Devonian Strata of Alpena and Presque Isle Counties, Michigan

George M. Ehlers and Robert V. Kesling

1970

FRONT COVER

Thunder Bay Limestone at the type locality, 30-8-11 SE. Photograph taken at very low water stage in 1964.

(60)

MICHIGAN BASIN GEOLOGICAL SOCIETY

GUIDE BOOK
FOR
FIELD TRIPS

In Connection With

GEOLOGICAL SOCIETY OF AMERICA
NORTH-CENTRAL SECTION MEETING

KELLOGG CENTER, MICHIGAN STATE UNIVERSITY, EAST LANSING
MAY 6 - 10
1970

Harold B. Stonehouse
Field Trip Chairman

The field trips are arranged in connection with the

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CONTENTS

Devonian Strata of Alpena and Presque Isle Counties, Michigan

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A GUIDEBOOK PREPARED FOR THE NORTH-CENTRAL SECTION OF THE GEOLOGICAL SOCIETY OF AMERICA

CONTENTS

Introduction

Geologists go on field trips for many reasons. Stratigraphers hope to find evidence for linking formations to those in other areas, thereby extending their paleogeographic maps. Consultants look for high-calcium rocks near good lake ports, or for structures that might trap petroleum. Some paleontologists search for new kinds of fossils to round out the record of past life. Paleoecologists examine the detailed relationships of fossils and sediments to understand why animals lived in certain environments, how they died, and what led to their burial. Others of the geologic clan may have different motives for taking to the field. Whether your interest centers on the rock succession, economic potential, evolution, or ancient life habitats, we hope that the Devonian strata exposed in Alpena and Presque Isle Counties will yield you a degree of satisfaction and that the trip will be a pleasant experience.

We may be rightly accused of writing a guidebook that does no guiding. We have reasons. The uncertainties of May weather in this region preclude advance planning of stops and a timetable. That is why we accompany the printed book with a last-minute schedule of field activities. A warm spring day would be welcome, but driving, blanketing snow is certainly possible.

In only a day and a half, we cannot show all of the exposures used in making our geologic map; indeed, we cannot adequately study all of the type localities. Under these circumstances, we decided to use this guidebook to present an updated list of localities, rock sections, and faunal lists. The reader can pursue for himself such additional collecting, mapping, or field study as he desires.

Paleontology is the key to understanding the Devonian history of this region and establishing its relation to other areas. We are well aware that much remains to be done in this field. Faunas are still incompletely known, and, for some groups, taxonomic revisions are overdue. Perhaps, this field excursion will excite some of the participants to help with these difficulties.

In compiling this book, the senior author wrote the section on pre-Traverse formations and the junior author the section on Traverse Group formations. In many parts, we relied on information published by previous workers; special credit is due to G. Arthur Cooper and A. Scott Warthin for their contributions. Other data was used from unpublished theses at The University of Michigan, with credit acknowledged. The maps were revised in the course of recent field work and summarize our findings over many years.

In preparing the book, we had the excellent and very necessary assistance of Mr. Karoly Kutasi in photography and Mrs. Helen Mysyk in typing. Their devoted efforts in the midst of other pressing duties at the Museum of Paleontology enabled the publication to precede the trip. (We once doubted this was possible). We thank them heartily.

May you have a safe and successful field excursion.

ILLUSTRATIONS

Formations

Ferron Point Formation .... Pl. 3, fig. 5; pl. 19, figs. 3, 4; pl. 20, figs. 1, 2

Localities

Fossils

Localities

In the following list, each locality is identified by four elements: number of the Township North, number of the Range East, 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 numbers, some used in publication, by the Michigan Geological Survey, The University of Michigan, and the United States National Museum; this list was started around 1926 and added to from time to time; where the localities from the old Survey-University-National Museum list can be recognized and identified, the number is given in the present list. Only localities in Alpena and Presque Isle Counties are given here.

Alpena County

30-8-11 SW: Beach on S side of Partridge Point about 4 miles S of Alpena, on shore of Squaw Bay; exposures extend from SE$\frac{1}{4}$ sec. 10 to SW$\frac{1}{4}$ sec. 11, Alpena County. Survey Loc. 54. Squaw Bay Limestone, type locality.

30-8-11 SE: Bluffs on NE shore of Partridge Point facing on Thunder Bay, 4 miles S of Alpena, extending from center into SE$\frac{1}{4}$ sec. 11; nearby ditch exposures along Partridge Point Road appear to be Squaw Bay Limestone; Alpena County. Survey Loc. 35. Thunder Bay Limestone, type locality.

30-8-22 NE: Ledges along US 23 and Lake Huron shore about 6 miles S of Alpena and just S of Squaw Bay, Alpena County. Survey Loc. 73. Antrim Shale.

31-6-15 SE: Cut of Detroit & Mackinac R.R. (abandoned section), SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 15, just E of Bean Creek Road, about 1$\frac{1}{2}$ miles E of Lachine, Alpena County. Antrim Shale.

31-6-21 NW: Ditch along M 65 (Leer Road), S of Lachine and N of Morrison Creek, about 1/8 mile S of NW corner sec. 21, Alpena County. Survey Loc. 43. Antrim Shale.

31-6-36 SE: Dump pile by old "gold mine" shaft on N side of Taylor-Hawks Road about 3/4 mile NE of Herron and 0.3 mile W of SE corner sec. 36, Alpena County. Survey Loc. 72. Squaw Bay Limestone and Antrim Shale.

31-7-1 S: Low cuts and ditches on Long Rapids Road (River Road) about $\frac{1}{2}$ mile NW of Norway Point Dam, short distance N of center of S line sec. 1, Alpena County. Survey Loc. 76. Four Mile Dam Formation (small bioherm).

