) was furnished by Mr. Monaghan:

SiO_2	21.54
CaO	37.89
MgO	1.26
Al_2O_3	4.58
FeO	2.37

Loc. 24. Boom Company's dam. This locality is on Thunder Bay river, seven miles above Alpena and two miles or more above the preceding locality. (Sec. 2, R. 7 E., T. 31 N.) The mill site was formerly known as Trowbridge's mill, and is mentioned under that name by Rominger (loc. cit. p. 44). Along the left bank of the stream the shales are exposed in a cliff about 15 feet high. The lowest beds are bluish sandy lime shales, breaking irregularly and having a sub-concretionary character. They weather brown, and leave much earthy residuum. Fossils are rare. In appearance these shales resemble somewhat the lower exposed beds of the Fletcher dam section, and both are not unlike the blue beds of the Warner brickyard (Loc. 25). Spirifer and small corals occur in it, and it shows sun-cracks similar to those of the blue shales of the Fletcher dam. The thickness exposed is about four feet, but the total thickness is probably much greater.

This stratum is succeeded by a foot of grayish subcrystalline limestone, full of a small variety of *Cyrtina umbonata,* identical with that found in a similar bed overlying the clay of Dock street northeast of Alpena (Loc. 1c). Judging from the appearance of the rock and the fossils alone, these two beds may be readily correlated. That they are the same bed is, however, not proven. On the right bank of the river, below the dam, six feet of the bluish shales (which at times become somewhat strongly calcareous, but generally have a distinct shaly character and show sun-cracks) are shown, overlain by the Cyrtina bed. Some of the upper beds of this blue shale series are of a more calcareous character, and weathered to a brownish color. They then resemble the upper beds of the Fletcher dam series, but they are quite certainly not equivalent.

Above the Cyrtina bed, on the left bank, are again about six feet of bluish shales, similar to those below, but somewhat more fissile. These are practically unfossiliferous, as far as has been ascertained, and are overlain by calcareous beds which become more and more fossiliferous near the top. The upper beds are weathered, where they are uncovered in the building of a road, and here a large collection of fossils was obtained. Among the species abundantly represented are: *Spirifer mucronatus, Athyris fultonensis, Atrypa reticularis, Spirifer granulosus, Pentamerella dubia, Cyrtina hamiltonensis* (small but robust type), *Stropheodonta demissa, Cyrtina umbonata alpenensis.*

Among the rarer species are: *Camarotoechia* cf. *dotis, Stropheodonta nacrea, Cryptonella rectirostris, Eunella lincklaeni,* Conocardium, Pleurotomaria (several species), *Phacops rana, Striatopora rugosa,* Pentremites, tegminal spines of crinoids, etc.

The relation of these shales to those of the preceding locality is not quite clear. Rominger considers them below those of Fletcher dam, and makes the former series about 50 feet thick. This relation is probably the true one, but needs verification. The great similarity of the Cyrtina bed near the base of this section to that found overlying the Dock street clay, suggests their identity. If this is the case, and the beds of the Fletcher dam overlie those of the present section, the lower part of the Thunder bay series, from the Alpena limestone to the coral bed of Fletcher's dam, is not over 70 or 80 feet, if as much. As will be seen from a comparison of faunas, there are good reasons for believing that the shales of the Warner brickyard (Loc. 25) are the same as those exposed at Fletcher dam. This correlation is, however, only a tentative one and requires verification in the field.

Loc. 25. Warner brickyard. This locality is in the southwestern portion of Alpena, and about due northwest of Stony Point. The top bed here consists of about a foot of thin-bedded limestone, frequently with shaly partings, and quite fossiliferous, containing the following characteristic species: *Dolatocrinus triadactylus, Striatopora rugosa, Codaster* cf. *canadensis,* a large Fistuliporoid bryozoan (which is very common), and *Craspedophyllum archiaci.* This species occurs commonly in slender, isolated fragments, as at Fletcher dam, and associated with it is the small clustered species of Ceratopora (?) found at that locality. Other species found in these beds are: *Orthis (Schizophoria)* cf. *propinqua* (small), *Rhipidomella vanuxemi* (?), *Atrypa reticularis* (common), *Spirifer audaculus, Gypidula romingeri* (young), *Pentamerella papillionensis* (?), *Cyrtina hamiltonensis, Stropheodonta* cf. *costata* (rare), Cryptonella, Zaphrentis, Aulopora, *Favosites alpenensis, Dendropora alternans,* Fenestella, Loculipora.

Below these calcareous beds are shales with occasional bands of argillaceous limestone, the latter only a few inches thick. In the exposed portion the shales have weathered to a brownish gray, but lower down they are blue. They are highly fossiliferous, Bryozoa predominating. The following species have been noted:

Athyris fultonensis (common), *Atrypa reticularis*, Spirifer, *Eunella sp.*, *Striatopora rugosa*, *Dendropora alternans*, Ceratopora, *Dolatocrinus triadactylus*, Fenestella, Loculipora, other Bryozoa, Crinoid stems.

The association of species suggests that these beds are the same as those exposed at Fletcher dam. This seems to be particularly indicated by the abundance of *Craspedophyllum archiaci*, which nowhere else has been noted in equal abundance. The beds of these two localities are provisionally correlated, but this correlation must be verified. They are in proper alignment along the strike of the strata. The following analysis of the blue shale of the Warner brickyard was kindly given me by Mr. Monaghan:

ANALYSIS OF THE WARNER BRICKYARD CLAY.

SiO_2	54.46	The same with the Ca and Mg calculated as carbonate.	SiO_2	54.46
Al_2O_3	17.26		Al_2O_3	17.26
Fe_2O_3	4.66		Fe_2O_3	4.66
CaO	6.60		$CaCO_3$	11.79
MgO	2.82		$MgCO_3$	5.92
	85.80			94.09
Difference CO_2 organic matter, alkalies and loss	14.20		Difference largely organic matter and alkalies	5.91
	100.00			100.00

Loc. 22. Stony Point. This is on the shore of Lake Huron, just south of Alpena and southeast from the preceding locality. The surface of the country over an acre or more exposes ledges of a gray, argillaceous limestone, with numerous weathered-out corals, chief among which are *Craspedophyllum archiaci*, Stromatopora, Favosites, *Cyathophyllum travensense*, etc. The rock extends perhaps 50 feet out into the lake, after which it is lost to view. Rominger mentions quite an extended list of fossils from this locality (loc. cit. p. 42). As before noted, the Stony Point ledges lie 80 feet or more above the Alpena limestone. If, as there is reason to suppose from the correspondence of the faunas, the Stony Point and Fletcher dam limestones are equivalent, the shales and limestones included between the basal members at the latter locality and those at the Boom company's dam must have a thickness of from 60 to 70 feet, provided the Cyrtina bed at the base of the Boom company's dam is equivalent to that of Loc. 1 and, like it, not over 10 feet above the Alpena limestone. If this is the case, the beds which yield the rich brachiopod fauna of Loc. 24 lie about midway between the Stony Point and Alpena limestones.

Loc. 23. Partridge Point. At this locality the highest beds of the Thunder bay series are exposed, the overlying black St. Clair shales appearing on Sulphur Island, southeast of the point. No exposures have been noted between this locality and Stony Point, and the character of the intervening strata, some 50 feet or more in thickness, is still unknown.

The cliff facing the lake at Partridge Point is about 12 feet high and covered with a foot or more of shell-bearing gravel. The upper beds of the series are poor in fossils, *Spirifer mucronatus* being about the only species found. The limestone of the upper four or five feet of the cliff is thin bedded and more or less lenticular, with shaly partings between the layers. The beds consist mostly of irregular lenses a foot or more in diameter and of unequal thickness. These limestones are dark bluish-gray on fresh fracture, but weather yellow and brown. They generally consist of comminuted crinoid stems and small corals (Favosites, etc.), with comparatively few brachiopods (*Atrypa reticularis, Meristella rostrata, Camarotoechia*, etc.).

Three and a half to four feet from the top of the cliff is a more or less continuous layer of Cystiphyllum, with occasionally other large rugose corals. This has been traced the entire length of the section, but the corals are most abundant near the middle portion. All the corals are prostrate. For about a foot above and below this layer, Pentremites, Codaster, Nucleocrinus, Dolatocrinus and Megistocrinus occur not infrequently.

Among the limestone beds corals of the genera Favosites and Craspedophyllum are common, the former being represented by various species, including *F. alpenensis* and *F. placenta* of the type found at Fletcher dam. Craspedophyllum is represented by *C. caespitosum* and *C. archiaci.* Cystiphyllum, Cyathophyllum and Stromatopora of various species are likewise common, and large heads of Syringopora are not infrequently met with. One of these measured over two feet in diameter. Bryozoa are also common. In some layers, particularly the shaly ones, brachiopods (*Meristella rostrata, Cyrtina umbonata, Athyris fultonensis*, etc.) predominate, though these are never very abundant.

The lower portion of the cliff consists of shales with thin-bedded calcareous layers. These are readily worn away by weathering and wave attack, and the more resistant beds above project. The undermining is a comparatively rapid process, and falls of rock masses from the cliff above occur almost nightly.

The shaly layers contain few fossils, but the interbedded calcareous layers are rich in them. Some of these latter appear to be made up of Bryozoa, particularly the frondose types (Fenestella, Polypora, Loculipora, etc.), and these are often beautifully preserved, not infrequently showing something of their original contour. Trilobites are rare, only a few specimens of *Phacops rana* having been found.

The capping beds of the Traverse group of this region consist of a brownish granular dolomite of considerable hardness. These beds, 10 feet of which are recorded in well No. III,—1, are exposed along the shores of Thunder bay on the south side of Partridge Point. In the absence of fossils, it may be indifferently referred to either the Traverse or higher beds. It is here included in the former group.

No exposure of the black shale has been found on Squaw bay, its occurrence there resting on the authority of Dr. Rominger. The shale, however, is prominently exposed on Sulphur Island.

LITTLE TRAVERSE BAY REGION.

A.—WELL RECORDS.

Only a few wells have been put down in the Petoskey or Little Traverse bay region, and of only one of these, the Charlevoix well No. 3, have I seen the samples.

Bay View Well.

Reported by H. P. Parmelee and A. J. Richards. Completed July, 1895.

