STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

Publication 44, Geological Series 37
GEOLOGY
of the
MACKINAC STRAITS REGION
and
SUB-SURFACE GEOLOGY
of
NORTHERN SOUTHERN PENINSULA

by
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FOREWORD

To the Commissioners and Director of the Department of Conservation

Gentlemen:

Ever since the rock formations of Michigan have been studied by geologists the peculiar brecciated limestone formations of the Mackinac Straits region have been a puzzle. The effects of weathering on them, creating the famous Arch Rock, Sugar Loaf, Rabbits Back, Castle Rock, Big Crack of Mackinac Island, and many other features, have enhanced the scenic value of the region. Such features are readily explained, but although several hypotheses had been advanced, the causes of the brecciation remained unexplained, and the position of the formation in the geological column, its area! extent, and subsurface extension were incompletely known.

In the early days of our State's history the limestones had some economic value. They contained masses of gypsum which were quarried and burned for plaster and ground for fertilized. Some of the limestone was used for building purposes, some was calcined for mortar and plaster. Those industries are almost forgotten. When the war made it necessary to find new sources of petroleum every exploration tool geologists know had to be put to work; new tools and means of study had to be devised; every sort of oil trap had to be searched for and explored. We have long known the rock traps that hold oil—the anticlines, "pinch-outs," and others. In Michigan "pinch-outs" of rock formations received little consideration until the war need arose, because such conditions exist around the rims of our Michigan Basin under the Lake Huron and Lake Michigan basins, and particularly in the northern third of the Southern Peninsula, where exploration for petroleum was not active.

Earlier studies made during the agitation for the Mackinac Straits bridge and the discovery by the late O. F. Poindexter of large faults or rock slips in the rock exposed in the cut on U.S. Highway 2, west of St. Ignace, had shown that it is highly advisable that more detailed studies of the breccia and clay shales be made before construction of the bridge be undertaken. Also the rock cuts made in excavating for the causeway and ferry mole uncovered and exposed fresh sections of the rock that afforded new clues that could be studied to advantage before being destroyed by weathering.

For these reasons a contract was undertaken in 1943 between the Department of Conservation and the University of Michigan to make a detailed study under the direction of the Geological Survey Division of the surface exposures of the limestones and shales of the Straits area and the rims of the immediately over-lying rocks in the northern part of the Southern Peninsula, and to carry the study of the subsurface extension of the rocks under the Southern Peninsula to the oil-bearing areas to the south insofar as information is available from boreholes drilled for limestone, oil, gas, and water exploration.

Dr. Kenneth K. Landes and Dr. George M. Ehlers of the Geological Department of the University accepted assignment to make the study. The terms of the contract were carried out; the field work and subsurface studies were completed and reports written. Professor Landes wrote all the report excepting the discussion of the stratigraphy of the bedded rocks, which was written by Professor Ehlers and the chapter on the glacial geology which was written by Professor George M. Stanley also of the Department of Geology of the University. Fossils and rock samples collected during the study, the property of the Geological Survey Division of the Michigan Department of Conservation, are deposited with the Museum of Paleontology of the University of Michigan where they are available for study.

I have the honor to present herewith this report and recommend that it be published as Publication 44, Geological Series 37 of the Geological Survey Division of the Department of Conservation.

Respectfully submitted,

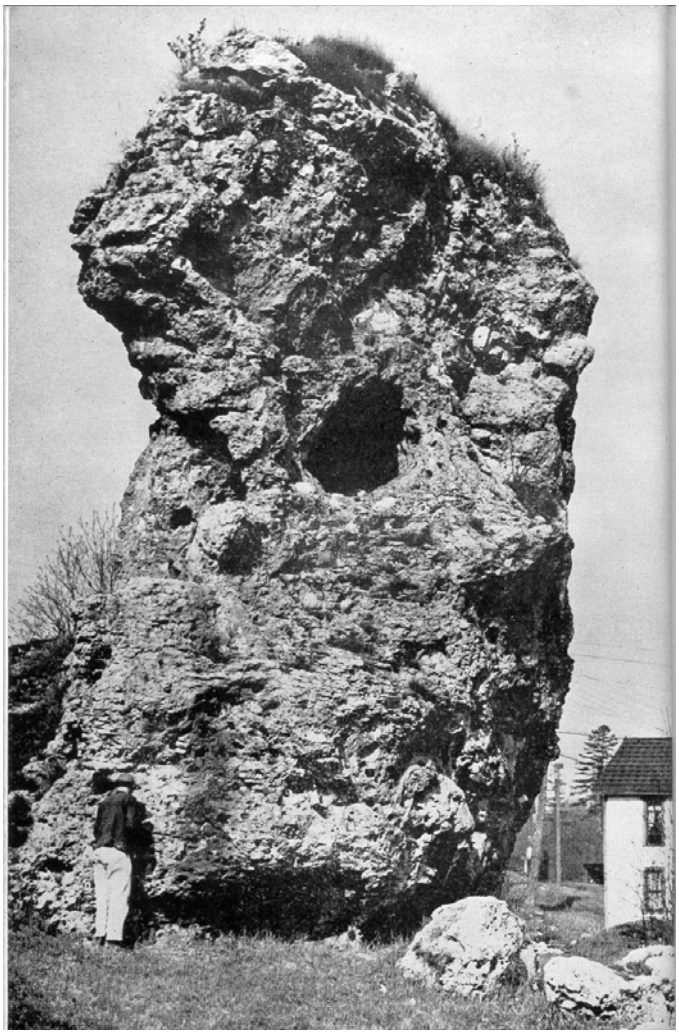
State Geologist,
August, 1945.

INTRODUCTION

The objectives of the project reported upon in this bulletin were three-fold: (1) to determine the rock formations and their distribution in the Straits area; (2) to correlate these formations with formations penetrated in deep wells drilled in the central part of the Southern Peninsula; and (3) to determine the possibilities for stratigraphic oil "traps" on the northern flank of the Michigan Basin. The following chapters contain the information assembled by the writers in their attempts to attain these objectives.

The rock formations from the base of the Salina to the top of the Detroit River were studied at their outcrop on

the north rim of the Michigan Basin, and by means of well cuttings from their subsurface extension to the south. To complete the study the outcrops of the same formations on the south rim of the Basin, in southeastern Michigan, northern Ohio, and southwestern Ontario are to be studied and the rocks correlated with the subsurface section in southern Michigan. When that work is completed and the results published the Salina-Detroit River rocks should be known entirely across the Michigan Basin where exposed at the surface and also where buried under a thick section of younger rocks. It is to be hoped that these bulletins will assist in the discovery of more oil deposits and also provide research information necessary for such construction projects as the Straits bridge and ferry docks, and provide information for further study of the structure and stratigraphy of Michigan rock formations.



Frontispiece. St. Anthony's Rock.

Previous Work

In the one hundred and twenty-five years that have elapsed since Dr. John J. Bigsby, British Army surgeon and writer of geological narratives, visited the Straits area, many geologists have passed through this region and have written of what they found. The first were geological explorers; those who followed were primarily interested in either the stratigraphy (including the breccia) or the Pleistocene history of the region. Few spent very much time in the district, and all of the work was reconnaissance in scope. As the more important contributions of these men are described in subsequent chapters, only a brief sketch of their visits to the Straits is given here.

Bigsby visited Mackinac Island and the north shore of Lake Huron in 1819 and in 1820.[1] During 1820 Henry Rowe Schoolcraft also visited the area and described the rocks in a book published in 1821.[2] Twenty years later the rocks of the Straits area were described by Michigan's first State Geologist, Douglass Houghton, and C. C. Douglass, Assistant Geologist. These men were at Mackinac Island and St. Ignace in August, 1839, and their reports were published in 1841.[3] James Hall, famous State Geologist of New York, was employed on the Foster and Whitney survey of the Lake Superior Land District to study the stratigraphy. His description of the rocks of the Straits area appeared in print in 1851.[4] In 1860 the second State Geologist, Alexander Winchell, visited Mackinac Island and wrote of what he saw.[5] Nine years later his brother, N. H. Winchell, made a reconnaissance trip through Presque Isle, Cheboygan, and Emmet counties, paying particular attention to the economic possibilities of the rocks. His report was not published until 1875.[6]

Dr. Carl Rominger opened a new era in geological studies of the Straits area with the first detailed stratigraphic investigation. In 1873 his report on the Paleozoic rocks of the Upper Peninsula was published[7] and was followed three years later by his monograph on the Lower Peninsula.[8] These two reports contain descriptions of the stratigraphy and paleontology of the rocks on both sides of the Straits and on the various islands in the region. About 40 years ago another geologist, Dr. G. P. Grimsley, visited the Straits region and reported on the gypsum deposits.[9] Prof. A. W. Grabau published abstracts concerning the Mill Creek section,[10] and the Mackinac breccia[11] in 1906 and 1907, and a more complete discussion of the breccia in 1913.[12]

For many years Henry H. Hindshaw roamed northern Michigan in search of commercial stone deposits. His views on the origin of the breccia were quoted by R. A. Smith in 1914.[13] A year later Dr. Smith brought out his report on Michigan Limestones, in which the rocks of the Straits area are described.[14] W. H. Norton, after visiting and studying the type locality, included a discussion of the Mackinac breccia in his classification of breccias published in 1917.[15] In 1939 O. F. Poindexter reported on the breccia at the faulted section along U.S. Highway 2, and made detailed studies of the rock cores from test holes drilled by the Mackinac Straits Bridge Commission,[16, 17] and in 1940 mapped and described the lithology of many of the breccia out-crops in the St. Ignace Peninsula.

The prominent raised beaches of Mackinac Island, and other glacial and post-glacial features of the Straits

region, have long interested physiographers. Taylor, beginning in 1892, and later Leverett, published a series of papers and reports on the Pleistocene and Recent History of this area.[18-26]

Professor I. C. Russell also contributed to this branch of the science, and at the same time paid some attention to the bed rock geology.[27] In recent years Dr. G. M. Stanley has published reports on the raised beaches[28] and on the valley submerged beneath the waters of the Straits.[29] S. G. Bergquist studied the drumlins in the counties of Presque Isle, Cheboygan, and Emmet, and elsewhere.

The stratigraphy and physiography of the Straits region are described in the guidebooks issued for the 8th and 11th annual excursions of the Section of Geology and Mineralogy of the Michigan Academy of Science, Arts, and Letters. The 8th Annual Excursion Guidebook was for Charlevoix, Emmet, and Cheboygan counties; the physiographic part of the guide was prepared by S. G. Bergquist, and the stratigraphic discussion was prepared by G. M. Ehlers. The 11th Excursion guidebook, prepared by O. F. Poindexter, G. M. Ehlers, George Stanley, and W. A. Kelly, describes the St. Ignace peninsula and Mackinac Island.

Field Work

The field work on which this report is based was carried on during the summer and early fall of 1943. The writers, assisted by Walter Landes, rodman, surveyed the Straits area from the outcrop of the Engadine dolomite on St. Ignace peninsula southward to the areas where the bedrock disappears beneath the glacial drift near the northern end of the Southern Peninsula. North Fox Island and all the Beaver Islands, including Isle Le Galet in Lake Michigan, between the Beaver Group and the mainland, and Bois Blanc, Round, Mackinac, Goose, and the St. Martin Islands in Lake Huron were visited.

Office Work

Subsurface stratigraphic studies were carried on from November, 1943, to October, 1944. In this investigation cuttings from drilled wells were glued to graphic log cardboard strips, scale 20 feet to the inch, and thus by means of actual graphic "rocklog" strips the character of the rocks, changes in lithology, and the regional structure were studied. Particular attention was paid to the stratigraphic section from the base of the Salina group to the base of the Dundee limestone throughout the entire north half of the Southern Peninsula. In other words, the series of rocks which was surveyed in the outcrop was followed underground by means of well records down the north flank of the Michigan Basin. In this cooperative project of the Michigan Geological Survey a large amount of data on both surface and subsurface were available, and detailed surface and subsurface studies could be combined. The benefits derived from this combination to the study of both surface and subsurface stratigraphy are considerable. Unfortunately in this as in earlier studies the conditions are not ideal; the scarcity of well records in the northern part of the peninsula at this time makes an excessive amount of interpolation necessary.

Acknowledgments

This report is the result of a cooperative project between the Geological Survey Division of the Michigan Department of Conservation and the Department of Geology of the University of Michigan. Thanks are due to both of these organizations for their financial support and to the Horace H. Rackham School of Graduate Studies, University of Michigan, for a research grant which aided in meeting the University's share of the obligation.

The writers enjoyed and appreciated the encouragement, assistance, and advice readily given by the members of the staff of the Michigan Geological Survey, especially Dr. R. A. Smith, State Geologist, Miss Helen Martin (who first suggested the Straits area for study), Mrs. Lucille Esch, Mr. O. F. Poindexter, and Mr. Rex P. Grant. Professor George M. Stanley accompanied one of the writers (Landes) in a trip to the Mackinac Straits region in 1942. During this trip progress was made on the development of the breccia origin theory given in this report. Many discussions on the geological problems were held with another colleague, Professor A. J. Eardley. Dr. George V. Cohee of the Geological Survey, U. S. Department of the Interior, while engaged on a cooperative project between the Federal and State Geological Surveys and the Department of Geology, University of Michigan, read a part of the manuscript and supplied new data of value. Miss Marie Tharp, graduate student at the University of Michigan, prepared and contributed maps and cross sections of the Detroit River group. Mr. Raymond Hunt, consulting geologist of Mount Pleasant, kindly supplied data on the "Trenton" well on Drummond Island. Thanks are due Prof. W. A. Kelly of Michigan State College for his courtesy in contributing samples from wells drilled in northern Michigan. Some of the photographs used in this report were taken by Mr. Walter Hastings, official photographer for the Michigan Department of Conservation.

Similarities between the Mackinac breccia and the breccias of the Tri-State Zinc district were called to our attention by Mr. Carl Addison of the Pure Oil Company, who at one time worked on a Federal geological investigation of the zinc ores in the Tri-State district. Mr. Charles Mueller, late geologist for the United States Steel Corporation, brought to our attention the analogy between the collapse which we believe formed the Mackinac breccia and collapses which occur during and following mining operations.

The writers appreciate and express thanks to Mr. Walter Russell for his thoughtful kindness in bringing our work to the attention of the Mackinac Island Commission, and the kindness and hospitality of the Commission in

furnishing quarters in Fort Mackinac during the 1942 and the 1943 field seasons. Thanks are also given to the officers of the Michigan Limestone and Chemical Company of Rogers City for many kindnesses.

The writers also desire to express thanks to Mr. Frank Laway for the use of his boat and other valuable assistance in the island studies, and to various other citizens of the Straits area for their hospitality and their aid in finding outcrops.

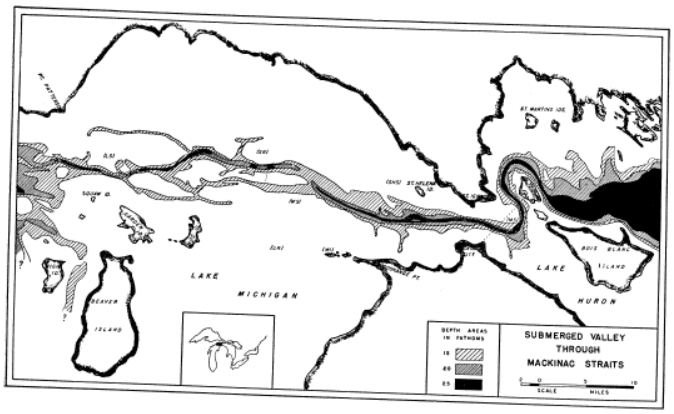


Figure 1. Submerged channel of Mackinac River.

[1]Bigsby, John J., Geological and Mineralogical Observations on the Northwest Portion of Lake Huron; Am. Jour. Sci., Vol. 3, 254-272, 1821. Notes on the Geography and Geology of Lake Huron. Geol. Soc. London, Tr. (2) 1:175-209 (1824).

[2]Schoolcraft, Henry Rowe. Narrative journals of travel through the northwestern regions of the United States, 419 pp., Albany, 1821.

[3]Houghton, Douglass, Michigan Senate Documents, 1841, Vol. 1, p. 486 and p. 548.

[4]Hall, James, Upper Silurian and Devonian Series: Geology of the Lake Superior Land District, Pt. II, U. S. 32 Cong. Spec. Sess. Ex. Doc. 4, pp. 140-166, 1851.

[5]Winchell, Alexander, First biennial report of the progress of the Geological Survey of Michigan, Lansing, pp. 57-69, 1861.

[6]Winchell, Newton Horace. The Economical Geology of the region of Cheboygan and old Mackinac, in the counties of Presque Isle, Cheboygan, and Emmet, State of Michigan: Mich. St. Bd. of Agric., 12th Ann. Rept., 1873, pp. 103-107, 1875.

[7]Rominger, C. L. Paleozoic rocks (Upper Peninsula): Michigan Geol. Surv., Vol. I, pt. 3, 1873.

[8]_____ Geology of the Lower Peninsula, Michigan Geol. Surv., Vol. III, 1876.

[9]Grimsley, G. P., The gypsum of Michigan and the plaster industry: Michigan Geol. Surv., Vol IX, pt. 2, 1904.

[10]Grabau, A. W., Discovery of the Schoharie fauna in Michigan; Science, n. s. 23, 467, 1906.

[11]_____ Subareal erosion cliffs and talus in the lower Devonian of Michigan: Science, n. s. 25, 295-296, 1907.

[12]_____ Principles Of Stratigraphy, New York, 1913, 547-548.

[13]Smith, R. A., The occurrence of oil and gas in Michigan: Michigan Geol. Surv., Pub. 14, 206-207, 1914.

[14]_____ Limestones of Michigan; Michigan Geol. Surv., Pub. 21, 103-311, 1916.

[15]Norton, W. H., A classification of breccias; Jour. Of Geol., Vol. 25, pp. 192-193, 1917.

[16]Poindester, O. F., A Geologic Section Across the Straits of Mackinac, Report Mich. Acad. of Sci., 1940. Unpublished.

[17]_____ and others—Preliminary Report on Straits of Mackinac drilling, Dec. 1939. Unpublished report.

[18]Taylor, F. B., The highest old shore line on Mackinac Island: Amer. Jour. Sc. (3), 43, 210-218, 1892.

[19]_____ The Muniscong Islands; Amer. Geol., Vol. 15, 24-33, 1895.

[20]_____ The second Lake Algonquin; Amer. Geol., Vol. 15, 100-120, 162-179, 394-395, 1935.

[21]_____ Niagara and the Great Lakes; Amer. Jour. Sc. (3), Vol. 49, 249-270, 1895.

[22]_____ Old shore lines of Mackinac Island and their relations to the lake history (abst): Geol. Soc. Amer., Bull. 26, 68-70, 1915.

[23]Leverett, Frank, and Taylor, F. B., The Pleistocene of Indiana and Michigan, and the history of the Great Lakes, U. S. Geol. Survey Mon. 53, 1915.

[24]Leverett, Frank, Surface geology of the Northern Peninsula of Michigan, Michigan Geol. Survey, Pub. 7, 1910.

[25]_____ Surface geology of the Southern Peninsula of Michigan, Mich. Geol. Survey, Pub. 9, 1911.

[26]_____ Surface geology and agricultural conditions of Michigan: Michigan Geol. Survey, Pub. 25, 1917.

[27]Russell, I. C., A geological reconnaissance along the north shore of Lakes Huron and Michigan; Michigan Geol. Survey, Rept. 1904, 1905.

[28]Stanley, G. M., Lower Algonquin beaches of the Upper Great Lakes, (abst): Geol. Soc. Amer. Proc. 1935, 107, 1936.

[29]_____ The submerged valley through Mackinac Straits: Jour. Of Geol., vol. 46, No. 7, 966-974, 1938.

[30]Bergquist, S. G., The distribution of drumlins in Michigan: Mich. Acad. Sci., Arts, and Letters, Vol. 27, 451-464, 1942.

Chapter I. PLEISTOCENE GEOLOGY

GEORGE M. STANLEY

The area surrounding the Straits of Mackinac was heavily glaciated during the last or Wisconsin stage of the great Ice Age and undoubtedly also in all or most of the preceding glacial stages of the Pleistocene. However, no deposits of pre-Wisconsin ice have been recognized anywhere within the area, and any earlier deposits were presumably removed by ice scour of the last stage, unless preserved in a few places under a cover of the latest drift.

Submerged Valley Through Mackinac Straits

However, one feature seems to date from pre-Wisconsin time—a submerged channel in the Straits. Soundings have shown a deeply submerged channel extending through Mackinac Straits from a little north of the Beaver Islands to a deep part of the Lake Huron basin east of Mackinac Island and north of Bois Blanc Island. The channel bottom is over 150 feet below lake level in much of its western part, and is more than 200 feet below lake level in its passage through the narrows of the Straits as well as throughout its semicircular sweep about the north end of Mackinac Island east of the narrows.

That this channel was formed by a river draining eastward is obvious from the general easterly slope of its floor. Consideration of the ultimate escape of drainage toward the sea leads to the same conclusion inasmuch as no place for discharge from the Lake Michigan basin is found elsewhere at so low a level. On the other hand the Lake Huron basin must have offered low passages leading to the Atlantic during the waning of the last ice and prior to the great uplift in the northeast which followed the final retreat of the ice. Very likely such occasions obtained also at the close of the pre-Wisconsin glacial stages and perhaps also in pre-glacial time.

The submerged valley has been described previously and in more detail by the writer.[1] The original incision into the rock floor of the Straits was probably made before the Wisconsin stage and re-occupied by an eastward flowing river between the stages of the Algonquin and Nipissing Great Lakes. The existence of this valley is an added problem to the construction of a highway bridge to span the Straits.

Deposits From The Wisconsin Ice

Glacial drift is scanty on the St. Ignace peninsula, on the islands of the Straits and in eastern Presque Isle County, but over large areas north of Little Traverse Bay and toward Mackinaw City the drift attains considerable thickness. The hilly features of the moraine lack significant trends over most of the region and interpretation of successive positions of the ice border is not as feasible as in southern Michigan. Leverett considered this an interlobate tract between the Michigan and the Huron ice lobes, formed after the main Port Huron moraine was laid down and perhaps simultaneously with the building of Manistee moraine.[2]

Laminated clays of reddish color are found in many places buried beneath the surface till as far south as Frankfort, Benzie County. These clays definitely ante-date the latest stand of the ice front thereabouts and were formed in glacial waters, but the exact time and circumstances of their origin are not yet understood.

Small morainic areas have been noted on Beaver Island and on South Fox Island but they are too fragmentary to afford much information as to time of origin by correlation with other moraines. The latest moraine in the Southern Peninsula of Michigan seems to be the one known as the Cheboygan moraine which extends northwest-southeast and parallels the shore from Mackinaw City to Cheboygan. It was formed by ice retreating northeastward with slight readvances toward the southwest.

Such a movement of ice presents somewhat of a problem when compared with the indicated directions of movement outside of and beyond the moraine. Several clusters of drumlins between Alpena and Cheboygan trend northwest to southeast and prove glacial motion along a southeastward course or almost at right angles to the movement which formed the Cheboygan moraine. Some of the drumlins east of Mullet Lake are only six miles distant from the moraine. Drumlin-like flutings in the till surface near Onaway at the west edge of Presque Isle County, well illustrated on aerial photographs, have nearly the same direction. They appear to be a result of the same ice movements that produced the drumlins. The drumlins of Les Cheneaux Islands have similar trends and though they are much farther north across the Straits region, they may also have been caused by the same ice movements.

Only a small part of the large sand and gravel plains of northern Emmet and Cheboygan counties is outwash; the outwash is along the headwaters of the west branch of Maple River in Center and Pleasantview townships north of Petoskey. Most of the plain areas were the bed of glacial Lake Algonquin which covered much of the area after the ice had abandoned the region.

The Ancient Shorelines

The transition from the melting away of glacial ice to the period of submergence of most of the Straits region by lake waters is not distinctly marked. There are good reasons for believing that the spreading lake waters which advanced on the land as the ice front retreated belonged to an early phase of Lake Algonquin and that the highest level reached by this early lake was not as high as the strong shoreline built by the later Lake Algonquin. The beaches formed by the early lake were probably destroyed during the time when they were submerged and washed over by waves at the higher level that made the Algonquin beach, which in Michigan is the highest and oldest of the several ancient shorelines.

THE ALGONQUIN SHORELINE

The Algonquin shoreline is perhaps the most important physiographic feature and boundary in the Straits region as well as throughout the northern Great Lakes area. In Michigan the Algonquin shoreline was made by a rising lake which like all rising lake levels had particular ability to develop a strong shoreline. The shore is especially conspicuous as it is the highest of the ancient strands and generally marks the change from a gently sloping plain or terrace to more rugged upland. In most places the boundary is a steep, wave-cut slope in the higher moraine or a line of rock cliffs, as on Mackinac Island, but elsewhere, especially at embayments, a broad, gravel ridge marks the upper limit of the ancient surf.

The outlet of Lake Algonquin was for a long time at Kirkfield, Ontario, with drainage eastward to the Ontario basin, but with the withdrawal of the ice sheet and consequent widespread northeastward uplift of the continent the outlet and the level of the lake were raised until the lake waters overflowed to the south by way of Port Huron and Chicago creating a three outlet stage of Lake Algonquin which endured for a long time. The Port Huron and Chicago outlet areas were not affected by the uplift, as they were south of the "hinge line"—that is,

south of the southern edge of the uptilted area and in the area of horizontality. Consequently as uplift continued, lake level remained stabilized on the outlets at Port Huron and Chicago while the northern shores emerged from water and the Kirkfield outlet was eventually abandoned. The Algonquin beach was formed during, or in a pause within, the slow transitional period when drainage shifted to the southern outlets, that is during a three-outlet stage, a time of rising lake waters when their working, cutting, building power was at a maximum. Over the Mackinac Straits region the waters of Lake Algonquin gradually rose and encroached on the land to the position where the lake built the great Algonquin beach and then as the uplift continued, the lake waters gradually receded to a lower level. Meanwhile erosion along the Port Huron outlet seems to have lowered the lake sufficiently to cause abandonment of the Chicago outlet, because a broad rock floor prevented similar cutting down of that outlet, and to divert all the waters of the lake eastward past Port Huron to the lower Great Lakes.

Lake Algonquin was the most expanded body of water in Great Lakes history during the stage when the Algonquin beach was formed. The northern parts of Emmet, Cheboygan and Presque Isle counties were an archipelago of islands. The largest island covered about five townships of Emmet County north of Little Traverse Bay. Wide arms of water stretched from Petoskey to Mackinaw City and to Cheboygan. Most of the present day islands of Mackinac Straits region were entirely submerged but small parts of Mackinac, Beaver and South Fox Islands were high enough to stand above the lake. Northward from the present Straits, Lake Algonquin covered the entire St. Ignace peninsula and nearly all of the eastern four counties of the Northern Peninsula. The geography of Algonquin time was indeed a contrast to that of the present day.