31-7-12 NE: Exposures on banks and in bed of Thunder Bay River below Seven Mile Dam (also currently called Six Mile or Norway Point Dam). Water ponded upstream by dam cover former sites in sec. 2 of Trowbridge's Mills, Boom Company Dam, and original Seven Mile Dam, Alpena County. Survey Loc. 47. Norway Point Formation, type locality.

31-7-17 NW: Small ledges in fields just NW of center of sec. 17, near Lancaster Truck Trail (Glennie Road, between M 32 and Herron Road), about 2 miles NNE of Paxton, Alpena County. Survey Loc. 44b. Thunder Bay Limestone (Warthin & Cooper, 1943, p. 593).

31-7-17 C: Exposures at road corner on Lancaster Truck Trail (Glennie Road, between M 32 and Herron Road) in ditch in front of house, about 2 miles NNE of Paxton, Alpena County. Survey Loc. 44a. Squaw Bay Limestone.

31-7-17 S: Small rock cut on Lancaster Truck Trail (Glennie Road, between M 32 and Herron Road), about 1/8 mile S of 31-7-31 C, $\frac{1}{2}$ mile E and nearly 1$\frac{1}{2}$ miles N of Paxton Quarry, Alpena County. Survey Loc. 44. Antrim Shale.

31-7-30 NE: Huron Portland Cement Company shale quarry (Paxton Shale Quarry) S of M 32 about 8 miles W of Alpena, Alpena County. Survey Loc. 34. Antrim Shale.

31-8-3 SE: Bioherm on W side of Long Lake Road, $\frac{1}{4}$ mile N of Hamilton Road, 2 miles N of Detroit & Mackinac R.R. yards (at northern edge of Alpena), Alpena County. Survey Loc. 108. Alpena Limestone, bioherm.

31-8-3 E: Exposure on W side of Long Lake Road between Hamilton and Bradbury Roads, in SE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 3, Alpena County. Alpena Limestone (Grabau locality).

31-8-4 NE: Exposure at corner of section, about 3 miles N of Alpena, Alpena County. Alpena Limestone, reef limestone.

31-8-4 SE: Road cut on US 23 near Hamilton Road, $2\frac{1}{2}$ miles N of Chisholm Street bridge, in $S\frac{1}{4}$ $SE\frac{1}{4}$ sec. 4, Alpena County. Survey Loc. 75. Alpena Limestone, bioherm and flank beds.

31-8-7 C: Exposures on banks and in bed of Thunder Bay River below Four Mile Dam, $\frac{1}{4}$ mile S of center of sec. 7, Alpena County; on S side of river, steeply dipping Norway Point beds cap remnant of Four Mile Dam reef core. Survey Loc. 41. Four Mile Dam Formation (bioherm at type locality) and Norway Point Formation (basal beds).

31-8-9 NW: Ditch along French Road near its angle and intersection with Hamilton Road, in $NW\frac{1}{4}$ $NW\frac{1}{4}$ sec. 9 (road parallel to Detroit & Mackinac R.R. at this place), Alpena County. Part of Survey Loc. 88a. Norway Point Formation (silicified rhynchonellids).

31-8-11 NE: Location given by R. A. Smith (1916) for Owen Fox Quarry, then abandoned, across the road from the Richard Collins Quarry, Alpena County. This does not agree with Warthin & Cooper (1943), who place the Fox Quarry at the present site of the abandoned Thunder Bay Quarry in Alpena. Alpena Limestone, the type section studied by Grabau in 1902.

31-8-12 NW: Location given by R. A. Smith (1916) for Richard Collins Quarry, then abandoned, Alpena County. This does not agree with statements by Warthin & Cooper (1943), who place the Collins Quarry at the present site of the Huron Portland Cement Company Quarry at Alpena. Alpena Limestone, type section studied by Grabau in 1902.

31-8-13 W: Quarry of Huron Portland Cement Company Quarry (formerly Michigan Alkali Company) on eastern edge of Alpena, Alpena County; Wessel Road forms boundary between this quarry and the abandoned Thunder Bay Quarry (31-8-14 NE). Survey Loc. 40. Genshaw Formation (upper beds exposed in ditch and floor of quarry near crusher), Newton Creek Limestone (type locality, named for small stream once flowing across quarry site), and Alpena Limestone (type section, originally named for sections in the Richard Collins Quarry, Owen Fox Quarry).

31-8-14 NE: Abandoned quarry of Thunder Bay Quarries Company, eastern edge of Alpena, Alpena County; Dock Street Clay Member extends to Wessel Road, the eastern edge of this quarry, but does not extend across the road into the Huron Portland Cement Company Quarry. Survey Loc. 53. Alpena Limestone (several bioherms formerly exposed in wall, now obscured by water in quarry and dumped fly-ash refuse) and Dock Street Clay Member of Four Mile Dam Formation (type section, formerly well exposed along R.R. cut leading from quarry floor S toward loading docks on Thunder Bay) and overlying limestones of Four Mile Dam Formation.

31-8-15 C: Site of projected quarry and kiln of Foxton brothers S of Detroit & Mackinac R.R. tracks about 3/4 mile NW of train yards in NW part of Alpena, in $SE\frac{1}{4}$ $NW\frac{1}{4}$ sec. 15, Alpena County. Survey Loc. 74. Alpena Limestone and Dock Street Clay Member of Four Mile Dam Formation.

31-8-16 SE: Exposures and roadside ditches along US 23, at sites of Presbyterian Church, Fletcher Motel, and Grove Tavern properties, just N of intersection of US 23 and Long Rapids Road (River Road, M 32), in $NE\frac{1}{4}$ $SE\frac{1}{4}$ sec. 16, Alpena County. Norway Point Formation. This is the location of Survey Loc. 88, which was described as: Cut on abandoned Boyne City, Gaylord, & Alpena R.R. tracks and field outcrops to the north, on the W side of the "New Shore Road" (new US 23) about $\frac{1}{2}$ mile NW of Chisholm Street Bridge, Alpena, $N\frac{1}{2}$ $SE\frac{1}{4}$ sec. 16, T 31 N, R 8 E. Lower Norway Point Formation. (Scattered outcrops, including some caps over bioherms, occur for $\frac{1}{2}$ mile E of here, but no Four Mile Dam or Alpena till near locality 74.)

