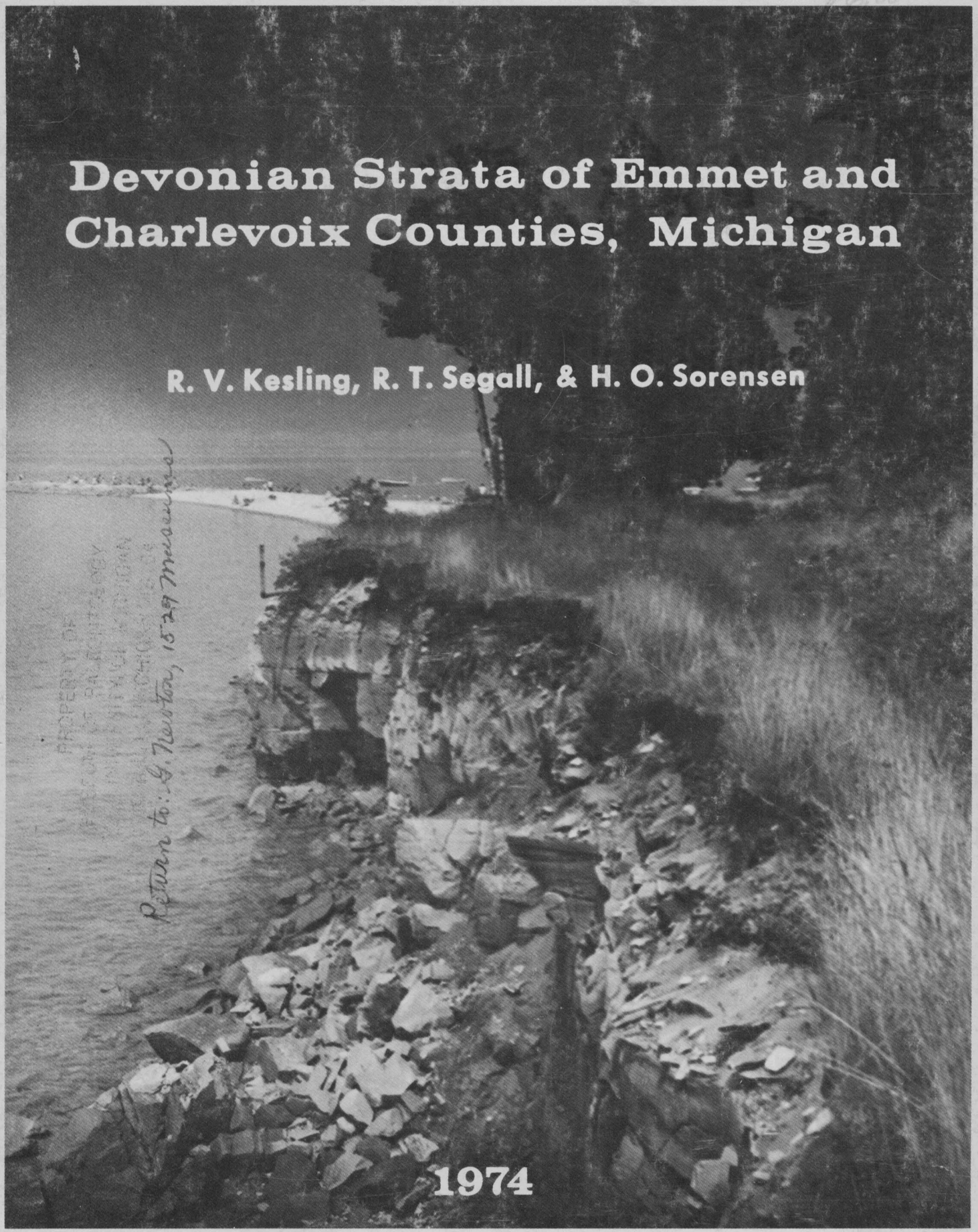
Devonian Strata of Emmet and Charlevoix Counties, Michigan

R. V. Kesling, R. T. Segall, & H. O. Sorensen



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COVER -- "Upper blue shale" of the Gravel Point Formation (below) and Charlevoix Limestone (above) exposed in ledge along shore of Little Traverse Bay near the former site of the Pennsylvania Railroad station in Bay View. Locality 35-5-33 NW. Photo by Kesling, 1973.

FRONTISPIECE -- Type exposure of the Petoskey Formation. Abandoned Northern Lime Company Quarry near the shore of Little Traverse Bay in Petoskey. Locality 35-5-32 SW. The bioherm of stromatoporoids is at the right. US 31 and M 131 pass over the top of the exposed strata. Photo by Kesling, 1973.

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No. 7

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By

R. V. Kesling, R. T. Segall, & H. O. Sorensen

INTRODUCTION

GUIDEBOOKS VARY. Until a few years ago, many were little more than a time table and mileage log, with cryptic notations on the formations to be seen at each stop. In contrast, some are now elaborate productions, divided into chapters dealing with each and every geologic process for which the region provides the slightest evidence. This guidebook lies somewhere in the middle, with emphasis on the fossils of the formations.

Although the formations of Emmet and Charlevoix Counties have been studied for over a century, their stratigraphy remains to an unfortunate degree disjointed. The medium for production of a coherent history of the Traverse Group undoubtedly will be paleontology. Hence, we provide the field geologist with photographs to help identify the significant macrofossils where they occur -- in quarries and in natural exposures. We urge you to learn the characteristic kinds of marine animals which inhabited the seas during the successive intervals, to observe how they were entombed in the sediment, to note their associations with other animals and with physical processes recorded in the rocks, to draw your own conclusions on the events and their setting, and finally to exchange your ideas with others through publication.

In writing this guidebook, we have attempted to summarize what has been learned about the Devonian Traverse Group in these two counties, adding some data which we have gathered from field work. The more we study the rocks and fossils, the more admiration we have for the keen insight of Christopher C. Douglass (1841) and for the pioneer work accomplished by Alexander Winchell and by Carl Ludwig Rominger in the latter half of the 1800's. In the years that followed, contributions were made by Adamaeus W. Grabau (1902) and R. A. Smith (1916), the latter mostly concerned with economic potential of the strata.

Recognizing that very little was actually understood about the relationships of the known exposures, the Michigan Geological Survey in 1926 sponsored a concerted field investigation of all Middle Devonian strata in the Lower Peninsula. The party included E. O. Ulrich (United States Geological Survey) and Ermine C. Case, George M. Ehlers, Charles F. Deiss, and A. Scott Warthin, Jr. (all of The University of Michigan).

One might expect that such an illustrious and enthusiastic crew would solve all the geological problems during the excursion and promptly publish their findings. This did not transpire. They constructed an accurate list of localities visited, one which is still the base of the standard reference; they made extensive collections, which were divided between the United States National Museum and The University of Michigan; and they made field notes. Mostly, their observations and conclusions still reside in the notebooks. Some were incorporated in E. R. Pohl's published description a few years later (1929). As for the fossils which went to The University of Michigan, some were identified and added to the collections in the Museum of Paleontology, but three dozen cartons of fossils in the original wrappings are still stored in the basement of the Museums Building.

Our examination of the records of the 1926 expedition reveals an unusual division of effort. Field labels with the fossils are in handwriting which is not that of Ulrich, Case, or Ehlers. From this we may presume that the younger members of the party, Deiss and Warthin, were given the task of gathering fossils from each unit, under the direction of the older members. Ulrich kept no notebook; instead, he dictated his observations to Ehlers, who filled 44 pages with these words and with sketches of the stratigraphic relationships. Case kept his own notebook, amassing 32 pages of similar information. Here, then, were two competent senior scientists at each successive outcrop, one vocalizing his interpretation of the rocks and fossils, the other (presumably out of earshot where possible) jotting down his own thoughts on the division into units, thickness of the exposure, and important

TEXT-FIG. 1 -- The combined expedition of University of Michigan, United States National Museum, and Michigan Geological Survey in 1926. Dr. E. O. Ulrich (right) proclaims his fossil evidence to a skeptical Prof. E. C. Case (left) and an amazed Prof. G. M. Ehlers (center). From the field note books still preserved, we can surmise that the procedure was repeated many times.

features of the record. At only a few localities did one note-taker defer to the other. Agreement was only general at best. Later an attempt was made to combine the data into one set of typewritten pages; at that time it was discovered that no one had made an entry at Locality 14, so Professor Case penciled in a note: "Let Ehlers do this."

The 1926 records make us wonder. In the nearly half a century which followed, has geology become any more of an exact science? Or any more of a cooperative venture?

Under the auspices of the United States National Museum, around 1928, E. R. Pohl of Vanderbilt University and G. O. Raasch of the Milwaukee Public Museum re-traced the itinerary of the 1926 expedition through Charlevoix and Emmet Counties. We have Pohl's published account (1929) and a typed copy of Raasch's notes. Comparison shows that uniform agreement was scarcely any closer to reality than it had been in the Michigan Geological Survey trip three years earlier.

Since Pohl's article, small contributions to our knowledge of the stratigraphy were made in guidebooks prepared for the field trips of the Michigan Academy of Science, Arts & Letters and (later) of the Michigan Geological Society (since become the Michigan Basin Geological Society). Significant observations on the Petoskey Formation were made by G. A. Cooper in the Devonian correlation chart and article published in the Bulletin of the Geological Society of America (1942).

Additions and revisions of the fauna were more extensive. A good view of the growth of paleontology can be obtained from Erwin C. Stumm's published check lists (1951, 1961). Not much has been added since, except a few coral studies by Stumm and his students.

We establish two new formations in the Traverse Group. The unwieldy extent of the Petoskey Formation has been known for many years. In 1942 Cooper called attention to the presence of Upper Devonian species in the uppermost beds, but no one has yet ventured to divide the sequence.

Erection of new formations is pretty much an art. The purpose of new stratigraphic units is to contribute to the understanding of the geologic history of the region in which they occur. By current rules, each must be mappable. Sometimes these criteria conflict, as when a significant time unit is represented by only a few feet of strata. Then the geologist must decide whether the science of geology is better served by setting up a formation that is mappable only at an expanded scale, or by leaving the beds in a formation which spans an important time bound-

ary. It is not an easy decision. We believe that ultimately the regional history will be worked out more precisely by creation of two new formations, even though one of them is thin.

To that end, we introduce in this guidebook the Whiskey Creek and Jordan River Formations. Both are exposed along the Lake Michigan shore north of Norwood in Charlevoix County. The Whiskey Creek is the sequence called the "Chert Beds" by Winchell; it contains a Middle Devonian fauna. The Jordan River is the unit between the Whiskey Creek and the black Norwood Shale; it yields Upper Devonian fossils.

Perhaps as important as the introduction of information on new exposures is the summary, at periodic intervals, of the state of the old exposures. Even now, the operations of the Penn-Dixie Cement Corporation have effectively eliminated -- by bulldozing, random distribution of spoil and waste, and expanded quarrying -- the small quarries to the west of the main quarry. No longer is it possible to study the contact of the Gravel Point Formation and Charlevoix Limestone in the abandoned Bell Quarry (Loc. 14e); in fact, we cannot even be certain about the location of the site without re-surveying the section lines. Nor can we see the section of Gravel Point strata in the old W. E. Smith Quarry (Loc. 14c); the place is buried under spoil piles. The same pattern of obfuscation prevails in the Charlevoix quarries. There, the operations of the Medusa Portland Cement Company have filled and blanketed the old No. 1 quarry of the Charlevoix Rock Products Company (Loc. 9), the No. 2 quarry (Loc. 12), and the abandoned Charlevoix City Quarry (Loc. 10); even the access roads have been relocated. Within the city of Petoskey, the old Jarman Quarry (Loc. 17) offered a fine example of the Gravel Point-Charlevoix contact. Between the widened road bed on the west and fill for the Grant City shopping center on the east, the quarry has been reduced to a small muddy pond -- with no rock visible around the perimeter. North of Norwood along the Lake Michigan shore the present high lake level has inundated important outcrops. In the same area, the Lake Shore Drive, built in the 1930's by the Works Project Administration, still clearly exposed ledges along the right-of-way in 1949; now most of the outcrops are hidden by brush and trees, and portions of the road have been shifted inland. Hence, it is well to assess the available exposures in an area from time to time.

TEXT-FIG. 2 -- A memorable occasion in 1926. At the end of the joint expedition into the Devonian of Michigan, Dr. E. O. Ulrich of the U. S. National Museum and Prof. E. C. Case of the University of Michigan shake hands -- perhaps partly in mutual congratulations and perhaps partly in a conciliatory truce -- and the transaction was recorded by the faithful Kodak of young Prof. G. M. Ehlers.

We regard this publication as another progress report, setting forth what we have recently noted in the field. As will be emphasized from time to time, much remains to be learned. In particular, correlation with formations of other areas and the whole realm of

paleoecology stand out as future goals.

For permission to study outcrops we are indebted to many persons in the region. In particular, we thank officials of the Medusa Portland Cement Company for their courtesy: Keith Roberts, Director of Mineral Research; Elbert W. Kaiser, Plant Manager at Charlevoix; and Sandy Gidsen, Quarry Supervisor. Officers of the Penn-Dixie Cement Corporation extended the privilege of studying exposures in their quarry at Petoskey. In addition, several land owners welcomed us onto their property for measuring and photographing sections.

In getting this guidebook through the presses, we have been favored with the assistance of Mr. Karoly Kutasi in photography and Ms. Helen Mysyk in typing. Both were outstanding, as usual, and deserve our deep appreciation.

LOCALITIES

In the following list, each locality is identified by four elements: number of the Township North, number of the Range West, number of the section, and letters for the part of the section (as close as possible to the actual site). Many localities were identified on a previous list by consecutive numbers, some of which have appeared in publications; this list was started around 1926 by the Michigan Geological Survey, The University of Michigan, and the United States National Museum, with additions from time to time. Where these old localities on the list can be recognized, the number is mentioned in the present list. Only localities in northwestern Lower Peninsula are given here.

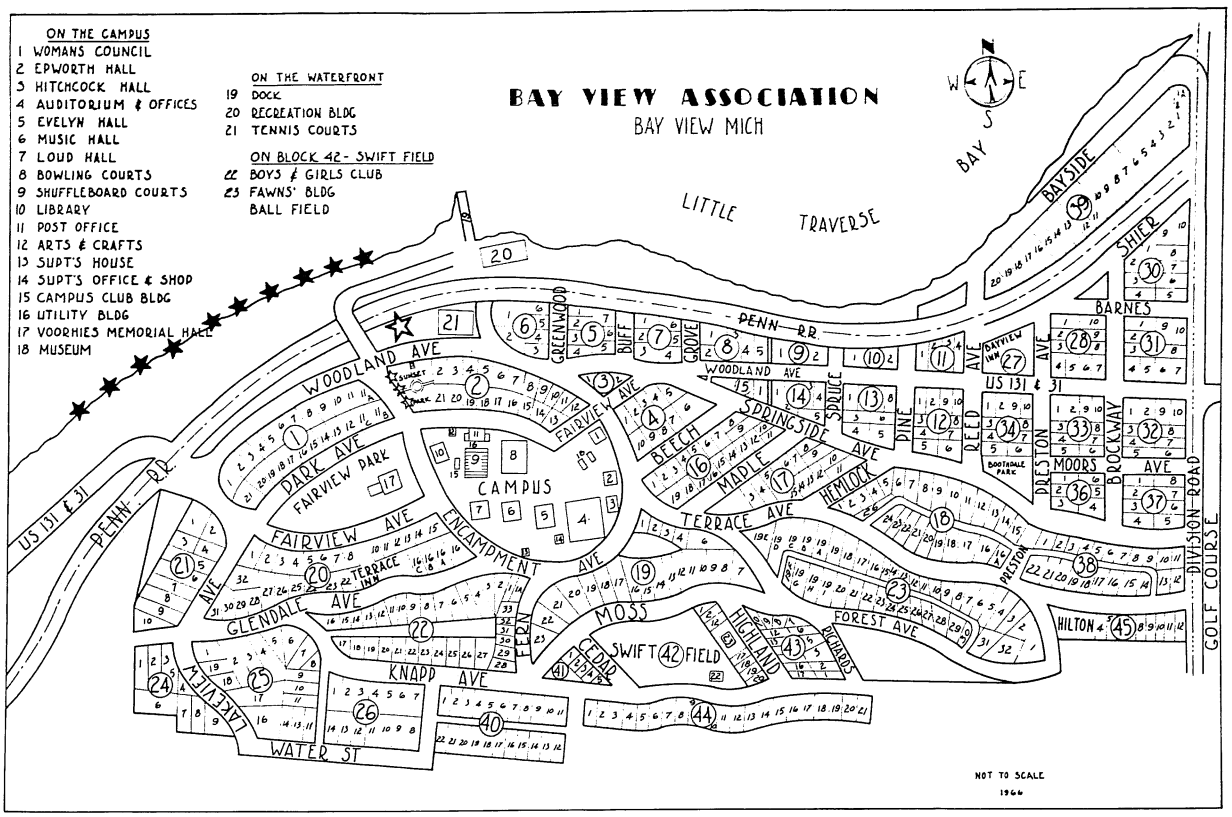
Traverse Group in Emmet County

35-5-27 S: Kegomic Quarry, also called Old Brewery Quarry and Mud Lake Quarry, between US 31 and M 131 and not far from their intersection, about 1 mile east of Bay View in SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 27. Pentamerella petoskeyensis zone of Petoskey Formation (with Potter Farm Formation fauna). Loc. 21. The water-filled part of the quarry was considerably enlarged and altered by dredging in the 1960's and additional strata were exposed by bulldozing on the southeast shore; these operations have ceased. Now, the quarry lies between Pickerel Lake Road and the Pennsylvania Railroad, but the approach from M 131 is different from that shown in the land plat maps.

35-5-31 S: Old Rose Quarry in Petoskey. Elderly natives recall a small quarry near the landward end of the U. S. Government Breakwater. Probably lowermost Charlevoix and/or upper Gravel Point Formation. Area now occupied by fill and buildings.

35-5-32 NE: Natural outcrop described by Winchell as "near the head of Little Traverse bay, south of the point" -- his Loc. 855. Expansion of the Petoskey-Bay View settlement has changed the topography and exposures so that this can no longer be identified with certainty. The position, between the cliffs at Bay View (35-5-33 NW) and the abandoned Northern Lime Quarry in Petoskey (35-5-32 SW), suggests the strata formerly seen there were Charlevoix Limestone. Winchell's Loc. 856, "about twenty rods west of this locality.. extending along the beach for three-fourths of a mile and forming an escarpment," was undoubtedly the site which became the Northern Lime Company Quarry.

35-5-32 E: Section exposed in 1933 in ditch on east side of Encampment Avenue in Bay View, paved over before 1938. Section extended from western intersection of the horseshoe-shaped Encampment Avenue and US 31 southward for about 50 yards. It was separated from the exposures near the Pennsylvania R.R.

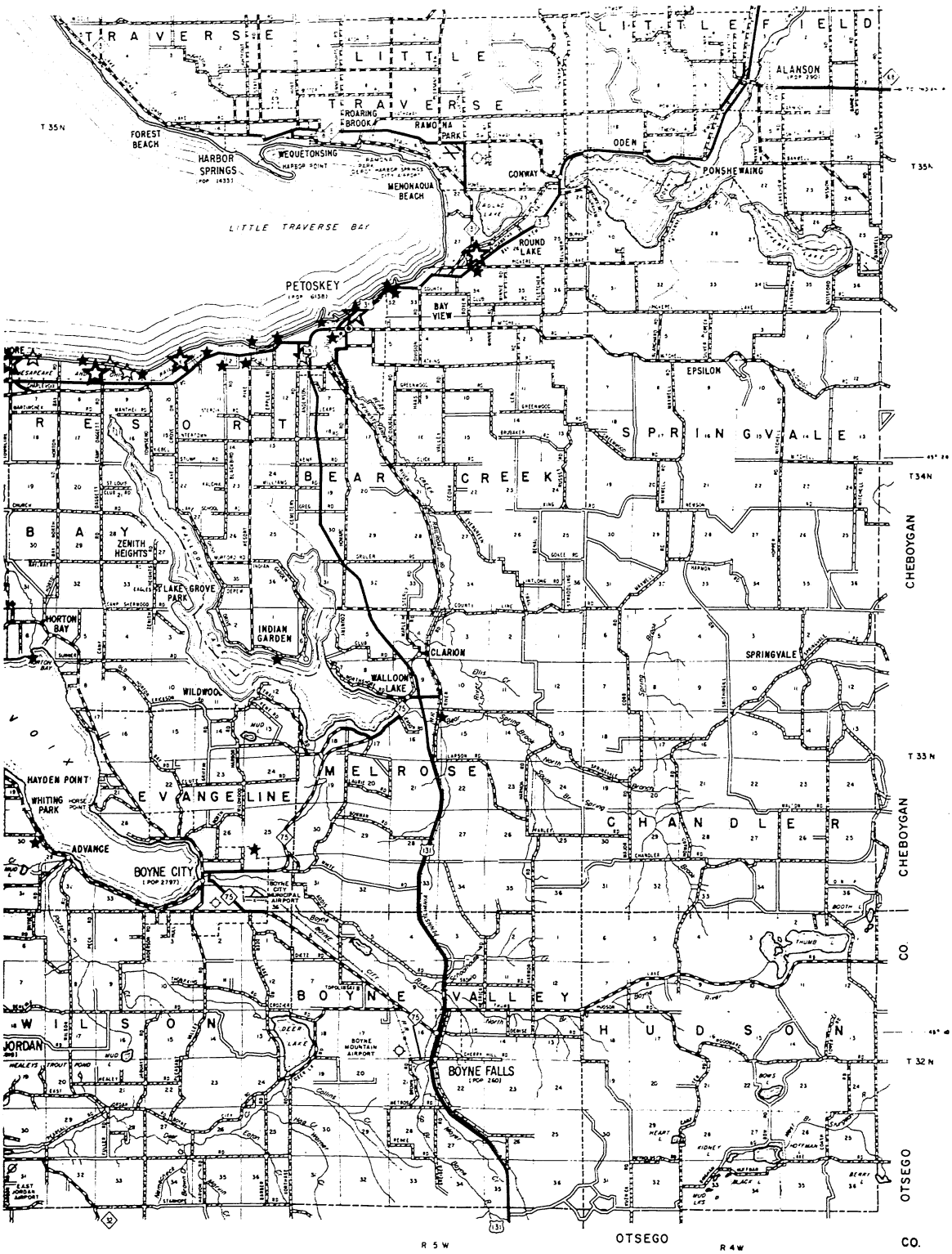


TEXT-FIG. 3 -- Map of Bay View, Michigan, showing locations of exposures described here. The large open star marks the site of the railway station, torn down in the 1950's. The small open stars indicate the site along Encampment Avenue where Prof. G. M. Ehlers measured a section in 1933. Black stars mark cliffs along the shore where the upper part of the Gravel Point Formation and Charlevoix Limestone crop out.

station by a covered interval of 300 feet horizontally, 22 feet vertically, and approximately 27 feet stratigraphically. Same Petoskey Formation strata as those at Kegomic Quarry, described and measured by Prof. George M. Ehlers. Loc. 18b. Site of section now along Encampment Avenue between Woodland Avenue and Park Avenue, near the center of the E line of sec. 32.

35-5-32 SW: Abandoned Northern Lime Company Quarry, bordering Little Traverse Bay in eastern part of Petoskey. Charlevoix Limestone and type locality of Petoskey Formation. Loc. 18. This exposure is northeast of the Waterfront Softball Field, between the Chesapeake & Ohio Rail Road and US 31 (Bay View Street). It can be reached from US 31 by turning west on Lake Street, then right on the first street (before reaching Wachtel Avenue and the U. S. Government Breakwater), and passing south of the Dr. Gray Waterfront Building and the Softball Field on a winding secondary lane. US 31 here traverses the rim of the old quarry. Only after much difficulty can the secondary lane be followed to its eastern end and intersection with US 31. The area between the quarry and the Bay is called Waterfront Park on city maps. An intriguing exposure of stromatoporoid reef here.

MAP 1 -- Charlevoix County and southern part of Emmet County, showing locations of major exposures, past and present. Large open stars indicate main quarries with strata still exposed; small open stars indicate abandoned, inactive, or destroyed quarries; and small



solid stars indicate other exposures. Note the concentration of exposures near the shores of Little Traverse Bay and Lake Michigan. Inset map of Michigan gives location of the area.

35-5-33 NW: Ledges along shore of Little Traverse Bay near the former site of the Pennsylvania Railroad station at Bay View. (See cover.) "Upper blue shale" of Gravel Point Formation and Charlevoix Limestone. Loc. 18a. Property now owned by Bay View Association; exposures are west of the dock and tennis court.

35-5-34 N: Highway shoulder and creek bed on south side of US 31 about 200 feet east of junction with M 131, about 1 mile east of Bay View near center of N line of sec. 34. Petoskey Formation, same strata as those in nearby Kegomic Quarry. Loc. 21a.

34-5-6 NE: Exposures reported by Winchell and Rominger along Bear Creek near its mouth. Probably lower part of Charlevoix Limestone. Area now occupied by fill and buildings along waterfront.

34-6-1 NW and 2 NE: Shore of Little Traverse Bay 1 to 1½ miles west of mouth of Bear Creek, near north end of Resort Pike. Gravel Point Formation. Loc. 19.

34-6-1 C: Ledges at water's edge 1 mile west of Bear Creek. Gravel Point Formation. Winchell's Loc. 40. Located now at foot of Catholic Cemetery on west edge of Petoskey; very little rock exposed. Continues into 34-6-1 NW and 2 NE (Loc. 19), where better exposures are present.

34-6-1 SE: Antrim Lime Company Quarry, western part of town of Petoskey, located just east of Greenwood Road and opposite Greenwood Cemetery; also known as the Jarman Quarry. Gravel Point Formation in pit and Charlevoix Limestone on periphery. When visited in July of 1973, the old kiln had been torn down and most of the quarry had been filled with sand and rubble; the eastern part of the quarry probably lies under the parking lot (constructed around 1967) of the new Grant City shopping center. No exposures now available. Loc. 17.

34-6-2 SE: Small roadside exposure a short distance south of intersection of Resort Pike and US 31, near corner of section 2. Basal beds of Charlevoix Limestone. Loc. 16.

34-6-2 SC: Small exposure on west side of Blackbird Road, south of US 31 and near center of S line of section 2. Basal beds of Charlevoix Limestone. Loc. 16.

34-6-2 SW: Extreme east end of Penn-Dixie Cement Corporation Quarry (formerly Petoskey Portland Cement Company), about 1 mile west of Petoskey. Lowermost Charlevoix Limestone exposed at and near small drainage channel (formerly a creek?); elsewhere in quarry, only Gravel Point strata exposed. Part of Loc. 14.

34-6-3 S: Penn-Dixie Cement Corporation Quarry (formerly Petoskey Portland Cement Company), near shore of Little Traverse Bay, north of US 31, and west of Petoskey. Gravel Point Formation. Loc. 14.

34-6-3 SW: West end of Petoskey Portland Cement Company as it was in 1926. Gravel Point Formation. Loc. 14a.

34-6-4 SW: Abandoned Bay Shore Lime Company Quarry 1, 4 miles west of Petoskey, near west line of section. Quarry last reported by Grabau as his Loc. 46. Gravel Point Formation. No longer identifiable; part of Penn-Dixie Quarry operations.

34-6-5 S: Dome-like elevation on shore described by Winchell as his Loc. 863 and ½ mile west of his Loc. 862. Gravel Point Formation. No longer identifiable.

34-6-6 SE: Small abandoned quarry in southwest corner of sec. 5, low bluffs and ledges near water's edge, and several other small quarries, forming a continuous exposure of a mile in length to the west of the first-mentioned quarry.

Charlevoix-Petoskey contact at almost constant height above lake level. Loc. 12a of Pohl and Raasch (unpublished), probably including the next listed locality.

34-6-6 S: Abandoned Bay Shore Lime Company Quarry 2, Grabau's Loc. 47. Site was identified by G. M. Ehlers as south of center of sec. 6.

34-6-6 SW: Abandoned Northern Lime Company Quarry, called Main Curtiss and two smaller quarries by Pohl, near shore of Little Traverse Bay and north of Bay Shore, near end of Townline Road. Charlevoix Limestone and Petoskey Formation. Loc. 13, which also included shore bluffs to the west in Charlevoix County at 34-7-1 SE. At present only the Charlevoix beds are well exposed; slump has obscured most of the Petoskey exposures.

34-6-8 NE: Abandoned Bell Quarry (called "Rose" quarry by Fenton & Fenton, 1930) and ledges on shore, near northeast corner of section. Upper Gravel Point Formation and basal Charlevoix Limestone. Perhaps this locality is now incorporated in the Penn-Dixie Cement Corporation Shale Pit, the latter extending south (down dip) from the former quarry. Loc. 14e.

34-6-9 NE: Beach exposure recorded by Grabau as his Loc. 44, about 1/3 mile west of 34-6-9 N (his Loc. 42A-F, "Rose's quarry"). Gravel Point Formation. Probably obscured by road bed of Penn-Dixie Quarry operations.

34-6-9 N: Abandoned "Rose's quarry" of Grabau (his Loc. 42A-F) and W. E. Smith Quarry of R. A. Smith, about 1 mile west of main quarry when it was operated by Petoskey Portland Cement Company and about 1/8 mile south of Little Traverse Bay, in NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 9. Gravel Point Formation, below "upper blue shale." Loc. 14c. The site has been modified by operations of the Penn-Dixie so that the quarry can no longer be identified.

34-6-10 NW: Test pit $\frac{1}{4}$ mile south of west end of the Petoskey Portland Cement Company Quarry as it was in 1926. Gravel Point Formation. Loc. 14b.

Traverse Group in Charlevoix County

34-7-1 SE: Bluffs along shore near Bay Shore and west of the abandoned Northern Lime (Main Curtiss) Quarry. Charlevoix Limestone. Included in Loc. 13. Part of Winchell's Loc. 865.

34-7-2 W: Abandoned Superior Quarry of Northern Lime Company near Nine Mile Point (Khagashewung Point, Kawgachewing Point), nearly 2 miles west of Bay Shore Quarry (Loc. 13). Charlevoix Limestone and Petoskey Formation. Loc. 15. The bluffs at this place were studied by Rominger (his Loc. 26) before quarrying began. The quarry is probably the same as the Bay Shore Lime Company Quarry No. 3 known to Grabau (his Loc. 48) and said to be at the end of Khagashewung Point.

34-7-3, 4, 8: Exposures along shore of Little Traverse Bay for 2$\frac{1}{2}$ miles west of Nine Mile Point. Gravel Point Formation. Loc. 15b. Rominger's Loc. 27.

34-8-27 N: Rocks exposed below water level $\frac{1}{2}$ mile west of dock at Charlevoix, near center of north line of section. Probably "upper blue shale" of Gravel Point Formation. Last reported by Rominger.

34-8-28 SE SE: Abandoned main (No. 1) quarry of Charlevoix Rock Products Company, about 3/4 mile west of Charlevoix. Gravel Point Formation ("upper blue shale") and Charlevoix Limestone. Loc. 9. Now filled with spoil.

34-8-28 S SE: Small test pit just north of road between the two Charlevoix Rock Products Company quarries. Charlevoix Limestone. Loc. 12a of Pohl and Raasch (unpublished). When they visited the place around 1928, the pit was nearly filled with dump material, but one face clearly showed the oolitic bed of the section in the main quarry.

34-8-28 S: Abandoned No. 2 quarry of Charlevoix Rock Products Company, about $\frac{1}{4}$ mile southwest of main quarry, just north of center of south line of section. Charlevoix Limestone (with oolitic layers and foreset beds), "upper blue shale" of Gravel Point exposed along drainage channel to the east. Loc. 12. Quarry modified by Medusa Portland Cement Company activities and no longer identifiable.

34-8-28 SW: Medusa Portland Cement Company Quarry. Gravel Point Formation and Charlevoix Limestone.

34-8-28/29: Ledges and bluffs on Lake Michigan shore at Gravel Point (Pine River Point, South Point), $1\frac{1}{2}$ miles west of Charlevoix; best exposures nearly on line between secs. 28 and 29. Gravel Point Formation, type locality. Loc. 8 (Winchell's Loc. 880; Rominger's Loc. 28; Grabau's Loc. 49).

34-8-29 S SE: Abandoned small quarry of Wolverine Lime Company, about 3/4 mile west of site of Charlevoix City Quarry. Position of beds uncertain; probably Gravel Point Formation. Loc. 11.

34-8-29: Shore of Lake Michigan from Gravel Point to about 1 mile southwest. Gravel Point Formation. Loc. 8a.

34-8-33 NW NE: Abandoned Charlevoix City Quarry, immediately south of quarry road used until 1960 (which followed the south line of sec. 28), about $\frac{1}{2}$ mile southwest of Charlevoix Rock Products Co. Main Quarry. Petoskey Formation and/or upper part of Charlevoix Limestone. Loc. 10. Used for garbage dump by the city of Charlevoix for many years; now buried under spoil from Medusa Portland Cement Company Quarry. Probably "Lamphear's Quarry," Loc. 56 of Grabau's list, which was said to be in the northern part of sec. 33.

33-9-22 SE and 27 NE: Ledges and bluffs along Lake Michigan, extending from exposure of Norwood Shale at type locality (1 mile north of Norwood) to point about $\frac{1}{2}$ mile north, including exposures along secondary road (which ends at Whiskey Creek), low bluffs near shore, and pavement and ledges dipping south at water's edge during low-water stages of Lake Michigan (in 1973 many beds under water and not available). Jordan River Formation, type locality; Whiskey Creek Formation, type locality. Loc. 7c.

33-9-26 N: Small test pits in limestone, about 1 mile north of Norwood in northern part of section 26. Whiskey Creek Formation. Loc. 7b. One pit, now somewhat obscured by subsequent gravel operations, is in the $S\frac{1}{2}$ $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 26, between Whiskey Creek and Van Orman Creek (shown in nearly correct positions in maps here, but wrongly in the land plat maps of Charlevoix County); this locality was found this year only after advice from Mr. George Light, Sr., who served for many years as commissioner. Along a secondary road leading northward from the S edge of $SW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 26, there are some additional pits in the wooded area in the $NW\frac{1}{4}$ of the section, but these have been largely obscured by slump and dumped chunks of concrete (which nearly fill them).

33-8-6 NW: Outcrop along shore of Lake Michigan, about 3 miles southwest of Gravel Point. Gravel Point Formation. Recorded by Winchell as his Loc. 882 and by Rominger as his Loc. 29.

33-6-6 S: Low cliffs on peninsula tip at west edge of Horton Bay on Lake Charlevoix (formerly Pine Lake). Whiskey Creek Formation. Loc. 4. Locality is reached by Boyne City Road, Van Hoesen Road, and short private road to the east; property owned in 1973 by Mr. Moleska. Exposure varies with water level in lake; at most, a few feet of lime rock are above water. Beach rubble around Horton Bay but no other outcrops.

Exposures of Norwood Shale

33-9-27 NE: Rock cut along old Lake Shore Drive (last repaired in the 1930's), near Lake Michigan shore about 1 mile north of the pier at Norwood. Loc. 7a, type locality. Traverse Group beds (Jordan River Formation) exposed within 13 feet stratigraphically of the block shale.

33-7-3 NW: Abandoned quarry at Kamp Kairphree on shore of Lake Charlevoix (Pine Lake), about 5 miles southeast of Charlevoix. Camp now called Camp Sea Gull. Loc. 3.

33-7-3 E: Exposures in ravine about 3/4 mile southeast of Kamp Kairphree, extending from bridge on County Highway 630 (Boyne City Road) to shore of Lake Charlevoix. Loc. 71.

Exposure of Antrim or Norwood Shale

33-6-1 S: Pit along road leading west from Indian Garden (Lake Grove Road) near shore on peninsula between arms of Walloon Lake, at edge of Echo Beach, edge of Emmet County. Probably Antrim Shale. Loc. 20.

Exposures of Antrim Shale

32-9-3 E SE: Shore and bluffs on Lake Michigan, approximately 1 mile south of Norwood but in Antrim County. Type locality, Loc. 1.

33-6-30 NE SE: Exposures on both sides of Ferry Road (along south shore of Lake Charlevoix), about 3/4 mile northwest of Advance, Charlevoix County. Place now called Fairview Beach Resort. Loc. 70.

33-5-15 NW: Ditch beside north-south road parallel to Pennsylvania Railroad (River Road) and $\frac{1}{4}$ mile south of Walloon Lake station, Charlevoix County. Loc. 6.

Exposures of Ellsworth Shale

33-6-25 SW: Abandoned shale pit of Boyne City Brick Company, in northeast corner of Boyne City, Charlevoix County. Loc. 5.

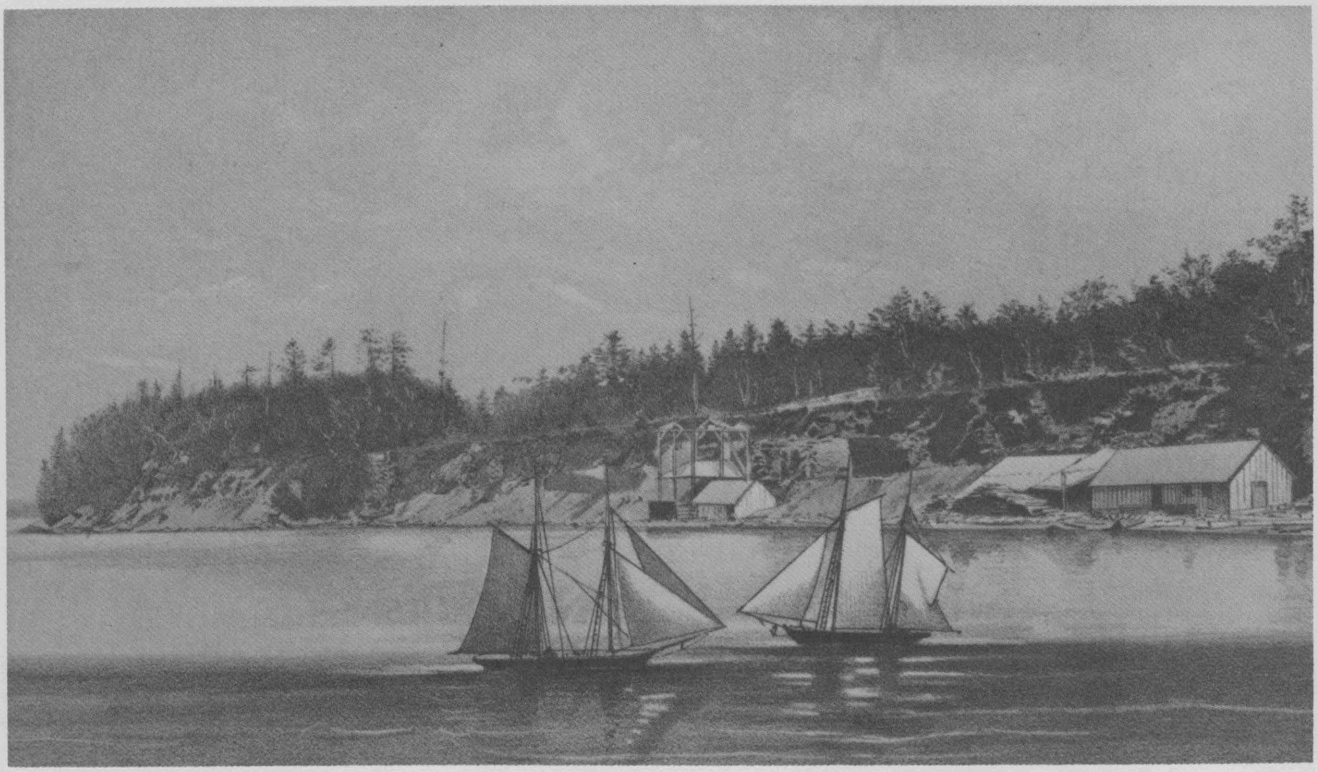
32-7-24 NW: Abandoned shale pit about 1 mile northeast of center of East Jordan, Charlevoix County. Loc. 69.

32-8-23 SE: Shale pit of Petoskey Portland Cement Company (now Penn-Dixie Cement Corporation), 1 mile south of Ellsworth, Antrim County. Type locality, Loc. 2.

31-9-12 C: Bluff on Lake Michigan shore about 1 mile southwest of Eastport, Antrim County. Bluff is just west of center of section. Loc. 67.

PREVIOUS WORK

To understand the interpretations of stratigraphy, it will be helpful to look at the exposures visited by geologists in the past. Their descriptions of localities often leave much to be desired in accuracy, partly due to the early maps and partly to the subsequent changes wrought by civilization. Then, too, additional exposures have come into being as quarries were opened, most of them for cement rock. At the same time, the mills along Bear Creek that offered exposures in the time of Rominger have long since disappeared, their sites no longer recognizable and presumably incorporated in the city of Petoskey. Some small quarries and test pits have been swallowed up by expansion of the present quarries. In table 1, we have included only the exposures along the shore or within a short distance of the shore; we have tried to establish the equivalency of localities mentioned by previous workers. In this, it has proved impossible to guess at the precise outcrops seen by Houghton and described as limestone "noticed, at intervals, forming the bed of the lake."



TEXT-FIG. 4 -- "Limestone Bluffs, Little Traverse Bay," the frontispiece of Geological Survey of Michigan, Volume III, 1876. Original a lithograph by Julius Bein. This place is now the type locality of the Petoskey Formation, the abandoned Northern Lime Company Quarry in Petoskey. Today, the marina of Petoskey is at the right in this picture and Bay View lies beyond the point at the left.

Houghton

Of all the past scientists to whom Michigan geology and geologists are indebted, one of the foremost must be Douglass Houghton. He gave up his practice as a physician, surgeon, and dentist and at 28 became the first State Geologist. The year was 1837. With a broad vision of the significance of the state's natural resources, Houghton combined a dashing, intrepid love of adventure. Because of his noted work on the mineral deposits and his tragic death by drowning in Lake Superior during a storm on October 14, 1845, many people think of him only as a geologist of the Upper Peninsula. Yet he must be credited with the initial reconnaissance of the strata in the Lower Peninsula as well.

His Second Annual Report to the legislature in 1839 (House Documents, 1839, No. 23: reprinted in Fuller, 1928, p. 167-338) contains information on what is now known as the Devonian Traverse Group. In Houghton's own section of the Report of the State Geologist, he recorded his observations on the rocks of that age in what later became Alpena and Presque Isle Counties on the northeast and Emmet and Charlevoix Counties on the northwest. Only by boat could he and his party transport their instruments, food supplies, and camping gear to the remote sections of the state during the field season. Hence, most of his work in the unsettled part of Michigan was limited to the lake coasts and river valleys. Among other notations on the Alpena region he wrote (Fuller, 1928, p. 176-177):

TEXT-FIG. 5 -- Charlevoix City Quarry, probably the same as "Lamphear's Quarry" (Grabau's Loc. 56 in his list). Charlevoix Limestone. Long abandoned, it served for many years as the city dumping ground for Charlevoix. Now it has been filled with debris and rubble by the Medusa Portland Cement Company. Original photograph by G. M. Ehlers in 1926 was poorly preserved as a negative. The picture was restored by double reversal on negative material with filters, through the ingenuity of Karl Kutasi. Locality 34-8-33 NW NE.

Between Charity islands and the southerly cape of Thunder bay, limestone appears at short intervals, but at such low levels (usually forming the bed of the lake) as to be of no practical value. At this latter point the rock occurs in an abrupt cliff, which rises directly from the water, to a heingt of from ten to twenty feet, and is continued for the distance of half a mile.

The limerock alternates with layers of a fissile clay slate, the latter of which composes about two thirds of the whole out cropping rock forming the face of the cliff. The limestone may be easily quarried, and portions of it would answer tolerably well for architectural purposes, but as a whole, in consequence of the irregular shapes into which the rock is liable to separate, it is of inferior quality.

At a distance of something less than two miles, southeast from the cliff just mentioned, a dark colored and highly bituminous shale occurs, forming a small island. This island, which, during the past season, in consequence of the high water, has been nearly submerged, is usually denominated Sulphur island.

This bituminous shale, which is seen to extend a considerable distance around, forming the bed of the lake, dips below the limestone just described, and may be regarded as of no great thickness....

Limestone is again seen in the bed of Thunder Bay river, at a distance of about one mile from its mouth. Over the out-cropping edge of the rock the waters descend in a series of very brisk rapids...

TEXT-FIG. 6 -- Charlevoix Lime Products Company Quarry No. 1. Man holds hat at the level of the "ostracod zone" of the Charlevoix Limestone as measured and recorded by the field party of 1926. Locality 34-8-28 SE SE. Type locality of the Charlevoix Limestone. Photo by G. M. Ehlers, 1926.

Other outcrops are mentioned on nearby islands and on the mainland to the north. The first-described limestone is the Thunder Bay Limestone on Partridge Point, and the bituminous shale is the Upper Devonian Antrim Shale. We can certainly understand young Houghton's confusion on the superposition, since he did not have the time to trace out the contact between the two formations; he probably did not see any exposures of the Squaw Bay Limestone on the southwestern shore of the peninsula nor any of the black shale on the mainland.

His voyage of 1838, on which he was reporting, took him through the Straits of Mackinac and into Lake Michigan. He wrote (ibid., p. 181-183):

> From the island of Mackinac to Little Traverse bay, rock does not appear upon the immediate shore of the lake, though hills based upon limestone, stretch at a distance, through the interior. These hills approach very near the head of the bay mentioned, where they attain an elevation of several hundred feet; and as a whole they probably constitute the most elevated and regular chain of hills on the peninsula.
>
> On the easterly side, and near the head of Little Traverse bay, the lime rock crops out. It continues for a distance of nearly a mile, forming an abrupt cliff, elevated from 10 to 20 feet.
>
> This rock varies from a dark blue and compact limestone to that of a grayish color and subcrystalline structure. The rock may be easily quarried, and portions of it will answer a tolerable purpose as a building stone. But much of it is of an inferior quality; for the dark blue limestone is subject to break into irregular fragments, while much of the gray rock is either too flaggy, or contains so large a proportion of

> argillaceous matter in its composition as to render it unfit for use.
>
> At a distance of from two to three miles westerly from the place of out-crop just mentioned, the rock again appears, in a continuous cliff, elevated from 15 to 20 feet.
>
> The inclination of the rock is here northwesterly. It continues for a distance of about three-fourths of a mile, when it dips beneath the water of the lake. This series of rocks no doubt overlies that last described.

Houghton then described the section of strata exposed, nearly 16 feet total, of which the underlying limestone and the basal four feet of an 8-foot bluish clay were under water. We have some difficulty in placing Houghton's section; his "bluish clay" could be the upper blue shale of the Gravel Point Formation. If this be true, then he was nearly six miles west of the near-shore outcrops "near the head of Little Traverse bay." On the other hand, his indicated distance of "two to three miles" would place his section lower in the Gravel Point Formation somewhere near Locality 19. Houghton continued (ibid., p. 182):

> Limestone was noticed, at intervals, forming the bed of the lake, as far south as the northerly cape of Grand Traverse bay. At this latter place it was last seen to rise above the surface of the water, attaining an altitude of from 4 to 8 feet.
>
> This rock contains large quantities of imbedded hornstone in irregular layers, varying from 2 to 12 inches in thickness. The siliceous matter having been deposited in this successive layers gives the whole mass of hornstone a beautifully zoned appearance.

In this account there can be no doubt that he was observing the Whiskey Creek strata which Winchell later labeled the "Cherty Beds." The site is Locality 7c, 1 to 1½ miles north of Norwood.

Houghton also recorded the black shale in the region (ibid., p. 183):

> About four miles southeasterly from the lime rock last described, and just within Grand Traverse bay, a dark colored bituminous slate, containing nodules of iron pyrites crops out, and continues at intervals for a distance of a mile. It closely resembles that before described as occurring at Sulphur island, near Thunder bay, except that it is not so highly charged with bituminous matter. The rock is of no practical importance.

The locality later became the type for the Antrim Shale, Locality 1.

Douglass

With the urging of Douglass Houghton, the Governor of Michigan during the winter of 1837-1838 appointed six men to assist in the work of the survey. One of these was Columbus C. Douglass, given the title "assistant to the geologist." According to the reminiscences of Bela Hubbard (in Fuller, 1928, p. 20-40), another assistant, he was a member of a field party with Houghton, Douglass, and a dog named "Dash" in 1837, the year the Survey was authorized. They pushed northward in the "short campaign" to the Indian country in Saginaw Valley to search for salt springs.

In the Second Annual Report (1839), of which excerpts from Houghton's part were quoted above, Douglass appended an account of the timber, soils, swamps, wells, streams, marl, bog iron, boulders, clay, coal, etc., in Ingham, Eaton, and Jackson Counties. And in the Third Annual Report (January 12, 1840), Douglass appended observations on the geology, soils, and topography in Jackson, Calhoun, Kalamazoo, Eaton, Ionia, Kent, Ottawa, Van Buren, and Allegan Counties. Considering the transportation available in those days, all members of the Survey were energetic and hard-working individuals. Douglass had proved by the beginning of 1840 that he could conduct survey work on his own.

In that summer, an expedition was organized to explore the coasts of the Upper Peninsula. Houghton was in charge, of course, and accompanied by Douglass and Hubbard. They left Detroit on the steamer Illinois and arrived at Mackinac on May 23rd. Here they purchased two "Mackinac" boats and hired six French-Indian "voyageurs" to row on the waters and to do the tenting and cooking ashore. By July 3rd they were encamped at Copper Harbor. The

field season was rather far advanced before Douglass was sent south to survey the northern portion of the southern peninsula. Nevertheless, he managed to add new information on the strata bordering both Lake Huron and Lake Michigan.

He submitted his section of the Third Annual Report on January 4, 1841. For the first time, names were coined for rock units in the state. The following excerpts from his tables (in Fuller, 1929, p. 579, 580) show the degree of descernment reached by Douglass at this early stage (see opposite page).

In his discussion, Douglass attempted to identify the fossils found in his "Thunder bay limestone," "Black bituminous limestone," and "Blue limestone" of the Lake Huron rocks and in his "Little Traverse bay limestone" and "Blue limestone" of the Lake Michigan rocks. Although he referred them to incorrect but similar species known in Europe, it represents the first attempt to establish correlations by fossils in Michigan -- a step in the right direction, even if on the wrong foot.

We now know that the stratigraphy is not quite as simple as Douglass believed. His major contribution was the establishment of the general sequence of formations on both shores, correcting Houghton's error on the relative position of the black shale.

Winchell

Alexander Winchell concealed his personal sorrows and disappointments beneath a flurry of activity. To his brilliant mind, all aspects of human endeavor served as inspiration for immediate investigation -- geology, zoology, agriculture, botany, religion, and ethics. He was intense in his research one day, popular lectures the next, and writing as time permitted. Protracted attention to one problem was seldom possible, for other lines cried out for his attention. With all his involvements, Winchell managed to make many and diverse contributions.

His attack on the geology of Antrim, Grand Traverse, Benzie, and Leelanaw Counties, as they were then constituted, was more protracted than most of his projects, extending over the eight years (with several interruptions) before formal publication in 1866. He specifically described and measured the rock succession at numbered localities in considerable detail, identifying the fossils of each as best he could in the field. He tried to group the strata into characteristic "Beds" which could be recognized wherever they might crop out. As he pieced together a composite section, it came out thus (1866, p. 48):

Unit	Thickness	Locality
Chert Beds	24 ft.	884
Magnesian Beds	35	865
Acervularia Beds	23	858, 861, 862, 863
Tropidoleptus Beds	15	857, 862, 880, 881
Stromatopora Beds	44	855, 856
Total	141 ft.	

It is not surprising that this first attempt to establish the sequence of rocks contained some errors, in an area where warping changes the tilt of the beds as many as nine times within one mile, where unconformities wiped out some beds from the record, and where ecology played a considerable role in the distribution of the Middle Devonian marine animals. Today, with additional rock sections exposed in quarries and with the accumulated observations and interpretations of several workers in the region, we can see the mistakes made by some of these early geologists; and yet, could we have done any better under the circumstances?

The designations of the "Beds" did not lead to sure identification. The "Tropidoleptus" proved to be a Strophodonta, and Winchell himself issued a supplement to the report in which the name was changed to Bryozoa Beds. As later investigators pointed out, Stromatopora can be found at several levels in the section and are not distinctive of one in particular. The serious misinterpretation concerned the relative position of the units. Winchell's "Tropidoleptus Beds" were equivalent to the lower part of the Gravel Point Formation (as exposed), cropping out on Pine River Point. His "Acervularia Beds" included the blue shales at the top of the Gravel Point, and his "Magnesian Beds" were

Rocks of Lake Michigan

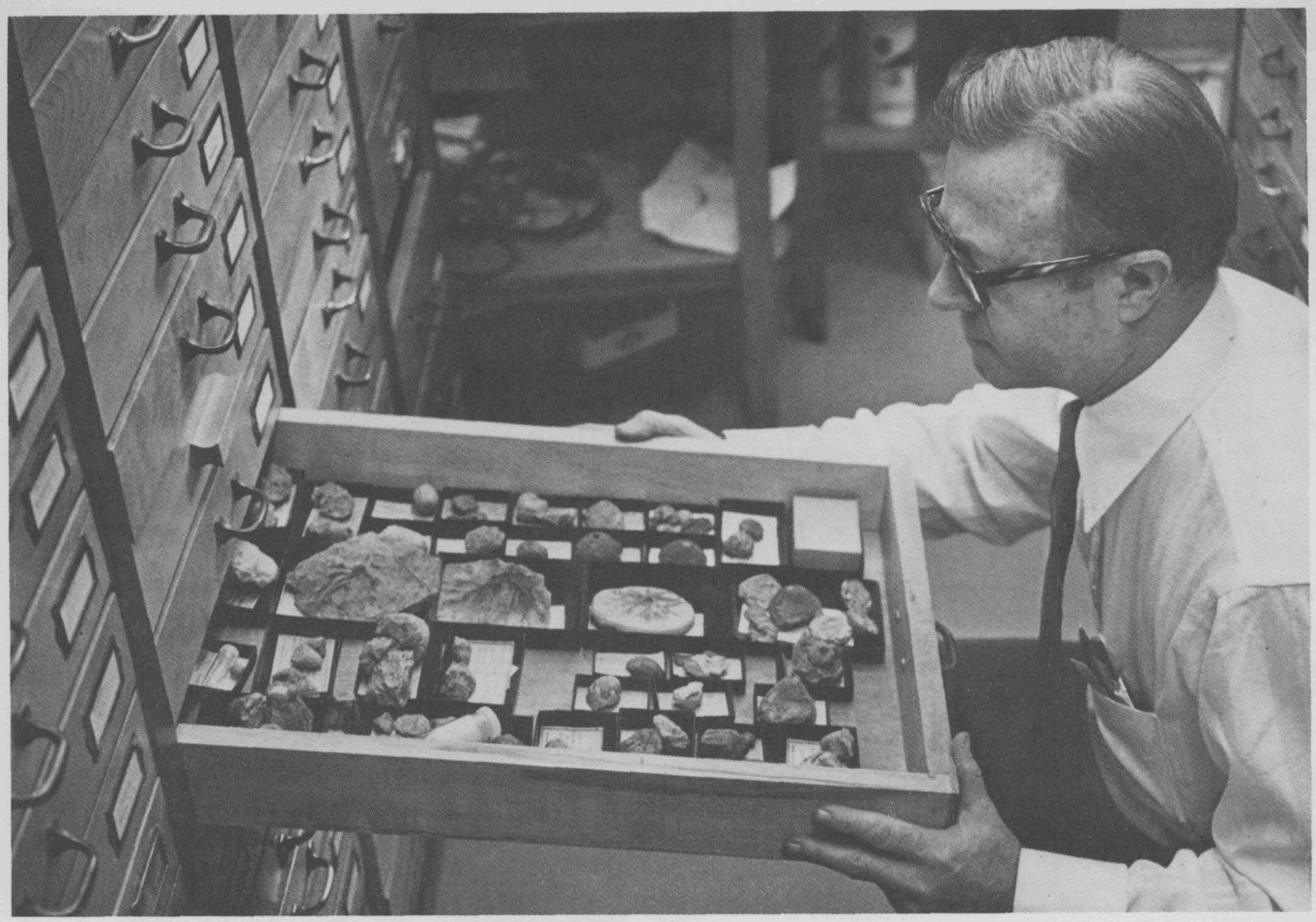
Townships		
	Tertiary and superficial materials	Bowlders of granite, &c. Clay, sand, &c.
16 N.	Manistee limestone	
31-32 N.	Shales	1. Light blue argillaceous. 2. Black, containing pyrites.
33 N.	Corniferous limestone	Containing beds of hornstone.
34 N.	Little Traverse bay limestone	Beds of limestone, intermixed with clay and chert.
34 N.	Black bituminous limestone	Composed of congeries of shells.
34 N.	Blue limestone, in thick regular layers.	
	Mackinac limestone.	Very porous and much shattered.

Rocks as seen forming the coast of Lake Huron

Townships		
	Alluvium.	
	Tertiary and superficial.	
20, 26 N.	Point aux Gres limestone	Light colored arenaceous, containing septarea.
27 N.	Shale.	Black bituminous, containing pyrites.
28 N.	Thunder bay limestone	Beds of limestone and gray clay or shale, containing abundant fossils.
30, 31 N.	Black bituminous limestone	Bituminous, composed of congeries of shells.
32, 33 N.	Blue limestone.	Compact and in thick strata.
	Mackinac limestone.	Very porous and the upper portion much shattered.

the Charlevoix Limestone. The rocks exposed in Petoskey and called the "Stromatopora Beds," however, were the lower part of the Petoskey Formation; hence, they are stratigraphically above the "Magnesian Beds" instead of at the base of the Traverse Group.

All things considered, Winchell's published rock sections for nine localities, together with his comments on other exposures, still consti-



TEXT-FIG. 7 -- The unspectacular key to Devonian stratigraphy in the Michigan Basin. The paleontologist -- that prober of long-deceased creatures -- enjoys the thrill of assimilating and extrapolating all the clues, finding and fitting the pieces of the puzzle, trying to deduce what Michigan was like some 350 million years ago. Here R. V. Kesling, Director of the Museum of Paleontology at The University of Michigan, looks through the collections for critical fossil evidence, accumulated over the span of a century by Alexander Winchell, Carl Rominger, G. M. Ehlers, and many others. Photo by C. I. Smith, Chairman of Geology and Mineralogy, Univ. Mich., Oct 1973.

tutes an important source in studying the geology of the Traverse Group along Lake Michigan.

Rominger

On April 17th, 1871, the state legislature decided to replace Prof. Winchell with Dr. Carl L. Rominger. A more dedicated, persevering geologist would have been hard to find. Like Houghton, Rominger was at the time of his appointment a successful physician; but there the similarities end between these two exceptional men. Each was right for his time. Houghton, the daring adventurer, was perfect for the initial exploration; Rominger, the methodical and untiring worker, was ideal for filling in details and pushing the frontiers inland.

The remarkable Rominger became the "compleat geologist," as well known for his work in the copper country as for his descriptions of Paleozoic corals, as noted for his

TEXT-FIG. 8 -- Uppermost Charlevoix Limestone in pit and Petoskey Formation in wall. Northern Lime Company Quarry in Petoskey, type locality of Petoskey Formation. Locality 35-5-32 SW (old Loc. 18). Photo by G. M. Ehlers, Aug 1926; compare with recent photo in frontispiece.

stratigraphy as for his identification of fossils on which he based correlations. More exciting and colorful than his published reports are his field notebooks, which are preserved in the Michigan Historical Collections at The University of Michigan. They reveal a Michigan much different from the state we see today. In his haste to record observations of all kinds, Rominger paid scant attention to spelling and punctuation and often lapsed into his native German, especially when the progress was full of danger and difficulty.

In 1872, his excursion took him to Emmet and Charlevoix Counties. On Thursday, July 25th, Rominger "left Mackinak at ½ passed 8 and arrived with fair wind at the lighthouse point" on McGulpin Point, then sailed on down the coast to Cross Village. On board he kept writing in his diary:

> ... no rock visible all along the shore line until to the head of little Traverse bay where on the south side of the bay about 1 mile east of the mouth of bear creek the rock crops out, first in the bottom of the lake with a gravelly shore line then in perpendicular bluffs 30 feet high [the site of present-day Petoskey] ... on the west side of bear creek mouth for some distance the rock beds have disappeared and loose detritus and drift material principally composed of the different Hamilton rocks form the shore and adjoining terraces.
>
> Freiday 26. ... visited the rock bluffs east of bear creek
>
> Saturday 27. our camp is at the dock built by the owner of the small sawmill on bear creek. I intend to remain there as long as necessary to investigate the next surrounding country ...

The time needed proved considerable, and Rominger remained in the area until the 5th of August.

TEXT-FIG. 9 -- Petoskey Formation, type locality. Abandoned Northern Lime Company Quarry near shore of Little Traverse Bay, east side of Petoskey, showing bioherm (reef) of stromatoporoids and the adjacent beds (stratified). Locality 35-5-32 SW (old Loc. 18). Photo by G. M. Ehlers, Aug 1926.

He correctly interpreted the stratigraphic relationships:

> Comparing the sect. west of bear creek with the sect. east of it I come to the following conclusion the series east is highest, the blue colored beds at the base are probably above the top strata of the western section, the acervularia and Strom. Wortheni are confined to the lower strata. Acervularia pustulifera et cespitosa are restricted to the upper strata ... the outcrops west of bear creek are by fire fallen timber and by the falling rock from above much more covered up than I found them 4 years ago when a far greater abundance of fossils could be collected.

On Sunday, July 28th, he wrote that he "ascertained on the exposure nearest to our camping place the true condition of things." His notebook continued:

> Monday 29 Juli. passed night a thunderstorm with rain. sailed out about 8 oclock towards pine river with contrary wind. landed about 4 or 5 miles west of bear creek by wading to the shore. a very instructive section is seen there [probably near Locality 14c] ... $\frac{1}{4}$ mile west of this escarpment an other still more extensive one is seen lowest black carbonac. acervularia beds abounding in fossils [apparently Winchell's Locality 862] ... the high sea did not allow me to land any more and I postpone the visit of the remainder of the shore line to the future. we arrived at pine river 4 oclock and entered Pine lake [now Lake Charlevoix] at the lower end of which we encamped.
>
> Tuesday 30 Juli. a severe wind blew down the Pine Lake so as to prevent us from sailing up. I then went to the rock exposures at the headland west of Pine river the rocks there amount to from 15 to 20 feet [Locality 8] ...

Although it had been reported to Dr. Rominger that no exposures were to be found on Pine Lake, he was determined to see for himself. The wind rose "to a perfect gale" on Tuesday night and continued with fine rain all through Wednesday. On Thursday he sailed to the end of the lake, climbed the highest hill and measured it as 270 feet high, and started back. The wind shifted and they had to lay over night about $1\frac{1}{2}$ miles below the sawmill. On Friday he got up at 4 o'clock and picked out some fossils from the drift, which he identified as species from the region. Because of the unfavorable wind, he did not reach the dock at Pine River until 11, and the "hard blowing" wind forced him to remain there for the rest of the day. On Saturday he sailed again into Little Traverse Bay, observing the rock bluffs along the way. With a few more stops, he closed the 1872 field season.

The following year he spent much of the summer in the southern part of the state. However, on Monday, August 18th, Rominger was near Norwood at the northern end of Grand Traverse Bay (near Localities 1 and 7a). He noted the next day that:

> ... the outcrops of black shales was limited to the portion south of Norwood and about 1 mile north of Antrim. all the remainder of the shore is a sand beach until near Browns town.

In the year 1874, Dr. Rominger left on Wednesday, May 20th, from Detroit on a vessel bound for Alpena; he arrived there late Friday, the 22nd and immediately started collecting. By the middle of July he had worked his way westward to Mullet Lake. On Saturday, July 18th, the mail carrier gave him a ride to Little Traverse Bay. He was surprised to find at the mouth of Bear River, where he had camped at the sawmill and dock two years previously, "a new village came into existence name Petoskey." On Monday, July 20th, he retraced his earlier route along the shore to the west, and at the end of the day recorded:

> it is very peculiar to see in such small distances so great and frequently changing variations in the appearance of the rock and the alternately great profusion of fossils and their sudden absence in the same strata.

During the next ten days he investigated the lake shore in the vicinity, making copious notes and collecting fossils from many localities. He worked out a composite section, which he estimated to have a thickness of about 100 feet, of "the strata seen in all the outcrops from bear river to the Khagochewing point [Nine Mile Point, Locality 15]."

The field work of 1872-1874 led to Rominger's article on "Geology of Lower Peninsula," published as Part I of Geological Survey of Michigan, Volume III. The Hamilton Group formed Chapter 6, pages 38-63. Exceptionally more studied and polished than the field notes, the published description essentially incorporated the same interpretation. Concerning the rock bluffs at Petoskey, Rominger wrote (1876, p. 55):

> Prof. A. Winchell considers the position of these beds as lowest in the rock series of Little Traverse Bay, but from my own observation I am inclined to consider them as representing the upper part of the series, and as equivalent with other strata which by Winchell have been designated as buff magnesian limestone.

Rominger described about 90 feet vertical relief with strata exposed along Bear Creek above lake level. Buff magnesian limestone was highest in the section, exposed at the railroad bridge across Bear Creek. At Ingall's mill, some 40 feet lower, were ledges of hard blue limestone. At "Porter's old mill site" 6 to 8 feet of blue shale were in the bed of the creek; other limestones extended downward to the foot of the race at Ingall's mill, "amounting to 20 feet in the outcrop." From that point to the mouth of the creek, several rock ledges were exposed.

Several other outcrops were discussed, with the fossils found in each. Rominger did not attempt a composite section, although he estimated the thickness of the exposed rocks at from 125 to 130 feet (1876, p. 62).

Grabau

In many of his ideas Amadeus W. Grabau was far ahead of his time. Every observation and every geological experience was catalogued

in his mind. The synthesis came out in his lengthy treatise on the pulsation theory in The Rhythm of the Ages, written so long ago that only the older geologists have read it -- and they have had time to forget about it. And yet this work contains surprisingly modern ideas on global tectonics.

With his characteristic knack for patiently putting two and two together, Grabau visited and revisited the exposures of the Traverse Group across the northern part of the Lower Peninsula, from Thunder Bay to Traverse Bay. Although he had spent two field seasons, he termed his report "a preliminary analysis" (1902, p. 164), and stated (ibid., p. 165):

> The conclusions herein given, in so far as they depend upon palaeontologic research, must be considered as tentative and subject to modification, should the final studies of the fauna demand it.

In general, Grabau found the stratigraphic succession to be as described by Rominger, and supplemented his interpretation with measured sections (in the manner of Winchell, but differing in precise details and divisions).

The Grabau report stood as the standard reference on the Traverse Group in this region for over a quarter of a century, and even today, it contains some suggestions that are well worth consideration for future investigations.

Smith

As a staff member of the Michigan Geological and Biological Survey, R. A. Smith conceived his responsibility to be singular: to encourage development of Michigan's resources through geologic testing and reporting. His publications show firm adherence to this aim. But his correspondence with other geologists reveals that he could and did recognize shortcomings of previous work, and that he could correct and extend the geology of nearly every county in the state. It is unfortunate that he did not incorporate these changes into publication, for our science would certainly have benefited thereby.

His most extensive work was the "Limestones of Michigan," issued by the Survey in 1916. In it he discussed the deposits in 24 counties, ranging in age from Precambrian to Carboniferous. For selected localities, including some in Emmet and Charlevoix Counties, Smith gave new measured sections. These are helpful in determining what strata were exposed at the time of his writing. His tables of chemical analyses of rock samples are still important references.

Pohl

Drawing upon the notes of the Michigan Geological Survey party of 1926, and supplementing the information with his own field observations, Erwin R. Pohl published on the Traverse rocks in Michigan in the U. S. National Museum Proceedings in 1929. It was in some respects an improvement over the report of Grabau, particularly in the attempt to correlate between isolated exposures.

As concerns the area of Emmet and Charlevoix Counties, Pohl's chief contribution was the division of the strata into defined units (1929, p. 5): "the Gravel Point stage, the Charlevoix stage, and the Petoskey formation." He attempted to construct as accurate a composite section as possible through "key localities." In each stratigraphic section, the units were divided into zones, and the zones into beds. In Pohl's paper, plate 1 was a series of sections arranged to show the suggested correlation of zones and beds at 9 localities; plate 2 was a composite section with two significant gaps representing covered intervals.

Pohl was not himself satisfied that the stratigraphic relationships were understood, either between northeastern and northwestern parts of the Lower Peninsula, or between localities within the latter. He wrote (1929, p. 4):

> "Complex" becomes but a mild term when applied to actual stratigraphic, biologic, and structural conditions within the Traverse. For a clear understanding of the subject as a whole it must therefore be separated into its component parts and each discussed individually with evidences for the present interpretation, finally by summary comparison drawing similarities and variances between the separately described

> portions. Stratigraphically, for present purposes, Traverse rocks in Michigan may be studied independently in their eastern and western occurrences, primarily because of the impossibility of direct lithologic or faunal correlation between the two. Each area will be seen to constitute an entity of sequential events in itself.