This well is 120 paces northwest from the door of the G. R. & I. R. R. Bay View station, 4½ feet above the bay, and 40 feet from the shore. The record is as follows:

0— 4	Shingle.
4—264	Cream limestone.
264—462	Medium grey limestone
462—473½	Dark limestone.
473½—498½	25 feet of cellular blue shale.

Flow, 200 bbls. an hour.

At 450 feet depth a hard stratum was found, in which only a foot and a half a day could be drilled. Beneath this the water was struck. In all the rock, except this indurated bed, the drillings were from 10 to 12 feet per day.

Petoskey Well.

H. P. Parmelee, Charlevoix; C. S. Hampton, G. S. Richmond, Petoskey. Drilled in 1888.

This well is 33 feet north of the Chicago & West Michigan railroad station, near the end of Lake stret, Petoskey, and 180 feet from Bear river. A flow of sulphuretted water, relatively low in NaCl, was obtained.

The well is drilled in an old drift-filled valley, or rock gorge, for rock is found in place five feet from the surface on either side.

The following record was obtained:

Feet.	
0 to 30.	Glacial gravel, etc.
30 to 280.	Limestone strata, highly fossiliferous throughout the entire depth. The fauna is nearly the same as that found in the surface bed. Color light gray, a few strata quite dark and much harder.
280 to 295.	Ten to 15 feet of blue shale, no fossils. Beneath this was a flow of quite pure water, somewhat charged with H_2S.
295 to 355.	A nearly solid bed of Acervularia limestone, without a trace of mollusca or other corals. Color light, often creamy white.
355.	A thin layer of gray lime rock of incoherent structure.
355 to 435.	Dark shale 80 feet in thickness, equivalent to Bell shale.
435 to 555.	About 120 feet of crystalline limestone (Dundee limestone) of same color, texture and composition throughout.

Charlevoix Wells.

Three wells were put down in Charlevoix within 50 feet of each other. I have examined the samples of well No. 3 and from it obtained the following record.[46] The upper 230 feet were of unconsolidated material, showing the existence of an old buried valley under Charlevoix.

46 See Water Supply Paper No. 31, p. 87. The beds down to 300 feet are rather dolomitic. L.

Record of Charlevoix well:

Feet.
0 to 230. Drift, subdivided as follows:
0 to 6 feet. Sand.
6 to 15 feet. Gravel.
15 to 170 feet. Fine sand.
170 to 176 feet. Gravel.
176 to 230 feet. Sand: quicksand at 214 feet.
230. Fine-grained earthy limestone, effervescing with dilute HCl. It is identical in color and texture with bed f of Loc. 39, but the characteristic plant remains of that rock are absent. It also agrees with some of the darker portions of bed g, Loc. 39. No fossils found in the samples.
240. Gray limestone, agreeing in color and texture with bed e, Loc. 46. It effervesces freely with dilute HCl. No fossils in samples.
250. Earthy or chalky, brownish, porous, much oxidized clayey limestone with a strong clay odor, being in fact in large part clay, but with sufficient lime to give it coherence, and cause free effervescence with dilute HCl. It corresponds in texture with the lowest bed of Loc. 48, but is darker and somewhat more porous. The same pieces when broken are of an ochre color.
260. Dark gray argillaceous and somewhat shaly limestone, effervescing freely in dilute HCl. Similar to but more earthy than bed e, Loc. 36.
270. Finely stratified shale, effervesces feebly with strong HCl. Compact in texture.
280. Fossiliferous whitish limestone, containing *Atrypa reticularis* and other fossils. It effervesces freely with dilute HCl.
290. White crystalline limestone containing considerable crystalline calcite. It carries fragments of *Acervularia davidsoni.* The rock is of the same type as bed g, Loc. 39, but is whiter than that rock and somewhat more crystalline. Some portions of the samples are compact and argillaceous.
300. White chalky limestone, non-argillaceous, fossiliferous, and effervescing freely with dilute HCl.
315. Brownish, earthy and argillaceous limestone, with a strong clay odor; Bryozoa and other fossils have been observed. It effervesces freely with dilute HCl.
322. Gray calcareous clay of very uniform texture, partially oxidized. It effervesces freely in dilute HCl, but is nevertheless a good clay.
330. Gray, compact calcareous clay rock, but of massive character, and effervescing freely in dilute HCl.
335. Fragments of *Acervularia davidsoni* with the calices free from matrix, and evidently embedded in clay. No clay is, however, retained.
345. Gray calcareous shale, mixed with pure white limestone, the latter containing Favosites and Acervularia.
350. Gray argillaceous limestone, and some white limestone, with fragments of Spirifer and Acervularia.
355. Gray limestone. *Acervularia davidsoni* is abundant. Favosites and *Atrypa reticularis* also occur.
360. Gray, compact, semi-argillaceous limestone; fossils not observed, except crinoid stems. Much shale is mixed with the limestone.
367. Fragments of *Acervularia davidsoni* and Favosites.
370. Compact, gray, argillaceous limestone; no fossils observed. It is almost a clay.
375. Fine-grained, compact, argillaceous rock, not unlike the lower beds of Loc. 42 or those of Loc. 43.
387. Limestone and black shale.
390. Gray argillaceous limestone with whiter limestone containing Acervularia.
400. Chalky clay. Crumbles and soils fingers. Cream colored.
402. Bluish gray clay, slightly calcareous, effervescing feebly with HCl.
410. Compact, brown to gray limestone, weathering earthy.
415. Cream colored calcareous clay, identical with the rock at 400 feet,
420. Limestone similar to that at 410 feet. No fossils.
430. Cream colored earthy clay, somewhat more calcareous than that at 402 feet.
443. Brown banded limestone, mingles with black and gray shale containing *Atrypa reticularis,* etc.
447. Bluish clay, non-effervescent.
460. Same as preceding.
470. Same as preceding.
482. Same as preceding.

No fossils have been observed in any of the samples of blue clay seen.

B.—RECORDS FROM OUTCROPS.

The outcrops studied are along the shore of Little Traverse bay, on the northwestern side of the Lower Peninsula of Michigan. It is from this region that the formation derives its local name. The outcrops are much less satisfactory than are those of the Alpena region, and the rocks are much less fossiliferous. The shore of the bay extends along the strike of the strata, and hence nearly the same beds are exposed in the various sections. Only in the southwestern portion of the shore line, where the shore trends across the strike, is a rapid stratigraphic ascent made. Owing to the existence of a number of minor folds or undulations whose axis is normal to the strike of the strata, a number of beds which would otherwise be below the water level are brought to the surface. The thickness of the exposed beds is not much over 100 feet, while the total thickness is probably between 550 and 600 feet. The exposures begin about a mile and a half east of Petoskey, near Bay View, and extend with numerous interrruptions to near Norwood village, beyond which the Black shales appear on the shore. The total distance along the shore from the point of first appearance* to the final disappearance of these strata is over 30 miles. What the normal dip of the strata of this region is has not been ascertained.

Loc. 38. Opposite Bay View station. In the building of a road at this locality about four feet of limestone were quarried near the lake. These, with similar beds shown at the bottom of the bay, are among the highest beds of this region. They are thin-bedded argillaceous and bituminous limestones, often with thin, shaly partings. Bituminous matter is common, and the rock often smells strongly of petroleum. When weathered, as near the surface, it is porous, soft and friable, and deeply stained by iron hydrate. The fossils, *Spirifer mucronatus*, *S. consobrinus* (?), *Cyrtina hamiltonensis*, *Strophcodonta erratica*, *Productella*, Bryozoa, etc., generally stand out in relief, being more or less silicified. Some slabs of the rock are covered with coarse intersecting ridges, of the thickness of a finger or less, which may represent casts of marine algæ or may be those of large sun-cracks. They are unjointed, and cross each other at all angles.

The same strata are shown in a cutting behind the beach, near the railroad. The upper beds here are a fine, uniform-grained, non-fossiliferous rock, smelling strongly of petroleum. It has been weathered yellow and become very soft, being easily crumbled between the fingers.

Loc. 39. Petoskey. In the first quarry, near the northeastern end of the section, the following succession of strata is shown. In the eastern end the dip is northeastward, while further west it is four degrees to the southwest:

a. The lowest bed exposed is a dark, grayish-brown, fine-grained, friable limestone, freely effervescing in dilute HCl, porous and with a strong petroleum odor: 4′.

b. Light, creamy-gray, fine-grained limestone, freely effervescing in dilute HCl, soft and porous and with the stratification line marked by bluish bands occurring at intervals. It contains a few pelecypods (Edmondia?) and occasionally Favosites: 4′.

Between this and the next overlying stratum is an inch or two of shaly matter.

c. Porous, fine-grained limestone, weathering dark brown. Near the western end of the quarry it constitutes the lowest bed: 3.5′.

This bed is separated from the one next above by three or four inches to a foot of shaly rock. The shaly partings are frequently carbonaceous, thin films of the coaly matter covering the laminæ. No plant remains have been identified. Bed c is much like bed a. It contains similar car-

* For the position of the relative outcrops see the map, Plate VIII.

bonaceous films, and has also a bituminous odor. It is very soft and friable in places.

d. Lighter colored limestone, similar in all respects to bed b. No fossils found. Stratification is well marked, and bituminous films are common: 3.75′.

c. Similar rock, but filled with small masses of Stromatopora. The aspect of this mass is that of a brecciated limestone, or like a conglomerate in which the pebbles are fragments of coralline. Where the rock has been exposed to the weather for some time it is rough surfaced, with numerous solution hollows: 26′.

In some parts the lower four or five feet are like the rock below,—massive and uniformly fine-grained, with few or no fragments of Stromatopora. In most places, however, the rock is full of this fossil throughout, being in fact a coral breccia. The Stromatopora fragments are of all shapes and sizes, often angular, and so far as observed never entire. A fragment, with the abruptly cut-off layers of growth, is illustrated in the annexed figure. Solution seems to have gone on to a considerable extent in these heads before they were buried by the coral sand which now forms the limestone. Cracks and solution cavities are not uncommon in the coralline masses, and these are filled by the coral sand.

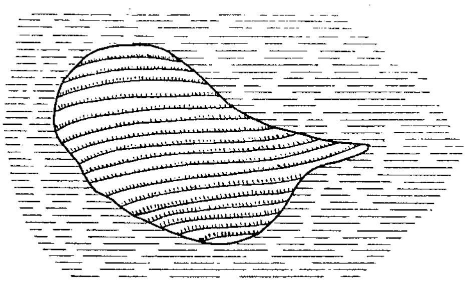


Fig. 3. Section of a worn Stromatopora head.