31-8-18/20: Various exposures on hills on S bank of Thunder Bay River, formerly within approximate boundaries of the F. N. Potter farm, including $E\frac{1}{2}$ sec. 18, SW corner sec. 17, and much of sec. 20, just W of Alpena, Alpena County. Survey Loc. 89. Norway Point Formation and Potter Farm Formation (type locality).

PLATE 1

1 - Dundee Limestone - Rogers City Limestone contact in foreground; thin-bedded unit 1 of the magnesian Emanuella zone of the Rogers City above unit 7 of the Dundee in a weathered quarry face. Loc. 35-5-23 SE, Calcite Quarry.
2 - Bell Shale, upper part (unit 6), on bank of drainage ditch in Kelley's Island Quarry. Loc. 32-9-6 NW.
3 - Dundee Limestone on nearby face, Rogers City Limestone in distance. Loc. 35-5-23 SE, Calcite Quarry.
4 - Dundee Limestone, weathered quarried face. Loc. 35-5-23 SE, Calcite Quarry.

PLATE 1

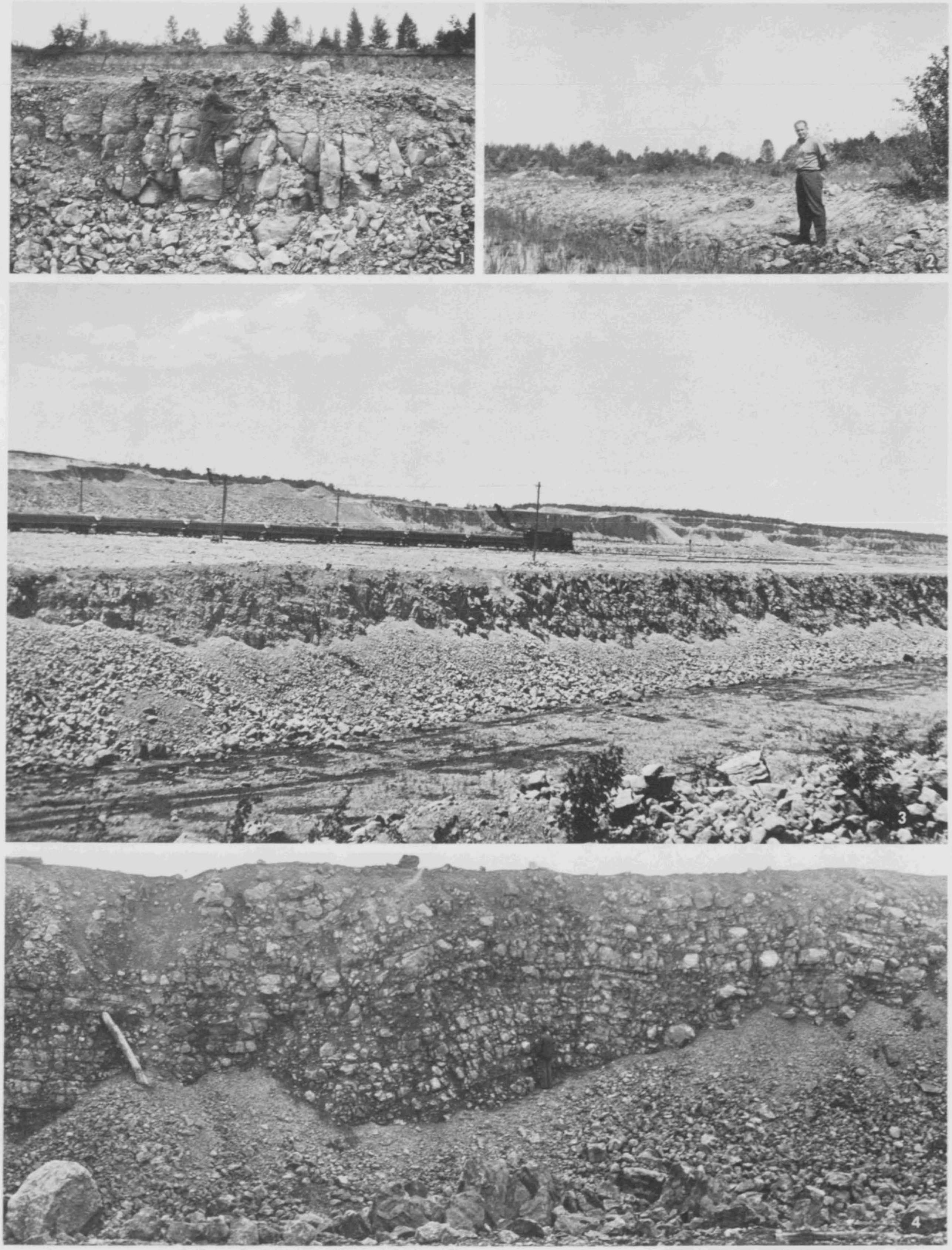
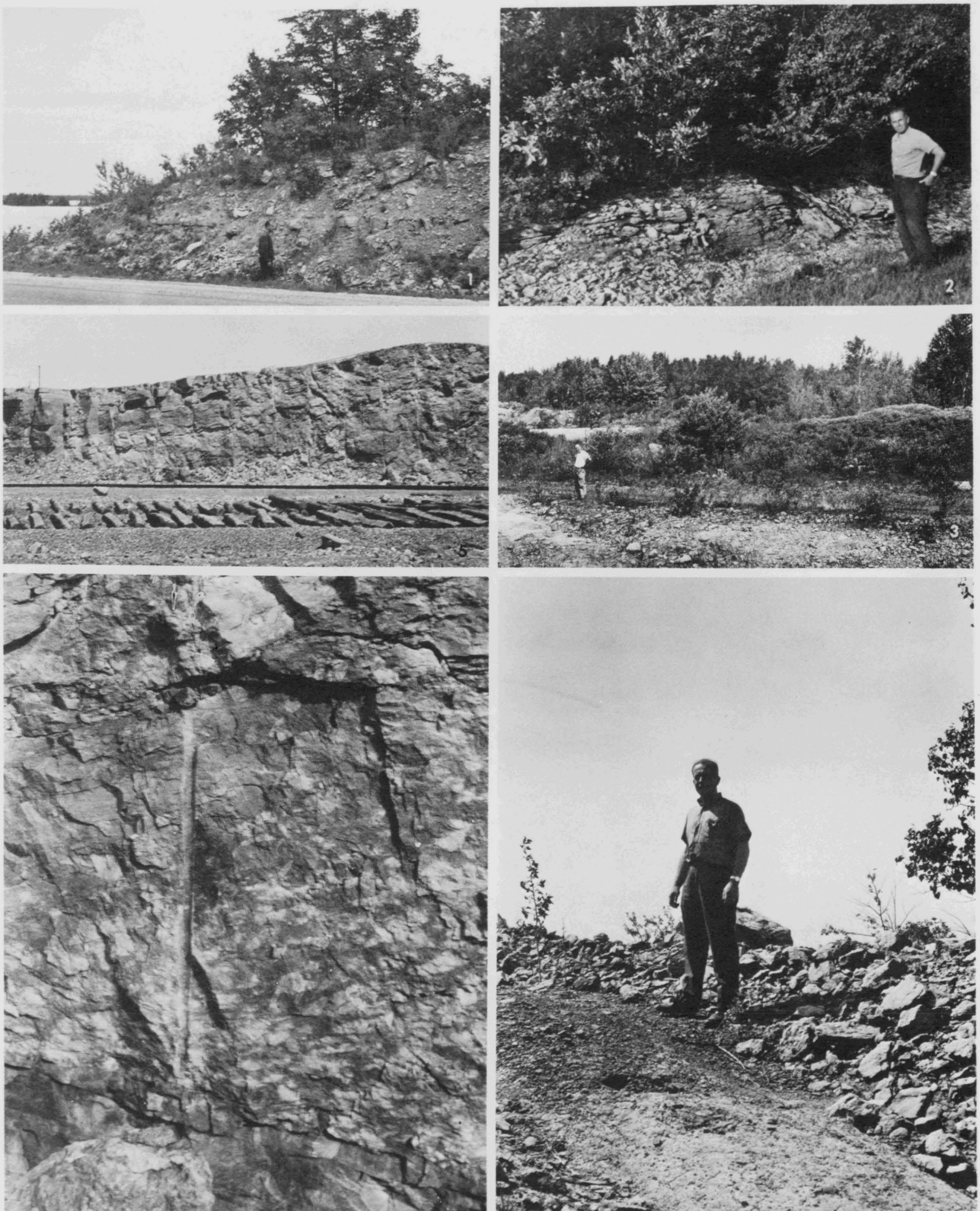