One of the most interesting facts connected with the Algonquin shoreline is its deformation. The shoreline is horizontal around southern lakes Huron and Michigan and only 27 feet above present water level, but its elevation increases northward from the "hinge-line" which extends from Grand Bend, Ontario, across Lake Huron, and Saginaw Bay, past Standish, Arenac County, Michigan and northwestward (about N. 68° W.). Although the altitude of the shore is 607 feet above sea level south of the hinge-line, it rises to 709 feet at Harbor Springs, Emmet County (at the south edge of the area of this report) to 813 feet at Mackinac Island, to 863 feet at Hessel, Mackinac County and to a much greater altitude at Sault Ste. Marie. These differences in a once horizontal beach illustrate the large upwarp of the land in the northeast which took place in response to removal of the glacier's weight.

Around embayments and wherever a gravel ridge marks the Algonquin shore, a series of successively lower ridges are generally found down to 40 or 50 feet which are known as the "upper group" of Algonquin beaches. They are excellently displayed on the short target range and on the western slopes of Mackinac Island, and also north of Bliss and south of Cross Village in Emmet County. They appear to be the result of continued uplift of the land which elevated this area with consequent change of water level after the Kirkfield outlet of Lake Algonquin had been abandoned. Below the lowest of these beaches, none are found for some distance and the lake is presumed to have discovered a newly ice-freed outlet eastward across Ontario and to have drained down rapidly so that its waves were unable to form distinctive shorelines until a relatively stable level was again established.

LOWER ALGONQUIN SHORELINES

The procedure just described was apparently repeated a number of times; that is, periods of fixed outlet which lasted for sufficient time to develop marked beaches were followed by quick lowering, of lake level as the retreating ice front released new and lower drain-ways. Below the upper group of Algonquin beaches are several intervals quite devoid of good beaches, interspaced with shorelines which are fairly strong though not at all comparable to the Algonquin beach itself. These several shorelines are known collectively as "lower Algonquin". The discontinuity in spacing of these lower beaches is in striking contrast with the regular beach successions of the upper Algonquin group, or of the post-Nipissing group. A conspicuous beach of this lower group, having an elevation of 718 feet is in northern Mackinac Island on the "Battlefield" of August 4, 1814. Other good examples are at a corresponding level on the hills behind St. Ignace. A number of lower and later beaches are some distance below the Battlefield Beach on Mackinac Island,[3] in the St. Ignace area and on the mainland south of Mackinac Straits. The summit of Round Island, opposite Mackinac Island Village, is a broad pattern of shoal ridges associated with one of these shorelines.

From relationships of all these shorelines with later shorelines seen only much farther northeast, the conclusion is warranted that the lake continued to fall intermittently to still lower levels, even far below the level of the modern lake in Mackinac Straits. It seems likely that lowering proceeded to such an extent that the submerged valley of the Straits (fig. 1) was used by a river flowing into the Huron basin from a separate lake in the Lake Michigan area. The geography of this period was wholly different from the geography during formation of the Algonquin beach. Most of the modern islands in Mackinac Straits area were then joined with the mainland; Mackinac Island was a headland reaching out from Cheboygan County by way of Bois Blanc and Round islands.

The sequence of falling lake levels terminated when the lowest outlet from the Huron basin, the channel of the Mattawa valley east of North Bay, Ontario, was freed of ice and permitted unobstructed flow of glacial and lake drainage eastward into the Ottawa River. Glacial obstruction of outflow had then performed its last role in

the development of the Great Lakes and continental uplift remained the only factor for later change. Only about 20 per cent of the total upwarp of the Algonquin beach had taken place by this time. Much the greater part of the uplift came later with great effect on the geography of the lakes region. The Mattawa-Ottawa outlet eastward from Georgian Bay was located in the most northeasterly part of the lake whose level it now controlled. Here continental uplifting was at a maximum, therefore lake level rose steadily higher and lake waters flooded over the shores to the south and west. Thus a period of intermittently subsiding lake levels, with a total drop of a few hundred feet, was followed by a period of steadily rising lake levels until the lake once again overflowed to the south.

THE NIPISSING SHORELINE

The return of southward discharge past Port Huron brought another culminating lake level known as the Nipissing stage and the formation of the Nipissing beach. This beach is directly analogous to the highest Algonquin beach in strength of development and in being the product of a two-outlet lake stage after a period of rising water. About 85 per cent of the uplift of the Algonquin beach had by now taken place and the lakes had reached more nearly their modern outline in contrast to their wide extent in Algonquin times. Consequently the Nipissing beach was affected by only the last small fraction of postglacial uplift. It is only slightly tilted and is generally close to the modern shore. Lake Superior was not yet separated from the lower lakes but was connected by a narrow strait through the St. Mary's valley.

In the area covered by this report, the Nipissing beach rises 23 feet from 615 feet at Harbor Springs, Emmet County in the south to 688 feet at Hessel, Mackinac County in the north but in the same distance the Algonquin beach rises 154 feet. This difference in differential rise of the two beaches demonstrates that the Nipissing shoreline was affected by only a minor amount of the movement of continental uplift. The Nipissing beach is well shown on Mackinac,[3] Round Bois Blanc islands, the Fox islands, and the Beaver islands, in most places it is a terrace at the foot of a sharp wave eroded bluff or is a conspicuous gravel bar. The wave cut bluff is well shown on the fairway of the Mackinaw City golf course and about one mile south of Mackinaw City where the highway to Petoskey crosses the beach; at intervals along the highway from Mackinaw City to Cheboygan especially about the outskirts of Cheboygan where the bluff extends up the river and encircles Mullet Lake. A magnificent Nipissing gravel spit is just north of the St. Ignace airport. Well developed bars are on Mackinac Island; one near British Landing- another immediately southwest of the lower entrance to Fort Mackinac has a church on it. At each of these places a significantly deep trough like depression is behind the gravel ridge which was built by rising waters and surf that heaped gravelly materials up the general off-shore slope.

POST-NIPISSING SHORELINES

The abandonment, due to continued uplift, of the eastward North Bay (Mattawa) outlet of the post glacial Nipissing. lakes was the last major drainage change in Great Lakes history and was followed by total discharge southward past Port Huron. Post-Nipissing uplift has gradually raised the Mackinac Straits region out of water and in favorable places, regular successions of post-Nipissing beaches have been formed. North of British Landing on Mackinac Island, twenty-eight successive gravel ridges were counted, well distributed between the Nipissing (elevation 630 feet above sea level) and modern shores (at 583 feet above sea level), with an average difference in level between any two consecutive beaches of less than two feet. The number of beaches in this series varies in different places and is not significant except that the number generally increases northeastward due to widening out in that direction of the vertical interval in which they occur. In some places no good beaches may be recognized below the Nipissing, and in most places the succession is incomplete. Only where materials accumulated abundantly from along shore drifting is a full series of these beaches found. The separation of Lake Superior and appearance of the "Sault" (St. Marie) was accomplished by uplift about midway in post-Nipissing time. Since studies of Niagara gorge and the rate of retreat of Niagara falls have shown this total interval to be about 4000 years, St. Mary's rapids probably came into being at about the time of Christ. Thereafter Lake Superior's level was controlled by its own outlet at the Sault on which it pivoted during subsequent tilting. Around the northeast coast of Lake Superior, the Nipissing shoreline is more than 100 feet above Lake Superior, but at Duluth it has been submerged by the rising water.

STACKS AND SEA-CAVES

Wave erosion in the bedrock about St. Ignace and Mackinac Island has left a number of striking features such as stacks, frequently known also as skerries and chimney rocks, and some sea-caves. Most of the stacks and caves are associated with either the Algonquin or Nipissing shorelines and are developed in the brecciated limestones. Where the breccias offered superior resistance to erosion, stacks were developed.

On the St. Ignace peninsula several mesa-like plateaus of bedded rock rise from 100 to 200 feet above the lake. They are surrounded by lowlands, generally less than 50 feet above the lake, dotted with inland lakes and swamps. The Nipissing shoreline skirts these plateaus and connects some of them with large gravel bars which enclosed large bays or lagoons. Wave erosion cut back the more exposed fronts of the plateaus into sharp cliffs, stripping the stratified limestones and shales from the scattered plugs of more resistant breccia.

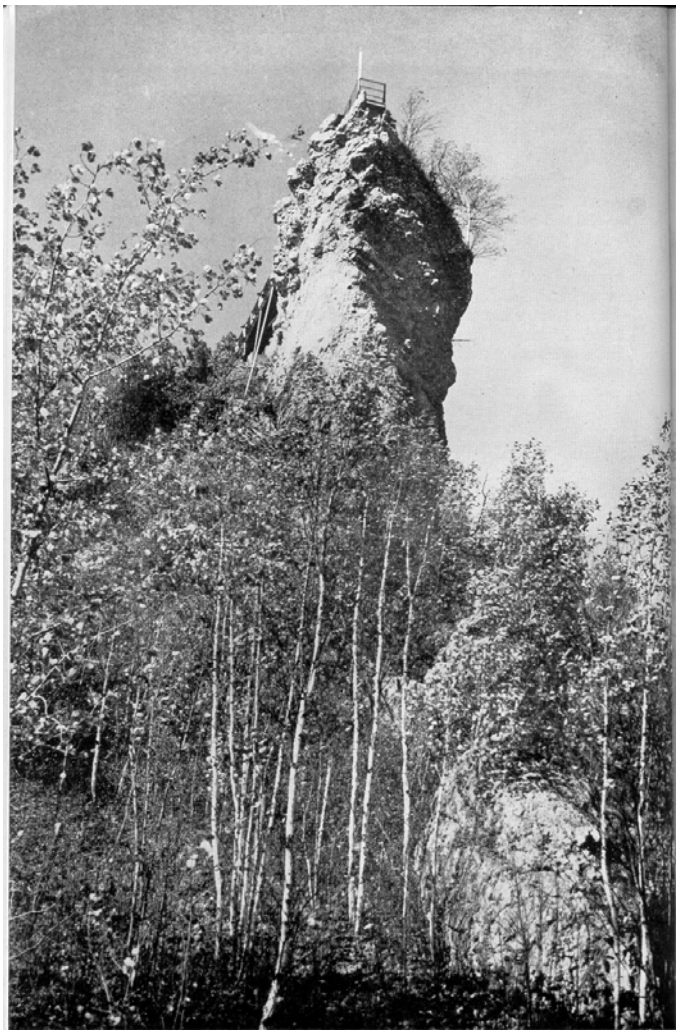


Plate I. Castle Rock, St. Ignace.

St. Anthony's Rock (frontispiece) in the central part of St. Ignace is a splendid example of a stack, situated several yards in front of the Nipissing cut cliff. Castle Rock, (pl. I) though not a true stack, is a more conspicuous feature overlooking the main highway north of town; it stands up boldly, buttressing a sharp Nipissing headland from which it was not quite isolated by the waves. Also along the cliffs in the north part of St. Ignace and at Gros Cap to the west, columns of breccia mark out distinctive promontories of the Nipissing shore (pls. XVIII, XX).

On Mackinac Island[3] the breccias are shown in the same fashion and in greater abundance. The most prominent stack is Sugarloaf Rock which stands 75 feet above the surrounding flat and 300 feet east of the Algonquin shore cliff with which it is associated. A smaller stack protected the southwest corner of the Mackinac Island of Algonquin time and wave erosion removed some of the weaker material from it, producing Skull Cave. Scott's Cave in the northeast part of the island was formed at the Nipissing stage of the lake and clearly exhibits the effects of wave erosion on its smoothed and rounded floor. About 500 feet northwest of the cave a small stack is on the Nipissing terrace, and a larger stack at the same level, known as Friendship's Altar, is about 600 feet north of British Landing Road. Robinson's Folly, Lover's Leap, Sunset Rock and many others including the cliff near the South Sally Port of Fort Mackinac, are conspicuous pinnacles of breccia projecting from the Nipissing cliffs. Devil's Kitchen, Fairy Arch and the eminence at Arch Rock are related in the same way to the Nipissing shore.

All these features are evidence of the erosional activities of the waves but each one has a considerable vertical elevation and indicates only roughly the level of the lake which formed it. The altitudes of the ancient strand lines are much better obtained from the gravel beach ridges or eroded terraces.

[1]Stanley, G. M.: The submerged valley through Mackinac Straits, Jour. Geol., Vol. 46, pp 966-974, 1938.

[2]Leverett, Frank, and Taylor, F. B.: The Pleistocene of Indiana and Michigan and the history of the Great Lakes, U. S. Geol. Surv., Mon. 53, pp. 302-315, 1915.

[3]Stanley, G. M.: Pre-Historic Mackinac. Michigan Dept. Cons. Geol. Surv. Div. Pub. 43, Geol. Ser. 36, 1945.

Chapter II. STRATIGRAPHY OF SURFACE FORMATIONS

GEORGE M. EHLERS

CLASSIFICATION OF ROCKS

Previous Classifications

Dr. J. J. Bigsby, a British Army surgeon and author of numerous papers on the geology of Canada and the United States, probably made the earliest study of the rocks of the region bordering the northern part of Lake Huron. Dr. Bigsby (1821, pp. 266, 268-269 and 1824, pp. 193-195)[1] briefly described the brecciated rocks of Michilimackinac, now known as Mackinac Island, but presented no classification showing the stratigraphic relationship of the breccia to other rocks of the Mackinac Straits region.

Douglass Houghton, the first State Geologist of Michigan, divided (1840a, pp. 214-220 and 1840b, pp. 74-82)[2] the sedimentary rocks of the Northern Peninsula into the "Lake Superior Sandstone", "Lower Limerock and Shales" and the "Upper Limerocks." The Lake Superior sandstone contains strata most of which are of Upper Cambrian age. The Lower Limerock and Shales include formations now assigned to the Middle and Upper Ordovician. The Upper Limerocks comprise strata of Silurian and Devonian ages.

Houghton (1840a, p. 218 and 1840b, p. 78)[2] stated that the Upper Limerocks may be divided into a "lower, or Pentamerus portion", a "middle, or Polypyferous portion" and an "upper, or Mackinac and Manitoulin portion." The lower and middle portions contain strata which are now placed in the Niagaran series of the Middle Silurian. Strata on Manitoulin Island, which Houghton probably had in mind when defining "the upper, or Mackinac and

Manitoulin portion", are older than any rocks on Mackinac Island and also are of Middle Silurian age. According to Houghton (1840a, p. 218 and 1840b, p. 78)[2] the "upper portion of the rocks (Upper Limerocks) form the base of that group of islands, east from Mackinac, known as the Cheneaux, as well as the island of Mackinac and the range of hills extending westward on the mainland, commencing with the bare point of rock, known as the Sitting rabbit" (now known as Rabbit's Back). Les Cheneaux Islands are now thought to be underlain by the Engadine dolomite, the highest formation of the Niagaran series in the Northern Peninsula. Mackinac Island and the "range of hills" on the St. Ignace peninsula of the mainland west of Mackinac Island are composed chiefly of a Middle Devonian formed breccia, the Mackinac breccia, in which the blocks of dolomite, limestone and shale of Upper Silurian and Middle Devonian ages.

Houghton (1840, p. 222 and p. 82)[2] noted that the "middle and upper portions of the upper group of limestones" (apparently Houghton's Upper Limerocks) contain veinlets of gypsum in the bed of Lake Huron near St. Martin's Island and at several points on the coasts west of Mackinac. The strata having this gypsum belong to the Salina group of the Upper Silurian and on later pages of the present report are assigned to the Pointe aux Chenes formation.

Houghton (1840a, p. 221 and 1840b, p. 81)[2] briefly mentioned the "shattered condition" of the rocks on Mackinac Island, their "vesiculated structure" and susceptibility to disintegration. The rocks to which his remarks apply belong to the Mackinac breccia described in detail in Chapter III.

In his Fourth Annual Report to the Senate and House of Representatives, Houghton, (1841, p. 486)[3] presented a table to illustrate the order of super-position of the rocks of the Northern Peninsula. Examination of this table and Houghton's description of the strata listed therein (pp. 480-486)[3] show that Houghton had recognized several additional lithologic units since his work of the previous year. The division of the "Upper Limerock Group", which undoubtedly is the same as "the Upper Limerocks", into two parts "the Drummond Island and Mackinaw Limestones" is of interest because he recognized that these limestones were different and perhaps realized that the "Mackinaw limestone" was younger than the "Drummond Island limestone." Houghton did not intend to use the terms for exact stratigraphic units because he stated (1841, p. 484, foot-note)[3] that "the names which have been affixed to the several sand and lime rocks are regarded as merely temporary, and are introduced, for the present, barely to facilitate description."

C. C. Douglass, Assistant Geologist working with Douglass Houghton, gave additional information on the rocks of the Straits area in a paper which is incorporated as a part of the State Geologist's Fourth Annual Report to the Senate and House of Representatives. In this paper Douglass (1841, p. 545)[3] presented tables showing a classification of the rocks along the shores of Lakes Michigan and Huron. He (p. 548)[3] described the "Mackinac limestone" in considerable detail and noted the occurrences of this rock on Mackinac, Round and Bois Blanc Island, on "Sleeping Rabit" (=Rabbit's Back) and in the bed of the lake west of old Fort Mackinac as far as "point Wabachance" (=Waugoshance Point). It is evident from his description that Douglass observed the brecciated rocks of the Mackinac Straits region and noted sections of strata, which are now in this report assigned to the Upper Silurian St. Ignace formation (new formation name) and the Middle Devonian Bois Blanc formation (new formation name). The St. Ignace and Bois Blanc rocks seen by Douglass are present as large blocks within his "Mackinac limestone", which is now designated the Mackinac breccia.

Douglass (p. 545-table and p. 550)[3] reported the occurrence of "Corniferous limestone" in T. 33 N. in his classification of the rocks of Lake Michigan. Douglass' Corniferous limestone is not the Corniferous limestone of Ontario and New York, which is now known as the Onondaga limestone. The Corniferous limestone, which Douglass noted, with little doubt is a very cherty limestone of the Middle Devonian Traverse group exposed on the shore of Lake Michigan about one mile north of Norwood in T. 13 N. of Charlevoix County.

James Hall (1843, pp. 118, 512, 519, 682 and map)[4] in his classic monograph on the geology of the fourth geological district of New York, gave information which contributed much to the knowledge of Michigan geology. In his discussion of the Onondaga salt group, which is typically exposed in New York, he (1843, p. 118)[4] noted that strata of the upper part of this group are present as far west as Mackinac Island. In chapter 23 dealing with a discussion of the rocks of states west of New York, Hall (p. 512)[4] again noted that "the upper part of the Onondaga salt group, and possibly a small portion of the Waterlime group" were observed at Mackinac Island. In the same chapter he (p. 512)[4] stated that "the limestone of the Helderberg series, principally the Corniferous and Onondaga masses, form the rocks of many of the bays and harbors; characteristic fossils of the masses being recognizable in those examined." On page 519 of his monograph, Hall presented a table to show which strata of various states were equivalent to formations of the New York section. A heading, "Michigan Survey," at the top of the column of Michigan rock terms indicates that Hall attempted to coordinate his findings with those of Douglass Houghton and C. C. Douglass of the Michigan Geological Survey. In the table Hall showed the Mackinac limestone as equivalent to the Onondaga salt group. He correlated the "Little Traverse bay limestone", "Black bituminous limestone," and "Blue limestone in thick regular layers" with New York formations occupying positions between the Onondaga salt group and the Onondaga limestone. The three Michigan limestones noted by Hall and the "Thunder bay limestone," which he doubtfully correlated with the same New York formations, are younger than the Onondaga limestone of New York and are now included in the Traverse group of Michigan. In the table of formations Hall correlated the

"Corniferous" of Michigan with the Corniferous and Onondaga limestones of New York.

The colored geological map of the middle and western states, which appears at the back of Hall's monograph, is of considerable geologic interest. On this map the northern, southeastern and southwestern parts of the Southern Peninsula are shown as being underlain by Helderberg rocks. Belts of color representing progressively younger strata towards the central area of the Southern Peninsula indicate the existence of a basin structure. The recognition of the Michigan Basin should be credited to Douglass Houghton since as Hall stated (1843, p. 682)[4] Houghton supplied him with the geological map of Michigan.

An important contribution to the classification of the rocks of the Mackinac Straits area was made by James Hall in J. W. Foster and J. D. Whitney's "Report on the geology of the Lake Superior Land District", published by the United States government in 1851. Hall (1851, pp. 161-162)5 assigned the marls, gypsum and vesicular and gashed limestones of Mackinac Island, the St. Martin islands and the mainland north of St. Ignace to the Onondaga Salt group, which is typically exposed in the state of New York. Most of the strata of the Onondaga Salt group are now included in what is known as the Salina group. As explained later in this report, the marls, chiefly green and red shales, and gypsum noted by Hall are included in the newly named **Pointe aux Chenes formation** (new formation name) of the Salina group. The vesicular and gashed limestones observed by Hall are now included in the St.

Ignace formation of this report. The St. Ignace formation is assigned to the Bass Islands[6] group, which is believed to be younger than the Salina group. Hall (1851, p. 162)[5] recognized that the fossiliferous "lower Helderberg series" of New York, now known as the Helderberg group, was not in the Straits region. He noted (p. 162)5 the breccia of Mackinac Island and stated: "I cannot but regard the brecciated mass as terminating the Onondaga salt group, or perhaps more properly, as marking the era of the commencement of the succeeding group, which, as will be shown, corresponds with the upper Helderberg limestones of New York." He also recognized (pp. 162-163)[5] that the "lower Helderberg series" of New York, essentially the Helderberg group of present day terminology, is absent in the region and that the "upper Helderberg series," embracing the Schoharie grit and Onondaga and Corniferous limestones of Hall's time, rests directly on the "Onondaga Salt group."

With little doubt Hall (1851, pp. 163-166)[5] believed that the breccia of the Straits area, designated the "Mackinaw limestone" by Houghton and the "Mackinac limestone" by Douglass, belonged to the "upper Helderberg series." The basis for this belief was Hall's recognition of fossils in blocks of the breccia which are identical with fossils found in the Schoharie grit and Onondaga limestones of New York. It is most significant that Hall (pp. 166, 224-225, 228)[5] reported the occurrence of the trilobite *Phacops anchiops* in the cliff of Arched Rock on Mackinac Island. This trilobite, now known as *Anchiopsis anchiops* (Green), is as stated by Hall (p. 166)[5] characteristic of the Schoharie grit of New York. Hall undoubtedly obtained the trilobite from blocks of limestone within the Mackinac breccia. The blocks belong to a formation which in this report is designated the Bois Blanc formation. The rocks of this stratigraphic unit contain not only *Anchiopsis anchiops* (Green) but many other fossils diagnostic of the Schoharie grit and Onondaga limestone.

Hall (1851, p. 165)[5] stated that the upper beds of the upper Helderberg series come to the level of the water "in the neighborhood of Presqu'ile, on the western shore of Lake Huron." The strata at this locality, which is about 70 miles southeast of Mackinaw City, belong to the Dundee limestone and are younger than beds of the upper Helderberg series exposed in the vicinity of the Straits of Mackinac.

Alexander Winchell, the second State Geologist of Michigan, (1860, pp. 57-69)[7] used the terms "Onondaga Salt group" and "Upper Helderberg group" for the rocks of the Straits area in much the same manner as James Hall. Winchell (1860, pp. 58-59)[7] assigned to the Onondaga Salt group certain rocks of Monroe County which are now placed in the Upper Silurian Bass Island group and Middle Devonian Detroit River group. He included in the Upper Helderberg group the strata of Crawford's quarry, the site of the present Michigan Limestone and Chemical Company's quarry at Rogers City, the strata of Middle Island about 28 miles southeast of Rogers City, and of Thunder Bay Island about 40 miles southeast of the city. The rocks at these three places are younger than typical upper Helderberg deposits and are now included respectively in the Dundee and Rogers City limestones, Rogers City limestone, and the Traverse group. The Dundee strata of the Judge Christiancy quarry at Dundee, Monroe County and at Mongaugon (=Sibley, two miles north of Trenton), Wayne County, and apparently beds of the Traverse group of Little Traverse Bay were placed in the Upper Helderberg group by Winchell (pp. 64-65)[7].

Winchell (p. 60)[7] reported the occurrence of a "cherty and agatiferous conglomerate" on Mackinac Island and the mainland west of this island which he believed occupied the position of the Oriskany sandstone of New York and "may not improbably be regarded as representing that formation." This conglomerate most likely is a broken or weathered block or cherty dolomite or limestone of the Bois Blanc formation and is in the Mackinac breccia. The geological map of southeastern Canada and the northeastern part of the United States, published in the "Atlas of Maps and Sections" in 1865 and intended to accompany the "Report on the Geology of Canada by W. E. Logan and others (1863, 983 pages)[8] gives information on the classification and distribution of the rocks of Michigan. On this map (1865, pl. I)[9] the region adjacent to St. Ignace and Mackinac Island is shown as being underlain by "Onondaga"

strata, which as indicated by Logan (p. 345)[8] are equivalent to the Onondaga salt group of New York. The Beaver Island group in Lake Michigan and the northern, southeastern and southwestern parts of the Southern Peninsula are shown as being occupied by "Corniferous & Oriskany." Since the "Corniferous & Oriskany" of the entire region covered by the map were indicated by one color, it is impossible to tell whether only one or both of these formations are at a particular locality. The classification and distribution of the strata of Michigan as shown on the map was obtained, as Logan stated (1865, p. 16)[9], from information given him by Alexander Winchell and James Hall and from the results of studies by Houghton and others.

In 1875 N. H. Winchell (1875, pp. 103-107)[10] adopted the views of his brother Alexander Winchell in classifying the rocks of the Mackinac Straits area. He stated (p. 103)[10] that the strata which "constitute the base of Mackinac Island," are a part of the Water-lime Group and "belong to the lower part of the *Lower Helderberg*" and those of the elevated part of this island belong to the "*Upper Helderberg*." The two sets of strata, according to N. H. Winchell (p. 103)[10], "are separated by an 'agatiferous conglomerate' supposed to be equivalent to the *Oriskany Sandstone*, which at Crawford's Quarry appears near the bottom of the outcrop as a 'brown calcareous sandstone, and in Southern Michigan and Northern Ohio as a 'white saccharoidal sandstone.'" N. H. Winchell, like his brother, was mistaken in believing that the "agatiferous conglomerate" and "brown calcareous sandstone" are equivalent to the Oriskany sandstone. The "white saccharoidal sandstone" of Southern Michigan and Northern Ohio, mentioned by Winchell, is now known as the Sylvania sandstone, a formation which is younger than the Oriskany sandstone.

N. H. Winchell (pp. 103-106)[10] incorrectly assigned rocks of several particular localities in the Southern Peninsula to positions in his stratigraphic classification. Most of these errors have been recognized by later students of Michigan stratigraphy. Evidence given in this report indicates the correct stratigraphic assignment of the rocks of the Straits area noted by Winchell.

In 1873 Carl Rominger (1873, pp. 14, 29-31)[11] used the term "Onondaga Salt group" for dolomite and green and red variegated shale with some gypsum overlying the Middle Silurian "Niagara group" (=Niagaran series) of the Northern Peninsula of Michigan. In this usage he followed the terminology of James Hall. Now, in this report, the strata of Rominger's "Onondaga Salt group" are assigned to the Pointe aux Chenes formation of the Salina group.