And, regarding the Little Traverse Bay area, he stated (1929, p. 6):

> Local deformation of small magnitude but extreme complexity has so confused the general attitude that it is possible to state only the already well known fact, that to the north lower and lower rocks appear on the surface where the cover of drift has been removed, and that to the southward the Middle Devonian disappears from sight under the younger black shales and later beds to reappear again for the first time in northern Ohio.

Recent Work

The additions to our knowledge of the geology of the region after Pohl's paper are minor. In 1933 Professor George M. Ehlers, who had participated in the 1926 expedition, had the opportunity to study a significant section of strata exposed by municipal improvements along Encampment Avenue in Bay View (east of Petoskey). It established the exact position of the beds formerly known only at Kegomic Quarry. This information was used in a figure showing correlations in the 1938 guidebook of the Eighth Annual Field Excursion of the Michigan Academy of Science, Arts and Letters (Geology and Mineralogy Section). Unfortunately, the vertical scale was incorrect on the two columns at the right of this figure, giving a misleading impression of the position of the beds.

In 1942, Dr. G. Arthur Cooper of the United States National Museum, with others, published the Devonian correlation charts in the Bulletin of the Geological Society of America. In discussing the Petoskey, Cooper called attention to the inclusion of strata carrying an Upper Devonian fauna.

In 1947, Dr. George V. Cohee summarized the distribution of Devonian rocks in subsurface, including well records from Antrim County, just south of the outcrop area in Charlevoix County, in the United States Geological Survey Oil and Gas Investigations, Preliminary Chart 28. Cohee offered a tentative correlation of the Emmet-Charlevoix exposures with those in the Alpena-Presque Isle region. Acknowledging that "it has been difficult to correlate these strata on the basis of fauna," he suggested that "it is probable that this is due to facies changes with environment controlling the types of organisms living in the waters in which these rocks were deposited."

The Michigan Geological Society ended its 1949 excursion with seven stops in the vicinity of Bay View, Petoskey, Bay Shore, and Charlevoix. Among other things, the guidebook pointed out the puzzling nature of the Petoskey stromatoporoid deposit at the Northern Lime Company Quarry in Petoskey, the presence of gypsum crystals in the "upper blue shale" at the Bell Quarry, and the irregular contact and apparent angular relationship of the Charlevoix Limestone and Petoskey Formation in the quarry and shore bluffs at Bay Shore.

Meanwhile, through the years, additions were made to the collections in the Museum of Paleontology at The University of Michigan. From around 1930 to 1960, many field trips were made to the region. However, no results of these studies were published. Fossils collected then were used in preparing this paper.

THICKNESS OF TRAVERSE GROUP

Because the lower and upper boundaries of the Traverse Group, as presently defined, can be easily identified in well cores and cuttings, the total thickness of the group can be established in places very close to the outcrop area. The upper boundary is at the base of the black Norwood Shale and the lower boundary is at the base of the thick blue Bell Shale. Fortunately, the Bell continues under the whole of the northern part of the Lower Peninsula with undiminished thickness, providing an accurate reference for locating the stratigraphic position of

TABLE 1 -- LOCALITIES ON AND NEAR THE SHORE OF LAKE MICHIGAN, FROM NORTHEAST TO SOUTHWEST

Description of exposure	Houghton (1839) = H Douglass (1841) = D	Winchell (1866) Locality Nos.	Rominger (1876)*	Grabau (1902) Locality Nos.	Smith (1916) = S Mich. Geol. Survey Locality Nos.	
Kegomic or Old Brewery Quarry, 1 mile E of Bay View, SW¼ sec. 27, T 35 N, R 5 W					S	21
Highway shoulder and creek bed, 1 mile E of Bay View, center N line sec. 34, T 35 N, R 5 W						21a
Ledges at RR station in Bay View, NW¼ sec. 33, T 35 N, R 5 W.				38	S	18a
Near head Little Traverse Bay, S of the point, NE¼ sec. 32, T 35 N, R 5 W.	H, D	855	R			
20 rods W of above, extending 3/4 mile SW, secs. 32, 31, T 35 N, R 5 W.	H, D	856	R	39		
Northern Lime Company Quarry, near E end Petoskey, sec. 32, T 35 N, R 5 W.			22	39	S	18
Along Bear Creek, near its mouth, sec. 31, T 35 N, R 5 W, and sec. 6, T 34 N, R 5 W.	?D	W	23			
Ledges at water's edge 1 mile W Bear Creek, near cent. sec. 1, T 34 N, R 6 W.		857	24	40		19
50-foot bluff about 1/3 mile W of previous locality, W¼ sec. 1, T 34 N, R 6 W.		858	R?	41		19
2½ miles W of mouth of Bear Creek, bluff, SW¼ sec. 2, T 34 N, R 6 W.		861		42		
Penn-Dixie (Petoskey Port. Cem. Co.) Quarry, SW¼ sec. 2 + SE¼ sec. 3, T 34 N, R 6 W.					S	14
Beach exposure, 1/3 mile W of Grabau's 42, near E line sec. 4, T 34 N, R 6 W.				44		
Old Rose Quarry, in Petoskey, center S¼ sec. 31, T 35 N, R 5 W.					?	
Cliff 10 to 12 feet high, ½ mile E of Grabau's 46, center S line sec. 4, T 34 N, R 6 W.				45		
Abandoned "Rose's quarry" of Grabau, W. E. Smith Quarry of Smith, NW¼ NE¼ sec. 9, T 34 N, R 6 W.				42	S	14c

TABLE 1 -- Continued

Description of exposure	Houghton (1839) = H Douglass (1841) = D	Winchell (1866) Locality Nos.	Rominger (1876)*	Grabau (1902) Locality Nos.	Smith (1916) = S Mich. Geol. Survey Locality Nos.
Nearshore exposure, beds dipping steeply W, SW¼ sec. 4, T 34 N, R 6 W.		862			
Bay Shore Lime Co. Quarry 1, 4 miles W Petoskey, SW¼ sec. 4 near W line, T 34 N, R 6 W.			R	46	
Abandoned Bell Quarry ("Rose Quarry" of Fenton & Fenton), near NE corner sec. 8, T 34 N, R 6 W.					S 14e
Dome-like elevation ½ mile W of Winchell's 862, sec. 5, T. 34 N, R 6 W.		863	25		
Bay Shore Lime Co. Quarry 2, near Bay Shore, S of center sec. 6, T 34 N, R 6 W.				47	
Abandoned Northern Lime Co. (Main Curtiss) Quarry, SW¼ sec. 6, T 34 N, R 6 W.					S 13
Bluffs along shore at Bay Shore, west of quarry, sec. 1, T 34 N, R 7 W.		865			13
Abandoned Superior Quarry of Northern Lime Co., near E line sec. 3, T. 34 N, R. 7 W.					S 15
Bay Shore Lime Co. Quarry 3, end of Khagashewung Point (may be same as above).				48	
Bluffs at Khagashewung (Kawgachewing, Nine Mile) Point, E¼ sec. 3, T 34 N, R 7 W.			26		S 15
Shore of Little Traverse Bay for 2½ miles W of Khagashewung Point, secs. 3, 4, 8.			27		S 15b
Below water level ½ mile W of dock at Charlevoix, near center N line sec. 27, T 34 N, R 8 W.			R		
Abandoned Charlevoix Rock Prod. Co. Quarry 1, SE¼ SE¼ sec. 28, T 34 N, R 8 W.					S 9
Abandoned Charlevoix Rock Prod. Co. Quarry 2, near center S line sec. 28, T 34 N, R 8 W.					S 12
Gravel Point (Pine River Point, South Point), NW¼ sec. 28 to W line, T 34 N, R 8 W.	D	880	28	49	8
Shore outcrop ½ mile S of Gravel Point, line between secs. 29/32, T 34 N, R 8 W.		881		50	

TABLE 1 -- Continued

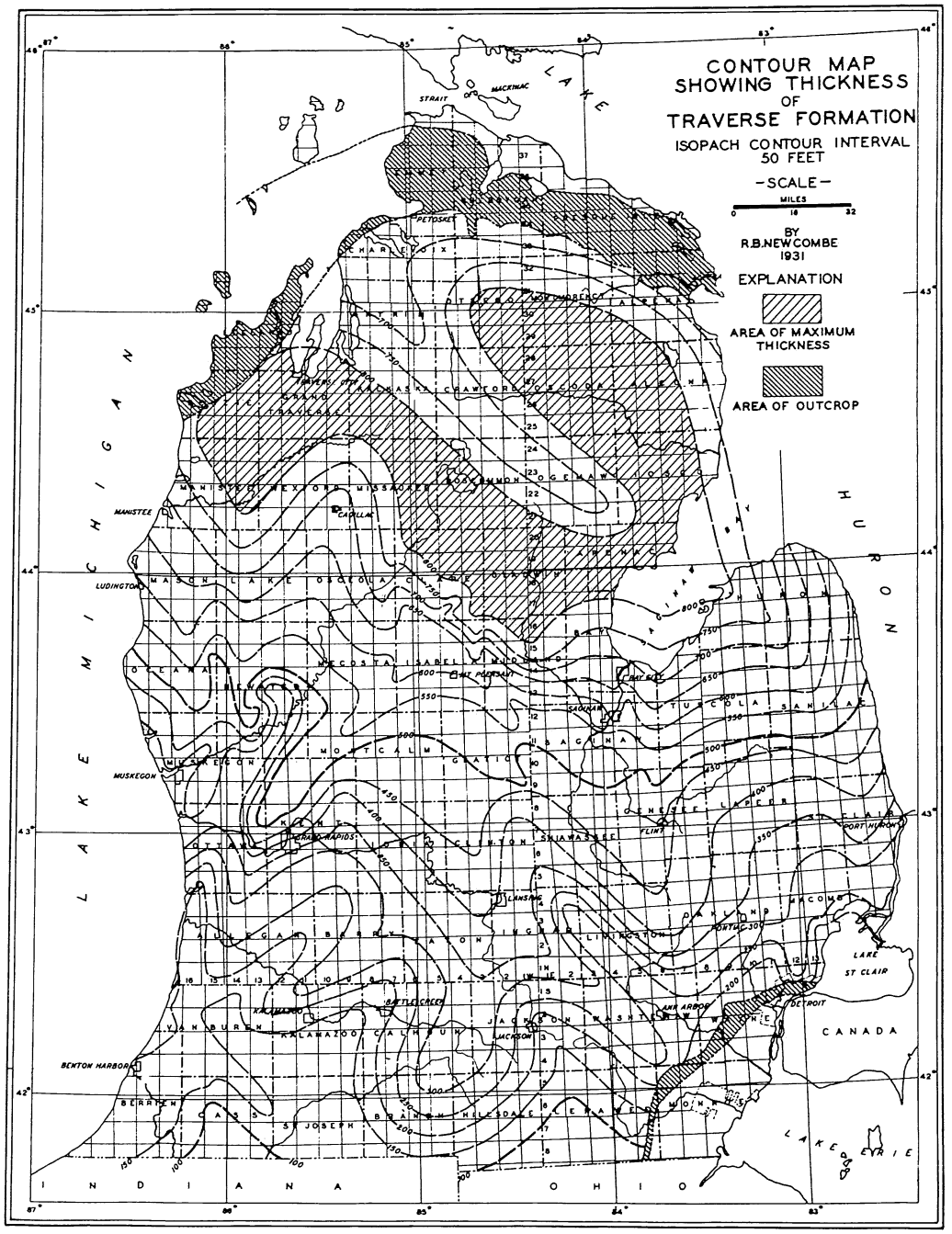
Description of exposure	Houghton (1839) = H Douglass (1841) = D	Winchell (1866) Locality Nos.	Rominger (1876)*	Grabau (1902) Locality Nos.	Smith (1916) = S	Mich. Geol. Survey Locality Nos.
Shore from Gravel Point to 1 mile SW (includes above), secs. 29 + 32, T 34 N, R 8 W.			R			8a
Wolverine Lime Co. Quarry, abandoned, small, S½ SE¼ sec. 29, T 34 N, R 8 W.					S	11
Outcrop along shore of Lake Michigan, NW¼ sec. 6, T 33 N, R 8 W.		882	29	x		
Ledges and bluffs, 1 to 1½ miles N of Norwood, NE¼ sec. 27, SE¼ sec. 22, T 33 N, R 9 W.	H, D	884	30	51		7c
Small test pits in limestone in N half of sec. 26, T 33 N, R 9 W.						7b
Road cut along lake, 1 mile N of Norwood pier, near cent. + NE¼ sec. 27, T 33 N, R 9 W.						7a
Black shale along shore, 1 mile S of Norwood, SE¼ sec. 3, T 32 N, R 9 W., Antrim Co.	H, D	888	R	x		1

* In the Museum of Paleontology, filed under "Devonian Localities," is a copy of Dr. Rominger's unpublished list of important Devonian localities from Alpena County to Charlevoix County. His Localities 22-30 include exposures in Emmet and Charlevoix Counties.

higher Traverse formations.

In 1933 Robert B. Newcombe presented an isopach map of the Traverse rocks in the Michigan Geological Survey Publication 38 as his figure 13 (see our text-fig. 10). Records of drilling after that date show that his map was seriously in error in Charlevoix and Antrim Counties. A more accurate estimate of Devonian thicknesses was made by Cohee (see our text-fig. 11), based on the available well records which penetrated the complete group of rocks up to 1947. With still more well data now stored in the Subsurface Laboratory of the Department of Geology & Mineralogy at The University of Michigan, we prepared text-figure 12, which covers parts of Emmet, Charlevoix, Cheboygan, Antrim, and Otsego Counties. It seems doubtful that the Traverse is less than 700 feet thick at any place in Antrim County, and some wells penetrate over 800 feet of Traverse there. The average thickness in the vicinity of Charlevoix and Petoskey may be assumed to be near 700 feet.

Records from six wells near the Charlevoix County outcrops show rather consistent units throughout the Traverse Group. These wells are (1) Lawrence Wolgamott #1 in NW¼ NW¼ SE¼ sec. 19, T 32 N, R 8 W, (2) Sohio Petroleum Company, East Jordan Lumber Company #1 in S½ NE¼ NW¼ sec. 9, T 31 N, R 7 W,

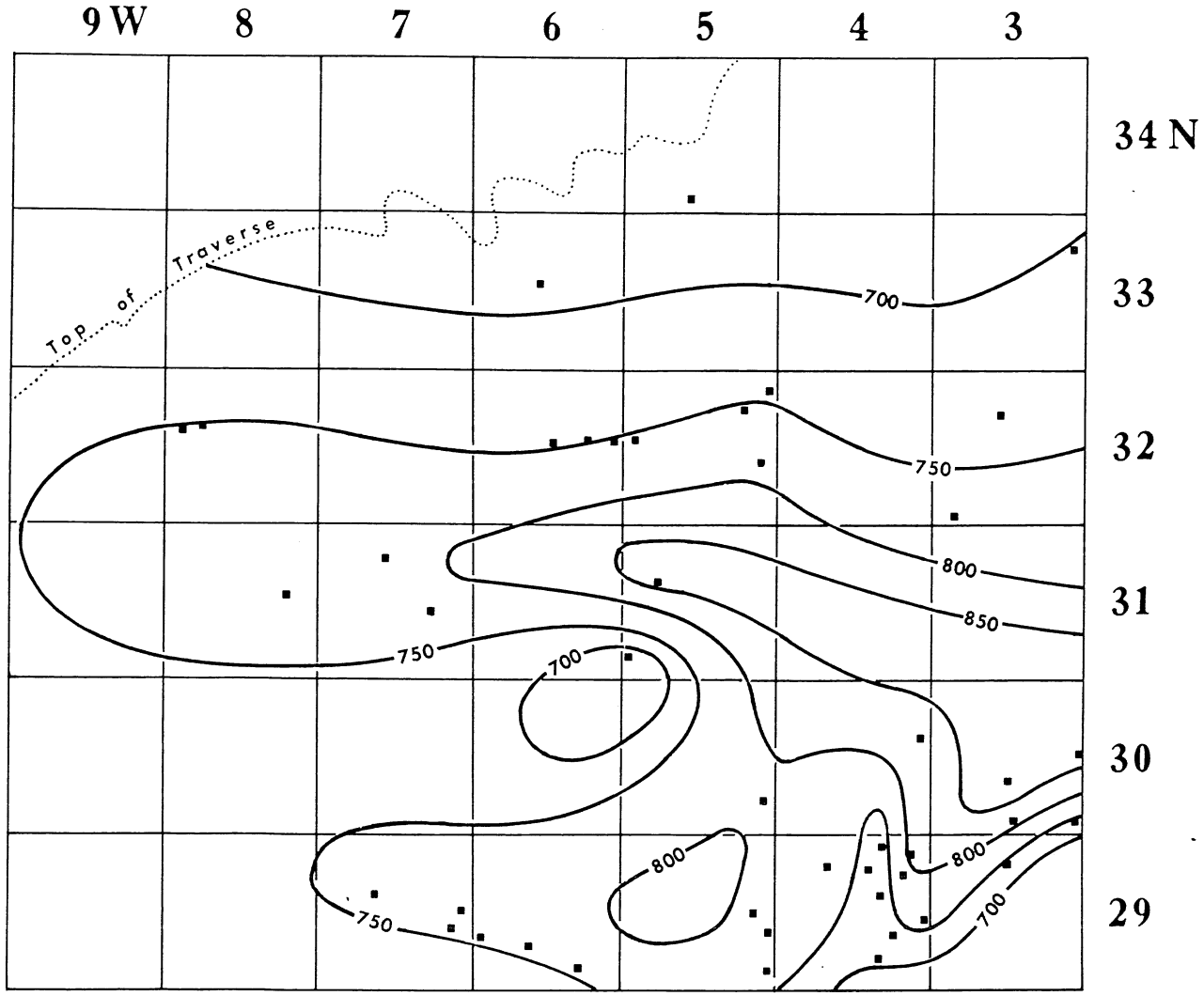


TEXT-FIG. 10 -- Isopach map showing thickness of Traverse Group. From Newcombe, 1931, fig. 13.

(3) Boyne Oil & Gas Company, W. W. Bailey #1 in SE$\frac{1}{4}$ NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 14, T 32 N, R 6 W, (4) Arthur Smith #1 in NW$\frac{1}{4}$ SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 18, T 32 N, R 5 W, (5) Ohio Oil Company, State-Boyne Valley #1 in NE$\frac{1}{4}$ SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 24, T 32 N, R 5 W, and (6) W. M. Brown #1 in SE$\frac{1}{4}$ SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 12, T 33 N, R 3 W; other data on these wells is given in table 2.

TEXT-FIG. 11 -- Isopach map showing thickness of Traverse Group. From Cohee, 1947.

The key to correlate the well records with outcrops is the oft-cited Bay View Well, completed in July, 1895, and located "120 paces northwest from the door of the G. R. & I. R. R. Bay View station, $4\frac{1}{2}$ feet above the bay, and 40 feet from the shore" (Grabau, 1902, p. 197). As a detailed log of the strata, this record leaves much to be desired, but it has the distinction of beginning at the easily recognized Gravel Point-Charlevoix contact and penetrating into the Bell Shale (at 450' it produced a flow of good water at 200 barrels per hour). It serves to establish the exact stratigraphic distance between the top of the upper blue shale of the Gravel Point Formation and the top of the Bell Shale -- $469\frac{1}{2}$ feet at Bay View.



TEXT-FIG. 12 -- Isopach map showing thickness of Traverse Group in parts of Antrim, Otsego, Charlevoix, Cheboygan, and Emmet Counties. Based on data from wells (locations marked by small squares).

Comparison of the Bay View data with the generalized stratigraphy shown in table 2 identifies Unit 11 of the table as the uppermost bed of the Gravel Point Formation. It can also be seen that the Traverse strata above the Gravel Point (at least in the area immediately south of the outcrops) amount to 150 to 160 feet, generally characterized as 85 feet of limestone, 15 feet of shale (nowhere exposed), and 60 feet of limestone, dolomite, and chert. The wells (especially the W. W. Bailey #1) also reveal the nature of lower Traverse beds that are concealed by glacial cover to the north of the outcrops.

TABLE 2 -- SELECTED WELL RECORDS TO SHOW GENERAL STRATIGRAPHY AND TOTAL THICKNESS OF THE TRAVERSE GROUP IN REGION. For each well, figures represent thickness of unit and distance below black shale.

Unit	1		2		3		4		5		6	
Norwood black shale		0		0		0		0		0		0
Traverse Group Upper part												
14 Limestone (dolomite, chert)	57	57	63	63	61	61	51	51	63	63	67	67
13 Shale, gray	15	72	7	70	13	74	14	65	24	87	5	72
12 Limestones	80	152	95	165	84	158	83	148	64	151	85	157
Gravel Point Formation												
11 Shale, blue, soft	10	162	8	173	11	169	16	164				
10 Limestones			18	191	17	186			49		25	
9 Shale, blue, soft	85 ls		8	199	2	188			sh, ls	200	sh	182
8 Limestone		247			47	235					50	232
7 Shale, gray	5	252			9	244					20	252
6 Limestones, buff to gray			361 ls, sh, anhyd		174	418	473 ls, dolo		351 ls, dolo		169	421
5 Shale, limy, gray					6	424					21	442
4 Limestone, dolomite	410 ls, dolo			560	95	519				551	80	522
3 Shale, limy, light gray			23	583	14	533			14	565	15	537
2 Limestone, dk-gray to buff		662	96	679	116	649		637	72	637	95	632
Bell Shale												
1 Shale, blue, soft	100	762	101	780	94	743	90	727	113	750	70	702
Top Bell to top Gr. Point	510		615		491		489		486		545	

TABLE 2 -- Continued

	Name	Sec.	T.	R.	Township	County	Elev. (ft.) MSL
1	Lawrence Wolgamott #1	19	32N	8W	Banks	Antrim	878
2	East Jordan Lumber Co. # 1	9	31N	7W	Echo	Antrim	841
3	W. W. Bailey # 1	14	32N	6W	Wilson	Charlevoix	783
4	Arthur Smith #1	18	32N	5W	Boyne V.	Charlevoix	723
5	Boyne Valley # 1	24	32N	5W	Boyne V.	Charlevoix	968
6	W. M. Brown # 1	12	33N	3W	Wilmot	Cheboygan	778

INTERPRETING THE RECORD

Geologists have come a long way in the last half century, but they still have room for original research on the distributions of ancient sediments and animals. The days of "pancake" paleogeography have gone (for the most part), the concept of graded shelf sediments has been drastically curtailed, and the original meaning of facies is being altered. Nevertheless, as more examples of various facies models are investigated, some further modifications are indicated to bring the Paleozoic rocks into accord with observed modern sediments and structures.

In a recent textbook, Blatt, Middleton, & Murray note (1972, p. 185, 187):

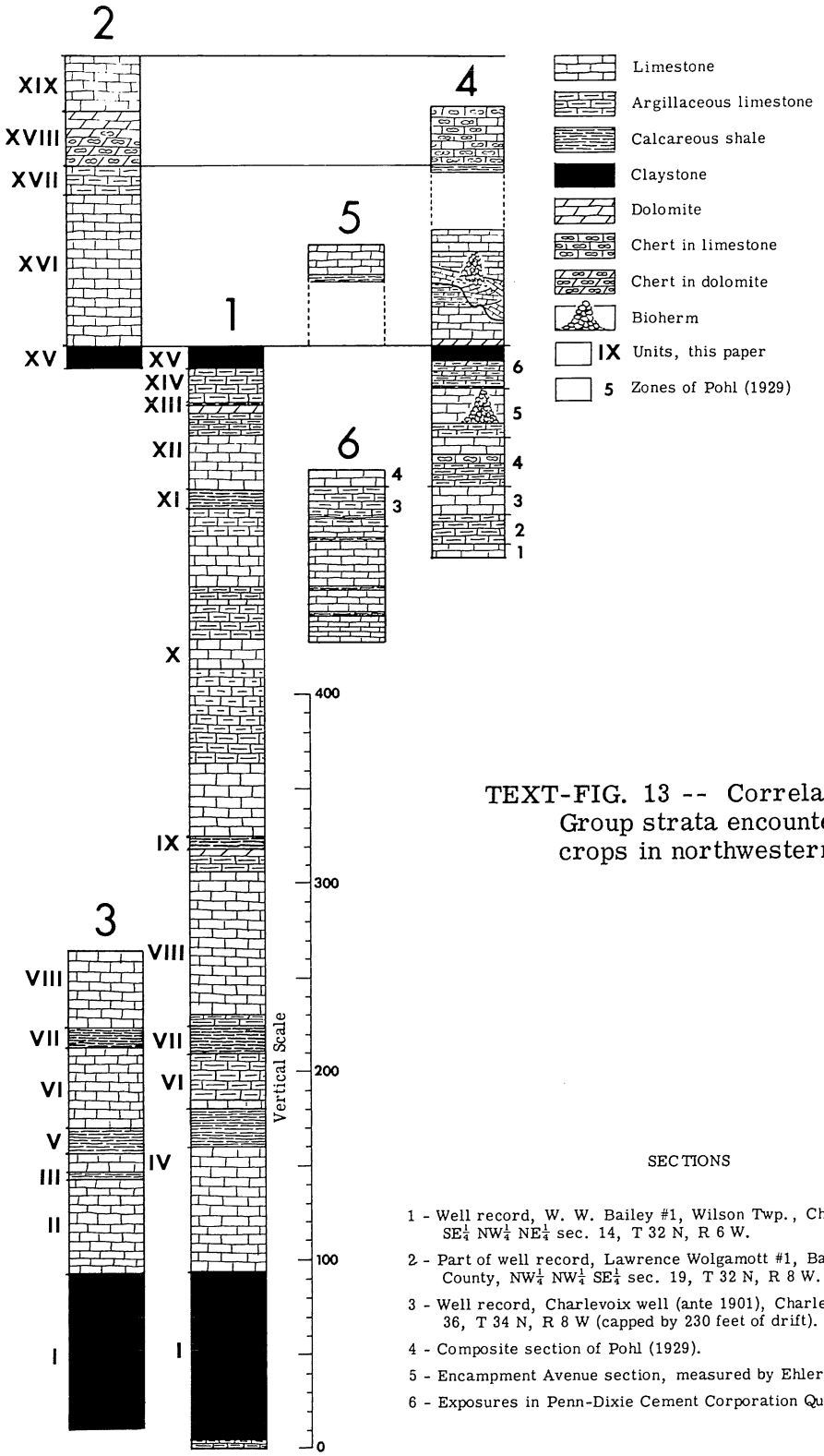
> There is clearly a close connection between the environment of deposition and the nature of the sediment deposited. For the geologist working with ancient sedimentary rocks, however, the primary data are the rocks and the environment must be interpreted from them.... In ancient deposits the vertical sequence of facies is generally much easier to observe than the lateral sequence, a circumstance that is the exact opposite of the situation in modern sediments.

This observation is certainly significant as regards the Traverse Group of Devonian rocks in Michigan.

Walther's principle. -- Present analysis of sedimentary rocks stems largely from Johannes Walther's three-volume Einleitung in die Geologie als historische Wissenschaft published in 1893 and 1894. A modern translation of his key statement (Blatt et al., 1972, p. 187-188) is:

> The various deposits of the same facies area and, similarly, the sum of the rocks of different facies areas were formed beside each other in space, but in crustal profile we see them lying on top of each other... it is a basic statement of far-reaching significance that only those facies and facies areas can be superimposed, without a break, that can be observed beside each other at the present time.

The truth of Walther's interpretation cannot be denied; and yet in application several "kickers" become apparent. (1) It is presupposed that all sedimentary types of an extensive area will, by transgressions and regressions of the sea, leave their record in the particular vertical sequence which is available for study. (2) For the principle to be valid, no breaks can exist in the sequence; either local nondeposition or subsequent erosion can result in a small unconformity, difficult to detect but essential in understanding the history of the area. (3) An original depth of water must be inferred for each sediment type to reconstruct the paleogeography; this is not easy for certain beds. (4) Unless the records of a large region are studied, the original spatial relations of sedimentary provenances become a matter of guesswork. Often the result is an oversimplified interpretation from an oversimplified record; or an "ideal" model with incomplete substantiation in the record.



TEXT-FIG. 13 -- Correlation of Traverse Group strata encountered in wells and outcrops in northwestern Lower Peninsula.

SECTIONS

1 - Well record, W. W. Bailey #1, Wilson Twp., Charlevoix County, $SE\frac{1}{4}$ $NW\frac{1}{4}$ $NE\frac{1}{4}$ sec. 14, T 32 N, R 6 W.

2 - Part of well record, Lawrence Wolgamott #1, Banks Twp., Antrim County, $NW\frac{1}{4}$ $NW\frac{1}{4}$ $SE\frac{1}{4}$ sec. 19, T 32 N, R 8 W.

3 - Well record, Charlevoix well (ante 1901), Charlevoix County, sec. 36, T 34 N, R 8 W (capped by 230 feet of drift).

4 - Composite section of Pohl (1929).

5 - Encampment Avenue section, measured by Ehlers in 1933.

6 - Exposures in Penn-Dixie Cement Corporation Quarry, this paper.

Furthermore, we are coming to realize that time is a highly significant factor. The deposits laid down in a rapidly advancing or retreating sea may differ greatly from those deposited in a very slowly shifting sea.

The time element. -- One might suppose that paleontology could provide all that is necessary for the time element. This is more nearly accomplished for Cretaceous to Recent, in which interval the planktonic foraminifera serve as time indicators for horizons. In the Paleozoic, however, nearly all of the preserved fauna is benthonic, closely attuned to particular depths or sediment types. For example, appendix 2 shows that the fauna of the Gravel Point is more nearly like that of the lower part of the Petoskey Formation than like that of the shallow-water Charlevoix Limestone which immediately overlies it.

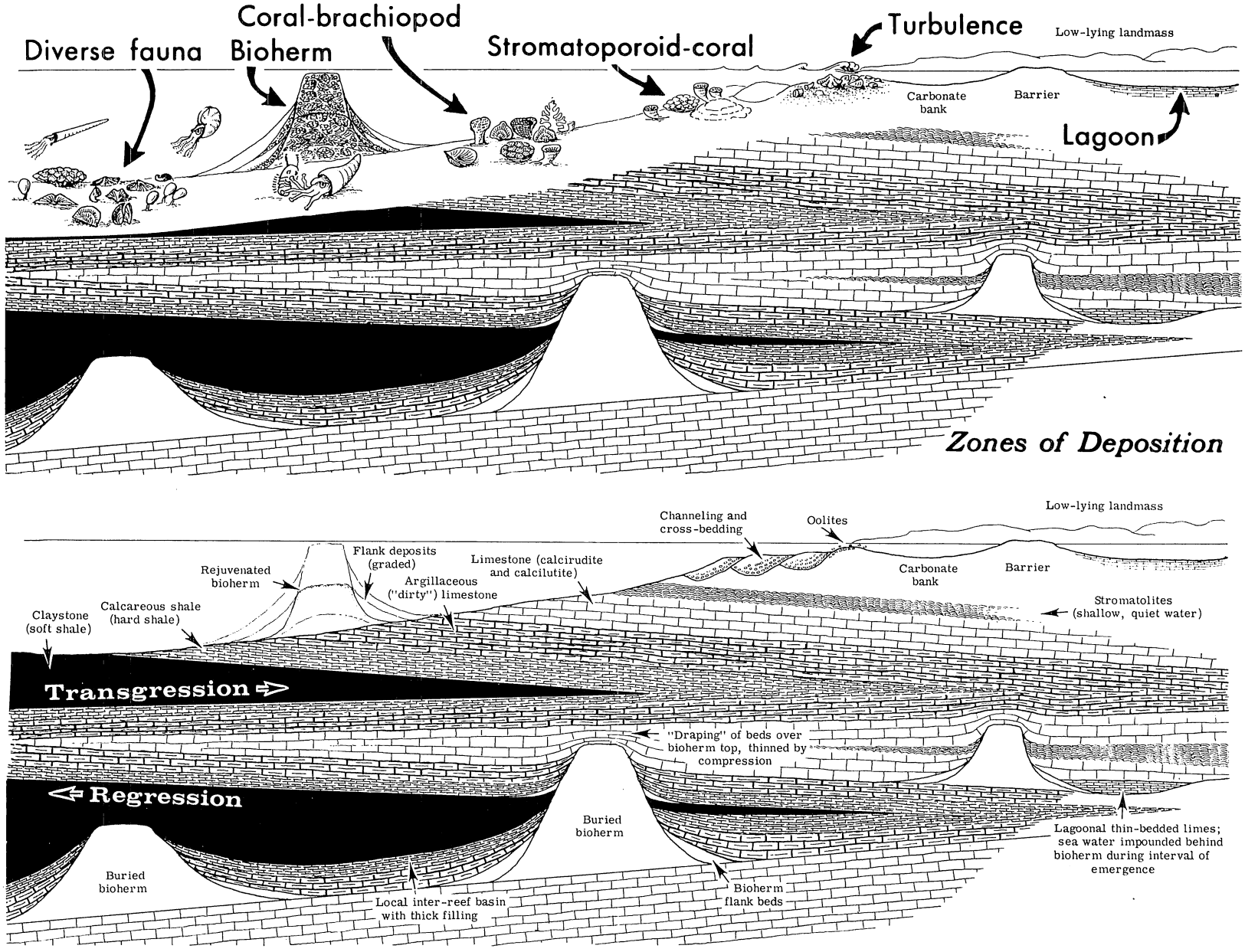
Perhaps the most reliable use of paleontology is still the correlation of stratigraphic units from one place to another. This is only a very general index of time. Even with the advances made in population studies and other aspects of the "new" paleontology, the measurement of time by fossils remains too unsophisticated to use for interpreting local geologic history on a bed-by-bed basis. Hence, even though the faunas in the Traverse Group of Emmet and Charlevoix Counties give a general indication of evolutionary gaps (and therefore unconformities) within the record for Middle and Upper Devonian, they do not answer the question of how much time was involved in deposition of each unit.

Changes in sea-floor topography. -- One major problem in the Michigan Devonian does not directly concern Walther's principle and its application in time and space. Instead, it centers on the introduction of topographic features, either orogenic or biogenic, which constitute a new sedimentary environment. The problem is unique neither to Michigan nor to the Devonian. Examples abound in many places and in many sections of the geologic column. Let us consider that Walther's idea, and for that matter nearly all of the facies concept, is predicated on a constant topography subjected to fluctuations of sea level; thus transgression shifts all environmental zones toward the landmass, and regression shifts them seaward; and the resultant pattern in this idealized model is a neat set of parallel zigzag bands of sediment types. But let us suppose that folding suddenly creates an anticline or dome within the basin or that conditions locally stimulate coral growth to produce a bioherm. Here is a new sedimentary environment. It has no previous history. It may not correlate with any other sedimentary environment. Indeed, if it is large enough, it may reverse the inclination of the bottom over a considerable distance and thereby influence all the previous environments through an extensive area. Furthermore, the effects of new folds or bioherms are not limited to the type of sediment deposited at the new depth; the structures may change currents, provide new source areas, and even alter such factors as energy, oxygen, and temperature.

A model. -- One approach to interpretation of the vertical succession of facies is the construction of a model. In theory, the model represents a logical compilation of all factors -- sediment types, sedimentary environments, and the fossil record -- into a meaningful reconstruction of conditions in the past. Our attempt is shown in text-figures 14 and 15. If it serves no more useful purpose, it brings into critical focus certain unexplained relationships.

A principle shortcoming of our model -- and of others that have been proposed -- is the omission of the effects of rock deformation during the period. Another shortcoming is that one cross section cannot show all the sedimentary and ecological situations that existed over a large area.

Certain associations show up time after time in field observations. These provide a base for assigning the Middle Devonian beds to particular depths of deposition. To start, overturned large coralla and broken blocks of stromatoporoids, some weighing hundreds of pounds, are invariably associated limestones in the Traverse Group. Close inspection of these rocks often reveals them to be actually carbonate sands and silts. Such shifting and breakage calls for high energy, and these are attributed to the zone of turbulence in very shallow water.


Diverse fauna
Coral-brachiopod Bioherm
Stromatoporoid-coral
Turbulence
Low-lying landmass
Carbonate bank
Barrier
Lagoon
Zones of Deposition
Low-lying landmass
Channeling and cross-bedding
Oolites
Flank deposits (graded)
Limestone (calcirudite and calcilutite)
Rejuvenated bioherm
Argillaceous ("dirty") limestone
Carbonate bank
Barrier
Stromatolites (shallow, quiet water)
Claystone (soft shale)
Calcareous shale (hard shale)
Transgression
"Draping" of beds over bioherm top, thinned by compression
Regression
Buried bioherm
Lagoonal thin-bedded limes; sea water impounded behind bioherm during interval of emergence
Buried bioherm
Local inter-reef basin with thick filling
Bioherm flank beds

In many sequences, a bed of this limestone lies in contact with a bed of limestone containing unbroken corals and stromatoporoids, some of the former in living positions. These lived and were buried below the zone of violent turbulence, but still in shallow water. Common sequences of beds show progressive decrease of carbonates and increase of clay. The logical interpretation is that clay, derived from weathering on a low landmass, was carried to the deeper parts of the basin, whereas larger carbonate particles settled out somewhere on the slopes. Such units as the "upper blue shale" of the Gravel Point Formation in the Emmet-Charlevoix region or the Bell Shale in the Alpena-Presque Isle region are nearly carbonate-free -- so-called "soft" shales. They are persistent and contain a variety of invertebrates. Just as faunal diversity increases away from the shore in modern foraminifera (Walton, 1964, p. 209), so general diversity of invertebrates seems to have increased in the same direction during the Devonian.

Although the zones vary somewhat from one occurrence to another, it is possible to designate them as shown in text-figure 14: turbulence, stromatoporoid-coral, coral-brachiopod, and diverse fauna. Bioherms contain mostly shallow-water forms, and the sediments associated with them vary from the zone of turbulence at the top (and throughout the center of the structure) to deeper water zones at the far edges of the graded slump debris constituting the flanks, even to the zone of diverse fauna in some cases. These zones are like those used by Kesling (1970, in Ehlers & Kesling) in the Devonian of northeastern Michigan.

Lagoons are included in our model, even though the closest beds which qualify for this zone are the Welleria beds of the Gravel Point Formation near Afton in Cheboygan County. Other Michigan Devonian units of lagoonal origin are the quarried stone at Onaway (Koehler Limestone) and the Newton Creek Limestone in Alpena County.

Some specific features indicated in the model deserve discussion separately. They include oolites, stromatolites, "draping" of beds over bioherms, folding, local basin fillings, and rejuvenated bioherms or channel fillings.

Oolites. -- Certain similarities suggest that the setting of the Traverse sedimentation was like that of the present Bahama Platform. The coral-algal reefs of today occur on the windward side of the carbonate platform in patches, particularly between lines of low islands. In the vicinity of Andros Island, oolites are developed on the leeward side of the island. We suspect, therefore, that our model should similarly show the bioherms on the windward side of the low landmass and the oolite beds on the leeward side.

Ooliths, the subspherical sand-size grains composing an oolite deposit, accumulate their coatings slowly and at intermittent intervals. Weyl (1967) has demonstrated that very slight changes in the pH of carbonate-charged seawater result in dissolution or precipitation. The formation of an oolith involves a precipitated coating while the grain is actively being moved and a "hardening" phase of the coating while the grain is buried. A grain moving along a tidal bar gains only 2 ppm of calcium carbonate in 3 minutes, so that a thick accumulation must involve numerous interruptions of the process.

Blatt, Murray, & Middleton (1972, p. 420, 421) state:

> Today ooliths are found only where strong bottom currents exit. Commonly this represents areas of tidal bar accumulation or within tidal deltas. In the ancient record the oolite commonly shows abundant evidence for current transport such as large-scale cross-bedding. There appears to be

TEXT-FIGS. 14, 15 -- Hypothetical model of sedimentation incorporating several features noted in the Traverse Group strata of Michigan. Significant but not indicated in the sketches are the many modifications brought about tilting and folding during the period. Parts obviously not to scale. To judge from the continuity of numerous stratigraphic units throughout the region of this study having no significant change in thickness, the distance from shore to deep mud flats may have been over 100 miles. Greatest depth may not have been over 150 feet.

> little doubt that the marine oolitic coatings represent a direct inorganic precipitate of aragonite deposited with brief interruptions on moving particles. The independent evidence that the particles were moving during formation of the coating is that the oolitic rings are continuous around the grain.... The tidal setting is one in which a grain can be moved periodically and still stay within the same depositional setting for a sufficiently long period of time to develop a thick oolitic coating. The theory also confirms the generalization that an oolitic coating on a particle is evidence for current transport in an environment where the grain is periodically and repeatedly buried and exhumed from the sediment.

We envisage just such conditions to have prevailed during the time when the middle part of the Charlevoix Limestone was formed. In the area west of Charlevoix, the old quarries exposed these beds and revealed the following association of features: numerous local unconformities, units composed of well-developed ooliths, cross-bedding, and channeling. Intervals of subaerial exposure are indicated for certain beds by the weathered "rotten-stone" texture and by irregular laminae strongly discolored by limonite. There is ample evidence to support a very shallow depth of deposition.

Stromatolites. -- In the lower part of the Charlevoix Limestone and at several levels in the Gravel Point Formation there are beds of thinly and somewhat irregularly laminated limestone. Many of these alternate with thicker bedded unlaminated limestone. We interpret the laminated beds as stromatolite layers.

The classic investigation of Logan, Rezak, & Ginsburg (1964) resulted in the recognition of several types based on the geometric form. Discrete, vertically stacked hemispheroids, such as those observed forming today where exposed intertidal mud flats are subjected to scouring action of waves, are not found in the Traverse Group strata. Instead, the laminae tend to be laterally continuous. Modern kinds of this form have been termed the "Collenia type" or "mode S" and occur on protected intertidal flats.

The complex of green (Chlorophyta) and blue-green (Cyanophyta) algae that produce the organic mats common on carbonate intertidal flats in the Caribbean region at the present time trap carbonate particles on their sticky surface. Upon decay, they leave no trace of their unicellular structure. Similarly, fossil stromatolites show no evidence of skeletal structure, and the interpretation of their origin must rest with the similarity in lamination to that of living algal mats.

It is impossible to say whether the Traverse Group stromatolites were formed in intertidal situations. That they formed in rather quiet and very shallow water seems highly probable, par-

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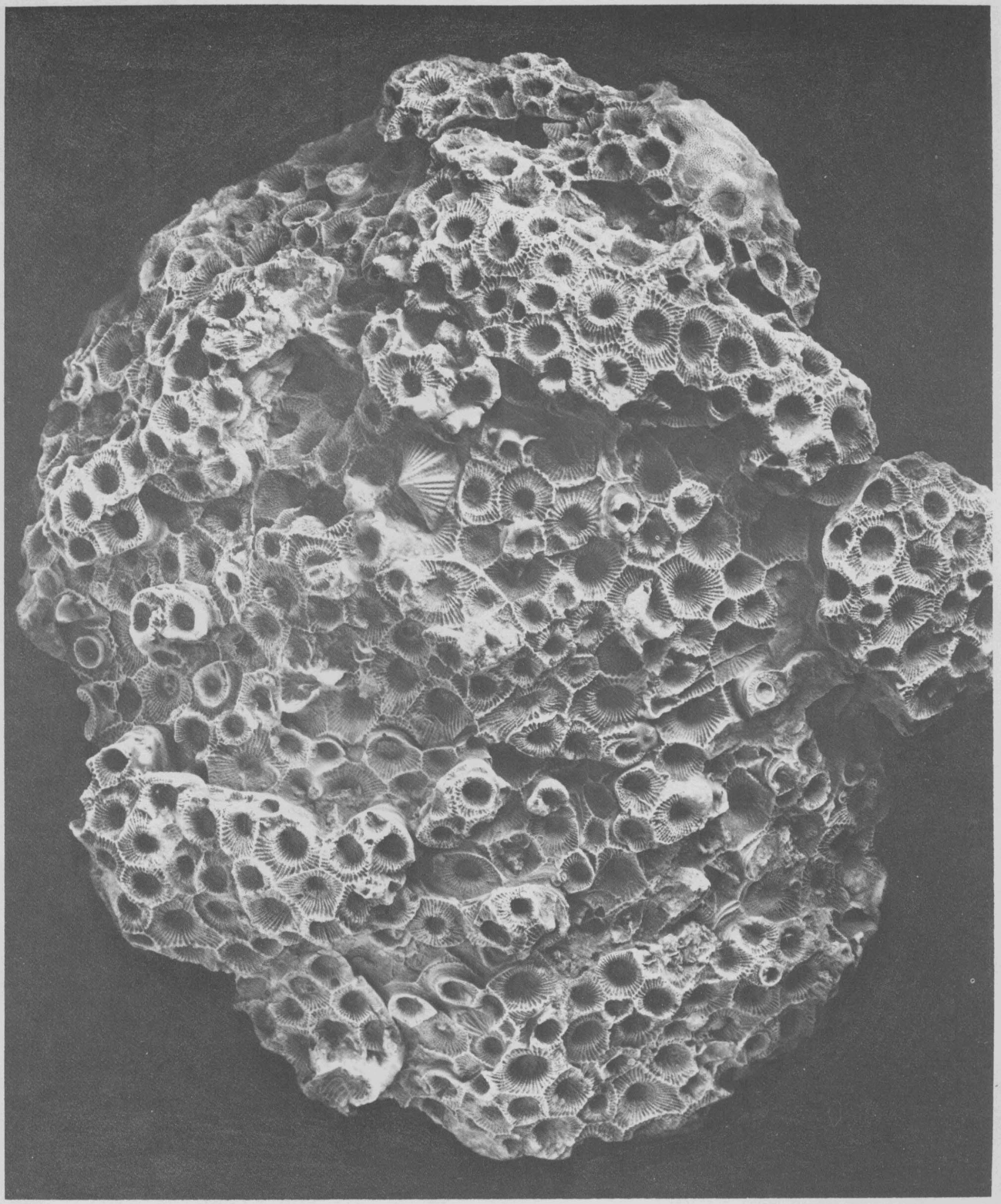
EXPLANATION OF PLATE 1

Figure x $2\frac{1}{2}$

FIGHT FOR LIVING SPACE. On the deep-water mud flats, the bottom of the colonial coral Hexagonaria constituted one of the rare little tracts of clean, hard, calcareous surface available. It was precious territory battled over by the coiled worm Spirorbis, the brachiopod Devonalosia radicans, various bryozoa, and other little marine creatures seeking a place to attach and live out their normal lives. Stakes were high: to keep from being smothered by the mud that was gradually but inexhorably building on the bottom, and to control space for intercepting enough current-borne food particles for survival. This small coral head died and lay -- probably tilted from its original growth position to expose most of its underside -- on the sea bottom while the "lower blue shale" unit of the Gravel Point Formation was accumulating. Sedimentation was very slow. One generation of tiny settlers grew, aged, died, and their skeletons in turn provided a firm place for their descendants to fasten for life. UMMP 17059, a specimen probably picked up by Alexander Winchell over a century ago on the shore of Little Traverse Bay.

PLATE 1

PLATE 2



ticularly in conjunction with the other evidence pointing to shallow-marine deposition of the Charlevoix Limestone.

"Draping" of beds over bioherms. -- Geologists have a tendency to ascribe some of the thinning of units over bioherm tops to thinner original deposition at these elevated places on the sea floor. This is difficult to disprove. Nevertheless, within the area studied in this guidebook, numerous examples can be found of beds which continue over a wide area without appreciable change in thickness and which suddenly arch and thin over bioherms.

Pohl (1929, p. 23) suggested:

> It appears unquestionable that the miniature closed anticlines and synclines which are so abundant at all exposures of the Traverse beds in western Michigan are due to an entirely local and indigenous cause. The positions of numerous, compact Prismatophyllum and Stromatopora reefs are seen to be geographically and stratigraphically fortuitous, and upon consolidation the strata would naturally conform to the irregularities caused by these more compact masses.

Folding. -- It is difficult to determine how many little anticlines and folds exhibited along the Lake Michigan shore are formed by "draping" and settling of strata over buried bioherms, how many are due to intra-group folding, and how many were caused by deformation at a much later time. To find out, numerous holes would have to be drilled and cored in and near the outcrop areas.

Pohl (1929) seems to have also had some doubts about the structures along the shore. On page 17 he declared:

> Reef structures of limited vertical and lateral extent are one of the commonest features throughout the Gravel Point. While the distinction between lithologic layers is unusually sharp there is not the slightest suggestion of broadly unstable conditions within the series. The vertical lithologic variation is to be explained rather on the basis of differential, not too shallow water current sorting and the tendency on the part of sediments to fill in the depressions between the comparatively rapidly developing Prismatophyllum and Stromatopora reefs.

On page 23, however, he stated:

> Reefs of large dimensions are, however, entirely absent, and for the explanation of the larger domes, anticlines, basins, and synclines we must look to other causes. One undoubted emergence and probably deformation on a slight scale has already been shown to have occured within the Traverse. The oscillating character of the central basin portion of the Devonian province has just begun to be appreciated.

Thus Pohl, in all fairness to his readers, offers a choice of "not the slightest suggestion of broadly unstable conditions" OR "the oscillating character of the central basin portion of the Devonian province."

EXPLANATION OF PLATE 2

Figure x 1

STRUGGLE FOR SURVIVAL. The anchored animal was at the mercy of local conditions in the Middle Devonian, just as it is today. The deep-water mud flats were perhaps as secure from change as any of the environments during Gravel Point time. Nevertheless, on rare occasions a smothering blanket of gray clay particles swept over the inhabitants -- probably triggered by slight shifts in currents or by small-scale submarine slides. Like other corals, Hexagonaria soon became immovable, unable to escape from the spot where it first settled. But when disaster struck the colony, any surviving individuals or clusters of individuals strove to rise above the fine-grained tomb, driven by self-preservation. Whatever energy was available went immediately into vertical extension of the corallites; if this proved sufficient to bring the animals above the mud level, then proliferation was possible and the restoration of the colony began. This Hexagonaria percarinata head is from the exposures along Bear Creek, collected last century by Winchell. UMMP 15645.

TEXT-FIG. 16 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Locality 34-6-3 S (old Loc. 14). Harry Sorensen stands on second bench of quarry. Elevations of surface appear to be caused by underlying bioherms (reefs). Photo by Segall, 1972.

TEXT-FIG. 17 -- Probably uppermost Gravel Point Formation. Shale pit of Penn-Dixie Cement Corporation. Near or at Locality 34-6-8 NE (old Loc. 14e). Pit opened in recent years, possibly incorporating the site of the abandoned Bell Quarry. Photo by Kesling, 29 Sep 1973.

Some further observations on evidence for folding are offered below.

Local basin fillings. -- Some evidence can be found for small-scale folding during Traverse Group time. For example, the uppermost unit of the Gravel Point Formation, known as the "upper blue shale," is about 10 to 15 feet thick in most outcrops and in well intercepts in Charlevoix and Antrim Counties. Its composition and fauna are also remarkably constant.

Yet the Penn-Dixie Cement Corporation in recent years has opened a quarry for shale in this unit and discovered a 40-foot thickness. Evidently this shale body was found by an extensive drilling program, for it is a down-dip extension of the old Bell Quarry (Locality 14e of the Michigan Geological Survey party of 1926). This quarry was known to R. A. Smith in 1916 and was described in detail by Pohl in 1929. The latter measured a section of nearly 54 feet of strata at the locality, including 48 feet of upper Gravel Point and about 6 feet of lower Charlevoix. He saw both contacts of the "upper blue" and measured it at 8 feet. During the 1950's, when G. M. Ehlers and R. V. Kesling collected fossils at the place, the upper contact was somewhat obscured by slump, but the thickness was estimated at less than 10 feet. It is remarkable that within rods this shale thickens to 40 feet.

The drainage ditch from the shale pit to Lake Michigan discloses an anticline but its origin remains obscure. It may be significant that one unit (see measured section) pinches out at the axis of the anticline; it would seem that deposition of that unit was interrupted at the anticline. If the fold were formed by "draping" over the top of a buried bioherm, one might expect all units to thin over the axis and to resume their "natural" thickness on the other side.

Intra-group folding and small-scale deformation might also account for another enigma of the "upper blue shale" -- selenite crystals. Some of these crystals are developed as bars and some as "fish-tail" twins; few exceed 3 cm. Inconspicuous in outcrop, the crystals are fairly common on certain weathered surfaces of the shale. The edges, and sometimes the lateral surfaces, of the crystals are irregularly erose, as though from partial solution after crystallization. When this dissolving took place we do not know. Selenite crystals were reported at Locality 14e by Pohl (1929, p. 11) and some were noted by Kesling and his students in field trips during the 1950's at the abandoned Charlevoix Rock Products Company Quarry No. 2 near the south line of sec. 28, T 34 N, R 8 W. At the latter locality, the selenite crystals were found in dumped and weathered piles of the shale. Just where the crystals occur within the unit has not been determined. One would doubt that they are ever in the same layer as the diverse invertebrates, such as the little clam Conocardium emmetensis, the compound coral Hexagonaria, the brachiopods Atrypa, Athyris, Strophodonta, and Cranaena, and various bryozoa including Sulcoretepora. Whatever their distribution, the selenite crystals indicate an interval of evaporation and concentration.

The following sequence of events is suggested. About 10 to 15 feet of clay mud accumulated in normal marine water in the diverse fauna zone. Then uplift and warping created a temporary evaporite basin, with local shallow synclines that were filled in with the unconsolidated bluish-gray mud as selenite was being precipitated from the concentrated brine.

In connection with the "upper blue shale" Pohl noted (1929, p. 18):

> At present there are too few occurrences of the "Blue Shale" known to be able to state definitely the amount of variation in its thickness nor to what causes this variation is due. It is now known to range between 6 and 11 feet at different localities. The upper surface wherever seen is slightly undulating; but whether this undulation was caused by sub-aerial or sub-marine erosion it is impossible to determine with the information now at hand.

Rejuvenated bioherms or channel fillings? -- One of the persistent problems in stratigraphy of the area concerns the abandoned quarry of the Northern Lime Company in the city limits of Petoskey, Grabau's Locality 39 and the Michigan Geological Survey's Locality 18. Attention was directed to this particular problem in the 1949 guidebook (Kelly, 1949), without suggesting a final solution. The diagram presented in this guidebook pointed out the overhanging projec-

TEXT-FIG. 18 -- Petoskey Formation. Kegomic Quarry, in old collections noted as Lang's Quarry or Mud Lake Quarry or Old Brewery Quarry or East Bay View Quarry. Locality 35-5-27 S (old Loc. 21). Kesling collects fossils from level at which the cystoid Lipsanocystis cf magnus was found. Strata here are nearly horizontal; a few yards to the north, however, they dip strongly toward the west (see text-fig. 19 on opposite page). Photo by Karl Kutasi, 25 Jul 1973.

tions of stratified beds into a reeflike mass and (indirectly) the absence of flank deposits of biohermal material.

This is a simplified but fair presentation of the problem. In the midst of well-stratified beds is a vertical mass of rounded and broken corals and stromatoporoids. Is the vertical mass the weathered remnant of a bioherm, the remains of flank deposits, or coral and stromatoporoid fragments filling a channel in Petoskey strata? Or could it, by some process, be a highly restricted accumulation of conglomeratic debris?

The first measured section of the strata at this interesting place, the type locality of the Petoskey Formation, was by Alexander Winchell (1866, p. 41), who included it in his Locality 856. He measured 46 feet of strata, and termed

TEXT-FIG. 19 -- Petoskey Formation. Near center of exposures on east bank of pond which fills much of the old Kegomic Quarry. Locality 35-5-27 S (old Loc. 21). Strata here dip strongly toward the west; a few yards south of this site, they are nearly horizontal (see text-fig. 18 on opposite page. Kesling kneels on unit within a few feet stratigraphically above the Pentamerella petoskeyensis bed. Photo by Karl Kutasi, 25 Jul 1973.

the rocks the "Stromatopora Beds." Fourteen feet above the base he described a 20-foot unit as:

> C. Limestone, pale buff, massive, brecciated in places, vesicular; falling down in huge blocks. Becomes more regular westward. It has a rude concretionary structure from the abundance of Stromatopora (with large cells).

Winchell added, below his description of the section:

> The Stromatopora at this exposure is by far the most abundant fossil, constituting the principal mass of No. C, and rendering it a veritable coral reef. Fine specimens of this coral can be collected in any quantity, even to a shipload... These forms are found both erect and prostrate. At other times they are more spherical, attaining a diameter of four or five feet, and giving the rock or reef a confused concretionary structure.

A particularly detailed account of the exposure was given by Rominger (1876, p. 54, 55), who commented on strata in the bluffs "at the foot of the newly built village of Petoskey, the present terminus of the Lansing and Saginaw Railroad." He said:

> The upper strata forming the vertical part of the bluffs are not always so regularly stratified; by weathering, the seams of the bedding become obliterated on the surface of the exposed walls,

TEXT-FIG. 20 -- Gravel Point Formation. Petoskey Portland Cement Company Quarry. Locality 34-6-3 S (old Loc. 14). North side of quarry near east end, showing small Hexagonaria bioherm and dip of strata towards the east. Photo by G. M. Ehlers, 15 Sep 1933.

> which sometimes appear to be one solid mass. By digging into them, however, the stratification becomes clearly observable.... Fossils are very abundant in these upper layers, but are not equally distributed in the horizontal extension of a bed. We may, in one part, for a distance of many yards, scarcely see a fossil imbedded, when suddenly the same stratum becomes so com pletely crowded with them that the whole rock mass is a compact agglomeration of fossils, leaving no room for any inorganic limestone particles between.

His observation on the bedding being "clearly observable" on fresh exposures might be questioned, but the general relationships are true.

Grabau saw the locality after quarries had been opened in the bluff. He recorded (1902, p. 200):

> In some parts the lower four or five feet [of his 26-foot unit e in the middle of the bluff] are like the rock below, --massive and uniformly fine-grained, with few or no fragments of Stromatopora. In most places, however, the rock is full of this fossil throughout, being in fact a coral breccia. The Stromatopora fragments are of all shapes and sizes, often angular, and so far as observed never entire.... Solution seems to have gone on to a considerable extent in these heads before they were buried by the coral sand which now forms the limestone. Cracks and solution cavities are not uncommon in the coral-line masses, and these are filled by the coral sand. The Stromatopora are not the only fossils. Cyathophylloid corals, Favosites, Conocardium and others have been found, and are sometimes common. The majority of the Stromatopora masses lie overturned, or in some other abnor-mal position, which clearly indicate motion.

Notice that Grabau's statements are more descriptive than explanatory, although there is a strong suggestion that erosion played an important role in the formation of the deposit.

One year later, Grabau wrote about the Devonian reefs, and his comments are worth

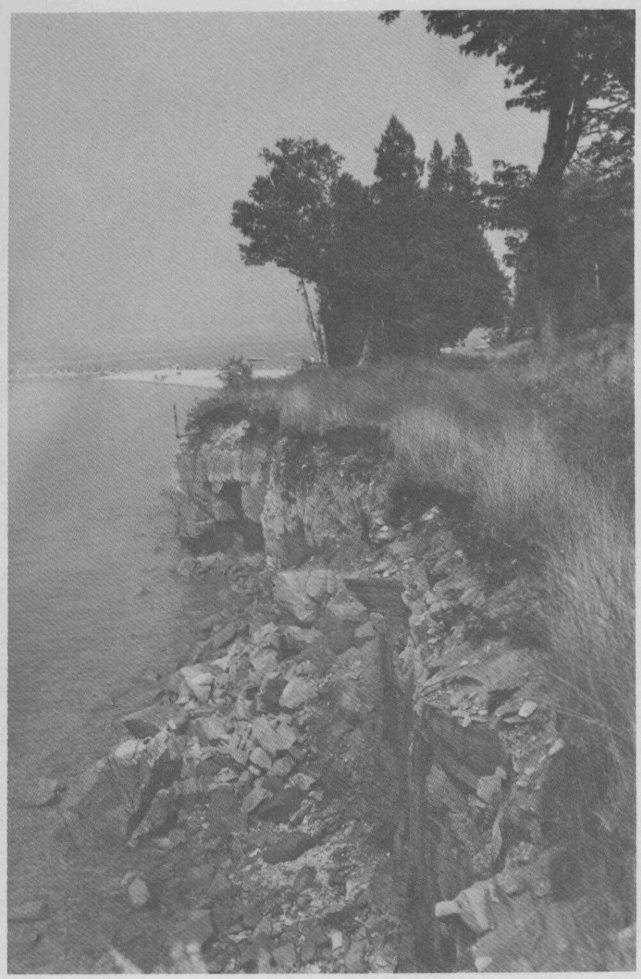
TEXT-FIG. 21 -- Gravel Point Formation. Medusa Portland Cement Company Quarry. Locality 34-8-28 SW. East face of quarry showing local syncline and anticline typical of the region. Photo by Sorensen, 1972.

quoting in full about the Traverse Group in this region (1903, p. 339, 340):

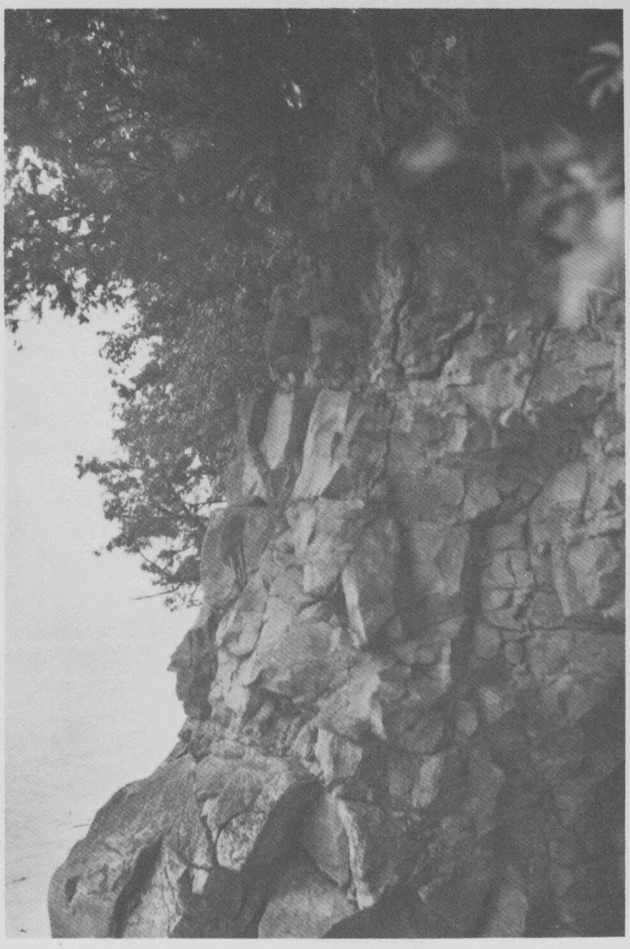
> No actual exposures of reefs occur on Little Traverse bay, but in the cliffs between Petoskey and Bay Shore a number of sections of marginal zones of reefs are furnished. In these sections the rock is chiefly a uniformly grained fragmental lime sandstone (calcarenite; see postea), or consolidated coral sand, with occasional beds composed wholly of crinoidal fragments. Fine grained beds of lime-mud sand (calcilutite) are also found. At intervals the section passes near enough to the reef to show the presence of numerous coral fragments. The fragments are all much worn and broken, and are embedded as boulders or pebbles in the stratified lime sands. Where they are abundant they constitute a veritable coral conglomerate (calcirudite) such as may be found near the borders of modern reefs. Good exposures of such conglomeratic beds are found in the quarries and shore sections east of Petoskey, where these coral pebbles (chiefly Acervularia and Favosites and the hydrocoralline Stromatopora) give the rock a strikingly mottled appearance.... Within the thicker beds themselves the phenomena of contemporaneous erosion, of the wedging out of strata, and, occasionally, of cross-bedding and ripple marks are met with.

There is a certainty that Grabau spoke of the exposure at his Locality 39, for at that time (1903) there were no other quarries "east of Petoskey"; actually, the main quarry was then at the eastern edge of the village, and it has since become engulfed by the expanding Petoskey. Here, Grabau's interpretation is unquestionably flank beds of a bioherm.

Other than the generalizations already quoted, Pohl (1929) had little to say in interpreting the Northern Lime Company Quarry. In his detailed section (p. 14) he described the 26-foot unit in much the same way that Grabau described it in 1902. It is perhaps illuminating that in all other sections Pohl was able to assign a zone and bed number to each measured unit, to be used in correlating with other measured



TEXT-FIG. 22 -- "Upper blue shale" of Gravel Point Formation (near water level) overlain by Charlevoix Limestone (forming bluff). Exposed in Bay View on shore of Little Traverse Bay looking north to beach of the Bay View Association. Locality 35-5-33 NW (old Loc. 18a). Photo by Kesling, 27 Jul 1973.



TEXT-FIG. 23 -- Charlevoix Limestone. Shore bluffs along Lake Michigan north of Bay Shore village. Locality 34-6-6 SW (part of old Loc. 13). Photo by Kesling, 26 Jul 1973.

sections; in this case, however, he headed the section as "Zones undifferentiated." Of the 26-foot unit he said (1929, p. 14):

> ... The major portion of the thickness is composed of isolated, broken, and overturned Stromatopora heads, in some places filling the bed from top to bottom in reeflike structure. The interspaces between the reefs are filled with a thick-bedded, often foreset, matrix of fragmental, "coral sand." The thickness of the bed remains constant laterally....

We may call attention to the following features: (1) stratified beds at the sides of the coral-strom mass are not arched over or even upward at the junction, (2) the fossils are densely packed in the vertical structure, (3) all the stromatoporoid heads show strong abrasion, nearly all are overturned and broken, and they constitute a "compact agglomeration" (Rominger) or "veritable coral conglomerate" (Grabau) -- the whole deposit reeks of high-energy environment, and (4) the junction between the stratified and unstratified deposits is irregularly serrate, sometimes with "fingers" of bedded strata projecting into the coral-strom mass and some-

TEXT-FIG. 24 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Locality 34-6-3 S (old Loc. 14). Exposed face of quarry shows strata rising towards the east at this place (towards right of picture). Shovel appears to rest atop beds arched over a bioherm. Photo by Kesling, 29 Sep 1973.

times with "fingers" of the latter extending a short distance into the stratified facies.

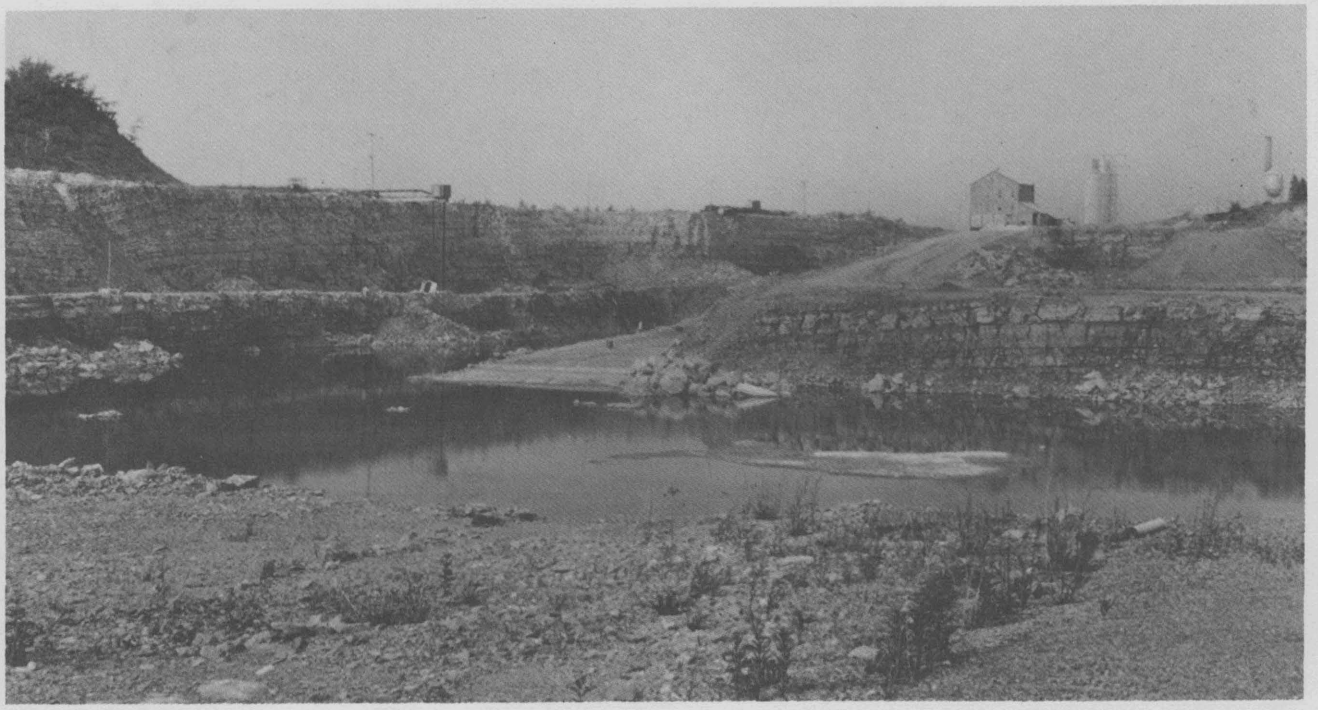
No one explanation seems to satisfy all the requirements. The problem seems to call for more penetrating and pertinent observations. Our suggestion is that the coral-strom accumulation is actually the flanks of a bioherm. Just where the bioherm core was situated we do not know. Perhaps it was eroded away at the present shoreline of Lake Michigan. The abundance of abraded and broken huge stromatoporoid heads was probably due to frequent and violent storms, which strewed the uprooted and dying animals in a narrow zone on the lee side of the bioherm. Decomposition of the organic content was rapid, but considerable time probably elapsed before regularly stratified beds (limestones) accumulated to the level of the strom-coral debris. In the meantime, the hard parts of the dead animals were subjected to the erosive and corrosive actions of the epifauna and epiflora which undoubtedly found the mounded-up coral and stromatoporoid skeletons an ideal habitat; these temporary inhabitants may have been responsible for much of the seemingly abraded surface of the fossils. The absence of well-developed flank deposits may be explained as follows: the bioherm was never very high as an elevation above the sea floor, its builders were periodically killed off, and the mound of their rubble served at some later date as the nucleus for settlement by other stromatoporoids and corals. Such destruction and rejuvenation could have occurred again and again, each time producing an addition to the mass which was indistinguishable from the previous one. On occasion the slumping and sliding of storm-

TEXT-FIG. 25 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Locality 34-6-3 S (old Loc. 14). Numerous small-scale warps and bedding irregularities shown in quarry wall. Photo by Kesling, 29 Sep 1973.

created debris extended farther than before, making an irregularity in the junction with the slowly and steadily accumulating bedded limestones.