PLATE 2



31-8-18 C: Road cuts and ledges on and near Four Mile Dam Road (Lake Winyah Road) extending about 3/4 mile S from dam, Alpena County. Survey Loc. 89a. Norway Point Formation and Potter Farm Formation (part of type section).

31-8-18 E: Shale bank on SW side of Thunder Bay River on Potter Farm about 1 mile below Four Mile Dam (reached by car along power-line service road, about 1.1 miles from dam), Alpena County. Survey Locs. 46, 89b. Norway Point Formation.

31-8-19 SW: Shallow abandoned quarry on N side of M 32 just W of intersection with Four Mile Dam (Lake Winyah) Road, about 2 miles W of Evergreen Cemetery, in SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 19, Alpena County. Survey Loc. 37. Potter Farm Formation.

31-8-20 NW: Field exposures near and cuts along abandoned tracks of Boyne City, Gaylord, & Alpena R.R., just W of bridge piers over Thunder Bay River, Alpena County. Survey Loc. 89c. Potter Farm Formation (lower part).

31-8-20 S: Road cuts on M 32 on S side of old Potter farm, $\frac{1}{2}$ to 1 mile W of Evergreen Cemetery, Alpena County. Survey Loc. 89e. Potter Farm Formation.

31-8-20 SE: Exposures on eastern slope of hill on old Potter farm, between Cemetery shale pit (31-8-21 SW) and radio station transmitter, N of M 32, Alpena County. Survey Loc. 89d. Potter Farm Formation.

31-8-21 SW: Small shale pit and adjacent exposures in corner of Evergreen Cemetery, Alpena (more or less continuous with 31-8-20 SE exposures on hillside), Alpena County. Survey Loc. 68. Potter Farm Formation.

31-8-28 NE: Clay pits (now filled) at abandoned Warners Brick Yard on N side of Third Street at its angle in southwest part of Alpena, in SE corner NE$\frac{1}{4}$ sec. 28, Alpena County. Survey Loc. 111. Potter Farm Formation.

31-8-29 NE: Abandoned Nicholson Limestone Quarry S of Paxton branch of the Detroit & Mackinac R.R. and W of Potter Park, Alpena, in center of S$\frac{1}{2}$ NE$\frac{1}{4}$ sec. 29, Alpena County. Survey Loc. 36. Potter Farm Formation.

31-8-34 NW: Excavations at Alpena City Waterworks and ledges cropping out on beach at Stony Point, south edge of Alpena, near NW corner of sec. 34, Alpena County. Survey Loc. 90. Potter Farm Formation.

31-9-5 W: Outcrop beside Hamilton Road, about 4/10 mile NE of Locality 31-9-6 SE, in NW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 5, Alpena County. Newton Creek Limestone, near middle of formation.