The Stromatopora are not the only fossils. Cyathophylloid corals, Favosites, Conocardium and others have been found, and are sometimes common.

The majority of the Stromatopora masses lie overturned, or in some other abnormal position, which clearly indicate motion. The matrix in which the masses of coral are embedded is of a sugary character, rather soft and crumbling, and effervesces freely in dilute HCl. The fossils which it contained are mainly dissolved out, and the cavities often lined with calcite crystals. No analyses have been obtained,* but report credits this rock with a high per cent of $CaCO_3$, which in some instances approaches 100. Some specimens of *Atrypa reticularis* have been obtained from the upper portion of this stratum. This stratum may be traced along the railroad track to within a short distance of the railroad station.

* The following commercial analysis was published by E. R. Sly:

$CaCO_3$	91.25
$MgCO_3$	4.00
Balance	4.75
	100.00

Mr. H. P. Parmelee says that it runs up to 98 per cent L.

f. Overlying the Stromatopora bed is a cream-colored limestone, which appears much shattered in the cliff. Fallen blocks, which appear to be from this bed, are of an earthy, rather argillaceous character, effervesce freely in dilute HCl, and contain numerous carbonaceous films representing narrow, reed-like plants. Other fragments, apparently from this bed, contain Favosites, but rarely other fossils. The bed is inaccessible. Estimated thickness, 4.5′.

g. This is the highest bed in this section. It consists of a granular lime-sandstone* of a sandy feel, and effervesces freely dilute with HCl. It is somewhat darker than the rock below and contains numerous large coral heads, which apparently grew where they are now found. *Diphyphyllum panicum* makes up the greater portion of the bed. It occurs in abundance at the foot of the cliff, and must have fallen from above. The species appears to be restricted to this bed. Associated with it is Cystiphyllum and Favosites, while *Atrypa reticularis* and *Gypidula romingeri* also occur, though sparingly. The thickness of this bed is estimated at 5.6′. The top of the cliff is formed by a layer of stratified sand several feet in thickness.

The total exposure of rock in this section is 50 feet.

These beds are the Stromatopora beds of Winchell, who considered them the lowest of the series. Rominger, on the other hand, considered them as belonging to the higher members of the group, and with this view I concur. As will be shown below, the name Stromatopora beds is not applicable to other exposures of this series, where the prevailing coral is Acervularia, while in some portions fossils are entirely absent. The name Petoskey limestone is more serviceable for purposes of correlation, since these beds are so finely exposed at Petoskey. Moreover, beds at a lower horizon are fully as rich in Stromatopora, and would equally well deserve the name.

Loc. 40. About a mile west of the mouth of Bear creek, ledges are exposed at the water edge, consisting of a thin-bedded, fossiliferous limestone. The lowest beds seen are somewhat shaly in character and are crowded with large shells of *Stropheodonta nacrea*. Associated with them is *Spirifer mucronatus,* which is likewise abundant. Overlying these beds are gray limestones containing *Acervularia davidsoni*, Favosites and crinoid stems, besides other fossils. Next above these limestones gray, calcareous shales occur again, in which *Stropheodonta nacrea* is the prevailing species. *Spirifer mucronatus* and *Atrypa reticularis* occur with it.

These beds are so well characterized by the prevailing fossil, *Stropheodonta nacrea,* which is an easily recognized form, that for purpose of reference I shall call them *Stropheodonta nacrea* beds. They will be referred to again in other sections, where they are apparently exposed again. These are the lowest of Winchell's "Tropidoleptus beds" (loc. cit. p. 42), the upper beds being those of locality 41. In the supplement to his report, Professor Winchell changes the name to Bryozoa beds, since the supposed Tropidoleptus proved to be a Stropheodonta (*S. erratica*). Winchell assumed that these beds and those of the next locality, which overlie them, were stratigraphically above the Stromatopora beds of Petoskey. This is probably an error, for the well sections show the upper beds of this region to be of the type exposed in the Petoskey quarries.

* The term lime-sandstone is used throughout for rock made up of coral sand, i. e. a fragmental limestone.

These beds furthermore appear to underlie those carrying the Acervularia clays (Acervularia beds of Winchell), since a continuous section at Loc. 46 from these clays into the Petoskey limestone does not reveal them.

Loc. 41. About one and one-half miles west of the mouth of Bear creek is a low bluff, about twelve feet in height, and extending for several hundred feet parallel to the shore, and a short distance behind it the cliff shows gray, fine-grained limestone beds with shaly partings, often several inches in thickness. These limestones contain *Acervularia davidsoni, Favosites* cf. *alpenensis, Atrypa reticularis, Stropheodonta nacrea* (of large size, occurring chiefly in the more argillaceous portions of the rock), *Pentamerella* cf. *dubia,* and *Spirifer mucronatus,* besides Stromatopora and other fossils. The black parting shales contain *Pterinea flabellum, Stropheodonta erratica,* and Modiomorpha. The limestone is dark-gray, fine and uniformly grained, weathering to a light-gray color. It effervesces freely with dilute HCl, and has an argillaceous odor, a clayey residuum remaining on weathering. The masses of coral in it are generally more or less worn, and the contact between them and the matrix is a sharp and regular one, showing that the fragments have been rolled about and worn smooth. This shows that at least some of the coral heads were dislodged from their anchorage, and marks this limestone as probably formed on the outer portion of the growing reef.

The dip of the strata is as high as ten degrees to the northeast. This is near the southwest end of the bluff; in the northeastern end the dip is more nearly horizontal.

These beds are No. C of Winchell's section, with possibly a portion of his higher beds.

Loc. 42. This locality is described by Winchell as situated in the S. W. ¼ of Sec. 2, T. 34 N., R. 6 W., Loc. 861. The section begins about two and one-half miles west of the mouth of Bear creek, and between it and the preceding locality is a long, high drift-bluff, with no rock exposures. The bluff at the eastern end of the section is about fifteen feet high, and at its foot is a talus of four or five feet. The highest bed of the section is exposed at the eastern end and is designated bed I. The succession from above downwards is as follows:

42I. The upper beds of the section consist of a bluish calcareous shale, which weathers into a brownish-gray clay and contains many fossils, which may be collected on the talus. Chief among these are *Spirifer audaculus,* a small but strongly spinous species of Productella, *Atrypa reticularis, Stropheodonta erratica, Favosites alpenensis, Acervularia davidsoni,* Cyathophyllum, and Hederella; also from blocks probably from this bed: *Cyathophyllum traversense, Gypidula romingeri, Phacops rana, Craspedophyllum archiaci,* Platyceras, and others. Thickness, 4′.

42H. Next below this is a limestone with shaly partings between the beds, especially in the lower portion. It contains numerous corals, among which Acervularia predominates: 6′.

42G. Next below this and forming the lowest bed in the eastern portion of the cliff, is a gray, porous lime-sandstone, consisting of fragments of brachiopods and other organisms finely comminuted. It is somewhat petroliferous and has a sandy feel. *Stropheodonta erratica* and other brachiopods and a few corals have been observed in it: 6′.

The dip of the strata in this region is from five to six degrees to the northeast, i. e., towards Petoskey.

These strata may be traced westward for half a mile or more to Rose's* quarry, where a deep section is opened, exposing the lower members of this series. Before reaching the quarry, bed G and the overlying ones have been cut off owing to the steady westward rise of the strata. At the quarry the axis of the low anticline in which these beds are involved is located, beyond which the strata dip westward. At the axis the upper beds have been worn away down to the blue clay, bed D.

42F. Blue clay, rich in fossils. In every respect except thickness like bed D: ¾′.

42E. Limestone with Acervularia, cup corals, and other fossils, which occur chiefly near the top of the bed, where it is more shaly. The limestone is dark-gray, fine-grained and crystalline: 1¼′.

42D. Blue, highly fossiliferous clay, rich in fossils, among which the following are the most characteristic: *Acervularia davidsoni*[47] (well-preserved, complete heads up to six inches or more in diameter), *Cyathophyllum traversense,* and *Favosites alpenensis* often in large heads. Other species of common occurrence are *Stropheodonta costata, Pentamerella* cf. *papillionensis, Athyris fultonensis, Terebratula traversensis, Cyrtina hamiltonensis, Eunella lincklaeni, Atrypa reticularis,* and a number of others. The thickness of the clay is 3′.

This is the bed more particularly designated as Acervularia bed in Winchell's section.

42C. Shaly argillaceous blue limestone, sometimes in several layers near the top, with thin shale partings: 2′.

42B. Compact, creamy-gray, fine-grained limestone with conchoidal fracture. This contains numerous heads of Stromatopora, all apparently perfect, and ranging in size up to two or three feet. The rock is much shattered and looks concretionary, owing to the presence of the Stromatopora. The latter is generally surrounded by a film of carbonaceous matter, which appears to be the original animal matter. At the top of this stratum, and also at intervals within it, are thin beds of black carbonaceous shales (sometimes stained brown by iron hydrate), and full of flattened shells of *Stropheodonta erratica,* with a few other fossils. The thickness of this stratum is about 5′.

42A. Cream-colored limestone similar to the preceding, but lighter colored. It is fine-grained, compact and with conchoidal fractures, and

* Now property of Michigan Lime Co.

47 The statement is frequently made that our species, identified with the European *Acervularia davidsoni,* E. & H., has no secondary wall, and that hence our species is not Acervularia. Rominger placed it under Cyathophyllum, while Simpson (Bull. N. Y. State Museum No. 39, 1900, p. 218) has originated the new genus Prismatophyllum, with *Cyathophyllum rugosum* as the type, and placed this species under it. It is true that there is no real secondary wall in our species, the appearance of such a wall being produced by the uniform arrangement of a circle of dissepiments, and the stoppage of the shorter septa at this point. But this is also true of typical European species, in which the longer septa and often the ends of the shorter septa also pass beyond this wall of cysts. Whether such a wall is or is not the morphologic equivalent of the secondary wall of Craspedophyllum and Diphyphyllum, where the septa do not extend beyond that secondary wall, does not affect the question as to the generic equivalence of the American and European species. If we regard the prismatic species of Cyathophyllum as congeneric with Acervularia as represented by American species,—as Rominger, Simpson and others have done,—all of these species should be placed under the genus Acervularia, and Simpson's generic name Prismatophyllum becomes a synonym. I believe that Simpson is right in separating the prismatic species generically from Cyathophyllum. The name *Acervularia davidsoni* has been retained for the present for our species, leaving the exact generic and specific determination for future investigation.

effervesces freely with dilute HCl. A few specimens of Favosites and other fossils have been seen. The beds are from one to two feet thick, and some of them are separated by thin bands of brown, bituminous shales. Thickness exposed, about 8′.