Rominger (1873, pp. 14, 22-29)[11] used the term "Helderberg group" for the rocks of the Northern Peninsula which are above the "Onondaga Salt group." On two pages of his report he (pp. 22-23)[11] pointed out that in New York and other states the Helderberg group has two divisions and that only the upper division is represented in Michigan. On later pages (pp. 26-28)[11] he noted the occurrence of thin, even-bedded, light-colored dolomites at the base of the breccia, which composes most of the Helderberg group of Mackinac Island and vicinity, and stated that these dolomites occupy an intermediate position between the rocks of the Onondaga Salt group and "well-characterized upper Helderberg strata." The finding of a few supposed lower Helderberg types of fossils in the dolomites led Rominger (p. 28)[11] to state that "we may safely take the intermediate beds as contemporaneous with the lower Helderberg group." The results of the study made by the writers in 1942-43, however, indicate that the thin, even-bedded, light-colored dolomites, which are now included in the St. Ignace formation, are older than any strata of the "lower Helderberg group" of Rominger's time. Rominger (p. 24)[11] described the "upper division" of the Helderberg group in the Northern Peninsula as consisting of "uneven-bedded limestones, and by cherty and argillaceous layers" and stated that blocks of these strata had become undermined by weathering and had "tumbled down-hill into open clefts between the breccia rocks." The uneven-bedded, cherty and argillaceous limestones noted by Rominger undoubtedly belong to the Bois Blanc formation defined and described in later pages of this chapter. Although some blocks of these limestones may have fallen into fissures of the breccia as stated by Rominger, most of the blocks undoubtedly were incorporated in the breccia at the time of its formation. The fact that Rominger (p. 24)[11] stated that "fossils are very abundant in this upper division and in the subjacent terminal strata of the brecciated limestone" indicates that Rominger himself was aware of the incorporation of blocks of the fossiliferous, cherty limestones in the breccia. The numerous species of fossils from the Helderberg group listed by Rominger (pp. 25-26)[11] prove that he was correct in correlating the fossiliferous, cherty limestones with the "corniferous" (=Onondaga) limestone of "Canada West" (=Ontario).

In his "Geology of the Lower Peninsula" Rominger (1876, pp. 23-24)[12] used the term Helderberg group for several exposures in the Mackinac Straits area. He correctly recognized that the strata at McGulpin's Point and at the top of Mackinac Island belonged to the very fossiliferous upper division of the Helderberg. He was successful in tracing these strata, composing the Bois Blanc formation of this report, to the Beaver Islands by means of drift material. He assigned ledges on the lake bottom adjacent to Whiskey Island in Lake Michigan and on Round and Bois Blanc Islands in Lake Huron to the lower part of the Helderberg group. These ledges are older than the fossiliferous cherty limestones and are included in the St. Ignace formation defined and described later in this chapter.

Rominger (pp. 24-35)[12] correlated the Helderberg strata of the Straits region with certain rocks of southeastern Michigan. He stated that dolomites in Lenawee, Monroe and Wayne counties, which many years later were placed in the "Monroe formation," were equivalent to the lower division of the Helderberg group of Mackinac Island. He correlated strata exposed in quarries near Trenton, Wayne County, and the Judge Christiancy

quarries on Macon Creek with the upper division of the Helderberg group. The strata of all these quarries belong to the Dundee limestone, a formation which occupies a stratigraphic position above the highest rocks of the Helderberg group.

In his report as State Geologist for the years 1891-1892, M. E. Wadsworth (1892, pp. 84-86)[13] published tables showing the classification of the rocks of Michigan. In the table classifying the rocks of the Upper Peninsula he (p. 84)[13] followed Hall, Winchell, and Rominger in applying the new York terms "Onondaga (=Onondaga salt group)," "Lower Helderberg," and "Upper Helderberg" to strata of this region. In the table of the deposits of the Lower Peninsula he (pp. 85-86)[13] used the term "Upper Helderberg" for strata, which now are included in the Dundee limestone and the underlying Detroit River group. Below the "Upper Helderberg" he recognized a sand, which he doubtfully designated "Oriskany." This "sand" may be the Sylvania sandstone of present terminology. Below the doubtful Oriskany Wadsworth noted "Silurian limestones," which unquestionably include strata of Middle and Upper Silurian ages.

In Wadsworth's report (p. 66)[13] for the years 1891-1892, A. C. Lane presented a classification of Michigan rocks in which appear the formation names "Dundee limestone" and "Monroe Beds." In 1895 the Dundee limestone was described by Lane (1895, pp. 25-26)[14] who stated that the name Dundee "is nearly equivalent to Corniferous or Upper Helderberg." At the same time Lane (pp. 26-28)[14] described the "Monroe Beds," noting that "the period of the Monroe beds is that of the Salina and Lower Helderberg."

In two papers Lane (1899a, p. 88 and 1899b, pl. 2)[15 16] noted the occurrence in southeastern Michigan of the Sylvania sandstone, which is typically exposed in northwestern Ohio. He (pl. 2)[16] referred to the Monroe strata as "Monroe above Sylvania sandstone" and "Monroe below Sylvania sandstone."

W. H. Sherzer (1900, pp. 35-40, 43-100, pl. 1)[17] in his report on the geology of Monroe County, Michigan, described the Monroe beds and Dundee limestone in much detail. He followed Lane in differentiating the Monroe rocks above and below the Sylvania sandstone.

In 1909, A. C. Lane, C. R. Prosser, W. H. Sherzer and A. W. Grabau (1909, pp. 553-556)[18] presented a detailed classification of the Monroe strata. In this classification the strata were divided into the "Lower Monroe or Bass Islands[19] Series," the middle Monroe, consisting of the Sylvania sandstone, and the "Upper Monroe or Detroit River series." All of the Monroe strata were considered by these geologists as being of Upper Silurian age.

Many years later, C. R. Stauffer (1916, pp. 72-77)[20], M. Y. Williams (1919, pp. 18-22)[21] and J. E. Carman (1927, pp. 481-506 and 1936, pp. 253-266)[22 23] published papers which show that the Lower Monroe or Bass Island series is of Upper Silurian age but that the Sylvania sandstone and Upper Monroe or Detroit River series are of Devonian age. The opinions of these geologists and other references pertaining to the classification of the Monroe strata are given in later pages of this chapter, particularly in the discussion of the nomenclature of the Detroit River rocks.

The extensive use of the names Monroe and Dundee for strata in southeastern Michigan resulted in the application of these names to rocks of the Mackinac Straits area. Lane (1895, p. 28 and pl. 63)[14] as early as 1895 included gypsum and salt beds of this area in the Monroe Beds, noting in the legend of the record of a deep well at St. Ignace that the Monroe Beds were equivalent to the "Lower Helderberg and Salina." At the same time he (p. 26)[14] stated that the Dundee limestone was at the "northern end of the Lower Peninsula to Mackinaw City." In the record of a second deep well at St. Ignace, Lane (1902, pp. 227-228)[23] again included beds of gypsum, red and blue shale and some dolomite in the "Monroe" which now are known to belong to the Salina group. On a geological map of Michigan, Lane (map opposite p. 224)[23] shows the distribution of the Monroe and Dundee strata in the Straits region. In the legend of the map the Dundee is indicated as being equivalent to the "Corniferous, Upper Helderberg" and the Monroe as including "Waterlime, Salina, Onondaga." G. P. Grimsley (1904, pp. 80-83, 97)[24] in a discussion of the gypsum deposits of St. Ignace followed Lane in the usage of the term Monroe. I. C. Russell (1905, pp. 44-45)[25] used the term "Monroe formation" for strata which he stated are "about the equivalent in age of the Manlius and Salina." Russell noted the Mackinac breccia and several other beds of the Straits area which Hall had described and assigned to the Helderberg group. He described the breccia of the region and apparently included it in the "Monroe formation." A geological map by A. C. Lane inserted opposite page 40 of Russell's report shows a small area at the northern end of the Southern Peninsula, the St. Ignace Peninsula, some islands of the Beaver Island group, and all of Mackinac and Bois Blanc Islands as being underlain by the Monroe. All of Beaver Island and a northwest-southeast trending belt of land south of Mackinaw City are shown as being occupied by the Dundee limestone. In 1909 A. C. Lane published a detailed description of the geologic section of Michigan. In a table to illustrate the geologic column of Michigan, Lane (1909, table opposite p. 42)[26] assigned the "Salina" and "Lower Monroe or Bass Island"[19] strata to the "Upper Silurian or Ontarian," the "Middle Monroe, Sylvania" sandstone and "Upper Monroe or Detroit River" rocks to the "latest Ontarian, possibly Eo-Devonian," and the "Dundee" limestone to the "Meso-Devonian." Lane (pp. 60-61, 63, 67, 69-70)[26] referred the rocks of several localities in the Straits area to these stratigraphic divisions. He (p. 70) noted that A. W. Grabau (see Grabau, 1906, p. 467; 1907, pp. 718-719; 1908. p. 267)[27] had reported the discovery of a typical Schoharie fauna in the Dundee limestone of Mill Creek, four miles southeast of Mackinaw City. The occurrence of Schoharie fossils in the rocks of the Straits area was, as Lane stated (1909, p. 70)[26], known to

James Hall. The strata containing Schoharie fossils do not belong to the Dundee limestone but to an older formation, the Bois Blanc formation of this report. R. A. Smith in his report on the occurrence of oil and gas in Michigan (1914, pp. 25-27, 242-243, and figs. 2-3)[28] and his paper on limestones of Michigan (1916, pp. 156-159, 198, 203-205, 235, 242 and figs. 7 and 9)[29] adopted Lane's classification and mapping of the rocks of Straits area and described in detail the lithology of several outcrops. R. B. Newcombe (1933, p. 38-39, 44-45, figs. 1-2)[30] and other workers followed Lane in the application of the names Salina, Monroe and Dundee to the rocks of the Straits region.

A. W. Grabau was an exception to most students of Michigan geology in that he recognized the need for the term "Mackinac limestone." In his discussion of the fauna of the Dundee limestone published in W. H. Sherzer's geological report on Wayne County, Michigan he (1913, pp. 365-366)[31] noted that the Mackinac limestone probably was older than "the Dundee limestone of Northern Michigan" and "for this reason and because the faunas are to a certain extent distinct, it is well to use a distinctive name for this formation." He (p. 365)[31] furthermore stated that "on the view that the Mackinac limestone (the so-called Dundee of the Mackinac region) is the approximate equivalent of the Onondaga and Schoharie of New York, the succeeding Bell shales of Northern Michigan represent in part the horizon of the Marcellus, but with a different type of sedimentation." From this statement it seems that Grabau included the Dundee limestone of the northern part of the Southern Peninsula in the Mackinac limestone.

In recent years a few changes were made in the nomenclature of the rocks of the Mackinac Straits area as proposed by Lane and adopted by others. On the centennial geological map[32] of Michigan compiled by Helen M. Martin and published in 1936, much of the Straits area previously mapped as Monroe was indicated as being underlain by the Mackinac limestone. The term Mackinac limestone, proposed by Houghton and Douglass of Michigan's first geological survey, was used because beds within this limestone, which is a breccia, were known to contain Onondaga and possibly younger faunas. In 1938 G. M. Ehlers and R. E. Radabaugh (1938, p. 444)[33] showed that the lower part of the previously designated Dundee limestone of the northern part of the Southern Peninsula contains a typical Dundee fauna but that the upper part, which they named the Rogers City limestone, contains a different fauna. They also noted that the Dundee limestone was younger than the Mackinac limestone.

Proposed Classification

The rocks of the Mackinac Straits region occupy a position between the Engadine dolomite at the top of the Middle Silurian Niagaran series and the Dundee limestone of the Middle Devonian Erian series.

The proposed classification of these strata, the Engadine dolomite and the Dundee limestone is shown in table 1. The series terms and most of the group terms in this table are in common use and are noted in the recent correlation papers by C. K. Swartz et al (1942)[34] and G. Arthur Cooper et al (1942)[35]. The present paper proposes to use Bass Island and Detroit River as terms for groups, which hitherto have been designated as "beds," "formations," and "series."

Pointe aux Chenes is proposed for strata which in recent reports have been designated by the group term Salina. Further study may show that the Salina group of the Straits area contains several formations and that the Point aux Chenes formation is its uppermost division.

St. Ignace is used for light-colored, even-bedded dolomites and few thin shales which the early geologists placed in the Onondaga salt group or Helderberg and which later workers assigned to the Salina or Monroe. The few, poorly preserved fossils collected from these dolomites suggest the inclusion of the dolomites in the Bass Island group.

Garden Island is proposed for a thin formation consisting of dolomite and dolomitic sandstone. This formation, which is exposed only on Garden Island in Lake Michigan, contains an Oriskany fauna and is the oldest Devonian unit in the Straits area.

Bois Blanc is proposed for strata composed chiefly of cherty limestones and dolomites with numerous fossils characteristic of the lower Onondaga fauna of New York and Ontario. Further study of the fossils in the beds of the upper part of the formation may show that the upper beds should be separated from the rest of the stratigraphic unit.

Formations of the Detroit River group have not been differentiated in the Straits area. Outcrops are very few and have not yielded fossils which might aid in the recognition of formations composing the group in southeastern Michigan. The identification of the group in the Straits region is based on lithology, stratigraphic position and especially on the study of logs and rock samples of many deep wells.

Strata occupying a position between the lower part of the Pointe aux Chenes formation and the base of the Dundee limestone are involved in the brecciation of the region. The term **Mackinac breccia**, rather than the older term Mackinac limestone, is used to show the extent of this brecciation and the true character of the rock. The Mackinac breccia is described in detail in Chapter III.

POINTE AUX CHENES FORMATION

NOMENCLATURE: The name Pointe aux Chenes is proposed for the Upper Silurian formation occupying a position between the Middle Silurian Engadine dolomite and the overlying Upper Silurian St. Ignace formation defined on later pages of this report. The name is chosen for the reason that several exposures of the

stratigraphic unit are in the area near Pointe aux Chenes, a headland on Lake Michigan about nine miles northwest of the city of St. Ignace.

System	Series	Group	Formation	
Devonian	Erian	Cazenovia	Dundee limestone	
	Ulsterian	Detroit River	Formations not differentiated—largely unexposed	Mackinac breccia
		Onesquethaw	Bois Blanc	
		Deerpark	Garden Island	
Silurian	Cayugan	Bass Is.	St. Ignace	
		Salina	Pointe aux Chenes	
	Niagaran	Lockport	Engadine dolomite	

Table 1. Classification of the rocks of the Straits of Mackinac region.

DISTRIBUTION: The formation underlies most of the large St. Ignace peninsula north of the Straits of Mackinac; narrow areas on the western, northern, and eastern sides of Mackinac Island; the St. Martins Islands north of Mackinac Island; and St. Martins Point east of St. Martins Islands (see map fig. 2 in pocket). It is possible that some of the drift-covered Cheneaux Islands located east of St. Martins Point and now believed to be underlain by the Engadine dolomite, may prove to be based on Pointe aux Chenes strata when the drilling of deep wells reveals the type of rock beneath the glacial deposits.

Outcrops of the formation are few in number largely because the shales, which compose most of the unit, were carved into a lowland by pre-glacial streams and subsequently were covered by glacial, glacial-lake, and dune deposits; and also because exposures caused by recent erosion or by human excavation quickly weather into soil and become covered by vegetation.

LITHOLOGIC AND PALEONTOLOGIC CHARACTERS: As a result of its lack of resistance to erosion and its cover by drift, soil, and vegetation, the formation exhibits exposures of very small thicknesses from which only an incomplete knowledge of the lithology and superposition of the strata may be obtained. Fortunately the known outcrops and the records of a few deep wells show that the formation consists of green and red shale with thin beds of dolomite of varied lithologic character and small irregular masses and thin beds of gypsum.

Strata occupying a position near the base of the formation are exposed on the right or south bank of the Carp River about half a mile above its mouth on St. Martins Bay approximately 11 miles north of St. Ignace. They consist of very fine-grained, ash-gray dolomites, mottled and shaded with pink; and a few thin layers of indurated shale. Only two feet of rock were visible above the mid-summer high water level of 1943. Dr. Carl Rominger, who had opportunity to study the outcrop at a very low stage of the river stated (1873, p. 30)[11] that the dolomites are in "uneven rugose layers of six to eight inches in thickness, and are inter-stratified with thin seams of shaly and marly substances; numerous cellular cavities, filled with calc-spar and occasionally with sulphate of baryta, are seen in the rock, which has a fine-grained, somewhat earthy fracture. The strata, of which six feet are exposed, have a gentle dip to the southeast, which would bring them under the variegated marls of St. Martins Island. In the opposite direction, the first rocks met with are the Niagara limestones. The immediate contact of the two formation is, however, nowhere to be seen." (Onondaga Salt Group of Rominger = Salina group, and the Niagara limestones = Niagaran series with Engadine dolomite at the top).

About two and a half miles northwest of the Carp River outcrop and south of the center of sec. 12, T. 42 N., R. 4 W., two very small outcrops of green shale are in a Forest Service road at the crossings of two minor tributaries entering the Carp River from the north. The shale may occupy a position below the dolomites near the mouth of the Carp River. This stratigraphic relationship, however, cannot be substantiated until detailed information relative to the super-position of the shales and dolomites of the formation becomes known.

About four miles northwest of the two outcrops of shale and about one and a half miles north of the intersection of the Forest Service road with a road extending from Moran to East Lake is a point close to the boundary between the Engadine dolomite and Pointe aux Chenes formations. South of this point the road descends to the lowland and marshes of the Carp River which with little doubt are underlain by Pointe aux Chenes strata. A short distance north of the point numerous blocks of Engadine dolomite indicate that ledges of this formation are near to the surface. About one mile north of the mapped formational boundary the Engadine dolomite is exposed in the ditches of the Moran-East Lake road at several places between the center of sec. 27, T. 43 N., R. 4 W., and a road leading eastward about a quarter of a mile south of the center of the section.

Extensive pavement-like exposures of the Engadine dolomite are on both sides of a road leading westward to Kenneth between points one and two miles northwest of the center of sec. 27. The dolomite blasted from the bed of the road along the north lines of secs. 28 and 29, and piled around telephone poles, contains very poorly-

preserved remains of a large pelecypod which seems to be *Megalomus canadensis* Hall. This characteristic Guelph species indicates the occurrence of the Guelph fauna in the upper part of the Engadine dolomite, and aids in locating the Engadine-Pointe aux Chenes contact, which must be between the northern parts of sees. 28 and 29, and the lowland along the Carp River.

Pointe aux Chenes dolomites which may not be far above the Engadine-Pointe aux Chenes contact, are exposed along the shore of St. Martins Bay in the NE¼ sec. 34, T. 42 N., R. 2 W., about one and three-quarters miles north of St. Martins Point. Their lithologic character and thickness are noted in the following description of the section:

Section of strata exposed along shore of St. Martins Bay, Lake Huron, about one and three-quarters miles north of St. Martins Point

	Thickness Feet
Pointe aux Chenes formation:	
3. Dolomite, light-buff to cream-colored, with bands of very small oolites	1
2. Dolomite, oolitic, buff to brown, weathered joint-faces showing cross-bedding of oolites	2
1. Dolomite, light buff gray to cream-colored, fine-grained, some layers apparently with very small oolites. Exposed along shore and on lake bottom	5
Total	8

The dolomites at this locality somewhat resemble buff, thick-bedded, oolitic dolomites in the upper part of the St. Ignace formation, which overlies the Pointe aux Chenes. They differ from the St. Ignace dolomites in having well defined oolites rather than oolites which are difficult to discern because they have been modified by dolomitization. Their position in the Pointe aux Chenes formation is low, possibly below the dolomites exposed along the Carp River about eight miles to the west.

Big and Little St. Martins Islands located four and two miles west of St. Martins Point are underlain by Pointe aux Chenes strata with a covering of glacial drift. Green shale and a few thin beds of ash-gray, fine-grained dolomites, some of which have a pink tinge and resemble the dolomites of the Carp River, are at the surface of the low land adjacent to the south shore of Big St. Martins Island in the southern part of sec. 12, T. 41 N., R. 3 W. Undoubtedly the abundant fragments of red and green shale along the northwest shore of the island in the NE¼ sec. 2, T. 41 N., R. 3 W., were cast on the shore by storm waves and ice from ledges beneath the water. Rominger (1873, p. 30)[11] noted that informants had observed gypsum in place on Big St. Martins Island and in blocks along the shores of both Big and Little St. Martins Islands. Although gypsum was not found by Rominger or the writers, it is very likely that gypsum is on the islands but is covered by drift. The shale, dolomite, and gypsum of the two islands doubtless occupy a position in the formation above the dolomites exposed along the shore one and three-quarters miles north of St. Martins Point and on the south bank of the Carp River.

Pointe aux Chenes strata are at or relatively near the surface of the upland south of the lower course of the Carp River in parts of secs. 29, 30, 31, and 32, T. 42 N., R. 3 W. Numerous exposures of green and red shale with some thin beds of gray, fine-grained dolomite are in the ditches along U. S. Highway 2 in sees. 30 and 31, where this highway crosses a ridge between one and two miles south of the Carp River. Red and green shale is encountered when excavating basements for some of the houses adjacent to this part of the highway and is exposed in the ditches of the road on the south line of sec. 30 about half a mile west of Highway 2. The highest strata visible along Highway 2 probably are 100 to 150 feet above the dolomites exposed on the Carp River.

Thin-bedded to laminated, green and red, dolomitic shale can be seen in many of the ditches of the roads in the vicinity of Allenville on the Duluth, South Shore, and Atlantic Railway about four miles west and one mile south of sec. 30, T. 42 N., R. 3 W. Some of the best exposures of the shale, which doubtless occupies a higher stratigraphic position than the strata along U. S. Highway 2, are in the ditches of the road on the south line of sec. 32, T. 42 N., R. 4 W., between Allenville and a point a third of a mile to the west.

A very small exposure of the formation is about 100 yards east of Massey's Hotel, located on the southern shore of Brevort Lake three and a half miles west of Allenville. The outcrop, which is in a path leading to a small wharf, shows six inches of green shale about two and a half feet above the lake, and an over-lying thin-bedded gray dolomite one and a half feet in thickness.

About five feet of green and red shale are exhibited in a pit at the abandoned Round Lake C.C.C. Camp located three and a half miles south of Massey's Hotel and slightly less than a quarter of a mile west of the center of sec. 23, T. 41 N., R. 5 W. (pl. IIA). Much of the shale in the pit, which is only three-fourths of a mile northeast of Pointe aux Chenes and a half mile north of U. S. Highway 2, has weathered to a clayey mass since excavation ceased about five years ago.

Slabs of thin-bedded to laminated, grayish-green, dolomitic shale are in numerous low piles that average five feet in diameter just beyond the shoulders of U. S. Highway 2 in the SE¼ sec. 23, T. 41 N., R. 5 W. (pl. IIB). The slabs of shale evidently were picked up by a power shovel from the road bed and dumped beyond the sides of the highway. The ledges beneath the highway from which the slabs were taken probably occupy a stratigraphic position above the softer shales of the C.C.C. Camp pit.

A very few irregularly shaped masses of mottled white and gray gypsum with some accompanying brownish-tinged selenite are in a pile with various kinds of rock on the south side of the highway. The gypsum was associated with some of the shale beneath the bed of the highway or was transported from some other ledge of the formation by the Pleistocene ice.

About half of a mile farther west small and large slabs of the same thin-bedded, grayish-green, dolomitic shale are on the sides of U. S. Highway 2 in the SW¼ sec. 23,

approximately a third of a mile north of Pointe aux Chenes, and a few hundred yards west of a road leading northward to the C.C.C. Camp. This rock probably was derived from the highway bed at this place, but may have been hauled from the roadbed in the SE¼ sec. 23.

Plate II. A. Weathered green and red shale of Pte. aux Chenes formation in pit at Round Lake C.C.C. Camp.

Plate II. B. Slabs of fossiliferous, dolomitic shale of Pte. aux Chenes formation beside U.S. Highway 2 in the SE¼ sec. 23, T. 41 N., R. 5 W., about 1 mile E. of Pte. aux Chenes.

The slabs at both places contain *Medusaegraptus graminiformis* (Pohlman), *Lingula media* Ruedemann, *Orbiculoidea bertiensis* Ruedemann, *Whitfieldella* sp. cf. *W. subsulcata* Grabau, *Rhytimya buffaloensis* Ruedemann, *Modiolopsis* sp.—possibly new, *Leperditia scalaris* (Jones), fragments of eurypterids and excrementa of worms or other invertebrates (pls. IV, V). Most of these fossil species are characteristic of the fauna of the Bertie formation constituting the uppermost division of the Salina group of New York.

Green shale, which probably is stratigraphically higher than the dolomitic shale noted above, is at the shore of Lake Michigan in the SE¼ sec. 36, T. 41 N., R. 5 W., about two and a quarter miles southeast of Pointe aux Chenes. Slightly less than a mile to the southwest a similar shale is on the beach in the SW¼ SE¼ sec. 31, T. 41 N., R. 4 W.

Numerous pits, from which gypsum was taken many years ago, are in the SW¼ and the NW¼ SE¼ sec 31, T. 41 N., R. 4 W. These old workings probably are those noted by Alexander Winchell (1861, pp. 57-58)[10] as occurring "in the vicinity of Little Pt. aux Chene" and by Carl Rominger (1873, p. 30)[11] as having been "opened near Point aux Chenes." Many of the pits having a depth of 10 to 15 feet may be clearly recognized immediately south of U. S. Highway 2. Soil, bushes, and trees now cover the dolomite, shale, and gypsum which once must have been visible in the excavations. A few blocks of white gypsum with roughly spherical and irregular bands of brownish-tinged crystals are in the remains of an old dump which is crossed by a path leading to the lake shore from Mr. Manville's cottage on the south side of U. S. Highway 2.

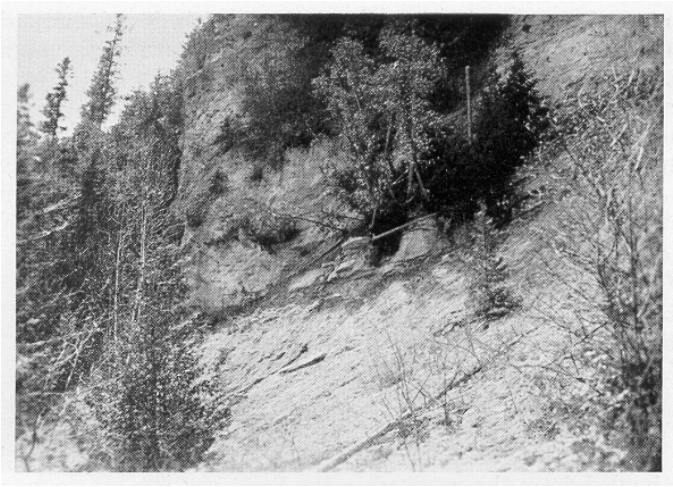


Plate III. A. Contact of Pte. aux Chenes and St. Ignace formations in cliff at Dwightwood Spring, Mackinac Island. Contact present just below ledge of dolomite shown at center of view. Indurated breccia composes vertical cliff above and to left of dolomite.