31-9-5 NE: Exposures along Hamilton Road in NE$\frac{1}{4}$ sec. 5, Alpena County. Upper part of Genshaw Formation (above Killians Member).

31-9-6 S: Ledge beside Hamilton Road in SW$\frac{1}{4}$ sec. 6, about 3/10 mile ENE of Locality 31-9-7 NW, Alpena County. Lower part of Alpena Limestone.

31-9-6 SE: Outcrops beside Hamilton Road, about $\frac{1}{2}$ mile NE of Locality 31-9-6 S, Alpena County. Lower part of Alpena Limestone in the SW exposure and Newton Creek Limestone nearby in the NE exposure.

31-9-7 NW: Outcrop adjacent to Hamilton Road about 0.2 mile E of the NW corner of section, Alpena County. Lower part of Alpena Limestone, probably near the 1-foot shale bed.

31-9-7 S: Outcrop beside road leading E from little-used NE-trending road, near S line of SW$\frac{1}{4}$ sec. 7 and a short distance E of Norwegian Creek, Alpena County. Lower part of Alpena Limestone.

31-9-10 NE: Abandoned quarry of El Cajon Cement Company at El Cajon Beach on Lake Huron, S of end of

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PLATE 2

1 - Rockport Quarry Limestone, lower beds exposed along US 23. Loc. 34-8-31 S.
2 - Rockport Quarry Limestone exposed along US 23. Loc. 34-6-15 C.
3 - Bell Shale, upper beds. Loc. 32-9-6 NW, Kelley's Island Quarry.
4 - Bell Shale - Rockport Quarry Limestone contact, exposed in bulldozed strip in same quarry.
5 - Alpena Limestone, bioherm and flank beds. Loc. 31-8-14 NE, old Thunder Bay Quarry.
6 - Alpena Limestone, showing some coral heads tilted in their original attitude at the edge of the reef. Same locality.

Hamilton Road, center of W½ NE¼ sec. 10, Alpena County. Survey Loc. 49. Genshaw Formation (lower beds).

31-9-15 SW: Sinkhole at El Cajon Bay (NOT El Cajon Beach), the small inlet at the head of Misery Bay (also known as Little Thunder Bay), in NW¼ SW¼ sec. 15, about 5 miles ENE of Alpena, Alpena County. Survey Loc. 48. Genshaw Formation (above the Killians Member).

31-9-16 NE: Exposure along North Point Road about ¼ mile S of the NE corner sec. 16, eastern Alpena County near Misery Bay. Lower part of Genshaw Formation.

31-9-18 NW: Outcrop NE of Huron Portland Cement Co. quarry, beside E-W trending secondary road, Alpena County. Upper part of Alpena Limestone.

31-9-18 SW: Quarry of the Alpena Portland Cement Company, abandoned before 1915, "near the shore of Thunder Bay about three-fourths of a mile east of the quarry of the Michigan Alkali Company, but at a lower level" (R. A. Smith, 1916, p. 179), Alpena County. Alpena Limestone, including bioherms.

31-9-18 N: Outcrop beside secondary road trending NE in NE¼ NW¼ sec. 18, near Norwegian Creek and E of Huron Portland Cement Company Quarry, Alpena County. Upper part of Alpena Limestone.

31-9-18 S: Gilbert Olson's Quarry, abandoned before 1915, in SE¼ SW¼ sec. 18; "the exposure forms a low mound adjacent to a swamp. Across the road the surface is much higher and limestone is exposed at many places in SW¼ sec. 18" (R. A. Smith, 1916, p. 181), Alpena County. Alpena Limestone, "fragmental reef limestone."

32-6-5 SE: Road cut along Leer Road between Olsen Road and Norwegian Church, near center of E line of SE¼ sec. 5, Alpena County. Alpena Limestone.

32-6-9 W: Sinkhole near Leer Road, in NW¼ SW¼ sec. 9, Alpena County. Probably Alpena Limestone.

32-6-15 SW: Sinkhole known as the "Punch Bowl," 250 x 150 feet in area and 40 feet deep, near M 65 (road veers around edge of it), about 3 miles NNE of Long Rapids, Alpena County. Probably Alpena Limestone at bottom.

32-6-16 NW: Four sinkholes E of Leer Road between its intersections with Enger and Mellon Roads, once known as the "Four Holes," Alpena County. Probably solution of Alpena Limestone.

32-6-25 S: Cuts and ditches along Fitzpatrick Road on NW flank of Orchard Hill. Potter Farm Formation.

32-6-28 C: Sinkhole just W of M 65 about 1 mile NNE of Long Rapids, in NE¼ SW¼ sec. 28, Alpena County. Probably from solution of Alpena Limestone and collapse of Norway Point Formation.

32-6-33 N: Sinkhole near corner of MacArthur Road and secondary road, about ½ mile NE of Long Rapids, in NE¼ NW¼ sec. 6, Alpena County. Probably caused by solution of Alpena Limestone and collapse of overlying strata.

32-6-34 C: Sinkhole in NE¼ SW¼ sec. 34, Alpena County. See 32-6-33 N.

32-6-34 SE: Sinkhole just N of Long Rapids Road near southeastern corner sec. 34, Alpena County. See 32-6-33 N.

32-7-5 SW: Abandoned "Griffin" or "Bolton" limestone quarry and adjacent field outcrops, on SW side of Detroit & Mackinac R.R. tracks and just N of Maple Lane Road, about 1¼ miles W of Bolton Road, 1/8 mile W of Zawarska (formerly Minton) Road, and ¼ mile E of Kaszubowski Road, about 1¼ miles NW of village of Bolton, in SE¼ SW¼ sec. 5, northern Alpena County. Survey Loc. 95. Alpena Limestone.