The hypothesis that the coral-strom mass is a filling of an erosional submarine gully filled with coral-strom conglomerate would explain the breakage and abrasion very well. However, one would expect in such a steep-sided gully some inward slumping of the walls; we find no evidence to account for the compaction and competence necessary for the strata to have maintained such steep walls and overhangs. The hypothesis that the fossil deposit is the product of a violent turbidity current also has drawbacks: the narrow confines of the coarse material and the height of its accumulation. Modern turbidity currents tend to move quantities in mass, not to fracture and abrade individual elements; and their deposits tend to be spread out as a broad wedge. Other hypotheses may be thought up. We are open to new suggestions.

This discussion is not intended to be an exhaustive list of the depositional and stratigraphic problems in the area. It merely serves to indicate that all things are not explained, and to hopefully stimulate some of the users of this guidebook to seek answers to some of the "little matters" as well as to the "big picture." It is our humble feeling that the "big brush" can cover up some very fascinating aspects of geology.



TEXT-FIG. 26 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Locality 34-6-3S (old Loc. 14). Lower bench of quarry, partly covered by shallow water. Photo by Sorensen, 1972.

TRAVERSE GROUP FORMATIONS

Type locality and name. -- No one can doubt that the type locality of the group is along the shores of Little Traverse Bay. Back in 1841 Christopher C. Douglass referred to the rocks there as the "Little Traverse Bay limestones." In the works of Alexander Winchell and Carl Rominger, which followed, the strata were called the Hamilton because of their correlation with the New York section.

The first appearance in print of "Traverse Group" was on page 66 of the 1893 Report of the State Board of Geological Survey for the years 1891 and 1892 published for the State of Michigan. To whom the name should be credited is another matter. "Traverse Group" appeared as an entry in a geologic column in a section of the report by M. E. Wadsworth entitled "Report of the State Geologist for 1891-1892." However, Wadsworth recorded (1893, p. 66) that

> The sections of these wells were, for the most part, made under Mr. [Charles E.] Wright's administration, but no manuscript report to accompany them had been prepared by him. The material obtained from the borings has been worked over by Dr. [A. C.] Lane and the sections have been amended from the new data obtained.

Who was the author -- Wadsworth, Wright, or Lane? Warthin & Cooper (1943, p. 572) preferred to credit Lane as the author of the present group name.

Two years later, Lane reported (1895, p. 24):

TEXT-FIG. 27 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Locality 34-6-3 S (old Loc. 14). Tom Segall points to stromatolite reef at base of measured section; beds bend over the reef. Photo by Sorensen, 1972.

TEXT-FIG. 28 -- Gravel Point Formation. South side of Petoskey Portland Cement Company Quarry near east end. Near Locality 34-6-2 SW (part of old Loc. 14). Hexagonaria reef at right and off-reef beds in center of picture. Darker colored limestone near top shows greatest thickness in sag of strata. Photo by G. M. Ehlers, 15 Sep 1933.

TEXT-FIG. 29 -- "Upper blue shale," topmost unit of the Gravel Point Formation, overlain by basal beds of Charlevoix Limestone. Cut along small stream at east end of Petoskey Portland Cement Company Quarry. Locality 34-6-2 SW (part of old Loc. 14). Dr. G. Arthur Cooper of U. S. National Museum collecting fossils from "upper blue shale." Photo by G. M. Ehlers, about 18 Jun 1956.

> Winchell used the name Little Traverse, but it seems to me that the prefix "Little" can be dropped, inasmuch as the outcrops of both the Little Traverse and Grand Traverse, the names applied by the early voyagers to the short-cuts across the mouths of the two bays which indent the northwest coast of the peninsula, belong to this group.

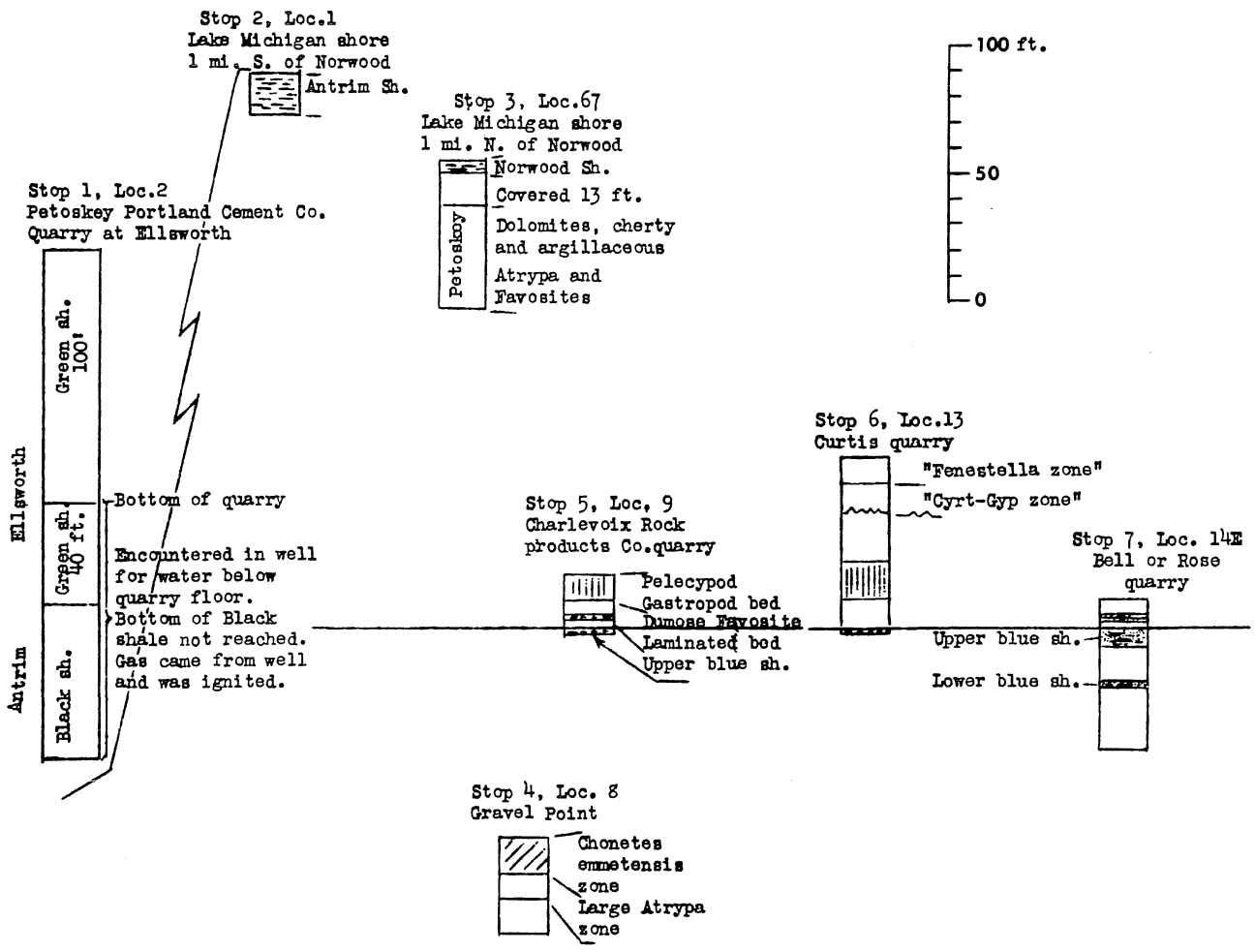
In this publication, Lane left little doubt whatever about the limits of the group. He said (1895, p. 24):

> ... Lithologically the formation may, in fact, be considered very well marked and consists of bluish calcareous shales and limestones or dolomites, which lie below black bituminous shales and above a yellowish cherty limestone.

He placed the Traverse Group above the Dundee Limestone and below the St. Clair Shales. Terminology of these bounding units have changed, but the extent of the Traverse Group is still accepted and used today.

Divisions of the Traverse Group. -- One of the primary difficulties in working out the areal distribution and continuity of strata within the Traverse Group in the northwestern Lower Peninsula is the same problem faced in any region -- identifying units and their equivalents even though the series of strata is beset with facies changes and unconformities. The difficulty in this region is increased because the stratigraphic span at each exposure is limited, numerous flexures intervene between outcrops, and bioherms expand units locally.

To comprehend the extent of lateral changes and to map with greater accuracy, it is necessary to correlate surface exposures and well records. Our attempt to set up a reference section for units in the Traverse of this region

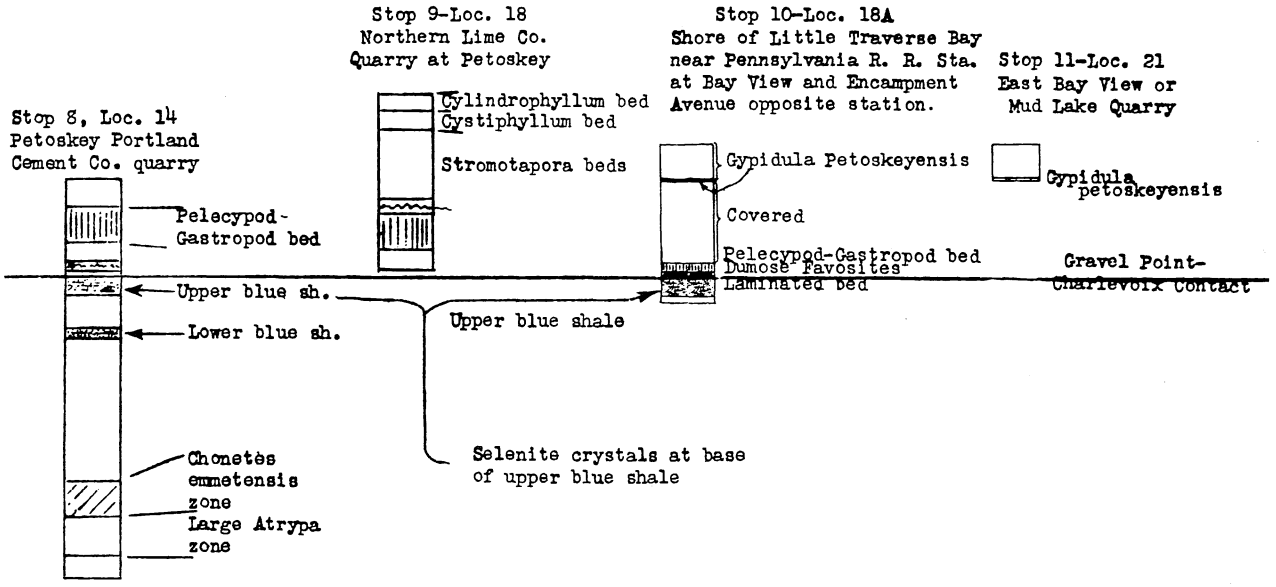


is shown in text-figure 13 on page 36. No doubt alterations will improve it in the future. For the present it serves to bring together the old published records and our additions, and to focus upon some of the unresolved questions about geology.

In the reference section, unit I is the Bell Shale, not very different in thickness or lithology from its outcrop area in Alpena and Presque Isle Counties (see Ehlers & Kesling, 1970, p. 40-47). Units II through the lower half of X (alternating limestones and shales) are also known only in subsurface in Emmet and Charlevoix Counties. The upper part of unit X through unit XV constitutes the Gravel Point Formation; although it shows local variations aplenty, we find no reason to subdivide it at this time. Unit XVI, which displays no exceptional variations in well cores, includes the Charlevoix Limestone, the Petoskey Formation, and possibly the lower part of the Whiskey Creek Formation. Units XVII through XIX (about 75 feet of strata) are here removed from the Petoskey Formation and made into the Whiskey Creek and Jordan River Formations on faunal evidence.

The new formations are not as cleanly exposed as we would desire. Nowhere do we see the upper or lower contacts of either the Whiskey Creek or the Jordan River. Nevertheless, faunal indices (appendix 8) reveal that the restricted Petoskey Formation is most closely allied faunally with the Potter Farm Formation of Alpena County, whereas the Whiskey Creek Formation is more clearly allied to the Thunder Bay Limestone. The formational boundary of the Petoskey and Whiskey Creek Formations deserves special scrutiny. Thick continuous

TEXT-FIG. 30 -- Correlation of old measured sections in the area. Copied from Ehlers' (1938) chart but with corrected vertical scale for sections at Localities 18a and 21. The placement with reference to the Gravel Point - Charlevoix contact shows that the "Gypidula" (actually Pentamerella) bed is most likely below the Cystiphyllum and Cylindrophyllum beds, and may not be present at the type locality of the Petoskey Formation.



sections of the Petoskey Formation are exposed in Petoskey at the old abandoned Northern Lime Company Quarry (Locality 35-5-32 SW; old Loc. 18) and on the western edge of Emmet County at the old Curtiss Quarry (Locality 34-6-6 SW; old Loc. 13). The type locality of the Whiskey Creek Formation is along the Lake Michigan shore north of Norwood (Locality 33-9-22 SE and 27 NE; old Loc. 7c), about 24 miles from the Northern Lime Quarry and about 17 miles from the old Curtiss Quarry. Possibly, the units thicken and thin; possibly, the facies changes from one locality to the others; possibly an extensive unconformity separates the formations. Even though the reference section (text-fig. 13) indicates that the Norwood and Emmet County exposures do not overlap, still we have wondered if the bryozoan bed at the top of the Curtiss Quarry section could possibly be the same as the bryozoan bed near the base of the Norwood exposures. Both are mats of fenestellids; but the Norwood bed also contains numerous crinoid plates, none of which have been found at Curtiss Quarry. For the present, we place all the lower beds north of Norwood at Locality 33-9-22SE and 27NE in the Whiskey Creek Formation.

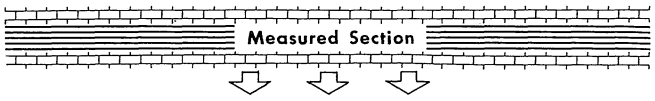
The intraregional correlation of sections (text-fig. 30) shows several changes in the position of marker beds relative to the top of the Gravel Point Formation. Physical evidence of unconformity at the top of the Charlevoix Limestone can be observed at several localities. Precise location of some of the formational boundaries must await more exposures. If only we had the margin of the peninsula everywhere stripped clean of glacial debris and soil! -- and (as long as we are wishing) weathered for at least fifty years to free the fossil fauna!

Gravel Point Formation

Type locality and name. -- In 1929 Pohl published the description of this lowest exposed division of the Traverse Group. He called it the "Gravel Point stage." Although not specifically designated, the type locality must be the strata exposed along the shore of Lake Michigan in Charlevoix County at Gravel Point, which at various times has also been known as Pine River Point and South Point. It is $1\frac{1}{2}$ miles west of Charlevoix at Locality 34-8-28/29 (old USNM-UM-MGS Loc. 8; Winchell's Loc. 880; Rominger's Loc. 28; and Grabau's Loc. 49). Many other -- and more extensive -- exposures are present in Emmet County.

Sections. -- For the type locality, we refer to the section published by Winchell (1866), the one recorded by Ulrich and Ehlers during the 1926 expedition, and the one published by Pohl in 1929. In addition, some notes are preserved from the Pohl and Raasch excursion to nearby exposures around 1927.

Winchell said (1866, p. 46), "A limestone reef extends around the point, and just on the south of the point the rock rises in a broad swell, affording the following section."

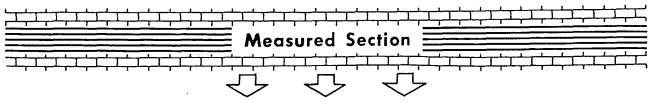


Gravel Point Formation at Type Locality

Section published by Winchell (1866, p. 46, 47) for his Loc. 880 at "Pine River Point."

Bed	Thickness Ft.
D. Shaly bituminous bands, corresponding perhaps to the Lignite of 862	
C. Limestone, containing Acervularia, Tropidoleptus, Favosites, Zaphrentis, Strophomena nacrea and a little Stromatopora	4
B. Limestone, very shaly and thinly laminated, containing Fenestella, Stictopora, Tentaculites, Trematopora, Choetetes, Chonetes scitula, Tropidoleptus (3 species), Cyrtia Hamiltonensis, Spirifera Marcyi (typical), S. mucronata (4 inches broad), Strophomena (with regular clean ribs and flat dorsal valve), Spirigera concentrica, Terebratula?	10
A. Limestone, thick or thin-bedded, dark, highly calcareous, with green stains. Contains Atrypa reticularis, Spirifer mucronatus, Strophomena nacrea, &c...	5

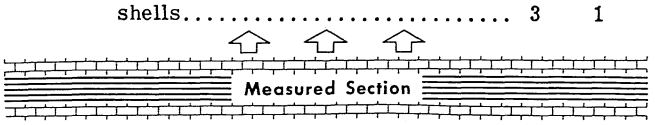
Although the type locality was inspected by other geologists after Winchell, the next section was measured on 10 Aug 1926 by Ulrich and Ehlers when the combined expedition visited the place. They recorded about $7\frac{1}{2}$ feet of strata.

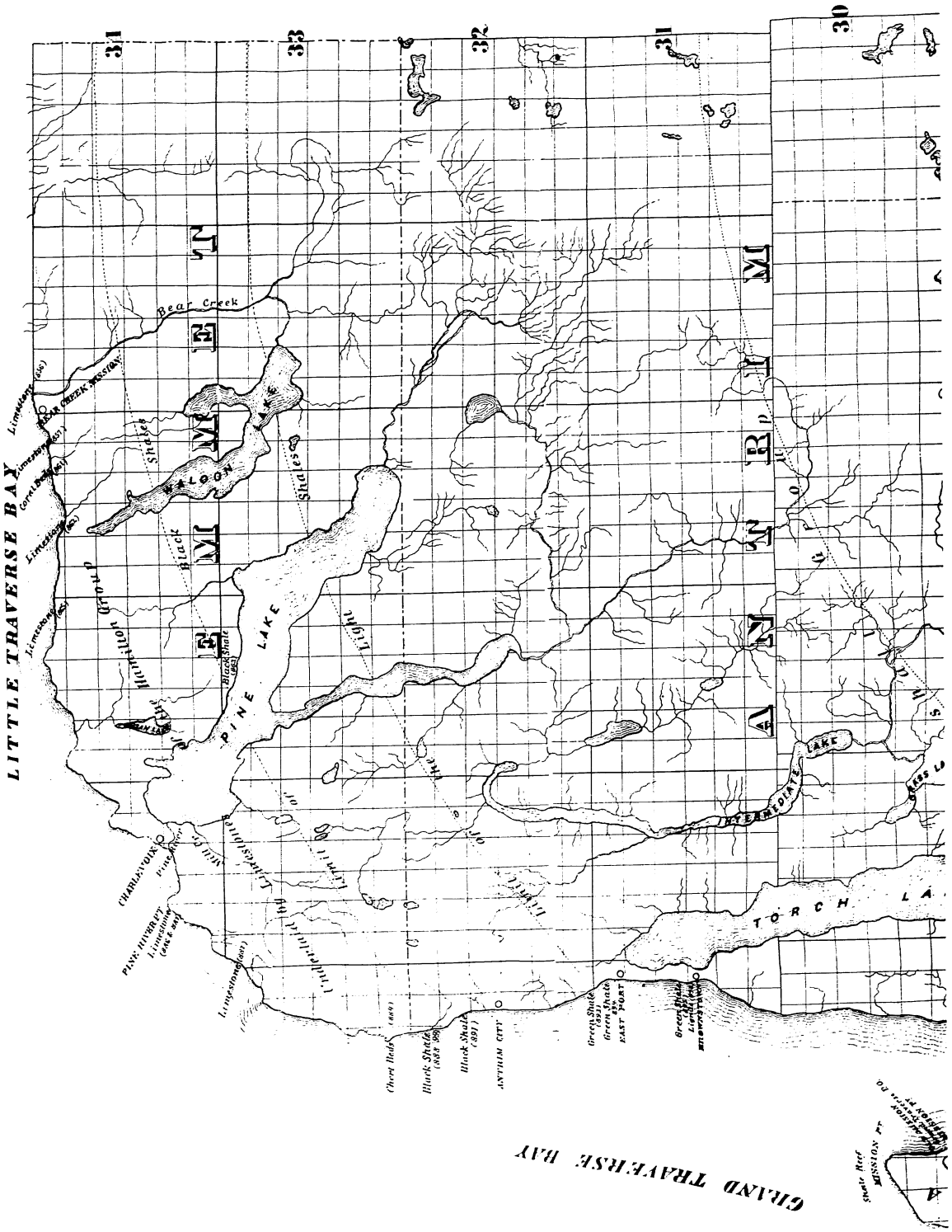


Type Locality of Gravel Point Formation

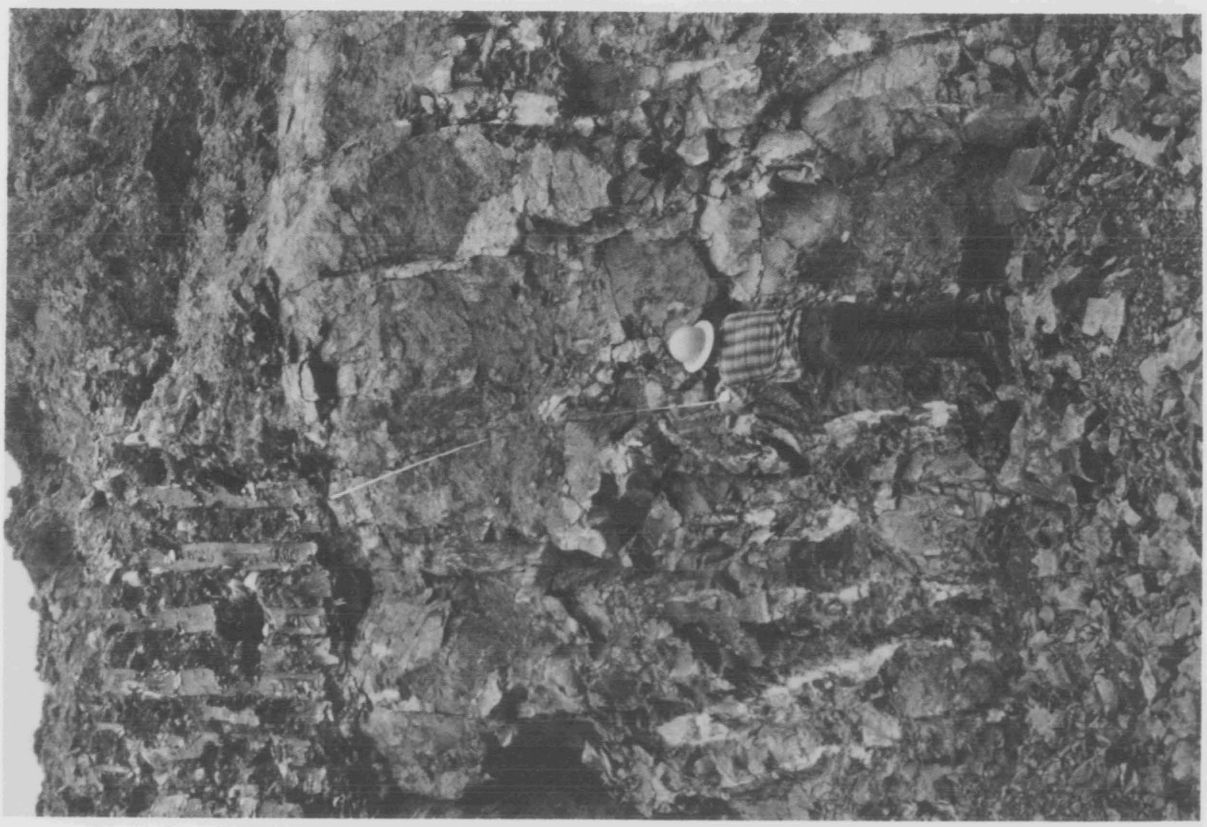
Ledges and bluffs along shore of Lake Michigan, at Gravel Point (= Pine River Point, = South Point), $1\frac{1}{2}$ miles west of Charlevoix. Locality 34-8-28/29 (old Loc. 8). Section recorded by Ulrich and Ehlers, 10 Aug 1926.

Zone	Thickness Ft.	In.
4. Limestone, irregularly bedded, shaley, weathering yellow or blue. Characteristic fossils, numerous ostracods. Otherwise fauna normal. A few inches near middle not carrying the characteristic fossils.....	3	
Above Zone 3 the beds suggest more wave action.		
3. Limestone similar to Zone 2 but more unevenly bedded. Pholidostrophia abundant associated with a very wide mucronate Spirifer.....	0	6
2. Limestone, yellowish-gray with more uneven bedding and with abundance of Pholidostrophia. Zones 2 and 3 suggest quiet water conditions, possibly lagoon.....	0	9
1. Argillaceous limestone, dark gray with fairly even sedimentary planes so that rock may be split readily. Middle part apparently barren, lower 2 inches with many fossils as Pholidostrophia iowaensis, trilobites, Spirifers, etc. Especially characteristic is an abundance of Chonetes emmetensis, which is also present in upper foot associated with somewhat different species of shells.....	3	1

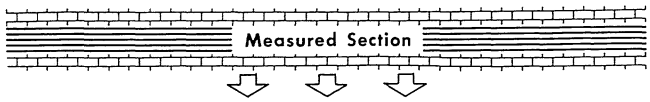




TEXT-FIG. 31 -- Part of map accompanying Winchell's Report (1866), showing the location of some of his measured sections and his generalized geologic boundaries.



Pohl and Raasch in 1927 stated: "The entire section is a series of elevated domes, anticlines and synclines (all closed structures). The base of the section is to be seen about 1/8 mile s. of Gravel Point in one small dome almost at water level. The sequence is easily followed eastward across the beach (the beds dipping into a low bluff) in which lies a small quarry. The highest bed is found near Gravel Point in a small syncline (closed)." With slight modification, their section was published in 1929 by Pohl.



Gravel Point Formation at Type Locality

Ledges and bluffs along shore of Lake Michigan at Gravel Point (= Pine River Point, = South Point), 1½ miles west of Charlevoix. Locality 34-8-28/29 (old Loc. 8). Section published by Pohl (1929, p. 7, 8).

Zone	Thickness Ft.	In.
Gravel Point stage		
4. Light brown, cryptocrystalline, extremely massive, pure limestone with a conchoidal fracture, breaking easily in all directions into small fragments with sharp edges. In appearance like lithographic limestone, with no semblance of bedding planes. The fauna is not abundant but is quite varied, comprising a dumose Favosites, a distantly [sic!] mammillated Stromatopora, small Athyris, large Craspedophyllum, costate Stropheodonta, and Prismatophyllum. A dark gray shale at the top carries abundant small Stropheodontas in particular	2	6
3. "Emmetensis zone." Bed 2. This zone is a recurrence of the lithology and fauna of the lower part of zone 1. The rock is thin-bedded, finely crystalline to semimassive, brown limestone and the fossils are beautifully preserved with the calcareous shells intact. Two and a half feet from the base is a slightly more shaley layer 3 inches thick carrying a solitary coral fauna in addition to the typical association. This bed is characterized by the large number of shells of a nacreous nature (Pholidostrophia) preserved with a pinkish color	9	8
Bed 1. A sharp change in lithology accompanies the abrupt introduction of several new faunal elements, among which Chonetes emmetensis Winchell is the most conspicuous. The Spirifer-Stropheodonta-Cystodictya association continues in this bed along with the new introduction. The bed consists of a semimassive, flakey, buff-gray, shaley limestone, with a few long, reddish, organic markings, and has no true bedding planes. Frequent shale like layers a few inches in thickness separate the heavy limestones toward the base but the topmost foot and a half is composed of a practically barren, buff-gray, shaley limestone again with worm borings	4	6
2. "Large Atrypa zone." Lower 12 inches lithologically similar to beds below but introducing a new association of species, consisting of a mucronate Spirifer, concava-like Stropheodonta, and Cystodictya. Twelve inches above the base are seen many worm borings, and the character of the lithology changes to a brownish gray, very finely crystalline to massive, slightly shaley limestone. The lowest beds are seemingly reworked material filling in the interspaces between the reef heads below. The predominant sediment throughout this zone is of brownish-gray, massive limestone carrying numerous worm borings, but is interrupted at intervals by thin bands of semicrinoidal, crystalline limestone. In general, the entire zone carries a continuous fauna	8	
1. Base of exposed Traverse Group in western Michigan. Bed 3. Dark brown, massive limestone in four bands nearly 1 foot thick each separated by thin, 2-inch beds of brown to black limey shale. Entire bed bituminous, very fossiliferous below with pel-		

TEXT-FIG. 32 -- Gravel Point Formation. Medusa Quarry. Locality 34-8-28 SW. Tape extends through bed 23 of section by Sorensen and Segall, overlain by the plastic "upper blue shale." Photo by Sorensen, 1972.

TEXT-FIG. 33 -- Gravel Point Formation. Medusa Quarry. Laminated layer (bed 19 of measured section) termed "tiger rock" by quarrymen. Photo by Sorensen, 1972.

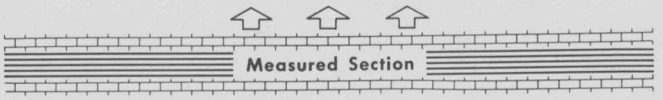
TEXT-FIG. 34 -- Gravel Point Formation. Rare sinkhole exposed in Penn-Dixie Cement Corporation Quarry. Locality 34-6-3 S (old Loc. 14). Photo by Kesling, 29 Sep 1973.

ecypods, brachiopods, and individual corals. The top layer contains enormous heads of stromatoporoids, a small digitate Favosites, and many Gypidulas..... 4

Bed 2. Light brown to buff, shaley limestone introducing a predominating element of Atrypa and Gypidula, the latter often 2 inches in length. Several bands carry much bituminous matter 2 6

Bed 1. Exposed in a dome on shore one-eighth mile south of Gravel Point. The basal bed is a dark brown to black, thin-bedded, shale-like limestone with an abundance of crinoidal fragments and crushed Athyris 1 2

Above this is a lighter brown, fragmental limestone carrying a heavy coral fauna composed of Prismatophyllum, small digitate Favosites, Stromatopora (small mammillate type, mammillae about $2\frac{1}{2}$ mm. apart), Zaphrentis, Conocardium, and Athyris 2



Two exposures of Gravel Point strata were near enough to the type locality for Pohl and Raasch to list them as "8d" and "8c" in their field notes of around 1927. For their locality 8d, these two geologists entered "Shore of Lake Michigan for $\frac{1}{2}$ mile below creek mouth in Section 31, town of Charlevoix, Mich." This is not clear; the closest point in sec. 31, T 34 N, R 8 W, is over three miles from Charlevoix, and sec. 31, T 34 N, R 7 W lies entirely below the waters of Lake Charlevoix. From their descriptions, Kesling, who visited the area with Ehlers in 1949, believes that they were actually

TEXT-FIG. 35 -- Gravel Point Formation. Penn-Dixie Cement Corporation (formerly Petoskey Portland Cement Company) Quarry, face near west end. Locality 34-6-3 S (old Loc. 14). Photo by Ehlers, around 1965.

in sec. 31, T 34 N, R 8 W and that they intended to say "county of Charlevoix" instead of "town of Charlevoix." The creek mouth in section 31 is McGeach Creek, which is nearly two miles southwest of Gravel Point. Hence they seem to have been about $\frac{1}{2}$ mile north of Locality 33-8-6 NW, which was visited by Winchell (his Loc. 882) and by Rominger (his Loc. 29). Pohl and Raasch were unable to measure a section; they recorded in their field notes: "Ledges on beach a few feet above water level. Structure complicated by doming... The beds have a very steep dip. The exposure is largely obscured by swamp and beach deposits." They described the following rock types:

(1) Blue Shale with fossils weathered out. A preponderance of Atrypa, Acervularia, and cup corals = Blue Shale, Gravel Point Form.

(2) A chocolate-colored, conchoidally fracturing crypto crystalline chipstone with associated Stromatoporoids = Zone 3 of Gravel Point Form.

(3) A brown shaly limestone with well-preserved fossils. Phacops and Asteropyge collected. (Unlike anything exposed in Traverse Bay sections).

(4) A bed indistinguishable from the laminated layer of the basal Charlevoix.

(5) A crystalline rather massive white limestone made up of fossils, particularly Fenestellids, Crinoid joints, a medium-sized plicate Gypidula and a rather large Athyris. This is the most conspicuous member of the group.

Pohl and Raasch described their locality 8c as "Along unimproved road about $\frac{1}{2}$ mile s.e. of Loc. 8d." There, about 10 feet above lake level, they found that a "quantity of the C. coronatus-crinoidal limestone occurs as residual blocks in the brush." This lithology indicates that the limestone came from the lower part of the Charlevoix Limestone (see our map 4).

The greatest thickness of the Gravel

TEXT-FIG. 36 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry, west end. Note diverging strata near right margin of figure. Photo by Ehlers, around 1965.

Point, continuous from the lowest exposed unit to the top of the formation, is exposed in the quarry formerly operated by the Petoskey Portland Cement Company and now the property of the Penn-Dixie Cement Corporation. Because this quarry shows the Gravel Point strata to such advantage, it has been much photographed -- by Ehlers (text-figs. 20, 28, 35-38, 43), by Sorensen and Segall (text-figs. 16, 26, 27, 39, 40, 46, 53), and by Kesling (text-figs. 24, 25, 34).

Before the quarry was opened, the site which later became the eastern end of the quarry was a natural shore outcrop $2\frac{1}{2}$ miles west of the mouth of Bear Creek in the $SW\frac{1}{4}$ sec. 2, T 34 N, R 6 W. Here Winchell measured the following section and published it in 1866. He recorded the upper beds of the Gravel Point Formation as his "Acervularia Beds" (Acervularia is now Hexagonaria).

Measured Section

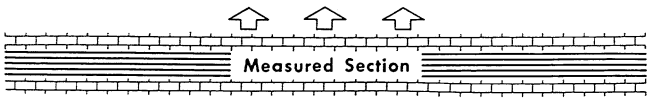
Gravel Point Formation in Natural Exposure at Locality 34-6-2 SW

Measured by Winchell (1866, p. 43, 44) as his Loc. 861 before the Petoskey Portland Cement Company began its quarry at the site.

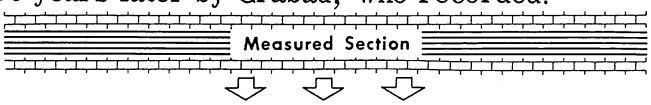
Bed	Thickness Ft.
D. Shale, bluish, argillaceous, imperfectly seen at top of bank	2
C. Limestone, varying from dark to light gray, in beds from one to four feet thick, with a rough, somewhat granular fracture. Considerable argillaceous matter in the upper part. Few fossils	23
B. Limestone, light or yellowish buff, varying to dark chocolate, argillo-calcareous, breaking with smooth fracture into irregular, sharply angular fragments, rather even-bedded in layers 6 inches to 2 feet thick. In the upper part alternating with bands of	

black bituminous calcareous shale and blue clay, 6 to 12 inches thick. The clay beds abound in beautifully preserved corals -- Acervularia Davidsoni, Favosites Alpenensis, Zaphrentis Traversensis, &c. The bituminous bands burn quite freely, and have frequently passed for deposits of mineral coal 17

A. Limestone, grayish brown, compact, argillaceous, uneven-bedded, with smooth conchoidal fracture, embracing in its upper part a 4 inch stratum of black bituminous argillaceous limestone replete with Atrypa reticularis and considerable numbers of Stromatopora and Acervularia Davidsoni .. ?



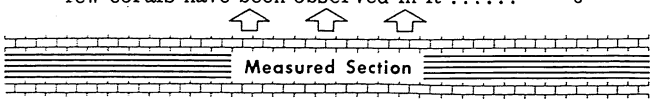
The same exposure was also measured 36 years later by Grabau, who recorded:



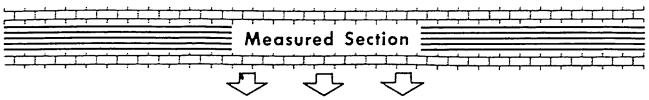
Gravel Point Formation Exposed along Little Traverse Bay at Locality 34-6-2 SW

Bluff about $2\frac{1}{2}$ miles west of the mouth of Bear Creek, before Petoskey Portland Cement Company started its quarry. Measured by Grabau (1902, p. 202, 203) as his Loc. 42. "The highest bed of the section is exposed at the eastern end ... The bluff [there] is about fifteen feet high ..."

Bed	Ft.
42I. The upper beds of the section consist of a bluish calcareous shale, which weathers into a brownish-gray clay and contains many fossils, which may be collected on the talus. Chief among these are Spirifer audaculus, a small but strongly spinose species of Productella, Atrypa reticularis, Stropheodonta erratica, Favosites alpenensis, Acervularia davidsoni, Cyathophyllum, and Hederella; also from blocks probably from this bed: Cyathophyllum traversense, Gypidula romingeri, Phacops rana, Craspedophyllum archiaci, Platyceras, and others	4
42H. Limestone with shaly partings between the beds, especially in the lower portion. It contains numerous corals, among which Acervularia predominates	6
42G. Next below this and forming the lowest bed in the eastern portion of the cliff, is a gray, porous lime-sandstone, consisting of fragments of brachiopods and other organisms finely comminuted. It is somewhat petroliferous and has a sandy feel. Stropheodonta erratica and other brachiopods and a few corals have been observed in it	6



By the turn of the century a small quarry had been opened up at the site of the main Petoskey quarry. Grabau called it "Rose's Quarry" and published the following section:



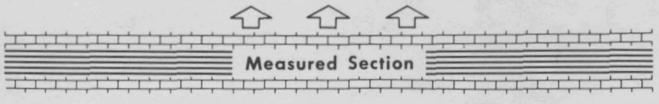
Gravel Point Formation Exposed along Little Traverse Bay at Locality 34-6-3 S

"Rose's quarry" of Grabau, about $\frac{1}{2}$ mile west of his Loc. 42 (beds G through I) and the future site of the Petoskey Portland Cement Company Quarry (still later the Penn-Dixie Cement Corporation Quarry). Described by Grabau (1902, p. 203); "At the quarry the axis of the low anticline in which these beds are involved is located, beyond which the strata dip westward."

Bed	Thickness Ft.
42F. Blue clay, rich in fossils. In every respect except thickness like bed D	3/4'
42E. Limestone with Acervularia, cup corals, and other fossils, which occur chiefly near the top of the bed, where it is more shaly. The limestone is dark-gray, fine-grained and crystalline	$1\frac{1}{4}$
42D. Blue, highly fossiliferous clay, rich in fossils, among which the following are the most characteristic: Acervularia davidsoni (well-preserved, complete heads up to six inches or more in diameter), Cyathophyllum traversense, and Favosites alpenensis often in large heads. Other species of common occurrence are Stropheodonta costata, Pentamerella cf. papillionensis, Athyris fultonensis, Terebratula traversensis, Cyrtina hamiltonensis, Eunella lincklaeni, Atrypa reticularis, and a number of others. The thickness of the clay	3
42C. Shaly argillaceous blue limestone, sometimes in several layers near the top, with thin shale partings	2
42B. Compact, creamy-gray, fine-grained limestone with conchoidal fracture. This contains numerous heads of Stromatopora, all apparently perfect, and ranging in size up to two or three feet. The rock is much shattered and looks concretionary, owing to the presence of Stromatopora. The latter is generally surrounded by a film of carbonaceous matter, which appears to be the original animal matter. At the top of this stratum, and also at intervals within it, are thin beds of black carbonaceous shales (sometimes stained brown by iron hydrate), and full of flattened shells of Stropheodonta erratica, with a few other fossils	5
42A. Cream-colored limestone similar to the preceding, but lighter colored. It is fine-grained, compact and with conchoidal fractures, and effervesces freely with dilute	

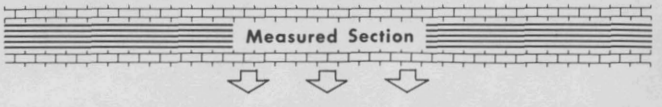
TEXT-FIG. 37 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry, west end. Locality 34-6-3 S (old Loc. 14). Photo by Ehlers, around 1965.

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



The quarry, by that time called the Petoskey Portland Cement Company Quarry, was visited by the 1926 expedition, but they could not agree on the interpretation of the strata. E. C. Case sketched an anticlinal structure in his field notes and labeled the lithology of the beds. He said, "The blue shale here in one dominant (lower) bed and several thinner above separated by fine grain compact limestones (bluish gray color). (At this point great doubt entered our minds). I believe the coral at top of foreground is base of the succession of coral layers in the old pit, but I am not so sure." Later, in the combined notes for the trip, he stated, "Let Ehlers do this. Discovered at last moment."

At the time of Pohl's publication (1929), nearly 76½ feet of strata were exposed in the Petoskey Portland Cement Company Quarry. He divided the beds as follows:



Petoskey Portland Cement Company Quarry
(now Penn-Dixie Cement Corporation Quarry)

Localities 34-6-3 S and 34-6-3 SW (old Locs. 14 and 14a). Section published by Pohl (1929, p. 9, 10).

Zone		Thickness Ft.	In.
Gravel Point stage.			
5.	Bed 2. Very light gray, granular, fossiliferous limestone, same as exposed at locality 14c in similar position. To top of section	2	
	Bed 1. "Cherty" chipstone, lower part "mottled." Light to dark		

TEXT-FIG. 38 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Photo by Ehlers, around 1965.

gray in color. Fossils scarce with one bed of Favosites noted 8

4. Bed 4. Hard, black-brown, bituminous limestone with black shale partings several inches thick. Limestone in beds about 1 foot thick with fossils scarce; Athyris, Atrypa. Corals common in shale at top: Favosites, Prismatophyllum. Costate Stropheodontas occur abundantly in black shale partings. One brownish black layer 1 foot thick near top contains a spectacular pelecypod fauna of undescribed species of Ilionia, Leiopteria, Actinopteria, Janeia, and a small Leptodesma-like new genus 6 6

Bed 3. "Coral bed." Heavy coral bed with Prismatophyllum masses several feet in diameter. Grey-brown cryptocrystalline "chert" or chipstone (lithographic limestone), becoming granular at top with shallow depressions filled with black shale. Fauna: digitate and turbinate Favosites, Prismatophyllum, Zaphrentis, Atrypa, and Athyris, Cryptonella, Crania, and a costate Stropheodonta 1 10

Bed 2. Brownish black "chert" (cryptocrystalline chipstone), in beds of moderate thickness with some black shale partings bearing corals and costate Stropheodontas. Several more granular, fossiliferous layers. One of these, 30 inches from top, contains Proetus, Phacops, Asteropyge, Pterinopecten, Actinopteria, Aviculopecten, Stropheodonta concava and costata types, a large mucronate Spirifer, Atrypa, Athyris, and crinoid joints 7 6

Bed 1. Dull gray, fossiliferous limestone with shale partings, in beds about 1 foot thick 13 6

3. "Emmetensis zone." Gray limestone in regular, rather thick beds splitting in thin slabs on weathering. Nacreous fossils conspicuous, frequently possessing a pinkish color. Corals developed in irregular, reef-like structures along certain beds. Rock adjoining coral reefs granular. Fauna: Chonetes emmetensis, Pholidostrophia, mucronate Spirifer, sol-

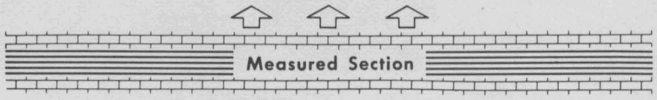
TEXT-FIG. 39 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry, sump in northeast corner of active quarry. Locality 34-6-3 S (old Loc. 14). Numbers identify beds in measured section of Sorensen and Segall. Photo by Sorensen, 1972.

itary and colonial corals 14 6

2. "Large Atrypa zone."
Bed 3. Barren, light gray, compact limestone with shalelike partings of similar composition. Mottled and iron-stained worm borings .. 3 6
Bed 2. Brown limestone carrying Gypidula 11

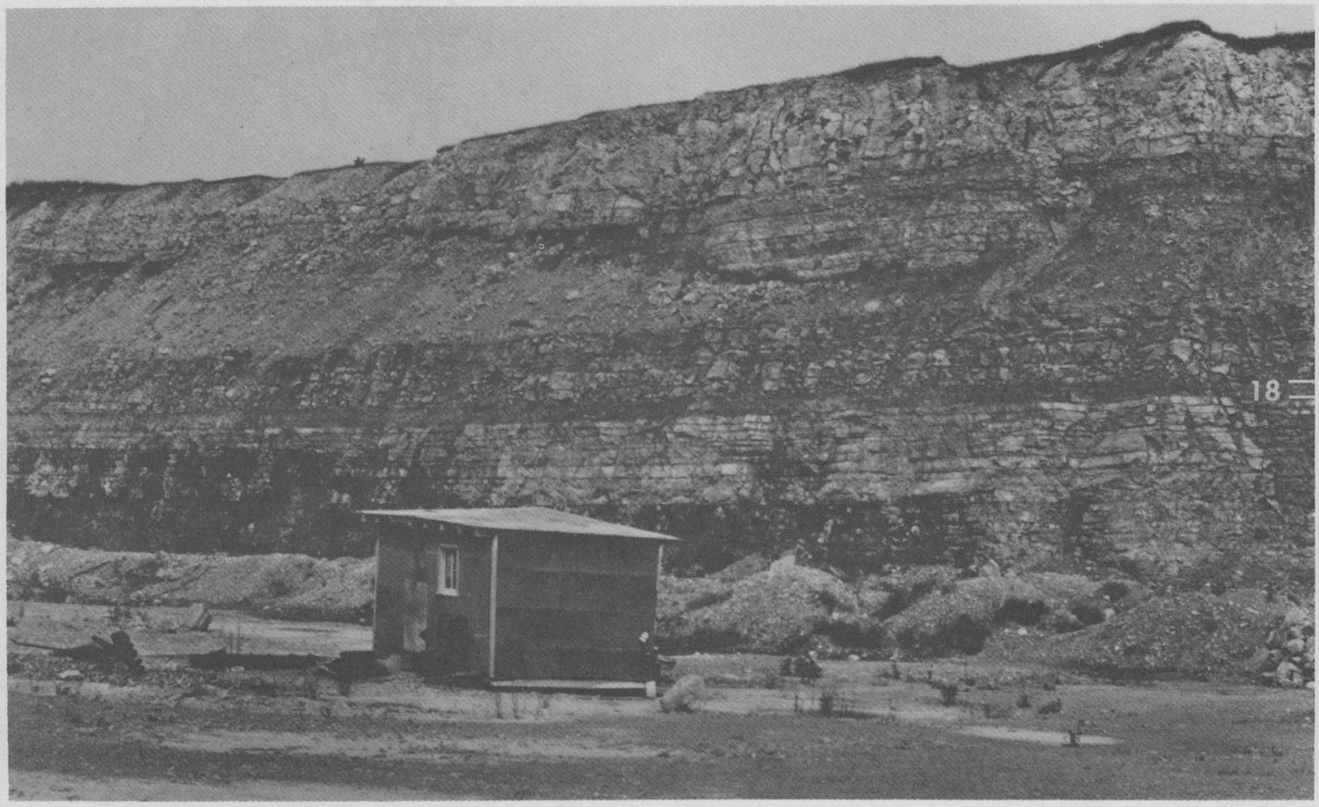
Bed 1. Thick-bedded, gray limestone with shaley bands. Limestone breaks into thin beds on weathering. Fossils conspicuous on bedding planes. Fauna: large Atrypa, Stropheodonta concava and costata types, mucronate Spirifer, Cyrtina, globose Athyris (almost limited to a single layer near middle), Spirifer eurycteines type, Douvillina (rare), Zaphrentis, digitate Favosites ... 10

1. Chocolate-brown, hard, fine grained, resistant limestone with numerous fossil fragments and crinoid joints, in thick beds. Fauna consists mainly of Gypidula, Prismatophyllum, Pholidostrophia. Bottom not shown.. 8



The section described above by Pohl in the Petoskey Portland Cement Company Quarry is almost exactly the same as that recorded with Raasch a year or two previously. At the end of their description, Pohl and Raasch noted:

> The beds underlying Division 5 [= Pohl's Zone 5, Bed 1] exhibit a very surprising structure near the east end of the quarry. In a pronounced syncline the various beds foreset over each other from both directions. There is, moreover, what appears to be a disconformable contact between Divisions four and five. These struc-



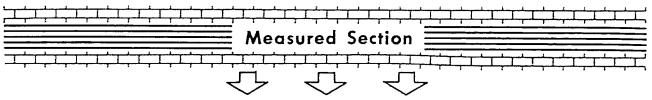
TEXT-FIG. 40 -- Gravel Point Formation. Penn-Dixie Cement Corporation Quarry. Locality 34-6-3 S. Center of south wall of active quarry, exposing strata from bed 8 to top of the measured section of Sorensen and Segall. Bed 18 labeled. Photo by Sorensen, 1972.

tures are interpreted as being local irregularities due to reef structures producing inequalities in the sea bottom.

At this quarry the 1949 field trip of the Michigan Geological Society made a scheduled stop. The explanation of the geology as provided by Prof. Ehlers in the guidebook was:

> The eastward dip of the limestone and shale in the eastern one-half of this quarry allows one to study almost the entire sequence of the Gravel Point. Only the lowest beds of the Gravel Point formation which include those between the top of the Koehler and the Chonetes emmetensis zone which are imperfectly exposed in the Gorbut School locality of the Afton area, cannot be seen here. The zone of Chonetes emmetensis occurs in a deep part of the quarry, about halfway between the western and eastern ends of the quarry. In the section one may see the alternation of limestone and shale so typical of the Traverse. Large coral heads are common in the limestone members, but there is no indication of reef formation. Two shale members known commonly as the "lower blue" and "upper blue", are comparatively thick, and both are very fossiliferous. The upper shale has been recognized as far west as Charlevoix.

In 1972 Sorensen and Segall measured over 91 feet of strata in this quarry, which was then operated by the Penn-Dixie Cement Corporation. They measured only the beds which were readily accessible from the quarry floor; comparison with Pohl's section shows that they examined lower beds in the Gravel Point Formation and that they did not record the highest beds. Sorensen and Segall's unit 17 is undoubtedly Pohl's zone 3, and their uppermost units correspond to Pohl's zone 4, bed 1. Hence, Pohl recorded 29 feet 2 inches of strata above the Sorensen-Segall section, and they saw 45 feet of strata more below the "Large Atrypa zone" than did Pohl.



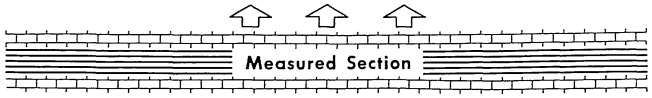
Penn-Dixie Cement Corporation Quarry

Localities 34-6-3 S and 34-6-3 SW (old Locs. 14 and 14a). Measured at various places in the quarry where beds could be reached from the quarry floor. Section by Sorensen and Segall, 27 and 29 Jun 1972.

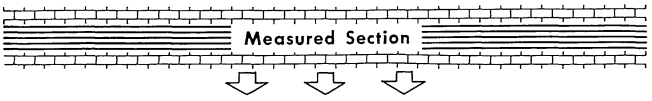
Unit	Thickness Ft.	In.
Pleistocene. Beach sand, gravel, marl.		
Gravel Point Formation		
19. Limestone; brown, cryptocrystalline, dense, weathers yellowish-brown, thin- to medium-bedded (1" to 1½'), Hexagonaria. (7' 8" exposed and measured below drift in abandoned quarry on S side of RR tracks. At least 25' exposed in vertical wall on S wall of operating quarry, too high to measure)	7	8 +
18. Limestone; chocolate-brown, weathers gray-brown, cryptocrystalline, dense, breaks angular and conchoidal, in places large heads of Hexagonaria. Thickness, color, and fracture pattern make this bed easy to locate in quarry wall	2	6
17. Limestone; brown, microcrystalline, medium-bedded (about 10" to 1' thick), some shale seams between bedding as much as 3" thick; fossiliferous with corals and brachs: Atrypa, Hexagonaria, Chonetes emmetensis. (Pohl's zone 3, Emmetensis Zone)	13	6
16. Limestone; brown, cryptocrystalline, dense, medium-bedded with interbedded shale, breaks angular with slight conchoidal fracture. Stipple (dark blue around worm boring or fossil fragments ?), weathers gray with some yellow iron stain, occasional Atrypa	4	8
15. Limestone; brown, cryptocrystalline, trace pyrite, weathers gray with tan along bedding plane, medium-bedded (8" to 1' thick), breaks angular with slight conchoidal fracture; shale seam between beds, some small Favosites, Atrypa, Strophodonta?	7	6
14. Shale; (Big Atrypa Zone of Pohl); gray, fossiliferous. Atrypa, Strophodonta, Cyrtina alpenensis, Chonetes emmetensis	1	4
13. Limestone; brown, cryptocrystalline, trace pyrite, fossiliferous. Fossils noted include bryozoans, Atrypa, Strophodonta, Favosites, and crinoid stems	1	0
12. Limestone; similar to bed 5 but very massive and contains pyrite	3	4
11. Limestone; gray to brown, weathering brownish, microcrystalline, medium- to massive-bedded, breaks angular. Hexagonaria and crinoid stems, small nodules that may be stromatoporoids in a zone about 8" from top	12	0
10. Limestone; gray, fine-crystalline, calcite crystals, massive, some limy shale, breaks angular, weathers gray to brownish, shaley at top, fossils include corals and brachs: Atrypa, Mucrospirifer, Strophodonta (large), crinoid stems	7	6
9. Shale; gray, calcareous, fossiliferous: Atrypa, spirifers, bryozoans, trilobite fragments	2	3
8. Limestone; gray, brownish where corals are present, microcrystalline, trace pyrite, thin- to medium-bedded (3" to 3' thick), breaks angular, some shale seams, large heads of Hexagonaria	10	0
7. Limestone; gray to brown, microcrystalline, some calcite crystals, weathers light-gray to tan, Favosites and brachiopod shells. 2" to 6" calcareous gray shale seam at base	2	6
6. Shale; gray, calcareous	0	6
5. Limestone; brown, fine-crystalline, resinous luster, lower 8" thin-bedded with light- to dark-brown laminae, breaks angular and blocky, thin 4" argillaceous bed in center of unit, in places upper 2' more massive and brown with large heads of Hexagonaria	4	6
4. Limestone; pale-brown, microcrystalline, iron staining, bedding 3" to 5", breaks angular, white earthy chert nodules in lower 2'. Gray shale seam at bottom	5	7
3. Limestone; brown, fine- to microcrystalline, one bed unit, light banding in upper part due to weathering. This bed bends up over porous brecciated appearance bioherm mass that is petroliferous containing asphaltic material, calcite and dolomite crystals	0	11
2. Limestone; dark-brown, cryptocrystalline, dense, similar to bed 1 but thinner bedding (1" to 2")	0	11
1. Limestone; dark-brown, dense, cryptocrystalline, breaks angular with sharp edges, weathers to light-gray with white streaks, petrolifer-		

ous, bedding 2" to 6", some laminations 1" to 2" apart that are wavy but not parallel	3	0
Total thickness	91	2
Covered interval to quarry floor	0	8

Note: Beds 1-8 measured in lower benches of quarry starting in the west wall (lowest strata) and working to the south and thence to the east wall. Beds 8-14 measured in second bench above sump and following quarry wall eastward. Beds 14-17 measured on south wall of the abandoned quarry back of the plant. Beds 18 and higher measured in the elongate old abandoned quarry south of the railroad tracks to the south of the plant.



Between this site and the mouth of Bear Creek, only about a mile west of the creek outlet, Winchell saw Traverse Group strata that undoubtedly belong to the Gravel Point Formation. He described the beds as located in SE$\frac{1}{4}$ sec. 1, T 34 N, R 6 W, "along the beach"; there is no beach in the SE$\frac{1}{4}$ sec. 1. From the description, we conclude that the place was our Locality 34-6-1 C. Here Winchell called the exposure the "Tropidoleptus Beds." The "Tropidoleptus" proved to be a Strophodonta, and Winchell issued a supplement to change the designation to "Bryozoa Beds."



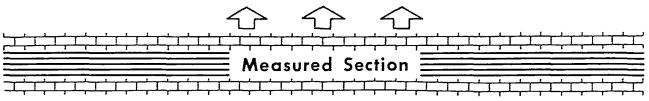
Gravel Point Formation Exposed Along Shore West of Bear Creek

Beds dipping about 8° and exposed along beach for 360 feet, about 1 mile west of mouth of Bear Creek. Locality 34-6-1 C. Measured by Winchell (1866, p. 42) as his Loc. 857.

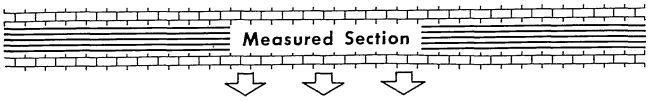
Bed	Thickness Ft.
E. Limestone, argillaceous, sub-crystalline, the thinner layers shaly, terminated by a few inches of black shale	14
D. Limestone, very dark chocolate colored, argillaceous, compact, much broken	3
C. Limestone, very dark, bituminous, in beds from six inches to one foot thick, shaly or subcrystalline	12
B. Limestone, dark brown, argillaceous, uneven bedded, breaking with a ragged uneven fracture	5
A. Limestone, dark, compact, argillo-calcareous, breaking with a smooth conchoidal fracture, much shattered	1

The following fossils occur in A: Favosites Alpenensis, Acervularia Davidsoni, Phillipsastraea Verneuili, a branching Cyathophyllid, Fenestella (small fenestrules), Serpula, Strophomena nacrea, Strophomena (large), Tropidoleptus carinatus, Spirifer mucronatus, Spirifer sp ?.

The following occur in the upper members: Favosites Alpenensis, Zaphrentis, Acervularia Davidsoni, Chonetes (small, flat), Chonetes (winged, large), Atrypa reticularis, Terebratula Romingeri, Nuculites.



At Locality 34-6-4 SW, Winchell saw natural exposures along the shore; the site later became the Bay Shore Lime Company Quarry 1. Still later the quarry was abandoned, and the place is now part of the property of the Penn-Dixie Cement Corporation, which has moved such massive quantities of rubble and waste into the general area that old landmarks could no longer be recognized in 1973.

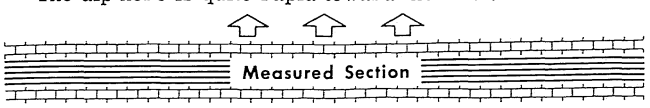


Gravel Point Formation Formerly Exposed Near Shore at Locality 34-6-4 SW

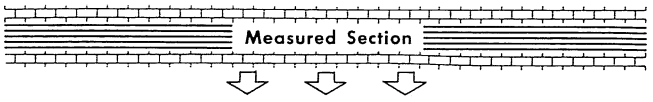
Natural exposure measured by Winchell (1866, p. 45) as his Loc. 862, before operations by Bay Shore Lime Company created a quarry there.

Bed	Thickness Ft.
C. Limestone, buff, massive but shattered, crinoidal stems abundant in the upper part	15
B. Coral clay	8"
Limestone as above the clay	2
Lignite, calcareous and earthy	1-3"
Limestone, buff, thick-bedded, shattered, with bands of lignite. Contains Acervularia, Stromatopora (wide cells), Zaphrentis, Favosites, Cyrtia, Tropidoleptus, and Gomphoceras	15
A. Limestone, dark, fine, compact, thin-bedded, with conchoidal fracture, extends under the water	12

The dip here is quite rapid toward the west.



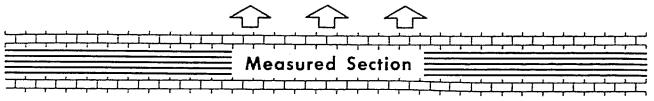
When Grabau wrote on the area in 1902, the site had become the Bay Shore Lime Company Quarry 1. There he recorded 33$\frac{1}{2}$ feet of strata:



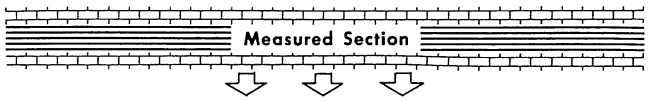
Gravel Point Formation Formerly Exposed in Bay Shore Lime Company Quarry No. 1

Locality 34-6-4 SW. Section measured by Grabau (1902, p. 205, 206) as his Loc. 46.

Bed	Thickness Ft.	In.
46K. Blue clay covered by drift, fossils not observed		
46J. Limestone, compact, dark and somewhat argillaceous, with Stromatopora and Acervularia, the former chiefly in the upper portion. All lie with the long diameter parallel to the stratification, and are usually broken and worn. They are frequently overturned, and in general are much like the rock of Rose's quarry at Petoskey (Loc. 39)... The dip of the bed is 5 degrees east	16	
46H. Blue clay with Acervularia davidsoni, Favosites alpenensis, Stropheodonta erratica, and many other species of the same type found in 42D, to which bed it is undoubtedly equivalent	1	3
46G. Compact limestone like 46I (sic!) with Favosites, Zaphrentis, etc., well stratified	1	6
46F. Black carbonaceous shale with Favosites, etc.		2
46E. Compact gray limestone with Zaphrentis, Favosites, and complete heads of Stromatopora	1	
46D. Black carbonaceous shale, fissile, with Stropheodonta erratica		5
46C. Stromatopora bed with large heads from two to three feet in diameter, mostly perfect and commonly covered on their surfaces by a carbonaceous film. Small Favosites and a few other corals also occur. This is the equivalent of bed B of Rose's quarry (Loc. 42). In some parts it is a regularly stratified limestone with scarcely any Stromatopora.	8	
46B. Black carbonaceous shale; no fossils seen		1-2"
46A. Compact limestone, with broken and worn fragments of Stromatopora lying in positions; in beds from one to two feet thick, separated by carbonaceous black shale 2 to 5 inches thick; exposed	4-5	
Total about	33	6



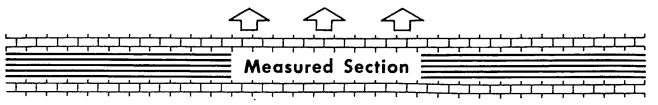
About "half a mile" west of his Loc. 862, Winchell found the westward-dipping strata had risen into a "dome-like elevation of strata, from the summit of which they dip in opposite directions." Such a doming of beds can be seen along the drainage ditch leading to the lake from the Penn-Dixie Shale Pit near or at the site of the old Bell Quarry. This suggests that the dome seen along the shore by Winchell may have been part of the same structure, although changes in dip are common throughout the area. The strata measured by Winchell were without question in the Gravel Point Formation:



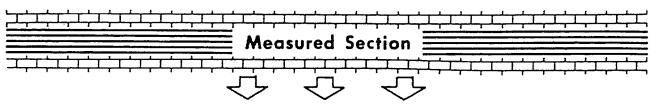
Gravel Point Formation Formerly Exposed in a Dome at Locality 34-6-5 S

Natural exposure measured by Winchell (1866, p. 45) as his Loc. 863.

Bed	Thickness Ft.
B. (Limestone, buffish, broken. Contains Stromatopora and Acervularia, and in the upper part, numerous crinoidal joints	?
(Limestone, similar to above, thick-bedded	4
A. Limestone, dark, fine, compact, thin-bedded, breaking with conchoidal fracture. Extends under water	8



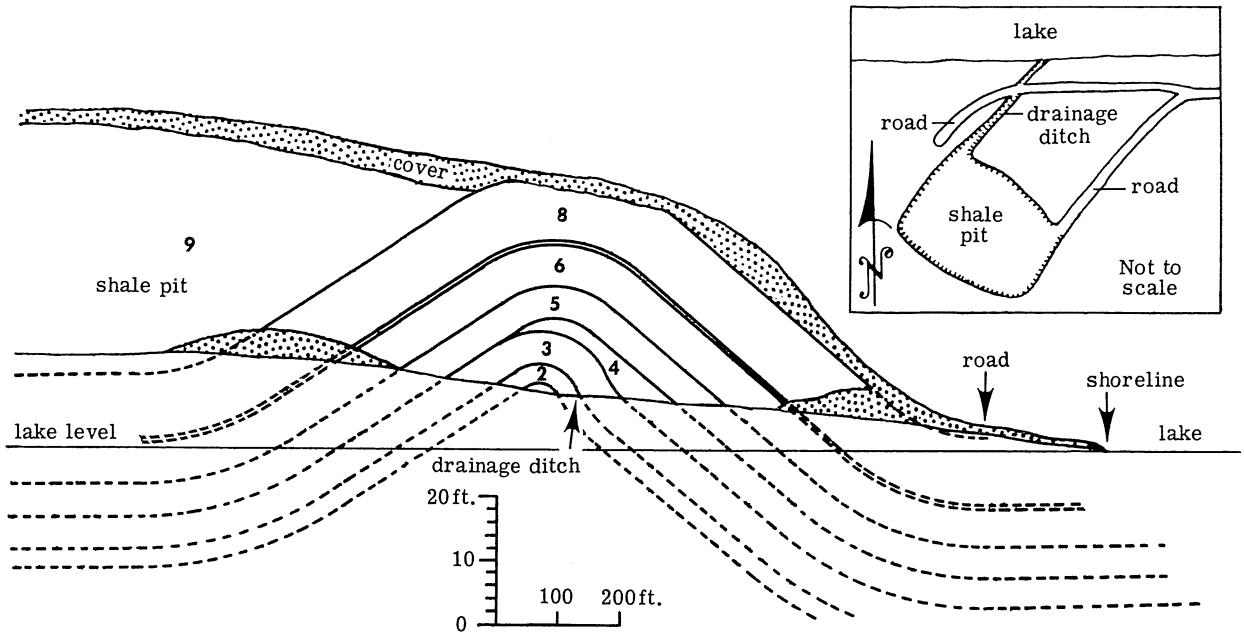
For many years the Bell Quarry (old Loc. 14e) provided weathered exposures for excellent collecting of fossils from the upper Gravel Point Formation. It also exhibited the contact with the overlying Charlevoix Limestone. In 1929, Pohl recorded 48 feet of Gravel Point and 5 feet 9 inches of Charlevoix at this quarry, already abandoned at that time:



Bell Quarry

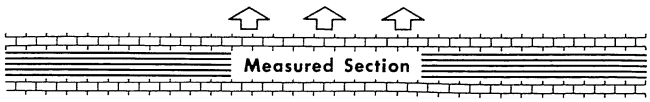
Quarry once operated between Petoskey and Bay Shore. Locality 34-6-8 NE (old Loc. 14e). Section published by Pohl (1929, p. 11).

TEXT-FIG. 41 -- Probably uppermost Gravel Point Formation. Penn-Dixie Cement Corporation Shale Pit. At or near Locality 34-6-8 NE (old Loc. 14e, the Bell Quarry). Pit and drainage ditch where section was measured by Sorensen and Segall. Photo by Sorensen, 1972.



TEXT-FIG. 42 -- Map and sketch showing beds exposed in shale pit and along drainage ditch of Penn-Dixie Cement Corporation Shale Pit. Locality 34-6-8 NE. See measured section by Sorensen and Segall. Bed 9 is the shale quarried for cement use.