These beds, though in some respects similar to the limestone of Petoskey, are from fifty to a hundred feet below it. The abundance of Stromatopora in bed B might lead to a confounding of these two beds the one with the other. In the present bed the Stromatopora heads lie in normal and apparently undisturbed position, while those of the Petoskey limestone are nearly always worn and fragmentary.

Loc. 43. Nathan Jarman's quarry, Petoskey. The location of this quarry is in the N. W. ¼ of the S. W. ¼ of Sec. 6, T. 34 N., R. 5 W. This quarry was opened in the hillsides above Petoskey at an elevation of about 80 feet above the lake, and distant from it about half a mile. The succession is as follows from above down:

43B. Light gray, compact limestone, much shattered in the quarry and in places thin-bedded, with occasional thin carbonaceous films. The rock has a conchoidal fracture, and effervesces freely in dilute HCl. No crystalline structure is shown under the microscope, the mass being extremely compact and fine-grained. Fragments of organic remains and calcite veins occur. Thickness exposed, 12′.

43A. Darker, fine-grained, somewhat more crystalline limestone, with petroleum odor: 6′.

Below this are other beds of similar quality, with some carbonaceous films.

These beds probably represent the lower portion of the Petoskey limestone, similar to those shown in the quarry at Petoskey. At the shore below this point the beds of Loc. 41 are exposed. The interval between these beds appears, therefore, to be in the neighborhood of a hundred feet,—taking into consideration the southward dipping of the strata over the half-mile interval.

Loc. 44. About a third of a mile west of the point where section 42 was measured (Rose's quarry), limestones crop out on the beach.

1. The first beds seen are apparently at some considerable depth below the limestone 42A. It is a dark, crystalline but fine-grained, compact limestone, with brachiopods (*Atrypa reticularis,* etc.) sparingly represented. It dips 10 degrees northeast.

2. Ledges are shown at intervals under the water of the bay, in going westward. Those clearly belong below the preceding. Some five feet or more of these limestones are shown in a series of low anticlines. About half a mile further west, the following section has been opened in a small quarry on the shore:

A. The lowest beds are gray, crystalline and somewhat fossiliferous limestones, rather shaly in the upper portion, and containing large heads of Acervularia and Stromatopora, over which the strata arch as on Thunder Bay Island. Some thin layers of black, bituminous, shaly limestone, with a strong petroleum odor, occur toward the top: 18 in.

B. Limestone similar to A, in beds from 6 inches to a foot in thickness. No coral heads seen: 3′.

C. Beach material.

Along the beach occur many slabs of shaly limestone containing *Stro-*

pheodonta nacrea in abundance. These are from ledges near by, but probably submerged.

For perhaps two miles along the shore, rock is exposed at the water's edge, with a few interruptions by sand and shingle beach. The dip of these strata vary in direction and amount, disclosing many small anticlines. Along a portion of this distance the dip is toward the shore at an angle of nearly 10 degrees. As the shore is along the strike of the strata, no great stratigraphic ascent is made. The *Stropheodonta nacrea* beds are represented by fragments all along the beach, and the beds are occasionally in place. Limestones with Acervularia and occasionally Stromatopora and Favosites, as well as other corals, crop out continually and appear to be closely related to the *Stropheodonta nacrea* beds. The total thickness of beds exposed appears to be not much over 10 feet, though this estimate may be far short of the truth.

The *Str. nacrea* beds of this locality are dark-gray, argillaceous, thin-bedded, shaly limestones, crowded with the *S. nacrea,* which is of large size. *Spirifer mucronatus* occurs with these, but other fossils are rare. The similarity of these beds to those of Loc. 40 is very striking, both in lithic and faunal characteristics. In both localities shaly strata, crowded with *Stropheodonta nacrea* and containing *Spirifer mucronatus,* are associated with limestones carrying Acervularia and Stromatopora. There are probably several alternations of such beds, aggregating a thickness of perhaps some 10 or 20 feet, or perhaps more. But I do not think that there is more than one horizon in this group where these strata occur. If the correlation of these strata with the beds of Loc. 40 is correct, it is probable that the lower bed (A) in the quarry on the beach is the equivalent of bed A of Loc. 42. The occurrence of Stromatopora *in situ* suggests this equivalency.

It must, however, be borne in mind that correlation of beds in isolated outcrops, and with only a few paleontological characters to relie on, is a very unsatisfactory matter, and the correlations here made should be considered as tentative and subject to revision.

Loc. 45. This is about half a mile east of the next locality, and is a cliff 10 or 12 feet high, with the base talus covered. The upper portion is a shattered drab limestone with numerous heads of Acervularia and Stromatopora, some of which are very large. The rock closely resembles bed B of Loc. 42. Below it is a similar though more compact rock. It contains black carbonaceous seams, which appear more particularly near the top of the bed. The cliff is nearly continuous with that of:

Loc. 46. This is at the Bay Shore Lime Company's first quarry. It is in Emmet county, four miles west of Petoskey or two and one-half miles east of Bay Shore. The locality is that described by Winchell under 862 (p. 45), and located in the S. W. ¼ of Sec. 4, T. 34 N., R. 6. W. Rominger also described this section (p. 57). The following is the succession, from the top downwards:

46K. Blue clay covered by drift, fossils not observed.

46J. Limestone, compact, dark and somewhat argillaceous, with Stromatopora and Acervularia, the former chiefly in the upper portion. All lie with their longer diameter parallel to the stratification, and are usually broken and worn. They are frequently overturned, and in general are much like the rock of Rose's quarry at Petoskey (Loc. 39): 16′.

This rock is burned for chemical works, the burning being from 9 to 12 hours, and on the average 750 barrels are burned per week. The rock effervesces freely in dilute HCl. The dip of the bed is 5 degrees east.

46H. Blue clay with *Acervularia davidsoni, Favosites alpenensis, Stropheodonta erratica,* and many other species of the same type found in 42D, to which bed it is undoubtedly equivalent: 1¼′.

46G. Compact limestone like 46I, with Favosites, Zaphrentis, etc., well stratified: 1½′.

46F. Black carbonaceous shale with Favosites, etc.: 2 in.

46E. Compact gray limestone with Zaphrentis, Favosites, and complete heads of Stromatopora: 1′.

46D. Black carbonaceous shale, fissile, with *Stropheodonta erratica:* 5 in.

46C. Stromatopora bed with large heads from two to three feet in diameter, mostly perfect and commonly covered on their upper surfaces by a carbonaceous film. Small Favosites and a few other corals also occur. This is the equivalent of bed B of Rose's quarry (Loc. 42). In some parts it is a regularly stratified limestone with scarcely any Stromatopora: 8′.

B. Black carbonaceous shale; no fossils seen: 1 to 2 in.

A. Compact limestone, with broken and worn fragments of Stromatopora lying in all positions; in beds from one to two feet thick, separated by carbonaceous black shale 2 to 5 inches thick; exposed 4-5′.

Loc. 47. Bay Shore Lime Company's second quarry, near Bay Shore. This locality is in the Buff Magnesian beds of Winchell, which he supposed to be next to the highest in the series. In this he was correct, but he erroneously placed these, and the underlying Acervularia and Bryozoa beds above the limestones of Petoskey (the Stromatopora beds). There can be little doubt from the present more satisfactory exposures, and the well records, that the "Stromatopora" and "Buff Magnesian" beds are equivalent. This equivalency was held by Rominger.

The cliff in the quarry consists of about 12 feet of porous, dolomitic, brown limestone, which effervesces feebly with strong HCl and gives off a strong petroleum odor. Under the microscope it shows a finely crystalline structure, the crystals being stained by iron oxide. Apparently overlying this rock, but only exposed at one locality, is a coarsely crystalline limestone, loose textured and consisting largely of fragments of crinoid stems. The cliff continues, with slight interruptions, to Bay Shore.

Loc. 48. This is the third quarry of the Bay Shore Lime Company, at Bay Shore, and forms the end of the Khagashewung Point section of Rominger. The following section is opened in the quarry, the thickness of the upper beds being estimated:

Drift		5—10 ft.
48 f.	Brown earthy dolomite (?)	6— 8 ft.
e.	Drab dolomite (?) breaking with square blocks	3 ft.
d.	Yellow saccharoidal dolomite (?)	2 ft.
c.	Grey dolomitic limestone like (e)	2 ft.
b.	Grey banded saccharoidal dolomitic limestone	10 ft.
a.	Brown earthy limestone, effervescing freely in dilute HCl	10 ft.
		35 ft.

The porous earthy beds usually give off a strong petroleum odor when freshly broken. No fossils have been observed in any of the beds during the hurried examinations made.

The dolomitic character of the upper beds of this series has not been verified as yet by chemical tests. Some of them may be limestone. Rominger, however, gives an analysis of one of these beds (exact position not given) which proves that some of them are at least good dolomites. The analysis gives:

	Per cent.
$CaCO_3$	58
$MgCO_3$	38
Al_2O_3 } Fe_2O_3 }	1.5
Insoluble residue chiefly SiO_2	0.5
	98.00

A number of exposures occur between Khagashewung Point (Bay Shore) and Pine River Point, three miles west of Charlevoix pier. These have not been studied as yet. A description of some of these is given by Rominger, from which it appears that the *Stropheodonta nacrea* beds crop out again.

Loc. 49. Pine River Point, three miles west of Charlevoix pier, is located in the N. W. ¼ of Sec. 28, T. 35 N., R. 8 W.

The limestones first appear on the beach in low anticlines, and are of a compact texture and dark color. They contain few fossils in the lower part, but higher up *Favosites* cf. *alpenensis, Acervularia davidsoni, Atrypa reticularis,* Spirifer, etc., are found. Beyond this are low cliffs, not more than five feet high, and rising to a height of 10 feet above the lake. They consist mainly of shaly limestones, with an occasional hard, compact bed less than a foot in thickness. The shaly beds are rich in fossils, especially *Stropheodonta nacrea,* while *Spirifer mucronatus* and *Atrypa reticularis* are likewise abundant. Another common species on certain layers is *Chonetes emmetensis.* This is closely related to *Chonetes mucronatus* which is characteristic of the Marcellus and lower Hamilton shales of New York. Other fossils observed in these beds are *Proetus sp., Paracyclas lirata, Tropidoleptus carinatus* (?), *Actinopteria decussata, Aviculopecten cf. insignis,* and other pelecypoda.