32-7-11 NW: Sinkholes S of Poland School, 2¼ miles N of Cathro, just east of Melville Road and ¼ mile

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PLATE 3

1 - Genshaw Formation (mostly under water at time of photograph). Loc. 32-8-23 SE, S end of Devil's Lake.
2 - Genshaw Formation, Killians type locality. Loc. 32-8-8 E, cut on French Road.
3 - Genshaw Formation, lower part (*Sieberella romingeri* zone). Loc. 34-6-17 NW, cut on US 23 near Swan Creek.
4 - Newton Creek Limestone and Alpena Limestone, when 1-foot shale (unit 3) of latter formed level between upper and lower quarries at old Michigan Alkali Quarry. Loc. 31-8-13 W.
5 - Ferron Point Formation, lower beds, somewhat slumped, atop W wall of Kelley's Island Quarry. Loc. 32-9-6 NW.


1

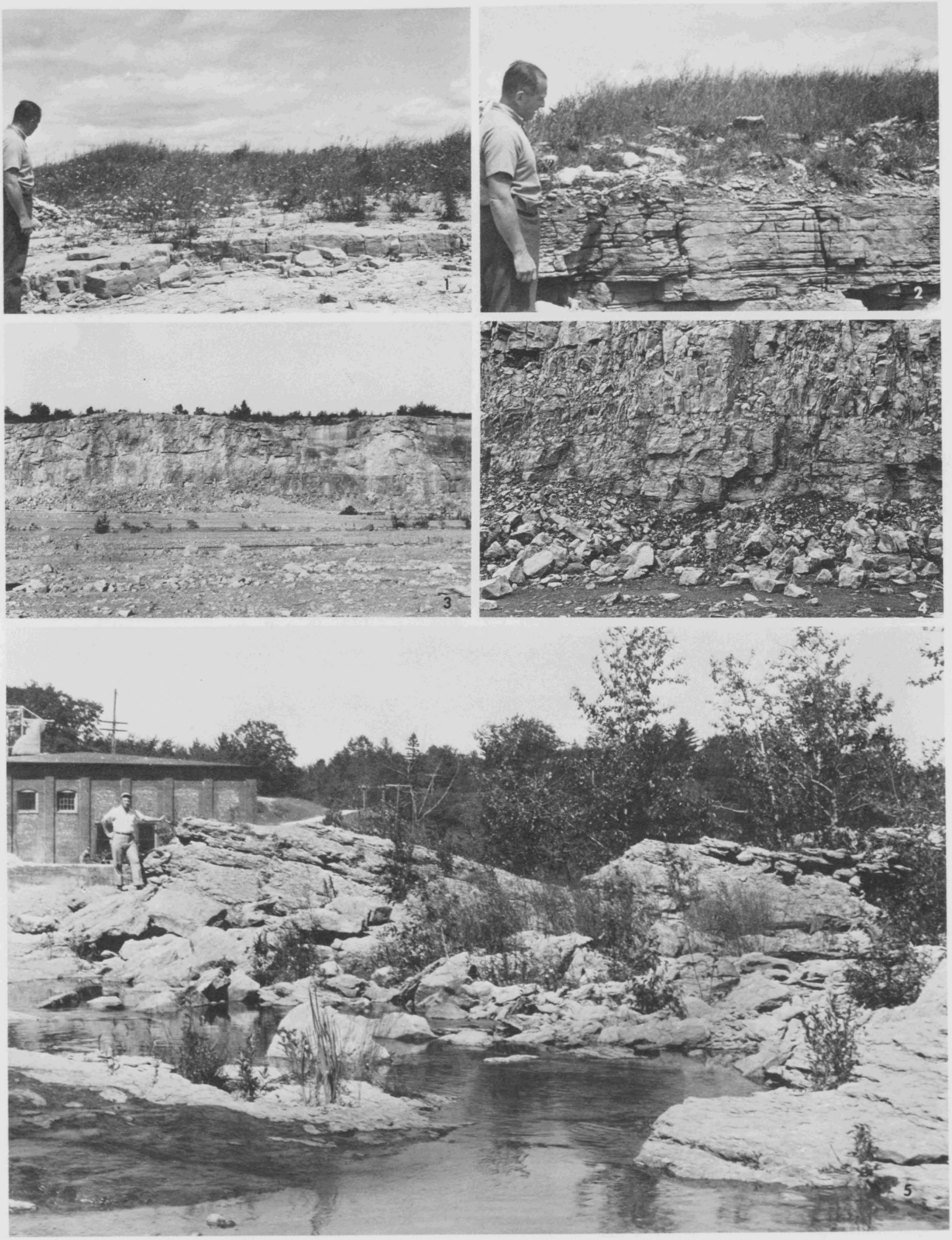

2


3


4


5

PLATE 4



south of Maple Lane Road, northern Alpena County. Survey Loc. 107. Newton Creek-Alpena contact.

32-7-14 NW: Road cut and small field exposures on E side of Melville Road between its intersections with Dagett and Lacomb Roads, Alpena County. Alpena Limestone.

32-7-15 NE: Road cut on Melville Road just S of intersection with Dagett Road, NE corner of section, Alpena County. Alpena Limestone.

32-7-17 SE: Exposures along Bolton Road between Cathro and Pilarski Roads, near Bolton School, Alpena County. Alpena Limestone.

32-7-29 C: Exposures on bank of North Branch of Thunder Bay River about $1\frac{1}{4}$ miles NW of bridge on Long Rapids Road at Male Store, near center of section, Alpena County. Survey Loc. 94. Four Mile Dam Formation and Norway Point Formation in older collections.

32-7-30 S: Road cuts and ditches along Orchard Hill Road, extending from T-junction with Ellsworth Road (on N side of Orchard Hill) for $\frac{1}{4}$ mile northward, just W of Orchard Hill School, along E line of SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 30, Alpena County. Survey Loc. 93. Potter Farm Formation, Norway Point rocks reported nearby to north (drift?).

32-7-31 W: Hillside on S side of Orchard Hill just N of sinkhole and small pond on N side of Long Rapids Road, near center of S$\frac{1}{2}$ NW$\frac{1}{4}$ sec. 31, about $2\frac{1}{4}$ miles W of North Branch bridge, Alpena County. Survey Loc. 91. Potter Farm Formation, gastropod beds.