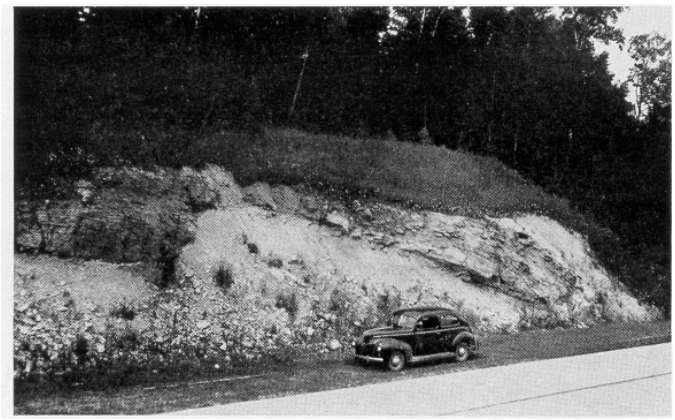


Plate III. B. Faulted strata in upper part of Pte. aux Chenes formation along U.S. Highway 2, 4 miles W. of St. Ignace. Man stands on down-thrown side of fault. Unit 1 of described section is shown above auto; unit 6 is highest, light-colored band at right side of view.

The shales at the Round Lake C.C.C. Camp, along U. S. Highway 2 and on the Lake Michigan shore, and the gypsum of the abandoned pits are in the type area of the

Pointe aux Chenes formation and are characteristic of the material comprising the upper third of the formation.

Strata near the top of the formation are exposed in a cut along U. S. Highway 2 in the eastern part of the SW¼ sec. 9, T. 40 N., R. 4 W., about four miles west of the business section of St. Ignace. Their lithological character, thickness and fossils are indicated in the following description of the section.

Section of strata exposed in cut along U.S. Highway 2 in eastern part of SW¼ sec. 9, T. 40 N., R. 4 W., about four miles west of St. Ignace

	Thickness Feet	Inches
Pointe aux Chenes formation:		
6. Shale, slightly calcareous, light-green, weathering into angular fragments	9	
5. Dolomite, light-gray to light brownish gray, thin- and even-bedded, with few specimens of *Leperditia alta* (Conrad) var. near base	2	8
4. Dolomite, brown, uneven-bedded, and in layers one-half to two inches in thickness, with numerous veinlets of calcite in irregular fractures and well-developed crystals of calcite along joints; *Leperditia alta* (Conrad) var. present in some layers	11	
3. Dolomite, brown, uneven-bedded, weathering into layers about six inches in thickness with numerous veinlets of calcite in irregular fractures and well-developed crystals of calcite along joints	2	
2. Shale, dolomitic, greenish-gray to buff greenish gray, very thin-bedded to fissile, with minute crystals of gypsum abundant in some layers. Rock contains many specimens of *Leperditia scalaris* (Jones) and *Modiolopsis* sp.—close to *M. dubius* (Hall) and less numerous remains of *Lingula media* Ruedemann, *Whitfieldella* sp. cf. *W. subsulcata* Grabau, *Modiolopsis* sp. — possibly new, and fragments of eurypterids. Fossils more abundant in upper part of unit than in lower part	1	4
1. Shale, slightly calcareous, dark bluish gray when wet and greenish-gray when dry. Uppermost three feet exposed by digging; remainder of unit covered with weathered shale and with little doubt consisting of the same type of shale	7–8	
Total	34–35	

The beds noted in the section are in a faulted block on the north side of the road and at the eastern end of the cut (see Pl. IIIB). About 15 feet of green and red shale with some very thin layers and lenses of gray, fine-grained dolomite are exposed in another faulted block approximately 100 feet to the west. These strata apparently belong to unit 6, which elsewhere has a maximum thickness of 18½ feet, but may occupy a position below the shale of unit 1.

Rocks of the highway cut are shown at other places in the area. The shale of unit 6 crops out in the SE¼ sec 8, T. 40 N., R. 4 W., beside a little-used wagon road which ascends a cliff from a point an eighth of a mile northeast of the Catholic Church at Gros Cap village to U. S. Highway 2. At this place the shale is 18 feet thick and the uppermost one to two feet is greenish-buff, thus differing from the underlying part, which is green. It is underlain by two feet of dolomite of unit 5 exposed in the road ditch, and is overlain by 22 feet and seven inches of St. Ignace strata. Parts of units 1 to 6 that are faulted are poorly exposed in the eastern part of the NW¼ sec. 9, T. 40 N., R. 4 W., along a private road just east of Dr. Stewart's home. The beds of units 1 to 6 are recognizable also in several faulted blocks in a cut on U. S. Highway 2 near the center of the NW¼ sec 15, T. 40 N., R. 4 W. The upper layers of unit 5 are at the level of U. S. Highway 2 about 125 feet south of Mr. C. C. Eby's gift shop at Castle Rock three miles north of St. Ignace. Directly west of this outcrop, weathered green shale of unit 6 is exposed in patches along a road being built by Mr. Eby to provide automobile transportation to a point near the top of Castle Rock. A short distance south of the outcrop of unit 5, the much weathered shale of unit 6 is visible in low cuts on the west side of Highway 2.

A particularly fine exposure of the rocks in the upper part of the Pointe aux Chenes formation and the contact of this formation with the St. Ignace strata may be seen in a cliff just south of Dwightwood Spring on the east side of Mackinac Island (see pl. IIIA). In the following description of the section shown in the cliff, the rocks noted as units 1, 2, and 3 are the eastward continuation of units 4, 5, and 6 of the cut along U. S. Highway 2 about four miles west of St. Ignace.

Section of strata exposed in cliff just south of Dwightwood Spring on east side of Mackinac Island

	Thickness Feet	Inches
St. Ignace formation:		
11. Dolomite, light-gray to light-buff, even-bedded; beds fractured and locally much brecciated	24±	
10. Shale, greenish-gray, hard, undoubtedly compressed in the course of regional brecciation	0	10
9. Dolomite, buff-gray with some streaks of light buff gray, brecciated; fractured condition possibly due in part to sub-marine gliding and in part to regional brecciation	1	
8. Dolomite, light-buff, fine grained, with few calcite crystals; weathers into layers 1 to 6 inches in thickness	1	6
7. Dolomite, light-buff, very fine grained, massive, with numerous particles of calcite in rounded cavities 1/32 to 1/16 inch in diameter; much fractured, with fractures occupied by calcite	1	8
6. Dolomite, light-buff, very fine grained with few rounded cavities having diameters of 1/32 to 1/16 inch and fillings of calcite; brecciated and cut with calcite-filled fractures	3	6
Total	32±	6

	Thickness Feet	Inches
Pointe aux Chenes formation:		
5. Shale, buff, fairly hard	4	
4. Shale, calcareous, greenish, with few calcareous grains, about 1/32 inch in diameter	1	
3. Shale, light-green, with few bands of red; upper part bluish-green, difference in color possibly due to greater moisture content	18	6
2. Dolomite, light buff gray to light-buff, thin- and even bedded	2	6
1. Dolomite, brown, uneven-bedded and in layers a half to two inches in thickness, with many irregular veinlets of calcite and well developed crystals of calcite in cavities and along joints; *Leperditia alta* (Conrad) var. numerous in some layers. Base of unit is about 30 feet from carriage road along shore of island and 22 feet above Lake Huron	8	6
Total	34	6

So far as known, the shale of units 4 and 5 are not well exposed elsewhere in the Mackinac Straits area. However, a part of unit 5 may be represented by the greenish-buff shale at the top of the 18 feet of green shale that crops out along the cliff road near the Catholic Church at Gros Cap village. The removal of a considerable covering of talus at this cliff road outcrop may reveal unit 4 and all of unit 5 of the section at Dwightwood Spring, Mackinac Island. The contact between the Pointe aux Chenes and St. Ignace formations in the cliff at Dwightwood Spring shows no evidence of a period of erosion; the formations seem to be conformable.

About 800 feet north of Dwightwood Spring and 200 feet north of the base of Arch Rock, the beds of units 1, 2, and 3 of the Dwightwood Spring section are exposed

below a copious spring which issues from, or from a short distance above, the contact of the Pointe aux Chenes and St. Ignace formations.

Green shale and buff dolomite are in a narrow bench beneath the lake from a point a few hundred feet south of Dwightwood Spring to a point approximately a half mile to the north. These strata, which may be seen best from the top of Arch Rock, are displaced blocks of rock of units 1, 2, and 3 to the Dwightwood Spring section, or occupy a position below the dolomite of unit one of this section.

Green shale, which probably occupies a lower stratigraphic position than the lowest rocks of the Dwightwood Spring section and the shale and dolomite of the shelf beneath the lake, constitute small areas of the lake bottom adjacent to the north end of Mackinac Island.

Brecciated green shale and dolomite of intervals 1, 2, and 3 of the Dwightwood Spring section are beside the road on the west side of Mackinac Island about a half mile south of British Landing.

The Pointe aux Chenes formation doubtless contains several beds of gypsum which are not shown in outcrop. Rominger (1873, p. 30)[11] reported the occurrence of "extensive patches of snow-white gypsum . . . . at the depth of eight to ten feet" in the bottom of Lake Huron adjacent to Goose Island, located nine and a half miles northeast of Mackinac Island. The "extensive patches" noted by Rominger may well indicate the existence of a distinct bed of gypsum rather than irregular masses of this mineral. Possibly two beds of gypsum were penetrated in a well drilled about two miles north of the business section of St. Ignace in sec. 31, T. 41 N., R. 3 W. In the record of this well the location of which is erroneously given as R. 1 W., instead of R. 3 W., A. C. Lane (1902, pp. 227-228)[23] noted the occurrence of 13 and 5 feet of gypsum at respective depths of 174 to 187 feet and 255 to 260 feet below the surface. In the record Lane also recorded the presence of "blue shale with gypsum" and a "gypsiferous dolomite." He assigned the gypsum, gypsum-bearing strata and associated red and blue shales and dolomites to the Monroe formation.

Although no beds of salt have been found in outcrop or in the few deep wells of the area, it is of interest to note that salt water and a vein of salt were recorded by A. C. Lane (1895, pl. 63)[14] in the record of the Mackinac Lumber Company well at St. Ignace. In the record the salt water and vein and associated red and blue shales are assigned to the "Monroe, i. e. Lower Helderberg and Salina," whereas they are now assigned to the Pointe aux Chenes formation of this report.

THICKNESS: The thickness of the Pointe aux Chenes formation is indicated by the records of deep wells, which unfortunately are few in number and lacking in detail. Information gained from these records show that the thickness of the formation on the St. Ignace Peninsula is between 500 and 600 feet.

STRATIGRAPHIC RELATIONSHIP: The slabs of grayish-green dolomitic shale along U. S. Highway 2 at points a third of a mile north and nearly one mile northeast of Pointe aux Chenes, contain an assemblage of fossil species, which is indicative of the Upper Salina Bertie formation of New York and Ontario. The ledges from which these slabs were taken during the course of construction of the highway occupy a position in the upper third of the Pointe aux Chenes formation.

The dolomitic shale of unit 2 of the section exposed in the cut of U. S. Highway 2 about four miles west of St. Ignace has *Lingula media* Ruedemann, *Whitfieldella* sp. of *W. subsulcata* Grabau, *Modiolopsis* sp. close to *M. dubius* Hall and *Leperditia scalaris* (Jones), which suggest the fauna of the Bertie formation. The dolomites of units 4 and 5 of this section have a variation of *Leperditia alta* (Conrad), a species also reported in this formation. The strata of units 2, 4, and 5 are in the upper part of the Pointe aux Chenes formation, the base of unit 2 being 35 feet below its top.

Although the upper third of the Pointe aux Chenes formation can be correlated with Bertie, the stratigraphic relationship of the rest of the formation is unknown. However, the possible relationships of the lower two-thirds of the formation may be indicated by a comparison of the Salina strata of the Mackinac Straits area with the Salina of New York and Ontario. In a relatively recent paper dealing with the correlation of the Silurian formations of North America by C. K. Swartz and others (1942, pp. 533-538, ch. 3)[34] the Salina group of western New York is described as being composed of five divisions, in ascending order as follows: The Pittsford shale, Vernon shale, Syracuse salt, Camillus shale, and Bertie waterlime. The Pittsford shale, which, with the higher divisions of the Salina group, has been described in detail by Winifred Goldring (1931, pp. 336-341)[36] and by D. H. Newland (1929, pp. 38-45)[37] is a thin formation having a lithology unlike any known Pointe aux Chenes strata. Although thin in New York and not reported in southwestern Ontario, the Pittsford shale may be represented by strata of equivalent age in the thick section of the Salina group of Michigan. The Vernon shale thins to the west of Syracuse, New York, where it has a thickness of 500 feet and its color changes from a deep red to green with some red. So far as known, the Vernon shale is not reported in Ontario. As the lithology of many of the Pointe aux Chenes shales is similar, some may prove to be of Vernon age. The Syracuse salt, according to Newland (1929, pp. 39-40)[7], does not represent a "horizon but a zone . . . . in which from one to five or six beds of salt occur at various levels associated with limestone, limey shale and some anhydrite." In the opinion of Newland (1929, pp. 40, 43)[7] the Syracuse salt or salt zone constitutes the lower part of the Camillus shale. The part of the Camillus above the salt zone consists of shale, thin magnesian and argillaceous limestones, gypsum, and anhydrite. The Camillus with beds of salt which probably represent the Syracuse salt zone, have been recognized in a few outcrops and many deep wells in Ontario by M. Y.

Williams (1919, pp. 83-84).[21] Since the Camillus strata have been traced in deep borings to the borders of Michigan, it seems very likely that these beds may be present in the very thick Salina section of this State. The writers believe that salt beds of possible Camillus-Syracuse age were in the lower part of the Pointe aux Chenes but were leached out in the Straits area prior to the deposition of the Middle Devonian Dundee limestone.

From these criteria it seems probable that at least the upper third of the Pointe aux Chenes is a correlate of the Bertie formation and that its lower two-thirds may contain strata equivalent in age to New York Salina beds below the Bertie. A final decision in regard to the stratigraphic relationships of the lower Pointe aux Chenes beds awaits the finding of more fossils and a study of carefully taken samples from more deep borings.

ST. IGNACE FORMATION

NOMENCLATURE: The name St. Ignace is proposed for the youngest known Upper Silurian formation of the Northern Peninsula. It is chosen because large segments of this stratigraphic unit are well shown in an extensive breccia, the Mackinac breccia, of the St. Ignace area.

DISTRIBUTION: On the St. Ignace Peninsula and Mackinac Island the formation is represented by large masses of strata within the Mackinac breccia. Because it is impossible to delineate the boundaries of these masses as well as those of huge blocks of Devonian rocks also in this breccia, the St. Ignace deposits of these two places have been mapped with the Mackinac breccia (see map in pocket).

South of an east-west line passing between Mackinac and Round Islands and just north of Garden Island in Lake Michigan the St Ignace rocks have not been greatly displaced by brecciation and as a consequence their areal distribution can be recognized (see map). All of Round Island and the northern part of Bois Blanc Island, which are southwest of Mackinac Island, are underlain by St. Ignace deposits. The northern part of Garden Island located in Lake Michigan about 35 miles west of St. Ignace, and all of Squaw and Whiskey Islands a few miles west of Garden Island have St. Ignace strata at or near the surface.

LITHOLOGIC AND PALEONTOLOGIC CHARACTERS: The formation, except for the upper part, consists of even-bedded, very light gray, cream-colored, and light-buff dolomites. Some of the dolomites contain slit-like gashes, probably resulting from the solution of celestite; and others, numerous small spherical cavities which originally may have been occupied by salt. Many beds exhibit both gashes and spherical cavities. Crystalline calcite and dolomite occupy the gashes and spherical cavities of some layers. Bluish to greenish-gray shale, in beds ranging from a few inches to a few feet in thickness, are an inconspicuous part of the formation. The upper part of the St. Ignace consists of thick-bedded buff dolomites overlying thick-bedded light-gray dolomites. Some of the buff dolomites are oolitic and present a sugary appearance on weathering. Some beds of both light-gray and buff dolomites contain frosted grains of quartz. The grains are larger and more abundant in the buff dolomites near the top of the formation than in lower beds. In the following paragraphs the descriptions of certain outcrops will give more detailed information in regard to the lithology, super-position, and fossil content of the St. Ignace strata.

A section of the beds in the lower part of the formation is shown clearly along the little used wagon-road which ascends the cliff near the Catholic church at Gros Cap village about five miles west of the business district of St. Ignace.

Section of strata exposed beside the little used wagon road ascending the cliff from a point one-eighth of a mile northeast of the Catholic church at Gros Cap village to U.S. Highway 2

	Thickness Feet	Thickness Inches
St. Ignace formation:		
9. Dolomite, light-buff to cream-colored and massive, containing minute spherical cavities and slit-like gashes	1	3
8. Dolomite, cream-colored to buff and fine-grained, with an earthy feel	3	9
7. Dolomite, very light buff to cream-colored, laminated and very fine grained, having an earthy feel; minute folds in laminae apparently due to submarine gliding; splits into layers an eighth to a half inch in thickness	3	6
6. Dolomite, grading from light buff at top to buff at base, finely crystalline and gashed, gashes especially abundant near base; weathered surface buff, having earthy feel, and showing uneven-bedding	2	
5. Dolomite, gray, and very fine grained, having numerous closely spaced joints and splitting into layers a fourth to a half inch in thickness; weathered surface bluish-gray; on weathering rock breaks into angular fragments	2	6
4. Shale, buff-gray with greenish tinge	4	7
3. Dolomite, light-buff to cream-colored, thick-bedded and with earthy feel	5	
Total	22	7
Pointe aux Chenes formation:		
2. Shale, green, except for greenish-buff in upper-most one to two feet, and red at base, with few layers or lenses of argillaceous dolomite two inches in thickness	18	
1. Dolomite, light-gray to light brownish gray, exposed in ditch beside road	2	
Total	20	

In the description of the stratigraphic section given above, 22 feet and seven inches of dolomite with little shale rest conformably on shale of the Pointe aux Chenes formation. A similar exposure of St. Ignace strata in contact with Pointe aux Chenes shale is shown in the cliff near Dwightwood Spring on Mackinac Island.

Either of these exposures may serve as a type section for beds in the lower part of the St. Ignace formation. The cliff at Dwightwood spring exhibits about 10 more feet of strata than the cliff near the Gros Cap church, but at least the upper 20 feet of rock at Dwightwood Spring are in a vertical cliff and inaccessible for close examination.

The exact succession of strata between the beds of the cliff near the Gros Cap church and Dwightwood Spring and rocks composing the upper part of the formation is

not known. This lack of information is due to the fact that the super-position of the beds must be determined from blocks of the formation within the breccia of the area instead of from more extensive exposures of undisturbed strata. Any attempt to correlate the rocks of these blocks is very difficult because the various beds show few lithologic differences and are almost lacking in fossils which might serve as stratigraphic guide-markers. Fortunately, the approximate positions of sections of strata in the middle part of the formation were recognized in the course of the field study; these positions and the lithology of the rocks composing the sections are discussed in the following paragraphs.

Strata which probably occupy a position not far above the highest beds of the cliffs near the Gros Cap church and Dwightwood Spring are shown in the ditches along Church Street on the western boundary of the St. Ignace State Park.

Section of strata exposed in ditches along Church Street, St. Ignace between its intersection with Graham Street and a road entering St. Ignace State Park from the west

	Thickness Feet	Thickness Inches
St. Ignace formation:		
5. Dolomite, light grayish buff to cream-colored, with some small slit-like gashes and numerous specimens of *Leperditia* sp. aff. *L. jonesi* Hall and *L. okioensis* Bassler; on weathering breaks into layers an eighth to a half inch in thickness. Elevation of base of unit—638 feet	0	10
4. Shale, dolomitic, gray, fissile	2	
3. Dolomite, light-buff, weathering to dark-buff	1	
2. Covered	16	
1. Dolomite, light buff gray to buff, with gashes and many fractures filled with calcite crystals	2	6
Total	22	4

Unit 1 is exposed in the ditch on the west side of Church Street just north of its intersection with Graham Street. Units 3, 4, and 5 are present in the ditch on the east side of Church Street at its juncture with the State Park road.

The dolomite of unit 5 with its numerous *Leperditia* may prove to be a stratigraphic marker and be helpful in the recognition of the super-position of the rocks of the middle part of the formation if it can be found in several outcrops. A special effort to locate this ostracodal dolomite should be made in any future attempt to determine the rock succession.

Numerous blocks of light-buff to cream-colored, fine-grained dolomite, containing numerous examples of the species of *Leperditia* found in unit 5, are along the shore of Lake Michigan about two and one-half miles west of the Church Street outcrop and about three-quarters of a mile northwest of Pte. la Barbe. Apparently the blocks were brought to the shore by storm waves and moving lake ice from a ledge which is now covered by the high water of the lake.

The *Leperditia*-bearing ledge, which has an elevation of only a few feet less than 581 feet, (the aproximate level of Lake Michigan during the summer of 1943) and unit 5 of the Church Street section, which has an elevation of 638 feet, very likely are part of the same stratum. The difference in elevation is due to the dropping of the segment of the formation containing the ostracodal layer northwest of Pte. la Barbe to a lower position than the level of the formation containing this layer along Church Street. Such differences in the elevation of beds of the formation, which were brought about by the collapse of the strata of the region, are of widespread occurrence and unless recognized may result in erroneous conclusions regarding the succession of the rocks of the St. Ignace formation.

Beds, which probably occupy a position not far above unit 5 of the Church Street section, are shown in a large block within a breccia exposed in the walls of the approach to the causeway intended for use as a ferry terminal about one mile southwest of the business district of St. Ignace and approximately a third of a mile west of the outcrop on Church Street. The beds of the block noted as units 3 to 11 in the following description are best exhibited in the east wall of the causeway approach and are illustrated in plate VI, B. The strata of units 1 and 2 can be seen by trenching beneath the base of unit 3 where it appears in the west wall.

Section of strata of a large block of rock within a breccia exposed in the walls of the approach to a causeway intended for use as a ferry terminal, about 1 mile southwest of the business district of St. Ignace

	Thickness Feet	Thickness Inches
St. Ignace formation:		
11. Dolomite, very light buff gray except for a few light-buff beds; upper 3 to 4 feet splits into layers about a quarter of an inch in thickness	7	6
10. Shale, calcareous, buff	1	4
9. Dolomite, light buff gray, finely crystalline, weathered surface white; lowest 6 inches with thin bands of secondary calcite	2	
8. Dolomite, light buff gray, with few spherical cavities about a thirty-second of an inch in diameter and some dessication fissures; on weathering rock breaks into layers a quarter to a half inch in thickness and becomes brown at surface	1	3
7. Shale, dark brownish gray, weathering into small angular fragments	1	6
6. Dolomite, buff, even-bedded, in layers 1 to 3 inches in thickness, weathered surfaces brown; very thin seams of secondary calcite on bedding planes	2	4
5. Dolomite, light-buff to buff, finely crystalline; some joints a half an inch in diameter, filled with breccia having calcareous brown matrix and some angular fragments of very light-gray dolomite	3	
4. Shale, calcareous, bluish-gray, with some layers of buff limestone averaging 2 inches in thickness	3	6
3. Dolomite, ranging from light-gray to light buff gray, finely crystalline, even-bedded in layers 2 to 15 inches in thickness; some beds with spherical cavities a thirty-second to a sixteenth of an inch in diameter, others with slit-like gashes a quarter to a half inch in length, resulting from solution of tabular crystals of celestite or other unknown mineral	14	
2. Dolomite, argillaceous, dark bluish gray, uneven-bedded, breaking into angular fragments	2	6
1. Dolomite, light-gray to cream-colored, with talcose feel. Elevation to base of unit 630 feet	6	6
Total	45	5

Numerous other blocks showing most of the strata described above are exhibited in the breccia composing the vertical walls of the approach to the causeway. Separating some of these blocks are large masses of higher St. Ignace and lower Bois Blanc beds. These occurrences are discussed in the section of this report dealing with the Mackinac breccia.

In the course of the field work it seemed likely that the *Leperditia* of unit 5 of the Church Street section would be found in the strata of the causeway approach. This expectation was founded on the fact that the base of unit 3 has almost the same elevation as unit 5 of the Church Street section and the probability that these units originally were on the same line of strike. Failure to find

a single valve of *Leperditia* illustrates again that large segments of the St. Ignace formation have dropped different distances during the course of brecciation of the strata.

Plate VI. A. Ledge of dolomite near top of St. Ignace formation. Cherty dolomite of Bois Blanc formation occupies hill above ledge. Eastern part of NW¼ sec. 9, T. 40 N., R. 4 W., about 4 miles W. of St. Ignace.

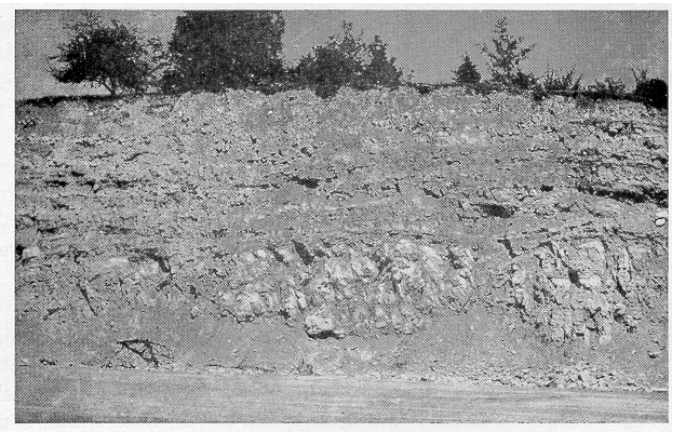


Plate VI. B. Dolomite and shale of St. Ignace formation in east wall of approach to proposed ferry terminal, 1 mile west of St. Ignace. Units 3 to 11 of described section shown in illustration.

The writers believe that the beds in the block of the causeway approach occupy a position above unit 5 of the Church Street section. This belief is suggested by the occurrence of dolomites like those of the block in small exposures in the bed of Church Street within a few hundred yards north of the exposure of unit 5. The small exposures are in a rise of the street, the highest outcrop reaching an elevation of nearly 50 feet above the top of unit 5. Even though the elevations indicate that the beds of the causeway approach are above the *Leperditia*-bearing dolomite of unit 5, it must be recognized that this apparent stratigraphic relationship may have been brought about by the unequal dropping of segments of the St. Ignace formation at the time of regional brecciation.

Several exposures of strata, which are in large breccia blocks and apparently occupy positions in the middle part of the St. Ignace formation, are worth noting because they ultimately may supply information leading to the determination of the exact stratigraphic succession. One of these exposures is above an abandoned limekiln on the south side of Rabbits Back ridge about four miles north of St. Ignace. The lithological character of the rocks of this outcrop is given in the following description:

Section of strata shown above abandoned lime kiln on south side of narrow ridge about an eighth of a mile southeast of highest point on Rabbits Back, about four miles north of St. Ignace

	Thickness Feet	Thickness Inches
St. Ignace formation:		
3. Covered—pieces of rock on surface are similar in lithology to strata of unit 2 and suggest that unit 3 may be composed of such material	5	
2. Dolomite, cream-colored, and very fine grained, weathering into layers a fourth to one inch in thickness; on extensive weathering breaks into small angular chips	14	
1. Dolomite, light-buff, very fine grained and thin-bedded; exposed by digging	1	2
Total	20	2

A small though interesting outcrop is exhibited a short distance west of the Michigan State Police Substation in St. Ignace.