The highest exposed beds of Pine River Point contain *Stropheodonta nacrea* and *Spirifer mucronatus* in great abundance. Some layers are made up of the comminuted remains of crinoid stems. *Atrypa reticularis* is common, and other fossils observed are *Pentamerella dubia* (?), *Stropheodonta costata, Spirifer sp.,* Gomphoceras, and Cyrtoceras (?).

The extreme abundance of *Stropheodonta nacrea* and the constant association with it of *Spirifer mucronatus* suggests that we have here another outcrop of the *S. nacrea* beds of Loc. 40. As these beds are regarded as the lowest exposed in this region, probably not far overlying the blue shale (Bell Shale) of the well records, it is of interest to note the abundance of *Chonetes emmetensis,* which, like its eastern representative, *C. mucronatus,* appears to be an essentially lower Hamilton fossil.

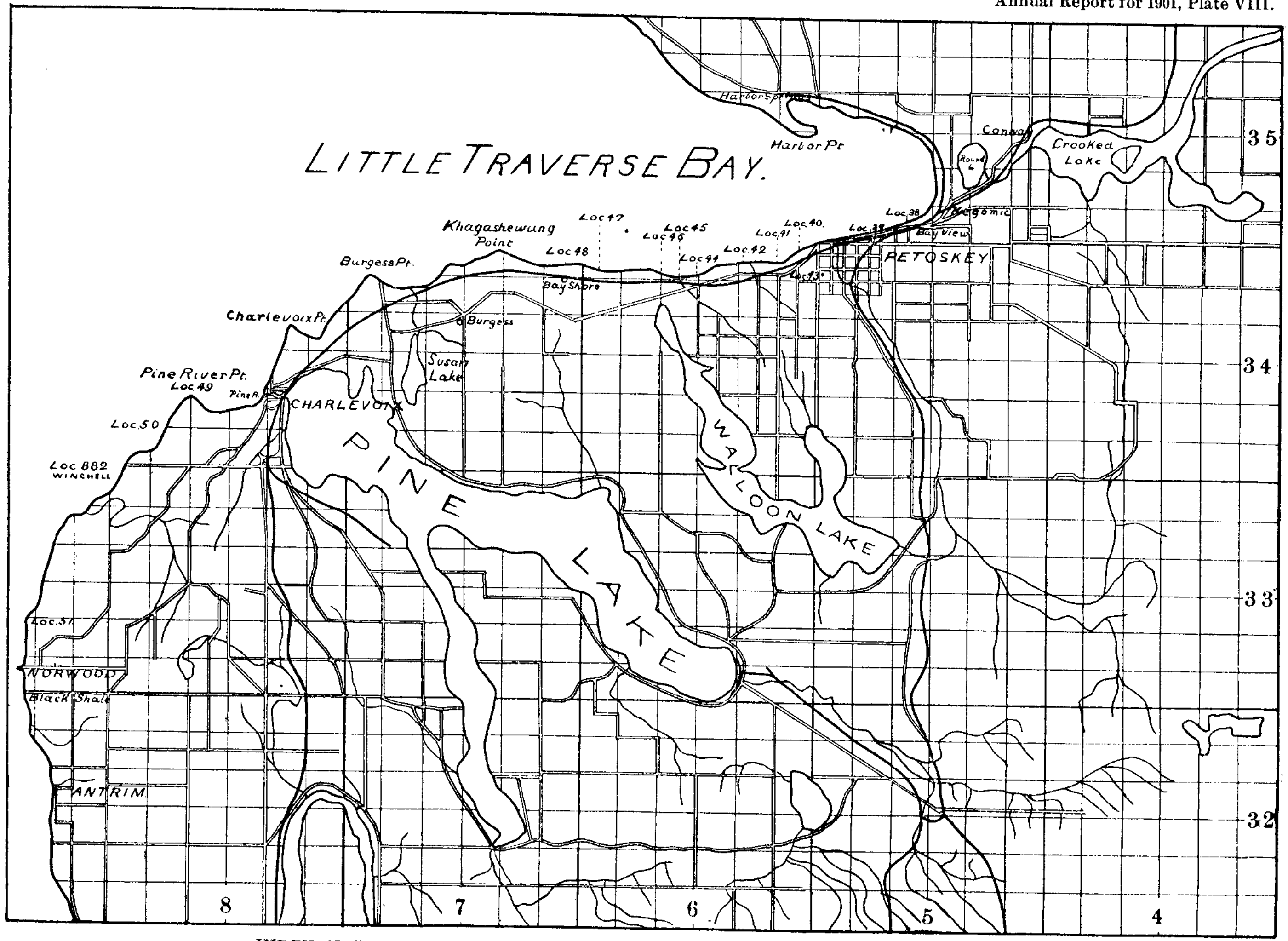
A short distance farther west, in an old quarry, about 15 feet of shaly limestones are exposed. The shaly layers have their surfaces covered with fronds of *Stictopora incisurata,* and with this occurs *Chonetes emmetensis* in great abundance, some layers of the shale being covered with this shell. *Stropheodonta nacrea* and *Spirifer mucronatus* are abundant and characteristic of these beds. Massive layers, two feet or more in thickness occur near the top. They are made up of brachiopods (*Atrypa reticularis,* etc.), and of fragments of these. A few small heads of Favosites have been observed, and crinoid fragments are abundant. These are the beds called by Winchell, Bryozoa beds in the appendix to his Grand Traverse report. He recognizes the correspondence of these beds to those exposed west of Bear river (Loc. 40), and calls attention to the occurrence of Acervularia on the beach further north, indicating the outcrops of the Acervularia clays, which overlie the Bryozoa beds. Rominger states (p. 59) that "the blue fossiliferous shale beds (Acervularia beds of Winchell) just reach the surface of the lake bottom, half a mile west from the dock at Charlevoix." This exposure was not found, having probably been covered by beach material.

Between the mouth of Pine river and Khagashewung Point (Loc. 49) the *Stropheodonta nacrea* beds (Bryozoa beds of Winchell) crop out again, for Rominger cites *Spirifer mucronatus, Chonetes emmetensis,* and other characteristic fossils as coming from strata exposed on this part of the shore. In the Charlevoix well, about 100 feet of the Petoskey limestone are shown, below which *Acervularia davidsoni* occurs in separate heads. The *Stropheodonta nacrea* beds are probably not over 50 feet below this, and these are the beds exposed on either side of Charlevoix, from two to three miles distant. It thus appears that Pine river lies in the axis of a gentle syncline, as Winchell suggested. Beyond the point the trend of the shore is southward, and the beds are seen to dip south at an angle of about 5 degrees. The exposures continue along the beach for a time, after which a stretch of sandy shore succeeds.

Loc. 50. Half a mile south of the previous locality (on the line between Secs. 29 and 32, T. 34 N., R. 9 W., Winchell Loc. 881), strata somewhat higher in the scale are exposed on the shore. The beds, which are somewhat shaly limestones, contain curious elongate hollows, also observed in certain strata of the preceding locality. These are probably due to the weathering-out of pyrite concretions. The dip continues to the southward. A little further on some heavy-bedded, gray, fine-grained limestones appear behind the beach. These belong above the shaly limestones and are filled with large heads of Stromatopora, generally worn and broken, and containing besides, Favosites, *Spirifer fimbriatus* and Meristella (?). This rock appears to be the limestone underlying the Acervularia clays, but may even represent part of the Petoskey limestone above it. Rominger mentions an outcrop on the shore three miles south of Pine River Point, without giving further details. Winchell also speaks of two outcrops beyond Pine River Point, the first (881) is at Loc. 50, as noted. The other (882), which is probably the one referred to by Rominger, is located by Winchell in the W. ½ of Sec. 8 (Sec. 6 on the map, which is probably correct), T. 33 N., R. 8 W. This locality I have not seen.

Five miles beyond Pine River Point is the last exposure of the Traverse beds of this region.

Loc. 51. The exact location of this exposure is, according to Winchell (884), in the N. E. ¼ of Sec. 34, T. 33 N., R. 9 W., in Emmet county. It is about a mile north of the pier at Norwood village, and consists of a cliff 12 to 15 feet high, and extending for a few hundred yards. The lowest beds of the section are shown near the northern end, and the average dip



INDEX MAP TO ROCK EXPOSURES NEAR LITTLE TRAVERSE BAY. A. W. GRABAU.

of the strata is 5 degrees to the south. The following succession has been determined:

A. The lowest exposed stratum has its upper surface about 5 feet above the water level. It is an argillaceous, shaly limestone, thin-bedded, and weathering a dark color. Near the top it contains specimens of Favosites, which were generally broken or worn before they became embedded in the rock. With them occur *Atrypa reticularis*. Thickness, 2 to 3′.

B. Compact, fine-grained dark limestone in beds varying from 2 to 6 or even 12 feet in thickness, and containing lenticular nodules of chert, the nodules sometimes nearly a foot thick: 3′.

C. Slaty limestones and slates, very fissile, in beds up to a foot in thickness, and separated by beds of banded chert 1 to 2 inches thick. Thickness about 5′.

D. From the point where the top of bed B dips below the water to the point where the top of bed D dips below the water, is about 300 feet. This, with a dip of 5 degrees, gives a thickness of about 26 feet for beds C and D, or of 21 feet for bed D. The top of the stratum shows beds whose surface are ripple-marked (oscillation ripples) and marked by sun-cracks. These beds are argillaceous limestones, readily effervescing in dilute HCl. Estimated thickness, 21′.

E. Shaly limestones similar to A, but more fossiliferous, containing *Spirifer* cf. *eatoni*, Cyathophyllum, Goniophora, and other fossils. Thickness, 5′.

F. Gray drusy dolomite, finely crystalline, and effervescing only on powdering, with strong HCl: 5′.

G. Darker dolomite, compact but crystalline, and containing fossils which are weathered out in relief and cavities from which pyrite concretions have weathered out. The cavities are stained by iron hydrate, and besides these there are numerous drusy cavities similar to those in F. Near the middle of bed G is a half-foot bed full of a small, undetermined cylindrical bryozoan. Stromatopora, Favosites, and a few other fossils also occur. Beds F and G are practically inseparable. Thickness, 4.5′. Total thickness, 45.5—46.5′.