Zone	Thickness Ft.	In.
Charlevoix stage.		
4. "Dumose Favosites bed." Thickness exposed		4-9"
3. "Laminated bed." Grey, coarsely crystalline, granular, porous limestone with the laminations, probably due to algal growth, decreasing in thickness upward and with the lower 2 inches and upper 6 inches unlaminated	2	9
2. Pure, buff limestone of lithographic texture	1	9
1. Reworked, fragmental clay shale ..		6
Gravel Point stage.		
6. Bed 3. "Blue Shale." Bluish-grey, incoherent, calcareous shale with numerous more coherent limey lenses. This bed quickly weathers to a sticky, gritless mud, carrying long selenite crystals and allowing the abundance of finely preserved fossils to roll free. The basal foot of this member is more pyritiferous than usual and carries a great number of small crushed Conocardium emmetensis Winchell. Fauna of entire bed: Atrypa, Athyris, costate Stropheodonta, Prismatophyllum, Cystodictya and many other bryozoa, and Conocardium are most abundant .		8
Bed 2. Same as zone 6, bed 2, of locality 14c		14
Bed 1. "Lower Blue Shale"		1
Section up to "Lower Blue Shale" is a duplicate of that at locality 14c		25



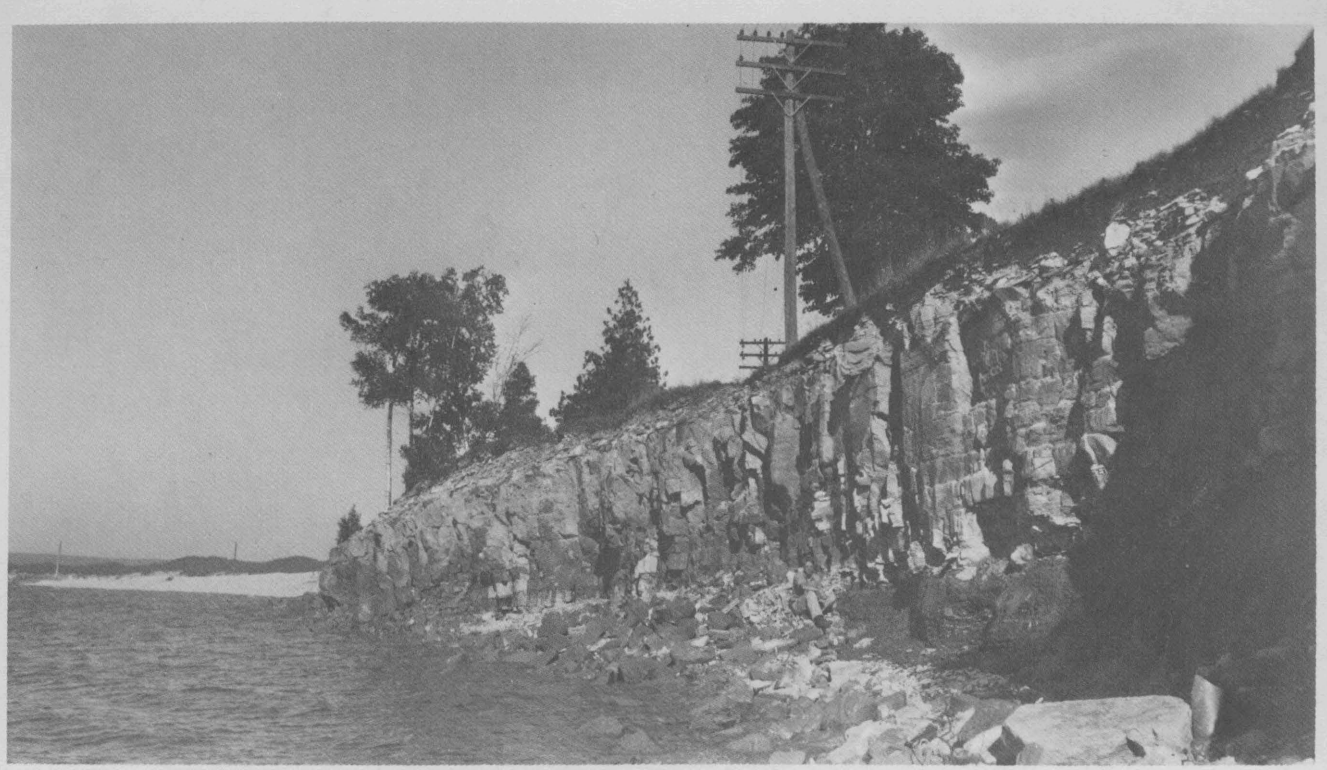
The Bell Quarry, old locality 14e, was still in existence in 1949 when the field excursion of the Michigan Geological Society visited the area. Ehlers stated in the guidebook:

> The Bell quarry shows a contact between the upper blue shale of the Gravel Point, and the overlying basal beds of the Charlevoix.
>
> Throughout the shale are scattered crystals of gypsum, probably the only instance where this mineral may be seen in a Traverse outcrop....
>
> The lower contact of the upper blue shale with limestone members of the Traverse is partially

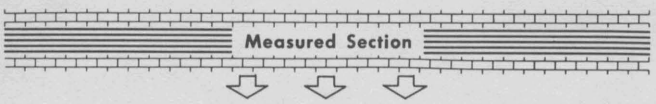
TEXT-FIG. 43 -- Gravel Point Formation and Charlevoix Limestone. East part of Petoskey Portland Cement Company Quarry. Locality 34-6-2 SW. "Upper blue shale" of Gravel Point indicated by fresh exposure (dark) at left of picture. Photo by Ehlers, about 18 Jun 1956.

concealed by slump. Note that the relationship between varieties of the coral Hexagonaria found in the blue shale and the limestone members here, parallel those observed between varieties of the same coral found in the Ferron Point shale and Genshaw limestone at the Black Lake stop. The occurrence suggests faunal variations as a result of environmental change.

And where is the Bell Quarry now? We wish we knew more precisely. Like other seemingly permanent and indestructible localities in the vicinity, it is probably buried beneath fill and rubble. In the same quarter section where it used to be, there is now the Penn-Dixie Cement Corporation Shale Pit. The section exposed in the shale pit and along the drainage ditch leading to the lake (text-figs. 17, 41, 42, 45) appears to lie entirely in the Gravel Point Formation. In the section measured in 1972 by Sorensen and Segall and presented below, their unit 7 seems to be Pohl's zone 6, bed 1 ("Lower Blue Shale" in his listing) and their unit 8 seems to be Pohl's zone 6, bed 2. The shale pit is operated, however, in a shale that is very similar lithologically to Pohl's zone 6, bed 3 ("Blue Shale" in his listing) and occupies the same stratigraphic position; but instead of the 8 to 16 feet thickness encountered in wells (see table 2, page 34) and in outcrops, the shale pit has as much as 40 feet of this unit! The most logical explanation is that down-dip the quarrying uncovered a local pocket of thick shale; this could be an inter-reef "low" that gradually filled with shale, or it could be a later structural basin into which eroded shale was re-deposited without disconformity prior to the deposition of the basal calcareous Charlevoix. Whatever the conditions of deposition, the shale pit occurrence appears to have been a local feature.



TEXT-FIG. 44 -- Gravel Point Formation and Charlevoix Limestone. Bluff at Bay View near Pennsylvania Railroad station. Locality 35-5-33 NW (old Loc. 18a). "Upper blue shale" is exposed near water level. Compare with cover picture. Photo by Ehlers, around 1953.



Penn-Dixie Cement Corporation Shale Pit

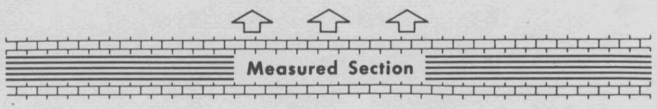
Pit in NE¼ NE¼ sec. 8, T 34 N, R 6 W, Emmet County, probably at Locality 34-6-8 NE, the site of the abandoned Bell Quarry, all traces of which have been eliminated by present quarrying operations. Section exposed in pit and along drainage ditch cut from pit northwest to Little Traverse Bay. Measured by Sorensen and Segall, 30 Jun 1972.

Unit	Thickness Ft.	In.
Drift. Sand.		
Gravel Point Formation		
9. Shale (quarried for use in cement manufacturing); light-gray to bluish-gray, evenly bedded, small pyrite crystals and few pyritized brachiopods and other fossils near base	40	
8. Limestone; dark-gray to brown, argillaceous, fine-grained, trace pyrite, medium-bedded (1 to 2 ft.), breaks angularly and blocky, pyrite, iron staining, weathers light-gray to yellowish in places, some chert nodules, lenses of hard crystalline limestone, thin shale seam in bedding planes, some brachiopods and Favosites. Mucrospirifer	10	
7. Shale seam, fossiliferous		6
6. Limestone; gray to slightly brownish, micro- to fine-crystalline, trace pyrite, massive-bedded with bedding planes 1 to 1½ feet apart; chert nodules, breaks angular with slight conchoidal fracture	6	3
5. Limestone; gray to brown, medium- to coarse-crystalline, disseminated pyrite, more massive in lower 2½ feet, breaks angular and blocky, some carbonaceous laminae in upper part, weathers brown. Contains fossils but poorly preserved due to crystallization	5	2
4. Limestone; light-gray, argillaceous (crystalline where limy), porous. Fossils include bryozoans, fragments of trilobites, crinoid stems and buttons. This bed pinches out where strata begin to dip southward and shale bed of quarry begins under drift on top; there bed 5 rests directly on top of bed 3	0 to 4'5"	

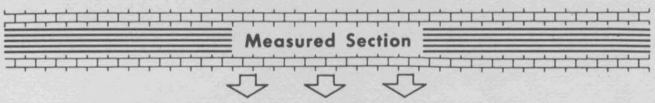
TEXT-FIG. 45 -- Probably uppermost Gravel Point Formation. Shale pit of Penn-Dixie Cement Corporation. Near or at Locality 34-6-8 NE (old Loc. 14e, the Bell Quarry). Beds not exposed until late 1960's. Photo by Kesling, 29 Sep 1973.

3. Limestone; pale-brown to gray, micro- to coarse-crystalline, trace pyrite, medium-bedded but weathers thin-bedded in places, breaks angular with slight conchoidal fracture, weathers light-gray to brownish, Favosites zone in lower part, some carbonaceous streaks, in places coarsely crystalline with good porosity .	5	
2. Limestone; pale-brown, fine- to medium-crystalline, trace pyrite, porous (1 ft. 10 in.), weathers to thin beds, laminated in lower 1 ft. 10 in. but thickens in places to 3 ft.	3	
1. Limestone; gray, fine- to medium-crystalline, argillaceous (more shaley at top), disseminated pyrite, weathers to thin beds and to light-gray in color, breaks angular and into thin pieces, contains Hexagonaria heads in places	1	6
Maximum thickness	75	10
Covered to water level in drainage ditch ..	2	0

Note: Two large cephalopods found in rubble along the drainage ditch thought to have come from unit 4.



An abandoned quarry, called the W. E. Smith Quarry by R. A. Smith (1916), offered still another exposure of the Gravel Point Formation in Emmet County. Here Pohl measured over 26 feet of the upper Gravel Point Formation in a section which terminated just below the "upper blue shale."



W. E. Smith Quarry of R. A. Smith
("Rose's quarry")

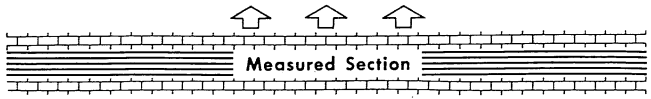
Quarry once operated about 1 mile west of Petoskey Portland Cement Company Quarry. Locality 34-6-9 N (old Loc. 14c). Section published by Pohl (1929, p. 10, 11).

Zone	Thickness Ft.	In.
6. Bed 2. Equivalent to bed 2 of locality 14e. Dirty, bituminous, light brown limestone with bands of fucoidal markings. Fossils, especially Prismatophyllum, common. Thickness exposed	10	
Bed 1. "Lower Blue Shale." Fossils abundant, large numbers of cos-		

TEXT-FIG. 46 -- Gravel Point Formation. Medusa Portland Cement Company Quarry, east wall. Locality 34-8-28 SW. Numbers identify beds in measured section of Sorensen and Segall. Photo by Sorensen, 1972.

		Ft.	In.
	tate Stropheodontas, Atrypa, digitate Favosites, Prismatophyllum, mucronate Spirifer, large Spirifer, Athyris, Cyrtina, Fenestella, and many encrusting, ramose, and flabellate bryozoa	1	
5.	Bed 8. Resistant, dark gray, fragmentally fossiliferous limestone with cryptocrystalline matrix weathering into large blocks. Fossils, especially Favosites, abundant at contact with lower shale	2	6
	Bed 7. Fossiliferous black shale. Costate Stropheodontas abundant. Atrypa, Fenestella		6
	Bed 6. Coralline, fossiliferous, fragmental limestone passing horizontally into chipstone similar to that in bed 5 below. Reef conditions with large masses of corals conspicuous, and fossiliferous black shale partings. Fauna: Prismatophyllum, Stromatopora (distantly mammillated and nodose forms), dumose and digitate Favosites, of many varieties, Cladopora, Zaphrentis, and and encrusting Trepostomes, Atrypa, Gypidula, Cyrtina (rare) costate Stropheodontas, Proetus	12	
	Bed 5. Similar to beds 2 and 3 but darker and less slabby. Black shale parting several inches from top of bed. The upper surface of the bed consists of black shale, locally stained red and covered by an abundance of markings similar to worm borings, one-quarter to 1 inch in diameter, several feet long and depressed. Depressions filled with material from succeeding bed (bed 6). Fauna: digitate Favosites and Athyris	1	6

	Ft.	In.
Bed 4. Granular, fragmental, fossiliferous limestone with Stromatopora, costate Stropheodontas. Fauna nearly same as in bed 6 above		6
Bed 3. Similar to bed 5 above		3
Bed 2. Covered interval	3	
Bed 1. Base of section exposed. Very light gray chipstone (lithographic limestone). Mottled, due to leaching. Fossils sparse: Atrypa	5	



In the Charlevoix vicinity, an exposure visited by the 1926 expedition "about 75 feet to the west of the west end of loc. 12" might be listed here as Locality 34-8-28 SW -- it having subsequently been incorporated in the new Medusa Portland Cement Company Quarry at that place. Ulrich and Ehlers noted:

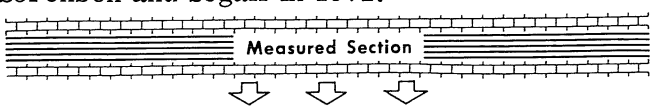
> Corals and stromatoporoids in great abundance in a reef limestone. This reef makes a ridge crossed by the road; the Chonetes-bearing bed of the base of the quarry rises directly upon the sides of the reef. Corals are of the Favosites digitatus type. Stromatoporoids of the Idiostroma type.

This outcrop was called "Loc. 12b" in the notes of Prof. Case, who on 10 Aug 1926 wrote in his notebook:

> About 100 feet north of the west end of the quarry a coral & stromatoporoid reef outcropping, 132± paces long E-W & not over 3 paces N-S.

Bearing in mind that the professor was of notably short stature, these dimensions translate into approximately 330 feet long by 7½ feet wide.

Within the last few years, the quarrying operations of the Medusa Portland Cement Company have exposed an appreciable section of Gravel Point Formation near Charlevoix. The strata seem to correlate with Pohl's zones 4 through 6. The rocks were photographed (text-figs. 21, 32, 33, 46, 53) and measured by Sorensen and Segall in 1972.



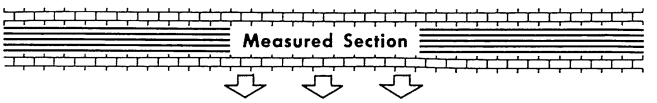
Medusa Portland Cement Company Quarry

Locality 34-8-28 SW. Measured at various places in quarry where beds could be reached from the quarry floor. Section by Sorensen and Segall, 28 Jun 1972.

Unit	Thickness Ft.	In.
Pleistocene. Glacial till and sandy gravel.		
Gravel Point Formation		
24. Shale (upper blue); gray, soft, some pyrite. Atrypa numerous, crinoid stems	7	0
23. Limestone; fine- to medium-grained, pale-brown to black, resinous luster, contains calcite. Weathers brownish, medium-bedded, breaks angular, rubbly in appearance, large heads of stromatoporoids and Hexagonaria. Contains Favosites and some brachs	17	0
22. Shale (lower blue); light-gray, soft, occasional large round stromatoporoids, some Favosites and broken brachiopod fragments; no Atrypa	2	0
21. Limestone; fine-grained, grayish yellow-green, dense, breaks angular, laminated in lower part. Scattered pyrite and many calcite crystals evident under magnification. (This bed is conspicuous light band over extent of quarry)	2	5
20. Limestone; cryptocrystalline, brownish-gray with light-gray blotches, thin- to medium-bedded, alternating bands of light- to dark-gray, dense, some thin beds of shaley limestone, sublithographic, breaks with slight conchoidal fracture, stromatoporoids and Favosites	10	0
19. Limestone; yellowish-gray, cryptocrystalline to medium, porous, surface iron-stained (more so at top), small cavities; laminated beds are "tiger rock" of quarrymen	2'6"-3'0"	
18. Limestone; buff to brown, thin-bedded, iron-stained	0	6
17. Limestone; fine-grained, pale yellowish brown, resinous luster, hackly fracture; secondary calcite and scattered pyrite; lower part massive, containing Favosites, stromatoporoids (some growing around Favosites) and Zaphrentis sp.; middle part thin-bedded; upper part porous and vuggy	2	6
16. Limestone; gray to slightly brownish, dense, lithographic (measured in second bench over sump)	1	0
15. Limestone; pale yellowish brown, fine-grained, resinous luster, very thin-bedded to platy, argillaceous	0	7
14. Limestone; pale-brown, sublithographic, dense, medium-bedded, angular to slight conchoidal fracture, trace of stylolites under magnification	8'0"-14'6"	
13. Shale seam; undulating	0	1

		Ft.	In.
12.	Limestone; dark yellowish brown, breaks angular, scattered pyrite. Stromatoporoids (4' diameter). Disconformity suggested at base	2	6
11.	Shale seam; gray to dark-gray, calcareous (undulating over hummocky surface suggesting unconformity) ..	0'6"-1'0"	
10.	Limestone; brownish-gray, lithographic, conchoidal fracture, occasional brachiopods	2	3
9.	Limestone; olive-gray to black, rough texture, microcrystalline, argillaceous, brachiopods, calcite very apparent upon magnification; fossils replaced by calcite	1	6
8.	Limestone; pale yellowish brown to pale-brown, very fine grained, angular, fossils include stromatoporoids, Favosites, Hexagonaria, horn corals (algal growth around some fossils). (Reef bed; however, at other parts of quarry there are no fossils but dense gray lithographic-type limestone ...	4	6
7.	Shale seam; gray, hard, calcareous, some Atrypa	1	0
6.	Limestone; grayish-green to brown, cryptocrystalline (same as beds 4 and 2 but somewhat more argillaceous and containing Atrypa), two shale seams at 1.5' to 2' intervals, weathers to light-tan with some iron staining, blue inclusions (stipple) suggesting mottling. Magnification shows scattered pyrite crystals present	7	0
5.	Shale seam; gray, calcareous	0	3
4.	Limestone; pale-brown, cryptocrystalline, argillaceous, some iron stain, dense, breaks angular, contains some sand grains; similar to bed 2; occasional brachiopods	3	7
3.	Shale seam; gray	0	1
2.	Limestone; pale yellowish brown, cryptocrystalline, argillaceous, iron stain due to pyrite, dense, occasional round pores	3	3
1.	Shale seam	0	1
	Maximum thickness	89	7
	Rock talus to water level in sump	6	0

An unusual occurrence was recorded by Ulrich and Ehlers on 9 Aug 1926 nearby. They compared the strata at the Wolverine Lime Company Quarry, a small pit about 3/4 mile west of the Charlevoix City Quarry, with strata exposed in the latter. If their correlation is correct, then a sharp local structure must be present; on the other hand, the location of the Wolverine pit and the strong southeast dip of strata in the Charlevoix City Quarry would indicate that the beds in the pit were Gravel Point in age. If the old Wolverine pits can be located, this should be checked.



Wolverine Lime Company Quarry

Small quarry or test pit about 3/4 mile west of the Charlevoix City Quarry. Locality 34-8-29 S SE (old Loc. 11). Section reported by Ulrich and Ehlers, 9 Aug 1926.

Zone		Thickness Ft.
2.	Highly crinoidal limestone with pyrite cubes plentiful. May represent zone 2 of Charlevoix City Quarry	4
1.	Like zone 2 of Charlevoix City Quarry (loc. 10) with great abundance of Chonetes in upper 6 inches. Chonetes of coronatus type, also long-hinged Spirifer. May represent the parting below zone 2 at locality 10	2

Sedimentation. -- A variety of rock types make up the Gravel Point Formation. The fossiliferous limestones are indicative of fairly shallow water, the soft thin-stratified shales of deeper water, and a few occurrences of stromatolites point to rare situations of shallow quiet areas, perhaps lagoons.

Bioherms are fairly common, but none reach great vertical extent. Devonian reef structures were probably as delicate as those living today, dependent upon a nicety of balanced depth, temperature, and food transport. We are tempted to believe that the lack of build-up in the Gravel Point bioherms is directly related to the frequent changes in depth -- as reflected in the numerous changes in lithology.

The presence of gypsum crystals (selenite) within the upper blue shale unit is not readily explained. The shale contains numerous species, all well preserved, and appears to be

TEXT-FIG. 47 -- Charlevoix Limestone. Near-shore exposures north of Bay Shore. Locality 34-6-6 SW (part of old Loc. 13). Thin limestone layers about 12 feet above lake level. Photo by Kesling, 26 Jul 1973.

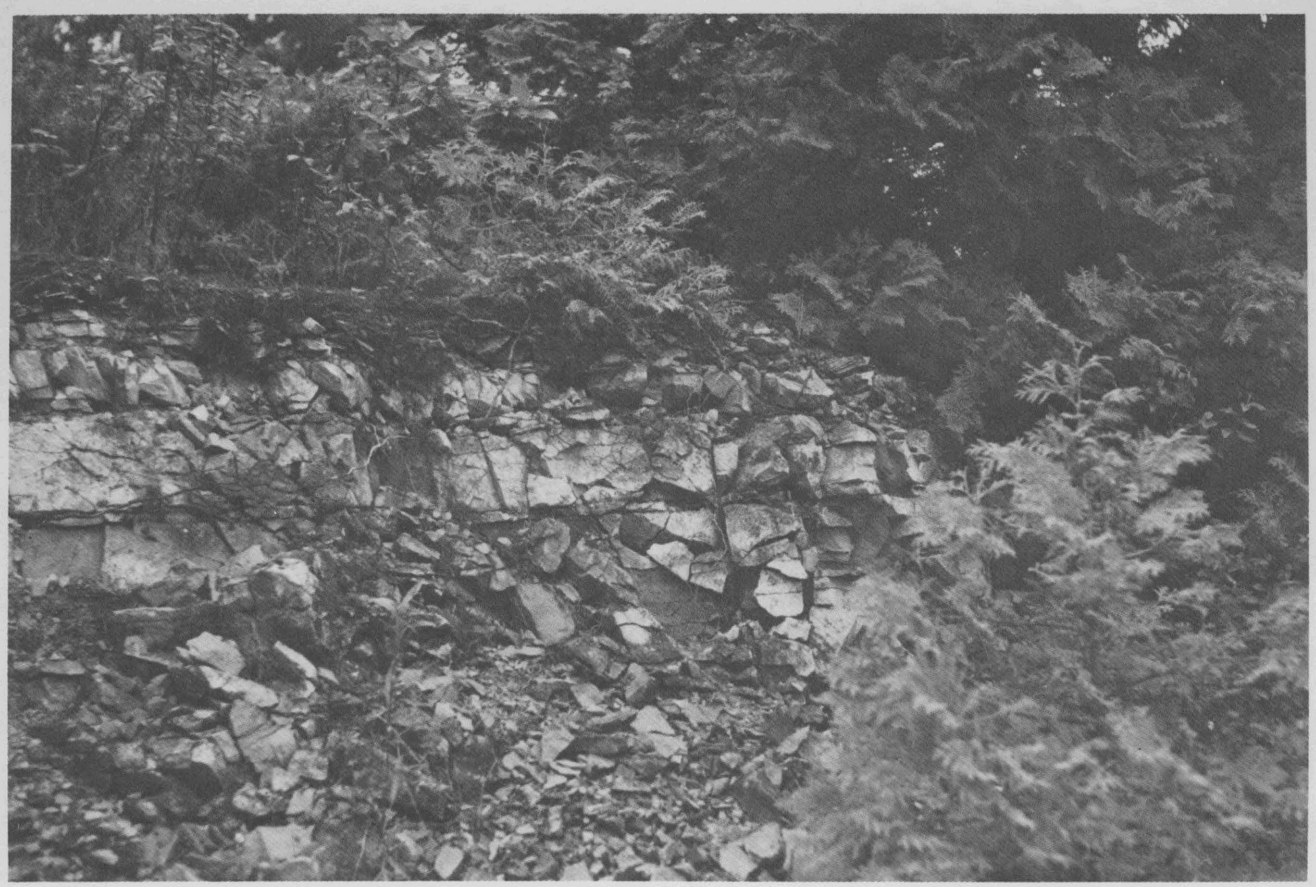
no different from similar shales which have been interpreted as rather deep and quiet water deposits. Presumably, the calcium sulphate was precipitated from normal sea water by evaporation. Our reconstruction of this phase of sedimentation involves two intervals: first, the shale was laid down in fairly deep water as mud particles; then uplift isolated basins in the region prior to Charlevoix lime deposition, and at that time evaporation produced precipitation of selenite seed crystals which grew by enrichment within the unconsolidated mud.

Fauna. -- As shown in appendix 2, the Gravel Point has 59 genera of invertebrates as published in paleontologic literature; a thorough list might be expected to be much longer. Most of this fauna consists of corals, brachiopods, and pelecypods (appendix 4), a balance very much like that of the Genshaw Formation.

Species from the Gravel Point Formation are listed in appendix 5. Comparison of appendices 5 and 6 reveals many species that are restricted to the Gravel Point. Of 87 species and subspecies listed in literature from the formation, only 42 are shared with other Devonian formations of Michigan (appendix 7). Faunal indices (appendix 8) spotlight the resemblance of the Gravel Point invertebrates to those of the Alpena Limestone and the Four Mile Dam Formation on the other side of the state, with indices of 40 and 26 respectively.

Charlevoix Limestone

Type locality and name. -- Pohl called the strata here included in the Charlevoix Limestone, the "Charlevoix stage." He said (1929,



TEXT-FIG. 48 -- Charlevoix Limestone. Near-shore exposures north of Bay Shore. Locality 34-6-6 SW (part of old Loc. 13). Strata are about 12 feet above lake level. Photo by Kesling, 26 Jul 1973.

p. 5), "The physical evidence for the separation of the Gravel Point and the Charlevoix beds has not been studied with sufficient intensity to warrant the establishment of the formational rank of these faunally distinct stages at the present time."

The term "Charlevoix limestone" was used by Cooper et al. (1942, p. 1752) and credited to Cooper and Warthin. In the 1949 guidebook for the Michigan Geological Society, the name "Charlevoix stage" was used again.

No type locality was designated by Pohl nor, to our knowledge, by subsequent authors. From our copy of field notes made by Pohl and Raasch, we know that Pohl was familiar with the exposures in the Charlevoix Rock Products quarries, both the number 1 (old Loc. 9) and the smaller number 2 (old Loc. 12), as well as in the Charlevoix City Quarry (old Loc. 10). Strangely, however, Pohl omitted all of these in his detailed sections. In fact, he described strata included in his Charlevoix stage only from the Bell Quarry (old Loc. 14e), the Bay View locality (old Loc. 18a), the Curtiss Quarry (old Loc. 13), and the lower part of the Northern Lime Company Quarry (old Loc. 18); all of these localities are in Emmet County! (Possibly, some of the Curtiss Quarry beds which Pohl described were intended to include the extensions along the shore into easternmost Charlevoix County.) We can only assume, therefore, that Pohl referred -- indirectly to be sure -- to various exposures in Charlevoix County when he named the Charlevoix stage.

TEXT-FIG. 49 -- Charlevoix Limestone (uppermost unit of section by E. C. Case). Low bluffs along shore of Lake Michigan just west of Bay Shore. Locality 34-7-1 SE (part of old Loc. 13). Photo by Kesling, 26 Jul 1973.

The Charlevoix is distinct lithologically and faunally from the Gravel Point below and the Petoskey above, originating under very different conditions. We prefer to regard it as a formation.

Sections. -- No great stratigraphic harm or permanent damage was done by Pohl's neglect to name a type section. Many of the good exposures which he studied are now covered by quarry waste -- the quarries of the Charlevoix Rock Products Company and the Charlevoix City Quarry; the Antrim Lime Company Quarry operated by Mr. Jarman in Petoskey is mostly filled in and has become a parking lot for a shopping center; and the quarries north of Bay Shore have deteriorated by weathering and slump. Nothing connected with the name Charlevoix is now exposed. Sic transit gloria mundi. Perhaps the best place to study the Charlevoix Limestone today is in the shoreline bluffs at Bay View. Kesling had the good fortune to examine most of the now "extinct" exposures during his field excursions with G. M. Ehlers in the period from 1949 to around 1961.

The lower strata in the formation could, until a few years ago, be examined in the quarries once operated by the Charlevoix Rock products Company in the area west of Charlevoix. The main (No. 1) quarry exposed a section measured by Ulrich and Ehlers in 1926 and by Pohl and Raasch around 1927. They recorded in their notes:

Measured Section

Charlevoix Rock Products Company No. 1 Quarry

Good locality of the Charlevoix Limestone. Locality 34-8-28 SE SE (old Loc. 9, incorrectly located in old notes as NW¼ sec. 28). Section recorded by Ulrich and Ehlers, 9 Aug 1926. Same units and measurements recorded by Case.

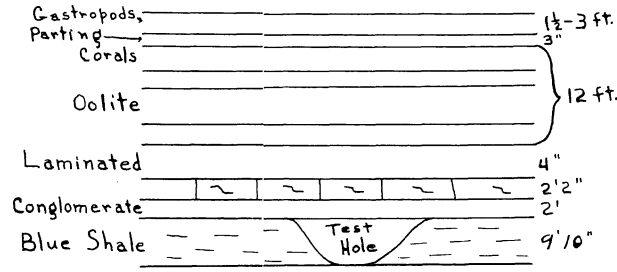
Zone		Thickness Ft.	In.
9.	Weathered, more clayey, yellow, corals as in Zone 6. On east wall contains gastropods and pelecypods. 4 feet exposed in E. wall. 3 feet in W. wall.....	4	
8.	Grayish, partly granular, fine grained limestone separated into 3 or 4 layers by clayey layers. Filled with ostracods (Primitiopsis).....	1½-3'	
7.	Similar to Zone 5. Partly filled with coquina.....		7-12"
6.	Limited by shaley limestone above. Upper half oolitic merging downward into a limestone with more or less ramose corals and sub-massive Favosites. More or less massive corals in lower part. All cream colored -- black specks, mostly porous with indeterminate fossils. Whole zone massive. Rises nearby into a reefy mass, top filled with corals -- dominant coral a dumose Favosites.....	12	
5.	Shaly limestone, light yellow to creamy gray, slightly granular.....	0	4
4.	Top 1 to 6 inches unlaminated, granular, abundant ostracods (Primitiopsis). Brown to yellow with black streaks and warm gray, porous. Wavy layers beginning with ½ inch intervals and decreasing to less than 1/8 inch. Lower 2 inches without waves.....	2	2
3.	Pure limestone, very finely crystalline (lithographic).....	1	9
2.	Granular limy sand with small quartz grains and calcite grains...	0	3
1.	Dark bluish gray shale with Atrypa and many other fossils. Atrypa especially abundant	1	3+

Measured Section

Measured Section

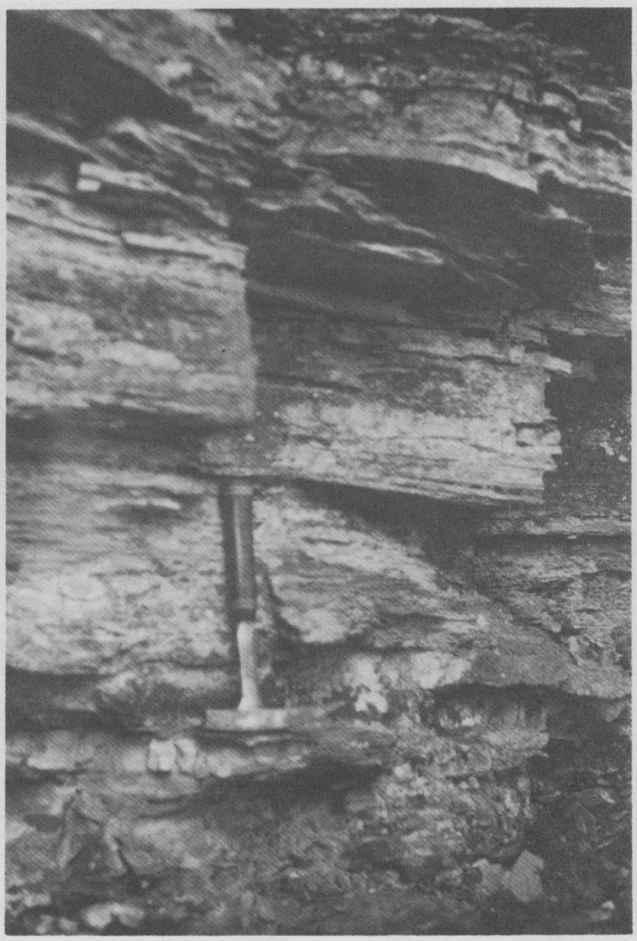
Charlevoix Rock Products Company No. 1 Quarry

Good locality of the Charlevoix Limestone. Quarry about 3/4 mile west of Charlevoix. Locality 34-8-28 SE SE (old Loc. 9). Section measured by Pohl and Raasch, around 1927.



Zone		Thickness Ft.	In.
8,9.	Limestone with frequent small gastropods, especially to be seen in Zone 9. At the base of Zone 9 there is a suggested break (of locals. 18, 17, 13, etc.) the base being made up of a compact bituminous dark brown finely crystalline shaly limestone with thin wavy black lines and plant remains.....	3	
7.	Shaly parting.....		3
6.	There appears to be a distinct break lithologically (and faunally) here as compared with the main mass of beds in the quarry. These begin with a buff coarse limestone and above that, about three feet from the base, small spherical oolites take the place of the granular structure and near the middle of the "sugar stone" bed become nearly a mm or two in size. This bed contains abundant pelecypod remains weathered a light umber but unidentifiable. The rest of the 12 foot bed contains numerous Favosites, especially near the top where they assume reeflike structure. A small Athyris is frequent in the interspaces.....	12	
5.	Creamy gray, slightly granular shaly limestone. Another slight break between this and bed below..		4
4.	Laminated, coarsely crystalline limestone. This bed is a gray, granular porous rock, with the laminations, probably due to algae, decreasing in thickness upward and with the lower two		

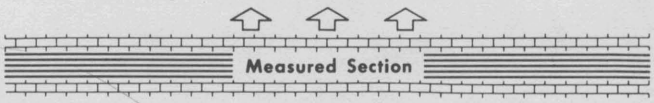
TEXT-FIG. 50 -- Charlevoix Limestone. Shore bluffs north of Bay Shore, Locality 34-6-6 SW (part of old Loc. 13). Photo by Kesling, 26 Jul 1973.



TEXT-FIG. 51 -- Whiskey Creek Formation. Type locality north of Norwood. Cherty beds in low bluff facing Lake Michigan. The place is now overgrown and the exposure is in total shade of small trees and bushes. Photo by Kesling, 29 Sep 1973.

	inches and upper six inches unlaminated.....	2	2
3.	Pure buff limestone of lithographic texture, grading into overlying zone.....	1	9
2.	Band of granular (gritty) limy sand, sharply bounding blue shale below..	3	
1.	The section begins in four test pits dug about 7 years ago by the Argo Company and according to the watchman there are 9'10" of the blue shale. Due to the long weathering the surface of the small dumps from these pits is covered with beautifully preserved free fossils among which Atrypa, Cystodictya and many other bryozoa, Acervularia, Favosites, Athyris, Stropheodonta costata, and Conocardium were the most abundant.....	9	10

Below this bed the well on the property shows 250 feet of lime rock "before sand is struck."



TEXT-FIG. 52 -- Petoskey Formation, type locality. Locality 35-5-32 SW (old Loc. 18). Large broken chunk of stromatoporoid as exposed in bioherm section of the face. Actual width of quarry face shown in picture is about 18 inches (490 mm). Photo by Kesling, 27 Jul 1973.

TEXT-FIG. 53 -- Gravel Point Formation. Medusa Portland Cement Company Quarry, face at sump. Locality 34-8-28 SW. Beds 1-8 and higher in measured section of Sorensen and Segall. Reef bed (bed 8) where pipe at extreme left makes a 45^{o} bend. Photo by Sorensen, 1972.

TEXT-FIG. 54 -- Petoskey Formation. Kegomic Quarry. Locality 35-5-27 S (old Loc. 21). View looking east across water-filled pit of old quarry. Photo by Ehlers, probably around 1949.

Both sets of measurements show about $22\frac{1}{2}$ to $24\frac{1}{2}$ feet of Charlevoix Limestone exposed above the "upper blue shale" of the Gravel Point Formation. The only photograph we have of this important old quarry was taken nearly half a century ago by Prof. Ehlers (text-fig. 5).

The Charlevoix Rock Products Company No. 2 Quarry was much smaller than the main quarry, but it was revived and quarried on a small scale into the 1950's as the Charlevoix Lime & Stone Company Quarry. For information on the rocks encountered in this quarry, we turn again to the sections by the Ulrich-Ehlers (1926) and Pohl-Raasch (1927?) teams.

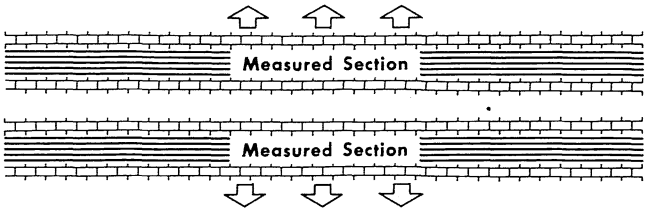
Charlevoix Rock Products Company No. 2 Quarry

Also known for some time (later) as the Charlevoix Lime & Stone Company Quarry; called a "test pit" by R. A. Smith. Locality 34-8-28 S (old Loc. 12). Section recorded by Ulrich and Ehlers, 10 Aug 1926.

Zone		Thickness Ft.	In.
	At West End of Quarry		
4.	Limestone with Cyrtina, etc., same as top of quarry, loc. 10.....	0	3
3.	Yellow shaly layer, contains Cyrtina (rare), large Spirifer (characteristic), Gypidula (rare). Fauna is same as that above and entirely the same as that of yellow band of loc. 10.....	1	8
2.	Limestone, crinoidal and containing pyrite cubes. Crinoidal layer not quite as coarsely crystalline as in loc. 11. This limestone the same as zone 2 of loc. 11.....	3	10
1.	Limestone, brownish gray and crystalline, few pyrite cubes at top. Large Chonetes of coronatus type. Limestone in floor of quarry has dip of about 5 to 12 degrees, seemingly increasing toward base of quarry -- direction of dip southerly. This limestone same as zone 1 of loc. 11.....	?	

At East End of Quarry

4.	Limestone with Cyrtina	7	
3.	Yellow shaly layer reduced to bedding plane.		
2.	Crinoidal layer.....	7	2
1.	Chonetes layer at bottom of quarry.		



Charlevoix Rock Products Company No. 2 Quarry

Also known for some time (later) as the Charlevoix Lime & Stone Company Quarry. About ½ mile southwest of Charlevoix Rock Products No. 1 Quarry. Locality 34-8-28 S (old Loc. 12). Section recorded by Pohl and Raasch, around 1927.

Zone		Thickness Ft.
3.	Several feet of rock, including toward the top a zone full of Gypidula and Cyrtina.....	?
2.	Lens of dirty weathered clay containing an abundant fauna: Atrypa reticularis, Spirifer sp. (large), S. mucronatus, Cyrtina, ramose bryozoa, fenestellids, Spirorbus, Aulopora, Stropheodonta sp. 2, Pholidostrophia, Asteropyge, etc. The fossiliferous clay band is reduced from a foot and a half at the southwest end of the quarry to zero near the middle of the quarry wall.....	0-1½
1.	Fragmental limestone at base, contains chiefly Chonetes coronatus and a large Spirifer, also Dendropora, but is made up largely of ground-up fossils. The floor dips very steeply southeast.....	3

In the pasture a few hundred feet west of the quarry, the ground is covered with the remains of a digitate Favosites and large masses of Idiostroma which have weathered out in place. This zone has not been located in section but is probably the coral reef from which the fragmental material of the C. coronatus zone was derived.

Years later, in the 1950's, quarrying operations exposed to the south (toward the access road at that time) a series of foreset oolite layers, occupying an estimated stratigraphic interval of about 4 feet. At that time, the exposed face of the quarry displayed so many unconformable bedding changes that different sections could be measured at every 5-foot horizontal interval.

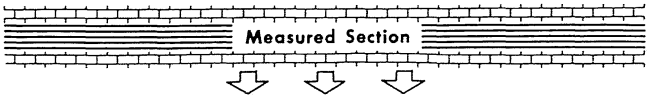
Other exposures of the Charlevoix Limestone were once present in the vicinity of the Charlevoix quarries during the 1920's. One of these was a test pit between the two quarries of the Charlevoix Rock Products Company at Locality 34-8-28 S SE (old Loc. 12a). Ulrich and Ehlers visited the site on 10 Aug 1926 and recorded:

> Test pit probably located on site of a sink hole. A bed found in place clearly equivalent to the gastropod-pelecypod layer (top zone at loc. 9, Charlevoix Rock Prod. Co. quarry) ¼ mile east. In loose cracked up blocks, clearly belonging above this layer are some with Chonetes and pyrite cubes, some with unleached gray limestone areas -- same as bed in City quarry (loc. 10); also blocks of the crinoidal bed; also many weathered blocks with numerous Cyrtina, etc.; and a few pieces of the shaly bed. From these facts it appears reasonably certain that the City quarry (loc. 10) beds are above the gastropod-pelecypod bed of loc. 9. The dip of the beds in the testhole is to the northward -- about 4' in the 100'; dip suggests the presence of a dome produced by underlying coral reef.

This place was also visited by Pohl and Raasch, who reported in their combined notes:

> Entire hole nearly filled with dump material but one face clearly showing oolitic bed of Zone 6 (locality 9) in place. The dump contains nearly all other beds of localities 9 & 12.

A small quarry once existed south of the access road leading west from the southern end of the town of Charlevoix. Around 13 feet of strata were exposed, probably all within the Charlevoix Limestone. Around the late 1920's, the city of Charlevoix decided to use this site for rubbish disposal, and soon the quarry was overflowing with junk and garbage. We have a good account of the section exposed in 1926 from the field notes of Prof. Case:

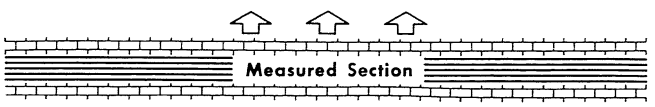


Charlevoix City Quarry

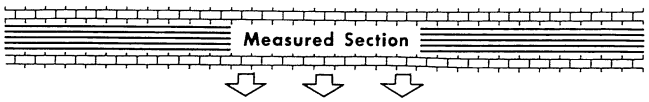
Already abandoned and used as a dumping ground in the

1920's. Quarry about ½ mile southwest of Charlevoix Rock Products Quarry. Locality 34-8-33 NW NE (old Loc. 10). Section recorded by E. C. Case, 9 Aug 1926.

Zone		Thickness Ft.	In.
4.	Reefy, rotten limestone with crystalline speckles in limy mud matrix. Fossils very rare in lower foot but increasingly abundant above. At top a rotten yellow limestone crowded with brachiopods, silicified in places under weathering in soil. Similar rock found ten feet above top of quarry which may have been shoved up by the ice or be a continuation of the beds. Only two feet visible in quarry, the rest drift covered.....	2	
3.	Calcareous cobbly shale, quite yellow with inclusions of soft limestone which carry most of the fossils. A considerable fauna comprising large and small Spirifers, Stropheodonta, large Chonetes, and Favosites of the digitatus type.....	1	6
2.	Above the parting are beds of more or less crystalline limestone not materially different from the limestone beneath the parting, but distinguishable by lithological peculiarities. Carries a few species that are characteristic of the overlying calcareous shale. The crystalline limestone of this bed has occasional shale partings...	2	4
	One quite persistent parting that suggests interruption of sedimentation for some time. This supposition of interruption based on the fact that top of underlying layer is undulatory and top of layer eroded under subaerial conditions and is followed by shaly carbonaceous films and in places with ferruginous haematitic material up to an inch or more in thickness, and can be followed around the quarry. However, in places the contact is between two solid layers without intervening material to indicate land or subaerial conditions. There are two or three other partings both above and below the main one, which simulate it but lack indications of subaerial conditions. So far as determined the fauna above the parting is distinct, with many forms not found in the bed below.....		0-1"
1.	All below the parting. Base of quarry a cement rock; fine-grained, yellow to gray. Thickness unknown. Exposed.....	7	



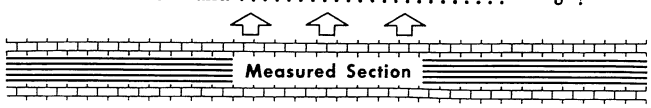
Another section of the old City Quarry was measured by Pohl and Raasch, with divisions somewhat different from those made by Case:



Charlevoix City Quarry

About ½ mile southwest of Charlevoix Rock Products Quarry. Locality 34-8-33 NW NE (old Loc. 10). Section recorded by Pohl and Raasch, around 1927.

Zone		Thickness Ft.
5.	Poorly exposed, Cyrtina-Gypidula zone	(?)
4.	Beds similar to coronatus beds below shale	2
3.	Shaly zone of weathered yellowish clay similar to that in the quarry at Loc. 12; fossils, however, much less common than at former locality	1½ ?
2.	Chonetes coronatus zone containing much crinoid matter. The matrix is not so ground up as in Loc. 12 and well-preserved fossils may be collected	7
1.	The floor of the quarry and several feet of the base of the section consist of gray-brown compact, bituminous-smelling thin bedded dolomite with small openings, probably being fossil fragments. This agrees closely with the upper beds at Loc. 9 except that the characteristic gastropod could not be found	3 ?



A rare photograph of the Charlevoix City Quarry was made by G. M. Ehlers in 1926 (text-fig. 4), perhaps the only photograph ever taken of this exposure.

The Charlevoix Limestone was exposed at Khagashewung (later Nine Mile) Point in near-shore cliffs, even before the quarry was opened into the limestone. Rominger saw it then, and described the strata in general in his 1876 publication:

Natural Exposures at Khagashewung Point

Charlevoix Limestone and Petoskey Formation exposed in vertical bluffs about 15 feet high near Khagashewung (Nine Mile) Point. Locality 34-7-2 W. Described but not measured by Rominger (1876, p. 58, 59); the following compiled from his account.

The highest beds observed on Khagashewung Point are

TEXT-FIG. 55 -- Petoskey Formation. Kegomic Quarry. Locality 35-5-27 S (old Loc. 21). Zone of Pentamerella petoskeyensis near water level, formerly called the "Gypidula zone," showing the abundance of this brachiopod before collections were made. Photo by Ehlers, 21 Aug 1926.

thin-bedded, light-colored, brittle limestone ledges, lying in a few places on top of the brownish dolomite rock.

The higher part of the Khagashewung cliffs is formed by layers of a porous, crystalline dolomite, of a brownish color, in thick, homogeneous beds, of variable finer or coarser grain. Fossils are generally rare, but in certain seams casts of Brachiopods, or dispersed specimens of Favosites, Cyathophyllum profundum, etc., are noticed. Other beds are a coarsely crystalline, crinoidal limestone, with many other fractured shells besides the Crinoid joints. Atrypa, Spirifer, Cyrtina, Strophodonta, Rhynchonella, are the recognizable forms; Proetus and Phacops are likewise to be found.

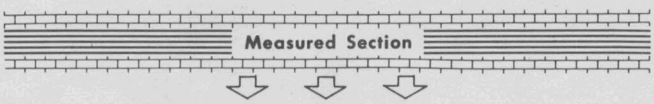
Then follow light-colored limestones with earthy fracture and of a thinly laminated structure, linear carbonaceous seams pervading them in the bedding plains (sic!). Their thickness is only a few feet, and they resemble the laminated dolomitic beds at the foot of the Petoskey bluffs, inclosing the same fish-bones and a few stems of Favosites.

Above them are some beds of a blue, argillaceo-arenaceous lime rock, containing many specimens of Cyathophyllum profundum, Favosites Hamiltonensis, Cystiphyllum Americanum, and Atrypa reticularis.

The lowest strata exposed along this point are light-colored, smooth-fracturing limestones, interlaminated with thin seams of shale, and with a bed of crystalline limestone almost entirely composed of Crinoid joints. Fossils are not numerous in them, and are of the usual kinds found in other outcrops.

The upper divisions described by Rominger were probably Petoskey Formation.

The Bay Shore Lime Company shortly thereafter opened up its No. 3 Quarry at the point. Grabau did not have time there to make a detailed section, but he recorded the following in 1902:

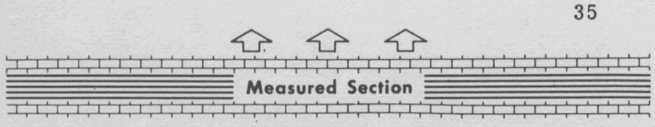


Bay Shore Lime Company Quarry No. 3
at Khagashewung Point

Charlevoix Limestone and/or Petoskey Formation once exposed in quarry at end of Khagashewung (Nine Mile) Point. Locality 34-7-2 W. Estimated thicknesses and compositions by Grabau (1902, p. 206).

TEXT-FIG. 56 -- Petoskey Formation. Abandoned Kegomic Quarry. Locality 35-5-27 S (old Loc. 21). Strata near top of section published by Pohl in 1929. Bedding is here nearly horizontal, in contrast to strong westerly dip just a few yards to the north. Photo by Karl Kutasi, 25 Jul 1973.

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

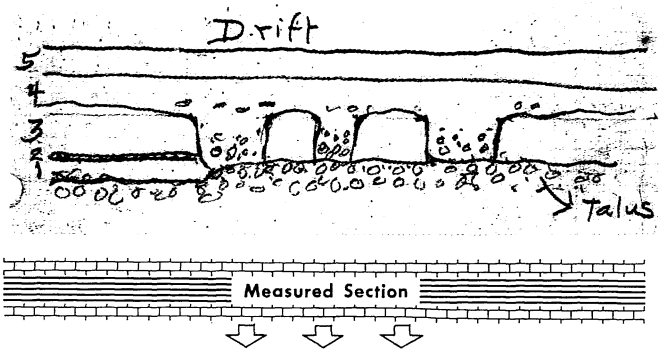


Later the No. 3 Quarry became the Northern Lime Company's Superior Quarry, and for many years displayed the unconformity between the Charlevoix and Petoskey formations. The quarry was already abandoned at the time it was studied by the combined field party in 1926. Pohl did not present a measured section for this exposure in his 1929 paper, but he did comment on the nature of the contact (1929, p. 19, 20):

> In a now abandoned quarry (locality 15), nearly 2 miles west of locality 13 on Nine Mile Point (near center sec. 2, T. 34 N., R. 7 W., Charlevoix County), bed 9 of the Charlevoix stage again exhibits the effects of erosion. This bed is here composed of a massive white limestone with numerous solution cavities, probably due to leaching contemporaneous with the pre-Petoskey denudation. This highest member of the Charlevoix section is deeply gutted and channeled, and the initial deposit of the Petoskey, a coarse shale about three-quarters of an inch thick, rests on the unevenly eroded surface of the beds beneath. The filling of the irregularities in the underlying series is completed by a fragmental, shaley limestone carrying overturned heads of a small-pitted Stromatopora and broken Gypidula shells. The first continuous layer of the Petoskey series

is a non-bedded, dirty, fragmental limestone with Gypidulas followed by a fossiliferous sand rock.

At Nine Mile Point the site of the old Superior Quarry can scarcely be discerned. Slump and brush obscure the faces. Fortunately, we can learn something about the geology from three sets of notes still kept at the Museum of Paleontology: Prof. Ehlers' transcription of Dr. E. O. Ulrich's observations, Prof. Case's sketch and notes, and the combined notes of Pohl and Raasch. The best description of the section was dictated by Ulrich and a sketch of the relationships was made by Ehlers (to which we have added formation names):

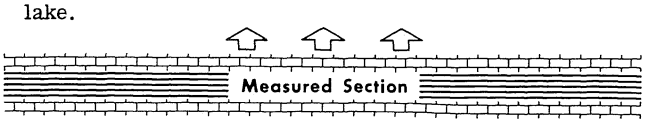


Superior Quarry at Nine Mile Point

Quarry near lake shore once operated by Northern Lime Company about 2 miles west of Bay Shore, at Nine Mile (= Khagashewung, = Kawgachewing) Point. Locality 34-7-2 W (old Loc. 15). Section recorded by Ulrich and Ehlers, 12 Aug 1926.

Zone	Thickness Ft.	In.
Petoskey Formation		
5. Limestone, yellowish-gray, granular mud lime, white speckled. Cavities suggest weathered out fossils. The stone in the quarry face more coarsely porous than underlying zone	8	0
4. Similar to above but with black specks. Specks becoming increasingly abundant toward the top. Black specks mainly crinoidal fragments; among the fragments are badly preserved ostracods, corals, stromatoporoids, and other fossils near the base	4	0
Charlevoix Limestone		
3. Limestone, porous, light-gray. This was cut by tidal currents, producing channels in which yellow clayey material accumulated at bottom; this material was apparently washed from the sides and may be seen on top of the zone. In bottom and on sides of the channels many stromatoporoids and some Favosites; these are less abundant in beds overlying the level of the channels. Smallest of the channels shows solution effect on the walls. Rock of this zone very brittle and fractures in various directions; it seems to be quite high in $CaCO_3$ ..	30-42"	
2. Thin brecciated clay, unconsolidated, with pebbles of lower zone. No pebbles rounded -- all angular due to breaking up of partly consolidated underlying material	0-4"	
1. Lime mud, exceedingly finegrained, yellowish-gray. At base, 3 inches of more porous rock containing athyroid and Murchisonia (small form apparently same as that of zone 9 of loc. 9..	3	8

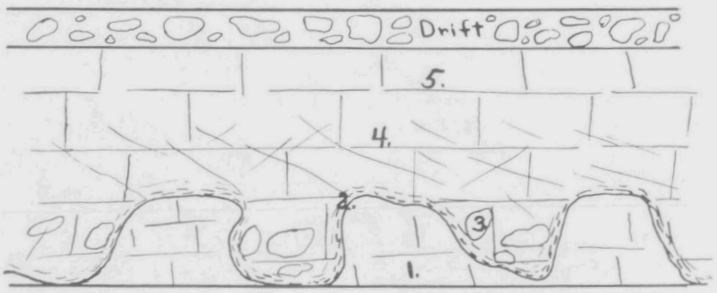
Lower half of quarry face covered by talus. Blocks of limestone with wavy structure, such as found below algal layer of loc. 13, found in bottom of quarry -- may have come from lower part of wall, now covered, or from pits in quarry floor. Bottom of quarry about 16 to 18 feet below base of zone 1 and about 15 feet above lake.



From the independent notes taken on that day by Prof. E. C. Case (reproduced below), we are assured that the relationships were as clear to him as they were to Ulrich and Ehlers. It is of interest that Case referred to the rubble-filled channels as "guts," which may have led Pohl (who had access to the notebook) to write that the unit was "deeply gutted."

TEXT-FIG. 57 -- Petoskey Formation, type locality. Locality 35-5-32 SW (old Loc. 18). Westward extension of the bluff, probably wall of the old quarry. Strata here definitely bedded, in contrast to the reef situated left of the picture. Photo by Kesling, 27 Jul 1973.

A similar sketch was made in their field notes by Pohl and Raasch:

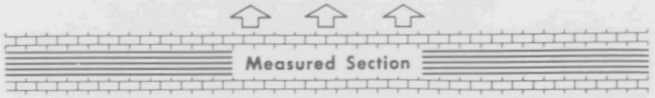


They distinguished sections in three parts of the quarry. The sketch above evidently referred to the west end, where they measured the following section:

Nine Mile Point Quarry (= Superior Quarry)

Shore of Little Traverse Bay at Nine Mile Point. Section measured by Pohl and Raasch around 1927. Locality 34-7-2 W. See sketch above.

Unit		Ft.	In.
5.	Fossiliferous sandrock. Top beds fine-grained, light-brown sandrock with a bituminous odor. Fauna: Cyrtina, Gypidula, Stropheodonta sp. 2 ?, fish plate (2), Athyris, crinoid joints, Atrypa (small), cavities of trepostomatous Bryozoa, Cranaena ?	5	
4.	Dirty limestone, fragmental with Gypidula, non-bedded. Toward the unconformity at the base the rock becomes harder, gray, and gritty, with crinoidal lenses. Gypidula and Stromatopora pustulifera	?	
3.	Filling of irregularities by overlying formation. Full of Stromatopora pustulifera and Gypidula. The contact with the bed below is extremely irregular and in places with a vertical wall or even overhanging face of the crags below	?	
2.	Shale at contact		3/4"
1.	Massive white limestone full of numerous cavities	?	



TEXT-FIG. 58 -- Petoskey Formation, type locality. Part of bluff west-southwest of reef, showing bedded strata. Photo by Kesling, 27 Jul 1973.

Pohl and Raasch noted further:

> In the middle of the quarry the talus cover is broken by a ledge of rock about 5 feet below the white massive layer (No. 1 of sketch). This consists of layers of fossiliferous brown, rather vitreous limestone, full of bituminous partings. With the exception of a single Athyris, the fauna consists entirely of mollusks, pelecypods, especially occurring in great profusion. These are the same probably as those of the Charlevoix Rock Products Quarry as is also the small, high-spired gastropod.

Regarding the section exposed at the east end of the quarry, these geologists recorded that

> ...the Cyrtina-Gypidula sandrock is again shown with the Stromatopora and Favosites at the base. The whole is more fossiliferous at this place, large Stropheodonta being conspicuous with the Favosites extending throughout. Also solitary corals.

The Cyrtina-Gypidula horizon does not impinge on the contact with the formation below at this point, but is underlain conformably by a limestone of fossil fragments embedded in a cryptocrystalline gray groundmass. The fragmental nature is emphasized by weathering. Idiostroma very abundant.

This immediately overlies the unconformable contact and reaches a maximum thickness of several feet. Below is the white limestone or its equivalent. (Here represented by a gray lithographic "chipstone").

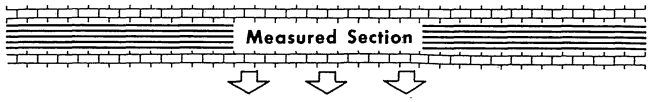
About ten feet below the pelecypod horizon the quarry floor consists of the brittle "lithographic" layer of the Charlevoix Rock Prod. Quarry. The "laminated layer" and the "dumose favosite zone" were noted in the dump.

The beds dip steeply toward the lake (north) and away from the quarry wall. The "lithographic bed" occurs 42 feet above the lake, but this figure needs to be corrected for the dip. (Loc.

15a exposes beds of Zone 3 Gravel Point Formation a short distance to west).

Throughout their descriptions, Pohl and Raasch referred to correlations with units of "Ulrich's section," but whether this section was a measured section or a composite section we have no idea. At any rate, we failed to find reference in any notes to a section which would match the numbered beds that Pohl and Raasch repeatedly correlated with in their field entries.

Along the lake shore in the eastern edge of Charlevoix County, Winchell saw and measured beds which are now assigned to the Charlevoix Limestone (text-fig. 49). He called them the "Buff Magnesian Beds."

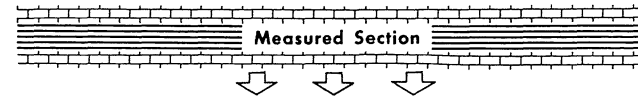


Charlevoix Limestone Near Bay Shore

"Buff Magnesian Beds" described by Winchell (1866, p. 46) at Locality 34-7-1 SE (his Loc. 865).

Bed	Thickness Ft.
E. Limestone, brownish-buff, magnesian, arenaceous, moderately, coherent, vesicular, thick-bedded, more grayish in the upper part, contains a few casts of shells in the lower part	15
D. Limestone, darker colored, somewhat argillaceous, in broken layers from 1 to 4 inches thick. Contains Nuculites	6
C. Limestone, brownish-buff, magnesian, silico-argillaceous, porous, vesicular in streaks, in beds from 1 to 2 feet thick. Contains a band of Favosites. Reaches to water level at east part of the exposure; further west is succeeded by the following:	15
B. Shale, calcareous, soft, blue	5
A. Limestone with Acervularia comes to view only at one point	?

Just over the county line, in Emmet County, the Northern Lime Company operated its Curtiss Quarry, working into the natural near-shore bluffs in section 6 (text-figs. 23, 47, 48, 50). Here in 1926, Ulrich and Ehlers measured 23 feet of strata above the blue shale of the Gravel Point Formation, and Case recorded a maximum of 26 feet 2 inches. Pohl evidently extended his section laterally to measure 31 feet 10 inches of Charlevoix strata between the top of Gravel Point and the base of the Petoskey Formation. The section by Ulrich and Ehlers:

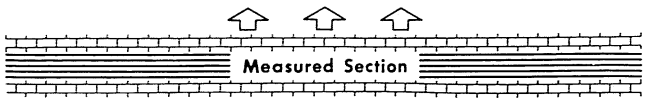


Curtiss Quarry near Bay Shore

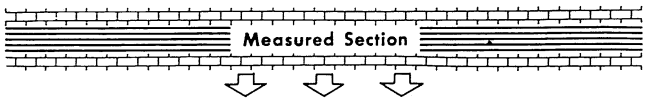
Northern Lime Company Quarry and shore exposures to the west of Bay Shore. Locality 34-6-6 SW (old Loc. 13). Section measured by Ulrich and Ehlers, 11 Aug 1926.

Zone	Thickness Ft.	In.
9. Limestone, weathered, largely decalcified, brown, containing great abundance of fossils. On outside of rock fossils have calcareous shells, within the shells largely wanting -- fossils as casts and molds. Cyrtina, Gypidula (smooth form and more plicated form), athyroids, Spirifers (abundant). corals of several kinds, Idiostroma (particularly abundant).. Corals mainly rugose, Favosites, Cyrtinas of 2 species. Tentatively this bed correlated with top bed of loc. 10	3	
8. Limestone, weathering buff; a thinner layer at base with gastropods and pelecypods. Along shore to the west the weathered zone appears more shaly	5	
7. Limestone, massive, buff, and probably magnesian, lower part light gray and yellowish and dark gray in upper part; fine grained	7'2" to 8'6"	
6. Limestone, yellowish, laminated in 2 bands. Lower band 1 ft., upper band 2 ft. Lower band yellow, in part made of broad laminated structure, but not continuous. Upper band is algal in origin -- with some laminated structure within	3	
5. Limestone, similar to preceding with dumose Favosites and algae well developed in middle part. Reef material up to 1 ft. thick	1	8
4. Limestone, yellow with laminations but without black streaks. Ripple marked and tidal guts		10
3. Limestone, gray with wavy structure, separations between wavy planes are darker than those of some layers above. Wavy structure possibly of algal origin		9
2. Sandy layer, same as zone 2 of loc. 9, mainly grains of calcite with a few grains of quartz		2-3"
1. Shale, calcareous, bluish-gray,		

practically unfossiliferous. This is same as zone 1 of loc. 9 5



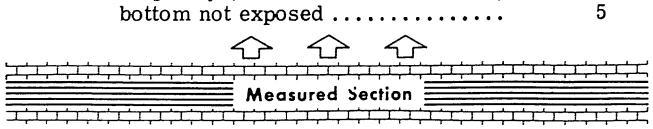
The section as measured by Case:



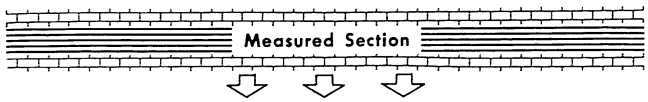
Curtiss Quarry near Bay Shore

Northern Lime Company Quarry and shore exposures to the west. Locality 34-6-6 SW (old Loc. 13). Section measured by E. C. Case, 11 Aug 1926.

Zone	Thickness Ft.	In.
7. Heavy, dark yellow, rotting, earthy, not shown in quarry face but exposed ½ mile S. [probably west]. A coquina in part	3-5	
6. Yellow limestone weathering shaley (= zone 9 in loc. 9)	5-6	
5. More massive gray limestone, a little lighter below, darker above, fine grained (= zones 5-8, loc. 9)	7'2" to 8'5"	
4. Wavy layer mixed with laminate type. Speckled black in spots, running in wavy laminae. (= zone 4, loc. 9)	3	
3. Shaley layer, floor of quarry. Wavy structure. (= zone 3 of loc. 9). 3'6". Divisible into:		
3. Same as zone 2 only running in a reef of dumose coral and algae up to 1' thick, irregular	1	8+
2. Finely laminated, no black streaks, very yellow, ripple-marked		10
1. 8"-10" wavy (? algal). Bluish patches which may be repetition of blue shale below	1	
2. Sandy layer, sparse occurrence of much rolled quartz grains (= zone 2 of loc. 9)		2-3"
1. Blue shale. Fossils rare but a fenestella type seen in small exposure in quarry (= zone 1 of loc. 9). Seen, bottom not exposed		5



The Curtiss Quarry section measured by Pohl:



Curtiss Quarry near Bay Shore

Main Curtiss and two smaller quarries operated at one time by the Northern Lime Company near the shore of Little Traverse Bay, just north of Bay Shore. Locality 34-6-6 SW (old Loc. 13). Section published by Pohl (1929, p. 13, 14).

Zone	Thickness Ft.	In.
Petoskey formation.		
2. "Fenestella zone."		
Bed 2. Similar to the crinoidal portion of zone 1 below, but carrying numerous broken fragments of Fenestellids. Thickness exposed	6	6
Bed 1. This bed is made up of numerous layers of rather coarse yellowish limestone, containing an overwhelming abundance of many Devonian types of bryozoa, but particularly the Fenestellidae, large and small Spirifers, and Gypidulas. The limestone layers are separated by fine shale partings	5	
1. "Cyrtina-Gypidula zone." The base of this bed, which is dirty throughout, is particularly fragmental. It lies unconformably and by overlap on the various beds of the eroded Charlevoix series. The lateral variation of the lithologic character, being made up at places throughout the thickness of the bed of coarse, crinoidal fragments, and at others of a finer, granular, dolomitic limestone, containing the typical association of the Cyrtina-Gypidula zone, indicates a differential sorting probably due to unstable conditions.....	0-12	
Charlevoix stage.		
9. Gray, fine-grained limestone with numerous cavities; breaking into small, angular fragments. Base stylolitic. Barren. Maximum thickness preserved	2	6
8b. Similar to bed 8a in litholologic character, but unfossiliferous	1	6
8a. Coral layer containing same fauna as below but in exceeding abundance. Darker gray, less compact, more resistant, and less brittle than bed 8		6-9"
8. Grey, lithographic, conchoidally fracturing chip-stone. Lower 6 inches finely and very unevenly and undulatingly laminated, dirty, granular, and porous. Fauna comprises a digitate and dumose Favosites and digitate Stromatoporas and an intermedia-like Ceratopora.	4	8

7.	Earthy limestone full of limonitic stains and containing wavy brown laminations. "Brown bed"	1	3
6.	Gray, partially porous and fragmentally grained, fine-grained limestone with numerous, thin, black, bituminous laminations	1	9
5.	"Pelecypod-Gastropod bed." Coarse, buff limestone in lower 3 feet, oölitic, with grains a millimeter or two in size, above. Two pelecypods, Edmondia mactroides Winchell and Edmondia ledoides Winchell and three gastropods, Pleurotomaria cavumbilicata Winchell, P. emmetensis Winchell, and P. parvispira Winchell are particularly abundant in, and are restricted to this bed	14	6
4.	"Dumose Favosites bed." Dolomitic, buff limestone with the typical fossil association of this bed as at Charlevoix Rock Products Co.'s quarry, etc.		3
3.	Massive, buff, dolomitic limestone, at places bituminous and laminar, with large discoidal lenses of fragmental limestone	3	
2.	Heavier, thin-bedded, shallow-water limestone with very uneven laminations and containing fine sand grain inclusions	1	
1.	Thin bedded, uneven, bluish-gray limestone, frequently coated brown due to weathering of contained pyrite. Thin shale like partings with numerous minute sand grains		4-8"

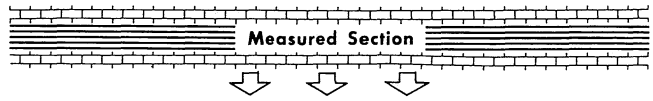
Gravel Point stage.

6.	Bed 3. Bottom of section exposed. The "Blue Shale" or uppermost bed of the Gravel Point was dug from a small test pit in the floor of the quarry bringing with it the typical association of fossils	10	

In 1949 the field trip of the Michigan Geological Society visited the place. Ehlers made some pertinent observations on the geology to be found near Bay Shore:

> As in the Northern Lime Company quarry, exposures of the Charlevoix and Petoskey may be studied here. The Charlevoix is represented by a dense sub-lithographic facies, commonly stylolitic and very similar to the Koehler at Afton, and the Rockport Quarry limestone at Black Lake. The Petoskey formation is represented by massive, crystalling limestone. Some beds of the Petoskey are highly fossiliferous, but none suggest a reef facies.
>
> The contact between the Charlevoix and Petoskey possesses a relief of about 40 feet. The irregularity of the contact is most marked west of the quarry where a slide of surface material exposes a brown limestone member of the Charlevoix. This bed shows a little dip toward the east, and projection of the dip suggests an angular relation between the Charlevoix and an inclined massive limestone member of the Petoskey. Followed to the east, and into the abandoned Bay Shore quarry, the base of the Petoskey rises to the east.
>
> One can also note a sharp contact between the sub-lithographic Charlevoix and the massive Petoskey. A pit in the lower part of the quarry is stated to have encountered the upper blue shale of the Gravel Point. The interval between the shale and the Petoskey here is considerably less than that in the Northern Lime Company quarry, and taken with other evidence abrupt change of lithology, inclined contact, cited, suggests an unconformity.