Section of strata shown in contact with indurated breccia of small hill about 200 feet west of the Michigan State Police Substation at St. Ignace

	Thickness Feet	Thickness Inches
St. Ignace formation:		
5. Calcite, buff-gray and crystalline, evidently deposited from waters which had passed through adjacent breccia		2
4. Dolomite, light-gray and laminated	1	6
3. Calcite, like unit 5 and similar in origin		2–6
2. Dolomite, light-buff gray to cream-colored and laminated; some layers brecciated	8	
1. Dolomite, brown, massive but showing layers 1 inch in thickness on weathered surface	1	
Total	10	10–14

The calcite of units 3 and 5, although a part of the section, is not of St. Ignace age; it was deposited after the brecciation of the rocks of the region.

The dolomites of this section are very similar in their lithology to those above the abandoned lime-kiln on the south side of Rabbits Back Ridge and may occupy about the same position in the formation. Their occurrence in a block within an indurated breccia is strikingly exhibited. A third small outcrop is a knoll several hundred yards southwest of the summer home of Dr. Kirk Stewart in the NW¼ sec. 9, T. 40 N., R. 4 W., about four miles west of St. Ignace. The lithological character of the beds at this place, which will be the site of a caretaker's house, is given in the following description of the section:

Section of strata on knoll several hundred yards southwest of Dr. Kirk Stewart's home in the NW¼, sec. 9, T. 40 N., R. 4 W., about 4 miles west of St. Ignace

	Thickness Feet	Inches
St. Ignace formation:		
3. Dolomite, similar to unit 1, except that some layers become brown on weathering	5	6
2. Shale or shaly dolomite, greenish-gray	1	6
1. Dolomite, light-gray and laminated, with slit-like gashes, earthy feel and conchoidal fracture	3	
Total	10	

Evidence that this section of strata exists as a block within a breccia is shown by outcrops of indurated and non-indurated breccia in the woods covering most of the knoll.

Beds which are higher in the formation are exhibited in a large block of westward-tilted strata adjacent to the indurated breccia of Castle Rock. The lowest of these beds, which are described below, is in contact with the breccia beneath a board walk near the top of Castle Rock; successively higher strata are shown in a ridge extending westward from Castle Rock.

Section of strata exposed in a large block of westward-tilted strata adjacent to the indurated breccia of Castle Rock, three miles north of St. Ignace

	Thickness Feet	Inches
St. Ignace formation:		
20. Dolomite, buff-gray to buff, with slit-like gashes	0	11
19. Dolomite, light-gray, very fine grained, with slit-like gashes	0	10
18. Shale, dolomitic, greenish-buff	1	
17. Dolomite, light-gray, very fine grained with very small gashes and earthy feel	1	5
16. Covered	5–6	
15. Dolomite, similar to unit 14 but with very few gashes and cavities; laminations on weathered surfaces	2	6
14. Dolomite, gray to light buff gray with spherical cavities and slit-like gashes coated with yellowish substance; spherical cavities more abundant in lower half	2	6
13. Shale, dolomitic, greenish-buff, with some layers hard and more dolomitic than others; basal two inches red	2	6
12. Dolomite, cream-colored, fine-grained, with large gashes; thick-bedded, upper one foot with laminae on weathered surfaces	5	
11. Dolomite, gray, fine-grained, with few slit-like gashes and earthy feel; laminae on weathered surfaces	1	
10. Dolomite, gray to buff-gray, with spherical cavities and slit-like gashes coated with yellowish substance	2	4
9. Shale, gray, compressed at time of regional brecciation	0	6
8. Dolomite, gray, very fine grained	2	
7. Shale, gray, compressed at time of regional brecciation	0	2
6. Dolomite, gray, very fine grained, with *Leperditia* sp. one foot above base	2	
5. Shale, brownish-gray, with many angular fragments of gray dolomite; fragmentation due to regional brecciation	0	6
4. Dolomite, very light buff gray, very fine grained with few slit-like gashes and earthy feel; thin-bedded with laminae on weathered surfaces; weathers into angular fragments	1	10
3. Dolomite, darker gray than unit 2, with numerous spherical and small tabular cavities coated with yellowish substance; buff-gray on weathering	0	10
2. Dolomite, light-gray, very fine grained, with earthy feel, and laminae on weathered surfaces	1	
1. Shale, greenish-buff, exposed by digging	4	7
Total	38–39	5

Unit 20 and some of the underlying units of the section are shown on the northern side of the Castle Rock ridge. About 200 feet west of the exposure of unit 20 a small outcrop shows three feet of gray, fine grained dolomite overlain by two feet of gray dolomite containing small grains of frosted quartz. These two beds of dolomite are stratigraphically above unit 20 and may not be separated from it by a covered interval of more than 25 feet. A poor exposure of pinkish- to reddish-gray fine grained dolomite, which occupies a position probably not more than five feet above the dolomite with frosted quartz grains, is in a lot intended for parking automobiles about 200 feet south of the small outcrop. About 150 feet southwest of the reddish-gray dolomite, a cut in the road leading to the parking lot exposes a very light buff gray to light-buff dolomite containing bands and lenses of fine and large grains of frosted quartz. This sandy dolomite, which probably is 10 to 20 feet above the reddish-gray dolomite, occupies a position near the top of the formation. A mass of breccia, of which the western limit is not visible, is on the north side of the Castle Rock ridge just west of the two dolomites having a combined thickness of five feet. A thick-bedded, buff, coarse grained dolomite six feet in thickness is near the top of the ridge about 600 feet west of the two dolomites. This dolomite is near the top of the formation and possibly occupies a position just above the very sandy dolomite of the road entering the parking lot. The succession, lithologic character, and thickness of the strata above unit 20 of the Castle Rock section are shown more clearly at other localities.

An exposure at the northwest end of a long abandoned quarry just east of the St. Ignace State Park, here designated the Hombach quarry, exhibits a section containing some of the dolomites of the Castle Rock ridge.

Section of strata exposed at the northwest end of the abandoned Hombach quarry, located about 500 feet south-southeast of the intersection of Hombach and Pero Streets, St. Ignace

	Thickness Feet	Inches
St. Ignace formation:		
2. Dolomite, light buff gray to cream-colored grading to light-buff at top, thick-bedded to massive; lowest 2 feet pinkish- to reddish-gray; upper part of unit coarser grained than lower; detached blocks possibly derived from lower half of unit, with many specimens of *Spirifer (Delthyris)* sp. aff. *S. (D.) corallinensis* (Grabau) and few samples of "*Cyathophyllum*" *hydraulicum* (Simpson Ms.) Grabau	16	
1. Dolomite, light-gray to cream-colored, fine-grained and thick-bedded, with scattered small frosted quartz grains in uppermost 4 to 5 feet; lowest 4 feet and 8 inches, exposed by trenching, somewhat finer grained and thinner bedded than rock above; base of unit about 2 feet above quarry floor	16	8
Total	32	8

The upper part of unit 1 of the quarry section and the dolomite with small grains of frosted quartz exposed about 200 feet west of the outcrop of unit 20 of the Castle Rock section with little doubt are parts of the same bed. The pinkish- to reddish-gray dolomite of the lowest two feet of unit 2 and the dolomite poorly exposed in the parking lot near the top of the Castle Rock ridge belong to the same bed. The uppermost layer of unit 2 may have a position below the very sandy dolomite of the road cut near the parking lot.

The fossils listed in unit 2 of the Hombach quarry section were found in detached blocks on the bottom of the quarry. (See pl. V, figs. 8-12 for illustrations of St. Ignace fossils.) The layer from which these blocks were derived was not found in the quarry wall. It is thought that the blocks were broken from one of the gray dolomites above the pinkish- to reddish-gray dolomite composing the lowest two feet of unit 2. However, it is

possible that the fossiliferous blocks may have come from a soil-covered ledge just above the top of unit 2.

Higher strata in the formation are shown at the southeast end of the Hombach quarry which at this point is almost covered by evergreens, hardwoods, and bushes.

Section of strata exposed at the southeast end of the abandoned Hombach quarry, about 750 feet south-southeast of the intersection of Hombach and Pero Streets, St. Ignace

	Thickness Feet	Thickness Inches
St. Ignace formation:		
3. Dolomite, very light gray to cream-colored, finely crystalline and thick-bedded; weathers to light-buff and contains poorly preserved molds of a simple tetracoral, *"Cyathophyllum" hydraulicum* (Simpson MS.) Grabau, a fenestellid, *Camarotoechia?* sp. a spiriferid and *Whitfieldella?* sp.	2	
2. Covered	5	6
1. Dolomite, light-buff to cream-colored and thick-bedded, with spherical and ovoid grains observable on moistened surfaces; some grains apparently oolites, others possibly water-worn particles of dolomite	8±	
Total	15±	6

The upper part and possibly all of unit 1 of the section at the southeast end of the quarry occupies a position above unit 2 of the section shown at the northwest end of the quarry. It is difficult to trace particular beds of unit 1 along the old quarry wall to unit 2 of the northwest section, because the strata for most of the distance between the ends of the quarry are covered by talus, soil, and vegetation. At one place along the old quarry wall the continuity of the beds is broken by a breccia pillar 30 feet in width and the identification of a particular bed on both sides of the pillar cannot be made with certainty. The lithologic character of unit 1 and the six feet of dolomite on the Castle Rock ridge exposed 600 feet west of the gray dolomite with fine grains of frosted quartz are very similar and suggest that the rocks belong to the same bed. The fossiliferous dolomite of unit 3 and the unexposed rock of unit 2 have a position above the highest beds of unit 2 of the section at the northwest end of the quarry.

About 6 feet of light-buff to cream-colored, thick-bedded dolomite, having a position in the upper part of the St. Ignace formation and the same lithologic character as the rock of unit 1 of the section exposed in the southeast end of the Hombach quarry, is shown in an old quarry on Mackinac Island. The dolomite of this quarry, located 750 feet east of an old lime kiln on the east side of the Fort Mackinac-Sugarloaf road, doubtless was worked by the British before the United States came into possession of the island.

Strata in the upper part of the formation are exposed in a small cliff on the south side of Bois Blanc Island. Their lithologic character and thickness are noted in the following description:

Section of strata exposed in a cliff on the south shore of Bois Blanc Island in Section 14 about 500 feet south of most western point of island

	Thickness Feet	Thickness Inches
St. Ignace formation:		
3. Dolomite, light-buff to cream-colored, massive, somewhat granular on weathering	9	
2. Dolomite, light-gray, massive, finely textured, with fine grains of frosted quartz	0	8
1. Covered. Blocks of light-gray to cream-colored, finely textured dolomite are present in abundance in rock debris between the base of unit 2 and the nearby shore, and doubtless were broken from covered ledges of unit 1	8	
Total	17	8

The dolomite of unit 2 may be another exposure of the upper part of unit 1 of the section shown at the northwest end of the Hombach quarry. Unit 3 may be a weathered phase of the dolomite of unit 2 of the same quarry section.

Beds having a position in the upper part of the formation are exposed in a high cliff on the northeast side of Round Island and are described below:

Section of strata exposed in a cliff on the northeast side of Round Island, about a quarter of a mile northwest of the northeast point of the island

	Thickness Feet
St. Ignace formation:	
6. Dolomite, buff-gray to buff, thick-bedded with some small cavities filled with calcite crystals; unit contains a small coral, cf. *"Cyathophyllum" hydraulicum* (Simpson Ms.) Grabau, fenestrellinids, *Camarotoechia?* sp. and *Whitfieldella sp.*	4
5. Covered—possibly occupied by dolomite similar to unit 4	5
4. Dolomite, gray, finely textured, with scattered small frosted grains of quartz near middle	8
3. Covered. Base at inner margin of a terrace apparently cut by a post-Nipissing lake. Units 3 to 6 inclusive present in a cliff above the terrace	37
2. Covered. Blocks of light-gray, fine-grained, gashed dolomite present on the surface to point about 6 feet below top of unit, suggesting that unit consists of light gray dolomite characteristic of most of the St. Ignace formation	21
1. Dolomite, light-gray, thin-bedded, and laminated, exposed on shore of island and also below lake level	1
Total	76

Units 1 and 2 and possibly part of unit 3 of the section on the northeast side of Round Island are portions of the middle part of the formation. Unit 4 and possibly unit 5 seem to be another occurrence of the dolomite of unit 1 of the section shown at the northwest end of the Hombach quarry. Unit 5, however, may contain the pinkish-to-reddish-gray dolomite at the base of unit 2 of this quarry section. Unit 6, which contains a few fossils, seems to correlate with a part of unit 2 of the quarry section.

Beds in the upper part of the formation are exposed in a continuation of the Round Island cliff at a point an eighth of a mile northwest of the place where the last section was studied. Their lithologic character is indicated in the following description:

Section of strata exposed in a cliff on the northeast side of Round Island about three eighths of a mile northwest of the northeast point of island

	Thickness Feet
St. Ignace formation:	
2. Dolomite, buff-gray to buff, thick-bedded, bedding planes unrecognizable in a moderately brecciated phase of the rock near central lower part of the cliff; cavities in brecciated part filled with crystals of calcite. A small simple coral and a *Favosites* with corallites 1 mm. in diameter present in the upper part of the unit in masses of chert; fractures in the chert lined with quartz crystals	30
1. Covered—base of unit 2 to shore of island	42
Total	72

The dolomite of unit 2 includes beds which occupy positions in the formation similar to positions of some of the strata exposed in the Hombach quarry. Further study of the beds, which are exposed in a vertical face in the cliff, probably will show the exact relationship of particular layers to strata of this quarry and the cliff exposure an eighth of a mile to the southeast. The cause of the brecciation of the dolomite of unit 2 is very interesting and is noted in another part of this report. The occurrence of a *Favosites* with small corallites in unit 2 also is of interest because this tabulate coral has not been found in any other outcrop of the formation.

Before describing the contact of the St. Ignace strata with beds of overlying formations, it is worth noting the outcrops of St. Ignace rocks on the islands of the Beaver Island group in Lake Michigan, because the locations of these outcrops aid materially in the mapping of the formational boundaries. Several pavement-like outcrops of light gray and cream-colored fine-grained dolomites and large shingle beaches of these rocks are along the shores of Squaw Island which is five miles north-northwest of Beaver Island. These dolomites, which no doubt are better exposed at lower water stages of Lake Michigan than the level of 1943, probably belong to the middle part of the formation. Light gray, finely crystalline, thin-bedded to massive dolomites, the weathered surfaces of which are white, crop out along the south and west shores of Whiskey Island 1½ miles southwest of Squaw Island. These dolomites, also visible on the lake bottom adjacent to the south and west shores of the island, probably occupy a higher position in the formation than the beds on Squaw Island. A pavement of gray to cream-colored dolomite, which splits into large slabs, is along the shore of the northernmost point of Garden Island about three miles east of Squaw Island. This dolomite which also is visible beneath the water of the lake for a short distance offshore, most likely has a position high in the middle part of the formation. A cream-colored to light buff, thick-bedded dolomite, which is in the upper part of the formation and probably is a westward continuation of some of the strata of the Hombach quarry, appears on the bottom of the lake adjacent to the northeast shore of Garden Island about one and three quarters of a mile southeast of the northernmost point of the island.

The highest St. Ignace strata on Garden Island, though unexposed, with little doubt are overlain by arenaceous dolomite or dolomitic sandstone of the Garden Island formation, which, as far as known, is the oldest Devonian unit in the Mackinac Straits area. The rocks of the Garden Island formation contain an Oriskany fauna and are exposed on the west shore of Garden Island about two miles south of the north end of the island. Their lithologic and paleontologic character and their relationship to the St. Ignace strata are discussed in more detail in the section on the Garden Island formation.

On Mackinac Island the St. Ignace deposits are overlain by strata of the Bois Blanc formation, which contains Onondaga fossils and is younger than beds of the Garden Island formation having an Oriskany fauna. The contact between the St. Ignace and Bois Blanc rocks is sharply defined in a ravine near Fort Holmes at the top of Mackinac Island (pl. VII) and is noted in the following description of the exposure.

Section of strata exposed in a ravine just east of a reservoir located about 200 feet north of Fort Holmes, Mackinac Island

	Thickness Feet
Bois Blanc formation:	
3. Dolomite, buff-gray to gray, interbedded with gray chert; beds of chert as numerous as those of dolomite, range from one to six inches in thickness with an average thickness of four inches; fossils scarce, *Amplexus* sp. *Heterophrentis?* sp., and *Favosites* sp. found in chert. Elevation of top of unit 879 feet	40
2. Dolomite, dull gray to dull bluish gray, with thin discontinuous buff streaks and with nodules and two- to six-inch layers of chert; some beds of the dolomite very argillaceous	5
Total	45
Disconformity	
	Thickness Feet
St. Ignace formation:	
1. Dolomite, oolitic, yellowish-buff, massive, having fractures and irregular cavities filled with calcite, and thin discontinuous masses of quartz sand in lower part; smooth rounded cavities in rock due to solution; much weathered surface buff to brown. Uppermost three to five inches has an earthy feel and apparently was leached prior to deposition of unit 2. The top of the dolomite has shallow solution channels and pits with little doubt made under subaerial conditions prior to the deposition of unit 2	12
Total	12

It is probable that the 12 feet of oolitic dolomite of unit 1 described above occupies a higher position in the St. Ignace formation than any strata previously noted. However, it is possible that this dolomite and the oolite-bearing dolomite of interval 1 of the section exposed at the southeast end of the Hombach quarry may be one and the same bed. Although the cherty dolomites of the Bois Blanc formation in the ravine did not yield fossils indicative of their age, there is no doubt that these rocks are of lower Onondaga age. Their lower Onondaga age is indicated by the occurrence of Onondaga species in other exposures of the same strata. It is interesting to note that the Garden Island formation is not present between the St. Ignace and Bois Blanc formations of the ravine. The rocks of this formation and older beds of Lower Devonian age, if older Lower Devonian beds were ever deposited in the Mackinac Straits area, were removed by erosion prior to the deposition of the Bois Blanc sediments.

The finely exposed strata of the ravine near Fort Holmes are in a large block within the breccia, which composes most of Mackinac Island. Extensively brecciated rock, which surrounds this block, can be seen by removing the soil on the south side of the ravine in the vicinity of the contact between the St. Ignace and Bois Blanc strata.

On Bois Blanc Island as well as on Mackinac Island the St. Ignace formation seems to be overlain by cherty dolomites of the Bois Blanc formation. The places on the island where this stratigraphic relationship is indicated are noted in the description of the Bois Blanc formation.

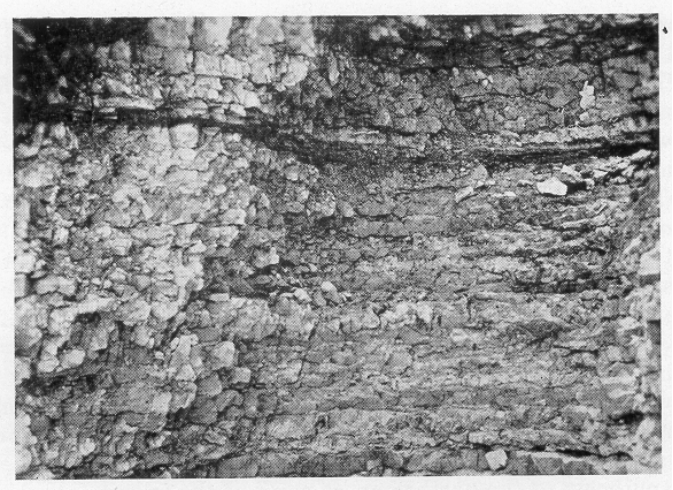


Plate VII. A. Interbedded chert and dolomite of lower part of Bois Blanc formation in ravine near Ft. Holmes, Mackinac Island. View taken a short distance upstream from that in B.

Plate VII. B. Contact of St. Ignace and Bois Blanc formations in ravine near Ft. Holmes, Mackinac Island. Man's hand at top of St. Ignace formation. Overlying Bois Blanc strata in sides and bottom of ravine.

The St. Ignace formation seems to be overlain by cherty dolomites of the Bois Blanc formation on the St. Ignace peninsula. This stratigraphic relationship is indicated by an exposure in a hill in the eastern part of the NW¼ sec. 9, T. 40 N., R. 4 W., about one-eighth of a mile southeast of the home of Dr. Kirk Stewart and about 4 miles west of St. Ignace. About 16 feet of very light buff to cream-colored, thick-bedded dolomite with small lenses of frosted quartz grains and few poorly preserved simple corals and brachiopods are shown approximately 25 feet above the country road on the west side of the hill (see Pl. VI A). The surface of the hill above the ledge, which occupies a position near the top of the St. Ignace formation, is strewn with broken chert, pieces of dolomite and fossils of the Bois Blanc formation. Although the contact between the two formations is not visible, the absence of loose blocks of the Garden Island formation indicates that the St. Ignace strata are directly overlain by the Bois Blanc rocks.

It is of interest to note that the ledge of St. Ignace dolomite in the hill has a strike of N. 20° W. and dips 20° NE. and that the east side of the hill and a smaller hill about one-tenth of a mile to the north are composed of a massive indurated breccia.

THICKNESS: The total thickness of the St. Ignace formation is difficult to determine because no exposures of the formation are known which would make possible the measurement of considerable thicknesses of strata. The occurrence of the beds in blocks in the breccia at various elevations may not present so great a difficulty in estimating the thickness if most of the strata of the formation were not so strikingly similar in their lithologic character. The similarity in the lithology of the rocks probably would not be a hindrance if numerous beds with recognizable fossil assemblages were present to serve as guide markers in the formation.

A consideration of the probable order of super position of the strata exposed in many blocks of the breccia leads the writers to believe that the thickness of the formation in the Mackinac Straits area is not less than 250 feet and not more than 300 feet.

STRATIGRAPHIC RELATIONSHIP: At present the correlation of the St. Ignace strata with rocks outside the Mackinac Straits area must be made on relatively little stratigraphic and paleontologic evidence. The stratigraphic relationships suggested in the following paragraphs may prove to be incorrect when the present study can be extended to an examination of the Upper Silurian rocks of the entire Michigan Basin.

The St. Ignace formation is assigned by the writers to the Bass Island[19] group, the rocks of which are known from the Bass Islands in western Lake Erie, places in northern Ohio south of these islands, southeastern Michigan, and western Ontario. This assignment is made because the St. Ignace strata occupy a stratigraphic position similar to beds of this group and resemble some of the beds in lithologic character. The few St. Ignace fossils, the stratigraphic positions of which are discussed in following paragraphs, also support the placement of the formation in the Bass Island group.

The species of *Leperditia*, which is in the dolomite of the middle part of the formation along Church Street in St. Ignace and along the Lake Michigan shore northwest of Pte. la Barbe, is closely related to *Leperditia jonesi* Hall and *L. ohioensis* Bassler. *Leperditis jonesi* Hall and *L. ohioensis* Bassler are respectively characteristic of the Cobleskill limestone of New York and the Greenfield of Ohio, the oldest formation of the Bass Island group. In the recently published correlation chart of the Silurian formations of North America by C. K. Swartz, et al (1942, pp. 533-538, 1 pl.)[34] the Cobleskill limestone is correlated with the Raisin River dolomite, the youngest formation of the Bass Island group. By most workers the Greenfield dolomite is considered to be the oldest formation of the Bass Island group.

Several specimens which seem to be identical with the questionable alga *Sphaerococcites? glomeratus* Grabau were found on blocks of dolomite on the bottom of the approach to the proposed ferry terminal one mile southwest of St. Ignace (pl. V, fig. 10). With little doubt they were blasted from the 14-foot bed of dolomite of unit 3 of the section exhibited in the rock walls of the approach; this dolomite, as previously noted, is in the middle part of the St. Ignace formation and probably occupies a position above the *Leperditia*-bearing dolomite exposed nearby on Church Street. The questionable alga, *Sphaerococcites? glomeratus* Grabau, is reported by Grabau (1910, p. 210)[38] as occurring in the Greenfield and Raisin River dolomites.

The dolomites of the upper part of the St. Ignace formation have more species of fossils than the rocks of the middle and lower parts of the formation, but unfortunately most of these fossils are so poorly preserved that their exact specific identity cannot be determined. A further search for fossils very likely will yield determinable species which may aid materially in the correlation of the St. Ignace strata.

The small brachiopod, found in detached blocks of dolomite from the upper part of the formation at the northwest end of the Hombach quarry and identified as *Spirifer (Delthyris)* sp. aff. *S. (D.) corallinensis* (Grabau) (see pl. V, figs. 8-9), suggests an assignment of the St. Ignace rocks to the Bass Island group. *Spirifer (Delthyris) corallinensis* (Grabau), to which the St. Ignace brachiopod is closely related, was first described from the Cobleskill limestone, which, as previously noted, has been correlated with the Raisin River dolomite of the Bass Island group. The species also has been recorded from the Decker limestone of southeastern New York, which has been correlated with the Cobleskill, and the Rondout limestone, which overlies the Cobleskill and Decker formations and hence would seem to be younger than the Raisin River dolomite. August F. Foerste[39] noted the occurrence of the species in the Kokomo limestone of Indiana. E. R. Cumings and R. R. Schrock[40] recorded the species in faunal lists of the Kenneth limestone of Indiana, which these writers (1927, pp. 76-77[41] and 1928, pp. 117-118, 121-123)[40] defined and separated from the Kokomo limestone of Foerste. In the correlation chart by C. K. Swartz and others (1942, pp. 533-538, 1 pl.)[34] the Kokomo limestone, comprising the lower part of the Kokomo limestone of Foerste, is correlated with the Greenfield dolomite. In the same chart the Kenneth limestone is shown as occupying a position between strata of the upper part of the Bass Island group and the top of the Upper Silurian of Indiana. Although the chart also states that the Kenneth limestone "may be Devonian," it seems very probable that the beds of this limestone containing *Spirifer (Delthyris) corallinensis* (Grabau) are of Upper Silurian age.

At several places in the area the dolomites of the upper part of the St. Ignace formation contain a very poorly preserved coral which seems referable to *Cyathophyllum hydraulicum* (Simpson Ms.) Grabau. This species is characteristic of the Akron dolomite of western New York and part of Ontario just west of Buffalo, New York. This dolomite, as previously noted, is thought to be equivalent to the Cobleskill limestone which C. K. Swartz and others have correlated with the Raisin River dolomite of the Bass Island group.

Although the paleontologic evidence indicates that the St. Ignace formation probably occupies a position in the Bass Island group, the exact stratigraphic relationship of the formation to strata now assigned to this group is uncertain. The few poorly preserved and provisionally identified fossils possibly suggest a closer relationship of the St. Ignace strata to the Akron-Cobleskill rocks than to others. The correlation of the Akron-Cobleskill rocks with the Raisin River dolomite by C. K. Swartz, et al (1942, pp. 533-538, 1 pl.)[34] leads one to look for some fossils of this dolomite in the St. Ignace deposits. Failure to find a single diagnostic Raisin River dolomite species in the St. Ignace formation casts doubt on a correlation of this formation with the Raisin River dolomite and on the correlation of the Raisin River with the Akron-Cobleskill strata.