32-7-31 NW: Road cuts and ditches on NW side of Orchard Hill, extending from junction of Herron and Ellsworth Roads for about $\frac{1}{4}$ mile eastward toward Orchard Hill School, along N line of NW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 31, less than $\frac{1}{2}$ mile W of 32-7-31 N; about $2\frac{1}{2}$ miles WNW of North Branch bridge and $\frac{1}{2}$ mile N of Long Rapids Road, Alpena County. Survey Loc. 92. Potter Farm Formation, Cystiphylloides beds.

32-7-31 N: Road cuts and ditches on N side of Orchard Hill along Ellsworth Road (between Herron and Martin Roads), extending from near T-junction with Orchard Hill road about 1/8 mile eastward, along N line of NW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 31, about 2 miles WNW of North Branch bridge and $\frac{1}{2}$ mile N of Long Rapids Road, Alpena County. Potter Farm, about same beds as 32-7-31 NW.

32-7-31 C: Road cuts on N side of Long Rapids Road and exposures on S side of Orchard Hill, between Herron Road and Martin Road, mostly between center and E line of sec. 31, about 1 3/4 miles W of North Branch bridge, Alpena County. Survey Loc. 42. Potter Farm Formation.

32-8-2 NE: Test pit in clearing at SW side of swamp, $1\frac{1}{2}$ miles NE of Lakewood, in NE$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 2, Alpena County, Survey Loc. 56. Genshaw Formation.

32-8-3 E: Roadside exposure along East Grand Lake Road (CO 405) about $\frac{1}{2}$ mile N of Lakewood (junction with US 23), near Dean School, northeastern Alpena County between Long and Grand Lakes. Genshaw Formation (this is probably Grabau's locality 12).

32-8-5 SW: Road cut on county road 634 (West Long Lake Road) about 1 mile W of junction with French Road, SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 5, northern Alpena County. Survey Loc. 98. Genshaw Formation (Killians Member).

32-8-8 E: Road cut on French Road, about $\frac{1}{4}$mile S of county road 634 (Long Lake Road), east line of sec. 8, Alpena County. Survey Loc. 52. Genshaw Formation; type locality of Killians Member.

32-8-11 SE: Exposure along US 23 about midway between Walmsley and Rockport Roads, near SE end of Long Lake, Alpena County. Grabau's locality 11. Genshaw Formation.

32-8-13 SE: Former site of Genshaw School on N side of Monaghan Point Road, about $1\frac{1}{4}$ miles E of US 23, poor exposures alongside and in roadbed; several abrupt drops in road level along this and

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PLATE 4

1, 2 - Koehler Limestone in quarries at Onaway. Loc. 34-2-5 N.
3 - Alpena Limestone, two bioherms in wall of old Thunder Bay Quarry. Loc. 31-8-14 NE.
4 - Newton Creek Limestone, lens-shaped bioherm in basal part. Loc. 31-8-13 W, Huron Portland Quarry.
5 - Four Mile Dam Formation type locality, reef core with flanking Norway Point Formation beds. Loc. 31-8-7 C.

Rockport Quarry Road ($1\frac{1}{2}$ miles N) are resistant beds in the Genshaw. Genshaw Formation, type locality.

32-8-15 S: Ditches along Maple Grove Road just N of its junction with Long Lake Road (CO 634), along one of old routes of Long Lake Road, near center of $S\frac{1}{2}$ sec. 15, near S end of Long Lake, Alpena County. Genshaw Formation, lower beds with Sieberella romingeri, Billingsastrea pauciseptata.

32-8-22 NE: Ditches along county road 634 (Long Lake Road) south of Long Lake, near junction with US 23, Alpena County; Long Lake Road was changed about 1950, but both old and new sections have roadside exposures. Survey Loc. 58. Genshaw, Sieberella romingeri zone.

32-8-23 SE: Sinkhole in bottom of Devil's Lake and outcrops on shore at S end of lake, $\frac{1}{2}$ mile S of the Narrows, near junction of Wessel Road and US 23, in $SW\frac{1}{4}$ $SE\frac{1}{4}$ sec. 23, about 5 miles N of Alpena, Alpena County. Survey Loc. 99. Genshaw Formation.

32-8-24 NE: Bank on S shore of Hell Creek (also called Long Lake Creek; the outlet of Long Lake) at private bridge about 1 mile E of the Narrows and 0.4 mile SW of Genshaw School, just S of center $NE\frac{1}{4}$ sec. 24, Alpena County. Survey Loc. 100. Genshaw Formation.

32-8-25 SW: Exposures along Wessel Road, nearly $\frac{1}{2}$ mile N of Bloom Road, about $1\frac{1}{4}$ miles S. of bridge at the Narrows, in $NW\frac{1}{4}$ $SW\frac{1}{4}$ sec. 25, eastern Alpena County. Survey Loc. 50. Genshaw Formation (including Killians Member).

32-8-25 SE: Exposure along Bloom Road about 3/4 mile E of intersection with Wessel Road, Alpena County. Genshaw Formation, Killians Member.

32-8-26 E: Exposures from excavations made for power-line poles, the line extending NE-SW, Alpena County. Genshaw Formation, Cyrtina alpenensis beds.

32-8-29 SE: Large area of reef limestone exposed on old Leon Manville farm in $S\frac{1}{2}$ $SE\frac{1}{4}$ of section, near junction of Bloom Road and French Road, Alpena County. Alpena Limestone, probably lower limestone unit.

32-8-34 SW: Road cut and field exposures beside US 23, near Bradbury Road, close to SW corner sec. 34, about $3\frac{1}{4}$ miles N of Chisholm Street bridge in Alpena, Alpena County. Survey Loc. 96. Alpena Limestone bioherm.