The formation was also studied in a road cut by the 1926 expedition, and there designated as Locality 16. Ulrich and Ehlers measured the following:

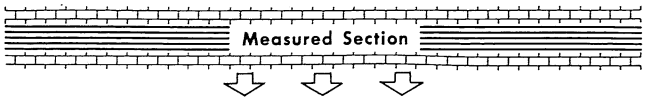


Old Walloon Lake Road Cut

Roadside exposure south of intersection of Resort Pike and US 31. Locality 34-6-2 SE (old Loc. 16). Section measured by Ulrich and Ehlers, 13 Aug 1926.

Zone		Thickness Ft.	In.
6.	Yellow-gray limestone with corals and stromatoporoids at base. Not measured. May reach several feet. Truncated at an angle by drift	?	
5.	Shale at contact		?
4.	Gray bed, porous	2	6
3.	Yellow gray limestone, fine grained	3	2
2.	Laminated limestone. Mud lime with black bands, light yellow gray	3	
1.	Similar to zone 3 but darker gray and finer grained	3	

Until the late 1960's, beds of Charlevoix age were to be seen in the old Antrim Lime Company Quarry at the edge of Petoskey, commonly known as the Jarman Quarry. Here Ulrich and Ehlers recorded the section in 1926:

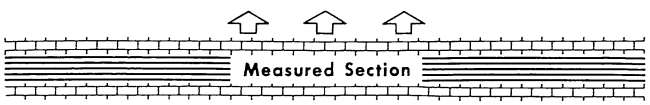


Antrim Lime Company Quarry in Petoskey
(Nathan Jarman Quarry)

Locality 34-6-1 SE (old Loc. 17). Section recorded by Ulrich and Ehlers, 13 Aug 1926.

Zone		Thickness Ft.
5.	Limestone above dumose coral zone. Some beds are also laminated. Carbonaceous layers abundant in rocks of upper half of quarry, some layers $\frac{1}{2}$ inch thick. Large reef formed of Stromatopora and digitate Favosites with some simple corals occurs at top of quarry at southwest end, possibly 3-4 feet thick. Dip of beds in quarry indicates a dome with apparent E-W trend	35
4.	Dumose Favosites zone of Charlevoix R. P. Co. (loc. 9). Not measured here, but 12 feet thick there	?
3.	Dark laminar layer, now forming base of quarry	?
2.	Gray limestone, below laminar bed, exposed in small pit at east end of quarry. Compressed, carbonized, blister-like forms collected	3
1.	Pit in bottom of quarry contains blue shale with great abundance of fossils. According to W. J. Jarman, owner, 4'6" of shale in pit	4-6

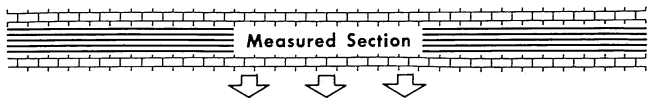
Base of fractured gray layer (zone 3) of loc. 15 is about 20' above base of dark laminar layer. According to W. J. Jarman drill hole in bottom of quarry encountered 80' of limestone.



When Pohl and Raasch visited the Antrim Lime Company (Jarman) Quarry, they interpreted the strata as embracing uppermost Gravel Point to lowermost Petoskey Formation. They recorded:

> The "Blue Shale" of the Gravel Point was exposed in the quarry floor but is now covered by water. From this point upward, the typical Charlevoix section is shown. The Pelecypod-Gastropod zone is unfossiliferous, as at Localities 18, 18a, etc. A number of feet of the Stromatopora zone of the Petoskey as developed at locality 18 is here shown. The upper part of the section is essentially the same as at Locality 18.

One exposure still showing the character of the Charlevoix Limestone is the bluff on Little Traverse Bay at the park in Bay View (see cover, text-figs. 22, 44). The section published by Pohl still applies:



Bay View Exposures

Strata exposed in ledges along shore of Little Traverse Bay near site of the Pere Marquette (later Pennsylvania) Railroad station at Bay View. Locality 35-5-33 NW (old Loc. 18a). Section published by Pohl (1929, p. 12).

Zone		Thickness Ft.	In.
Charlevoix stage.			
6.	"Pelecypod-Gastropod Bed." Massive, thick, bedded, brown limestone, barren below, thin bedded above with large, discoid, lenslike inclusions. Thickness exposed	7	4
5.	"Dumose Favosites Bed." Buff to brown, granular limestone with the leached corals occurring in abundance in two bands and with the characteristic fauna continuing into the bed shown above as in the Curtiss quarry (locality 13). Top layer finely and unevenly laminated		9
4.	Similar to bed 2 below	1	1
3.	Massive, brown, bituminous limestone breaking vertically into polygonal blocks	1	2
2.	"Laminated Bed." Similar to that at following section (locality 13) ..	1	3
1.	Bluish limestone with numerous, rounded sand grains. Material reworked from beds below with a few fragmental and worn fossils	1	7
Gravel Point stage.			
6.	Bed 3b. "Blue Shale." Same as at locality 14c	9	
	Bed 3a. "Conocardium Bed." Bluish grey, fragmental limestone, weathering brown. This is not a reef limestone, the corals being usually of solitary type. Preponderance of Conocardium emmetense Winchell, Fenestellas, Cladopora, Favosites, Zaphrentis, plicate Gypidula		12-14"
	Bed 2. Same as at localities 14c and		

	Ft.	In.
14e. Light brown, compact, bituminous limestone of reef composition. Isolated crystals of selenite occur throughout the matrix. Dominant fauna of reef corals and stromatoporoids, very numerous: Prismatophyllum, distantly and closely mammillated types of Stromatopora, Conocardium, costate Stropheodonta, Atrypa, and Phacops. Thickness exposed above water level	4	9

The above section was published in 1929. About two years before, in his joint excursion with Pohl, Raasch wrote in his field notes some comments concerning the correlation of the top bed of the bluff -- the so-called "Pelecypod-Gastropod Bed" -- which Pohl obviously considered to be the equivalent of his bed 5 at Curtiss Quarry and at Northern Lime Company Quarry. Raasch noted:

> The basal thick-bedded layers may belong to the next lower bed since the dumose Favosites continue, but as the lower beds of this zone at locality 13 were similar it was thought best to include them in this zone. Thickness of massive beds 6 feet 4 inches. Thin-bedded layers of same lithologic composition - 1 foot.

Around 1933, G. M. Ehlers studied the Bay View section once more. He wrote in his field notebook:

> Section (along) shore back of station as given by Pohl. Heavy brown bed at top of Pohl's section does not contain gastropods & pelecypods as stated by Pohl. This bed probably is same bed exposed in large Curtis quarry at Bay Shore.

In the 1949 guidebook, G. M. Ehlers said of the low bluffs along Little Traverse Bay at Bay View:

> The exposures along the lakeshore are among the few where the contact between the Gravel Point and the Charlevoix can be seen. Pohl mentions 13 feet of Charlevoix, including a basal bed containing fossils derived by erosion from the underlying Gravel Point.

Sedimentation. -- The Charlevoix displays evidence of higher energy processes than either the Gravel Point or Petoskey formations. Oolites, foreset bedding, sparse fauna, absence of soft shale beds, laminar structure (stromatolites) -- all point to nearshore deposition. No bioherms are known.

The presence of a thin band containing rounded sand grains at the base of the formation is evidence of a period of subaerial exposure. Whether this exposure encompassed all of the area or only nearby areas cannot be confirmed. Perhaps the unusual thickness of blue shale in the Penn-Dixie Shale Pit accumulated as a result of erosion of the upper unit of Gravel Point Formation from nearby exposures during this interval.

At the end of the shallow-water deposition, the Charlevoix strata were evidently lithified before exposure to the protracted subaerial erosion that is attested by the unconformity at Khagashewung (Nine Mile) Point.

Fauna. -- In notable contrast to the underlying Gravel Point Formation with 87 recorded species and subspecies, and to the overlying Petoskey Formation with 41, the Charlevoix has produced only 11 species and subspecies of macrofossils (appendix 7). Only three species are shared with other formations, and all three occur in the Alpena Limestone in Alpena County. Two species are in common with the Gravel Point Formation and one with the Petoskey Formation, indicating that the Charlevoix may be somewhat closer in age to the former; however, this evidence is hardly conclusive, based on such a sparse fauna. From the record as it exists, we can deduce that the Gravel Point and Charlevoix are both faunal (and presumably close time) equivalents of the Alpena Limestone on the northeast side of the Lower Peninsula of Michigan.

It is of some interest also that no bryozoa were recorded from the Charlevoix Limestone (appendix 10) although bryozoa were studied from the area by Winchell (1866), Deiss (1932), McNair (1937), Duncan (1939), and others. We conclude that the water was never deep enough during Charlevoix time for these animals to flourish.

Petoskey Formation

Type locality and name. -- The type locality of the formation must be regarded as the exposures in the city of Petoskey. Rocks once formed natural bluffs on the shore of Little Traverse Bay there (see text-fig. 4), and the exposures were continued inland as the Northern Lime Company operated its quarries. The bluffs and old quarry walls can scarcely be distinguished from each other today, but the rocks are clearly exposed and easily accessible by road.

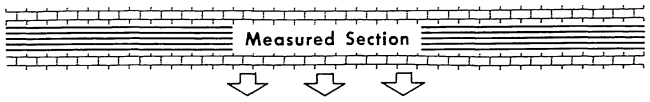
There can be little doubt that these strata, standing out boldly near the head of the bay, were seen and referred to by Douglass Houghton and other early geologists. When Winchell was at the place (his Locality 856), the only settlement was called Bear Creek Mission, a missionary-operated school for Indian boys. When Rominger came back to the site in 1874 he was surprised to find "a new village came into existence name Petoskey."

Grabau can be considered the author of the formational name. In 1902 (p. 201) he stated:

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

Sections. -- The type locality is one of the most interesting exposures of the Petoskey Formation, even though it is atypical (as pointed out by Grabau above). Near the middle of the bluff is a bioherm or bioherm-like structure, already discussed on pages 45-52. This prominent feature is bounded on either side by strata that are bedded and nearly horizontal. Various relationships are shown in the frontispiece and in text-figures 8, 9, 52, and 57-62.

The first measured section was made by Winchell, who recorded 42 feet of clearly exposed strata:

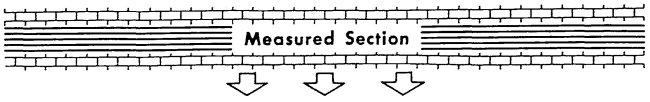


Petoskey Formation at Type Locality

Natural bluff measured by Winchell (1866, p. 41) as his Loc. 856, east of Bear Creek at Locality 35-5-32 SW. On his map, Petoskey is identified as Bear Creek Mission.

Bed	Thickness Ft.
D. Limestone, pale buff, very massive, breaking in regular blocks, somewhat arenaceous, inseparable from the following, except in its structure; containing the same fossils	12
C. Limestone, pale buff, massive, brecciated in places, vesicular; falling down in huge blocks. Becomes more regular westward. It has a rude concretionary structure from the abundance of Stromatopora (with large cells). Atrypa reticularis, Merista, Spirigera concentrica, Zaphrentis, Heliophyllum, Favosites, Cystiphyllum, Stromatopora (smaller cells), Cladopora, Conocardium, Tropidoleptus carinatus, and other species	20
B. Limestone, thin-bedded below, thicker above, broken, with a 10 inch band of dark soil (bituminous) at top and thinner ones below. Contains Atrypa reticularis, Favosites Alpenensis, &c	10
A. Talus or sloping beach of fragments	4

The type locality was also visited by Grabau, who looked closely at the stromatoporoid-filled feature, and more fully explained its origin in 1903 (see p. 49). He judged the total section to be 50 feet (1902, p. 201). He distinguished 7 units:



Petoskey Formation at Type Locality

Locality 35-5-32 SW. Compiled from the section by Grabau (1902, p. 199-201), who called it his Loc. 39.

Bed	Thickness Ft.
g. Granular lime-sandstone (made up of coral sand) of a sandy feel; somewhat darker than the rock below and contains numer-	

ous large coral heads, which apparently grew where they are now found. Diphyphyllum panicum makes up the greater portion of this bed, appearing to be restricted to it. Associated with it: Cystiphyllum and Favosites, while Atrypa reticularis and Gypidula romingeri also occur, although sparingly .. 5.6

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

e. Masses of Stromatopora having the aspect of a brecciated limestone, or a conglomerate in which the pebbles are fragments of coralline. Where weathered, the rock shows rough surfaces, with numerous solution cavities. In some places, the lower four or five feet like the rock below -- massive and uniformly fine-grained 26

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

Shaly rock. Partings are frequently carbonaceous, thin films of coaly matter covering the laminae. No plant remains identified 0.25-1.0

c. Porous, fine-grained limestone, weathering dark brown. Much like bed a, with similar carbonaceous films and bituminous odor. Soft and friable in places. Lowest bed at the western end of quarry 3.5

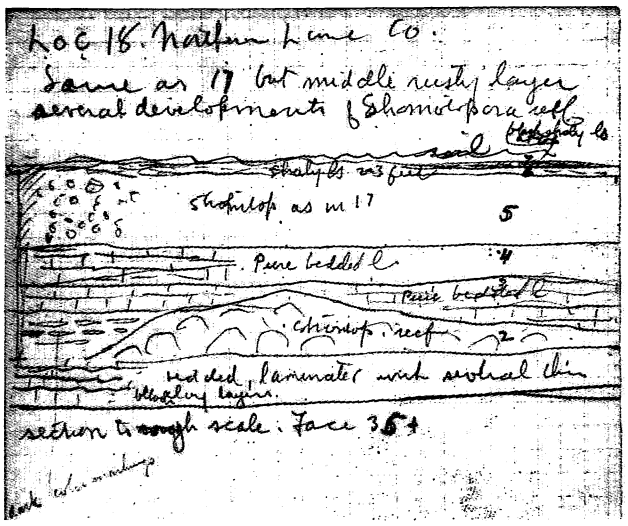
b. Light, creamy-gray, fine-grained limestone, soft and porous and with the stratification line marked by bluish bands occurring at intervals. Contains a few pelecypods (Edmondia ?) and occasionally Favosites 4

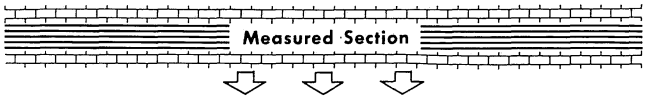
a. Dark, grayish-brown, fine-grained friable limestone, porous and with strong petroliferous odor 4

"Total exposure of rock in this section is 50 feet."

In 1926 E. C. Case made a sketch of the exposure (see below) and estimated the cliff face to be 35+ feet high. He interpreted the stromatoporoids as a reef.

Pohl published a complete section of strata at the type locality (1929), including 15½ feet of Charlevoix Limestone. He measured nearly 42 feet of strata in the Petoskey Formation.





Northern Lime Company Quarry in Petoskey

Type locality of the Petoskey Formation near the shore of Little Traverse Bay in Petoskey. Locality 35-5-32 SW (old Loc. 18). Section published by Pohl (1929, p. 14).

Zone	Thickness Ft.	In.
Petoskey formation.		
Zones undifferentiated.		
Bed 3. Granular, fine-grained, light gray limestone in heavy beds, full of isolated Stromatoporas. Partings of black shale between bedding planes. Fauna: digitate Favosites, Cylindrophyllum, compound Cystiphyllum, Gypidula	7	
Bed 2. "Cystiphyllum bed." Light gray, compact limestone in two beds, breaking into small, angular fragments. Fauna: digitate Favosites, Zaphrentis, Atrypa, Athyris, and Cystiphyllum	5	9
Bed 1. Fine-grained, brown limestone. The major portion of the thickness is composed of isolated, broken, and overturned Stromatopora heads, in some places filling the bed from top to bottom in reeflike structure. The interspaces between the reefs are filled with a thick-bedded, often foreset, matrix of fragmental "coral sand." The thickness of the bed remains constant laterally. Fauna: arbusculate Favosites, small-pitted and digitate Stromatoporas, and		

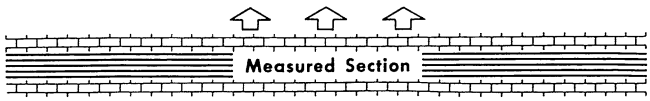
Atrypa 26

1. Bed 1. Reworked layers between the cessation of erosion of the Charlevoix beds and the beginning of prolonged deposition (?). Generally a light gray, fine-grained limestone carrying small, angular, limey fragments and with many irregular, bituminous partings. Top bed muddy, carrying a lenticular pebble conglomerate. Upper surface of underlying bed irregularly eroded ..... $1\frac{1}{2}$-3

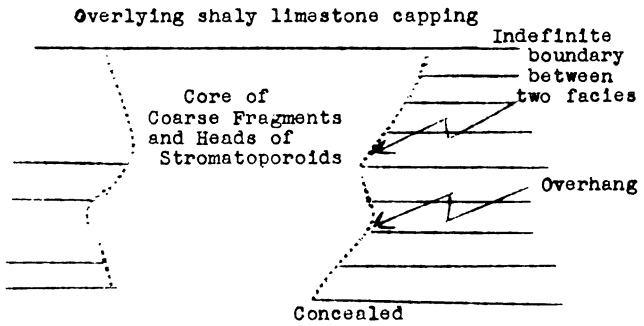
Charlevoix stage.

6 and 7. Granular, dirty, brown limestone full of wavy, bituminous laminae. Single bed 3 6

5. "Pelecypod-Gastropod Bed." Gray-brown, very fine-grained limestone. Massive and with conchoidal fracture 12



Prof. G. M. Ehlers, for one, was not completely certain of the origin of the stromatoporoid mass. In his 1949 guidebook for the Michigan Geological Society excursion, he offered this sketch:

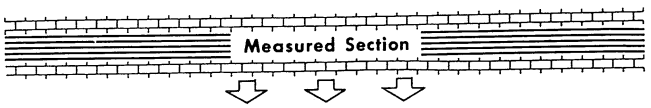


and posed a problem for the geologists to solve at the type locality of the Petoskey Formation:

> The interpretation of the exposures in this quarry furnish a controversial topic. Pohl, in his article on the Traverse, lists the occurrence of both the Charlevoix and the Petoskey. The Charlevoix is the evenly bedded, sub-lithographic to finely crystalline limestone now exposed at water level in the quarry, and for a vertical distance of about 10 feet above water level. The higher limestone poorly sorted and composed of unsorted large and small fragments, without, essentially, any signs of bedding. Is the contact an unconformable one, as Pohl says, or does it represent a rapid transition from a reef core to bordering lagunal facies? In the figure below emphasis is drawn to the indefinite contact between the two facies of limestone. Note that this contact is not sharp and that it slopes outward and upward. There is also an overhang relation between reef and flank beds.

We think the broken, worn, and overturned stromatoporoid heads were deposited on the flanks of a bioherm or reef. What do you think?

Strata somewhat higher in the Petoskey Formation are exposed in the Kegomic Quarry, which has been known by other names -- old Brewery Quarry, East Bay View Quarry, Mud Lake Quarry, and Lang's Quarry (text-fig. 54). This exposure is our Locality 35-5-27 S, about 1 mile east of Bay View; it was called Loc. 21 by the 1926 expedition. The quarry was already abandoned and partly filled with water when Ehlers visited it on 21 Aug 1926 (text-fig. 55); it was little changed except for some recent bulldozing of cover when Kesling and Kutasi were there on 25 Jul 1973 (text-figs. 18, 19, 56). Ulrich and Ehlers made the following section in 1926:



Kegomic Quarry
Old Brewery Quarry, Mud Lake Quarry

About 1 mile east of Bay View. Locality 35-5-27 S (old Loc. 21). Section measured by G. M. Ehlers, 21 Aug 1926.

Zone		Thickness Ft.
5.	Limestone with abundant fossils. Characteristic are Taenipora, Fistulipora (large ramose type), Stropheodonta sp. (mucronate type) and large sp	3
4.	Limestone above, subcrystalline with shale. Breaks up into small fragments; thickens to south. Contains usual fossils	3-4
3.	Sub-crystalline limestone interbedded with shale, filled with remnants of fossils; where weathered it is broken into small fragments. Becomes particularly shaly in upper two feet. A large and nearly smooth Gypidula and large Ceratopora characteristic of upper half. Favosites, alpenensis type. Most shaly in upper half to 2/3, particularly	

TEXT-FIG. 59 -- Petoskey Formation, type locality. Bluff west-southwest of stromatoporoid reef. Photo by Kesling, 27 Jul 1973.

so at north end of quarry. Large compound Cystiphyllum and Diphyphyllum panicum 6

2. Sub-crystalline limestone, gray, breaking into thin layers upon weathering. Abundance of Gypidula, same fauna as below 4

1. Shaly with great abundance of Gypidula -- noted at middle of arch in quarry 1

Pohl published his section of the Kegomic Quarry in 1929:

Kegomic Quarry

(Lang's Quarry, East Bay View Quarry, Old Brewery Quarry, Mud Lake Quarry)

Quarry once operated about 1 mile east of Bay View. Locality 35-5-27 S (old Loc. 21). Section published by Pohl (1929, p. 15, 16).

Zone	Thickness Ft.	In.
Petoskey formation		
Zones undetermined. Beds:		
10. Gray, shalelike limestone. Long, solitary corals. Thickness exposed ...		8
9. Fissile, black shale with minute, irregular limestone lenses and fossils weathering reddish. Fossils in shale few and crushed. Fauna: Phacops cf. rana, large Spirifer (eurytines type), mucronate Spirifer, Stropheodonta erratica and demissa, Ceratopora (large longitudinally striate), ramose bryozoa, Fenestella, Cyrtina (flat area, curved at beak), Cylindrophyllum, Hederella, digitate and arbusculate Favosites, and Cranaena	2	4

TEXT-FIG. 60 -- Petoskey Formation, type locality. Stromatoporoid bioherm or reef adjoining bedded strata. Photo by Kesling, 27 Jul 1973.

	Ft.	In.
8. Dark gray, bituminous, comparatively heavy limestone in eight-inch layers with large fucoids on fossiliferous shalelike partings. Shales composed of fossil fragments, probably deposited under more turbid water conditions. Fauna, especially the corals, abundant. Arbusculate and digitate Favosites, mucronate Spirifer, Gypidula, Stropheodonta erratica and demissa types, numerous frondose bryozoa, crinoid joints, two species of Cyrtina, Taeniopora, many types of Stromatopora, Aulopora, Striatopora, Certopora erecta type, Cystiphyllum, Cylindrophyllum panicum Winchell, and a smaller species, Fenestella, Atrypa, Athyris, Craniaena (with fine color bands), Pholidostrophia (flexed type), Conocardium species, Phacops, Athyris, and Cystodictya	3	6
7. Soft, fissile, black shale without fossils, containing inch-thick calcareous lenses with Spirifer cf. mucronatus, and Fenestellids		6
6. Buff, fine-grained, fragmental limestone in single bed becoming shaley at top. Mucronate Spirifer (most common), Favosites (arbusculate type), Ceratopora, Heliophrentis, Aulopora, many Trepostomes, Stromatopora (Idiostroma type), Gypidula, Stropheodonta erratica, digitate Favosites, Phacops species and Striatopora	3	
5. Crinoidal, fragmental limestone in thick beds, bluish grey weathering brown. Fauna as below with new elements, i.e., small Cyrtina, Fenestella, large, high-areaed Spirifer, and numerous species of Trepostomes	5	
4. "Gypidula Bed." Slightly calcareous shale doming in floor of quarry. Ex-		

TEXT-FIG. 61 -- Petoskey Formation, type locality. Bluff just east-northeast of stromatoporoid bioherm or reef. Photo by Kesling, 27 Jul 1973.

tremely fossiliferous but with few species. Great abundance of Gypidula, fine lined Spirifer, large, mucronate Spirifer, deeply sulcate Athyris, broad fronded Cystodictya ..... Quarry floor

A significant key section, one which may serve to place the Kegomic Quarry section in its proper relationship to the bluffs near the Bay View railroad station, was exposed in a ditch on the east side of Encampment Avenue, Bay View, during municipal improvements in 1933. Fortunately, the exposure was measured in detail by G. M. Ehlers at that time, for by 1938, when he returned to the site, the ditch had been filled and covered with pavement. The following section is copied directly from Professor Ehlers' notes:

Encampment Avenue Section

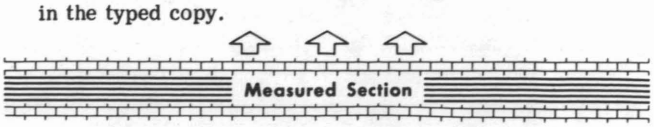
Strata formerly exposed in ditch on east side of Encampment Avenue, Bay View, Emmet County. Locality 35-5-32 E. Section extended from termination of Encampment Avenue with US 31 near Pennsylvania Railroad depot to point about 75 yards to the south (see text-fig. 3 on page 9). Measured by G. M. Ehlers, 1933.

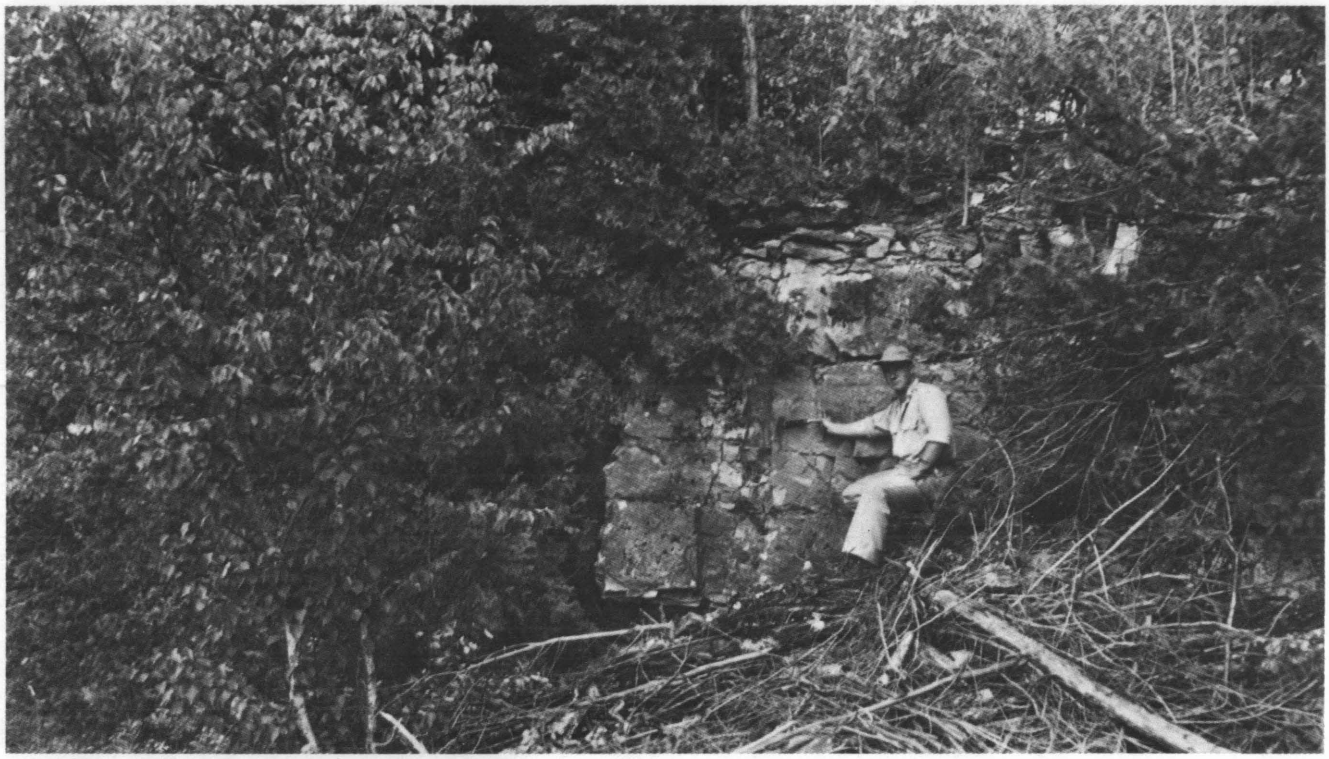
Unit		Thickness Ft.	In.
12.	Limestone, gray, very similar in lithology to interval 8. Numerous crinoid columnals; Cylindrophyllum panicum and simple corals	1	
11.	Limestone, buff to brown; friable -- probably due to weathering	1	
10.	Limestone, gray, similar in lithology to that of interval 8		10
9.	Limestone, shaley, with Favosites cf.		

TEXT-FIG. 62 -- Petoskey Formation, type locality. Close-up of bioherm or reef, showing the large truncated and broken chunks of stromatoporoids typical of the deposit. Such breakage and movement must have involved tremendous force. Photo by Kesling, 27 Jul 1973.

		Ft.	In.
	alpenensis and F. cf. nitella, Strophodonta cf. erratica and large Spirifer. Weathers into small pieces ...	1	3
8.	Limestone, gray, crystalline, with carbonaceous streaks, and petroliferous odor. Contains Spirifer of S. mucronatus type and numerous fragments of brachiopods and small crinoid columnals	1	6
7.	Limestone, buff to brown, very friable due to weathering	3	7
6.	Limestone, similar to interval 4 ...		8
5.	Shale, blackish-gray, weathering to buff and containing Fenestrellinids and Stropheodonta		4
4.	Limestone, gray when unweathered, buff-gray to buff when weathered, granular, with numerous small fragments of brachiopods, crinoid columnals and cryptostomatous bryozoa. Aulopora erecta present	1	8
3.	Shale, bluish-gray, weathering to buff and containing numerous fossils	4	
2.	Limestone, argillaceous, gray to buff-gray, with an abundance of Gypidula petoskeyensis. This interval is the same as the G. petoskeyensis bed of the Mud Lake quarry about 1½ miles to east	2	
1.	Covered interval, between contact of Gravel Point and Charlevoix formations in small exposure on shore just northeast of Pennsylvania Railroad station and base of interval 2	35+ *	

* In the original hand-written field notes, Ehlers gave the covered interval as 22'10"; the figure was increased in the typed copy.





TEXT-FIG. 63 -- Whiskey Creek Formation, type locality. Idiostroma bed above hammer held by R. V. Kesling. Ledges near Lake Michigan, a little more than a mile north of Norwood. Locality 33-9-22 SE and 27 NE (old Loc. 7c). Exposure now nearly obscured by brush and trees. Photo by G. M. Ehlers, 1949.

In the 1938 guidebook for the Eighth Annual Field Excursion of the Michigan Academy of Science, Arts, and Letters, Ehlers attempted to arrange the various units of the Traverse in a local correlation chart, using the information from his Encampment Avenue section to correctly place the Kegomic Quarry section. Because of two errors in vertical scale, the chart did not fulfill its expectations; we have corrected the scales in our text-figure 30. It indicates that the "Gypidula" (= Pentamerella) petoskeyensis zone at Encampment Avenue is at the same stratigraphic level as the middle of the Stromatopora beds at the type locality in Petoskey, and that the highest bed exposed of the Petoskey Formation is the Cylindrophyllum bed at the type locality. We do not know for certain that the "Gypidula" zone found by Ehlers in the Encampment Avenue excavations is actually the same as the "Gypidula" zone at the base of the recorded Kegomic Quarry section; most likely it is the same.

Other exposures have been mentioned in connection with the Charlevoix Ls.

Sedimentation. -- Units in the Petoskey Formation vary both lithologically and faunally. The rocks are much like those in the Gravel Point Formation, and may be assumed to have been deposited at similar depths.

The basal deposits of Petoskey age were laid down in this region as fillings in a rough and eroded topography. Although the bioherm at the type locality is the only one exposed, it is likely that others existed; indeed, they may have been rather common, inasmuch as we must judge the nature of the formation from very few localities. Other units seem to have been extensive.

Fauna. -- The Petoskey Formation, as here restricted, has yielded 34 described or listed genera of macrofossils -- far more than

TEXT-FIG. 64 -- Whiskey Creek Formation, type locality. "Cherty Beds" referred to by Alexander Winchell more than a century ago. Shore of Lake Michigan north of Norwood. Locality 33-9-22 SE and 27 NE, near middle of locality. Photo by G. M. Ehlers, 1949.

the Charlevoix Limestone (9) but notably less than the Gravel Point Formation (59) -- as shown in appendix 2. On a generic basis, the Petoskey is closer allied to the Gravel Point than to any of the formations in Alpena and Presque Isle Counties (appendix 3).

The 41 species that have been published from the Petoskey Formation include 28 found in other Middle Devonian formations in Michigan (appendix 7). Of these, only four are not present in either the Potter Farm Formation or the Thunder Bay Limestone (appendices 6 and 7). On the basis of shared species and subspecies, the faunal indices (appendix 8) reveal the closest affinity with the Potter Farm Formation.

Bryozoa are present. There are 12 species known from the formation, including only 1 not shared with other formations in the state (appendix 10). Of the shared species, 7 are found in the Norway Point Formation and 5 each in the Gravel Point, Ferron Point, and Alpena Limestone. This distribution can be interpreted as the reflection of the preferences of the bryozoan species for certain depths and sediments.

As compared with formations on the northeast margin of the Lower Peninsula, the Petoskey Formation is markedly deficient in echinoderms, mollusks, and trilobites but productive in corals and brachiopods.

The species restricted, in Michigan, to the Petoskey Formation are:

Aulacophyllum bilaterale
Bethanyphyllum robustum
Hallia zonata
Hexagonaria profunda
Syringopora crassata
Athyris lens
Atrypa traversensis
Oligorhachis littletonensis
Pentamerella athyroides
"Spirifer" consors

Strophodonta pentagonia
Strophodonta tenuicosta
Conocardium bifarum
Pentremitidea cloudi

Whiskey Creek, new formation

Type locality and name. -- We here name the formation for the Middle Devonian rocks cropping out on and near the shore of Lake Michigan between Norwood and Whiskey Creek (text-figs. 51, 63, 64). Neither the lower contact with the Petoskey Formation nor the upper contact with the Upper Devonian Jordan River Formation are exposed, although outcrops of Whiskey Creek and Jordan River are only separated stratigraphically by a few feet of covered interval.

Whiskey Creek is a small stream in southwestern Charlevoix County whose true location is shown on our map 3. On most maps its course is confused in part with that of Van Orman Creek, which lies to the south. Along the shore, outcrops of the formation do not reach the mouth of Whiskey Creek, terminating nearly half a mile south of it. In section 26, however, the long abandoned test pits extend within perhaps one-eighth mile of the creek.

The Whiskey Creek Formation includes the strata called the "Chert Beds" by Winchell at the type locality, which he termed Loc. 884 (1866, p. 47). Even at this date, Winchell was not the first geologist to study the rocks there, for the first State Geologist, Douglass Houghton, wrote about the "hornstone" layers and must have come ashore to examine the outcrop. Later, the place was visited by Rominger, Grabau, and others.

As shown in the following generalized section, the dolomites and dolomitic limestones containing the chert are bounded below and above by limestone units, which we also assign to the Whiskey Creek Formation. Although the succession of these units could be firmly established in 1949, when most of the collections were made for the Museum of Paleontology at The University of Michigan, the numerous changes in amount of dip made estimates of the covered intervals suspect. Now, the condition of the outcrops would make it difficult to even locate some of the units, and further study of the formation could only be done with bulldozer and/or numerous drill holes.

Units Exposed Along Shore of Lake Michigan North of Norwood

(with University of Michigan Collection Numbers)

Norwood Shale

Black fissile shale, a few feet at most, about 1 1/8 mile north of village limits.

Covered - about 10 feet (13 feet at most).

Jordan River Formation

Pugnoides-Melocrinus Shale. Gray soft shale, easily breaking down to release fossils. Does not form exposure on shore, but seen at water level or below. May reach 3 feet.

Schizophoria-Actinoptera Beds. Grayish-green soft argillaceous limestone, fossiliferous. Accessible only at low-water stages of Lake Michigan, NE$\frac{1}{4}$ sec. 27, T 33 N, R 9 W, about west of black shale outcrop. Most of fauna recovered from slabs from very shallow water; on beach readily covered over by sand and rubble. Only a few feet thick. 1948/D-13, 1949/D-11, 1956/D-42, 1958/D-29; collected together with overlying unit.

Whiskey Creek Formation

Upper Limestone. Argillaceous limestone, very thinly and irregularly bedded, containing Favosites of more or less dumose form. Exposed near shore about 1/8 mile north of black shale. 1946/D-15, 1949/D-10 (interval 10).

Coarse Dolomite. Brown coarsely crystalline dolomite. No fossils recorded. 1949/D-10 (interval 9).

Chert Bed. Dolomitic limestone to calcareous dolomite, with stringers and nodules of chert at intervals (closely spaces in some parts of cliff). Perhaps reaching 10 feet in discontinuous exposures. Some Favosites in non-cherty beds. 1949/D-10 (interval 8).

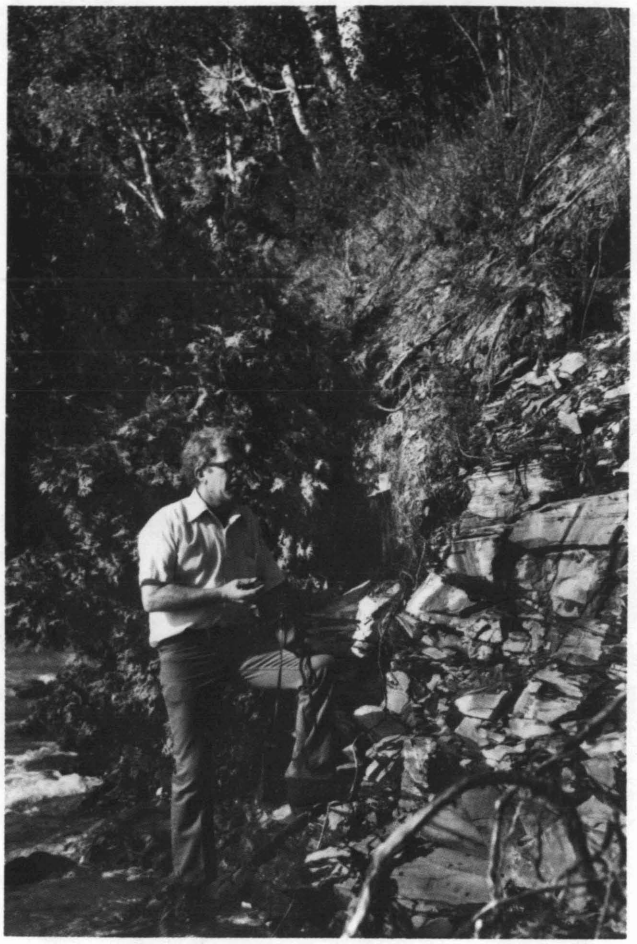
Stromatolite Bed. Sublithographic limestone with thin banding interpreted as stromatolites. No fossils. Probably thin unit. 1949/D-10 (interval 7).

Idiostroma Bed. Limestone with numerous stromatoporoids of Idiostroma type, weathers brownish-gray to gray. At soil level, some stroms partly silicified and weathered in sharp relief. Exposed along old road and on beach about 1200 feet north of blac k shale. 1946/D-16, 1949/D-13.

Covered - about 25 feet.

Atrypa Bed. Gray limestone, weathering brown, about 1 to 2 feet thick. Highly fossiliferous, with numerous Atrypa specimens weathered free. Exposed on shore about 0.3 mile north

TEXT-FIG. 65 -- Norwood Shale, type locality, about 1 mile north of Norwood. Locality 33-9-27 NE (old Loc. 7a). Black thin-bedded "paper" shale exposed on east side of Lake Shore Drive, a very secondary road between Norwood and Whiskey Creek. Photo by Kesling, 29 Sep 1973.



TEXT-FIG. 66 -- Antrim Shale near type locality, about 1 mile south of Norwood. Sorensen stands on one of the narrow strips of beach available at high-water level. Photo by Kesling, 29 Sep 1973.

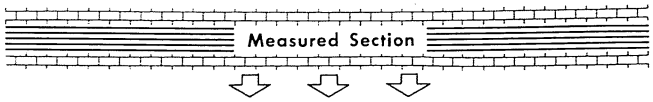
of black shale and on old road about 0.4 mile north of shale. 1946/D-14, 1949/D-10 (interval 3), 1971/D-29.

Bryozoa Bed. Gray limestone crowded with Fenestella type bryozoa, weathered in relief on surfaces. Numerous plates of crinoids, including Megistocrinus, Dolatocrinus, and a calceocrinid. Exposure about 1½ miles north of Norwood. 4 to 5 feet thick. 1949/D-10 (interval 2), 1971/D-30.

Lower Limestone. Buff-gray to gray thin-bedded limestone, weathering buff, unfossiliferous. About 1 foot exposed. 1949/D-10 (interval 1).

Covered to mouth of Whiskey Creek and beyond.

Sections. -- The type locality is Locality 33-9-22 SE and 27 NE, the popular exposure seen by many of the early geologists. The place holds archaeological interest also, for long ago the early inhabitants of the region went there to procure flint for making arrow heads and implements. The cherty beds of the formation constitute the Pi-wan-go-ning prehistoric site, as recently described by Cleland (1973, p. 85-87). The first measured geologic section was made by Alexander Winchell:

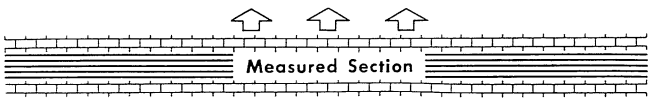


Whiskey Creek Formation at Type Locality

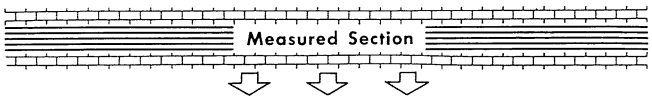
"Chert Beds" measured by Winchell (1866, p. 47) at his Loc. 884, incorrectly located as "NE¼ sec. 34, T 33 N 9 W"; approaching the exposures by small boat, he made errors in land-survey locations which are both understandable and forgivable. The extent of unobscured strata was then greater than it is now.

Bed	Thickness Ft.
E. Limestone, gray, in beds one to two feet thick, very hard, with cavities containing sulphide of iron, and calcareous spar	11
D. Limestone, gray, in laminae a quarter of an inch thick, with intervening sheets and concretions of chert. Contains a few Favosites	9
C. Limestone, brown, in beds one foot and less in thickness	4
B. Limestone, bluish, shaly	1
A. Limestone, bituminous, irregular, broken	1

The dip here is toward the southeast.



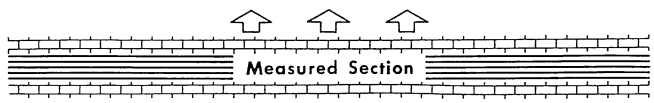
A more extensive section was made thirty-six years later by Grabau:



Whiskey Creek Formation at Type Locality

About 1 mile north of the pier at Norwood. Locality 33-9-22 SE and 27 NE. Section measured by Grabau (1902, p. 208, 209) as his Loc. 51.

Bed	Thickness Ft.
51G. Darker dolomite, compact but crystalline, and containing fossils which weather out in relief and cavities from which pyrite concretions have weathered out. The cavities are stained by iron hydrate, and besides these there are numerous drusy cavities similar to those in F. Near the middle of bed G is a half-foot bed full of a small, undetermined bryozoan. Stromatopora, Favosites, and a few other fossils also occur. Beds F and G practically inseparable	4.5
51F. Gray drusy dolomite, finely crystalline, and effervescing only on powdering with strong HCl	5
51E. Shaly limestone similar to A, but more fossiliferous, containing Spirifer cf. eatoni, Cyathophyllum, Goniophora, and other fossils	5
51D. From the point where the top of bed B dips below the water to the point where the top of bed D dips below the water, is about 300 feet. This, with the dip of 5 degrees, gives a thickness of about 26 feet for beds C and D, or of 21 feet for bed D. The top of the stratum shows beds whose surface are ripple-marked (oscillation ripples) and marked by sun-cracks. These beds are argillaceous limestones, readily effervescing in dilute HCl	21
51C. Slaty limestones and slates, very fissile, in beds up to a foot in thickness, and separated by beds of banded chert 1 to 2 inches thick	5
51B. Compact, fine-grained dark limestone in beds varying from 2 to 6 or even 12 feet (sic!) in thickness, and containing lenticular nodules of chert, the nodules sometimes nearly a foot thick	3
51A. The lowest exposed stratum has its upper surface about 5 feet above the water level. It is an argillaceous, shaly limestone, thin-bedded, and weathering a dark color. Near the top it contains specimens of Favosites, which were generally broken or worn before they became embedded in the rock. With them occur Atrypa reticularis	2-3
Total	45.5 to 46.5



From this same exposure, Winchell (above) had recorded 26 feet of strata, and Rominger (1876) said about 25 feet. The records of nearby wells (see our table 2) would support the lesser figures of measurement. Perhaps the average dip was not as much as the 5° assumed by Grabau.

An interesting but no longer clearly exposed outcrop of the Whiskey Creek Formation is at Locality 33-9-26 N (old Loc. 7b). The place was first noted by R. A. Smith (1916, p. 194):

> About 1½ miles northeast of Norwood, NE. ¼ section 26, T. 33 N., R. 9 W., high calcium limestone is exposed in a number of places along the top of one of the upper terraces and at the base of a series of ancient sand dunes. The area of the terrace at this point is considerable but the area of accessible limestone could not be determined. Apparently it is several acres.

> About 5 feet of light gray dense grained to lithographic limestone was exposed in two small openings formerly operated for lime burning. Other openings are reported in this vicinity but these were not discovered. Nothing could be learned as to the probable thickness of this bed.

The 1926 field party recorded the place only as "1 mile north of Norwood, about center of sec. 26, T. 33 N., R. 9 W." and noted:

> About 25 feet of very finely crystalline limestone, cream colored, exposed in small pit and on ridge. Limestone must be very high in $CaCO_3$. The black shales of the Antrim not seen in contact with this limestone but are present a short distance to the eastward in the brush. Contact reported by Winchell and Smith. Ask Smith about nature of contact.

When Kesling and Sorenson visited the site on 29 Sep 1973, the exposure was so changed that they doubted whether they were at the right place. Fortunately, Sorenson had brought along an old field map, probably constructed by pace and compass, made by R. A. Smith of the Michigan Geological Survey many years ago. This map was particularly accurate in the location of streams, which are incorrectly shown on the land plat map and on the county highway map. The exact site of the main pit, described under Localities, was confirmed by conversation with Mr. George Light, Sr., who had served as the local commissioner for many years. Slump and subsequent gravel operations have combined to reduce the original exposure to a rubble-covered flat. The fossils and lithology of the rock pieces suggest that the strata are above the cherty beds and below the Jordan River Formation. A thorough search of the vicinity did not disclose any black shale.

Other small pits were shown on Smith's map to lie in the NW$\frac{1}{4}$ sec. 26. Kesling and Sorenson followed a secondary access road to the place. All they could find were some small pits, at most a few feet across, filled with chunks of concrete -- presumably rubble from demolition of an old bridge. The limestone, thought to be in place, was similar to that in the main pit. No fossils were noted.

The exposure is involved in a local structure. It is south of the line through the exposure of Norwood Shale in section 27. Hence, the contact of Norwood Shale/Jordan River Formation must swing sharply to the southeast somewhere between Locality 33-9-27 NE (type exposure of the Norwood Shale) and Locality 33-9-26 N (this exposure of upper Whiskey Creek Formation).

The only other outcrop of the formation occurs some miles away at a point of land extending into Lake Charlevoix on the west side of Horton's Bay. Prof. Case was there on 6 Aug 1926 and observed:

> Reef of small corals associated with other fossils. Man at place says limestone penetrated 120 feet. Remnants of concretions (as at Norwood) on beach.

Slabs of the rock were collected by G. M. Ehlers on 6 May 1938 and accessioned at the Museum of Paleontology as 1938/D-29. In his field notes, Dr. Ehlers referred to the place as "Harmon's Cove," although the name does not appear on present maps.

The Whiskey Creek Formation at this exposure is involved in structure which exposes the Norwood Shale just three miles to the west-northwest at Camp Kairphree (now Camp Sea Gull). As shown on map 2, we call the intervening structure the Camp Sea Gull Syncline and interpret the Whiskey Creek Formation outcrop as near the axis of the Horton Bay Anticline.

Sedimentation. -- The lower part of the exposure at the type locality has lithology very similar to that of the Petoskey Formation at the top of the Curtiss Quarry section (Locality 34-6-6 SW), as described by Pohl above. For the present, we put these beds into the Whiskey Creek Formation, leaving the nature of the formational boundary for future determination.

The cherty beds in the middle of the formation are unique in the Traverse Group.

Fauna. -- In the faunal check lists compiled by Stumm (1951, 1961) the rocks here included in the Whiskey Creek and Jordan River formations were included in the "Upper Petoskey." The sparsity of published species from this area north of the black shale in southwestern Charlevoix County weakens the correlation with Middle Devonian formations in Alpena County. Only 16 genera are listed by Stumm for the Whiskey Creek-Jordan River sequence (see appendix 2). Only one species -- Trachypora proboscidialis Stumm & Hunt -- is found in

a formation of northeastern Michigan; it is present in the Thunder Bay Limestone. We suspect that other species are shared by these two formations, but their records are not taken into account by Stumm. Cooper et al. (1942), for example, call attention to the blastoid Heteroschisma gracilis (Wachsmuth), formerly placed in the genus Codaster, as common to the Thunder Bay Limestone and the Middle Devonian strata exposed north of Norwood.

In his study of Traverse Group brachiopods, Imbrie (1959) found three species of Strophodonta -- S. heteromys, S. levidensa, and S. rhabdosis -- all of which he listed as from the "uppermost Petoskey formation." We have not ascertained which of these came from Whiskey Creek and which from Jordan River beds.

Here is a potential thesis problem, establishing the exact faunal content of the Whiskey Creek Formation.

In the Bryozoa Bed of the section above, crinoids are represented by numerous plates; none are complete enough for specific indentification. Careful collecting might discover one of the Megistocrinus species in common with the Thunder Bay Limestone. In this bed, one conspicuous bryozoan is Scalaripora, with numerous sections of the characteristic "little ladders" once exposed on the surface of the outcrop.

The Atrypa Bed is crowded with specimens of an unidentified species of this brachiopod. A few other genera of brachiopods are also present.

The Idiostroma Beds are easily recognized by the presence of numerous of these branching pencil-thin stromatoporoids; a few Favosites also occur.

Above the Idiostroma Beds the fauna consists of a few kinds of corals. They appear to match the more abundant corals found in the exposure at Horton's Bay.

Jordan River, new formation

Type locality and name. -- The formation is here created for Upper Devonian strata exposed below the black shale along the Lake Michigan shore in southwestern Charlevoix County, about a mile north of Norwood at Locality 33-9-22 SE and 27 NE. This exposure lies within the boundaries of the Jordan River State Forest as shown in county plat maps and in our map 3.

The strata have previously been included in the Petoskey Formation, although Cooper et al. (1942, p. 1777) noted that the uppermost strata contained a fauna equivalent to that of the Sherburne Sandstone of the Skaneateles Lake region in New York state.

Unfortunately, the type locality is the only known exposure, and even it is inaccessible during stages of high water on Lake Michigan (text-fig. 67).

Sections. -- Because of the soft nature of the beds, the formation is not seen in contact with the Whiskey Creek Formation below nor with the Norwood Shale above, although it is exposed within about 10 feet of the latter. One might anticipate that the Upper Devonian Jordan River contact with the Middle Devonian Whiskey Creek will prove to be unconformable, inasmuch as the two appear to be equivalents to time-separated units in New York.

Cooper et al. (1942) stated:

> Above the Thunder Bay equivalent occurs a fauna that must be assigned to the Upper Devonian (Sherburne). Here occur a few feet of thin-bedded limestone and soft shale (?) containing Actinoptera, Schizophoria, Leptaena, and large Pentamerella. On top of this zone an undetermined thickness of shale (not over 3 feet) contains nodose Melocrinus, "Reticularia" cf. "R." laevis, and Pugnoides. The presence of the last two places the upper fauna as Sherburne ("Reticularia laevis") age. The "Reticularia" bed is overlain by black shale and greenish-gray limestone containing Styliolina and Buchiola which are correlated with the Naples (Cashaqua).

The lower unit which we assign to the Jordan River Formation is the Schizophoria-Actinoptera Beds. These characteristic fossils are very numerous in a few feet (at most) of grayish-green soft argillaceous limestone. Although the rock weathers very easily and does not form any extensive shelf along the shore, it is still more resistant that the overlying unit.

TEXT-FIG. 67 -- Site of Jordan River Formation type locality, the exposures now under water. Photograph taken from shore of Lake Michigan near outcrop of Norwood Shale looking northwest. Jordan River locality is somewhere near the point of land at the left. Photo by Kesling, 29 Sep 1973.

The upper unit is the Pugnoides-Melocrinus Shale, a soft gray shale forming a loose matrix around fossils, which are released by wave action whenever the water level is low enough to reveal the exposure. The non-resistant nature of the shale makes it difficult to estimate its thickness, but it probably has never exceeded 3 feet in the portion seen. The fossi from this unit are for the most part in the collection of the U. S. National Museum, having been given by Ehlers and others to Dr. G. Arthur Cooper for study.

Sedimentation. -- The color and texture of the beds is more nearly like that of the underlying Whiskey Creek than that of the overlying black shales. For that reason, the Jordan River is regarded as the uppermost Traverse Group formation.

Fauna. -- This needs further investigation! We can be certain that it is Upper Devonian and probably most closely related to the fauna of the Sherburne, as Cooper et al. suggested in 1942.

The Rhipidomella reported by Imbrie (1959), R. trigona Imbrie, was said to also occur in the Enfield Shale of New York. If this identification is correct, then the Jordan River Formation may be even younger than suggested by Cooper et al., equivalent to the Naples Group rather than the Genesee Group of New York state. Our present correlations would place the Jordan River as younger than the Squaw Bay Limestone of Alpena County, Michigan.

Overlying Upper Devonian Shales

Above the Traverse Group, including (as we do) the Upper Devonian Jordan River Formation, is a thick series of "black" shales resembling those in other parts of the Michigan Basin -- the Ohio Shale in central Ohio and east-central Kentucky, the Huron Shale in northwestern Ohio and southern Michigan, and the Kettle Point Shale in Ontario. The divisions of these shales in northern Michigan could be debated. Most workers prefer only two divisions, the black Antrim Shale below and the greenish Ellsworth Shale above. However, Cooper et al. (1942) recorded Styliolina, Paracardium, and Buchiola in some "hard greenish layers at the base of the black shale" a mile north of Norwood, at our Locality 33-9-27 NE (old Loc. 7a); furthermore, in their correlation chart, they divided the Antrim in two parts with a lower "'Antrim black shale" containing Buchiola and Paracardium and an upper typical "Antrim black shale."

Norwood Shale

It is of special interest to note that Rominger (1876, p. 66, 67) reported that

> North of Norwood, the black shales form bluffs 10 or 15 feet in height, which, rising a short distance back from the shore line, repose on the ledges of the dolomite beds of the Hamilton group.

Curiously, no other geologist has ever seen the contact of the black shale with rocks of the Traverse Group, and for many years no exposures of black shale were known at all north of the village of Norwood.

North of Norwood, at Locality 33-9-27 NE (old Loc. 7a), the 1926 expedition failed to find any black shale. Pohl and Raasch in 1927 did not find an actual outcrop, but they did find some concretions; with a few minor changes, their notes were published by Pohl (1929, p. 16, 17), who stated:

> Near the southernmost exposure some large "kettles," radially arranged anthracolite concretions having as a usual nucleus an arthrodiran plate, weathered from the immediately succeeding Waverlian black shale were observed, but no black shale was seen in contact with the underlying Petoskey beds.

The first appearance of the name "Norwood" for the shales exposed north of Norwood was by G. M. Ehlers in the 1938 guidebook. He did not define the term in any way, but listed the Norwood Shale as the overlying formation of the Squaw Bay in the Alpena area (see our text-fig. 75) and the "Petoskey" in the Norwood area (see our text-fig. 30). In addition, in his field maps developed over a number of years, Ehlers distinguished between the shale of the kind exposed north of Norwood (the Norwood Shale) and the shale of the kind exposed south of Norwood (the Antrim Shale). We follow his practice.

One difficulty predominates. The name "Norwood" was used in stratigraphy for the Norwood Tuff of the Oligocene Salt Lake Group in central Utah by Armand J. Eardley in 1944. Although Ehlers' usage predates Eardley's, the latter is given preference in the lexicon of geologic names by the United States Geological Survey -- and with justification, since Ehlers failed to accurately define the locality, nature, or extent of the Norwood Shale in 1938. This technical deterrent does not keep us here from discussing the Norwood Shale, although we might properly have placed the name in quotes throughout.

At the "type locality" (text-fig. 65) the Norwood Shale is a few feet exposed of black paper-shale lithology. The concretions reported by Pohl in 1929 had evidently all disappeared, possibly into rock gardens somewhere, by the time the locality was visited by Ehlers and Kesling in 1949.

Black shale of the Norwood type was seen in 1926 in a quarry at Kamp Kairphree on the shore of Pine Lake, at Locality 33-7-3 NW (old Loc. 3). The names have now changed to Camp Sea Gull on Lake Charlevoix. The exposure probably was the one seen by Rominger and reported (1876, p. 67) "on Pine Lake." We have not revisited the place to see the present state of the old quarry. On 6 Aug 1926, Ulrich and Ehlers made the following notes:

> Black shale. About 20 feet exposed, with concretions 4-5 feet in diameter at base. Conodonts.

TEXT-FIG. 68 -- Antrim Shale. Shore exposures south of Norwood. Locality 32-9-3 E SE, at or near type locality. Present high-water level of Lake Michigan limits exposures. Photo by Kesling, 29 Sep 1973.

Different from those found at Loc. 1 (south of Norwood) and probably come from different (probably lower) position in lower black shale of the Antrim. Forms are Miss. types.

E. C. Case was there, too, and made the following independent observation:

20-25 feet black shale, conodonts. Large concretions at base of quarry & one high up in shale. These concretions more shaley & some with large cracks & cavities filled with crystals (septaria-like). Upper concretions more shaley and pass into shale on sides. None with so decided a prismatic arrangement of certain zones as in those in L. Miss. near Norwood. Ulrich says few hops higher zone than Norwood because of characteristic conodonts. This to be proved.

Thus, we see that the skepticism of Case with regard to Ulrich's and Ehlers' interpretations extended right across the Middle-Upper Devonian boundary without unconformity.

Antrim Shale

Type locality and name. -- These black shales were called the St. Clair in the 1892 report of the Michigan Geological Survey, but this name was preoccupied. A. C. Lane in the 1 Sep 1901 issue of the Michigan Miner was first to apply the name Antrim in print. The following year (1902, p. 209) Lane again used the term and applied it to black shale exposed in low cliffs along the shore "about half a mile south of the pier at Norwood."

The locality which is thus the type locality is in Antrim County and was known long before the description by Lane. The black shales south of Norwood were noted by C. C. Douglass in House Document No. 27 (1841, p. 108) and by Alexander Winchell about twenty years later.

In 1876 (p. 67) Rominger, in addition to his unique report of black shale resting atop dolomites of the "Hamilton group," wrote that:

> South of Norwood village, the shales come close up to the shore in vertical bluffs... the total thickness of strata seen in the bluffs, and in the hillsides rising behind them, is not over 35 or 40 feet.

Sections. -- About a mile south of Norwood, at or near the type locality designated (indirectly) by Lane, at Locality 32-9-3 E SE (old Loc. 1), Ulrich and Ehlers on 5 Aug 1926 photographed (text-fig. 69) and recorded:

> About 15 feet of black shale exposed, with lenses and concretionary masses of vertically (radially) arranged structure. Masses consist of hard calcareous and bituminous material. Conodonts and Sporangia, and strap-like leaf (Pseudobornia or new genus, Ulrich Ms.) Conodonts and leaf suggest Miss. age of beds.

At the same time and place, Prof. Case was writing in his notebook:

> Contact of the black shale with the Traverse probably near the dock at Norwood. The large concretionary masses show radial arrangement of prismatic appearing structures -- perhaps crystals of (?) siderite. Reminiscent of concretions at Alpena but not spherical. Ulrich suggests algal or other organic origin for the prisms. Some poor fragments of fish bones in the nodules. Many with cavities in center as at Alpena. Sporangites, conodonts, plants in shale.

In the Pohl and Raasch expedition, the notes at this type locality are credited to Pohl and placed in quotation marks. Whether these were ever published we do not know.

> ½ mile south of Norwood there are several series of 10-15 foot cliffs composed of black shale of Mississippian Age carrying the typical kettles and fauna of the Huron and appearing exactly like the exposure at Kettle Point, Ont. Conodonts of the Mississippian type of Polygnathus and Prionodus are rather abundant, and Sporangites occurs thruout the section. At water level occur several thin beds of mottled shales, the mottling of which is due to worm borings and films of Taounurus some of which reach diameters of nearly 1'. One bed of about an inch in thickness contains pelecypods, etc. The concretionary masses which often reach a diameter of 6-10 feet and have a radially crystalline structure, and whose nucleus (often) consists of the plates of armored fishes, are most frequently depressed spherical and irregular(ly) appear in bands above the water surface. Smaller concretions of pyrite occur quite abundantly in several other bands near the water's edge, and are sometimes perfectly spherical, having diameters of about ½ inch.

These exposures are still available (text-figs. 66, 68), although limited by the present high water of the lake.

Black shale is also near the surface two or three miles south of Boyne Falls. On 7 Aug 1926 Prof. E. C. Case was there and entered in his notebook:

> Black shale with conodonts found in drift on hillside. No exposure but reported by Polish farmer to occur 4-5 feet below surface, exposed in digging "potato hole" and barn foundations as a solid floor.

There was some reason for doubt in Case's mind, for he did not trust the farmer's information with any more confidence than he accorded some of Dr. Ulrich's interpretations; he ended his entry with:

> (This Polish farmer did not clearly understand questions and his reports to be taken with care.)

Still another locality in this region with black shale of the Antrim type was known to Rominger, who said (1876, p. 67),

> ... near Bear Creek the railroad to Petoskey has laid open several sections through them, showing sparry, globular concretions inclosed.

An interesting exposure seen in 1926 was a small pit along the road leading west from Indian Garden (Lake Grove Road) at the edge of Echo Beach, near the border in Emmet County, our locality 33-6-1 S. This locality was Loc. 20 of the expedition in 1926, and described by Case as "north shore of Walloon Lake, 5½ miles south of junction of Walloon Lake road and M 11"; Case commented:

> Black shale in contact with blue-yellow shale above. Black shale heavier here and more solid. A few conodonts found. Top and bottom not seen.

This exposure is probably Antrim Shale rather than Norwood Shale.

Still another exposure of Antrim Shale is at Locality 33-6-30 NE SE, which was Loc. 70 in the final 1926 list. Here, along the south shore of Lake Charlevoix about 3/4 mile north-

west of Advance, at a place now called Fairview Beach Resort, black shale was exposed for many years on both sides of Ferry Road. We have not visited this locality recently and cannot say whether the shale is still visible in the roadside ditches.

At Locality 33-5-15 NW (old Loc. 6), in a ditch beside the north-south River Road (parallel to Pennsylvania Railroad tracks) and in an exposure $\frac{1}{4}$ mile south of Walloon Lake station in Charlevoix County, Ulrich and Ehlers saw black shale in 1926 and recorded in their field notes:

> Black shale in low road side cut with Sporangites and 2 species of lobate genus of Polygnathus, 1 species each of Gnathodus and Polygnathus. Other types of conodonts not observed; this absence and other reasons suggest that the exposures are somewhat higher than the black shale seen in Sec. 3, T. 33 N., R. 7 W., on the shore of Pine Lake (Location 3).

Distribution of the black shales over much of the region can be extrapolated from nearby well records.

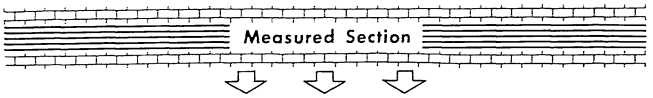
Ellsworth Shale

Type locality and name. -- Although for many years the formation was known informally as the "green shale" or the "shale near Ellsworth," it was not named in literature until 1932. In that year R. J. B. Newcombe (p. 159) referred to the Ellsworth Shale as the rock underlying the Marshall and Coldwater formations and overlying the Antrim Shale in the Muskegon oil field. He did not designate a type locality or further define the Ellsworth at that time. The following year (1933, p. 22, 49), however, he stated that the best exposure was $1\frac{1}{2}$ miles south of Ellsworth in the Petoskey Portland Cement Company's quarry in NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 26, T 32 N, R 8 W, Banks Township, Antrim County, Michigan; he also presented a detailed section at that time.

Subsequently, there has been much discussion of the age of the formation. Possibly, part of the formation may be Mississippian; but the lower part, at least, we regard as Upper Devonian and so include the Ellsworth here.

Sections. -- The type locality, Locality 32-8-23 SE (old Loc. 2), in the shale pit south of Ellsworth (text-fig. 72), is still the scene of active quarrying. It was part of the properties of the Petoskey Portland Cement Company that were sold to the Penn-Dixie Cement Corporation.

Here on 5 Aug 1926 Ulrich and Ehlers made the following section:



Petoskey Portland Cement Company Shale Pit

About 1 mile south of Ellsworth. Locality 32-8-23 SE (old Loc. 2). Section measured by Ulrich and Ehlers, 5 Aug 1926.

Zone		Thickness Ft.	In.
Drift		5-24'	
3.	Shale, greenish-gray, plastic when wet; contains a few bands of sandstone 1 to $1\frac{1}{2}$ inches thick	24	
2.	Argillaceous sandstone, olive, with reddish tinge. Rill marks		3-3$\frac{1}{2}$"
1.	Shale, greenish-gray and plastic when wet. Contains Sporangites which suggest Chara	36	6

According to Mr. Paul J. White, Supt. of Pit, 40 feet of green shale present below bottom of pit, shown in well drilled for water. Black shale encountered below the 40 feet of green shale. Gas came from well and was ignited. Hole now plugged. Mr. White stated that small bits of coal were sometimes encountered in the greenish-gray shale....

As Prof. Case studied this shale pit near Ellsworth on that day, he wrote in his field notes:

> 60+ feet exposed. Gray-green or gray-blue shale. Fine laminae breaking into small blocks & layers on weathering. All layers show large or small marks of flowage. Occasional sandy lense-like layers near top with coarse flowage marks on top. Clay olive-green on decay near top. Sporangites, worm tracks, & peculiar wiggly black thread-like thing. This shale above black shale. Base of quarry 60 feet above black shale & shale penetrated 40 feet in well, bottom not reached.
>
> Ulrich says both this & black shale Miss.; suggests Lineata (New Providence) or a higher Miss. shale as equivalent. Suggestion based on conodonts largely. No concretions in this shale but color banding from bluish to purple. This

shale does not rust as black shale & is a different thing, not a phase of black shale.

At the abandoned shale pit of the Boyne City Brick Company, Locality 33-6-25 SW (old Loc. 5), on 6 Aug 1926, G. M. Ehlers measured 60 feet 6 inches of greenish-gray shale and recorded Sporangites throughout the section. Dr. Ulrich concluded that the shale was the same as that they had seen at Ellsworth. In his notebook at this stop, E. C. Case wrote, "Only Sporangites found, no conodonts."

About 7 Aug 1926 the combined party reached exposures in "Road side at road corner about 1/8 mile E. of SE corner Sec. 10, T. 33 N., R. 5 W., and in railroad cut adjacent." This is Locality 33-5-15 NW (old Loc. 6). Ulrich stated:

Black shale in low road side cut with Sporangites and 2 species of lobate genus of Polygnathus, 1 species each of Gnathodus and Polygnathus. Other types of conodonts not observed; this absence and other reasons suggest that the exposures are somewhat higher than the black shale seen in Sec. 3, T. 33 N., R. 7 W., on shore of Pine Lake (Location 3).

The 1926 party observed Ellsworth Shale again, on the shore of Lake Michigan (Grand Traverse Bay) about one mile southwest of Eastport in Antrim County, at Locality 31-9-12 C (in the 1926 notes called Loc. 7; later changed to Loc. 67). Ulrich and Ehlers said:

Greenish-gray shale exposed in side of dune, shale contains Sporangites and shows rill marks. About 15 feet exposed. Shale rises in passing SE along shore. Shale is same as that exposed in Loc. 2.

Prof. Case said:

Aug. 7. To point on L. Mich. 8 or 9 mi. south of Norwood. Just beyond Abbott's garage. Here 6-8 feet of blue (upper) shale. Sporangites, black wiggles, flowage, etc. = Petoskey Portland Cement (lower part). This extends out under water.