These are the chert beds of Winchell, and Rominger describes these on page 60 of his report. Winchell gives 26 feet of strata; Rominger says about 25 feet. According to our measurements, which take account of the strong dip, the total thickness of these beds is fully 20 feet more.

Rominger gives the following analysis for the drusy dolomite of this section:

	Per cent.
$CaCO_3$	56.00
$MgCO_3$	39.00
Al_2O_3 and Fe_2O_3	2.8
SiO_2	0.4
	98.2

About half a mile south of the pier at Norwood the black[48] shales appear in low cliffs on the shore, gently dipping southward.

[48] It is this outcrop referred to by Winchell in 1860, p. 72, and even earlier in the first survey in 1841, H. D. No. 27, p. 108, by C. C. Douglass, which has led me, when informed by the U. S. Survey that the name St. Clair, which I had hitherto used, had been previously used in another sense, to apply the term Antrim to the shales lying above the Traverse, up to the Berea Grit, since they are well exposed here in Antrim county.—Lane.

THICKNESS OF THE TRAVERSE GROUP OF LITTLE TRAVERSE BAY.

In the Bay View well about 470 feet of limestones are shown above the blue clay. In the Petoskey well 325 feet are shown above the clay which is there found to be 80 feet thick. A 10 to 15 foot bed of blue clay was found at a depth of 250 feet below the surface of the limestone, or 75 feet above the blue clay at the base of the series. It is probable that this clay is the Acervularia clay, the well striking it at a point where fossils were scarce, since the record mentions no fossils. The thickness given is perhaps too great. Below this "a nearly solid bed of Acervularia limestone" was recorded. This appears to be the limestone exposed at the base of section 42, which often contains Acervularia.

In the Charlevoix well, as before stated, about 100 feet of the Petoskey limestone are exposed, below which the Acervularia clays occur, as shown by the perfect calices in the fragments of *A. davidsoni* and Favosites. Eighty feet below this, or about 110 feet below the first appearance of Acervularia in the well section, is the top of the blue shale. The record of the Charlevoix well is the most satisfactory, because the fragments from 5 to 10 feet intervals were carefully preserved. I shall consider the bed at 335 feet depth in the well, in which the fragments of Acervularia with perfect calices were found, as the Acervularia clay exposed in some of the sections. This would then give us a total of 110 feet for the lower strata below the Acervularia clay.

Putting together the records from the three wells, and from the exposures, we have the following succession and thickness of strata, which may be considered as a tentative summary of our knowledge of these beds:

	Feet.
Antrim black shale	
Chert beds	45-50
Petoskey limestone (the Stromatopora and the Buff Magnesian of Winchell)	360
Acervularia and *Stropheodonta nacrea* beds (Bryozoa beds of Winchell)	110
Basal shale (Bell shales)	80
Total	600

It thus appears that the thickness of the Traverse group throughout the northern portion of the southern peninsula of Michigan remains very nearly uniform. In the western region, mostly limestones were deposited, the shale being limited to the 80 feet basal layer, and to a few thin bands occurring at intervals. In the eastern area shale bands were more prominent, occurring at intervals in considerable thickness.

From our present limited knowledge of the faunas, correlation of the beds in opposite sides of the State is impossible. We may perhaps say that the Petoskey limestones and dolomites are, in general, the time equivalent of the Alpena limestone and the limestones of Thunder Bay Island. But beyond this little can be attempted in the way of correlation. The basal shale layer (Bell Shale) is of course an exception to this, for from its constant thickness it gives us a very clear and sharply-defined base for the Traverse group wherever it occurs in this portion of the lower peninsula.[49]

49 It is also recognizable to the south.—L.

DEEP WELLS AND PROSPECTS FOR OIL AND GAS.

Every time of prosperity brings extra activity in explorations of all kinds. These in Michigan take largely the shape of drilling,—mainly with the diamond drill in the upper peninsula; with the churn drill in the lower.

Drilling for coal has not generally been over 400 feet deep; for salt it has varied from 800 to 2000 feet, while for oil it is liable to be any depth and not infrequently over 2000 feet. A perceptible fraction of my time has been occupied in studying samples and answering correspondence before, after and during the drilling of these wells. I have taken special pains in the collection of data regarding these wells, because if they are not collected at the time they are likely to be forever lost, and at my own expense have subscribed to the Michigan Press Clipping Bureau that none might be completed without my hearing about it. It has done good service, and I think should be continued from the appropriation.

In the fifth volume of our reports, Vol. V, Part II, p. 85, I called attention to the prospects for oil and gas, and the beds and areas most likely to contain them, according to the information available to me at that time. In that report, and the sections at the end certain anticlinals were somewhat vaguely indicated. The recently issued coal report gives one section which if correct would indicate an anticlinal beneath Saginaw and between Lansing and Owosso, and to these I have called attention in the public press. Dr. C. H. Gordon's report was received so late that it had to be relegated to the end of the report, and only this reference to it inserted here. It is an important paper, for besides the anticlinal somewhere north of Mount Clemens, which I refer to below, he has located an anticlinal close to Port Huron. As Prof. Russell has remarked to me such an extensive basin as that of Lower Michigan can hardly exist without minor corrugations especially around the margin, which ought to collect oil in valuable quantities. We may, for instance, from Grabau's paper just above, infer the probable existence of such a minor anticlinal near Khagashewung Point (Plate VIII), and from the records below one east of Niles and one near Stronach are rendered somewhat likely.

One thing is worth noting,—that wells which yield only a barrel a day or less, and are liable to be scorned by those whose eyes are filled with visions of gushers, may nevertheless be of value, if conveniently located and enough of them can readily be obtained.

In describing them it will be most convenient to use a partly local, partly topical arrangement, because in certain districts all the wells have one object. In others wells for different objects throw mutual light. Coal records have been very largely summarized already in my recent report.

In discussing the borings and prospects for gas and oil it has been convenient to consider a southwestern and a southeastern district, which really extends to Port Huron, though it may be convenient on some accounts to divide it into two parts. I have also considered separately the possibilities around Saginaw. The prospects for Alcona county are included in the report. Some recent explorations serve as an excuse for describing some interesting wells in the upper peninsula. Finally I have made a few remarks about the northwest part of the lower peninsula at Muskegon and Manistee.

In studying explorations for oil and gas, one thing is apparent to the geologist—that the Neo-devonian black shales are responsible for most of the surface indications which start oil fevers and set people boring. It is also true that such indications have proved delusive. In fact, so far as surface indications in springs[1] are concerned, they indicate a leaky reservoir[2] if they indicate anything at all, and that is not a good sign for great accumulations below.

The same black shale is often mistaken for coal.[3]

It is true that deep wells into the drift, especially just above bed rock, will find quite frequently gas, and this may often pay for the well, for use in a house. But no great quantity can be expected, nor very long life.

Oily-smelling rock[4] at the surface, or gas or oil, have little value practically in this State in searching for oil. Almost all over the lower peninsula such strata can be found at some depth or other, and on the belt where the Devonian rocks lie beneath the drift, surface signs of oil may be expected.

SOUTHWESTERN DISTRICT.

It is not to be denied, however, that oil and gas-bearing strata exist beneath the southwestern point of the State,—both the Lower Devonian limestones, which yield the oil and gas around Petrolea, Canada, and the Trenton limestone, which is the famous oil rock of Ohio and Indiana. But the numerous wells drilled, and reported in Vol. V, at South Bend, Elkhart, Michigan City, Niles, Dowagiac, Constantine, Benton Harbor, Allegan and Kalamazoo, have not been successful in finding commercial quantities of gas. In spite of their failure, however, prospecting has not been entirely checked.[5]

It remains, therefore, to give a few facts regarding the new wells and new facts regarding those already reported on, and see what light they throw on the prospects for the future, the important thing being to see whether there is an upward flexure of the beds which might tend to collect the oil or gas.

[1] Kalamazoo Telegraph, 3 :9, 1901, also 10 :3, 1901.—Several wells in Lake township, Berrien county, strike gas in small quantities, and at Bridgeman a spring with a coating of oil was found by a planchette.
Niles Star, 6 :14, 1900.—Gas at New Buffalo at 60 feet.
Grand Rapids Herald, 1 :24, 1901.—Petroleum vein at cottage of Mrs. H. S. Cole, Benton Harbor.
See also Vol. V, Part II.

[2] I mean natural reservoir, though (Niles Sun, 12 :11, 1900; Detroit Tribune, 12 :13, 1900; Battle Creek Enquirer, 12 :25, 1900; Detroit News-Tribune, 12 :2, 1900; Detroit Journal, 12 :22, 1900) at Buchanan oil leaking from Lee & Porter's tanks was taken to be natural.

[3] Three Rivers Tribune, 9 :12, 1901.—Six-foot vein of coal at 150 feet near Benton Harbor.
Detroit Tribune, 6 :6, 1901.—Coal at 550 feet. Compare record of well below.

[4] Benton Harbor Palladium, 1 :23, 1901.

[5] Detroit Journal, 12 :26, 1901.—Near Niles by B. F. Earl.
Detroit Today, 10 :8, 1901.—Near Mendon by Darling Bros.
Allegan Chronicle, 4 :77, 1901.—Valley Oil, Gas & Coal Co., near Allegan.
Grand Rapids Herald, 3 :18, 1901; Allegan Gazette, 3 :9, 1901.—R. W. Brown, at Allegan.
Benton Harbor News, 6 :6, 1901, and 6 :26, 1901; Detroit Tribune, 6 :6, 1901.—Berrien Springs.
Niles Daily Star, 9 :7, 1901.

An important recent well is one at Berrien Springs, an authentic record of which we owe to Hon. Roscoe D. Dix.[6]

	Record.		
Gravel	40	40	
Blue clay	70	110	
Soapstone	440	550	Reached 550 noon June 5. Compare Benton Harbor at 280 feet, Niles at 415 feet.
Black shale with pyrite, bituminous	70	620	Compare Benton Harbor at 475 feet, Niles at 460 feet. Dowagiac at 675 feet.
Limerock with indications of salt water at bottom	80	700	Stopped at 670 feet, June 15. Compare Dowagiac at 874 feet.