Several differences of opinion exist regarding the classification and correlation of some of the rocks of the Bass Island and Salina groups of the Michigan Basin. It seems unnecessary to discuss these views in this report. It is hoped that a study of these groups exposed elsewhere in the Michigan Basin may eliminate the uncertainties in the stratigraphy and provide information as to the exact correlation of the St. Ignace formation.

GARDEN ISLAND FORMATION

NOMENCLATURE: The name Garden Island is proposed for a thin Middle Devonian formation which occupies a position between the Upper Silurian St. Ignace and the Middle Devonian Bois Blanc formations. The name is taken from the type locality on Garden Island, which is north of Beaver Island, in Lake Michigan.

DISTRIBUTION: The only known outcrops of the formation are along the westernmost point of Garden Island almost directly west of the center of the island; the point is in the SW¼ sec. 3, T. 39 N., R. 10 W., Charlevoix County, and forms the north cape of Indian Bay, the largest indentation of Lake Michigan in the western side of Garden Island.

The formation underlies a narrow belt of land having an east-northeast trend across Garden Island (see map). In the area adjacent to the Straits of Mackinac it is not exposed, but several outcrops indicate that it was eroded away prior to the deposition of the Bois Blanc formation. If not removed by erosion to the southwest of Garden Island, the formation forms the bed of Lake Michigan just south of Whiskey Island and north of Trout and Gull Islands (see map in pocket).

LITHOLOGIC AND PALEONTOLOGIC CHARACTERS: The few beds of the formation which could be examined during the summer of 1943 were covered almost entirely by the high water of Lake Michigan. They consist of light-buff, dolomitic sandstone, with frosted quartz grains, buff dolomite having few frosted quartz grains, and very hard buff gray to dark gray dolomite with few chert nodules and an apparent absence of quartz grains. The sandstone was found just awash at the extremity of the westernmost point of Garden Island and at intervals a few hundred feet to the northeast. Blocks of the sandstone and also of the buff dolomite are in the storm beaches adjacent to the shore. The buff dolomite and the hard buff gray to dark gray dolomite, which may be interbedded and which seemingly overlie the sandstone, were found at the shore line and on the lake bottom immediately south of the point. The dolomites contain *Zaphrentis?* sp. cf. *Z. cornuformis* Stewart, *Hederella?* sp. cf. *H. ramea* Clarke, *Leptostrophia magnifica* (Hall), *Costispirifer arenosus* (Conrad), *Plethorhyncha* sp. cf. *P. barrandii* (Hall), *P. oblata* (Hall), *P. pleiopleura* (Conrad), *Rensselaeria elongata* (Conrad), *Phacops* sp. cf. *P. cristata* Hall, and *Synphoria stemmatus* Clarke. The brachiopods *Rensselaeria elongata* (Conrad) and *Costispirifer arenosus* (Conrad), are the most abundant of the fossils noted (pl. VIII, IX).

THICKNESS: At the type locality probably not more than three feet of strata was seen. A greater thickness as well as a better idea of the super position of the beds may be recognized when the waters of lake Michigan are at a low level stage.

An estimate of the total thickness of the formation may be made from certain field relationships. At the northern point of Garden Island St. Ignace dolomites, which are at least 30 feet below the top of the formation, outcrop along the shore. About two miles southeast of the point numerous blocks of St. Ignace dolomite have been brought to the beach by ice-push and storm waves from bedded-rock a short distance off shore. Along the shore a few hundred yards south of the type exposure of the Garden Island formation, blocks of cherty dolomite of the overlying Bois Blanc formation are fairly numerous, suggesting the presence of nearby though covered ledges of this formation. The locations of these rocks indicate that the Garden Island formation is restricted to a narrow belt of land (see map). The narrowness of this belt and the gentle dip of the strata on the island indicate that the maximum thickness of the Garden Island formation probably is not over 25 feet and that the average thickness may not be more than 15 feet.

STRATIGRAPH1C RELATIONSHIP: The Garden Island formation is a correlative of the Oriskany sandstone of southwestern Ontario and New York as shown by the common occurrence in these formations of *Costispirifer arenosus* (Conrad), *Rensselaeria elongata* (Conrad), and several other species previously noted as present in the Garden Island strata at its type locality. It also is of the same age as the Ridgely sandstone of Maryland, Pennsylvania, Virginia, and West Virginia; the Little Saline limestone of Missouri; and the Backbone limestone of Illinois. Other formations containing an Oriskany fauna and hence having a time equivalence with the Garden Island strata have been indicated by G. Arthur Cooper and others (1942, ch. 4).[35]

The presence of Oriskany species in the Garden Island formation is of great interest since it proves the northwestward extension of the typical Oriskany fauna for a distance of nearly 350 miles from its occurrence in the Oriskany deposits in the vicinity of DeCewville about 15 miles southeast of Brantford, Ontario (see Stauffer, 1915, p. 5 and map 116 A).[42] With little doubt the Oriskany fauna entered Michigan in a westward spreading of the Oriskany sea from New York through Ontario.

An unconformity, not observable, exists at the base of the Garden Island formation. In eastern New York the counterpart of the Garden Island formation, the Oriskany sandstone, was deposited on eroded Lower Devonian strata comprising the Helderberg group. In western New York and southwestern Ontario the sandstone of the westward transgressing Oriskany sea lies on Upper Silurian strata. In the Mackinac Straits region the Garden Island strata of this sea with little doubt rests on the St. Ignace formation of Upper Silurian age; any Helderberg deposits and possibly Bass Island formations younger than the St. Ignace, which may have been in the Straits region, were removed by erosion in pre-Garden Island time.

Undoubtedly an unconformity is at the top of the Garden Island formation. Evidence for its existence is presented in the description of the Bois Blanc formation.

BOIS BLANC FORMATION

NOMENCLATURE: The name Bois Blanc is proposed for a Lower or Middle Devonian formation occupying a position between the Lower Devonian Garden Island formation, or the Upper Silurian St. Ignace formation where the Garden Island is absent, and the Lower or Middle Devonian Detroit River group. The name is chosen for the reason that the rocks of the formation are well-exposed on Bois Blanc Island situated in Lake Huron slightly less than 2½ miles southeast of Mackinac Island.

DISTRIBUTION: The formation underlies the southern two-thirds of Bois Blanc Island and a narrow belt of land along the northern shore of the Southern Peninsula between a point on Lake Huron about 28 miles southeast of Mackinaw City (pl. X) and Waugoshance or Crane Island 16 west of this city (see map). Its strata constitute the surface rocks of all of Gull, High, Trout, and Hog Islands, and a few smaller islands of the Beaver Island group in Lake Michigan. The southern half of Garden Island and the northern half of Beaver Island, the two largest islands of the group, also are underlain by these rocks.

Numerous large blocks of Bois Blanc strata are in the breccia which composes most of Mackinac Island and the St. Ignace Peninsula. The boundaries of most of the blocks are so poorly exposed that the blocks had to be mapped with the Mackinac breccia (see map in pocket).

LITHOLOGIC AND PALEONTOLOGIC CHARACTERS: The lower part of the Bois Blanc formation consists of interbedded chert and dolomite. The best exposed section of these strata is shown in the ravine near Fort Holmes at the top of Mackinac Island (pl. VII) and is noted in the description of the St. Ignace formation. A similar though considerably covered outcrop of the chert and dolomite is in the cliffs near the northern shore of Bois Blanc Island, the type locality for the formation. The exact location of the exposure and the lithologic character of its strata and those of the underlying St. Ignace formation are noted in the following description:

Section of strata along the shore and in cliffs in the northeastern part of sec. 9, Bois Blanc Island

	Thickness Feet
Bois Blanc formation:	
3. Dolomite, light-gray to buff-gray, interbedded with irregular layers of white to bluish-gray chert. The rock, covered in large part by soil and woods of young maple, is present in two cliffs; the upper one, about 25 feet in height, is about 600 feet south of the island shore; the lower one, 15 feet in height, is 300 feet from the shore. A prominent bench, probably cut by the waves of glacial Lake Nipissing, occurs between the two cliffs; a second bench, probably cut by a post-Nipissing lake, is present between the lower bluff and a third and lowest cliff noted in the description of unit 2. The benches decrease in width when traced westward; about a fourth of a mile to the west the cherty dolomite of unit 3 is present in a single bluff above the much narrowed lower terrace, which apparently corresponds to top of unit 2	40±
Total	40±
Disconformity—present but unexposed. The Garden Island formation, which rests on the St. Ignace formation on Garden Island, is as far as known not at the surface on Bois Blanc Island, apparently having been removed by erosion prior to the deposition of the Bois Blanc formation.	
St. Ignace formation:	
2. Dolomite, buff-gray to buff and thick-bedded, with little doubt composing most of a talus-covered cliff just south of a road adjacent to north shore of island. Dolomite in upper part of cliff is buff, has a sugary appearance, and contains very few poorly preserved remains of a small simple coral and a small *Spirifer?* sp.	32±
1. Covered—island shore to unit 2. Some, possibly all, of the covered unit is occupied by light buff gray to cream-colored, gashed, fine grained dolomite as suggested by low outcrops of this type of rock along shore about 300 feet east of this locality	5
Total	37±

Plate X. A. Block of very fossiliferous, cherty limestone of lower portion of middle part of Bois Blanc formation in Mackinac breccia. Slabs in talus weathered from nearly vertical beds. Cheeseman Road, 1 mile northeast of St. Ignace.

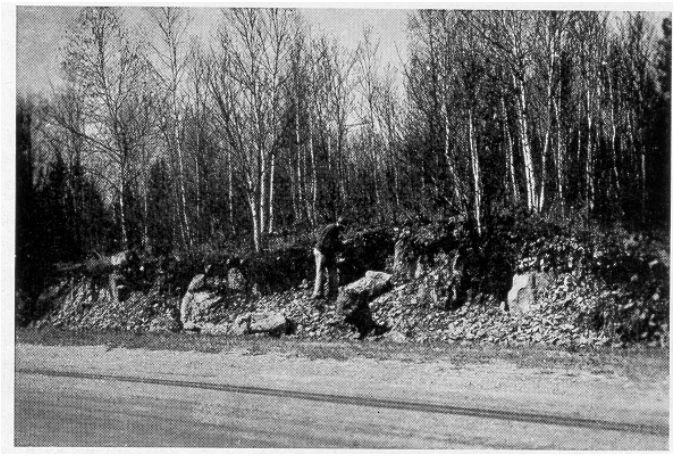


Plate X. B. Small bioherm in upper part of Bois Blanc formation on U.S. Highway 31 near Mackinaw City golf course. Core rock shown to right of man and flank beds to left.

Another outcrop of the beds in the lower part of the Bois Blanc formation is about two-fifths of a mile southeast of the cliff exposure. The lithologic and paleontologic character of these rocks and the lithology of the underlying St. Ignace dolomites are indicated in the following description:

Section of strata exposed between point on north shore of Bois Blanc Island near abandoned house and dock in northwest part of section 8 and point on little-used road about 600 feet inland

	Thickness Feet
Bois Blanc formation:	
6. Covered in large part along road to level of abandoned field. Unit occupied by interbedded chert and dolomite like that of unit 5; weathered-out chert abundant along road and in field just east of road. Fossils scarce, very poorly preserved, and identified as follows: *Amplexus* sp. and several other simple tetra-corals, *Favosites*—two species, *Emmonsia emmonsi* (Hall), *Dalmanella?* sp., *Rhipidomella* sp., *Pholidostrophia* sp., cf. *Amphigenia elongata* (Vanuxem), *Atrypa* sp., *Spirifer* sp., and *Cypricardinia?* sp.	15±
5. Dolomite, gray to buff-gray, interbedded with gray to bluish gray chert; beds two to six inches in thickness; unit exposed where road ascends an east-west trending cliff about a tenth of a mile southwest of outcrop of unit 2. Fossils scarce, chiefly simple tetracorals	8
4. Covered; probably occupied by rock similar to rock of unit 5	10±
Total	33
Disconformity—present but unexposed	
St. Ignace formation:	
3. Covered; with little doubt occupied by thick-bedded, light-buff dolomite; some beds of unit exposed two-fifths of a mile to the west in a cliff above the level of north shore road of island	30±
2. Dolomite, light-buff to cream-colored, thick-bedded to massive	10
1. Covered to lake level	3
Total	43±

In the description of the two sections presented above, the lower Bois Blanc strata are noted as resting disconformably on St. Ignace dolomites even though the contact between the rocks of the two formations is hidden from view by a cover of soil. The reason for believing that the Bois Blanc strata rest on St. Ignace dolomites rather than on Garden Island beds is that no detached blocks of the Garden Island formation were found at places adjacent to the covered contact. This belief is strengthened by the stratigraphic succession indicated by outcrops along the shore in the northwestern part of section 7 about three-fourths of a mile southeast of the exposure in the northwestern part of section 8. The highest St. Ignace rock at this place consists of cream-colored to very light buff dolomite with thin bands and irregular masses of medium to large grains of frosted quartz. Much of the dolomite shows coalescing rounded surfaces, which, though simulating the top of an algal layer, probably are of inorganic origin. On the shore just southeast of the easternmost outcrop of the dolomite is a small outcrop of the cherty dolomite of the Bois Blanc formation. The nearness of the lower part of the Bois Blanc formation to the St. Ignace dolomite is shown by the abundance of chert in the bed of the little-used, north shore road which almost reaches the point on the shore where the formational contact must exist. It is doubtful whether the covered interval between the Bois Blanc and St. Ignace rocks at this point is more than two feet. If any Garden Island strata are in this interval, it seems almost certain that blocks would be broken from them by waves and lake ice and be found on the shore. The absence of such blocks at this locality and also in sections 8 and 9 shows that the Garden Island rocks, if formerly present, were removed by erosion prior to the deposition of the Bois Blanc sediments. The disconformity between the Bois Blanc and St. Ignace strata is indicated not only by the absence of the Garden Island formation but by the absence of other Lower Devonian deposits which are especially well known in New York State.

Several outcrops of the cherty Bois Blanc dolomite, which is not shown in association with St. Ignace rocks, are worth noting because their occurrence is helpful to an understanding of the stratigraphy and the areal distribution of the formation. The cherty dolomite with few poorly preserved simple corals is exposed at intervals just above lake level along the shore of LaFayette Point at the eastern extremity of Bois Blanc Island and extends offshore for a long distance beneath the very shallow water of Lake Huron. A small outcrop of the dolomite is on the southern shore of Bois Blanc Island at Zela Point about three miles northwest of the village of Point aux Pins. Another small outcrop of the dolomite, which doubtless occupies a higher stratigraphic position than that at Zela Point, is present on the shore in section 33 about 1½ miles northwest of the village. Abundant chert and dolomite in beach material at two places on Garden Island in Lake Michigan indicate that ledges of the lower part of the formation are beneath the adjacent shallow water of the lake. One of these places is only a few hundred yards south of the type exposure of the Garden Island formation on the western side of the island in the SW¼ sec. 3, T. 39 N., R. 10 W. The other is along a prominent point near the middle of the eastern side of the island in sec. 31, T. 40 N., R. 9 W. The ledges of chert and dolomite at these localities probably would be visible on the shore at low water stages of Lake Michigan. Their geographic location aids materially in mapping the boundary between the Bois Blanc and Garden Island formations and in indicating that the Garden Island formation is relatively thin.

Ledges of dolomite, which probably occupy a position at or near the top of the lower part of the Bois Blanc formation, are on Gull and Trout Islands of the Beaver Island group. They are exposed along the shore of a small point on the western side of Gull Island about a half a mile south of the north end of the island. They crop out along the southern shore of Trout Island a short distance west of the southeastern point of the island. At both places the ledges consist of fine-grained, relatively hard, gray to bluish-gray dolomite with few chert nodules; the color of the weathered rock is light buff gray to light buff. The dolomite on Gull Island contains the trilobite *Anchiopsis anchiops* (Green) and poorly preserved brachiopods and gastropods. On Trout Island the dolomite has a few simple tetra-corals and stromatoporoids, a larger number of brachiopods identified as *Cymostrophia patersoni* (Hall), *Leptaena* sp., *Rhipidomella* sp. aff. *R. cleobis* (Hall), *R. livia* (Billings), *Spirifer duodenarius* (Hall), and *Stropheodonta* sp., a pelecypod *Cypricardinia?* sp., a cephalopod *Orthoceras?* sp., and the trilobites *Anchiopsis anchiops* (Green), *Phacops cristata* Hall and *Proetus* sp. The trilobite *Anchiopsis anchiops* (Green), although represented by few specimens, is the most conspicuous fossil of the dolomite on the two islands (pl. XI, figs. 8, 9). This species and the other definitely identified

species are characteristic of the lower Onondaga fauna of Ontario and New York.

The middle part of the Bois Blanc formation is composed of limestones, dolomitic limestones, and few beds of dolomite. The strata range in color from light-gray to light-buff. They contain nodules and irregular masses of chert which is much more abundant in some beds than others. Minor differences in the lithology of the rocks cannot be recorded in respect to their stratigraphic positions because no outcrops exhibiting thick sections of the middle part of the formation are known. Large blocks of rock, which are in the Mackinac breccia, (pl. X A) and are derived from the middle part of the Bois Blanc formation, show that such minor differences exist and that certain strata contain distinct fossil assemblages. The middle part of the formation is very fossiliferous. The numerous specifically identified fossils, noted in the rocks described in succeeding paragraphs, are characteristic of the lower Onondaga fauna of southwestern Ontario and New York.

Light-gray to light-buff, cherty limestones of the middle part of the formation are along the south shore of Bois Blanc Island, in section 27, between Rosie and Packard Points. They contain a few simple tetracorals, the compound tetracorals *Prismatophyllum* sp., and *Billingsastraea* n. sp., the tabulate corals *Alveolites squamosus* Billings, *Cladopora labiosa* (Billings), *Emmonsia emmonsia* (Hall), *E*. sp., *Favosites* sp. and *Syringopora hisingeri* Billings, the brachiopods *Amphigenia elongata* (Vanuxem), *Atrypa* sp. aff. *A. impressa* (Hall), *Chonetes hemisphericus* (Hall), *Costispirifer unicus* (Hall), *Fimbrispirifer divaricatus* (Hall), *Leptaena* sp., cf., *Pentamerella arata* (Conrad), and *Spirifer duodenarius* (Hall), the pelecypod *Conocardium* sp., and the trilobite *Anchiopsis anchiops* (Green) (pls. X, XI, XIV). A much larger number of lower Onondaga species will be recognized when more material is obtained from the very fossiliferous limestones at this locality.

Strata of the middle part of the formation are exposed along the shore of Lake Michigan at and on both sides of McGulpin Point located about 2-⅓ miles west and three-fourths of a mile north of the business district of Mackinaw City. They appear in small disconnected outcrops at lake level between places one-third of a mile southeast of the point, in sec. 11, T. 39 N., R. 4 W., and 1-⅛ miles southwest of the point, in the NW¼ NW¼ sec. 15, T. 39 N., R. 4 W. Most of the beds are very light buff, fine grained, cherty, dolomitic limestones, with a considerable amount of comminuted remains of fossils; the others are similar in lithologic character though light gray. The limestones contain the tetracoral *Billingsastraea verneuili* (Edwards and Haime), the tabulate corals *Emmonsia emmonsia* (Hall) and *Syringopora hisingeri* Billings, the brachiopods *Amphigenia elongata* (Vanuxem), *Centronella glansfagea* (Hall), *Camarotoechia tethys* (Billings), *Chonetes hemisphericus* Hall, *Costispirifer unicus* (Hall), *Spirifer duodenarius* (Hall), and *Strophonella ampla* (Hall), and the trilobites *Anchiopsis anchiops* (Green), *Calymene platys* Green, and *Phacops cristata* Hall (pls. X-XIV). Further collecting undoubtedly will add numerous other lower Onondaga species.

A large number of tetracorals and tabulate corals are in the limestone rubble of a storm beach on the lake shore near the center of the NW¼ sec. 15, T. 39 N., R. 4 W., about 1¼ miles southwest of McGulpin Point. The identified specimens include the tetracorals *Acrophyllum oneidaense* (Billings), *Billingsastraea verneuli* (Edwards and Haime), and *B*. n. sp. and the tabulate corals *Alveolites squamosus* Billings, *Ceratopora* sp., *Cladopora labiosa* (Billings), *Emmonsia emmonsia* (Hall), *E*. sp. Nos. 1, 2, and 3 *Favosites canadensis* (Billings), *F. winchelli* Rominger, *F*. sp.-l, 2, and 3, and *Syringopora hisingeri* Billings. Associated with the corals are the brachiopods *Frimbrispirifer divaricatus* (Hall) and *Spirifer duodenarius* (Hall) and the trilobite *Anchiopsis anchiops* (Green) (pls. X-XIV). The limestone, from which the corals and other invertebrates were derived, must compose the adjacent lake bottom and occupy a higher stratigraphic position than the strata exposed at intervals along the shore between this place and McGulpin Point.

Light-gray and light-buff limestones compose most of the rubble of storm beaches of a low headland in sec. 31, T. 39 N., R. 5 W., about 7½ miles west and 1½ miles south of the business district of Mackinaw City. The ledges, from which the limestone rubble was derived, probably are on the lake bottom adjacent to the headland.

During low stages of Lake Michigan beds of light buff limestone of the middle part of the formation are exposed along the shore of Big Stone Bay in sec. 21, T. 39 N., R. 5 W., between points an eighth and a half mile northwest of Mr. Frank Laway's pier. Many simple and compound tetracorals and a smaller number of other invertebrates, nearly all of which belong to lower Onondaga species, are present in the beach rubble broken from the limestone beds and cast on the shore by storm waves. The coral-bearing limestone may be the same as the limestone near the shore about 114 miles southwest of McGulpin Point.

A small outcrop of light-buff limestone with few fossils is at lake level about five-eighths of a mile northwest of Frank Laway's pier. About a fourth of a mile farther northwest the beach is covered with a very cherty limestone rubble derived from ledges on the lake bottom. The rocks at both places occupy positions below the coral bed and apparently are westward continuations of some of the strata exposed along the shore near McGulpin Point.

Small exposures of light-buff dolomites interbedded with light-buff to grayish-buff limestones are at lake level along the south shore of Waugoshance (or Crane) Island, about 17 miles west of Mackinaw City. Both types of rock contain a little chert. Fossils, which are representative of species found in the middle part of the Bois Blanc formation, seem to be more abundant in the

beds of limestone than in the dolomite. They occur as external and internal molds in the dolomite and as calcified or silicified remains in the limestone. A large number of lower Onondaga fossils are in the rock of the shingle beaches at this locality; possibly many of these rocks were broken from ledges on the lake bottom and cast on shore by storm waves.

Light buff gray, very cherty, dolomitic limestone is in the rubble of storm beaches between the northernmost point of Hog Island, located about 15 miles west of Waugoshance Island, and a point on the shore about three-quarters of a mile to the southwest. The ledges from which the rubble was derived are beneath the beaches and on the adjacent bottom of the lake. The tabulate corals *Emmonsia emmonsia* (Hall), *E*. sp., and *Favosites* Sp., the brachiopods *Amphigenia elongata* (Vanuxem), *Atrypa* sp., *Centronella glansfagea* Hall, *Chonetes hemisphericus* Hall, *Cymostrophia patersoni* (Hall), *Leptaena* sp., *Protoleptostrophia perplana* (Conrad), *Rhipidomella* sp., *Spirifer macrus* Hall and *Strophonella ampla* Hall, and the trilobite *Proetus crassimarginatus* Hall, were obtained from the limestone of the storm beaches.

Light gray, cherty, dolomitic limestones are at lake level along the eastern shore of Garden Island in sec. 7, T. 39 N., R. 9 W., about a third of a mile northwest of the southeastern point of this island. They contain a few simple tetracorals, a tabulate coral *Emmonsia* sp., the brachiopods *Amphigenia elongata* (Vanuxem), *Atrypa* sp. aff. *A. impressa* Hall, *Chonetes hemisphericus* (Hall), *Costispirifer unicus* (Hall), *Elytha* sp., *Fimbrispirifer divaricatus* (Hall), *Leptaena* sp., *Rhipidomella*, sp., *Schuchertella* sp., *Spirifer duodenarius* (Hall), *Spirifer varicosus* Hall, and *Stropheodonta* sp., the pelecypods *Cypricardinia?* sp., and *Limoptera* sp., a gastropod *Platyceras* sp., and the trilobite *Proetus crassimarginatus* Hall (pls. XI-XIV).

Similar beds of limestone are exposed just above lake level and are shown on the lake bottom at a point on Garden Island in the NW¼ sec. 13, and the NE¼ sec. 14, T. 39 N., R. 10 W. They probably occupy nearly the same stratigraphic position in the middle part of the formation as the beds noted in the preceding paragraph and contain a few simple tetracorals, the compound tetracorals *Billingsastraea verneuili* (Edwards and Haime), the tabulate corals *Emmonsia emmonsi* (Hall), *E*. sp. and *Favosites* sp., the brachiopods *Amphigenia elongata* (Vanuxem), *Atrypa* sp. aff. *A. impressa* Hall, *Chonetes hemisphericus* Hall, *Leptaena* sp., cf. *Pentamerella arata* (Conrad), *Schuchertella* sp., *Spirifer* sp., cf. *S. marcus* Hall and *S*. sp. aff. *S. varicosus* Hall.

Light-gray, cherty, dolomitic limestones similar to the limestones of the two Garden Island localities, and some beds of darker gray dolomite outcrop just above lake level on the shore of Beaver Island east of the center of sec. 23, T. 39 N., R. 10 W., about two-thirds of a mile northeast of the Beaver Island Coast Guard Station, which is located about three-quarters of a mile east of the business district of St. James. They contain a few simple tetracorals, the compound tetracorals *Billingsastraea verneuili* (Edwards and Haime), and *B*. n. sp., the tabulate corals *Emmonsia emmonsia* (Hall) and *Syringopora hisingeri* Billings, a bryozoan *Fenestrellina* sp., the brachiopods *Amphigenia elongata* (Vanuxem), Atrypa sp. aff. *A. impressa* Hall, *Centronella* sp., *Chonetes hemispherica* Hall, *Costispirifer unicus* (Hall), *Cymostrophia patersoni* (Hall), *Leptaena* sp., *Merisitella?* sp., *Pentamerella* sp. aff. *P. arata* (Conrad), *Pholidops* sp., *Protoleptostrophia perplana* (Conrad), *Strophonella ampla* (Hall), *Spirifer duodenarius* (Hall), S. sp. cf., *S. macrus* Hall and *S. varicosus* Hall, the pelecypods *Conocardium* sp. and *Limoptera* sp., and the trilobites *Phacops* sp. and *Proetus* sp. (pls. IX, XI, XII).