On the same day, 7 Aug 1926, the field expedition was at an abandoned shale pit in the NW$\frac{1}{4}$ sec. 24 about 1 mile northeast of the center of East Jordan. In the field notes they referred to the pit as Loc. 7a, but this was later changed in the master list of localities to Loc. 69. It is here Locality 32-7-24 NW. Ulrich observed (and Ehlers duly recorded):

About 27 feet of greenish-gray shale exposed. Shale same as that of location 2. Sporangites present.

STRUCTURE

As exposed, the edges of the Devonian formations in Emmet and Charlevoix Counties are crimped around the Michigan Basin like the crust of an old-fashioned pie. Two significant differences mar the analogy. First, the folds observed in the outcrop area are not confined to a marginal zone; subsurface records indicate that they continue downdip into the basin for at least an appreciable distance. Second, the folds are of various magnitudes, as though the "crimps" themselves were finely crimped. We can divide the discussion into "major folds" and "minor folds" without accurately defining the limits of either. In general, the major folds affect the strike of the beds over two miles in either limb, whereas the minor folds are more of the order of a fraction of a mile. As can be seen in map 2, however, the major folds are not all of the same sharpness (dips) nor of the same horizontal extent (spread).

Pohl (1929, p. 6) summed up the general pattern of folding in the region thus:

Local deformation of small magnitude but extreme complexity has so confused the general attitude that it is possible to state only the already well known fact, that to the north lower and lower rocks appear on the surface where the cover of drift has been removed, and that to the southward the Middle Devonian disappears from sight under the younger black shales and later beds to reappear again for the first time in northern Ohio.

Major folds. -- The region of study is bounded on the east by the broad Kegomic Quarry Syncline and on the west by the equally broad Charlevoix Syncline. Between them are (from east to west) the small gentle Penn-Dixie Syncline, the sharply folded Nine Mile Point Syncline, and the Camp Sea Gull Syncline. Between these synclines are the following anticlines: Bear Creek, Walloon Lake, Horton Bay, and Oyster Bay. Axes of all structures are northwest-southeast.

The Kegomic Quarry Syncline, developed between the eastern limit of Emmet County and the valley of Bear Creek, exposes the Petoskey Formation at Kegomic Quarry north of the line through the outcrop of the underlying Charlevoix Limestone at Bay View. This relationship can be substantiated by well records and the formational boundaries extended to the east, where the strata are concealed beneath the drift. The western limb of the syncline is complicated by minor folds (anticlinal) in the vicinity of eastern Petoskey and Bay View. The stratigraphic positions of the strata in this region were not clear to Winchell, who placed the Petoskey Formation beds exposed at the type locality below the Gravel Point Formation beds exposed west of Petoskey.

The Bear Creek Anticline is here named because its axis lies close to the course of Bear Creek. The structure is outlined by exposures of the Charlevoix Limestone. From the Charlevoix exposed at Locality 34-6-2 SW (east end of Penn-Dixie Quarry) to Locality 34-6-1 SE (site of the Antrim Lime Company Quarry in western Petoskey), the strike is WNW-ESE -- practically west-east; near Bear Creek the strike veers to nearly south-north, so that the Charlevoix is near water level at Locality 35-5-32 SW (old Northern Lime Company Quarry, type locality of the Petoskey Formation). Before the expansion of the town, Rominger saw rocks exposed in the creek at several mills; unfortunately, the sites can no longer be recognized nor the strata seen, so that we are unable to locate the axis of the anticline more accurately.

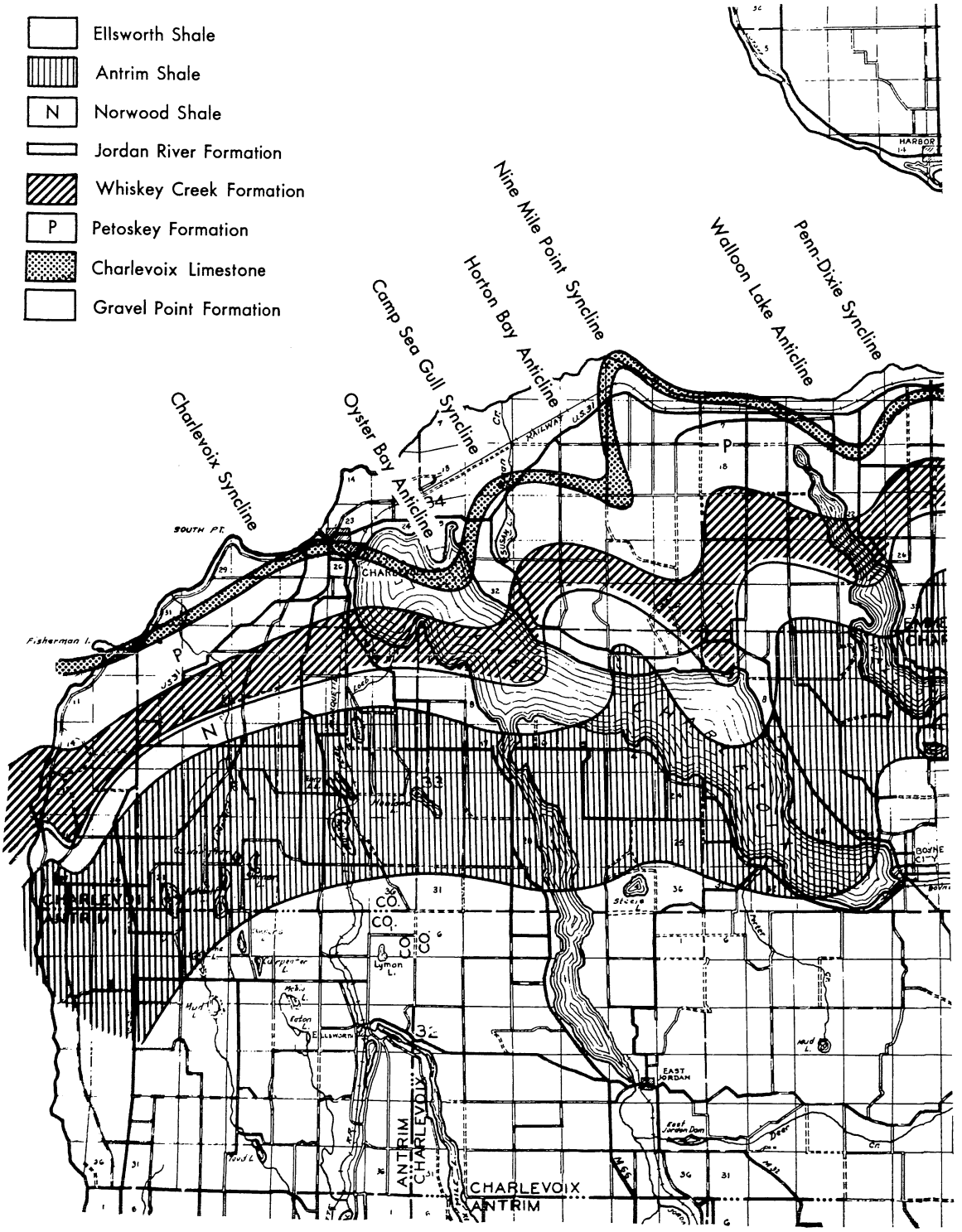
The Penn-Dixie Syncline is defined by Gravel Point Formation strata in the Penn-Dixie Cement Corporation Quarry and, formerly, along the shore to the east.

Evidence for the Walloon Lake Anticline can be seen in the exposures of Gravel Point Formation and Charlevoix Limestone near the shore of Little Traverse Bay north of Walloon Lake. At Locality 34-6-8 NE (old Bell Quarry; present Penn-Dixie Shale Pit) and at 34-6-2 SW (east end of Penn-Dixie Cement Corporation Quarry), the contact is present of the Gravel Point and Charlevoix. Between these two localities, at Locality 34-6-9 NE and Locality 34-6-9 N, Grabau described beds which were below the "upper blue shale" of the Gravel Point Formation. The beds at Locality 34-6-9 N were also studied by R. A. Smith, who called the place the W. E. Smith Quarry; his section confirms that the beds are below the "upper blue shale" and older than the beds exposed in the Bell Quarry or in the eastern end of the Penn-Dixie Quarry. The presence of older beds between exposures of younger demonstrates the presence of the Walloon Lake Anticline.

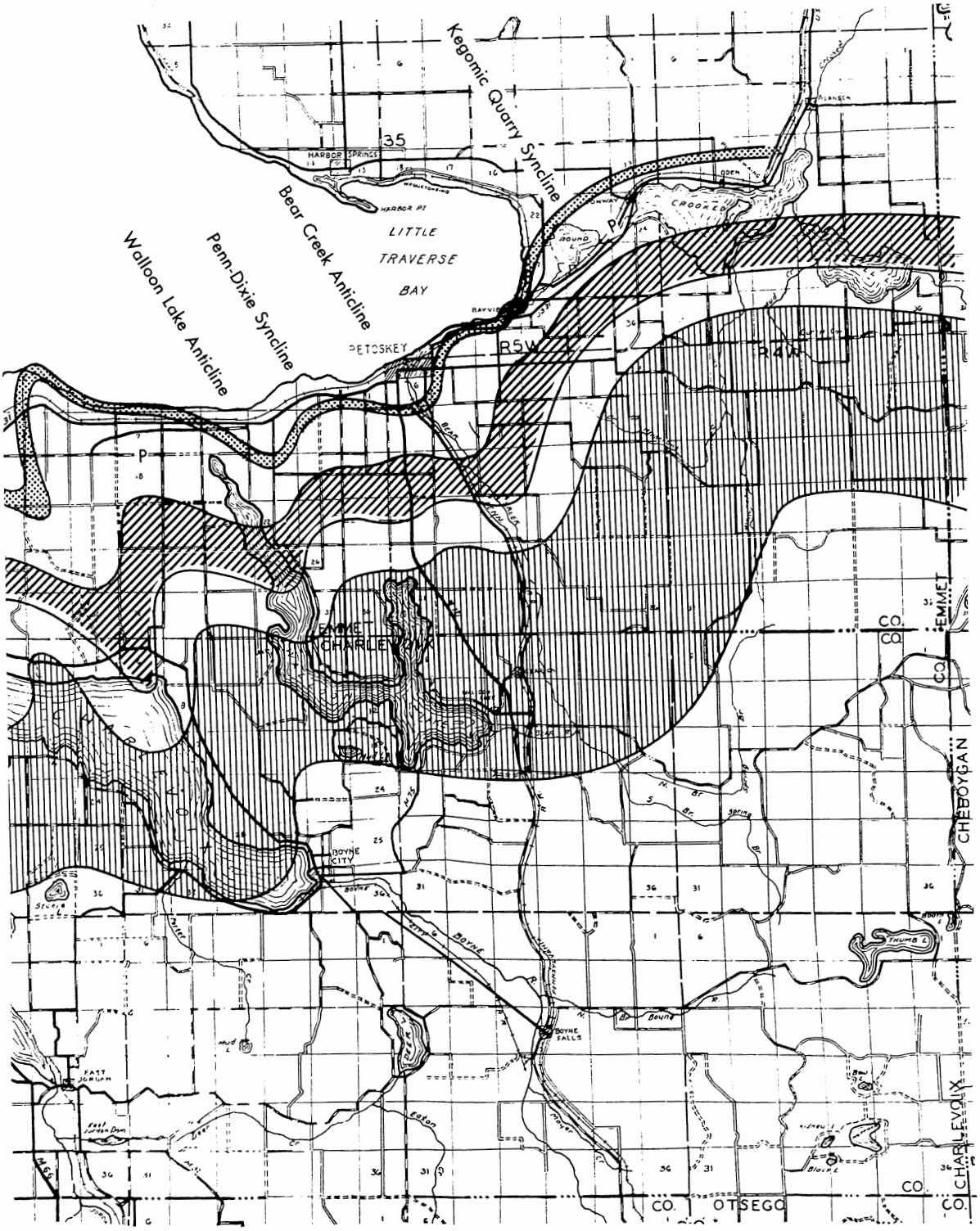
Nine Mile Point marks the nose of the Nine Mile Point Syncline as expressed in the Charlevoix Limestone. Between Locality 34-6-6 SW (Main Curtiss Quarry at Bay Shore) and Locality 34-7-2 W (Superior Quarry of Northern Lime Company at Nine Mile Point), the Charlevoix Limestone forms the shore of Little Traverse Bay. West of the point, at Locality 34-7-3, 4, 8, the Gravel Point Formation is exposed progressively lower in the section. As shown for the Horton Bay Anticline, next discussed, the strike must change sharply at Nine Mile Point, becoming north-south.

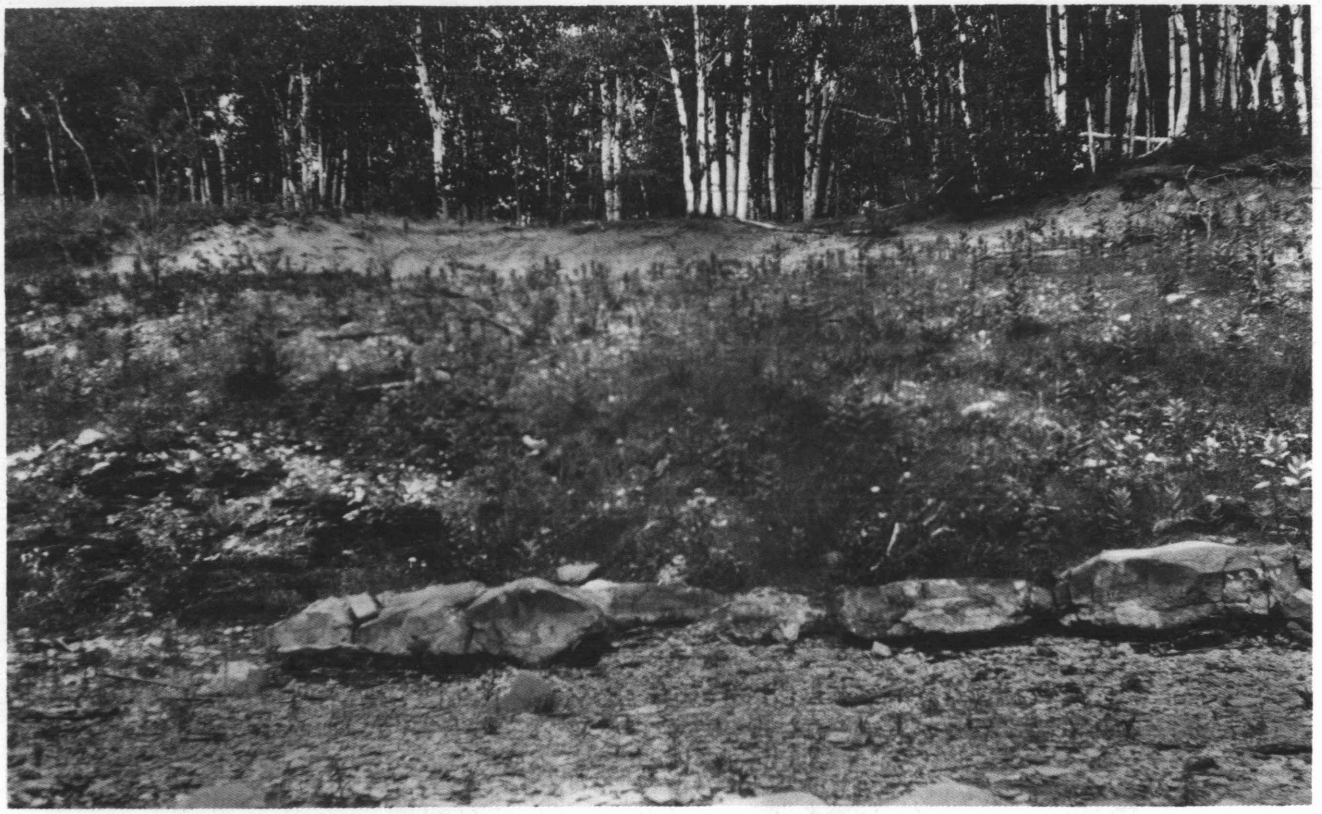
At Locality 33-6-6 S, at the tip of a small peninsula bordering Horton Bay, the Whiskey Creek Formation is exposed. A few miles to the west-northwest, at Locality 33-7-3 E, black shale outcrops in a ravine. The southward protrusion of the Whiskey Creek Formation indicates that the entire section of the Traverse Group is involved in a rather sharp anticline, which has its axis through Horton Bay and is here termed the Horton Bay Anticline.

The Camp Sea Gull Syncline is the structure responsible for exposing the black shale of the Norwood on the north side of Lake Charlevoix, at Localities 33-7-3 NW and 33-7-3 E. Were it not for this fold, the whole north shore of Lake Charlevoix as far east as Horton Bay



MAP 2 -- Structures in Charlevoix and Emmet Counties as outlined by Middle and Upper Devonian formations. Only the major folds are labeled. At some places, as many as nine reversals in dip occur within one mile.


Kegomic Quarry Syncline
Bear Creek Anticline
Penn-Dixie Syncline
Walloon Lake Anticline
LITTLE TRAVERSE BAY
HARBOR SPRINGS
HARBOR PT.
PETOSKEY
BAYVIEW
CROOKED
R5W
R4W
35
CHARLEVOIX CO.
EMMET CO.
CHEBOYGAN CO.
OTSEGO CO.
BOYNE CITY
BOYNE FALLS
EAST JORDAN
THUMB L.
BIG L.



TEXT-FIG. 69 -- Antrim Shale exposed south of Norwood. Locality 32-9-3 E SE, at or near type locality (old Loc. 1). Photo by G. M. Ehlers, 1926.

would be occupied by the Petoskey and Whiskey Creek Formations.

Between the Camp Sea Gull Syncline on the east and the Charlevoix Syncline on the west, strata form an anticline. For lack of a better name, we call it the Oyster Bay Anticline, after the small northward-extending bay from near the lower end of Lake Charlevoix. Evidence for this fold comes from subsurface records.

The Charlevoix Syncline is a broad feature. Between Pine River outlet (from Lake Charlevoix) and South Point (formerly Gravel Point), the outcrop belt of the Charlevoix Limestone comes near the shore of Lake Michigan. It is approximately at the town of Charlevoix that the strike changes from northwest-southeast to northeast-southwest. Eastward, the outcrop of the Charlevoix Limestone does not approach the shore until it comes to Nine Mile Point. Westward, the southwestern limb of the syncline extends into Lake Michigan somewhere near Fisherman Island, about midway between South Point and the village of Norwood.

The presence of this syncline was suggested many years ago by Alexander Winchell (1866, p. 47), who wrote,

> It would appear that the body of this exposure is in the same horizon as that at 857 -- the "Acervularia Beds," coming in above. It is obvious that the general dip of the strata at this point is toward Pine river, since the great abundance of Acervularia on the shore between here and Pine river proves that the "Acervularia Beds" at the top of the bluff pass under the harbor of Charlevoix. This conclusion is corroborated by the fact that, in travelling north, after passing that portion of the beach on the north side, in which Acervularia most abounds among the fragments, we succeed to enormous quantities of hard, fine and sharply angular fragments, whose position is not far above the "Acervularia Beds" (865,D)... It appears, therefore, that the

TEXT-FIG. 70 -- Contact of black and green shale units, probably both units in Antrim Shale. Pit along road leading west from Indian Garden, near shore of Walloon Lake. Locality 33-6-1 S (old Loc. 20). Photo by G. M. Ehlers, around 20 Aug 1926.

> rocks dip from both directions beneath the harbor of Charlevoix, and that Pine river finds its outlet along a partial synclinal axis, produced by local undulations of the strata.

Minor folds. -- Small scale undulations are very common, but in many cases it is impossible to say whether they are the result of compression or the draping of beds over the tops of buried reefs. Some small structures are closed, such as those recorded by Pohl (1929, p. 7) in the Gravel Point Formation near the type locality:

> ... the local structure is very complex. The entire region is underlain by more or less elevated domes and local anticlines and synclines which have an entire lack of consistent trend.

These were reported by Pohl and Raasch in field notes as "all closed structures." As such, they are undoubtedly products of draping.

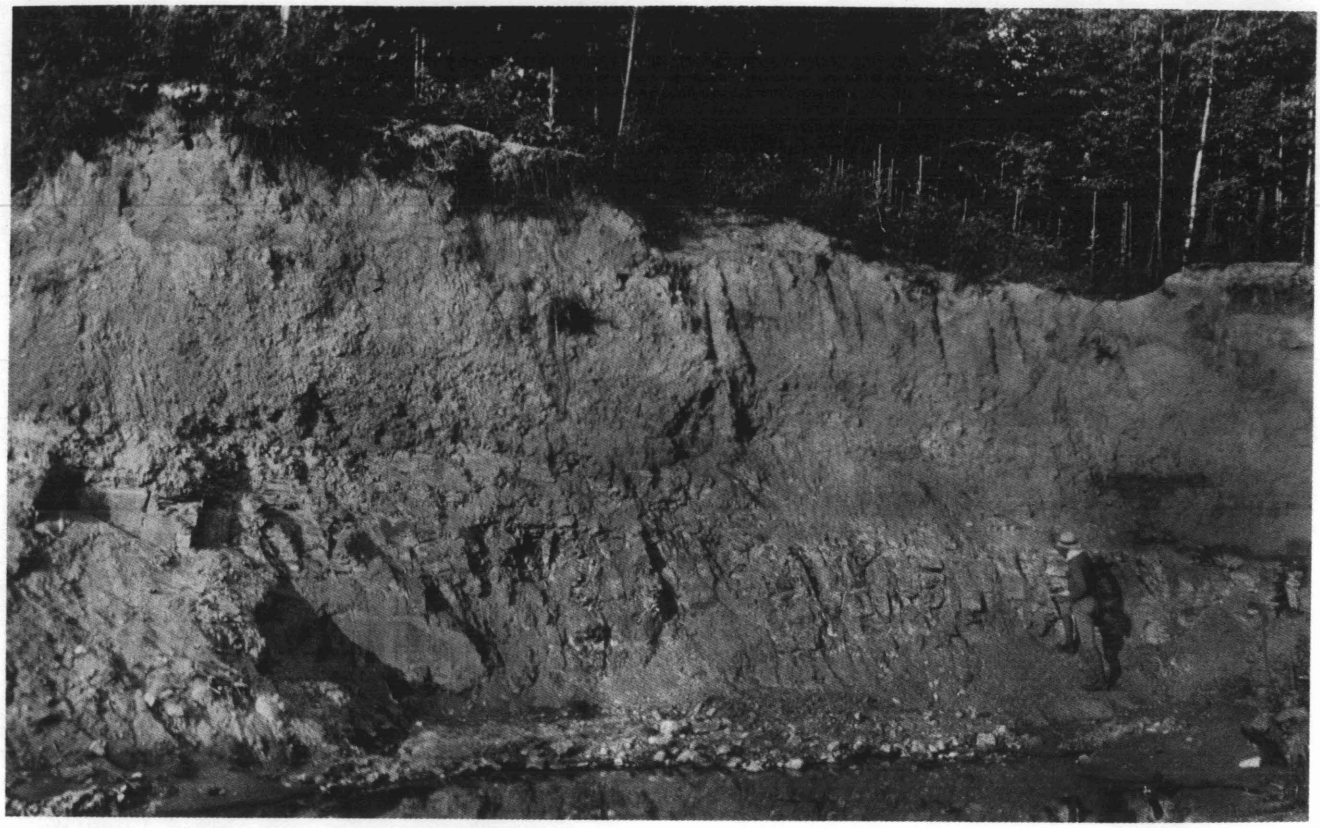
Along the coast, the bluffs and low cliffs show frequent changes in direction of dip. Winchell recorded some of them in his 1866 report (p. 45). At Locality 34-6-4 SW (his Loc. 862) and Locality 34-6-5 S (his Loc. 863), in a distance of less than a mile, Winchell observed:

> The dip here [862] is quite rapid toward the west, but the strata rise again in the distance of about half a mile, at 863, ... a dome-like elevation of the strata, from the summit of which they dip in opposite directions. ... Thirty rods further west these strata arch up again, disappearing finally with a westerly dip.

Thus, the reversals of dip show that this short section of shore exposures contains two synclines and anticlines of small amplitude.

Essentially the same features were seen by Rominger, who said in general:

> The strata have retained their original position, but their haorizontality is not perfect; they rise and sink in undulations, adapting themselves to the surface on which they were deposited. By means of these undulations, lower or higher strata come repeatedly to an exposure, or dis-



TEXT-FIG. 71 -- Greenish shale, perhaps above the Antrim Shale but more likely a local unit within the Antrim. Walloon Lake near Indian Garden. Locality 33-6-1 S (old Loc. 20). Photo by G. M. Ehlers, 1926.

> appear again, if we follow the horizontal level of the shore line of the bay, which approximately runs parallel to the strike of the formation, and would consequently always present the same rock beds if the strata remained perfectly horizontal.

These observations were echoed by Grabau (1902, p. 199), who wrote:

> Owing to the existence of a number of minor folds or undulations whose axis is normal to the strike of the strata, a number of beds which would otherwise be below the water level are brought to the surface.

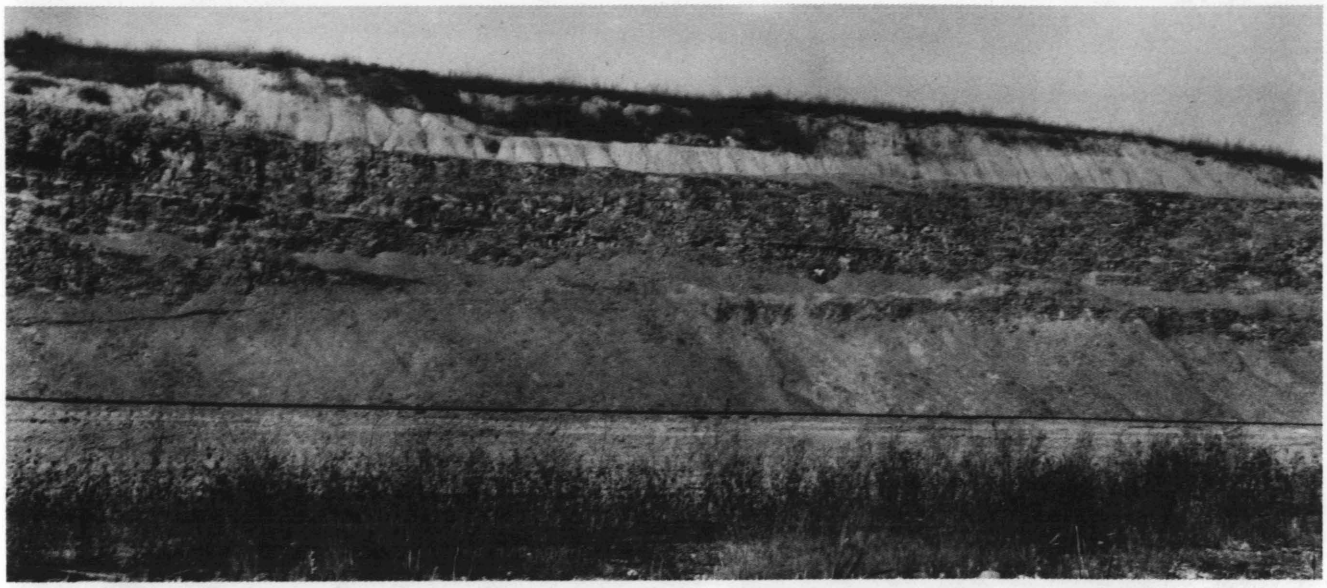
Grabau was also impressed by the small-scale folds in the Gravel Point Formation along the shore of Little Traverse Bay. At Locality 34-6-9 NE (his Loc. 44), he noted (1902, p. 205):

> For perhaps two miles along the shore, rock is exposed at the water's edge, with a few interruptions by sand and shingle beach. The dip of these strata vary in direction and amount, disclosing many small anticlines.

A small-scale feature was described by R. A. Smith (1916, p. 190), who said of the rocks near Charlevoix:

> The strata are locally very much disturbed. The general inclination of the beds is southward but it varies greatly in amount and direction from place to place. In one place, the dip is over five degrees to the north and an eighth of a mile distant over 22 degrees to the south ... The strike of the beds is in a general east and west direction but this is considerably modified locally by the sharp variations in dip.

He presented evidence for a little syncline involving Localities 34-8-28 SE SE (Charlevoix Rock Products Quarry 1), 34-8-28 S (Charlevoix Rock Products Quarry 2), and 34-8-33 NW NE (Charlevoix City Quarry). He stated (1916, p. 192, 193):



TEXT-FIG. 72 -- Ellsworth Shale, type locality. Shale pit of Petoskey Portland Cement Company (now Penn-Dixie Cement Corporation) near Ellsworth. Locality 32-8-23 SE (old Loc. 2). Photo by G. M. Ehlers, probably 5 Aug 1926.

> ... abnormal inclination of the beds occurs in this quarry. Apparently a small plunging anticline extends into the quarry from the southwest. The dip varies from 2 or 3 degrees to the northwest to about 7 degrees slightly east of north and directly toward quarry No. 1 of the Charlevoix Rock Products Company. Almost directly south the dip decreases to only 2 or 3 degrees. The dip is about 11 degrees south from quarry No. 1 and 7 degrees north from the city quarry, hence there most be a very pronounced trough or syncline in the strata between the two quarries. Since the southeastward dip in quarry No. 2 is about 20 degrees, the syncline apparently plunges to the east. South of quarry No. 1, the dip of the beds is said to be very gentle, therefore the abnormal dips noted above must flatten out quickly to the eastward.

Even though part of the unusual dips may be attributed to foreset beds typical of the Charlevoix Limestone, we believe Smith was correct in postulating a local syncline at this place.

These examples suffice to demonstrate the number and nature of the minor folds which characterize this region.

Unconformities. -- The relatively small area of exposures makes it difficult to judge the extent and development of unconformities in the region. Possibly, unconformities may be found to exist between all formations. Some evidence can be found for unconformities at the Gravel Point-Charlevoix and the Charlevoix-Petoskey boundaries. One might expect that unconformities are present at both the base and top of the Jordan River Formation, inasmuch as sedimentation was interrupted for a considerable time before and after its deposition; however, the only place where the time formation can be seen is at the type locality -- and there it is accessible only during low-water stages of Lake Michigan, and at best is poorly exposed.

As already discussed, the recent discovery of a local thick deposit of the "upper blue shale" at the top of the Gravel Point Formation at the Penn-Dixie Cement Corporation Shale Pit (Locality 34-6-8 NE) introduces a new factor into the geologic history of the region. Previous exposures and well records showed a rather consistent soft shale unit capping the Gravel Point Formation, varying little in thickness. The new shale pit is operating in some 40 feet of soft shale, instead of the usual 10 to 15 feet in this unit. One explanation which can be offered for such local thickening is the formation of a small basin after deposition of the soft

TEXT-FIG. 73 -- Ellsworth Shale. Pit and exposure northeast of Boyne City. Locality 33-6-25 SW (old Loc. 5). Photo by G. M. Ehlers, 1926.

mud and the accumulation of mud from surrounding areas to fill and level off the basin. Such folding was probably not general or extensive in the Gravel Point-Charlevoix interval, since well records show no place that had the whole of the "upper blue shale" removed by erosion before the Charlevoix Limestone was laid down. Interruption of sedimentation in the post-Gravel Point and pre-Charlevoix interval is also suggested by the presence of selenite crystals in the top shale of the Gravel Point Formation, presumably conclusive evidence of a period of evaporation and concentration of sea water. Change in conditions is also shown by the general lithologies and sedimentary features of the two formations: the Gravel Point Formation possesses many indicators of quiet off-shore deposition (consistent and even bedding except around bioherms, large and varied marine fauna, corals well preserved, etc.), but the Charlevoix Limestone has indicators of high-energy near-shore deposition (foreset bedding, oolites, sparse fauna, etc.) in parts of its section.

The unconformity at the top of the Charlevoix Limestone is better developed and convincingly documented. As shown above in the field sketches made by Ehlers, by Case, and by Pohl and Raasch, the contact of the Charlevoix and Petoskey formations at Locality 34-7-2 W, the abandoned Superior Quarry of the Northern Lime Company near Nine Mile (Khagashewung) Point. There the lower beds of the Petoskey fill old channels in the upper part of the Charlevoix Limestone, starting with an irregular coarse shale and continuing with a rubble of worn coral fragments.

The extent of the unconformity and the angularity between the Charlevoix and Petoskey is best known from the quarries and exposures near Bay Shore, at Locality 34-6-6 SW, near the county line. Here Ehlers (1949) estimated that

the contact had a relief of about 40 feet; whether he meant present topographic relief or original depositional relief is not certain. If he intended to say that the Charlevoix surface on which the basal Petoskey was deposited had 40 feet of stratigraphic relief, then his figure seems much too high; the entire Charlevoix Limestone at this locality, as measured by Pohl, is only about 32 feet thick. According to the units cut out by the pre-Petoskey erosion, as reported by Pohl, the maximum depth of erosion was around half the thickness of the formation -- about 16 feet. The inclination of the irregularly beveled surface of the Charlevoix is toward the west. The lowermost unit of the Petoskey at this place is 12 feet thick at the western edge and pinched out at the eastern edge. After at least partial consolidation, the Charlevoix strata at this locality were evidently tilted toward the east, planed off by erosion, and tilted back slightly toward their original attitude before the first layer of Petoskey was laid down. In summarizing his evidence, Pohl (1929, p. 19) said:

> At the Curtiss quarry (locality 13), a section through the entire thickness of the Charlevoix stage may be taken and here also may be seen the highest beds belonging to this division visible anywhere in the district. The thickness of this series from the base of bed 1 to the top of bed 9 is slightly short of 28 feet.... In the face of the quarry, running in a northwesterly direction, these beds are cut in downward succession by a distinct and pronounced, irregular, angular unconformity. Evidence points to a considerable time interval during which there was much erosion of the Charlevoix series. During the emergence, at various places and in particular the west end of the locality 13 quarry and west along the present lake shore, beds 9, 8b, 8a, 7, 6, and a few feet of the preceding "Pelecypod-Gastropod Bed," bed 5, were in some places partially, in others completely, removed by erosion. This, like most of the quarries in the region, is situated in the center of a longitudinal dome or anticline, and it is probable that during the post-Charlevoix emergence the beds were domed and then subjected to an irregular peneplaning effect. Accompanying this folding was a slight readjustment by faulting which is well exhibited in the south face of the quarry. This fault has a vertical throw of about 6 inches which does not continue into beds of the Petoskey formation although it can be easily traced through all the members of the Charlevoix. This can not be explained on the basis of incompetency, for if anything the beds of the Charlevoix are more competent than those of the Petoskey. Nor can it be dismissed by an argument based on "cushioning" for the basal beds of the Petoskey are compact and easily fractured. As if to further substantiate the importance of the unconformity there is a complete change of faunal and lithological characters above the break. In a series of small quarries, bluffs, and ledges near water's edge, forming a continuous exposure of a mile in length to the east of locality 13, the contact between the Charlevoix and the Petoskey series is exhibited at an almost constant height above lake level throughout the length of the exposure. The crinoidal Cyrtina-Gypidula zone of the Petoskey here rests on the irregularly eroded surface of one or another portion of the Pelecypod-Gastropod bed (bed 5) of the Charlevoix. We may thus see that the removal of beds from the top of the Charlevoix stage was not of restricted character, for over considerable distances there is a known deletion by erosion of between 12 and 15 feet. It is extremely probable that even greater thicknesses were deposited during Charlevoix time and subsequently denuded, but to what vertical extent can not be ascertained.
>
> The acceptance of the proof presented requires not only the withdrawal of the sea at the end of Charlevoix deposition, but also the emergence of the area for the minimum time necessary for the consolidation of the beds and for the removal of at least 15 feet of mostly tough limestones, before the earliest local encroachment by and deposition in the Petoskey sea.

The basal Petoskey contains foreset and cross beds. Pre-Petoskey deformation is also indicated by the fault (of slight throw) which, as reported by Pohl (1929, p. 18), at the Curtiss Quarry extends through the units of the Charlevoix Limestone and stops abruptly at the basal Petoskey Formation.

CORRELATIONS ACROSS THE STATE

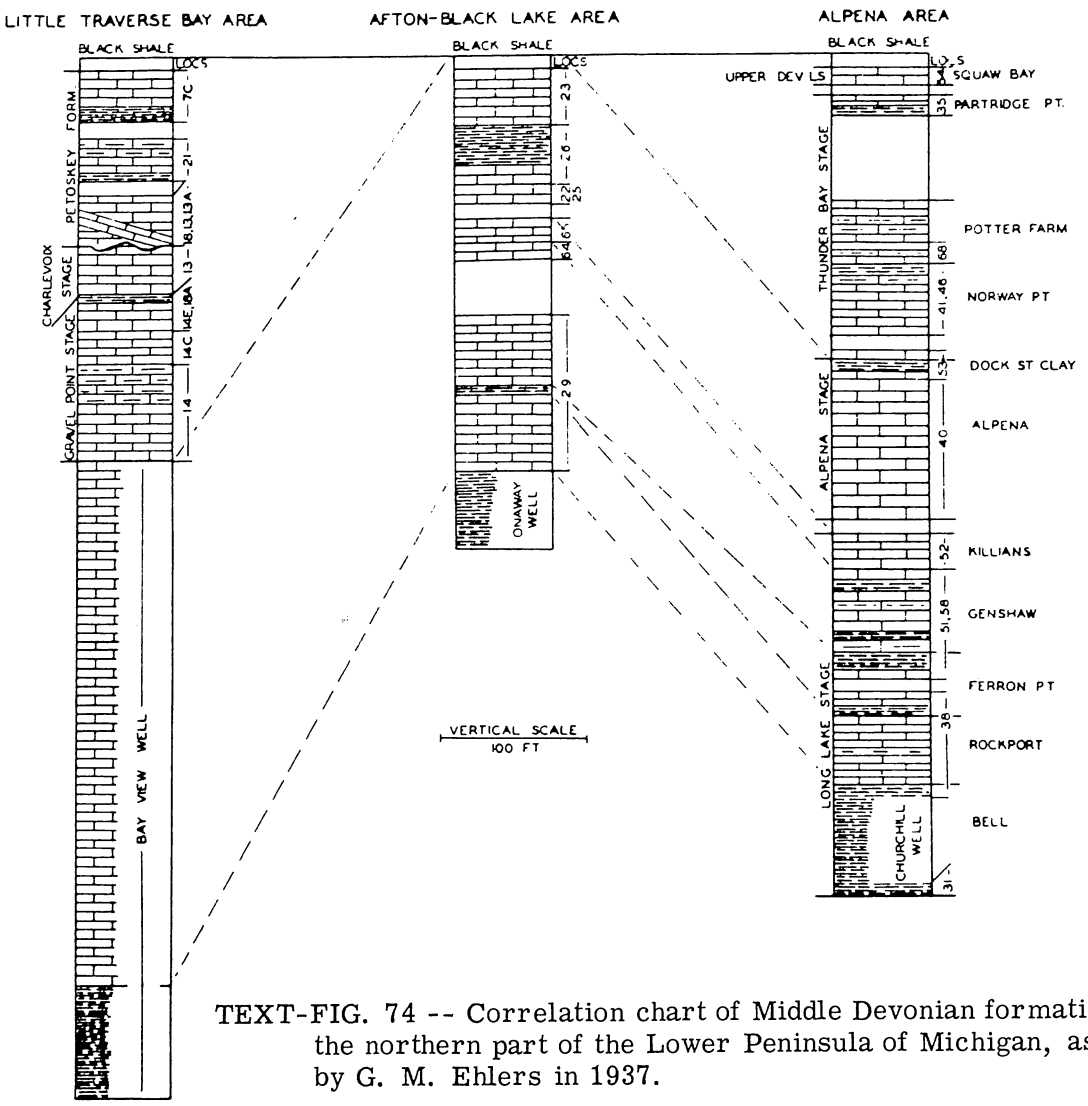
Let us begin by noting something uncontroversial. Horizons of time and sediment do not necessarily correspond. Certainly they do not today, for we have deposits being laid down of all sizes, compositions, and degrees of sorting known. Whereas the configuration of continents and depths of seas in the past were different, very few geologists doubt that at any moment in geologic time sedimentation went on much as it does still -- controlled by supply, waves, currents, distance from shore, depth, and other local factors. And there is no evidence that sedimentation over an extensive area ever leveled out at one particular kind of rock (excepting, of course, bentonites).

So we can agree that the boundary between major episodes in earth history does not represent everywhere the same precise moment. How then can we accomplish anything significant in correlation? To answer this question, we must look to the magnitude of the time involved. For example, the Devonian deposition took place over tens of millions of years; and although the rocks called Devonian at one place may not have occupied the same time interval as those called Devonian at another place, yet the difference is likely to have been an inconsiderable percentage. When we consider Middle Devonian at two distant localities -- set off below from Lower Devonian and above from Upper Devonian -- the difference in years was probably about the same as for the whole period, but the percentage is greater. And when we get to smaller units, such as formations, the chances are the percentage is considerable; there is even the possibility that a formation was completely deposited at one place before its sedimentation began at the other.

This brings us to paleontology -- its impact, its usefulness, and its potential in correlation. Rock types go on forever, but a species lasts only for a brief geologic interval. With paleontology, one can achieve a much finer degree of dating. Naturally, the identification of each kind of fossil must be done accurately; and despite the attention given to taxonomy and despite the accumulated knowledge in literature and despite the availability of material in museum collections, much remains to be learned about what constitutes a species. Longevity, evolution, population dynamics, migration, tolerances, and other factors are interrelated, but as of now we cannot insert them into a formula to derive a quick answer to the time-correlation problem.

Even with these difficulties, however, paleontology is the most useful key to placing sedimentary strata into their time relationship over a geographic expanse. The more we understand about the extinct animals and how they lived, the better our correlations based on them. Some creatures were closely attuned to bottom sediments, others were practically independent of what was being deposited below them; some survived for a long time, others soon became extinct or evolved into something different; some are remarkably constant in all characteristics, others are extremely variable; some were widespread, others limited to local populations. Let us not be overconfident about how much we really know, nor complacent about the status of science. Each population, each species, and each fauna is a special challenge. On the other hand, we should recognize that the span of most species is short enough to refine the dating of the strata wherever it occurs. And if all the species in a large fauna are studied, we come much closer to the truth.

Strangely, as much or more interest has been expressed for correlations of Michigan Devonian formations with those in New York as there has been for correlating formations within the state. None of the Traverse Group formations present in Emmet and Charlevoix counties has been extended beyond the county limits; a whole new set of stratigraphic names is used as close as the Afton-Onaway-Black Lake region in north-central Michigan. The reason seems simple enough. The stratigraphic successions in the northwestern, north-central, and northeastern regions of the Lower Peninsula of Michigan represent three sedimentary provenances -- different sets of conditions for depth, circulation, salinity, sediment supply, etc. for each interval of time. We have

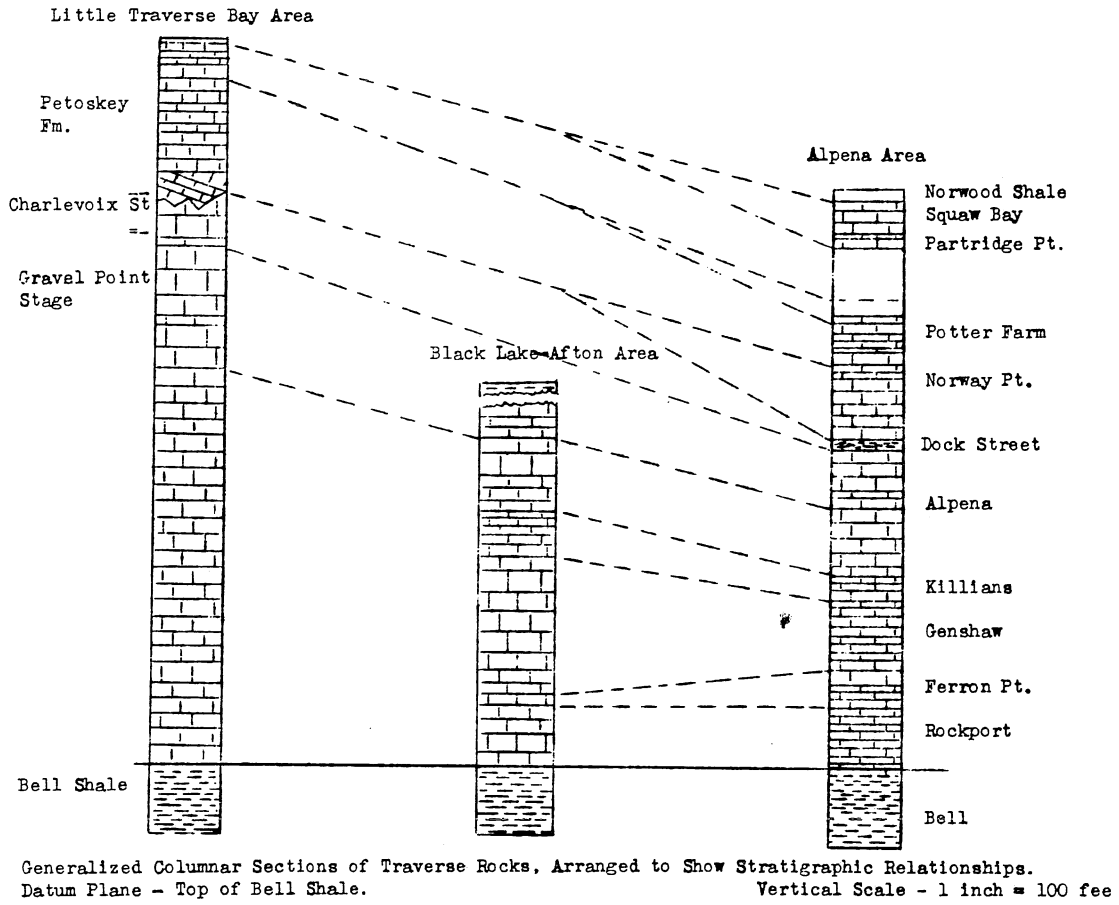


TEXT-FIG. 74 -- Correlation chart of Middle Devonian formations across the northern part of the Lower Peninsula of Michigan, as envisaged by G. M. Ehlers in 1937.

not yet reached sufficient understanding of Devonian history in Michigan to pinpoint the factors responsible for such differences. We need to know more about the roles played by diastrophism and reefs in controlling deposition, more about paleogeography of the Michigan Basin, more about configuration of the sea bottom and circulation, more about the sensitivity and tolerance of each species, -- the gaps in our understanding are numerous and varied. Our information-gathering is not even completed on paleontology or geology in the two counties. Definitive correlations are still to be sought.

There is no doubt that the rocks below the black Upper Devonian shale are general equivalents in the three outcrop regions of northern Michigan. Back in 1841, C. C. Douglass in his simplified stratigraphic successions of "Lake Michigan" and "coast of Lake Huron" (see our p. 21) strongly hinted at the correlation of his Little Traverse bay limestone and his Thunder bay limestone. Our concern, like that of many preceding geologists, is the correlation of formations within the Traverse Group.

In 1937, for the Seventh Annual Field Excursion of the Michigan Academy (celebrating



TEXT-FIG. 75 -- Correlation chart of Middle Devonian formations across the northern part of the Lower Peninsula of Michigan, as presented by G. M. Ehlers in 1938.

the centennial of the Michigan Geological Survey), Ehlers presented a simple correlation in which he indicated that the uppermost Traverse exposed in the Afton-Black Lake area was stratigraphically just below the lowest exposed Traverse in the Little Traverse Bay area and just below the Norway Point (as then defined) in the Alpena area (see our text-fig. 74).

In 1938 Ehlers attempted another correlation across the state (see our text-fig. 75). In it, he made the Gravel Point = Alpena, Charlevoix = Dock Street (member of Four Mile Dam Formation), lower Petoskey = Potter Farm, and upper "Petoskey" = unexposed strata below the Partridge Point (now the Thunder Bay Limestone). He concluded that several units of the Alpena area wedged out to the westward and had no equivalents in the Little Traverse Bay area, including the Norway Point, part of the Potter Farm, the Partridge Point, and the Squaw Bay.

Still later (1949) in another guidebook, Ehlers had a different correlation chart. In it he made the Beebe School Formation in the Afton region equivalent to the combined Charlevoix and Petoskey formations in Emmet and Charlevoix Counties, and to the upper Four Mile Dam Formation through Squaw Bay Limestone in Alpena County. His chart indicated that the exposed Gravel Point Formation was equal to the upper Alpena Limestone, Dock Street Clay, and part of the Four Mile Dam Formation; the Charlevoix was equal to the upper Four Mile Dam, the Norway Point, and the lower part of the Potter Farm Formation; and the Petoskey was equal to the upper Potter

Farm, Thunder Bay, and Squaw Bay Limestone.

The 1942 Geological Society of America correlation chart of Devonian formations prepared by G. Arthur Cooper and others showed the following correlations between northwestern and northeastern areas of Michigan: Gravel Point = Alpena; Charlevoix = Four Mile Dam Limestone; lower Petoskey = Norway Point; middle Petoskey = combined Potter Farm and Thunder Bay; and upper Petoskey above the Squaw Bay Limestone without equivalent in Alpena County.

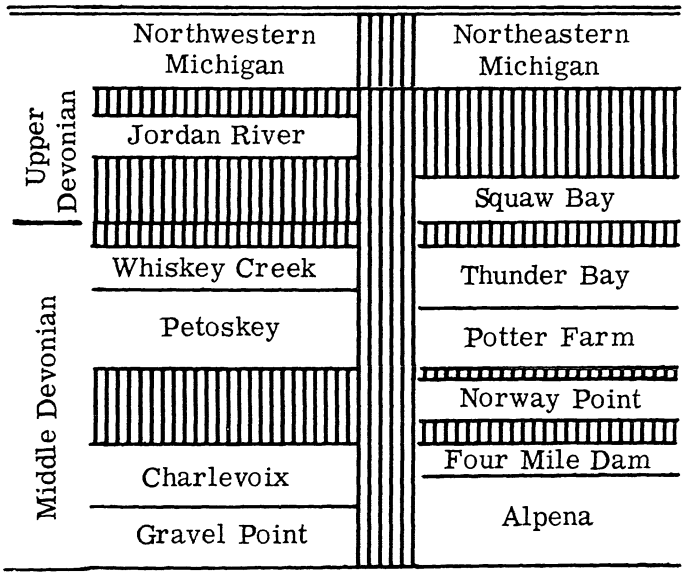
In Cooper et al., 1942, "Correlation of the Devonian sedimentary formations of North America," G. Arthur Cooper and A. Scott Warthin, Jr., suggested correlations for the Gravel Point and the Charlevoix. Of the Gravel Point Formation, they wrote (1942, p. 1763):

> At the base of the formation a foot of calcareous shale contains fossils like those in a blue shale 40 feet below the top of the Alpena limestone. At the top of the Gravel Point another blue shale, "the upper blue shale," or zone 6 of Pohl, contains crinoids and brachiopods similar to those of the Dock Street clay at the top of the Alpena. Therefore the interval occupied by the Gravel Point is essentially that of the upper 40 feet of the Alpena limestone. The Chonetes emmetensis, so abundant in the lower part of the Gravel Point limestone, also occurs at the base of the upper 40 feet of the Alpena.

Of the Charlevoix Limestone, they said (1942, p. 1752):

> Occurs on the shore of Lake Michigan in Emmet and Charlevoix Counties between the "Upper blue shale" (zone 6) of the Gravel Point limestone and the base of the Petoskey limestone. The "Upper blue shale" is correlated with the upper Alpena (approximately Dock Street clay) of Alpena County. The lower part of the Petoskey limestone at Bayshore is correlated with the Norway Point formation of Alpena County. Thus the Charlevoix occupies the position of the Four Mile Dam limestone and consists of a heterogeneous series of limestones ranging from platy lithographic limestone with green shale partings to limestone with coral and crinoidal debris and oölites. These all suggest nearshore action and accumulation. It is therefore suggested that the Charlevoix may represent a western shore phase of the Four Mile Dam limestone, but no fossils yet discovered support this contention.

Our analysis of faunas indicates the following correlation:



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EHLERS, G. M. (presumably the author, his name not appearing in the publication), 1937, Seventh Annual Field Excursion of the Mich.

EXPLANATION OF PLATE 3

(All figures x 1 except as noted)

Fossils from the Gravel Point Formation

FIGS. 1-6, Atrypa corrugata, UMMP 26503; Locality 34-6-9 N, old Loc. 14c, "Rose's Quarry" of Grabau, W. E. Smith Quarry of R. A. Smith; "lower blue shale." 7-9, Longispina emmetensis, UMMP 56025; Locality 34-8-28/29, Gravel Point. 10, Chonophyllum ponderosum, UMMP 56806; Locality 34-6-8 NE, old Bell Quarry; collected by Kesling. 11, 12, Stuartella traversensis, UMMP 49523; Winchell's Loc. 861. 13, 14, Schuchertella anomala, TYPES, UMMP 4116; Winchell's Loc. 861; probably zone 4, bed 3 of Pohl. 15, Heterophrentis sp., UMMP 35309; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 16, Heliophyllum sp., UMMP 35304; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 17, Crassiproetus traversensis, TYPE, UMMP 25547; shore of Little Traverse Bay; collected by Winchell. 18, Atrypa dignata, UMMP 56029; "Little Traverse Bay," probably near Locality 34-6-2 SW. 19, 20, Diversophyllum traversense, UMMP 56930; Locality 34-6-3 S, Penn-Dixie Quarry; "lower blue shale." 21, Hexagonaria cristata, TYPE, UMMP 5322; Little Traverse Bay near Petoskey; collected by Rominger. 22, Conocardium emmetense, UMMP 60886; Locality 34-6-8 NE, old Bell Quarry.

Fossils from Whiskey Creek Formation
Type Locality

FIG. 23, Aulocystis minuta, UMMP 34976, transverse section, x 2. 24,25, Aulocystis minuta parallela, TYPE, UMMP 34980, cross and transverse sections, x 2. 26, Crassiproetus norwoodensis, TYPE, UMMP 25444; uppermost exposure, could be Jordan River Formation.

PLATE 3

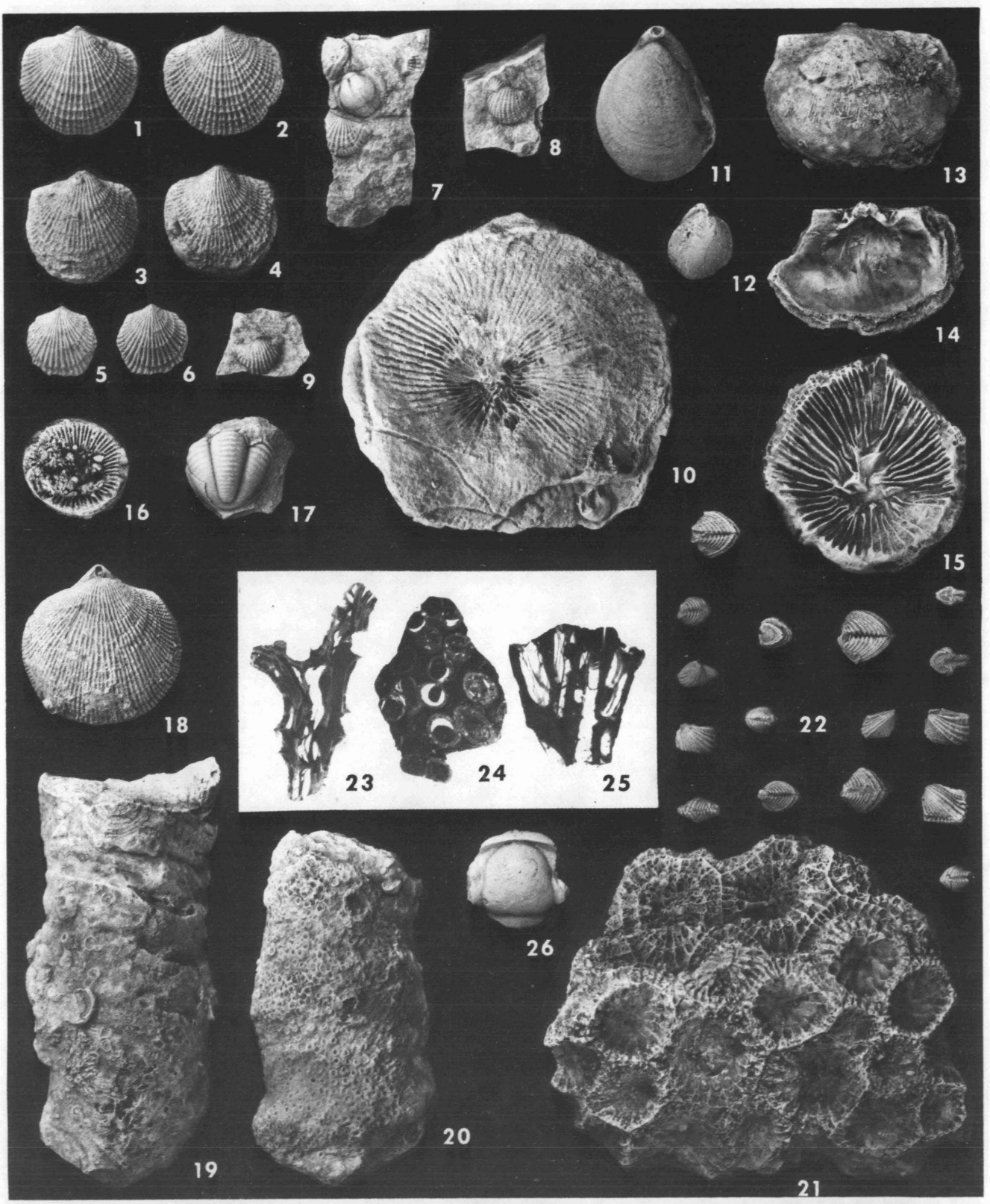
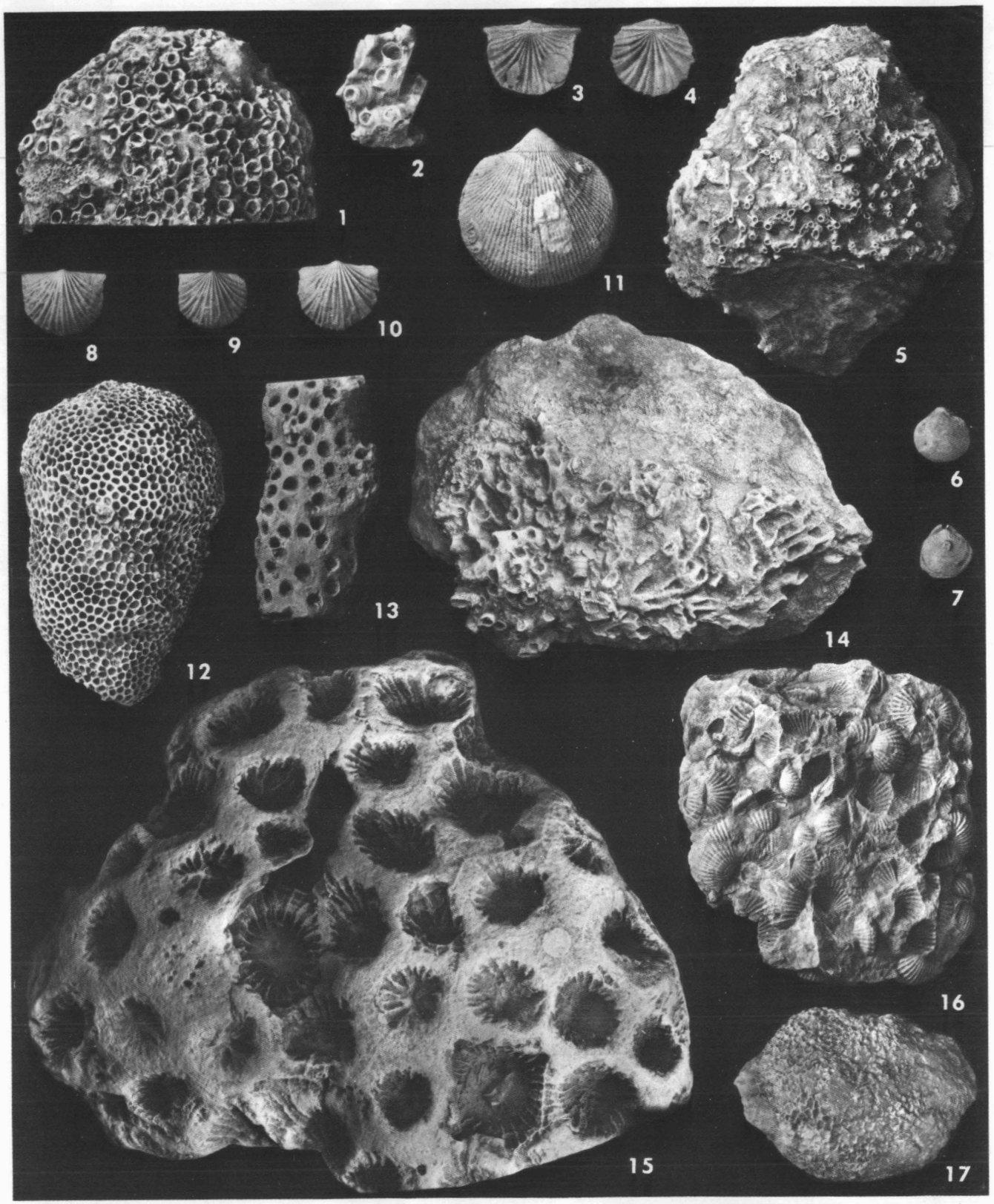


PLATE 4



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EXPLANATION OF PLATE 4

(All figures x 1)

Fossils from the Gravel Point Formation

FIG. 1, Pachyphragma erectum, UMMP 25238; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 2, Aulocystis fenestrata, UMMP 34394; Locality 34-8-28 SE SE, Charlevoix Rock Products No. 1 Quarry; "upper blue shale." 3, Strophodonta erratica, TYPE, UMMP 14923; shore of Little Traverse Bay; collected by Winchell. 4, Strophodonta erratica solidicosta, UMMP 50681; shore of Little Traverse Bay; collected by Winchell. 5, Aulopora michiganensis, UMMP 13159; Locality 34-6-8 NE, old Bell Quarry; collected by C. L. and M. A. Fenton (their "Rose Quarry"). 6, 7, Athyris ebora, UMMP 18429; Winchell's Loc. 862; collected by A. D. White. 8-10, Strophodonta costata, UMMP 56043; Locality 34-8-28/29, Gravel Point; collected by Grabau. 11, Atrypa dignata, UMMP 56029; "Little Traverse Bay," probably near Locality 34-6-2 SW. 12, Favosites alpenensis alpenensis, UMMP 19675; Locality 34-6-2 SW, east end of Penn-Dixie Quarry; "lower blue shale." 13, Trachypora alternans, UMMP 34366; specimen from Four Mile Dam Formation in Alpena Co. 14, Pachyphragma concentricum, UMMP 43970; specimen from Alpena Limestone in Alpena Co. 15, Hexagonaria cristata, UMMP 25625; shore of Little Traverse Bay; collected by Winchell; below "lower blue shale." 16, Longispina emmetensis, UMMP 4134; Locality 34-8-28/29, Gravel Point; "Emmetensis zone"; collected by Winchell. 17, Favosites alpenensis praevigens, UMMP 24367; Locality 34-6-3 S, Penn-Dixie Quarry; zone 2 of Pohl; identified by Dave Swann.

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EXPLANATION OF PLATE 5

(All figures x 2)

Gravel Point Formation. Thin sections of corals.

FIGS. 1, 2, Diversophyllum traversense, UMMP 14377, cross and transverse sections; Bear Creek; collected by Winchell. 3, Hexagonaria cristata, UMMP 15557, cross section; Locality 34-6-8 NE, old Bell Quarry; probably "lower blue shale." 4, Hexagonaria cristata, UMMP 25625, cross section; shore of Little Traverse Bay; collected by Winchell; below "lower blue shale." 5, Aulacophyllum hemicrassatum, TYPE, UMMP 19967, cross section; Locality 34-6-3 S, Penn-Dixie Quarry. 6, 7, Favosites nitella, UMMP 37956, cross and transverse sections; label reads "Petoskey region." 8, Heliophyllum sp., UMMP 35304, cross section; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 9, Favosites romingeri saetigera, UMMP 19673, transverse section; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 10, Favosites alpenensis alpenensis, UMMP 19675, transverse section; Locality 34-6-2 SW, east end of Penn-Dixie Quarry; "lower blue shale."