See also Grand Rapids Press, 7:9, 1901; Detroit Tribune, 6:6, 1901; Three Oaks Acorn, 7:12, 1901; Benton Harbor News, 6:6, 1901, and 6:26, 1901.

The striking feature of the Berrien Springs record is the depth at which the base of the black shale was found, greater than at Benton Harbor on one side or Niles on the other. This indicates a downward flexure of the strata.

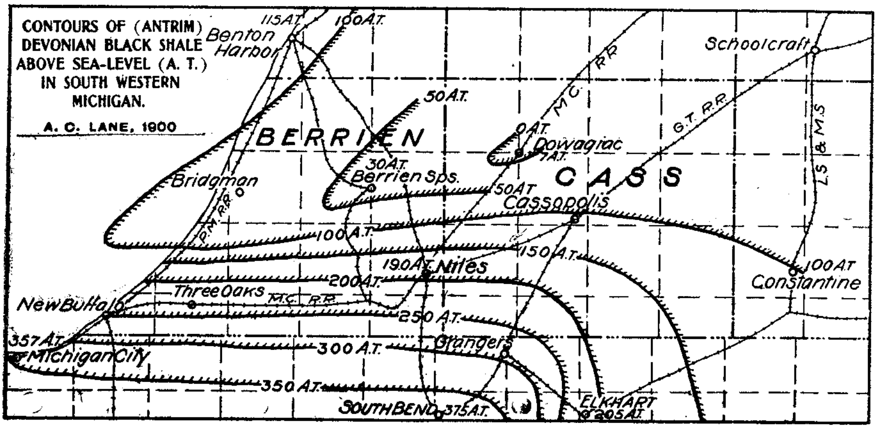


Fig. 4. Contours showing the elevation of the base of the Antrim (Devonian, New Albany) black shale, and the top of the Traverse (Hamilton) in Southeastern Michigan, above tide level, indicating an anticlinal pitching northeast, about 12 to 15 miles east of Niles.

The dip into the trough is also indicated by comparing with other wells as shown in the accompanying map. Fig. 4. While the strata all grow deeper to the northeast, there is a subordinate puckering or fluting, with a downturn between Niles[7] and Benton Harbor, and an upward turn

[6] Well 60 rods from north bank of St. Joseph river and about 50 feet, i. e., about 650 A. T.

[7] Five wells have already been put down in this neighborhood. Mr. F. W. Cook of the Daily Star and H. Gardner have helped me to gain information.

No. 1 was put down in 1865, close to the river and just below the bridge, was 500 to 700 feet deep, and yielding some gas.

No. 2. On Second street 20 rods this side of the railroad, yielding a large flow of water. One of the drillers told Mr. Cook that in driving for gas they met quite a little oil but were hired by the Standard Oil Co. to drive past anything of the sort. Drilled in 1885 to 1886.

No. 3. About same time (Plate XLIV of Vol. V), near C., C., C. & St. L. R. R., about 650 A. T.

No. 4. South of town one or two miles and on terrace 46 feet above river, i. e., probably above this. There was 70 feet 10-inch casing through clay, over 70 feet quicksand with water, 185 feet casing (or 280 says Dalton) to bed rock; then about 200 feet clay shale, toward bottom brown and bituminous, with petroleum smell; then limestone; at 546 feet strong brine, which rose to within 30 feet of the top, i. e., 15 feet above river. (Compare Berrien Springs at 700 feet, i. e., about 150 below tide.) Thereafter progress was but 3 to 6 feet per day to 580 feet. Cased with 5-inch casing, which was later recased to 880 feet to shut between Niles and Elkhart. Consequently the more hopeful district to explore is east and southeast of Niles, say near Edwardsburg on the Grand Trunk, or Mendon, where oil boring is said to be progressing.[8]

There was a deep well drilled at Bangor, the record of which I have not been able to obtain,[9] which might be of interest as showing whether there was a marked upward bend on the other side of the Berrien Springs trough or not. The elevation of the base of the black shale at Allegan (387 A. T.) and Kalamazoo (over 423 A. T.) shows that as a whole the dip is to the northeast, but not at all inconsistent with such minor flexure.

SOUTHEASTERN DISTRICT.

Lying, as this district does, close to the Toledo fields and two large business centers, this district has received a disproportionate amount of attention. Prof. Sherzer has recently[10] described quite fully the wells of Monroe county, but the dips seem to be uniform from 29 to 32 feet to the mile to the northwest, and no pitching folds have been located. To the records previously reported in Vols. V and VIII we may add old wells at Blissfield and Ypsilanti, whose records have been recently obtained, and wells recently drilled at Ann Arbor, Milan, Britton and Riga.

YPSILANTI.

A number of wells have been put down here for sulphuretted brines, derived by a combination of the waters from the Berea grit and the Traverse and Dundee limestones. The original well was the Cornwall mineral well on the river flats, about 680 A. T., the record being:

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out salt water, but got fresh water below, which rose as high as before. At 1000 feet they were told they had Trenton rock. (Compare rock at 1500 feet at Britton.) A little gas came in all the time, foaming up the water. At 1438 feet the well was abandoned. Dalton says his well was 1600 feet deep, and though higher than the down town wells seems to strike corresponding strata as soon. E. H. Crane of Colon is said to have a record.

No. 5 was but 200 feet or so from No. 4, across the river, and but 2 or 3 feet above the river level, i. e., about 636 A. T.

	Feet.
Clay, 10-inch casing	70.0
Water, sand and gravel	142.0
Eight-inch casing to bituminous shale as in No. 4.	
Casing 6-inch, shutting off water	503.3
Sand pocket, 6 inches salt water	504.0
15 feet from top, magnesian limestone	3.0
Gray limestone	6.4
Gray limestone	4.6

Then put down a packer and got some gas under salt water.

November 14, 1899.

What oil and gas appears in the wells is all from the Dundee or Canada horizon apparently, except that in Nos. 3 and 4 a little accumulation was noticed near the top of the Niagara. The Trenton was *not* reached.

[8] Detroit Today, 10:8, 1901. Darling Bros. heavy rock at 200 feet may also be on an upward bend.

[9] Except that it is 1260 to 1300 feet deep, is cased down 300 feet, and according to M. E. Maguire and C. B. Charles, flows a strong brine.

[10] Vol. VIII, Part I, Monroe County.

Pleistocene—		
Earth	8	
Clay	4	12
Gravel	18	30
Blue clay	4	34
Gravel	6	40
Fireclay	3	43
Hardpan gravel	5	48
Sand	32	80
Coarse gravel	9	89
Fine quicksand	20	109
Coldwater—		
Slate	241	350
Flint	5	355
Sandstone	38	393
Soft slate or sandstone	157	550
Bedrock (i. e., hard limestone) (?)	200	750

This is a very poor record. Of the Moorman well we have only the record of the casing. It is higher than the other (about 703 A. T.). At 125 to 150 feet there was fresh water. Down to 185 feet was the first casing to bed rock. At about 400 feet was the first flow, which was salter than the lower flow,[11] and was at one time cut off by a casing down to 550 feet.

At about 550 feet gas came in (H_2S), and the well continued down to about 965 feet.

The Atlantis well of T. C. Owen is about 80 feet higher, and the fresh water comes at 200 feet and the salt at 404 feet, directly under a very hard streak.

ANN ARBOR.

The old deep well at the court house, which is about 835 A. T., has already been reported by Winchell and Rominger. The following may be a provisional account of the new one,[12] which is about 875 feet A. T.

Pleistocene—			
Soil, find sand	45	45	Down 60, Sept. 14.
Large boulder at		80	
Gravelly, 10 ft. casing to	45	00	
Large boulder at		113	
Bluish clay	142	232	
To bedrock	3	235	Oct. 13.
Coldwater Shales—			
Bluish shales	30	265	Oct. 16.
Red shale	15	280	Oct. 17.
Plugged June 28 at 287 ft. and water above analyzed 4.3 per cent salts.			
Blue shale	75	355	to 375, Oct. 18.
Berea Shale—			
Black shale	30	385	to 400, Oct. 19.
Bluish shale	15	400	
Berea Grit—			
Sandstone	15	415	(No water noted).
Shale	60	475	to 425, Oct. 20; 465, Oct. 21; 475, Oct. 23.
Lighter shale with streaks of sand	85	560	to 505, Oct. 24; to 535, Oct. 25; to 570, Oct. 26; to 585, Oct. 31.
Salt water at		515	and below.

[11] See U. S. G. S. Water Supply Paper No. 31.

[12] Personal glance at samples. Record in Ann Arbor Daily Argus, Dec. 2, 1899; Jan. 5, Jan. 19, Feb. 16, Feb. 23; Ann Arbor Times, Feb. 15, June 28, July 1, July 6. Letters from Eberhard and notes from Prof. H. D. Campbell. Prof. Russell looked after the samples, and Mr. Frueauff of the Argus, at my request, took particular pains with the reporting.

Antrim Shales (Neodevonian)—

Black bituminous shale	20	580	
Black sand with white crystal	25	605	
Black bituminous shale	20	625	Nov. 3.
Black shale harder	48	673	
Black slate	27	700	680, Nov. 8.

Traverse Group (Meso devonian)—

Light slate	55	755	
Limestone (cherty)	15	770	
Limestone, very hard gritty and flint like (cherty)	35	805	
Black shale	45	850	
Sample at 810 appears like a dolomite)			
Limestone, some gas indications	33	883	Nov. 15.

(Samples appear like the shale from 825 to 885, probably a blue argillaceous limestone such as is characteristic of this group.)

Light shale	47	930
(Sample at 920 has note "struck hard.")		

Dundee (Corniferous) Limestone.

Limestone (at 960 feet struck a mineral water charged with H_2S which rose 300 feet and contained 13 per cent salts, according to Eberhard.[13])

November 18 operations were suspended for a month at the end of the first 1000 feet, in an oily dolomite or limestone. Between December 15 and December 28 work was resumed and remained the rest of the way in limestones or dolomites down to 1240 feet.

Monroe Beds—

There was a granular buff dolomite apparently at 1040 feet. On January 5 at 1065 feet a red rock with much iron was struck. From January 12 to January 19 the hole was reamed out and the 6½-inch casing carried down from 1000 feet to 1150 feet, shutting out the water. At 1235 feet the rock appears like a very fine-grained dolomite.