The strata exposed two-thirds of a mile northeast of the Beaver Island Coast Guard Station, in the southern parts of Garden and Waugoshance Islands, in the vicinity of McGulpin Point, and on the south shore of Bois Blanc Island between Packard and Rosie Points are in the lower portion of the middle part of the Bois Blanc formation. They are thin- and uneven-bedded light-gray to light-buff limestones, dolomitic limestones, and dolomites which are characterized by much chert and many brachiopods. The most conspicuous brachiopods are *Amphigenia elongata* (Vanuxem), *Costispirifer unicus* (Hall), *Fimbrispirifer divaricatus* (Hall), and *Spirifer duodenarius* (Hall).

Rocks of the upper portion of the middle part of the Bois Blanc formation are in an upland that has a northeastward-facing slope and extends southeastward from the vicinity of McGulpin Point to the neighborhood of Mill Creek about four miles southeast of Mackinaw City. Although nearly at the surface of the upland, the strata are visible only in a few outcrops which exhibit thin sections. However, an idea of the lithology and paleontologic character of some of the rocks is indicated by the descriptions of the outcrops noted in the following paragraphs:

About three feet of dolomitic limestone is shown in a highway cut in the slope of the upland about 1¾ miles west of the business district of Mackinaw City. The limestone, exposed on the south side of the SW¼ SE¼ sec. 11, T. 39 N., R. 4 W., just north of the house on the Pierce and Son dairy farm, is buff-gray when not weathered and brown when weathered. It contains a few small cavities lined with crystals of calcite, and a small number of very poorly preserved simple tetracorals, brachiopods, and trilobites.

The base of this limestone is 46 feet above the level of Lake Michigan, which, during the summer of 1943, was approximately 581 feet above sea level. If the strata in the vicinity of the road cut have a southward dip of about 60 feet per mile, as seems likely, possibly 75 feet of rock is between the limestone of the cut and the lowest strata exposed along the nearby shore of McGulpin Point.

The dolomitic limestone of the road cut is overlain by light-gray to light buff gray cherty limestones, which, under a thin cover of soil, cap parts of the upland

immediately northwest, west, and southwest of the highway cut. The presence of the cherty limestones is indicated by an accumulation of such material deposited as a shingle beach on the dolomitic limestone by Lake Nipissing or a post-Nipissing lake. Their existence is clearly shown by an abundance of pieces of the limestone in the soil of the cultivated fields on the upland just northwest and southwest of the road cut. Numerous slabs of the limestone, broken from ledges by plowing, have been piled along a fence on the north side of the field in the SE¼ SW¼ sec. 11, T. 39 N., R. 4 W., about an eighth of a mile northwest of the highway cut and the Pierce and Son farm house. A greater quantity of the rock has been plowed up in the field southwest of the house and placed along the fence on the south side of the NW¼ NW¼ sec. 14, T. 39 N., R. 4 W. An exceedingly large number of simple and compound tetracorals and tabulate corals are in the slabs of limestone and as weathered out specimens along this fence. It is very probable that most of the species of corals which are reported from the lower Onondaga fauna of southwestern Ontario, will be recognized in the material collected along the fence when all the specimens can be prepared for study. The lower Onondaga tetracorals *Acrophyllum oneidaense* (Billings), *Billingsastraea verneuili* (Edwards and Haime), *Chonophyllum magnificum* Billings, *Synaptophyllum arundinaceum* (Billings), and *S. simcoense* (Billings), and the tabulate corals *Alveolites aquamosus* Billings, *Ceratopora nobilis* (Billings), *Emmonsia emmonsia* (Hall), *Favosites canadensis* (Billings), *F. winchelli* (Rominger), *Thamnopora limitaris* (Rominger), *Pleurodictyum convexum* (d'Orbigny), and *P. cylindricum* (Michelin), which have been identified (pls. XII-XIV), probably represent not more than a fourth of the total number of species of the coral-bearing limestones beneath the thin soil at this locality. In addition to the corals, the limestone contains a species of *Astraeospongia*, a considerable number of stromatoporoids and massive types of bryozoa, and a few brachiopods and trilobites.

The thickness of the limestones between the thin soil-covered, coral-bearing bed at the fence and the top of the three feet of dolomitic limestone in the road-cut just north of the Pierce and Son farm house is about 26 to 27 feet, as indicated by the difference in elevation of the outcrops and the southward dip of the strata of approximately 60 feet per mile. The ground elevation of the fence near the southwest corner of the NW¼ NW¼ sec. 14, T. 39 N., R. 9 W., is 651 feet. The surface of the coral-bearing bed at this place is not covered by more than two feet of soil; its elevation therefore is about 649 feet. The elevation of the top of the dolomitic limestone in the roadcut is 630 feet. The difference of 19 feet in elevation between the stratigraphic surfaces also represents closely the minimum thickness of the intervening rock. Since seven to eight feet of strata must be added to the 19 feet of rock as required by a dip of 60 feet per mile, the total thickness of the limestone between the beds of the road-cut and the field at the fenceline is 26 to 27 feet.

The relationship of the coral-bearing limestone of the Pierce and Son farm to the coral bed on the lake bottom near the center of the NW¼ sec. 15, T. 39 N., R. 4 W., about 1¼ miles southwest of McGulpin Point is not definitely known. The possibility that the limestones at the two places, which are about three-quarters of a mile apart, may be one and the same bed is suggested by the occurrence in the strata of numerous corals and of many corals of the same species. This possibility also is suggested by the locations of the limestones at places which are on the general east-west strike of the rocks of the region. The fact that the limestone on the Pierce and Son farm is about 68 feet higher than the limestone along the shore southwest of McGulpin Point is strong evidence for believing that the two limestones are distinct and occupy different stratigraphic positions. Obviously this evidence could be eliminated by local folding or by the faulting which has occurred throughout the Mackinac Straits area. Until further field studies can demonstrate the existence of a fold or a fault, the writers believe that the two coral-bearing limestones are distinct, and that the limestone on the Pierce and Son farm occupies a higher position in the formation than the limestone along the shore.

Strata having a higher position in the upper portion of the middle part of the Bois Blanc formation than the coral-bearing limestone of the Pierce and Son farm are exposed near the SW corner sec. 14, T. 39 N., R. 4 W., about three-quarters of a mile south of this farm. The lowest bed outcrops close to the southwest corner of section 14 at the side of a road leading southward to French Lake. It is a light-buff limestone having a thickness of 18 inches and containing a few simple tetracorals, *Alveolites* sp, aff. *A. squamosus* Billings, and a medium-sized *Atrypa*, which has closely spaced, relatively fine plications. The elevation of this limestone is 616 feet and its position above the coral bed of the Pierce and Son farm probably is 10 to 15 feet. Eight feet of buff gray to buff, thin- and uneven-bedded limestone is shown in a cut in the road on the south side of section 14 about 200 feet east of the outcrop of the 18-inch limestone. It is separated from the top of the 18-inch limestone by a covered interval of 13 feet and has a few poorly preserved fossils which are more numerous in the upper three feet than the lower five feet of the rock. It contains a few stromatoporoids and simple tetracorals, a new species of the compound tetracoral *Billingsastraea*, the tabulate coral *Favosites*, the brachiopods *Atrypa* sp., *Meristella* sp., and *Rhipidomella* sp., the pelecypods *Conocardium* sp., and *Paracyclas?* sp., the cephalopod *Sphyradoceras* sp. cf., *S. clio* (Hall), and the trilobites *Anchiopsis* sp. aff. *A. anchiops* (Green), *Phacops* sp. aff. *P. cristata* Hall and *Proetus* sp.

Limestones, which probably occupy the same stratigraphic position as those shown in the vicinity of the SW corner sec. 14, T. 39 N., R. 4 W., and higher beds, which belong to the upper part of the Bois Blanc

formation, are exposed along Mill Creek about four miles southeast of Mackinaw City. The lithologic character and fossil content of the rocks along Mill Creek are noted in the following description:

Section of strata exposed in Mill Creek between mouth of creek and top of abandoned quarry about a tenth of a mile upstream

Bois Blanc formation:	Thickness Feet	Inches
22. Limestone, gray to buff-gray, becoming light-gray toward top; upper six inches laminated; stromatoporoids present, more abundant in lower three feet	5	
21. Limestone, shaly, gray to light buff gray, with very numerous specimens of *Idiostroma* sp., a small number of massive and nodular types of stromatoporoids, a few small simple tetracorals and brachiopods, two species of *Cladopora*, and a thick-stemmed species of *Alveolites*	2	8
20. Limestone, shaly, gray, similar to unit 18 in having an abundance of thin stromatoporoids and *Idiostroma*		7
19. Limestone, light buff gray, and granular, with nodular types of stromatoporoids and few *Idiostroma;* grades into rocks of units 15 and 17 and may be a lens		9
18. Limestone, very shaly, gray, with thin stromatoporoids piled on top of one another to form a biostrome; fenestillids present in small number...		10
17. Covered; red, residual clay and light gray band in hillside suggest that unit consists of leached limestone	4	
16. Limestone, light buff gray with few specimens of *Idiostroma* and other stromatoporoids	1	3
15. Limestone, light buff gray with numerous thin stromatoporoids composing a biostrome	1	3
14. Limestone, light buff gray, fine- to medium-grained and hard, weathering to light yellowish gray and containing thin stromatoporoids, a quarter to a half inch in thickness, a few simple tetracorals, a small-tubed *Cladopora*, *Emmonsia* sp., *Favosites* sp. aff. *F. canadensis* (Billings), crinoid columnals, the brachiopods *Athyris?* sp., *Atrypa* sp.,—with medium-sized plications, *Atrypa* sp.—with coarse plications, *Rhipidomella* sp. and *Spirifer* sp. cf. *S. varicosus* Hall, and the trilobite *Phacops* sp. aff. *P. cristata* Hall	2	6
13. Limestone, light-buff, thin-bedded, with thin stromatoporoids; earthy appearance in weathered condition	1	5
12. Limestone, light-buff and granular. This limestone is the lowest bed of an abandoned quarry in the hillside on the north side of Mill Creek and a few hundred feet northwest of the top of unit 10		10
11. Covered	25±	
10. Limestone, light buff gray, with *Idiostroma;* lowest 7 inches filled with *Idiostroma*, constituting a biostrome. Units 7 to 4 inclusive shown in vertical rock face on south side of creek beneath old broken highway bridge	1	7
9. Limestone, light buff, with many thin and few massive stromatoporoids and *Emmonsia* sp. aff. *E. emmonsi* (Hall)	2	
8. Limestone, light-buff, with an abundance of thin stromatoporoids an eighth to three-quarters of an inch in thickness composing a biostrome	9	
7. Limestone, light buff-gray, with few thin stromatoporoids, a small-tubed, branching *Cladopora*, *Emmonsia* sp. aff. *E. emmonsi* (Hall), and *Spirifer* sp. aff. *S. varicosus* Hall	3	
6. Dolomite, buff, granular, and partly crystalline, uneven-bedded	16	
5. Limestone, similar to unit 3	1	
4. Covered—beneath culvert under Michigan Central Railroad	10±	
3. Limestone, light-buff and granular, with small, irregular dark buff gray, crystalline areas, thin- and uneven-bedded, weathering to a brown. Rock contains a few thin stromatoporoids and simple tetracorals, a *Stropheodonta* with thin fine plications, poorly preserved pelecypods, *Sphyradoceras* sp. cf. *S. clio* (Hall), and *Anchiopsis* sp. aff. *A. anchiops* (Green), and out-crops between culverts of U.S. Highway No. 23 and Michigan Central Railroad	7	
2. Dolomite, buff, granular, thicker- and more even-bedded than unit 1, weathering to brown; most of unit present beneath culvert of U.S. Highway No. 23	8±	
1. Limestone, light buff gray to buff, with small irregular, dark buff gray, crystalline areas, thin- and uneven-bedded, weathering to brown. Rock contains stromatoporoids, which are more abundant in lower two feet, a small tubed *Cladopora*, *Favosites* sp., a poorly preserved gastropod and *Sphyradoceras?* sp. It outcrops between the mouth of the creek and the culvert of U.S. Highway No. 23. Dip near culvert nine degrees, S. 10 degrees W.	5	
Total	108±	8

The rocks of units 1 to 6 of the section described above are considered as belonging to the upper portion of the middle part of the Bois Blanc formation. The strata of units 1, 2, and 3 are lithologically like and have several species of fossils in common with the eight feet of limestone exposed in the road cut about 200 feet east of the southwest corner of section 14, T. 39 N., R. 4 W. The lithologic and faunal similarities are so evident that they suggest a continuity of the limestones of the road cut with some of the strata of units 1, 2, and 3. The rocks of units 7 to 22 inclusive belong to the upper part of the Bois Blanc formation and are characterized by the presence of *Idiostroma* and thin, explanate types of stromatoporoids, which have built up biostromes in some of the units (pl. XV).

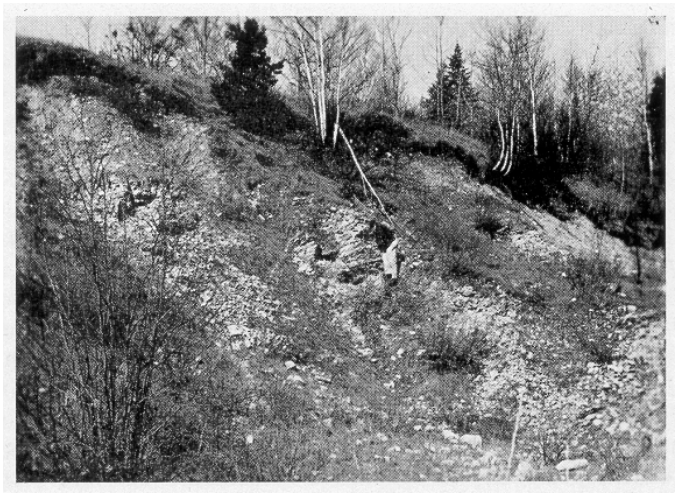


Plate XV. A. Strata of upper part of Bois Blanc formation in abandoned Mill Creek quarry. Figure of man shown at outcrop of units 19 to 22 of Mill Creek section.

Plate XV. B. A close view of Idiostroma—bearing, shaley limestone of unit 21 in abandoned Mill Creek quarry.

Several exposures of beds of the upper part of the formation are shown in the ditches and cuts of U. S. Highway 31 in the vicinity of the Mackinaw City golf course, which is located about three-quarters of a mile south of the southern boundary of Mackinaw City. The most northern exposure is in the ditch on the west side of the highway in the NE¼ SE¼ sec. 24, T. 39 N., R. 4 W. The rock at this place consists of 11 feet of thin-bedded limestone, which grades from light buff gray at the base to light-buff at the top. It contains many thin stromatoporoids, a few small simple tetracorals, the tabulate corals *Alveolites* sp., *Ceratopora* sp. cf. *C. nobilis* (Billings), *Cladopora* sp. 1 and *C*. sp. 2, numerous crinoid columnals, a few poorly preserved bryozoa, the brachiopods *Atrypa* sp. 1—with relatively fine plications, *Atrypa* sp. 2—with coarse plications, *Pentamerella?* sp., *Rhipidomella* sp. and *Spirifer* sp., the pelecypod *Paracyclas* sp. cf. *P. ellipita* Hall, a low-spired gastropod and the trilobite *Proetus* sp. The lowest bed of the limestone has an elevation of 661 feet, which is about 80 feet above the level of Lake Michigan. A covered interval of four to five feet is between the highest bed of the limestone and the lowest observable core rock of a bioherm exposed in the highway cut about 150 feet south of the uppermost limestone stratum. The core rock of the bioherm, which has a northeast-southwest trend, is best shown on the west side of the highway (see pl. XB). It consists of a massive, buff-gray limestone with numerous cavities in many of which are small scalenohedrons of calcite. Rounded and frosted grains of quartz are scattered throughout the rock and are so abundant in one band that they form a calcareous sandstone. An enormous number of entire and broken stromatoporoids and a smaller number of several branching species of *Cladopora* and *Favosites* are conspicuous in the core rock, the matrix of which must have been derived in large part from the comminution of the skeletons of these organisms. In addition to these fossils, the rock contains *Idiostroma* sp., the simple tetracorals *Amplexus* sp. and *Cystiphyllum* sp., the tabulate corals *Alveolites* sp., *Ceratopora* sp. cf. *C. nobilis* (Billings) and *Favosites* sp. cf. *F. canadensis* (Billings), numerous crinoid columnals, very poorly preserved bryozoa and brachiopods, the pelecypods *Conocardium* sp. and *Panenka* n. sp.—related to *P. canadensis* Whiteaves, several species of gastropods and the cephalopods *Acleistoceras* sp., *Brevicoceras?* sp. and *Nephriticeras?* sp. The thickness of the core rock including the calcareous sandstone in the road cut is about eight feet. An additional five feet of the rock is in the higher ground immediately west of the exposure on the west side of the highway. The flank-beds, where best shown on the west side of the road, consist of buff-gray to light-buff limestones which dip southward to southeastward from the core rock and have a thickness of five to six feet. Their texture becomes finer when traced from the core rock; some beds at a distance of only 75 feet from the core are very fine grained. Another exposure of beds in the upper part of the Bois Blanc formation is shown in a cut on the west side of the highway about one-tenth of a mile south of the bioherm. The lower five feet of this exposure consists of thin- and uneven-bedded, very light buff, granular limestone with *Idiostroma* and other stromatoporoids. The upper nine feet consists of thicker bedded, light buff gray to very light buff, granular limestone. In this limestone are two bands five inches in thickness which are filled with the remains of *Idiostroma* and thin explanate stromatoporoids; the bands occupy positions two and five feet above the base of the limestone. The fact that the limestones at this place resemble in lithology the flank beds of the bioherm a tenth of a mile to the north and are arched upward suggests very strongly that the limestones are part of a bioherm, the core rock of which is beneath the lowest bed of the exposure. In addition to *Idiostroma* and thin explanate stromatoporoids, the strata contain *Chonophyllum?* sp., *Heliophyllum* sp. and a few other simple tetracorals, the tabulate corals *Ceratopora* sp. cf. *C. nobilis* (Billings), *Cladopora* sp. and *Thamnopora* sp. cf. *T. limitaris* (Rominger), crinoid columnals and the pelecypod Conocardium sp. About six feet of nearly massive, light-buff to light buff gray, porous limestone is shown in a cut on the east side of the highway about two-tenths of a mile farther south. It contains stromatoporoids and branching species of *Cladopora* and *Favosites* like the core rock of the bioherm exposed in the road cut three-tenths of a mile to the north and doubtless composes the central part of another bioherm. The two bioherms probably occupy the same stratigraphic position although the bioherm to the north may be lower in the section.

Another exposure of strata in the upper part of the Bois Blanc formation is shown in a shallow trench on the upland about two miles southeast of Mackinaw City. The lithologic character, thickness, and fossils of the rock are noted in the following description:

Section of strata in shallow trench excavated for testing limestone in woods of young maple and birch in the center of the E½, Sec. 29, T. 39 N., R. 3 W., about two miles southeast of Mackinaw City

	Thickness Feet
Bois Blanc formation:	
4. Limestone, light yellowish gray, very fine grained, laminated, with spherical and irregularly shaped solution cavities and some gashes filled with transparent crystals of unknown mineral; some parts of rock considerably fractured	2–3
3. Covered	3±
2. Limestone, buff-gray, medium to very finely crystalline with few small disseminated crystals of calcite	3–4
1. Limestone, buff-gray to light-buff, weathering to buff or brown and splitting into thin, uneven layers; lower part with many vugs coated with limonitic material. The rock is characterized by abundant specimens of *Idiostroma* and thin explanate stromatoporoids and less numerous examples of dumose stromatoporoids and a ramose species of *Cladopora*. It also contains *Romingeria* sp. cf. *R. cornuta* (Billings), crinoid columnals, a small multicostate and a small costellate species of *Atrypa*, *Proetus* sp. and *Phacops* sp. cf. *P. cristata* var. *pipa* Hall and Clarke. Elevation of base of unit 698 feet	7–8
Total	15–18

The large number of *Idiostroma* and thin, explanate types of stromatoporoids in the limestone of unit 1 indicate that the strata of the trench belong to the upper part of the Bois Blanc formation.

Although the rocks of the trench, in the cuts along U. S. Highway 31 in the vicinity of the Mackinaw City golf course and in units 7 to 22 of the Mill Creek section have the same fauna, the positions of strata of one of these

exposures with respect to those of the other two are not definite. The lowest rock of the trench has an elevation of 698 feet and is 8 to 10 feet higher in elevation than the top of the core rock of the bioherm on Highway 31 nearest to Mackinaw City. The differences in elevation suggest that the beds of the trench are above the bioherm and its apparently equivalent biohermal strata exposed a short distance farther south along the highway. The base of the lowest beds along U. S. Highway 31, exposed in the ditch on the west side of the highway, has an elevation of 661 feet. Since the top of the highest bed of unit 22 of the Mill Creek section has an elevation of 635 feet, all of the Bois Blanc rocks along Mill Creek seem to occupy a position beneath the lowest bed on Highway 31. The lower elevation of the Mill Creek strata may be owing to the fact that they are farther down the dip than the beds of the highway. The lower elevation may be explained also by a greater downward movement of the rocks in the Mill Creek area than in the vicinity of the highway during the regional collapse of the strata. The relatively high dips of the rocks along Mill Creek and a breccia of post-Bois Blanc limestone in the creek a short distance upstream from the abandoned quarry indicate that a settling of the beds has occurred. The relative positions of the strata of the highway, trench, and Mill Creek as suggested by elevations may be incorrect. The rocks at the three places may be continuous and the strata along the highway and possibly in the trench may be a biohermal facies of some or all of the sediments of the upper part of the Bois Blanc formation of Mill Creek.

THICKNESS: The lack of exposures from which measurements of the thickness of the complete succession of the rocks of the Bois Blanc formation can be obtained make it necessary to estimate the thickness of this stratigraphic unit. The thickness of the cherty dolomites composing the lower part of the formation is estimated to be about 75 feet. The thickness of the lower portion of the middle part of the formation containing *Amphigenia elongata* (Vanuxem), *Costispirifer unica* (Hall), *Fimbrispirifer divaricatus* (Hall), and *Spirifer duodenarius* (Hall) probably is between 100 and 150 feet; the upper portion is between 75 and 100 feet thick. The thickness of the upper part of the formation probably is about 75 feet. The total thickness of the formation probably is not less than 325 feet nor more than 400 feet.

STRATIGRAPHIC RELATIONSHIP: The fossils of the Bois Blanc formation indicate that the formation is closely related to the Onondaga limestone of southwestern Ontario and western New York.

G. Arthur Cooper and others (1942, p. 1774)[35] have noted that the Onondaga limestone of western New York contains two faunas. According to these workers the lower fauna

> "having many Schoharie and Camden elements and characterized by *Amphigenia* and many corals is best developed west of New York on the southern peninsula of Ontario. The Schoharie elements include *Centronella*, *Strophonella ampla*, *Cyrtinaella biplicata*, *Calymene platys*, and *Terataspis*. Camden elements are *Eodevonaria* and *Anoplia*. Overlying the *Amphigenia* fauna is one characterized by *Paraspirifer acuminatus* occurring at the top of the Onondaga in New York. It also characterizes the top of the Columbus and Jeffersonyille limestones to the southwest but has not yet been found in the Ontario peninsula. So far as known its northern-most range is Pelee Island in Lake Erie and Wayne County, Michigan."

The lower part of the Bois Blanc formation contains the brachiopods *Amphigenia*, *Cymostrophia patersoni* (Hall), and *Spirifer duodenarius* (Hall), and the trilobites *Anchiopsis anchiops* (Green) and *Phacops cristata* Hall, all of which have been recognized in the Schoharie faunal element of the Onondaga limestone.

The lower portion of the middle part of the Bois Blanc contains the brachiopods *Amphigenia elongata* (Vanuxem), *Centronella glansfagea* (Hall), *Chonetes hemisphericus* Hall, *Costispirifer unica* (Hall), *Cymostrophia patersoni* (Hall), *Fimbrispirifer divaricatus* (Hall), *Pentamerella arata* (Conrad), *Strophonella ampla* (Hall), *Spirifer duodenarius* (Hall), *S. macrus* Hall, and *S. varicosus* Hall, and the trilobites *Anchiopsis anchiops* (Green), *Calymene platys* Green, *Phacops cristata* Hall, and *Proetus crassimarginatus* Hall, all of which have been identified as the Schoharie faunal component of the Onondaga limestone.

The coral-bearing limestone on the Pierce and Son dairy farm about two miles west of the business section of Mackinaw City has many of the species of corals that are in the underlying strata of the Bois Blanc formation. When the corals of this limestone and of all the strata of the middle and lower parts of the Bois Blanc formation are prepared for study, most of the species will be recognized as being identical with species of corals characteristic of the Onondaga limestone of southwestern Ontario and western New York.

When reporting the discovery of the Schoharie fauna in Michigan, A. W. Grabau (1906, p. 467, 1907, pp. 718-719; and 1908, p. 267)[27] noted that fossils of this fauna were obtained from limestones of Mill Creek, four miles southeast of Mackinaw City, and stated (1907, p. 718) "the outcrops containing the Schoharie fauna are all near the Michigan Central railroad crossing" of the creek. Many of the specimens of the species listed by Grabau (1907, pp. 718-719) are in the Museum of Paleontology of the University of Michigan. The lithologic character of the rock containing the specimens is identical with the character of the limestone of unit 3 of the Mill Creek section. The agreement in lithology and the location of the outcrop of unit 3 close to the crossing of the Michigan Central Railroad indicate that the fossils collected by Grabau almost certainly came from the limestones of unit 3. Although many of Grabau's fossils and fossils obtained by the writers are poorly preserved and possibly should be provisionally identified as to species, some of the species are identical with or closely related to species found in the Schoharie element of the Onondaga limestone.

Grabau (1907, p. 719)[27] was in error in believing that the limestones of Mill Creek with Schoharie species underlie beds on Mackinac Island with an Onondaga fauna. Grabau's error was due in part to his belief that the Schoharie grit underlies the Onondaga limestone. The Schoharie grit as noted by Winifred Goldring (1931, p. 384)[36] is a sandy facies of the Onondaga limestone. The fossils from Grabau's Onondaga limestone of Mackinac Island most likely were collected by him from blocks of the very fossiliferous lower portion of the middle part of the Bois Blanc formation. Such blocks are far more common in the breccia of Mackinac Island than rock masses containing the strata of the Mill Creek section. The strata of these blocks, which Grabau considered to have an Onondaga fauna, definitely occupy a position below instead of above the limestones exposed in Mill Creek.

Grabau also erred in correlating the strata in the breccia of Mackinac Island with the rocks of a breccia exposed in Mill Creek a short distance upstream from the abandoned quarry exhibiting the Idiostroma-bearing beds of the Bois Blanc formation. He stated (1907, p. 718) that "since beds of the Mackinac Island contain an Onondaga fauna, it is evident that they cannot be lower than those of Mill Creek, but the equivalent of the higher (brecciated) beds of that locality." The "higher (brecciated) beds" of Mill Creek compose a breccia of unfossiliferous limestone, which is stratigraphically above the highest rocks of the Bois Blanc formation and is assigned to the Detroit River group.