PLATE 5

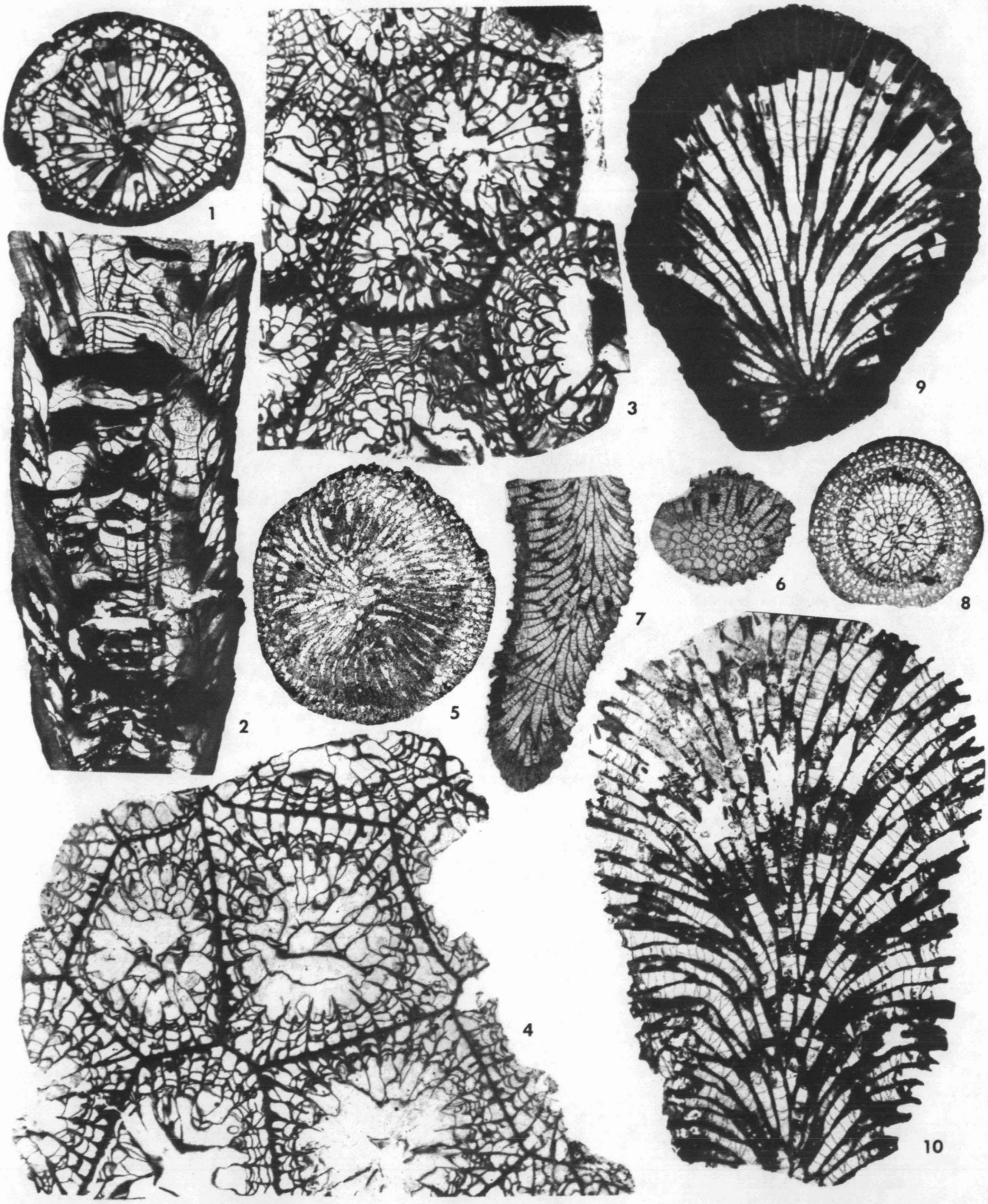
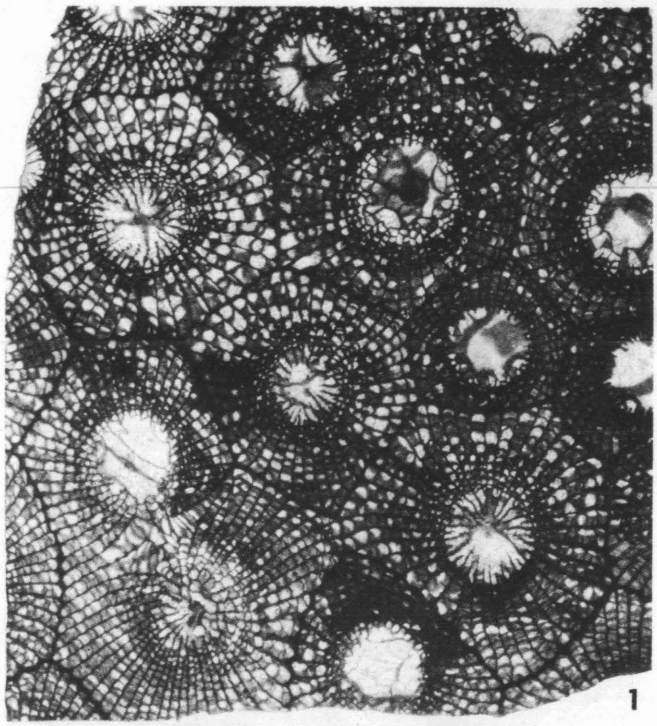


PLATE 6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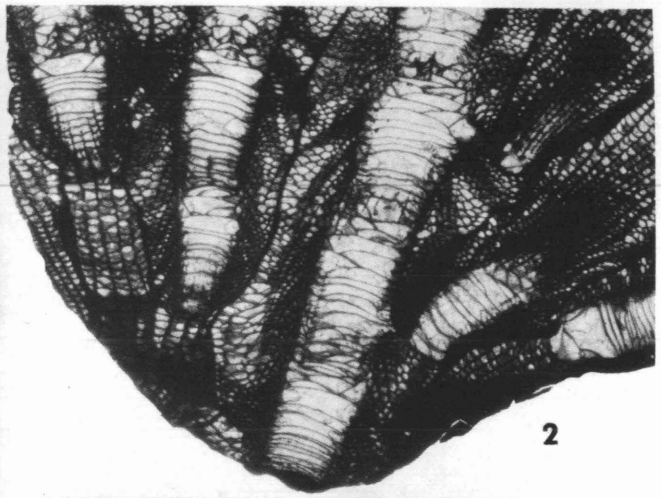
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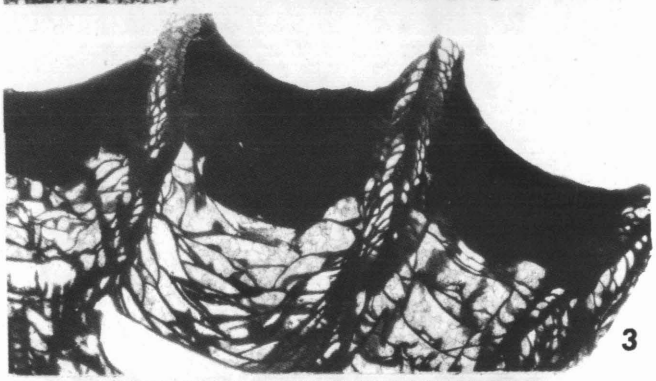
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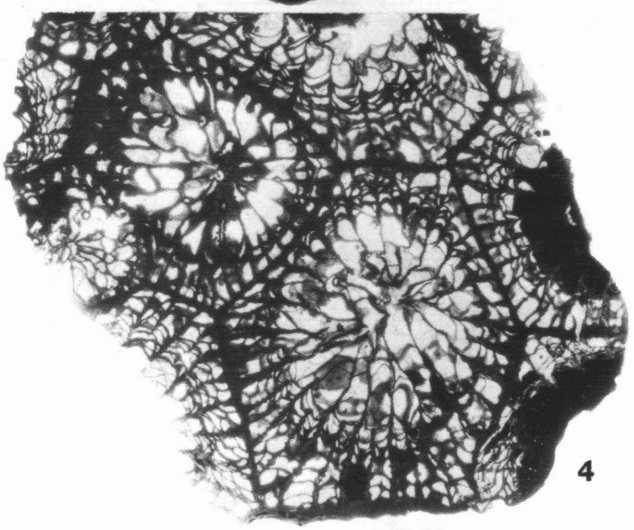
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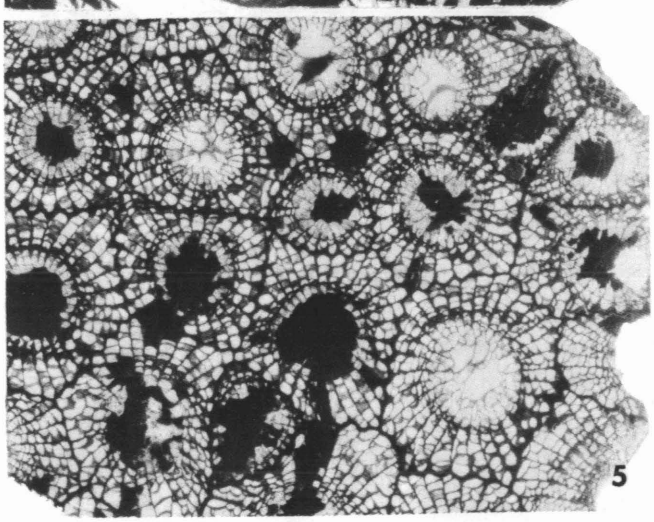
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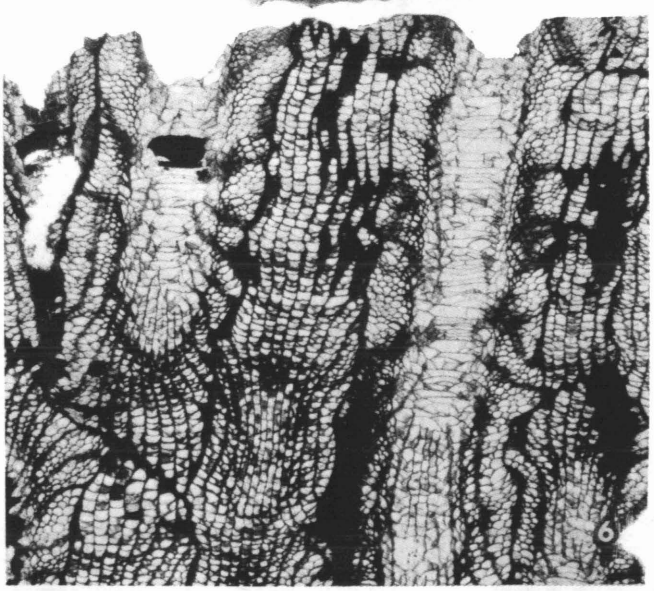
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EXPLANATION OF PLATE 6

(All figures x 2)

Gravel Point Formation. Thin sections of Hexagonaria.

FIGS. 1, 2, Hexagonaria sp., UMMP 18831, cross and transverse sections; Locality 34-6-3 S, Penn-Dixie Quarry; zone 3, bed 3 of Pohl. 3, 4, Hexagonaria cristata, UMMP 15557, transverse and cross sections; Locality 34-6-8 NE, old Bell Quarry; zone 6, bed 3 of Pohl. 5, 6, Hexagonaria cf. cristata microcarinata, UMMP 18852, cross and transverse sections; Locality 34-6-2 SW, east end of Penn-Dixie Quarry; zone 6, bed 1 ("lower blue shale") of Pohl.

APPENDICES

In the following appendices, most of the faunal lists and analyses is based on the check lists of E. C. Stumm (1951, 1961), with additions and revisions from published works since 1961. Only species and genera which have been listed in publications are included. In some cases this represents a taxonomic group rather fully; in other cases, however, the indicated sparsity of fauna is misleading, reflecting a lack of interest in the region by the specialists. An exhaustive revision of generic assignments and standings has not been attempted, although some obvious corrections have been incorporated. The appendices provide a quick assessment of what is available in literature on fossils of the Traverse Group.

To compare and correlate the taxa, lists are presented for formations in the northwestern and northeastern regions of the Lower Peninsula of Michigan; the former includes the Gravel Point Formation (GP), Charlevoix Limestone (CH), Petoskey Formation (PY), and the combined Whiskey Creek and Jordan River Formations (W/J), whereas the latter includes the Bell Shale (BS), Rockport Quarry Limestone (RQ), Ferron Point Formation (FP), Genshaw Formation (GF), Newton Creek Limestone (NC), Alpena Limestone (AL), Four Mile Dam Formation (FM), Norway Point Formation (NP), Potter Farm Formation (PF), and Thunder Bay Limestone (TB); the upper Devonian Squaw Bay Limestone has no equivalent in the Emmet-Charlevoix region and is not considered. The formations in the intervening region around Black Lake, Afton, and Onaway are omitted from this study; they will be investigated further in the near future.

Inasmuch as this guidebook is intended for field use, microfossils have been excluded from the compilations. Bryozoa are included separately, since many can be identified with only a hand lens. The groups presented are tetracorals, tabulate corals, brachiopods, molluscs, trilobites, and echinoderms.

Appendix 1

GENERA OF MACROFOSSILS RECORDED FROM FORMATIONS OF THE TRAVERSE GROUP IN NORTHWESTERN LOWER PENINSULA WHICH ALSO OCCUR IN OTHER TRAVERSE GROUP FORMATIONS OF MICHIGAN

	Northwestern				Northeastern									
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
TETRACORALS														
Aulacophyllum	x		x				x	x		x			x	x
Bethanyphyllum			x		x					x			x	x
Cylindrophyllum			x			x					x		x	x
Cystiphylloides	x		x		x	x	x	x		x	x		x	x
Diversophyllum	x													
Hallia			x										x	
Heliophyllum	x				x		x	x			x		x	
Heterophrentis	x		x		x	x	x	x		x			x	x
Hexagonaria	x	x			x	x	x	x	x	x	x			
Naos	x				x					x				
Scoliophyllum	x													

	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Stereolasma			x										x	x
Tabulophyllum	x		x		x			x		x	x		x	
Tortophyllum	x		x	x	x					x			x	
TABULATE CORALS														
Alveolites	x									x			x	x
Aulocystis	x		x	x	x	x	x	x	x	x	x	x		
Aulopora	x	x	x		x		x	x		x	x	x		
Cladopora	x		x					x			x	x		
Drymopora	x	x	x		x			x			x	x	x	x
Emmonsia			x		x	x		x		x	x		x	
Favosites	x	x	x	x	x		x	x	x	x	x		x	x
Pachyphragma	x		x		x		x			x	x		x	
Striatopora			x								x	x		
Syringopora			x											x
Thamnopora	x	x												
Trachypora	x		x	x	x	x		x		x	x	x	x	x
BRACHIOPODS														
Athyris	x		x				x	x				x		x
Atrypa	x		x		x		x	x		x	x	x		x
Chonetes			x	x	x	x	x	x		x		x	x	x
Cranaena	x						x	x	x			x	x	x
Cryptonella	x				x							x		
Cyrtina	x		x				x	x		x	x	x		x
Devonalosia	x													
Douvillina	x										x			
Elytha	x		x								x			
Heteralosia	x							x						
Leptaena				x										
Leptalosia	x							x		x	x	x		
Longispina	x				x	x	x	x		x	x			
Megastrophia	x				x					x	x	x		
Mucrospirifer	x		x		x		x	x		x	x	x	x	x
Oligorhachis	x		x								x			
Orthopleura	x													
Pentamerella	x		x	x	x	x	x	x	x	x	x	x	x	
Pholidostrophia	x			x	x	x	x	x		x		x		
Productella			x					x						
Pugnoides				x										
"Reticularia"				x										
Rhipidomella				x						x	x			
Schizophoria				x	x	x	x	x						
Schuchertella	x				x	x	x	x			x	x		
Spinocyrtia	x				x		x	x		x	x	x		
"Spirifer"	x							x						

	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
MOLLUSCA - GASTROPODS														
Euomphalus			x											
"Murchisonia"		x												
"Pleurotomaria"		x										x	x	
Tentaculites	x													x
MOLLUSCA - PELECYPODS														
Actinopteria	x													
Aviculopecten	x													
Conocardium	x		x									x		
"Edmondia"		x												
Ilionia	x													
Janeia	x													
Leiopteria	x													
Leptodesma	x													
Nuculites	x													
Paracyclas	x													
Pterinopecten	x													
Sanguinolites	x													
MOLLUSCA - CEPHALOPODS														
Acleistoceras	x								x					
Michelinoceras	x							x	x					
"Orthoceras"		x												
Tumidoceras	x													
CRUSTACEA - TRILOBITES														
Ancyropyge	x				x									
Cordania			x											
Dechenella (Basidechenella)	x						x	x		x	x	x	x	x
Greenops	x										x	x	x	x
Phacops	x		x	x	x		x	x		x	x	x	x	x
Proetus (Crassiproetus)				x			x	x	x	x	x		x	x

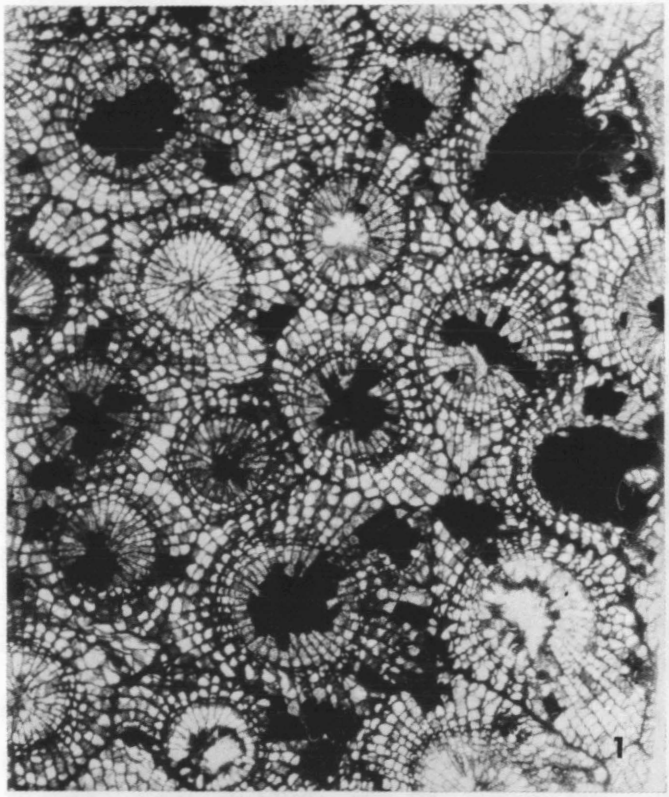
EXPLANATION OF PLATE 7

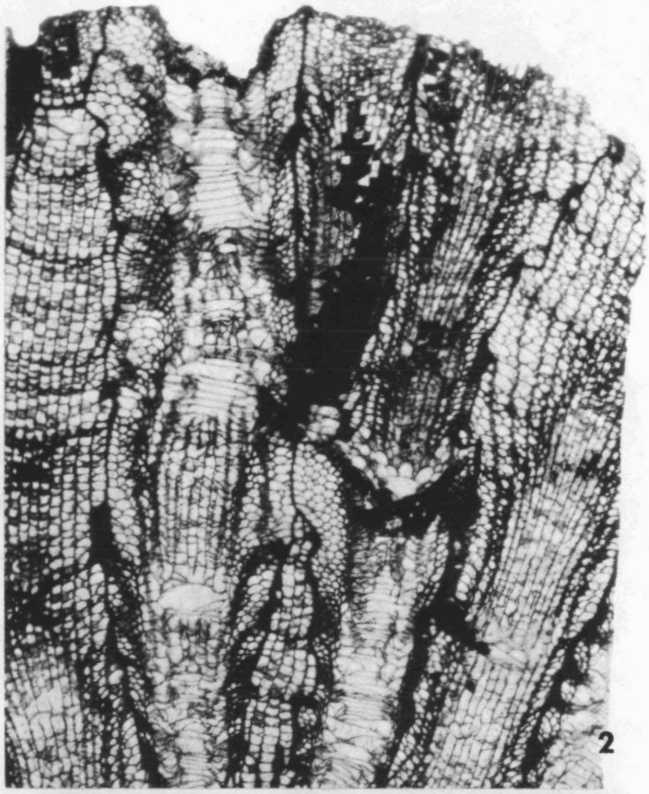
(All figures x 2)

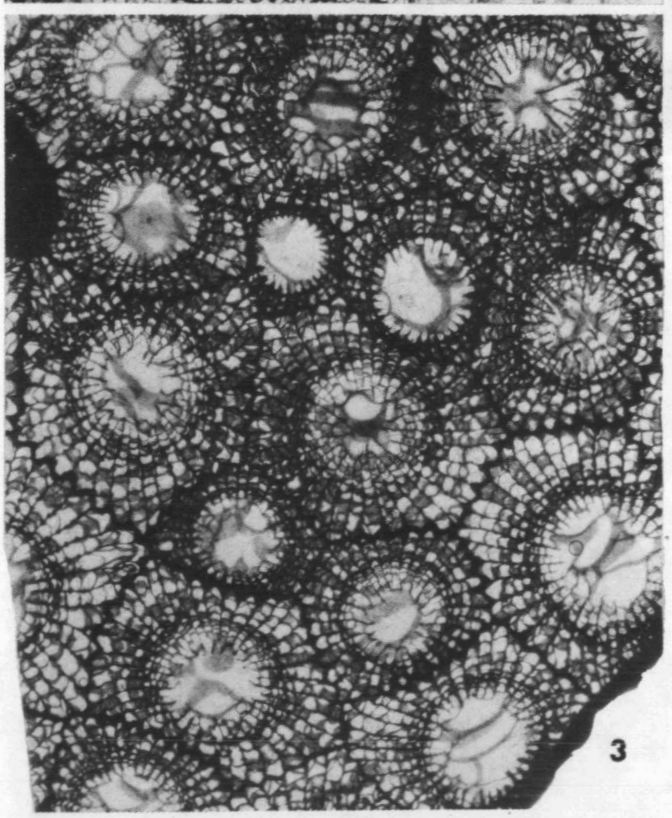
Gravel Point Formation. Thin sections of Hexagonaria.

FIGS. 1, 2, Hexagonaria cf. anna, UMMP 18850, cross and transverse sections; Locality 34-6-2 SW, east end of Penn-Dixie Quarry; zone 6, bed 1 ("lower blue shale") of Pohl. 3, 4, Hexagonaria percarinata, UMMP 18851, cross and transverse sections; Locality 34-6-3 S, Penn-Dixie Quarry; zone 4, bed 3 of Pohl.

PLATE 7







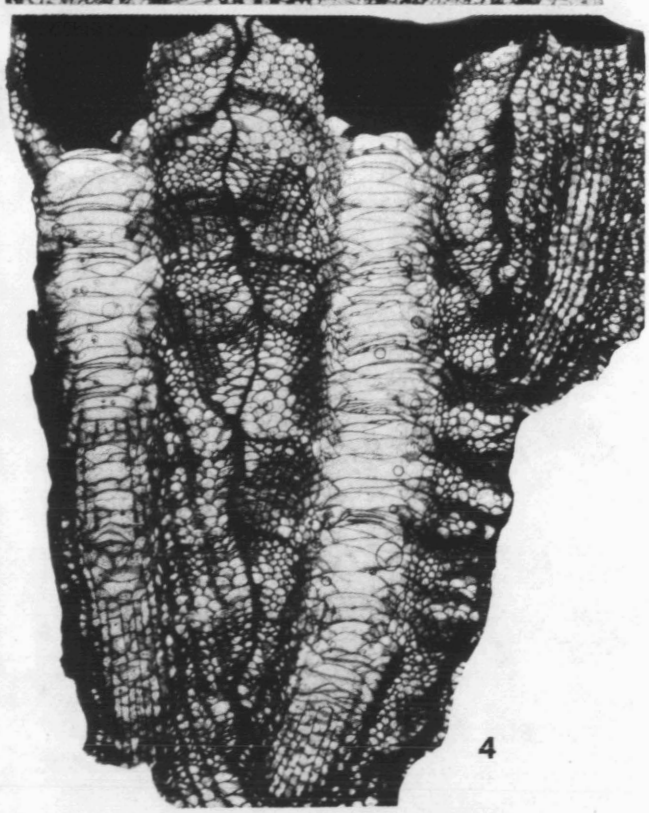
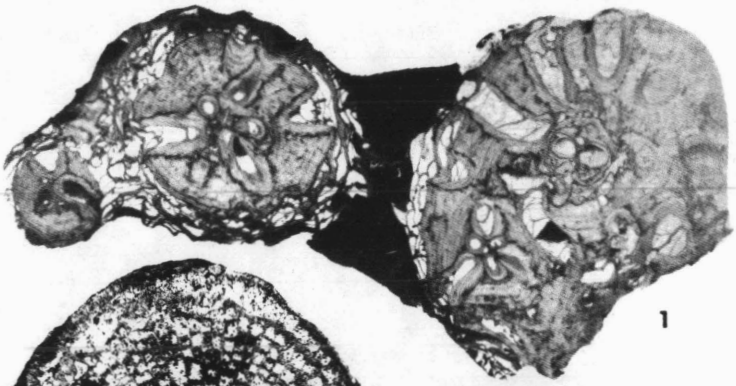


PLATE 8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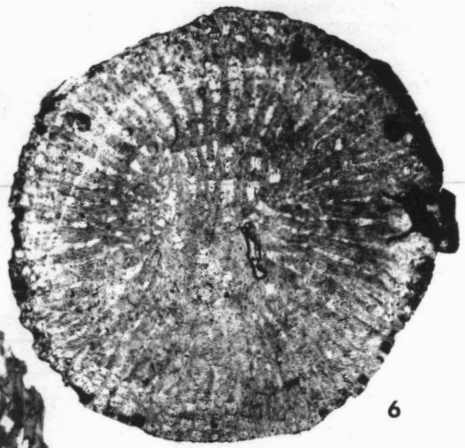
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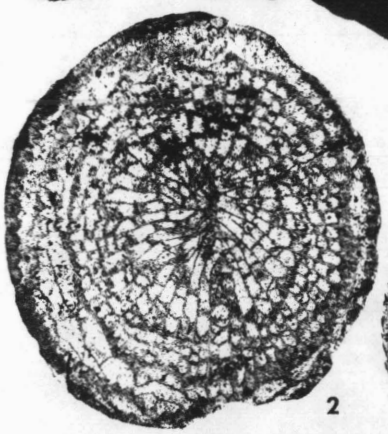
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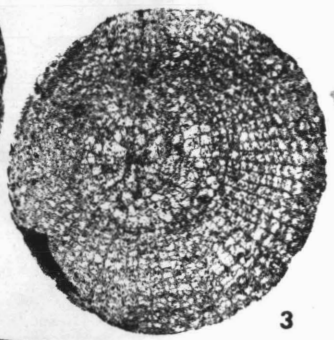
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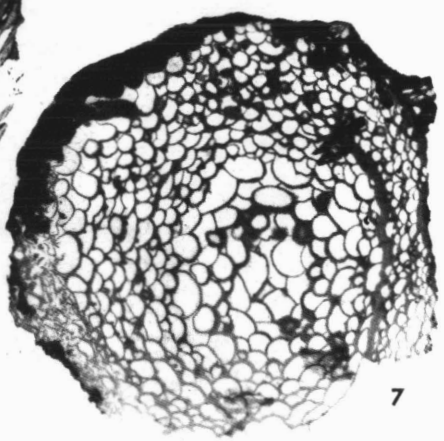
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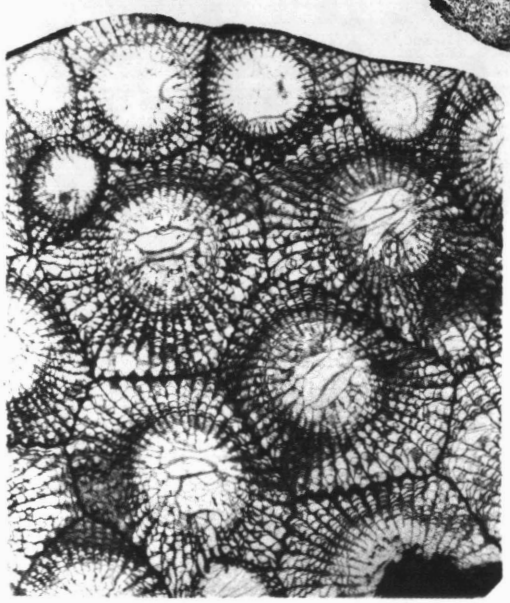
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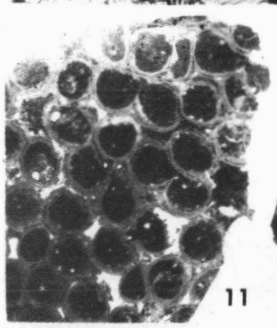
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ECHINODERMATA - CRINOIDS															
Megistocrinus	x										x	x			x
Melocrinus				x		x									
ECHINODERMATA - BLASTOIDS															
Codaster			x											x	x
Pentremitidea			x	x		x			x				x		x
Total genera	59	9	34	16		45	19	32	49	13	37	60	33	36	43

EXPLANATION OF PLATE 8

(All figures x 2)

Gravel Point Formation. Thin sections of corals.

FIG. 1, Trachypora alternans, UMMP 34366, cross section; specimen from Four Mile Dam Formation, Alpena Co. 2, Diversophyllum traversense, TYPE, UMMP 19978, cross section; Locality 34-6-3 S, Penn-Dixie Quarry. 3, Heliophyllum juvene, TYPE, UMMP 19986, cross section; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 4, 5, Striatopora sp., UMMP 37797, cross and transverse sections; Locality 34-6-3 S, Penn-Dixie Quarry; "lower blue shale." 6, Aulacophyllum mesodilatum, TYPE, UMMP 19969, cross section; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 7, Cystiphylloides americanum, UMMP 35301, cross section; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale." 8, Aulocystis fenestrata, UMMP 34394, cross section; Locality 34-8-28 SE SE, Charlevoix Rock Products No. 1 Quarry; "upper blue shale." 9, Favosites alpenensis calveri, UMMP 21947, transverse section; specimen from Genshaw Formation, Alpena Co. 10, Hexagonaria percarinata, UMMP 25148, cross section; Locality 34-8-28/29, Gravel Point.

Petoskey Formation. Thin sections of corals.

FIGS. 11, 12, Pachyphyllum erectum, UMMP 35002, cross and transverse sections; Locality 35-5-32 E, Encampment Avenue, Bay View; interval 4 of Ehlers' section. 13, Favosites romingeri romingeri, UMMP 21630, cross section; Locality 35-5-27 S, Kegomic Quarry.

Appendix 2

NUMBER OF GENERA OF MACROFOSSILS SHARED BY FORMATIONS OF THE TRAVERSE GROUP IN NORTHWESTERN AND NORTHEASTERN REGIONS OF THE LOWER PENINSULA OF MICHIGAN

	Northwestern				Northeastern									
Formation	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Gravel Point	--	4	22	7	24	10	21	28	7	25	25	21	17	16
Charlevoix	4	--	3	1	4	2	3	4	2	3	4	3	3	2
Petoskey	22	3	--	8	18	9	15	17	3	18	19	15	19	17
Whiskey Cr. -Jordan R.	7	1	8	--	11	7	9	8	5	10	7	7	7	6
Total genera present	59	9	34	16	45	19	32	49	13	37	60	33	36	43

Appendix 3

FAUNAL INDICES OF GENERA OF MACROFOSSILS SHARED BY TRAVERSE FORMATIONS (based on Appendix 2)

	Northwestern				Northeastern									
Formation	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Total genera present	59	9	34	16	45	19	32	49	13	37	60	33	36	43
Gravel Point	--	45	65	44	53	46	66	57	54	68	42	64	47	37
Charlevoix	44	--	33	11	44	22	33	44	22	33	44	33	33	22
Petoskey	65	33	--	50	53	41	47	50	23	53	56	45	56	50
Whiskey Cr. -Jordan R.	44	11	50	--	69	44	56	50	38	63	44	44	44	38

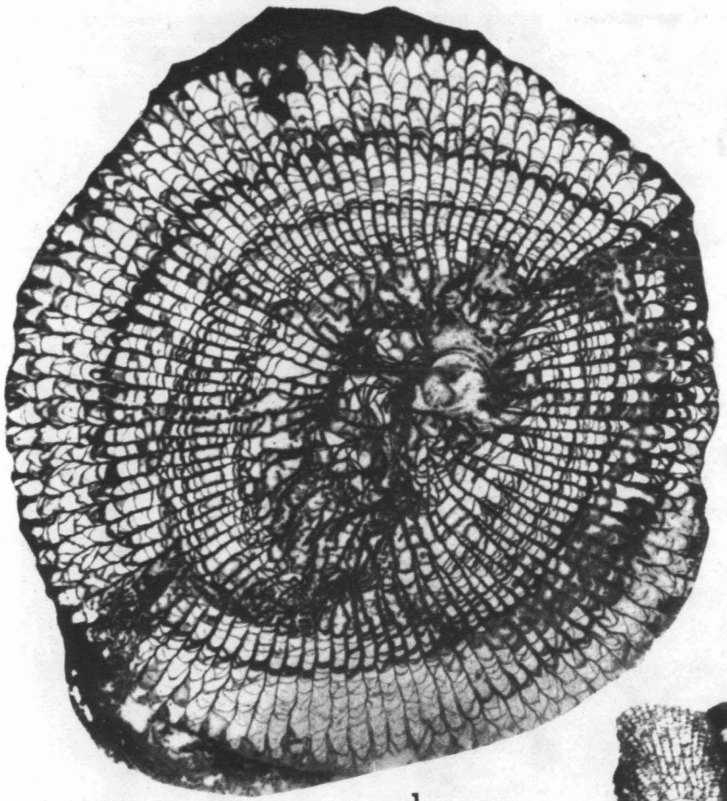
EXPLANATION OF PLATE 9

(All figures x 2)

Petoskey Formation. Thin sections of corals.

FIGS. 1, 2, Cyathophyllum robustum, UMMP 60884, cross and transverse sections; Locality 35-5-27 S, Kegomic Quarry. 3, Hallia zonata, TYPE, UMMP 19984, cross section; Locality 35-5-27 S, Kegomic Quarry. 4, Hallia vesiculata, TYPE, UMMP 19976, cross section; near Locality 35-5-27 S, east of Bay View at creek. 5, Aulacophyllum bilaterale, TYPE, UMMP 19968, cross section; near Locality 35-5-27 S, east of Bay View at creek. 6, 7, Cylindrophyllum panicum, UMMP 25267, cross and transverse sections; Locality 35-5-27 S, Kegomic Quarry.

PLATE 9



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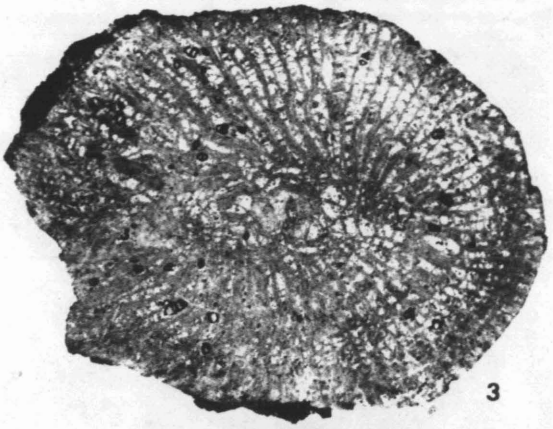

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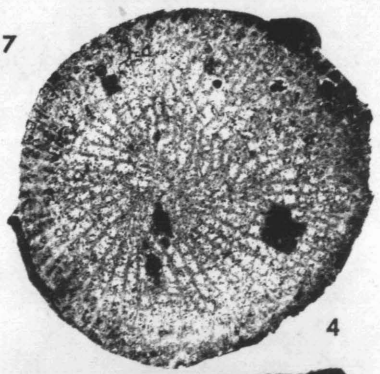

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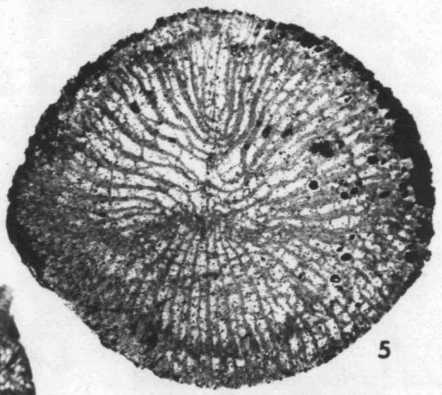

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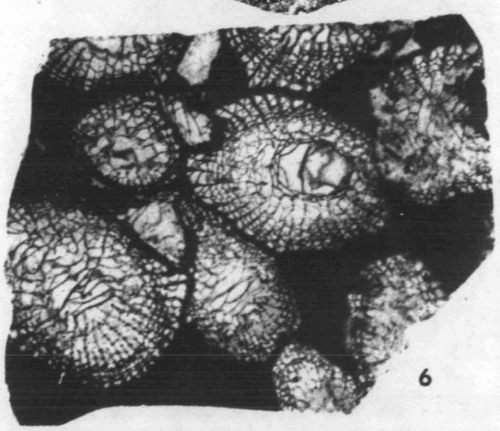

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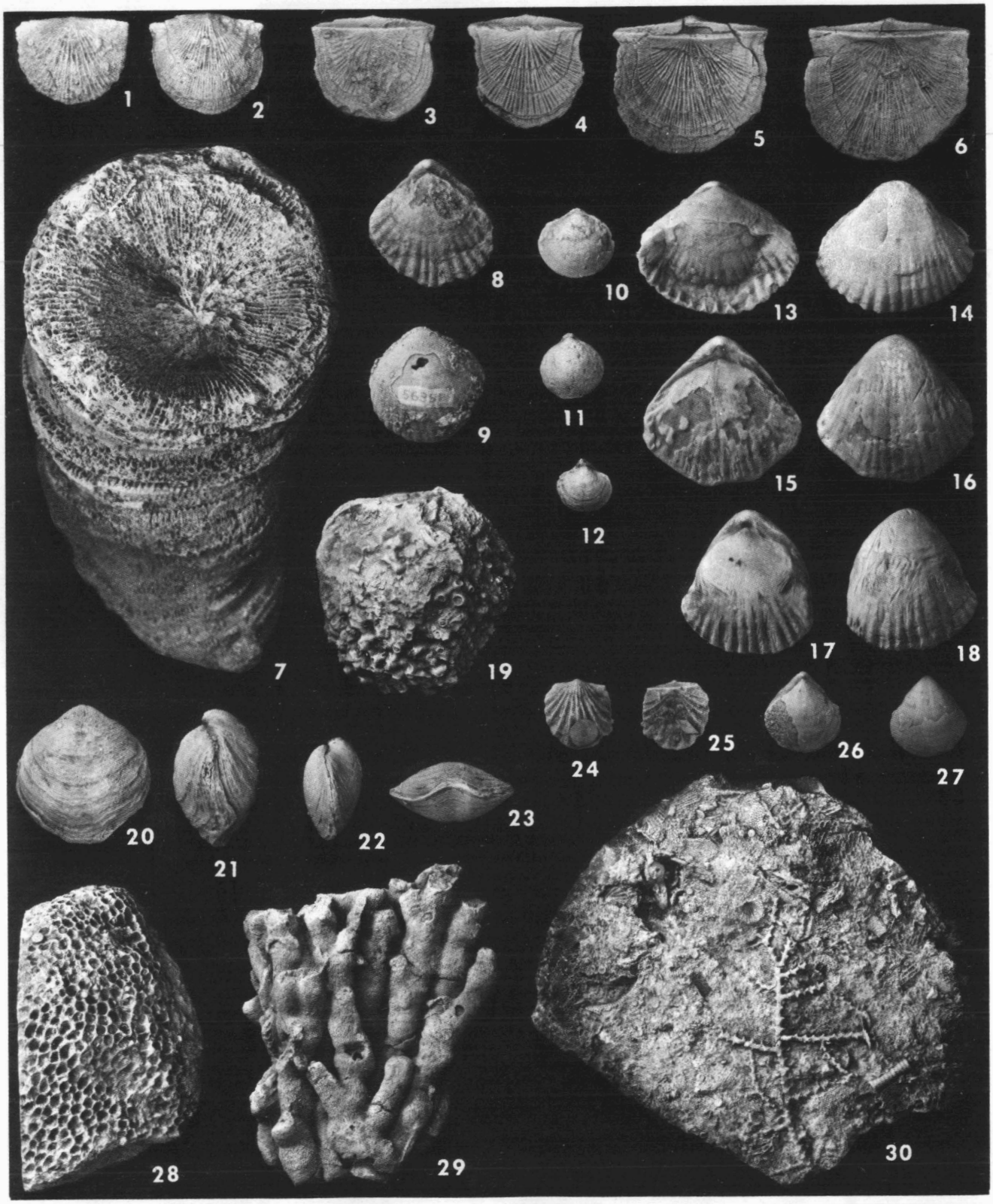
PLATE 10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Appendix 4

NUMBER OF GENERA IN EACH MAJOR TAXON RECORDED FROM FORMATIONS OF THE TRAVERSE GROUP

	Northwestern				Northeastern									
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Tetracorals	10	1	9	1	9	7	5	9	1	9	9	0	13	6
Tabulate corals	9	4	10	3	8	4	4	7	2	7	12	6	7	7
Brachiopods	20	0	9	8	16	8	16	24	5	15	24	18	7	10
Gastropods	1	2	1	0	0	0	0	0	0	0	1	1	1	1
Pelecypods	11	1	1	0	2	0	0	1	0	0	0	1	0	2
Cephalopods	3	1	0	0	0	0	0	3	4	0	1	0	0	0
Trilobites	4	0	2	2	4	0	4	4	1	3	5	4	5	5
Crinoids	1	0	0	1	5	0	0	0	0	2	5	2	1	8
Blastoids	0	0	2	1	1	0	0	1	0	0	1	1	1	3
Other echinoderms	0	0	0	0	0	0	3	0	0	1	2	0	1	1
Total	59	9	34	16	45	19	32	49	13	37	60	33	36	43

EXPLANATION OF PLATE 10

(All figures x 1)

Fossils from the Petoskey Formation

FIGS. 1-6, Strophodonta sp.; 1, 2, UMMP 60879, two from Locality 35-5-32 E, Encampment Avenue Bay View, unit 5 of Ehlers' section; 3-6, UMMP 60832, four from Locality 35-5-27 S, Kegomic Quarry. 7, Cyathophyllum robustum, UMMP 60831; Locality 35-5-27 S, Kegomic Quarry. 8, 9, Pentamerella sp., UMMP 56351; two from Locality 34-7-1 SE, cliffs west of Bay Shore; possibly Charlevoix Limestone, but probably Petoskey. 10-12, Athyris lens, UMMP 4428; three from Locality 35-5-32 SW, Northern Lime Quarry in Petoskey; collected by Winchell. 13-18, Pentamerella petoskeyensis, UMMP 14717; three from Locality 35-5-27 S, Kegomic Quarry, type locality. 19, Aulopora gregaria, UMMP 43977; specimen from Genshaw Formation, Alpena Co. 20-23, Athyris sp., UMMP 60833; two from Locality 35-5-27 S, Kegomic Quarry. 24, 25, Strophodonta erratica solidicosta, TYPE, UMMP 14930; Locality 35-5-32 NE, Winchell's Loc. 856. 26, 27, Pentamerella athyroides, TYPE, UMMP 4833; Locality 35-5-32 NE, Winchell's Loc. 856; collected by Winchell. 28, Favosites romingeri romingeri, UMMP 21630; Locality 35-5-27 S, Kegomic Quarry; collected by Ehlers. 29, Idiostroma caespitosa, UMMP 32403; Locality 35-5-32 NE, Winchell's Loc. 856; collected by Winchell. 30, Trachypora proboscidialis, UM MP 34421; specimen from Potter Farm Formation, Alpena Co.

Appendix 5

SPECIES OF MACROFOSSILS RECORDED FROM FORMATIONS OF THE TRAVERSE GROUP IN NORTHWESTERN REGION

TETRACORALS	GP	CH	PY	W/J
Aulacophyllum bilaterale Sloss			x	
Aulacophyllum hemicrassatum Sloss	x		x	
Aulacophyllum mesodilatum Sloss	x			
Bethanyphyllum robustum (Hall)			x	
Cylindrophyllum panicum (Winchell)			x	
Cystiphylloides americanum (Edwards & Haime)	x		x	
Cystiphylloides petoskeyense Stumm			x	
Cystiphylloides potterense Stumm			x	
Cystiphylloides tabulatum Stumm	x			
Cystiphylloides varians (Hall)	x			
Cystiphylloides cf. aggregatum (Billings)			x	
Cystiphylloides cf. conifollis (Hall)			x	
Cystiphylloides cf. varians (Hall)			x	
Diversophyllum traversense (Winchell)	x			
Hallia vesiculata Sloss			x	
Hallia zonata Sloss			x	
Heliophyllum juvene (Rominger)	x			
Heliophyllum tenuiseptatum traversense Stumm	x			
Heliophyllum sp.			x	

EXPLANATION OF PLATE 11

Fossils from the Petoskey Formation

(All figures x 1)

FIG. 1, Cyathophyllum robustum, UMMP 19622; Locality 35-5-27 S, Kegomic Quarry. 2-9, Aulocystis parva, UMMP 35019; Locality 35-5-32 E, Encampment Avenue, Bay View; collected by G. M. Ehlers. 10-12, Mucrospirifer sp., UMMP 60892; Locality 35-5-27 S, Kegomic Quarry. 13-18, Mucrospirifer profundus, UMMP 14335; specimens from Potter Farm Formation, Alpena Co. 19, Phacops iowensis, UMMP 29230; Locality 35-5-27 S, Kegomic Quarry; identified by E. C. Stumm. 20, 21, Hallia vesiculata, UMMP 60885; Locality 35-5-27 S, Kegomic Quarry; Pentamerella (formerly, Gypidula) bed. 22-25, Strophodonta sp., UMMP 60832; Locality 35-5-27 S, Kegomic Quarry. 30, 31, Athyris sp., UMMP 60883; Locality 35-5-27 S, Kegomic Quarry. 32, Stromatopora pustulifera, UMMP 56456; Locality 35-5-32 SW, N orthern Lime Quarry in Petoskey; collected by Grabau.

Fossils from the Whiskey Creek Formation

(All figures x 2)

FIGS. 33-38, Scalaripora sp., UMMP 60881; bryozoan bed at type locality of formation.

PLATE 11

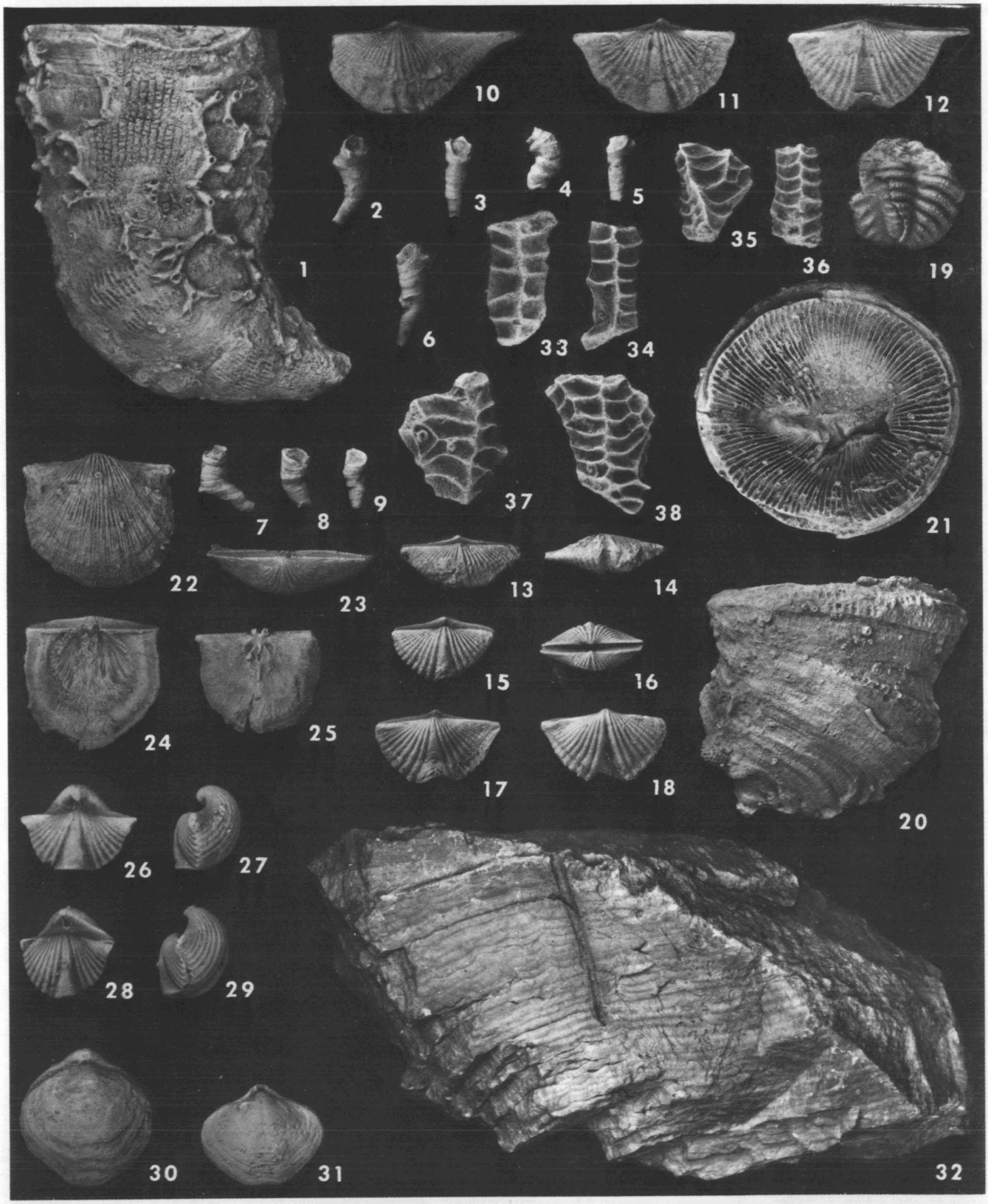
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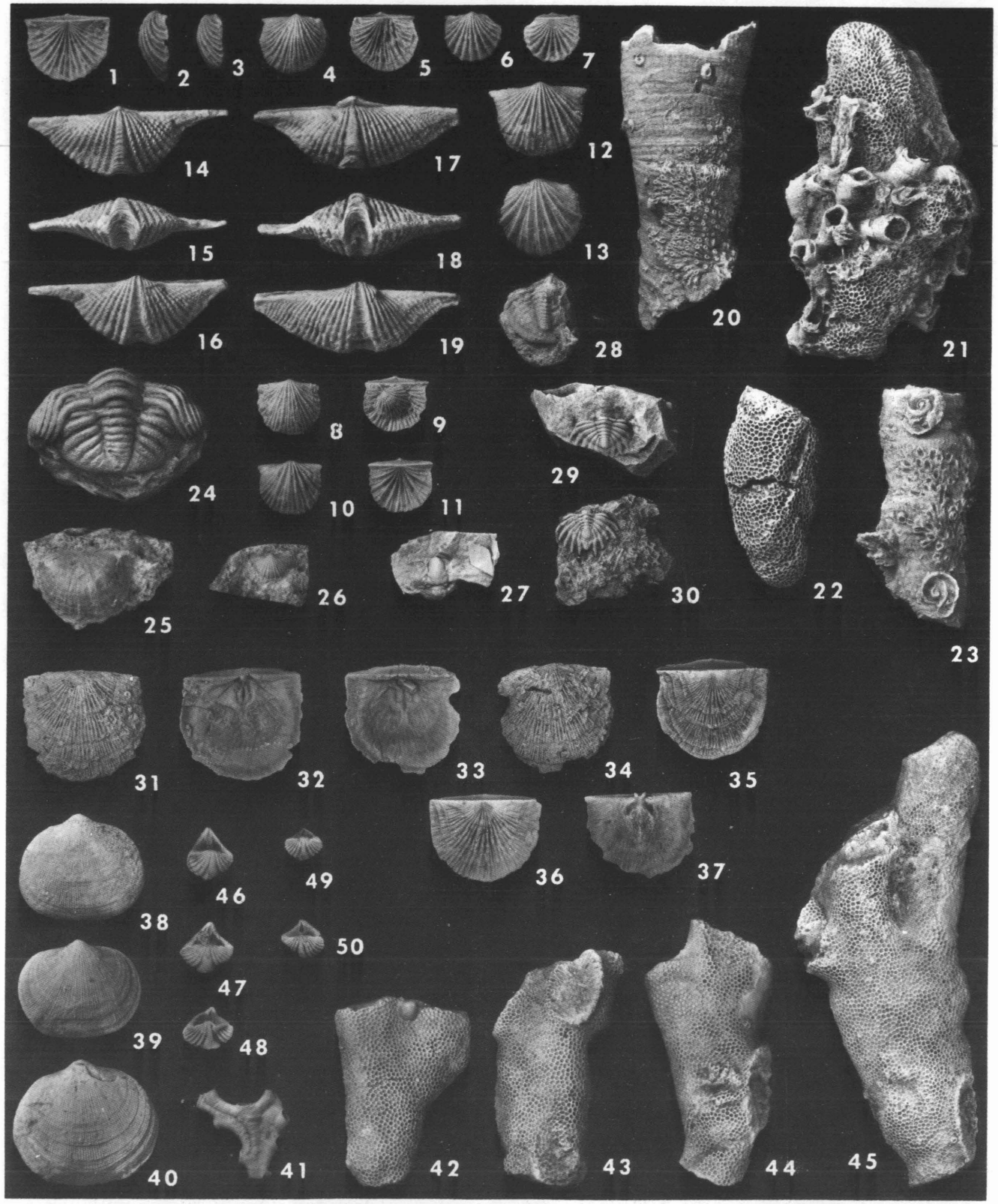
PLATE 12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Heterophrentis sp.	x		x	
Hexagonaria attenuata Stumm		x		
Hexagonaria cristata (Rominger)	x			
Hexagonaria cristata microcarinata (Sloss)	x			
Hexagonaria pauciseptata (Sloss)	x			
Hexagonaria percarinata (Sloss)	x			
Hexagonaria profunda (Hall)			x	
Hexagonaria cf. anna (Whitfield)	x			
Naos ovatus (Sloss)	x			
Naos ponderosus (Rominger)	x			
Scoliophyllum cf. lamellosum (Goldfuss)	x			
Stereolasma petoskeyense (Sloss)			x	x

EXPLANATION OF PLATE 12

(All figures x 1)

Fossils from the Gravel Point Formation

FIGS. 1-3, Strophodonta costata, UMMP 56043; Locality 34-8-28/29, Gravel Point; collected by Grabau. 4, 5, Strophodonta erratica fissicosta, UMMP 50683; shore of Little Traverse Bay; collected by Winchell. 6, 7, Strophodonta costata, UMMP 56038; Locality 34-8-28/29, Gravel Point; collected by Grabau. 8-11, Strophodonta erratica, UMMP 50680; shore of Little Traverse Bay; collected by Winchell. 12, Strophodonta erratica, TYPE, UMMP 14923; shore of Little Traverse Bay; collected by Winchell. 13, Strophodonta erratica solidicosta, UMMP 50681; shore of Little Traverse Bay; collected by Winchell. 14-19, Mucrospirifer grabaui, UMMP 31660; Locality 34-6-3 S, Penn-Dixie Quarry; zone 2 (Atrypa bed) of Pohl. 20, Aulopora conferta, UMMP 51023; Little Traverse Bay region; Perry Collection. 21, Aulocystis alectiformis, UMMP 34936; Locality 34-6-8 NE, old Bell Quarry; "lower blue shale." 22, Favosites nitella, UMMP 37956; "Petoskey region." 23, Aulopora socialis, UMMP 13158; Locality 34-6-8 NE, old Bell Quarry; collected by C. L. and M. A. Fenton at their "Rose" Quarry. 24, Phacops rana alpenensis, UMMP 29559; specimen from the Alpena Limestone, Thunder Bay Quarry at Alpena. 25, 26, Douvillina distans, UMMP 47240, 47241; both specimens from Four Mile Dam Formation in Alpena Co. 27, 28, Dechenella (Basidechenella) pulchra; TYPE, UMMP 25514, Locality 34-8-28/29, Gravel Point, Emmetensis zone; UMMP 28683, specimen from Dock Street Clay in Alpena Co. 29, Greenops aequituberculatus, TYPE, UMMP 28669; Locality 34-8-28/29, Gravel Point. 30, Greenops traversensis, TYPE, UMMP 28668; Emmet County; collected by Verhoeven, 1947; identified by E. C. Stumm.

Fossils from the Petoskey Formation

FIGS. 31-37, Strophodonta sp., UMMP 60879; Locality 35-5-32 E, Encampment Avenue in Bay View; unit 5 of Ehlers' section.

Fossils from the Whiskey Creek Fromation

FIGS. 38-40, Schizophoria mesacarina, UMMP 42147. 41, Aulocystis minuta, UMMP 34975. 42-45, Favosites norwoodensis, UMMP 60890; Atrypa bed. 46-50, Cyrtina sp., UMMP 60894; bryozoan bed. All specimens from type locality of the formation.

Tabulophyllum traversense (Winchell)	x		x	
Tortophyllum cysticum (Winchell)	x		x	
Tortophyllum milleri Pitrat				x
TABULATE CORALS				
Alveolites (Planalveolites) megastoma Winchell	x			
Alveolites (Lunatipora) michiganensis (Winchell)	x			
Alveolites strigillatus Winchell	x			
Alveolites cf. subramosus Rominger	x			
Aulocystis alectiformis (Winchell)	x			
Aulocystis alpenensis Watkins			x	
Aulocystis minuta Watkins				x
Aulocystis minuta parallela Watkins				x
Aulocystis parva Watkins			x	
Aulopora aperta Winchell	x			
Aulopora conferta Winchell	x			
Aulopora crassata (Winchell)		x		
Aulopora cyclopora Winchell	x			
Aulopora gregaria Watkins			x	
Aulopora michiganensis Fenton	x			
Aulopora "serpens" Goldfuss	x			
Aulopora socialis Fenton	x			
Aulopora sp.			x	
Cladopora sp.	x		x	
Drymopora partita (Winchell)	x			
Drymopora cf. jacksoni (Grabau)			x	
Drymopora sp.		x		
Favosites alpenensis alpenensis Winchell	x	x	x	
Favosites alpenensis calveri Swann				
Favosites alpenensis praevigens Swann	x			
Favosites alpenensis tenuimuralis Swann			x	
Favosites dumosus Winchell		x		
Favosites nitellus Winchell	x			
Favosites norwoodensis Stumm & Tyler				x

EXPLANATION OF PLATE 13

(All figures x 1 except as noted)

Fossils from the Petoskey Formation

FIGS. 1-3, Weathered surfaces of the Fenestella bed; Locality 34-6-6 SW, old Curtiss Quarry of Northern Lime Company, near Bay Shore, western edge of Emmet County.

Fossils from the Jordan River Formation

All from the type locality

FIGS. 4-6, Pugnoides sp., UMMP 60880; x 2. 7-9, Actinopteria sp.; 7, 8, UMMP 60893; 9, UMMP 60882. 10-21, three spiriferid brachiopods cf. Mucrospirifer, UMMP 60889.

PLATE 13

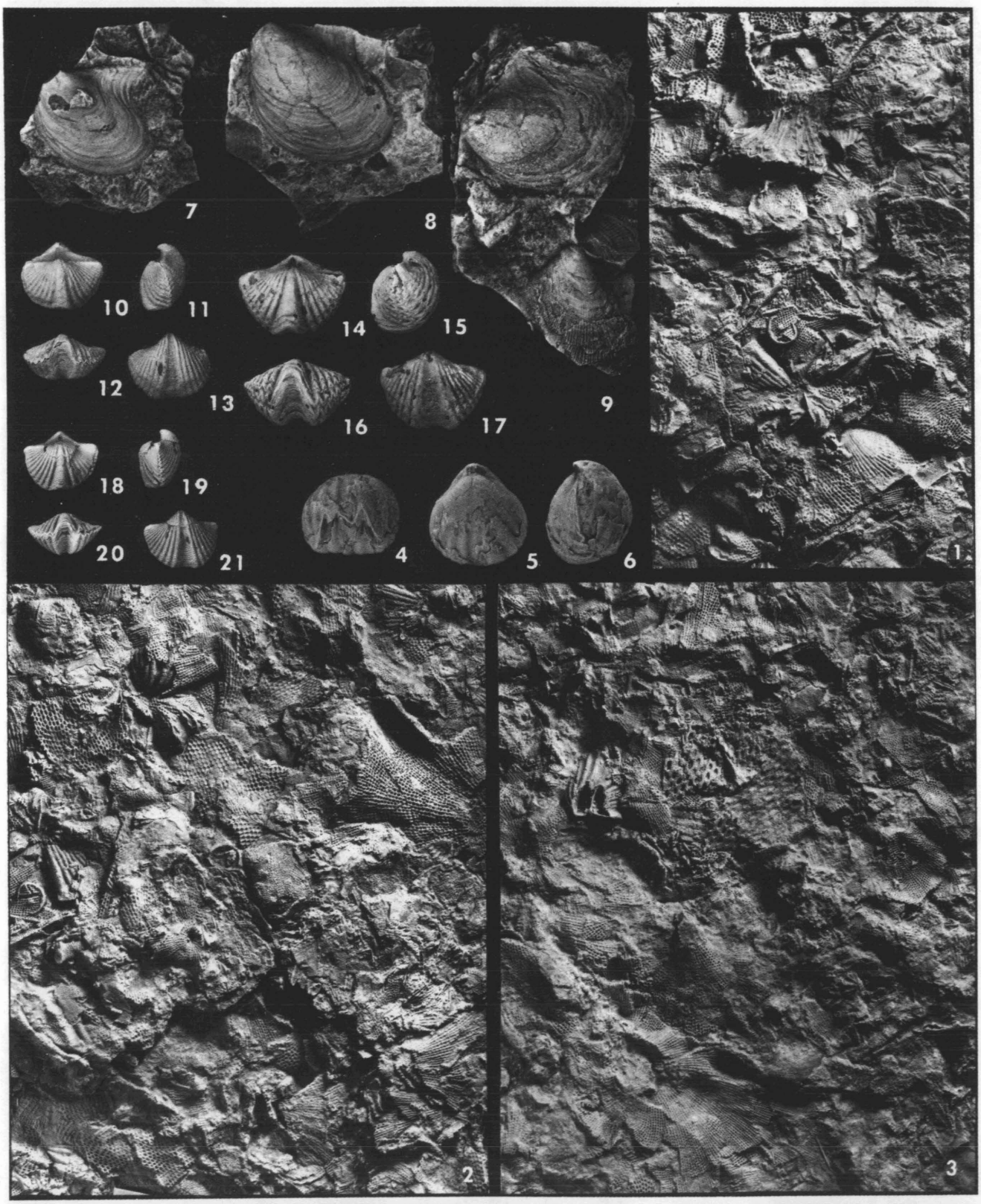
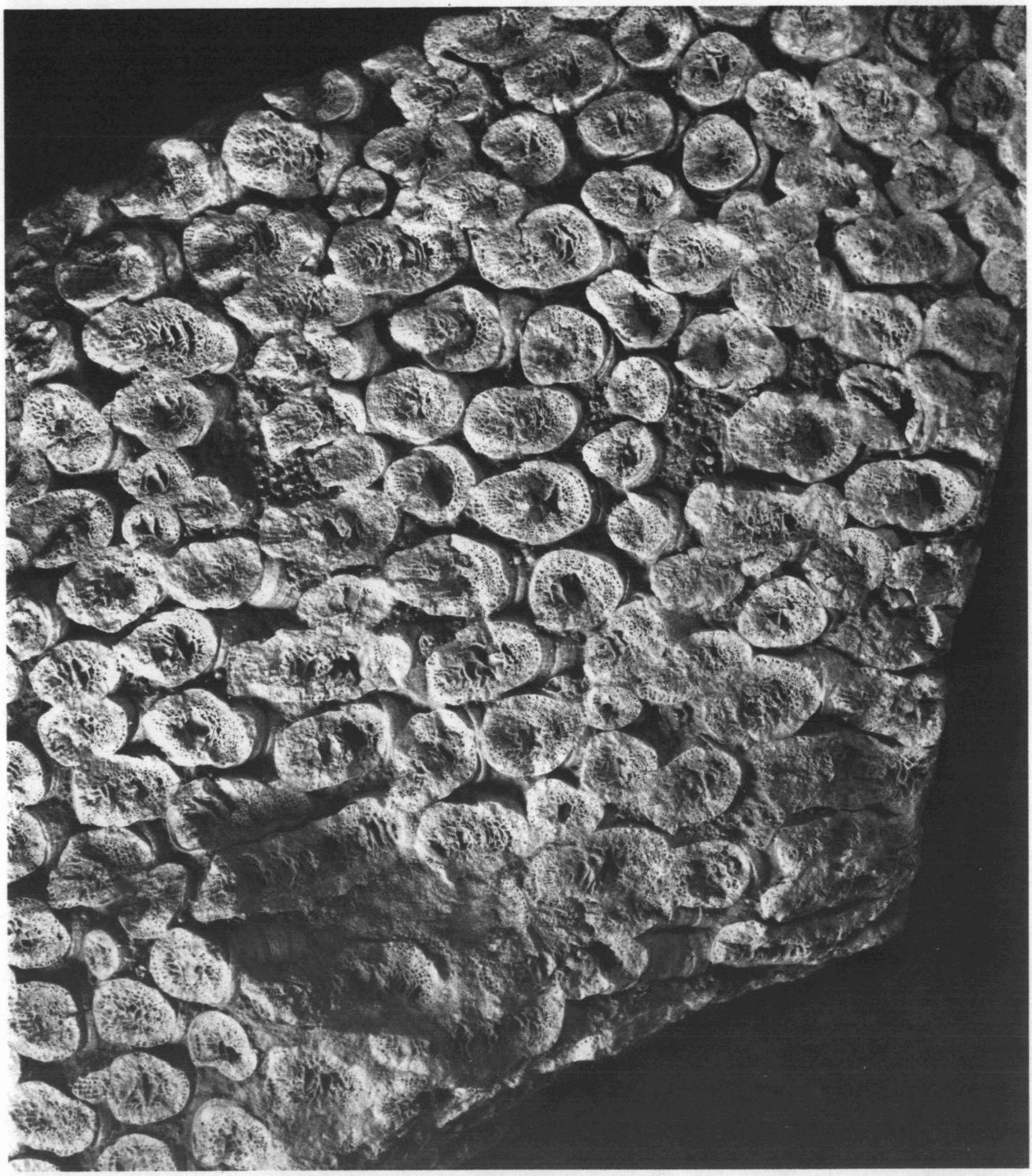


PLATE 14

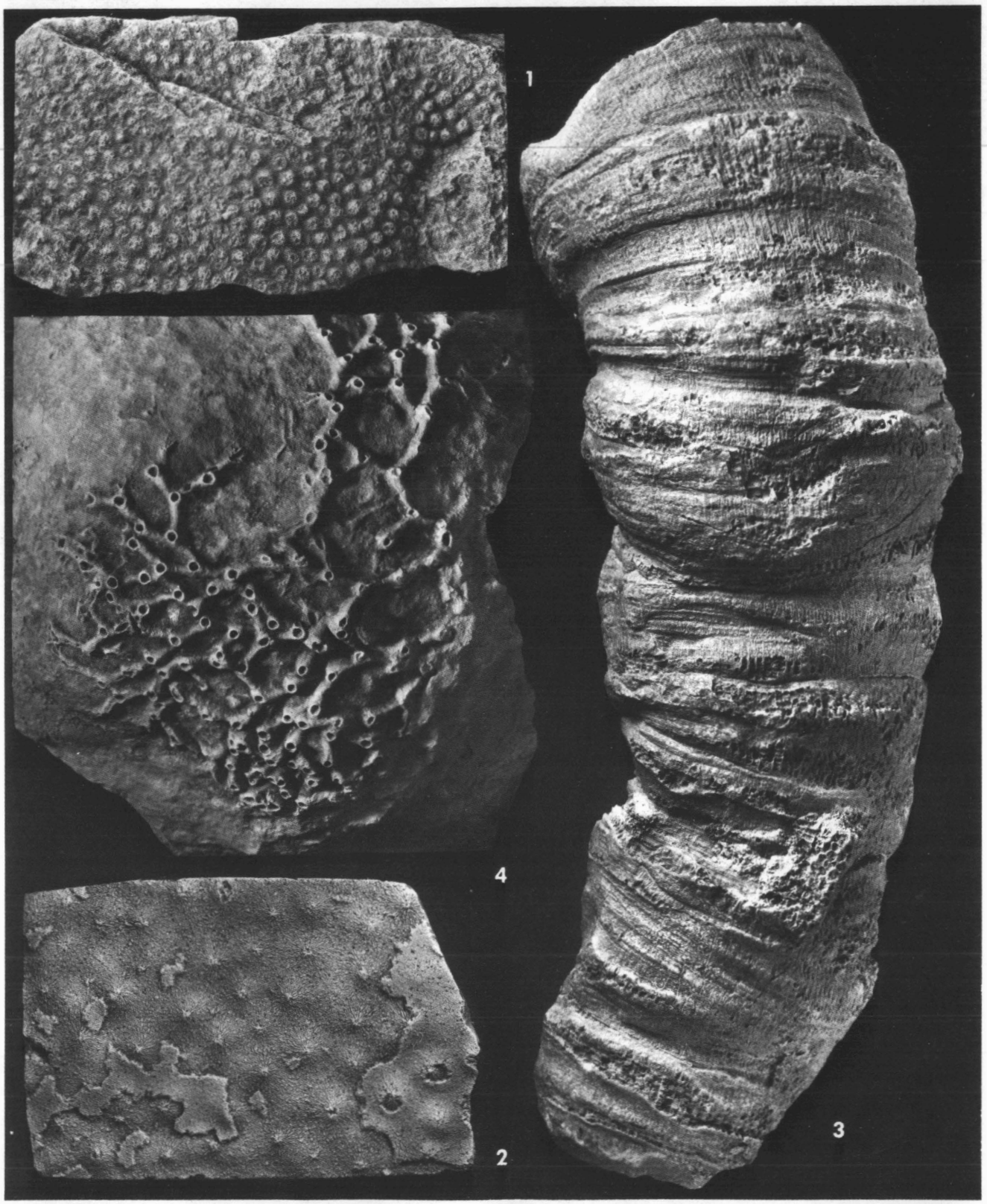
Charlevoix Limestone. Weathered surface exposing sections through Favosites dumosus, UMMP 60891; near Locality 34-6-8 NE, old Bell Quarry; bed 4 of Pohl; x 1.

PLATE 15



Petoskey Formation. Cylindrophyllum panicum, UMMP 25686, topotype; shore of Little Traverse Bay; collected by Alexander Winchell.

PLATE 16



	GP	CH	PY	W/J
Favosites placentus Rominger	x			
Favosites romingeri patella Swann			x	
Favosites romingeri romingeri Swann			x	
Favosites romingeri saetigera Swann	x	x		
Favosites cf. hamiltoniae Hall			x	
Pachyphragma concentricum Watkins	x			
Pachyphragma erectum (Rominger)	x		x	
Striatopora sp.			x	
Syringopora crassata Winchell			x	
Thamnopora magniventra Stumm	x			
Thamnopora sp.		x		
Trachypora alternans Stumm & Hunt	x		x	
Trachypora lineata Stumm & Hunt	x			
Trachypora proboscidialis Stumm & Hunt			x	x
BRACHIOPODS				
Athyris eborea (Winchell)	x			
Athyris lens (Winchell)			x	
Athyris sesquiplicata (Winchell)	x			
Atrypa corrugata Fenton & Fenton	x			
Atrypa dignata Fenton & Fenton	x			
Atrypa petosequa Fenton & Fenton	x			
Atrypa petosequa lata Fenton & Fenton	x			
Atrypa traversensis Fenton & Fenton			x	
Atrypa sp.			x	
Chonetes ensicosta Imbrie			x	
Chonetes hybus Imbrie				x
Chonetes cf. coronatus Hall			x	
Cranaena romingeri Hall & Clarke	x			
Cryptonella sp.	x			
Cyrtina sp.	x		x	
Devonalosia radicans (Winchell)	x			
Douvillina cf. inaequistriata (Conrad)	x			
Douvillina sp.	x			
Elytha filicosta (Winchell)	x		x	
Heteralosia sp.	x			
Leptaena sp.				x

EXPLANATION OF PLATE 16

(All figures x 1)

Fossils from the Petoskey Formation

FIG. 1, Coenostroma pustuliferum, UMMP 49524; shore of Little Traverse Bay just east of Petoskey; collected by Winchell. 2, Coenostroma monticulifera, UMMP 50667; Little Traverse Bay region; collected by Winchell. 3, Cyathophyllum rugosum, UMMP 60831; Locality 35-5-27 S, Kegomic Quarry. 4, auloporoid coral encrusted on spherical surface of stromatoporoid, UMMP 60895; Locality 35-5-32 SW, old Northern Lime Quarry in Petoskey; may possibly be from Charlevoix Limestone.