Total limestones and dolomites 310 1240

Sylvania sandstone—

Samples below 1240 are a fine (⅛ mm.) quartz sand as far as they are taken, 1270 feet. According to the newspapers at 1275 feet on February 10 another mineral water strong of H_2S with 17 per cent salts (Eberhard) was struck in limerock, in which a progress of but 7 or 8 feet per hour was made. The driller evidently did not report or recognize the sandstone, which may continue. By Wright it was taken as Oriskany.

At 1300 feet the rock is said to have been a little softer. The well was shut down February 26 at 1326 feet. It was then plugged at 283 feet and tested. Then a cement plug of 25 feet was put on top, but the analysis remained practically the same, to wit:

Specific gravity	1.039 or 1.0588
SiO_2	.0235 or .032 or .027
$(Fe\ Al_2)O_3$	.0305
CaO	1.040 or .885
MgO	.295
SO_3	.0245
Cl	3.20
Total S (H_2S in Sol)	.35
CO_2	
No K, Br, or I	

It will be seen by comparing the wells with those at Ypsilanti that the dip continues fairly steady to the northwest. This will also appear from the Milan well.

That the dip continues appears also by comparing the Sylvania sandstone with its position in wells near the Detroit river, for instance those given below.

[13] Campbell says the water analyzed was at 930 feet.

Specific gravity	1.094
$CaCl_2$	2.3975
$CaSO_4$	1.6331
$MgCl_2$	1.2336
K Cl	trace
NaCl	7.6163
Sr	?
I	......
Total	12.8705
Directly determined	12.89

Saturated with H_2S.

This is a characteristic water of the Dundee or Corniferous limestone.

J. B. Ford (Michigan Alkali Company), Wyandotte. The "limestone" is generally dolomite, sometimes anhydrite.

	No. 1.	No. 4.
Soil (surface) to	63	60
Limestone	262	195
Sylvania sandstone	372	375 435 to 460 "soapstone"
Limestone	830	783
Salt	876	1100
Limestone	968	
Salt	976	
Limestone	984	
Salt	993	
Limestone	1126	
Salt	1213	
Limestone	1223	
Salt	1300	

Stroh's brewery in Detroit, on Gratiot avenue, is geologically higher and the well is said to have gone through:

Blue clay	110	110
Hard pan	30	140
Boulders	14	154
Traverse group	164	300
Dundee limestone with sulphur water in Monroe beds to	615	
Sylvania sandstone	85	700
The lime rock hard at 730, sandy at 800, and hard pan 900 to 1150.		
Salt	55	1205
Limestone	201	1406
Salt	24	1430
Limestone	135	1565
Salt	250	1815
Limestone	282	2097

The Wyandotte well, reported in Vol. V, reached the Trenton at 2610 feet. To the south the Sylvania sandstone rises, outcropping, as we have said, in Monroe county, and at Trenton we have for one of the six Church wells:

Dundee—	
Light brown limestone	75-140
Softer light brown limestone	150-220
Monroe—	
Dark brown dolomite	230-280
Sylvania—	
White sandstone	290-400
Band of dolomite	410-420
Calcareous sandstone	420-470
Dolomite with much white chert	480-490
Shaley in streaks	500-590
	600-680
Gyspiferous dolomite, passing into	690-710
Bluish gray gyysum shales	720-840
Very rich in gypsum	850-880
Gypsum bed, the gypsum is really anhydrite	880-890
Dolomite	890-900
Gypsum	910-930
Dolomite, light yellow	940-950
Dolomite bluish and buff	960-980
Dolomite, light buff with some bluish	990-1000
Bluish gray gypsiferous shale	1019-1090
Deeper blue shale, (gypsiferous 1000-1185)	1100-1190
More largely cream colored dolomite (salt in some wells)	1190-1240
Largely bluish gypsiferous shales	1240-1290
Bluish passing into brownish dolomites	1290-1320
Brown dolomite with a smell of gas	1340-1370

To the north wells are very numerous. We cannot here give all the Solvay wells. They must be left for a special report. The Sylvania sandstone occurs in No. 6 from 410 to 490 feet, and in No. 10 from 420 to 523 feet, while the first salt begins in the one case at 873 feet, in the other at 891 feet.

Between them and the Wyandotte wells near the River Rouge, Mr. Dalton put down wells for the Tecumseh Salt Company in which, under dolomite, with heavy flows of sulphuretted water, the Sylvania sandstone was found from 365 to 492 feet, and the salt also came a little higher—at 828. This is higher than it is north or even than across the river, as shown in the Windsor well given below, but the pitch to the west is strong. The Detroit Salt Company got salt from 906 feet on. At the Brownlee well the salt comes in at 875 feet.

A little farther down river toward Wyandotte the River Rouge Improvement Co. put down a well for the United Alkali Co., the record of which is as follows, with notes from samples, which the survey owes to the kindness of Mr. H. M. Campbell:

Clay	80	80
Gray lime (dolomite)	270	350
White sand (cleanrounded glass sand, Sylvania	100	450
Dark sand (with chert and dolomite)	50	500
Lime (blue dolomite)	315	815
Salt	52	867
Lime (buff dolomite)	30	897
Salt	23	920
Lime (dolomite with acicular cavities)	25	945
Salt	15	960
Lime (buff dolomite)	35	995
Salt	70	1065
Lime (blue and buff dolomite)	95	1160
Gray lime	20	1180
Salt	20	1200
Salty shale and lime (anhydrite?, bluish, dolomitic)	125	1325
Salt	120	1445
Salt shale	15	1460
Salt	78	1538
Lime (dolomite)	35	1573
Sand (granular dolomite) last two total 62?	30	1603

WINDSOR.

Canadian Pacific Railroad. Well No. 11.

Dolomite, hard, white to	235
" " fawn	250
" marly drab	275
" " "	300
Limestone, dark color, petroliferous	325
Dolomite marly	335
" " drab	365
" " grey	390
" vesicular drab	410
Limestone	440
Dolomite, crystalline fawn	460
Limestone, drab	490
" "	535
Sandstone, quartzose (Sylvania)	590
Dolomite, fawn	600
" with Gypsum, grey	640
" shaly, drab, somewhat arenaceous	670
" drab grey	700–760
" fawn	800
" hard, drab grey	825
" shaly, grey	840
" fawn	880
" drab grey	925
" " "	960
" fawn grey	1030
" drab grey with gypsum	1070
" shaly, drab grey	1100
" drab grey	1127
Salt	1167

28 February, 1894,
H. P. Grunnell.

RIGA.

A well was put down here some two years ago, but owing to a dispute and legal proceedings the only record I can give is that from 1165 to 1275 feet the samples appear to be in the white dolomites of the Niagara, such as occur from 1570 feet down to the bottom of the Britton hole, and this is the depth at which they would be expected.

BLISSFIELD.

On Sec. 30, T. 7 S., R. 5 E., is a well costing $5,000 and 2402 feet deep, down to the Trenton. Only a meager record from memory could be obtained, which we owe to Horace Wood. It agrees fairly well with a 35-foot to the mile dip from Toledo to Adrian, i. e., there is no sign of a fold.

Drift	100	100
Gravel; water rose and filled first 8 inch casing	20	120
First limestone about (to (?) dark slate and black water)	300	420
Water in limerock at		1600
Struck Trenton at		2342
Trenton rock	60	2402

MILAN.

A few rods south of the line between Washtenaw and Monroe counties, a well has recently been drilled. A record and samples were kept by A. E. Putnam, and I made two flying visits during the progress of the well. The record may be summarized thus. The well is about 685 feet A. T.:

Pleistocene—		
Surface (drift, clay, quicksand about 60 feet, and clay)	130	130
Traverse—		
Cherty limestone	30	160
Blue shale	45	205
Blue shaly limestone	65	270
Limestone (fissure?)	28	298

The top of the Dundee cannot be clearly made out owing to the caving. It is surely somewhere between 165 and 298 feet, more probably at or near the latter figure.

Dundee—		
Limestone quite fine, H_2S water (brecciated and caving)	97	395
Monroe—		
Dolomite acicular, caving to 425 feet	30	425
" sandy	10	435
" with gypsum	20	455
Gypsum, mainly	80	535
Sylvania—		
Sandstones, pebbly at 820	288	823
Various veins of water, calcareous shale	7	830
Dark oily dolomite, more sulphuretted water	15	845
Cherty dolomite	55	890

BRITTON.

Here a well was recently put down at the remarkably low price of a dollar a foot for 1700 feet. Comparing with Milan, we find corresponding samples from 100 to 150 feet deeper. The top of the well is only about 20 feet higher, and the record is:

Pleistocene—		
Surface clay and gravel	93	93
Neodevonian (Antrim)—		
Black shales	67	160
Pyritiferous grey shale	15	175
" black shale	35	210
Traverse Group—		
Cherty dolomite	25	235
Green shale	30	265
Cherty dolomite	40	305
Blue calcareous shale	95	400
Dundee (Corniferous) Limestone—		
White or brownish crinoidal limestone with water and traces of oil and gas	100	500
Monroe		
Gypsiferous dolomite	75	575
Gypsum	50	625
Dolomite	50	675
Dolomitic limestone	33	708
Dark cherty dolomite	37	745
The same, bluer	5	750
Sylvania—		
Dolomitic sandstone	25	775
Gypsiferous dolomites	50	825
The same with a little chert and sand	75	900
Dolomitic sandstone	100	1000
Salt water		
Shale	15	1015
Casing to 1012 or 1015 feet.		
Dolomite, dark blue at 1180 feet	585	1500

Rope black, and H_2S at 1200, where there is a slow very salt seepage. There is said to be 30 feet of brown oily dolomite at 1400 feet. (?)

Dark brown oily dolomite	50	1550
Niagara—		
Light white sugary dolomite typical Guelph[14]	84	1643
Mineral water[15] at		1600

CaCl	20.507
$MgCl_2$	6.516
$MgSo_4$	1.685
Insoluble	.114
NaCl	39.452
	68.274

The balance being water of crystallization mainly. This is not as strong as a Dundee or Salina water would be at this depth.

At 1617 feet the thermometer stood at 63 degrees F.; at 945, 59 degrees F.

The water from the last bailing was at 52½ degrees F.

The water at the bottom is probably not as salt as above at 1200 feet, and there is some circulation going on.

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[14] Small residue of quartz, rounded or not, with minute particles of microcline, hornblende, magnetite, etc., usually about 0.2 mm. in diameter.

[15] Specific gravity, 1.059; 90.648 grains per litre by evaporation. Partial analyses by F. S. Kedzie.