The strata of the upper part of the Bois Blanc formation are characterized by an abundance of *Idiostroma* and thin, explanate stromatoporoids, which, with a smaller number of tabulate corals, have built up bioherms and biostromes. A few tabulate corals, brachipods, and trilobites from these beds seem to be related to species found in the Onondaga limestone and suggest that the beds should be included in the Bois Blanc formation. The strata may be younger than the highest rocks of the Onondaga limestone of southwestern Ontario; further paleontological study may show that they are faunally distinct from the limestone which contains the Schoharie faunal element.

DETROIT RIVER GROUP

NOMENCLATURE: The rocks of the Detroit River group are typically exposed along the Detroit River in southeastern Michigan. Before describing the occurrences of these strata in the Mackinac Straits area, it is necessary to note the various changes in the classification of the group.

The term "Monroe Beds" was used in a description of the geologic column of Michigan by A. C. Lane in a report by M. E. Wadsworth (1893, p. 66)[13] in 1893. In this column the "Monroe Beds" are shown as being overlain by the Devonian Dundee limestone. The downward extent of the beds is not clearly indicated by Lane; he apparently thought they were underlain by dolomite, salt, and anhydrite, which subsequently were placed in the Upper Silurian Salina group.

In 1895 A. C. Lane (1895, pp. 26-28)[14] defined the Monroe beds, noting that they extended "from the limestones of the overlying Dundee down to the lowest gypsiferous beds." As thus defined, the Monroe beds included all the strata between the base of the Dundee limestone and the top of the Niagaran series.

In two papers Lane (1899 a, p. 88 and 1899 b, pl. 2)1516 recognized the occurrence of the Sylvania sandstone in Michigan. This sandstone was named by Edward Orton (1888, pp. 4, 18-20)[43] from typical exposures near Sylvania, Lucas County, Ohio. Orton (1888, p. 19)[43] also stated that probably "the sand deposits of Monroe County, Michigan, belong to the same horizon." In one of his papers Lane (1899, b, pi. 2),[16] presented a geologic map of the Southern Peninsula on which was given the legend "Monroe below Sylvania sandstone" and "Monroe above Sylvania sandstone." He not only noted the presence of the Sylvania sandstone in Michigan but recognized that this sandstone was included in his Monroe beds. In 1909, A. C. Lane, C. R. Prosser, W. H. Sherzer, and A. W. Grabau (1909, pp. 553-556)[18] presented a detailed classification of the Monroe strata. In this classification the strata were divided into the "Lower Monroe or Bass Islands Series" including in ascending order the Greenfield dolomite, Tymochtee shales and limestones, Put-in-Bay dolomite, and Raisin River dolomite, the "Middle Monroe," consisting of the Sylvania sandstone, and the "Upper Monroe or Detroit River Series," containing in ascending order the Flat Rock dolomite, the Anderdon limestone, the Amherstburg dolomite, and the Lucas dolomite. The authorship of the various stratigraphic divisions are indicated by Lane, Prosser, Sherzer, and Grabau (1909, p. 556).

The rocks of the lower, middle, and upper Monroe were assigned by Lane, Prosser, Sherzer, and Grabau (1909, pp. 553-556)[20] to the Upper Silurian. This assignment was based in large part on the opinion of Sherzer and Grabau (1909, pp. 540-553)[44] that the faunas of these strata indicate that the rocks are of Upper Silurian age. In the most comprehensive work on the Monroe rocks, Grabau and Sherzer (1910, pp. 27-60 and 215-234)[38] used the classification of Lane, Prosser, Sherzer, and Grabau, and again assigned these rocks to the Upper Silurian.

C. R. Stauffer, (1916, pp. 72-77)[20] and M. Y. Williams (1919, pp. 18-22)[21] in their studies of the Devonian and Silurian rocks of Ontario reached the conclusion that the Sylvania sandstone and Detroit River series are of Devonian rather than of Upper Silurian age. In making this change in classification, Williams (1919, p. 22) pointed out that "the terms upper Monroe and lower Monroe are obviously no longer appropriate, since the so-called Monroe is now seen to belong to different geological systems, Grabau's alternate names "Detroit River" and "Bass Island" will hence be used."

In a paper on the "Monroe division" of rocks in Ohio, J. E. Carman (1929, pp. 481-506)[45] concluded that the Sylvania sandstone and the overlying Detroit River strata are of Devonian age, the Silurian-Devonian contact in Ohio being at the base of the Sylvania sandstone. In a later paper Carman (1936, pp. 253-266)[46] described in detail the Sylvania sandstone of Ohio, noting the unconformity at its base and the gradation of the water-laid phase of the Sylvania into the overlying Detroit River dolomite.

In this paper the Detroit River strata are regarded as a group. In southeastern Michigan, southwestern Ohio, and northwestern Ohio the Detroit River dolomites and Sylvania sandstone are underlain by dolomites of the Upper Silurian Bass Island group and overlain by the Middle Devonian Dundee limestone. The Dundee limestone in northwestern Ohio is erroneously designated the Columbus limestone. The Columbus limestone contains an upper Onondaga fauna and is older than the Dundee limestone. The Dundee limestone of the so-called Anderdon quarry near Amherstburg, Ontario, owned by the Bruner Mond Canada Limited, is incorrectly called the Onondaga limestone. An examination of several reports on the Devonian of southwestern Ontario leads to the belief that the Dundee limestone underlies large areas of southwestern Ontario where it is incorrectly designated the Onondaga limestone. In the Mackinac Straits area the Detroit River group is underlain by the Bois Blanc formation, most if not all of which is a correlative of the typical Onondaga limestone of southwestern Ontario. In the Rogers City area and apparently elsewhere in the northern part of the Southern Peninsula, the group is overlain by the Dundee limestone.

DISTRIBUTION: The Detroit River group underlies a wide belt of land in the northern part of the Southern Peninsula between the areas occupied by Bois Blanc and Dundee strata (see map in pocket). It also underlies the southern half of Beaver Island and probably all of North and South Fox Islands in Lake Michigan. Unfortunately most of the rocks of the group in the northern part of the Southern Peninsula are covered with Pleistocene glacial deposits several hundreds of feet in thickness. The few outcrops herein described give little information regarding the lithology, super-position, and thicknesses of the rocks composing the group. Such information has been obtained from a study of the drillings of deep wells and is discussed in the chapter on subsurface stratigraphy.

LITHOLOGIC CHARACTER: A limestone, which is believed to be near the base of the Detroit River group of the Mackinac Straits area, is exposed in the ditch on the west side of the road on the east line of section 30, T. 39 N., R. 3 W., about 1½ miles southeast of the southern boundary of Mackinaw City. The rock, which is shown in a very small outcrop about a quarter of a mile south of the northeast corner of section 30, is very light gray to white and very fine grained, and contains thin, tabular crystals of a mineral believed to be celestite.

Another limestone is shown in numerous low ridges and mounds in the NE¼ NE¼ sec 30, T. 39 N., R. 3 W., a very short distance northwest of the roadside outcrop. This limestone is dark gray, very fine grained and massive, and probably has a high percentage of calcium carbonate. Much of it is brecciated, the angular fragments being conspicuous on the weathered surfaces. Very small quantities of apparently wind-blown, frosted grains of quartz sand are in a buff-gray, brecciated phase of the limestone in a low mound of the rock on the northern edge of the outcrop about a quarter of a mile west of the road on the east line of section 30.

A limestone breccia, which has the same lithologic character as the breccia of the NE¼ NE¼ sec 30, T. 39 N., R. 3 W., is exposed in a test-pit at the top of the upland near the center of the E½ sec. 29, T. 39 N., R. 3 W., about an eighth of a mile southeast of the trench in which 15 to 18 feet of high Bois Blanc strata are exhibited. The pit is near the end of an abandoned logging road and about 630 feet west of the juncture of this road with another old logging road leading to the trench exposure. Several small outcrops of the breccia also are at the top of the hardwood-covered upland adjacent to the test pit.

A limestone breccia similar to rock of the test pit is in the bed of the old logging road about 200 feet west of the point where the trench with Bois Blanc strata reaches this road.

A limestone breccia is exposed on the north side of Mill creek. This exposure is a short distance upstream from the abandoned quarry containing the high Bois Blanc strata with *Idiostroma*, and thin, explanate stromatoporoids. The breccia is similar to those described above except that much of its matrix is lighter in color and more crystalline.

The breccia on Mill creek and with little doubt the breccias of the other localities were formed by collapse. The bed of limestone, which was the source of the material of the breccias, is thought to have a position in the lower part of the Detroit River group.

Rocks of the Detroit River group are poorly exposed on an abandoned farm in the NE¼ NW¼ sec. 2, T. 38 N., R. 4 W., about three miles south of the southern boundary of Mackinaw City and 1¾ miles north of Carp Lake. They are in small low mounds and a few test pits about an eighth of a mile south of a dirt road on the north line of section 2, and about the same distance east of an abandoned farmhouse. The lowest rock is a yellowish to buff gray, fine grained limestone, which shows a few laminae on its weathered surfaces and has a thickness of about one foot. This limestone is overlain by a very light gray to light buff gray, very fine grained and laminated dolomite which has an earthy feel. Some of the laminae of the rock are dark gray; groups of laminae are folded and broken as the result of submarine gliding. The dolomite, which is about two feet in thickness, is overlain by a similar dolomite, which is very light gray to cream-colored, has an earthy feel, and shows laminae

on weathered surfaces. Some layers of this higher dolomite contain slit-like cavities an eighth to a quarter of an inch in length, which probably were once filled with celestite or tabular crystals of another mineral. The dolomite has a thickness of three feet and is best shown in a test pit which has an elevation of 675 feet. About four feet of buff-gray, finely crystalline, massive limestone overlies the dolomite. Some parts of the limestone contain slit-like cavities one-half inch in length. The surfaces of the rock are much rounded by solution. A brecciated limestone, which is similar to the limestones of the upland southeast of Mackinaw City and like those probably was produced by the collapse of a bed of limestone, is shown in several exposures located east of the outcrops of the bedded limestones and dolomites. The exposures of the breccia have an alignment suggesting a north-south surface distribution of the rock at right angles to the strike of the limestones and dolomites.

Detroit River strata underlie Ile aux Galets, a very small island in Lake Michigan about 6¾ miles northwest of Cross Village, on the shore of Lake Michigan 18 miles southwest of Mackinaw City. Ledges of cream-colored, very finely crystalline dolomite with few small cavities are visible on the bottom of the lake along the north side of the island. Blocks of the dolomite compose a storm beach along the north shore west of the Ile aux Galets lighthouse. Numerous small blocks of breccia are at the surface just south of the lighthouse. Most of the angular pieces of the breccia consist of dark buff gray, very finely crystalline limestone. Some blocks are finely crystalline limestone with light and dark buff gray bands; a few pieces consist of very dark buff gray limestone having numerous small coalescing cavities. The matrix of the breccia is composed of a light buff gray and finely crystalline limestone with angular cavities formed by the solution of small pieces of the darker limestone. The breccia resembles very much the limestone breccias of the upland southeast of Mackinaw City. The limestone, from which the angular pieces of the breccia were derived, probably occupies a stratigraphic position above the cream-colored dolomite.

Blocks of dolomite are abundant along the eastern shore of North Fox Island near the north end of the island, which is located in Lake Michigan about 9¾ miles southwest of Beaver Island. Some of the dolomite is light buff gray with irregular masses of chert distributed parallel to the bedding. The few fossils in the rock are closely related to or identical with species found in the Bois Blanc formation. Some of the dolomite is buff and porous resembling some beds of dolomite in the Detroit River group of southeastern Michigan. A brownish-black dolomite is very common in the rubble along the shore. These dolomites probably were derived from ledges of the Detroit River group. All of the dolomites were carried to the shore by the Pleistocene glacier or by the waves and ice of Lake Michigan from ledges beneath the surface of this lake. All of North Fox Island probably is underlain by Detroit River strata. Beds of the Bois Blanc formation doubtless floor the bottom of the lake immediately west of the island.

Rocks of the Detroit River group are shown in the large quarry of the Michigan Limestone and Chemical Company at Rogers City, located on the shore of Lake Huron about 52 miles southeast of Mackinaw City. The lithologic character of the rocks and their relationship to the overlying Dundee limestone and higher Devonian formations are noted in the following description of the stratigraphic section exposed in the quarry.

Section of strata exposed in quarry of Michigan Limestone and Chemical Company at Rogers City, Michigan

	Thickness Feet	Inches
Traverse group (Bell shale):		
13. Shale, calcareous, bluish-gray and fossiliferous except at a few places	1–10	
Total	1–10	
Disconformity		
Rogers City limestone:		
12. Limestone, buff-gray to buff, medium grained, fairly thick-bedded and porous, containing *Hexagonaria sp., Favosites sp.*, a costellate *Atrypa, Buchelia, tyrelli*, (Whiteaves), *Omphalocirrus manitobensis* Whiteaves, and other gastropods	49	
11. Limestone, gray, finely crystalline, dense and thick-bedded, containing numerous specimens of a costellate *Atrypa*, and *Omphalocirrus manitobensis* Whiteaves	4–6	
10. Limestone. Lower 2 to 3 feet mottled buff and gray, magnesian and thin-bedded; upper 6 feet less mottled, less magnesian and thicker-bedded than underlying beds. Limestone contains numerous shells of a costellate *Atrypa*, a few specimens of *Gypidula sp.*, and *Omphalocirrus manitobensis* Whiteaves	8	6
9. Limestone, magnesian, with discontinuous, alternating buff and buff-gray bands, fine grained and thin-bedded, with molds of *Productella sp., Atrypa sp.*, and other brachiopods, pelecypods, *Tentaculites sp.*, and *Proetus sp.* A grayish-black clay with small pebbles of limestone is present at the base of the limestone; it has a thickness of ¼ to 1 inch and apparently is a residium	8–9	
Total	69–6–72–6	
Disconformity		
Dundee limestone:		
8. Limestone, gray, weathering to a buff-gray, composed of numerous shells of brachipods and a smaller number of other invertebrates. Characteristic fossils are *Hexagonaria sp., Atrypa costata* Bassett, *A. ehlersi* Bassett, *Brevispirifer lucasensis* (Stauffer), *Etheridgina? spinosa* Bassett, *Productella spinulocosta* Hall, and a species of *Athyris* identical with a species found in the Dundee limestone of southeastern Michigan	6	5
7. Limestone, gray, weathering buff-gray, with few chert nodules and remains of *Hexagonaria sp. Atrypa costata* Bassett, *A. ehlersi* Bassett, and other fossils	4–3	
6. Limestone, buff-gray to buff, weathering to brown, and thick-bedded, with *"Diphyphyllum" rectiseptatum* Rominger, *Hexagonaria* sp. with corallites averaging 8 mm. in diameter, *Hexagonaria sp.* with corallites 4 to 5 mm. in diameter, *Atrypa costata* Bassett, and *A. ehlersi* Bassett	59	
5. Limestone, buff-gray to gray, mottled, dense and somewhat magnesian in lower part, containing *Synaptophyllum?* sp., *Atrypa elegans* Grabau, *A. costata* Bassett, *Pentamerella sp.* cf. *P. parva* Bassett, and numerous specimens of *Paracyclas sp.*	72	
4. Limestone, slightly magnesian, dark buff gray to chocolate-colored, thin- and even-bedded with carbonaceous material on bedding planes, very finely crystalline; weathers into layers ¼ to ½ inch in thickness	2	9
3. Dolomite, buff, with some carbonaceous laminae except in upper 2 inches		10
2. Shale, buff-gray, mottled with brown. Shale is thickest in the lowest part of a small shallow pre-Dundee limestone erosion channel carved in the underlying breccia, unit 1. When traced upward along sides of channel, the stratum becomes thinner and then is overlapped by dolomite of unit 3		8
Total	142′ 8″–143′ 8″	
Disconformity		

Detroit River Group:

1. Breccia, composed of small and large angular blocks of buff dolomite and thin-bedded to laminated dark bluish gray limestone in a matrix of dark bluish gray shale and comminuted limestone; small light-purple crystals of fluorite present in few blocks of buff dolomite. Formerly about 24 feet of this breccia was exposed in a large test pit a short distance southeast of the crusher receiving the limestone from the quarry trains. Most of the rock is now covered by water; only 2 feet of the breccia is visible above the water where units 2, 3, and 4 were observed and studied	24
Total	24

This description, which in large part is similar to the description published by Ehlers and Radabaugh (1938, pp. 442-443)[33] notes the occurrence of 24 feet of Detroit River rock in a large test pit of the quarry. This rock, unit 1 of the section, is a breccia composed of blocks of buff dolomite and dark gray limestone in a matrix of shale and comminuted limestone. The blocks of buff dolomite, a few of which contain nodules of banded chert, are similar in lithology to dolomites in the Detroit River group of the Detroit River region of southeastern Michigan. The disconformity at the top of the breccia is most interesting in showing that the brecciation of the Detroit River rocks took place prior to the deposition of the Dundee limestone (pl. XVI, A, B).

The breccia forms the bed of Lake Huron adjacent to the quarry. Numerous blocks of buff dolomite, similar to the dolomite of the test pit, are dredged from the bottom of the small harbor used for anchorage of the company's stone-carrying freighters. A large block of buff, massive dolomite, six to seven feet in diameter, is on top of the breakwater built for the protection of the harbor. The lithology of this block, taken from the breccia of the lake bottom, is the same as the lithology of some beds of the Lucas and Amherstburg dolomites of the Detroit River group of southeastern Michigan.

THICKNESS: The thickness of the Detroit River group in the northern part of the Southern Peninsula cannot be determined by measurement of outcrops. The exposures in the area near the Straits of Mackinac are few in number and exhibit small sections of strata, which presumably occupy a position in the lower part of the group. Most of the rocks of the group, although underlying a wide belt of land in the northern part of the Southern Peninsula, cannot be observed and measured because they are covered by a thick deposit of drift.

The records of deep wells indicate that the thickness of the group in the northern part of the Southern Peninsula is about 700 feet. Detailed information in regard to the thickness and also the lithology of the rocks of the group is given in the chapter on Subsurface Stratigraphy, the part of this report dealing with the study of samples of these rocks obtained by drilling deep wells.

STRATIGRAPHIC RELATIONSHIPS: It is impossible at this time to correlate the few exposed beds of the Detroit River group in the Straits area with particular formations of the group of southeastern Michigan. The lowest beds of the Straits area are limestones and dolomites. They are distinctly different in lithologic character from the Sylvania sandstone, which on further study may prove to be the lowest formation of the Detroit River group in southeastern Michigan. They may represent a calcareous facies of this sandstone or may be equivalent to Detroit River strata occupying a position above the Sylvania sandstone. The lithologic character of many of the blocks of dolomite in the breccia beneath the Dundee limestone of the Rogers City region is strikingly similar to the lithology of the Amherstburg and Lucas dolomites of the Detroit River region. A correlation based on similarity in lithology should be considered as tentative. The occurrence of the various formations of the group in the northern part of the Southern Peninsula ultimately may be demonstrated by the finding and identification of fossils in cores and drill cuttings from deep wells.

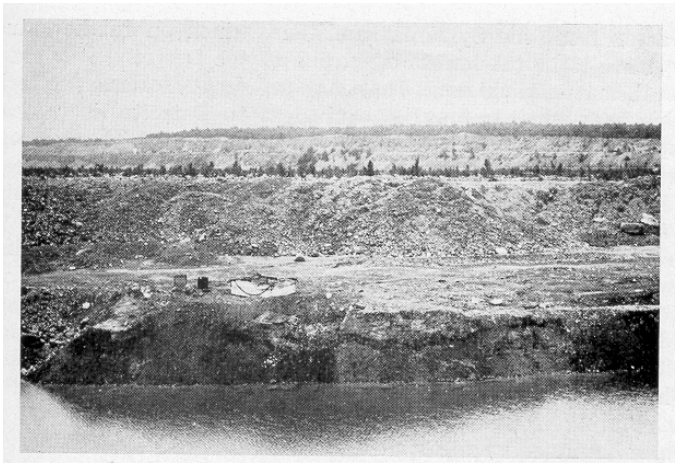


Plate XVI. A. Contact between Dundee limestone and brecciated Detroit River rocks at base of dark band in wall of water-filled test-pit of Rogers City quarry. Lower beds of Rogers City limestone and upper Dundee strata present in distant quarry wall.

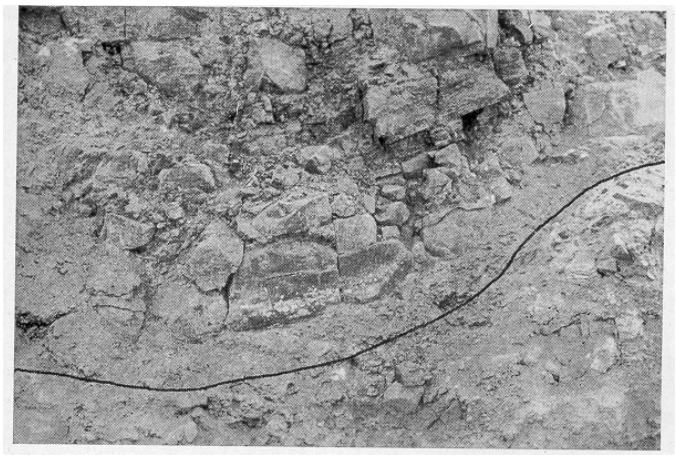


Plate XVI. B. A close view of part of contact shown in wall of test-pit. Line indicates approximate position of disconformity and represents part of one side of pre-Dundee erosion channel.

The occurrence of the Detroit River group between the Bois Blanc formation having a typical lower Onondaga fauna and the Dundee limestone having Middle Devonian fossils is of considerable stratigraphic interest. Most of the geologists who have studied the Devonian

rocks of Michigan, Ohio, and southwestern Ontario have stated that the "Upper Monroe" or Detroit River strata underlie the Onondaga limestone, or formations thought to be equivalent to this limestone. The position of the Detroit River rocks indicated by these workers is based on erroneous correlations of certain formations with the typical Onondaga limestone. The Dundee limestone of Michigan is one of the formations which, until recent years, has been correlated with the Onondaga limestone. It contains the brachiopods *Atrypa costata* Bassett and *Brevispirifer lucasensis* (Stauffer) and other fossils which indicate a fauna distinct from the fauna of the Onondaga strata. As noted by C. F. Bassett (1935, pp. 437-444)[47] the above mentioned brachiopods are in the "Upper Columbus" limestone of the Silica and Whitehouse quarries of northwestern Ohio and the "Onondaga" limestone of the Bruner Mond Canada Limited quarry one mile north of Amherstburg, Ontario. The Dundee limestone of southeastern Michigan, the "Upper Columbus" limestone, and also the "Lower Columbus" limestone (see Bassett, 1935, pp. 438-439, 442)[47] of northwestern Ohio, and the "Onondaga" limestone of the Amherstburg quarry contain the same fauna and belong to a single stratigraphic unit, which should be designated the Dundee limestone. In northwestern Ohio the Dundee limestone rests disconformably on the Lucas dolomite of the Detroit River group; in southeastern Michigan and at Amherstburg, Ontario, it overlies unconformably the Anderdon limestone, which is the highest formation of the Detroit River group at these places. In the Michigan Limestone and Chemical Company quarry at Rogers City the Dundee limestone with *Atrypa costata* Bassett, *Brevispirifer lucasensis* (Stauffer) and other fossils, characteristic of this limestone in southeastern Michigan, northwestern Ohio, and the Amherstburg, Ontario region, rests disconformably on the brecciated dolomites of the Detroit River group. North of Rogers City at many localities close to the Straits of Mackinac are exposures of the Bois Blanc formation with the typical lower Onondaga fauna of Ontario and western New York. Since the Bois Blanc strata underlie the Detroit River rocks in the Straits region, the Detroit River group in the northern part of the Southern Peninsula clearly occupies a position between the Bois Blanc and Dundee formations.

The stratigraphic position of the Detroit River group in the northern part of the Southern Peninsula seems to be duplicated in Ontario. According to C. R. Stauffer (1915, pp. 132-133)[42] the Detroit River strata in the vicinity of Goderich on the eastern shore of Lake Huron in Huron County, Ontario, are overlain by the "Onondaga" limestone, on which rests the Delaware limestone. In a list of fossils from the rocks at this locality, Stauffer (1915, pp. 134-135)[42] notes the occurrence of *Atrypa spinosa* Hall and *Spirifer lucasensis* Stauffer in the Delaware limestone. One of these brachiopods, *Spirifer lucasensis* Stauffer *Brevispirifer lucasensis* (Stauffer), is a diagnostic fossil of the Dundee limestone. The other brachiopod listed as *Atrypa spinosa* Hall, may be identical with the very closely related and characteristic Dundee species *Atrypa costata* Bassett. The absence of diagnostic lower Onondaga species in Stauffer's list and the inclusion of several other fossils which are represented in the Dundee fauna leads one to believe that strata above the Detroit River rocks at Goderich belong to the Dundee limestone and not to the Onondaga and Delaware formations. According to T. Sterry Hunt (1878, pp. 224-226)[48] a test well was drilled by Mr. Attrill close to the Lake Huron shore near Goderich in the early days of the Goderich salt industry. In a report on this experiment T. Sterry Hunt (1878, p. 242) states:

> "We now come to the consideration of an unexpected result of the examination of the cores from the Goderich boring; namely, the occurrence beneath 278 feet of beds, chiefly dolomite, which, according to the Geological Survey, underlie the Corniferous limestone of the region, of not less than 276 feet, chiefly of grey, non-magnesian, coralline limestone, abounding in chert, and seeming like a repetition of the Corniferous. Beneath this lower fossiliferous limestone, it will be noted, are dolomites with gypsum, succeeded by variegated marls, with an aggregate thickness of not less than 364 feet before reaching the saliferous strata, which latter have been penetrated 520 feet without reaching the underlying Guelph formation. Professor James Hall, who has kindly examined such specimens of corals as I have obtained from this limestone (Division III of the section) recognizes in them two species of Favosites, F. Winchelli and F. Emmonsi, together with a section of Acervularia or Diphyphyllum"

The "278 feet of beds, chiefly dolomite," which T. Sterry Hunt noted as underlying the "Corniferous limestone," with little doubt belong to the Detroit River group. The "Corniferous limestone" exposed on the Maitland River near Goderich is the Dundee limestone, designated the Onondaga limestone by Stauffer. The "not less than 276 feet, chiefly of grey, non-magnesian, coralline limestone, abounding in chert, and seeming like a repetition of the Corniferous" with little doubt is the "Corniferous" or Onondaga limestone and not a part of the Detroit River group as suggested by Stauffer (1916, pp. 74-75).[20] The sequence of strata from the Onondaga to the Dundee limestone in the Goderich region is therefore like the sequence of northern Michigan. When the Dundee limestone of other places in Ontario is distinguished by its fauna from the typical Onondaga limestone, the position of the Detroit River group between these two limestones will become more evident and aid materially in the mapping of the Devonian rocks of this region.

The Bois Blanc formation or its correlative, the Onondaga limestone, does not underlie the Detroit River group in the region adjacent to the western part of Lake Erie. It fails to reach this area either because it was overlapped by the Detroit River strata or was removed by erosion prior to the deposition of Detroit River sediments. The Detroit River rock rests unconformably on Upper Silurian dolomites of the Bass Island group.