	GP	CH	PY	W/J
Longispina emmetensis (Winchell)	x			
Megastrophia cf. concava (Conrad)	x			
Mucrospirifer grabaui Stumm	x		x	
Mucrospirifer profundus (Grabau)			x	
Mucrospirifer sp.	x		x	
Oligorhachis littletonensis (Stainbrook)			x	
Oligorhachis oligorhachis Imbrie	x			
Orthopleura sp.	x			
Pentamerella aftonensis Imbrie	x			
Pentamerella alpenensis Imbrie	x			
Pentamerella athyroides (Winchell)			x	
Pentamerella aulax Imbrie				x
Pentamerella intralineata (Winchell)	x			
Pentamerella petoskeyensis (Imlay)			x	
Pentamerella sp.	x			x
Pholidostrophia geniculatum Imbrie	x			
Pholidostrophia cf. nacrea Hall	x			
Pholidostrophia sp.				x
Productella sp.			x	
Pugnoides sp.				x
"Reticularia" cf. laevis				x
Rhipidomella trigona Imbrie				x
Schizophoria mesacarina Imbrie				x
Schizophoria sp.				x
Schuchertella anomala (Winchell)	x			
Spinocyrtia cf. euryteines (Owen)	x			
Spinocyrtia sp.			x	
"Spirifer" bidorsalis Winchell	x			
"Spirifer" consors Winchell			x	
Strophodonta cincta Winchell	x			
Strophodonta crassa Imbrie			x	
Strophodonta erratica Winchell	x		cf.	
Strophodonta erratica fissicosta Winchell	x			
Strophodonta erratica solidicosta Winchell	x			
Strophodonta heteromys Imbrie				x
Strophodonta imitata Winchell	x			
Strophodonta levidensa Imbrie				x
Strophodonta nanus Imbrie	x			
Strophodonta pentagonia Imbrie			x	

EXPLANATION OF PLATE 17

(Both figures x 1)

Fossils from the Petoskey Formation

FIGS. 1, 2, Cylindrophyllum panicum; 1, UMMP 50678, Little Traverse Bay region about 1 mile east of Petoskey, collected by Stuart Perry; 2, UMMP 60896, Locality 35-5-32 SW, abandoned Northern Lime Quarry in Petoskey.

PLATE 17

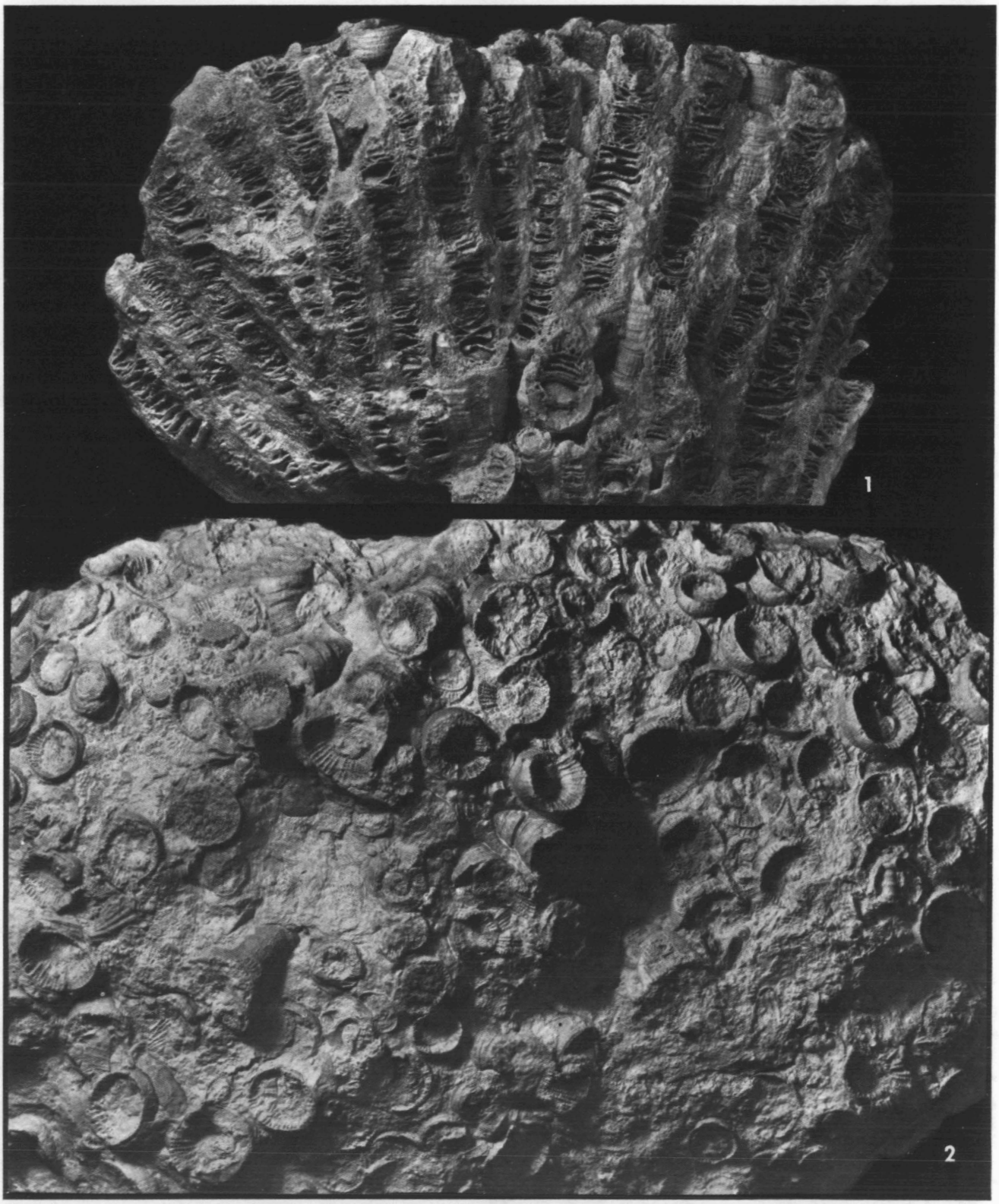
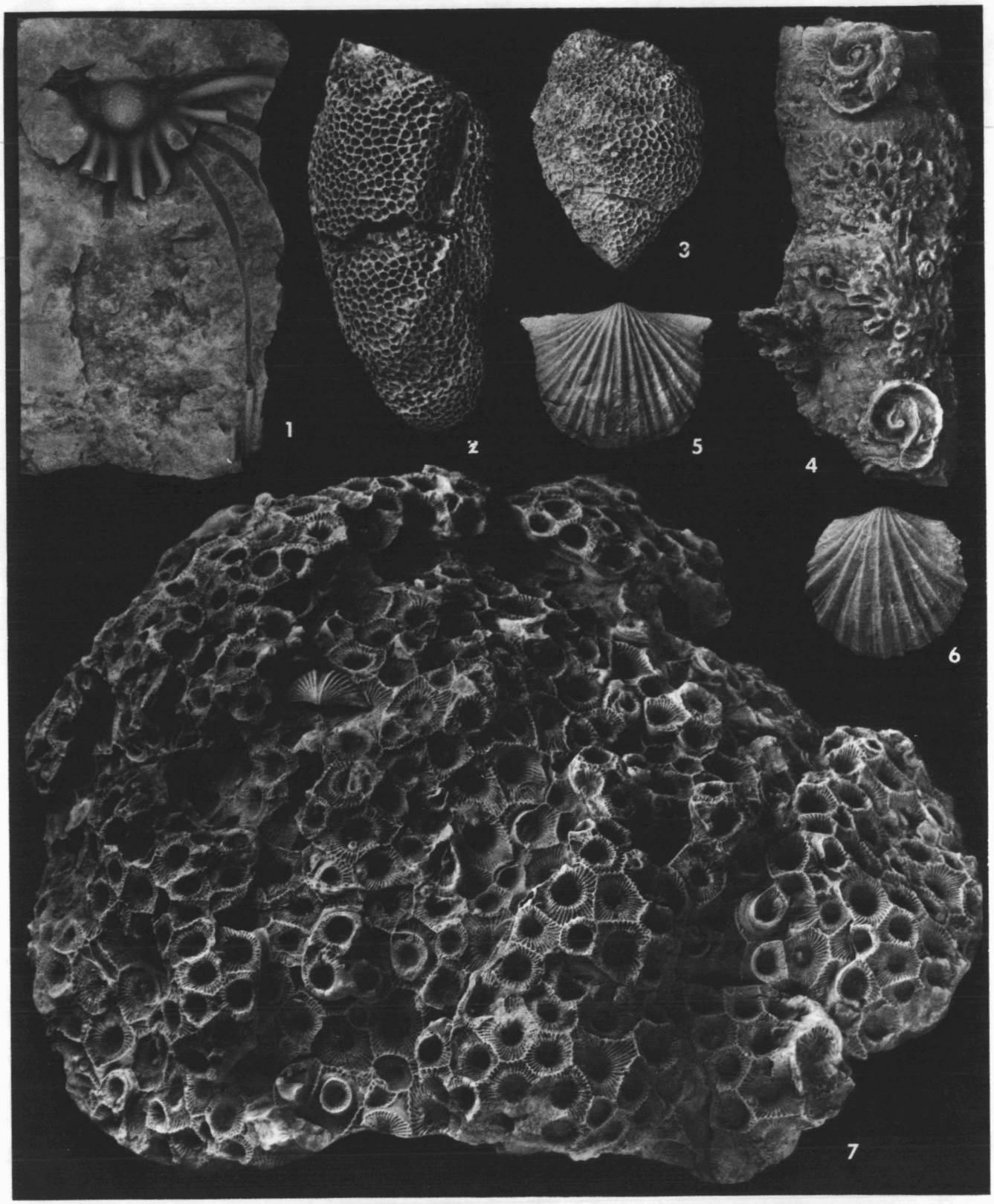


PLATE 18



	GP	CH	PY	W/J
Strophodonta tenuicosta Imbrie			x	
Strophodonta titan Imbrie	x			
Strophodonta titan titan Imbrie	x			
Strophodonta cf. demissa			x	
Strophodonta sp.	x		x	x
Stuartella traversensis (Winchell)	x			
Truncalosia gibbosa Imbrie	x		x	
MOLLUSCA - GASTROPODS				
Euomphalus sp.			x	
"Murchisonia" emmetensis Winchell		x		
"Murchisonia" mucro Winchell		x		
"Murchisonia" parvispira Winchell		x		
"Pleurotomaria" cavumbilicata Winchell		x		
Tentaculites subtilis Winchell	x			
MOLLUSCA - PELECYPODS				
Actinopteria sp.	x			x
Aviculopecten intercostalis Winchell	x			
Conocardium bifarum Winchell			x	
Conocardium emmetense Winchell	x			
"Edmondia" ledoides Winchell		x		
"Edmondia" mactroides Winchell		x		
Ilionia sp.	x			
Janeia sp.	x			
Leiopteria sp.	x			
Leptodesma sp.	x			
Nuculites oblonga Winchell	x			
Paracyclas hamiltonensis (Winchell)	x			
Pterinopecten sp.	x			
Sanguinolites (Grammysia ?) sulcifer Winchell	x			

EXPLANATION OF PLATE 18

(Figures x 2 except as noted)

Fossils from the Gravel Point Formation

FIG. 1, Ancyropyge romingeri, TYPE, UMMP 4934; Locality 34-8-28/29, Gravel Point. 2, Favosites nitella, UMMP 37956; "Petoskey region." 3, Favosites romingeri saetigera, UMMP 19673; Locality 34-6-8 NE, old Bell Quarry; "upper blue shale"; x 1. 4, Aulopora socialis, UMMP 13158; Locality 34-6-8 NE, old Bell Quarry; collected by Fenton & Fenton at their "Rose" quarry. 5, Strophodonta erratica, TYPE, UMMP 14923; shore of Little Traverse Bay; collected by Winchell. 6, Strophodonta erratica solidicosta, UMMP 50681; shore of Little Traverse Bay; collected by Winchell. 7, Hexagonaria percarinata, UMMP 15645; Bear Creek, Emmet County; collected by Winchell; x 1.

	GP	CH	PY	W/J
MOLLUSCA - CEPHALOPODS				
? Acleistoceras omicron (Winchell)	x			
? Michelinoceras pustulosum (Winchell)	x			
"Orthoceras" cf. exile (Hall)		x		
Tumidoceras lentum Flower	x			
Tumidoceras magnum Flower	x			
CRUSTACEA - TRILOBITES				
Ancyropyge romingeri (Hall & Clarke)	x			
Cordania sp.			x	
Dechenella (Basidechenella) pulchra Stumm	x			
Greenops aequituberculatus Stumm	x			
Greenops traversensis Stumm	x			
Phacops iowensis alpensis Stumm	x			
Phacops iowensis iowensis Delo			x	
Phacops rana norwoodensis Stumm				x
Phacops rana rana	x			
Phacops cf. rana			x	
Phacops sp.	x			
Proetus (Crassiproetus) norwoodensis Stumm				x
Proetus (Crassiproetus) traversensis Stumm	x			
Proetus sp.	x		x	
Scutellum tullium depressum Cooper & Cloud				x
ECHINODERMATA - CRINOIDS				
Megistocrinus latus Hall	x			
Melocrinus sp.				x
ECHINODERMATA - BLASTOIDS				
Codaster gracile (Wachsmuth)			x	
Pentremitidea cloudi Reimann			x	
Pentremitidea imparilis Reimann				x

EXPLANATION OF PLATE 19

Enlargements of fossils from the Gravel Point Formation, showing preservation of intricate details.

FIG. 1, Mucrospirifer grabaui, UMMP 31660; Locality 34-6-3 S, Penn-Dixie Quarry; Atrypa zone; x 3. 2, Longispina emmetensis, UMMP 49522; Locality 34-8-28/29, Gravel Point; x 3. 3, 4, Strophodonta erratica fissicosta, UMMP 50683; shore of Little Traverse Bay; collected by Winchell; x 3. 5, Greenops aequituberculatus, TYPE, UMMP 28669; Locality 34-8-28/29, Gravel Point; x 3. 6, Greenops traversensis, TYPE, UMMP 28668; Emmet County; x 3. 7, 8, Strophodonta erratica, UMMP 50680; shore of Little Traverse Bay; collected by Winchell; x 2. 9, Strophodonta costata, UMMP 56043; Locality 34-8-28/29, Gravel Point; collected by Grabau; x 2. 10, Aulopora conferta, UMMP 51023; Little Traverse Bay region; Perry Collection; x 3. 11, Aulocystis alectiformis, UMMP 34936; Locality 34-6-8 NE, old Bell Quarry; "lower blue shale"; x 2.

PLATE 19

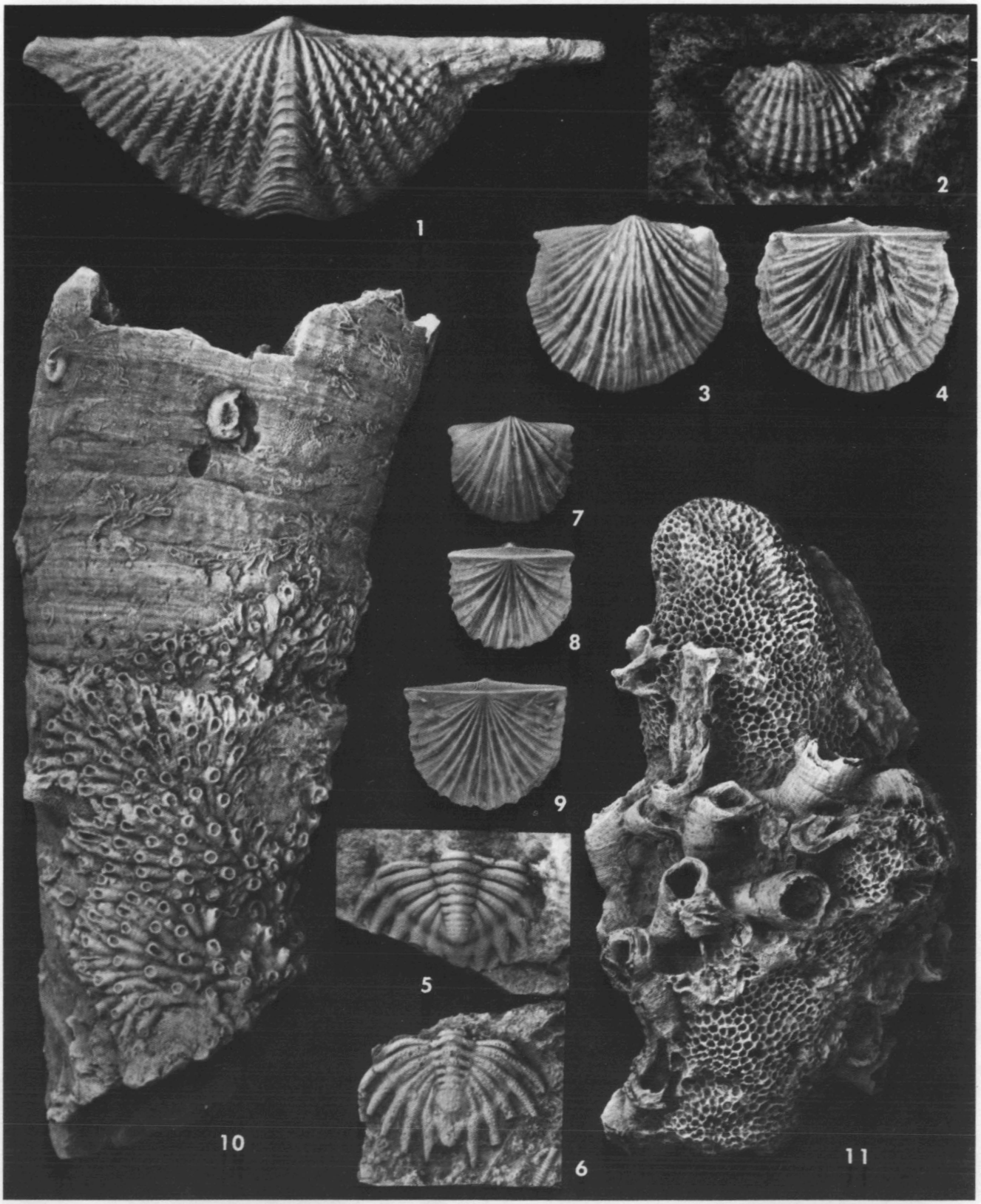
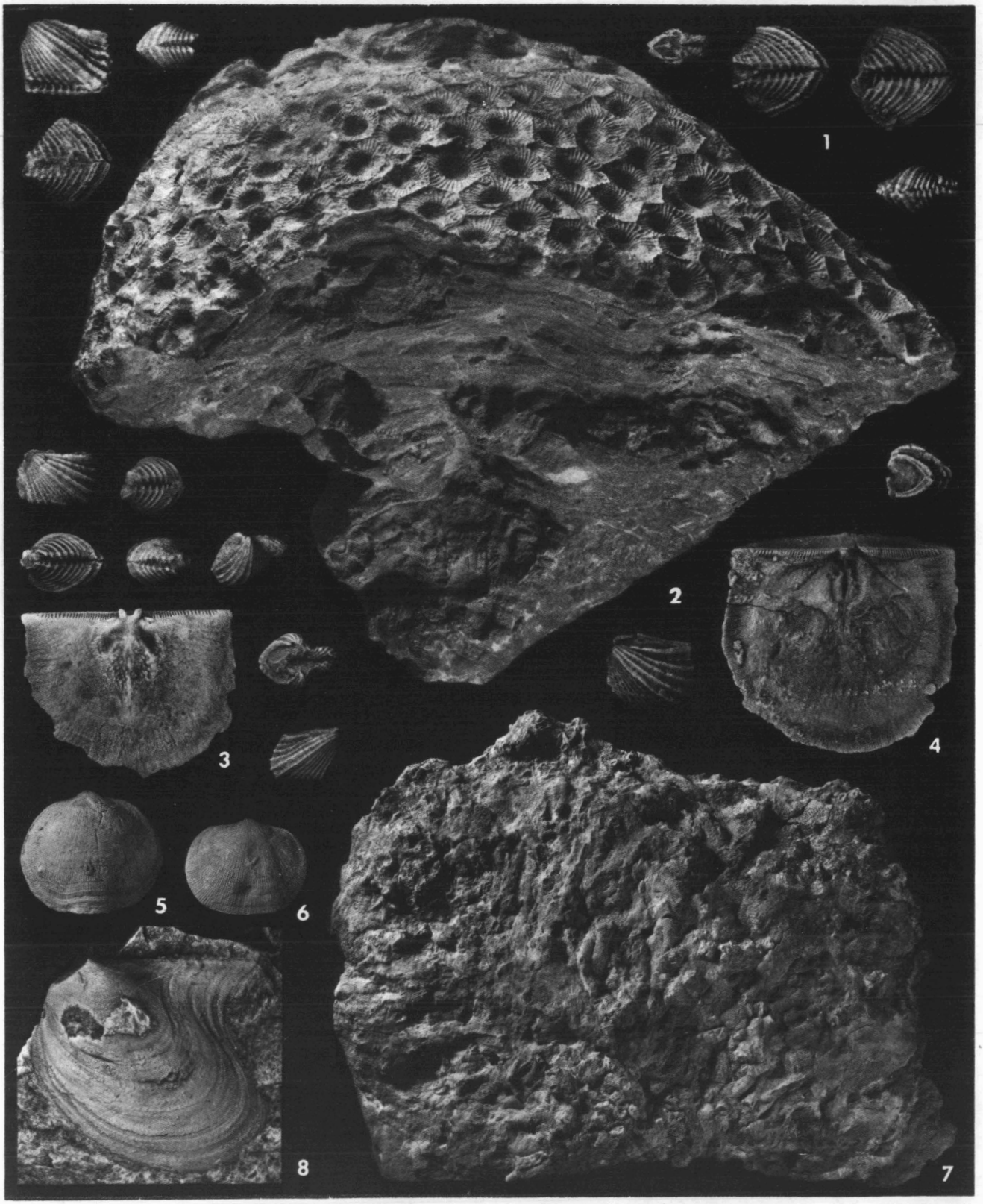


PLATE 20



Appendix 6

SPECIES AND SUBSPECIES OF MACROFOSSILS FROM FORMATIONS OF THE TRAVERSE GROUP IN NORTHWESTERN LOWER PENINSULA WHICH ALSO OCCUR IN OTHER TRAVERSE GROUP FORMATIONS OF MICHIGAN

	Northwestern				Northeastern									
TETRACORALS	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Aulacophyllum hemicrassatum	x		x				x						x	x
Cylindrophyllum panicum			x										x	
Cystiphylloides aggregatum			x										x	
Cystiphylloides americanum	x		x								x			
Cystiphylloides petoskeyense			x										x	
Hallia vesiculata			x										x	
Heliophyllum juvene	x										x			
H. tenuiseptatum traversense	x										x			
Hexagonaria attenuata		x								x	x			
Naos ovatus	x				x									
Naos ponderosus	x									x				
Stereolasma petoskeyense			x										x	
Tabulophyllum traversense	x		x					x		x	x		x	
Tortophyllum cysticum	x		x							x			x	

EXPLANATION OF PLATE 20

Fossils from the Gravel Point Formation

FIG. 1, Conocardium emmetense, UMMP 60886; Locality 34-6-8 NE, old Bell Quarry; 16 specimens; all x 2. 2, Hexagonaria percarinata, UMMP 26239; Locality 34-6-8 NE, old Bell Quarry; "lower blue shale"; x 1.

Fossils from the Petoskey Formation

FIGS. 3, 4, Strophodonta sp., UMMP 60879; Locality 35-5-32 E, Encampment Avenue in Bay View; unit 5 of Ehlers' section; two interiors, both x 2.

Fossils from the Whiskey Creek Formation at the type locality

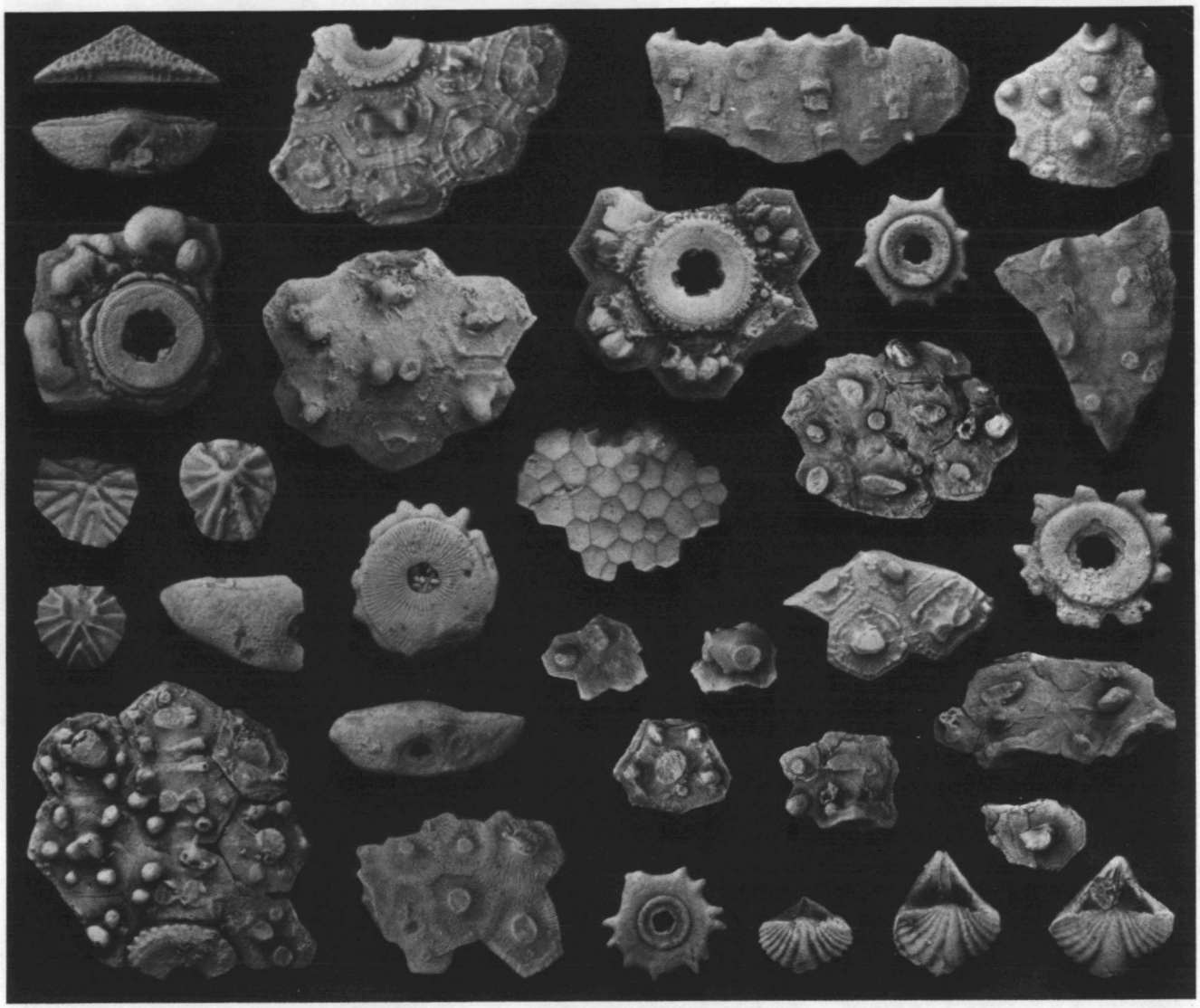
FIGS. 5, 6, Schizophoria mesacarina, UMMP 42147; two specimens, both x 1. 7, Aulocystis minuta parallela, TYPE, UMMP 34980; near center of N line of sec. 27; x 1.

Fossils from the Jordan River Formation at the type locality

FIG. 8, Actinopteria sp., UMMP 60893; x 2.

	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
TABULATE CORALS														
Aulocystis alectiformis	x									x				
Aulocystis alpenensis			x										x	
Aulocystis fenestrata	x									x				
Aulocystis parva			x										x	
Aulopora conferta	x				x									
Aulopora gregaria			x					x		x	x			
Aulopora "serpens"	x										x			
Emmonsia alpenensis			x		x	x		x		x			x	
Favosites alpenensis alpenensis	x	x	x						x	x			x	
F. alpenensis calveri	x							x	x	x				
F. alpenensis tenuimuralis			x						x	x			x	
F. nitellus	x									x				
F. placentus	x									x	x		x	x
F. romingeri patella			x										x	
F. romingeri romingeri			x										x	
F. romingeri saetigera	x	x								x				
Pachyphragma concentricum	x						x	x		x	x			
Pachyphragma erectum	x		x										x	
Trachypora alternans	x		x							x	x	x	x	x
Trachypora lineata	x										x		x	
Trachypora proboscidialis			x	x						x	x		x	x
BRACHIOPODS														
Chonetes ensicosta			x										x	
Devonalosia radicans	x							x		x	x	x		
Elytha filicosta	x		x											
Longispina emmetensis	x									x	x			
Megastrophia concava	x									x	x			
Mucrospirifer grabaui	x		x								x			
Mucrospirifer profundus			x									x	x	
Oligorhachis oligorhachis	x										x			
Pentamerella alpenensis	x									x	x			
Pentamerella petoskeyensis			x										x	
Pholidostrophia geniculata	x									x				
Schuchertella anomala	x										x			
Strophodonta crassa			x										x	
Strophodonta erratica	x									x	x			
Strophodonta erratica fissicosta	x										x			
Strophodonta nanus	x									x	x			
Strophodonta titan	x							x		x				

PLATE 21

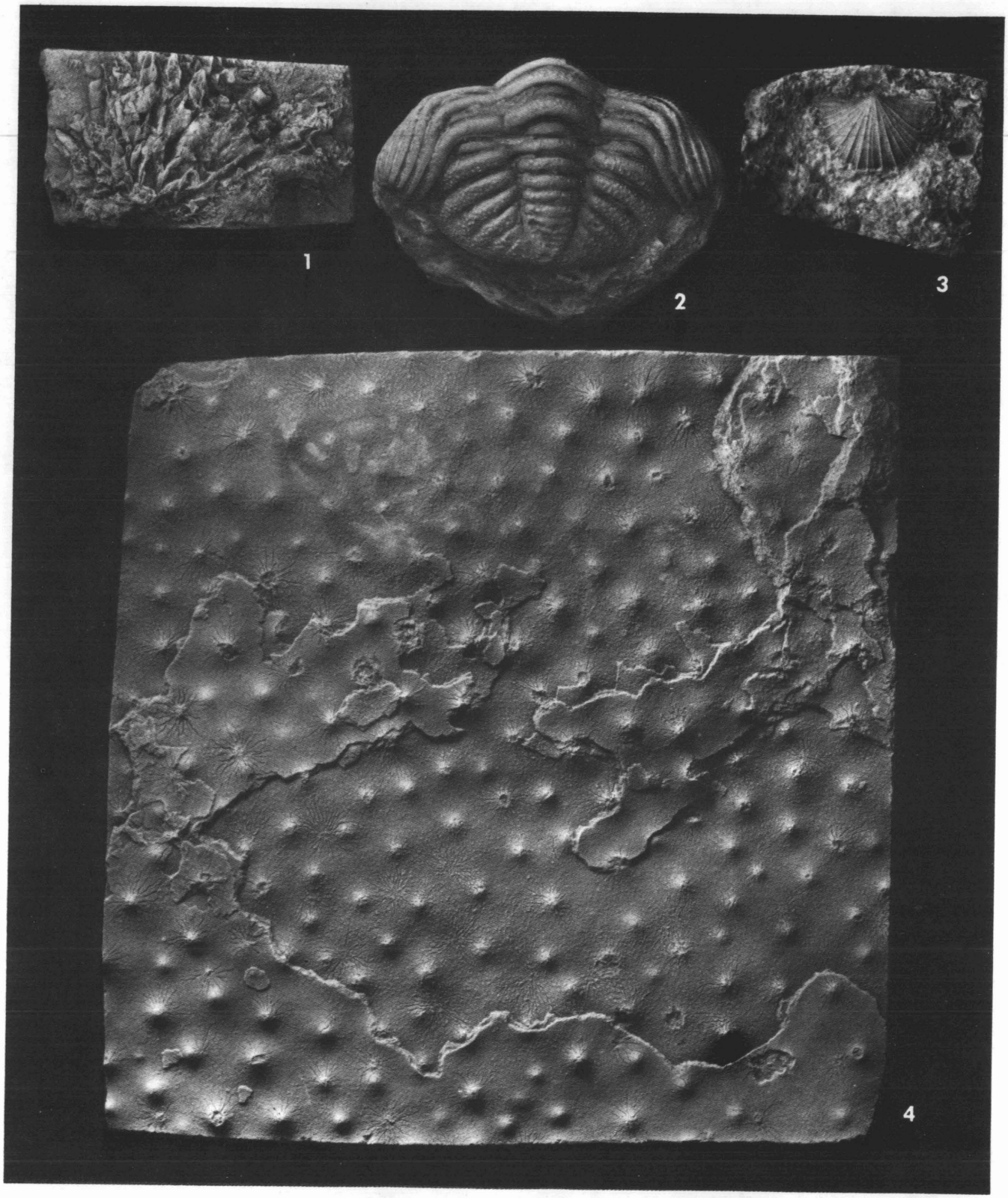


EXPLANATION OF PLATE 21

(All figures x 2)

Fossils from the Whiskey Creek Formation, bryozoan bed. Crinoid columnals and plates, representing Dolatocrinus, Megistocrinus (more than one species, perhaps three), and two calceocrinid species. Also (lower right), three small Cyrtina specimens.

PLATE 22



	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Strophodonta titan titan	x									x				
Truncalosia gibbosa	x		x					x		x		x	x	
TRILOBITES														
Ancyropyge romingeri	x				x									
Dechenella (Basidechenella) pulchra	x									x	x			
Greenops traversensis	x										x			
Phacops iowensis alpenensis	x				x			x		x				
Phacops iowensis iowensis			x								x	x	x	x
Phacops rana rana	x										x			
Proetus (Crassiproetus) traversensis	x										x			
ECHINODERMATA-BLASTOIDS														
Codaster gracile			x											x

Appendix 7

SPECIES AND SUBSPECIES OF MACROFOSSILS SHARED BY FORMATIONS OF THE TRAVERSE GROUP (based on Appendix 6)

	Northwestern				Northeastern									
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Total sp. + subsp.	87	11	41	15	46	18	34	44	12	60	88	29	55	46
Shared sp. + subsp.	42	3	28	1	5	1	2	9	3	29	27	5	26	6
Gravel Point[1]	--	2	10	0	4	0	2	7	2	24	23	3	9	3
Charlevoix	2	--	1	0	0	0	0	0	1	3	1	0	0	0
Petoskey[2]	10	1	--	1	1	1	1	4	2	9	7	4	24	5
Whiskey Cr.-Jordan R.	0	0	1	--	0	0	0	0	0	0	0	0	0	1

[1] Note: of the 42 Gravel Point species found in other Traverse Group formations, only 6 are not present in either the Alpena Limestone or the Four Mile Dam formation (Appendix 6).

[2] Note: of the 28 Petoskey species found in other Traverse Group formations, only 4 are not present in either the Potter Farm Formation or the Thunder Bay Limestone (Appendix 6).

EXPLANATION OF PLATE 22

FIG. 1, Pachyphragma concentricum, UMMP 35000; specimen from the Four Mile Dam Formation, Alpena Co.; x 2. 2, Phacops rana alepnensis, UMMP 29559; specimen from the Alpena Limestone, Thunder Bay Quarry, Alpena Co.; x 2. 3, Douvillina distans, UMMP 47241; specimen from the Four Mile Dam Formation, Alpena Co., x 3. 4, Parallelopora winchelli, UMMP 39477; Gravel Point Formation; shore of Little Traverse Bay; x 1.

Appendix 8

FAUNAL INDICES OF SPECIES AND SUBSPECIES OF MACROFOSSILS SHARED BY FORMATIONS OF THE TRAVERSE GROUP (based on Appendix 7)

	Northwestern				Northeastern									
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Gravel Point	--	18	24	0	9	0	6	16	17	40	26	10	16	7
Charlevoix	18	--	9	0	0	0	0	0	9	27	9	0	0	0
Petoskey	24	9	--		2	6	3	10	17	22	17	14	59	12
Whiskey Cr.-Jordan R.	0	0	7	--	0	0	0	0	0	0	0	0	0	7

Appendix 9

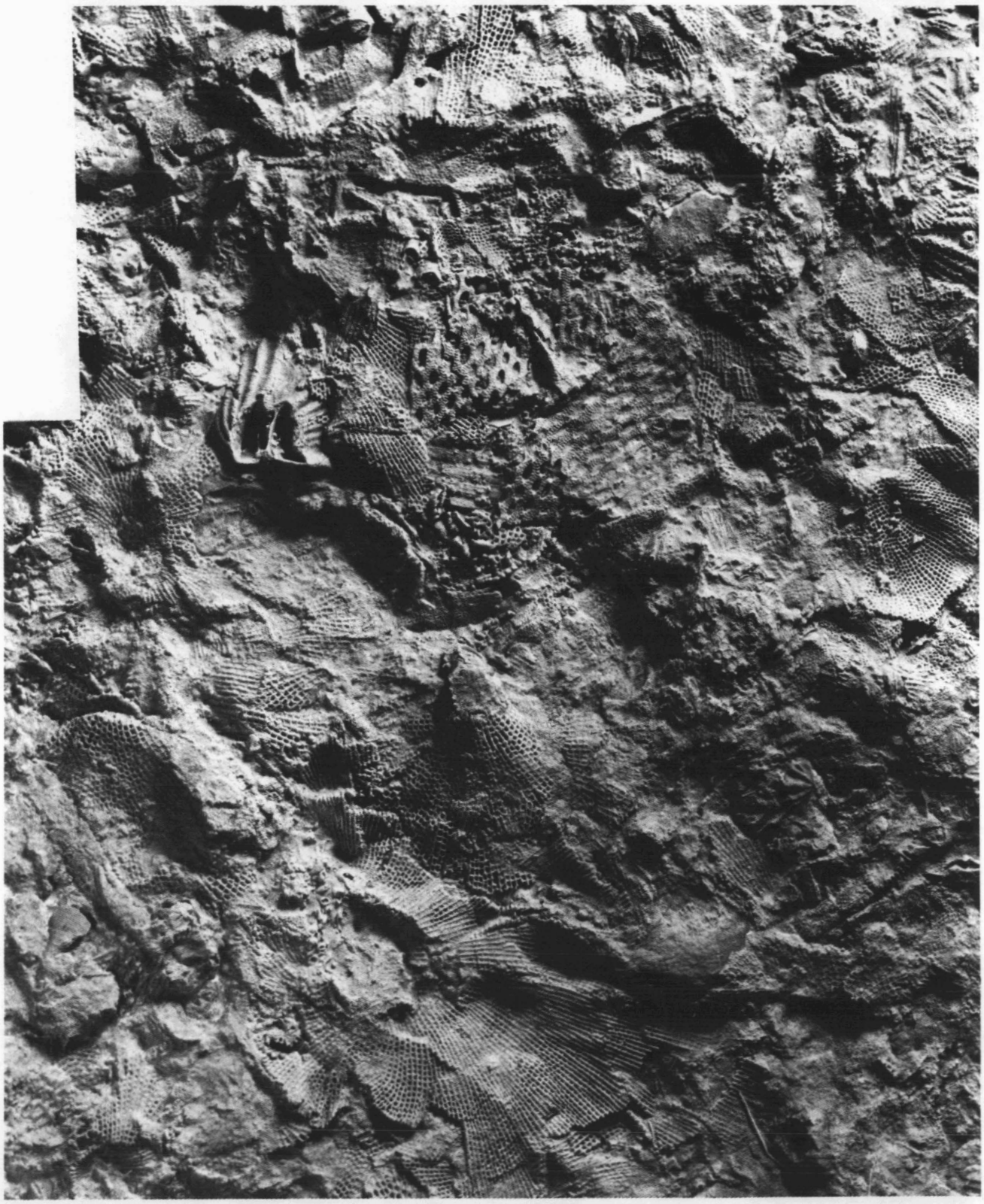
APPROXIMATE DISTANCES BETWEEN MAJOR LOCALITIES (miles)

	4	7a	7b	8	9	10	11	12	13	14	14c	14e	15	17	18	18a	19	21
4	--	15½	14½	10½	9½	10	10½	10	5½	7	6	6	6	8½	10½	11	8	12
7a	15½	--	½	7½	8	7½	7	7½	17½	21	19½	19	16	22½	24½	25	22	26½
7b	14½	½	--	7½	7½	7	6½	7½	17	20½	19	18½	15	22	24	24½	21½	26
8	10½	7½	7½	--	1¼	1	½	½	10½	14½	13	12½	9	16½	18¼	18½	15½	20
9	9½	8	7½	1¼	--	½	1¼	½	10	13½	12½	11½	8½	15½	17½	18	15	19½
10	10	7½	7	1	½	--	½	½	10½	14½	13	12	9	16½	18¼	18½	15½	20
11	10½	7	6½	½	1¼	½	--	¾	11	14½	13½	12½	9½	17	18½	19	16	20½
12	10	7½	7½	½	½	½	¾	--	10½	14¼	12½	12	9	16¼	18	18½	15¼	19½
13	5½	17½	17	10½	10	10½	11	10½	--	4	2½	1½	1½	6	7½	8	4½	9½
14	7	21	20½	14½	13½	14½	14½	14½	4	--	1½	2	5½	1½	3½	4½	1	6
14c	6	19½	19	13	12½	13	13½	12½	2½	1½	--	½	4¼	3½	5¼	5½	2½	7
14e	6	19	18½	12½	11½	12	12½	12	1½	2	½	--	3½	4¼	6	6½	3¼	7½
15	6	16	15	9	8½	9	9½	9	1½	5½	4¼	3½	--	7½	9¼	9½	6½	11
17	8½	22½	22	16½	15½	16½	17	16¼	6	1½	3½	4¼	7½	--	2¼	2½	1½	3½
18	10½	24½	24	18¼	17½	18¼	18½	18	7½	3½	5¼	6	9¼	2¼	--	½	3	1½
18a	11	25	24½	18½	18	18½	19	18½	8	4½	5½	6½	9½	2½	½	--	3¼	1½
19	8	22	21½	15½	15	15½	16	15¼	4½	1	2½	3¼	6½	1½	3	3¼	--	½
21	12	26½	26	20	19½	20	20½	19½	9½	6	7	7½	11	3½	1½	1½	4½	--

EXPLANATION OF PLATE 23

Petoskey Formation, Fenestella zone (zone 2, bed 1 of Pohl); Locality 34-6-6 SW, old Curtiss Quarry near Bay Shore, western edge of Emmet County; x 2.

PLATE 23



APPENDIX 9

In the above list, localities are identified by the old National Museum-Michigan Geological Survey--University of Michigan numbers. As indicated in the section on Localities, these are equivalent to:

4 33-6-6 S Peninsula west of Horton Bay, on Lake Charlevoix.

7a 33-9-27 NE Rock cut along old shore road 1 mile north of Norwood.

7b 33-9-26 C Small test pits about 1 mile north of Norwood.

8 34-8-28/29 Ledges and shore bluffs at Gravel Point.

9 34-8-28 SE SE Abandoned main quarry of Charlevoix Rock Products.

10 34-8-33 NW NE Abandoned Charlevoix City Quarry.

11 34-8-29 S SE Abandoned Wolverine Lime Company Quarry.

12 34-8-28 S Abandoned Charlevoix Rock Products No. 2 Quarry.

13 34-6-6 SW Abandoned "Main Curtiss" Quarry near Bay Shore.

14 34-6-3 S Penn-Dixie Cement Corporation Quarry near Petoskey.

14c 34-6-9 N Abandoned W. E. Smith Quarry west of Penn-Dixie.

14e 34-6-8 NE Penn-Dixie Cement Corporation Shale Pit; Bell Quarry.

15 34-7-2 W Abandoned Superior Quarry at Nine Mile Point.

17 34-6-1 SE Abandoned Jarman Quarry of Antrim Lime Co., Petoskey.

18 35-5-32 SW Abandoned Northern Lime Co. Quarry in Petoskey.

18a 35-5-33 NW Shore ledges on Little Traverse Bay at Bay View.

19 34-6-1 NW and 2 NE Shore of bay 1 to $1\frac{1}{2}$ miles west of Bear Creek.

21 35-5-27 S Kegomic Quarry 1 mile east of Bay View.

Appendix 10

SPECIES OF BRYOZOA RECORDED FROM FORMATIONS OF THE TRAVERSE GROUP IN NORTHWESTERN LOWER PENINSULA WHICH ALSO OCCUR IN OTHER TRAVERSE GROUP FORMATIONS OF MICHIGAN

	Northwestern				Northeastern								
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Ceramella casei McNair	x						x							
Eridocampylus obliquus Duncan	x						x				x	x		
Eridotrypella simplex Duncan	x				x		x					x		
Euspilopora kellumi McNair			x										x	
Hederella alpenensis Bassler	x						x	x		x		x		
Hederella concinna Bassler	x		x											
Hederella delicatula Bassler	x		x							x	x	x		x
Hederella filiformis (Billings)			x				x			x		x		

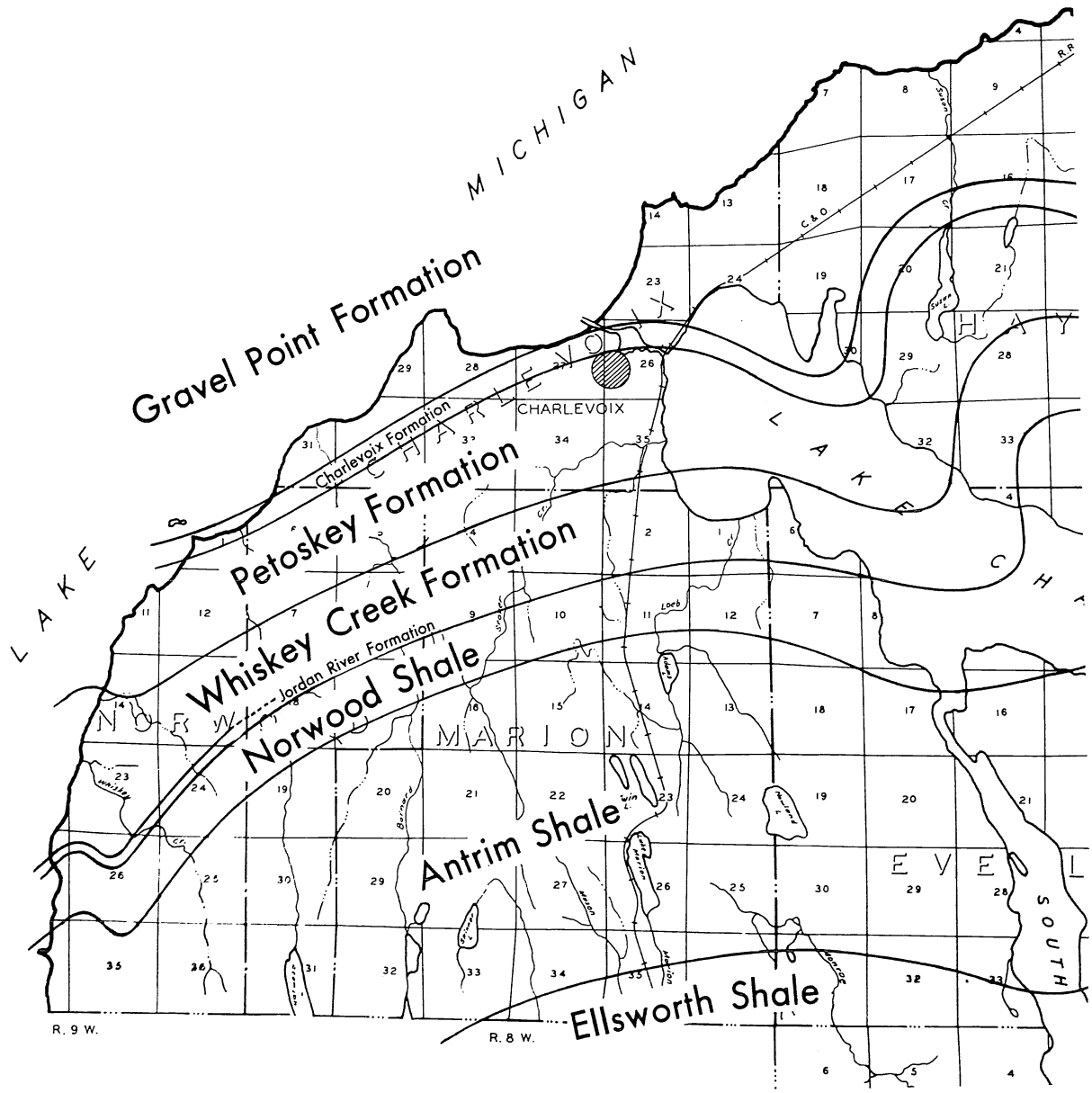
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Hederella magniventra Bassler	x									x	x	x		
Hederella michiganensis Bassler	x		x				x			x		x		
Hederella persimilis Bassler			x									x		x
Hederella robusta Bassler			x				x	x		x		x		
Hederella rugosa Bassler			x									x		x
Hernodia cooperi Bassler			x				x				x			
Isotrypa megista Deiss	x				x									
Loculipora implicata McNair			x								x		x	
Microcampylus tenuis Duncan	x							x					x	
Microcampylus traversensis Duncan	x						x	x						
Scalaripora variosa McNair	x										x	x		
Srereotoechus typicus Duncan	x											x		
Sulcoretepora hamiltonensis (Ulr.)	x													x
Sulcoretepora obliqua McNair	x		x				x			x	x			
Taenipora exigua Nicholson	x		x									x		

Appendix 11

NUMBER OF SPECIES OF BRYOZOA SHARED BY FORMATIONS OF THE TRAVERSE GROUP
(based on Appendix 10)

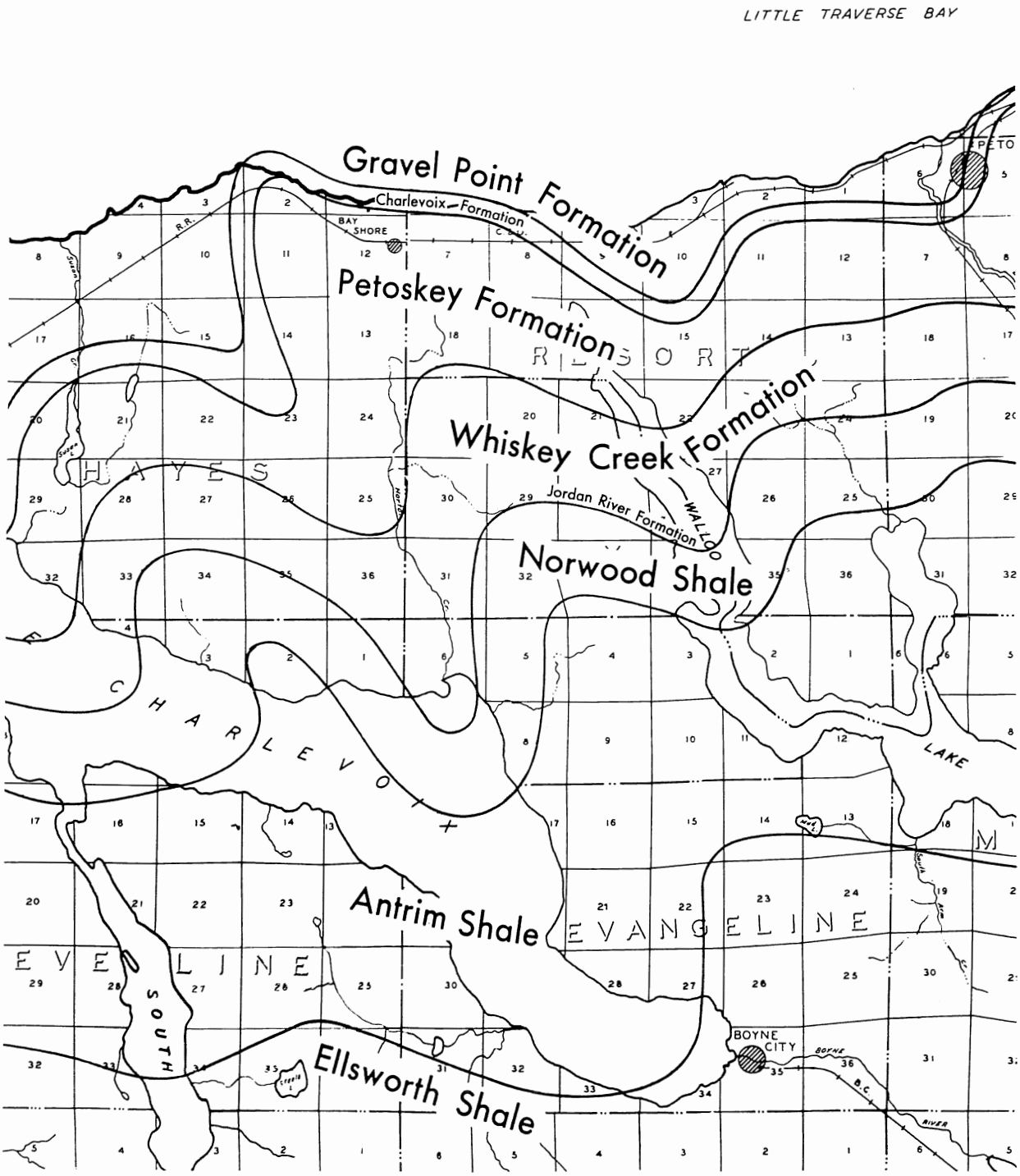
	Northwestern				Northeastern									
	GP	CH	PY	W/J	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB
Gravel Point	--	0	5	0	2	0	7	3	0	5	5	8	1	2
Charlevoix	0	--	0	0	0	0	0	0	0	0	0	0	0	0
Petoskey	5	0	--	0	0	0	5	1	0	5	4	7	2	3
Whiskey Creek-Jordan R.	0	0	0	--	0	0	0	0	0	0	0	0	0	0

MAP 3 -- Western Charlevoix County. Culture map.

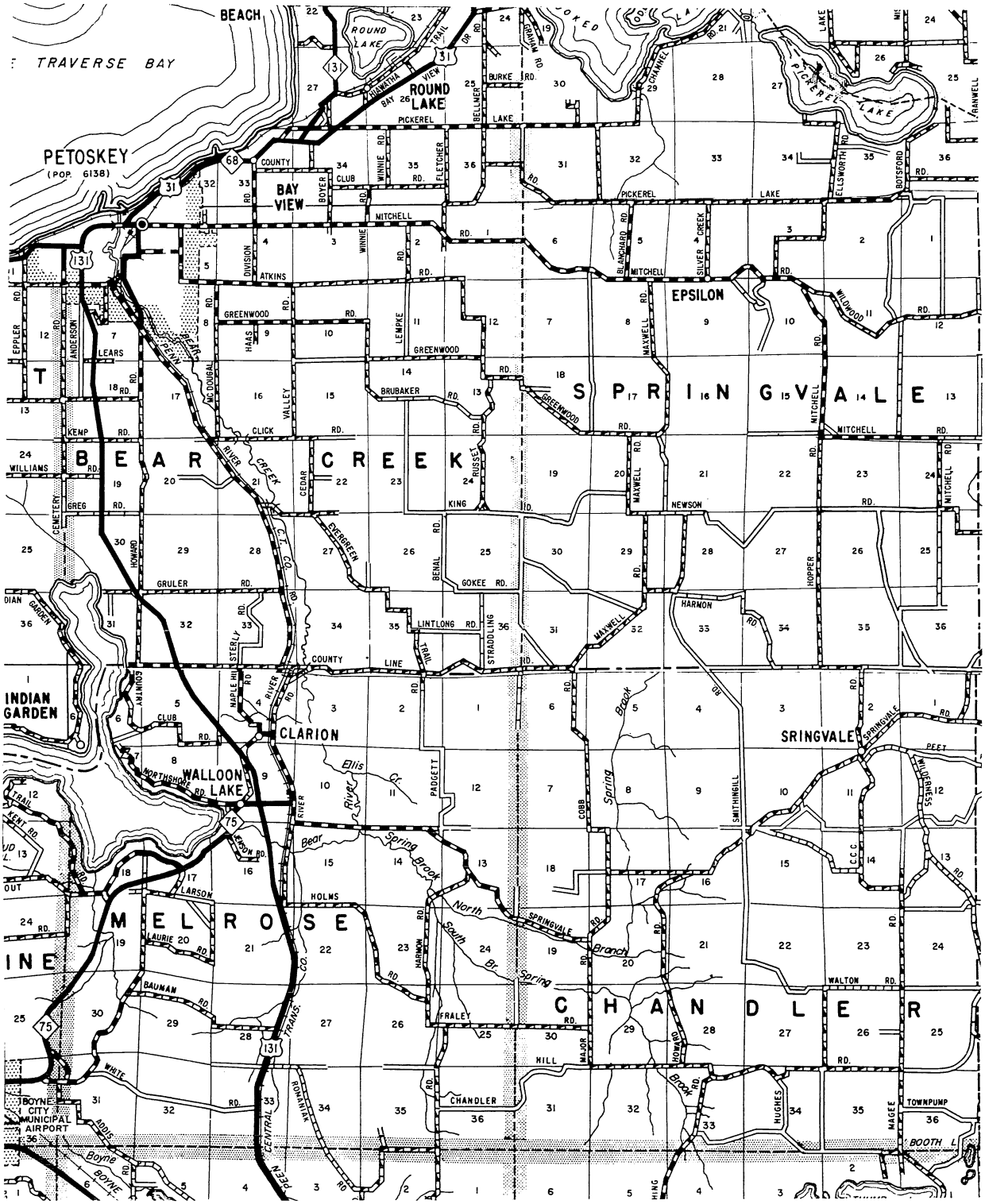


MAP 4 -- Western Charlevoix County. Geologic map.

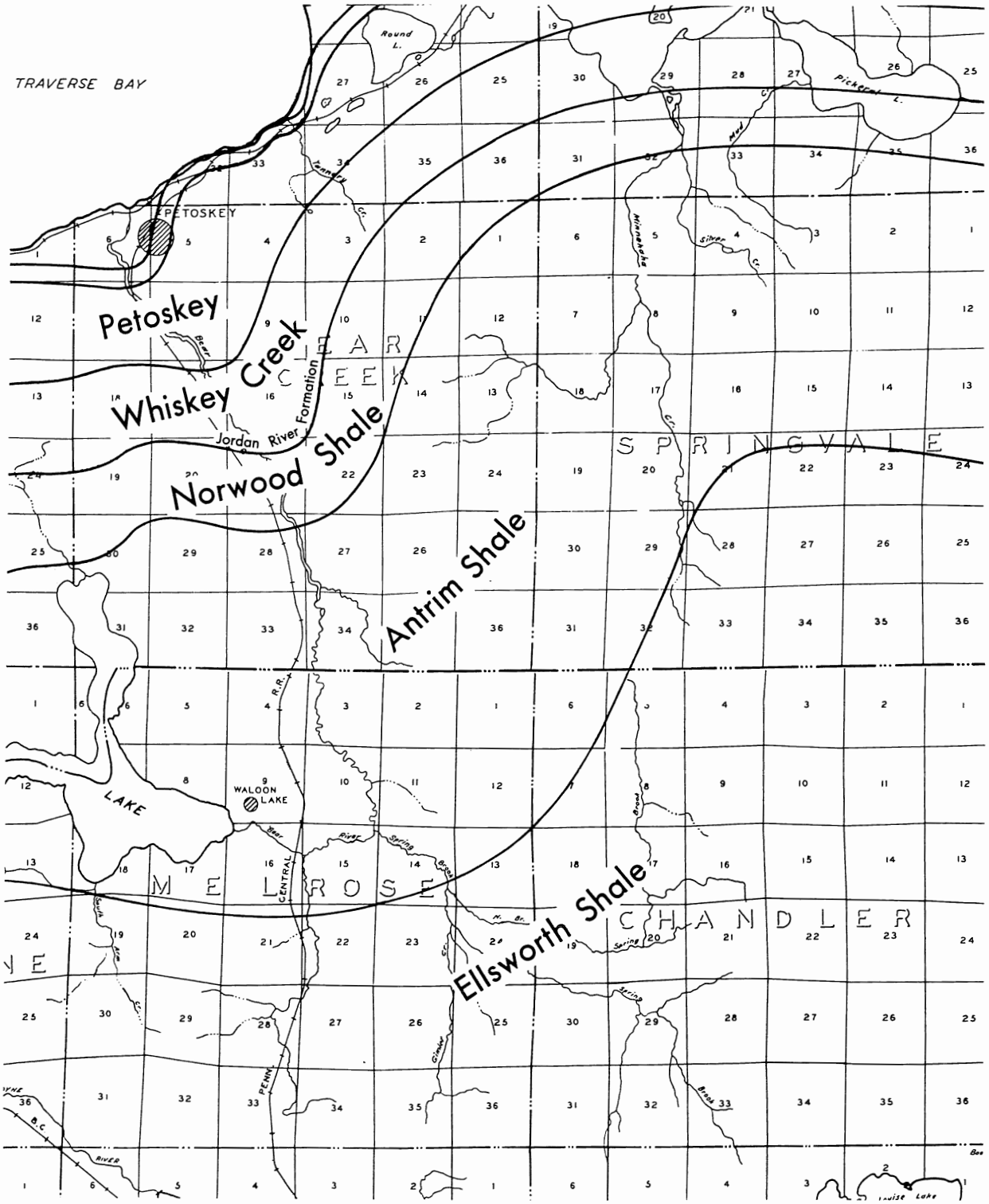
MAP 5 -- Central Charlevoix County and southwestern corner of Emmet County. Culture map.



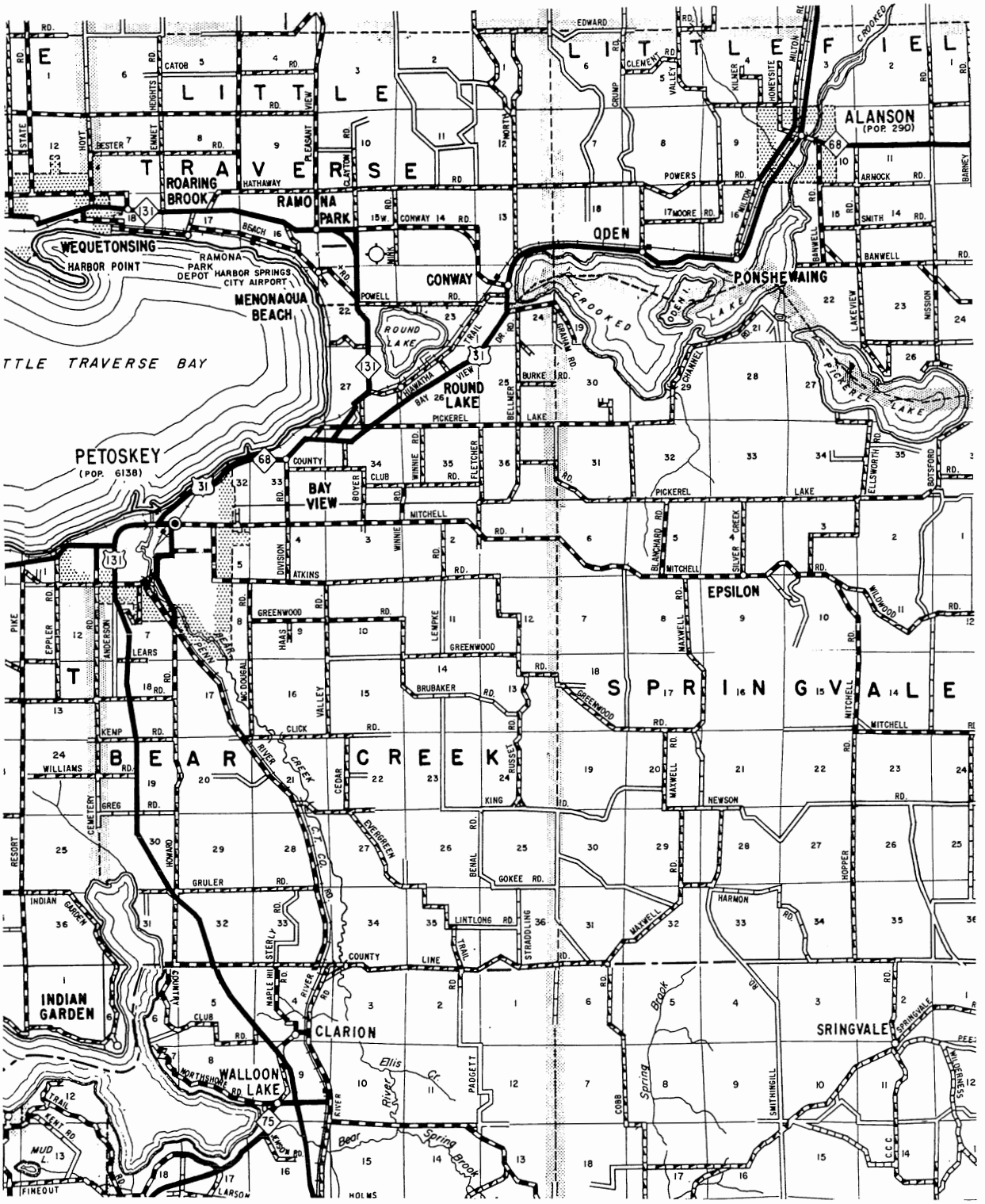
MAP 6 -- Central Charlevoix County and southwestern corner of Emmet County. Geologic map.



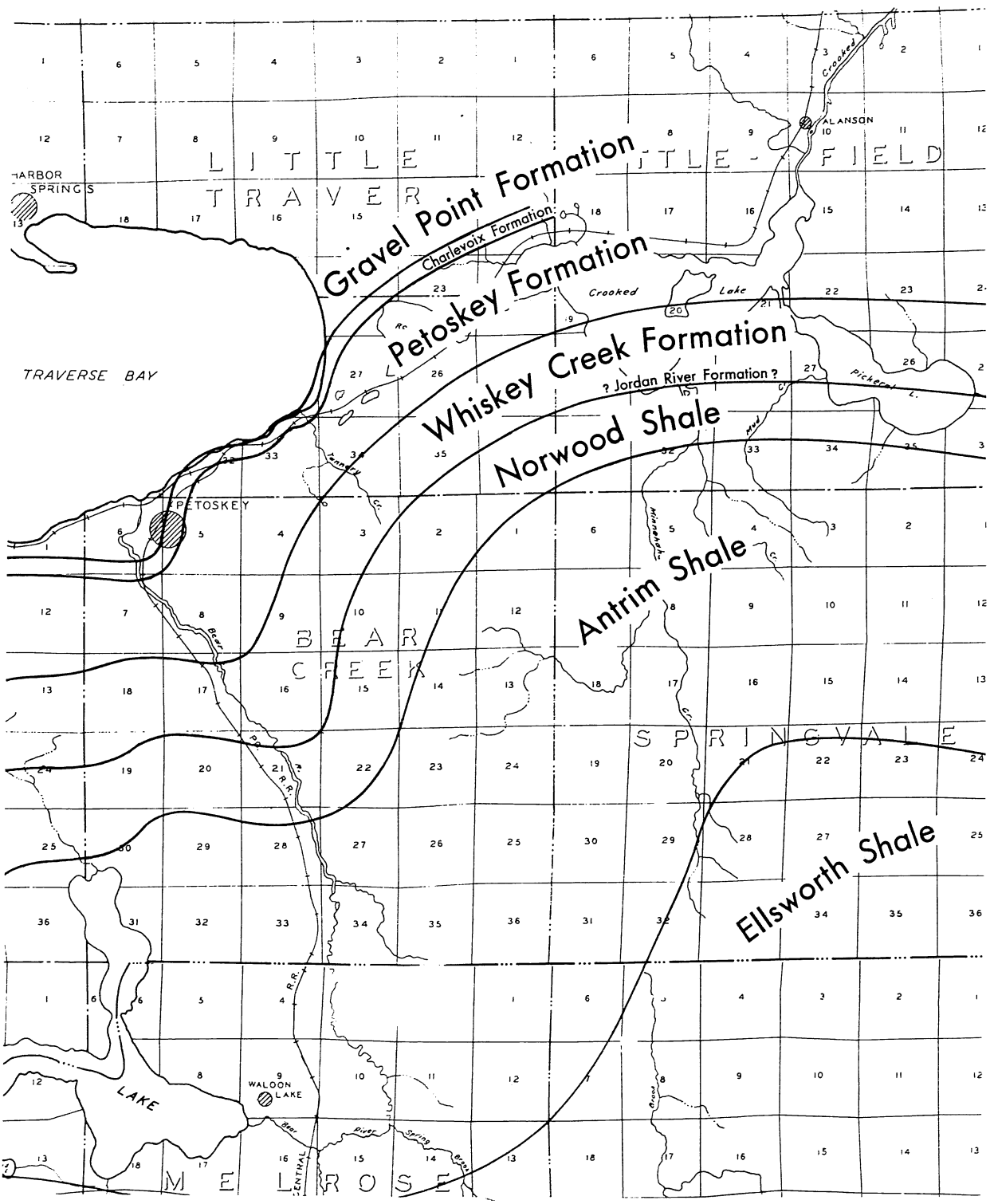
MAP 7 -- Eastern Charlevoix County and southern Emmet County. Culture map.



MAP 8 -- Eastern Charlevoix County and southern Emmet County. Geologic map.



MAP 9 -- South central Emmet County. Culture map.



MAP 10 -- South central Emmet County. Geologic map.

PLATE 24

EXPLANATION OF PLATE 24

Cyathophyllum robustum, basal section of corallite, encrusted with auloporoid, UMMP 19622; Petoskey Formation; Locality 35-5-27 S, Kegomic Quarry; x 3.

ILLUSTRATIONS

MAPS

PLATES

TEXT-FIGURES

PAPERS ON PALEONTOLOGY : No. 7

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