32-8-35 SW: Exposure along Long Lake Road near SW corner of section, not far from end of Bradbury Road, about 3 miles N of Alpena, Alpena County. Alpena Limestone, crinoidal with bryozoa.

32-9-3/4/9/10: Exposures on Middle Island, Alpena County. Rogers City Limestone, the only exposure in Alpena County.

32-9-6 NW: Abandoned quarry of Kelley's Island Lime & Transport Company (formerly Great Lakes Stone & Lime Company) near Rockport; N end of quarry extends into Presque Isle County, and W wall extends into $NE\frac{1}{4}$ sec. 1, T32N, R8E; northeast corner of Alpena County. Survey Loc. 38. Bell Shale (in drainage ditches near S end of quarry), Rockport Quarry Limestone (type locality), and Ferron Point Formation (at top of west wall); one of the sinkholes exposed in W wall also contains Genshaw fossils.

32-9-18 SE: Abandoned shale pit of the Alpena Portland Cement Company, N of Monaghan Point Road and about 1 mile E of former site of Genshaw School; property formerly owned by Mr. Worline, now owned by G. Curby and not open to public. Alpena County. Survey Loc. 51. Ferron Point Formation (type locality of upper units) and Genshaw Formation (lower $5\frac{1}{2}$ feet).

32-9-31 N: Outcrop along Bloom Road about 6/10 mile W of NE corner sec 31, near junction with Kirchoff Road, Alpena County. Lower part of Genshaw Formation, near Killians Member.

PLATE 5

1 - Four Mile Dam Formation, Dock Street Clay Member, at old Thunder Bay Quarry. Loc. 31-8-14 NE.
2 - Antrim Shale at Paxton Quarry. Loc. 31-7-30 NE.
3 - Squaw Bay Limestone type locality. Loc. 30-8-11 SW.
4, 5 - Thunder Bay Limestone type locality at low water level. Loc. 30-8-11 SE.
6 - Potter Farm Formation, steeply dipping beds on S side of Orchard Hill. Loc. 32-7-31 C.

PLATE 5

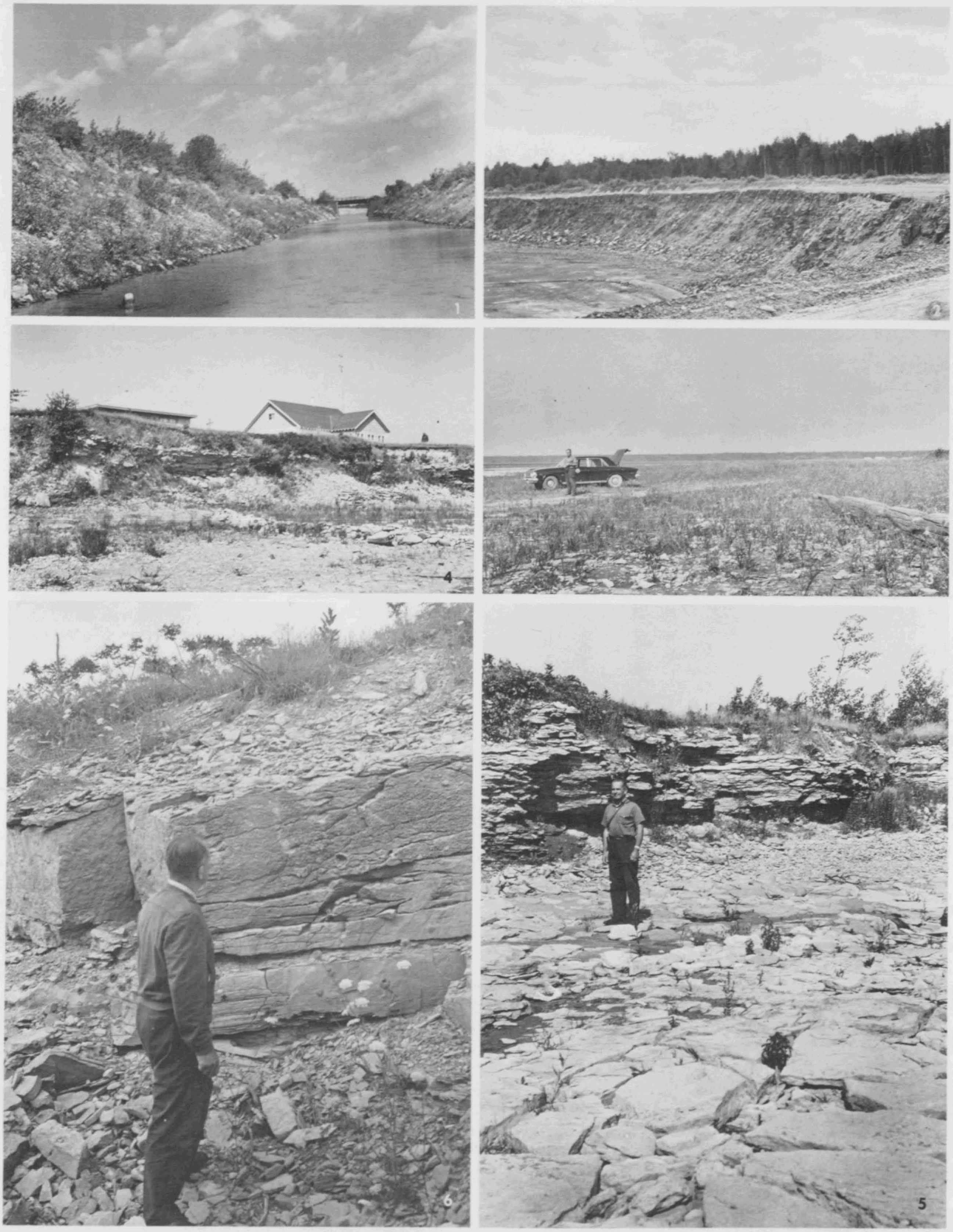
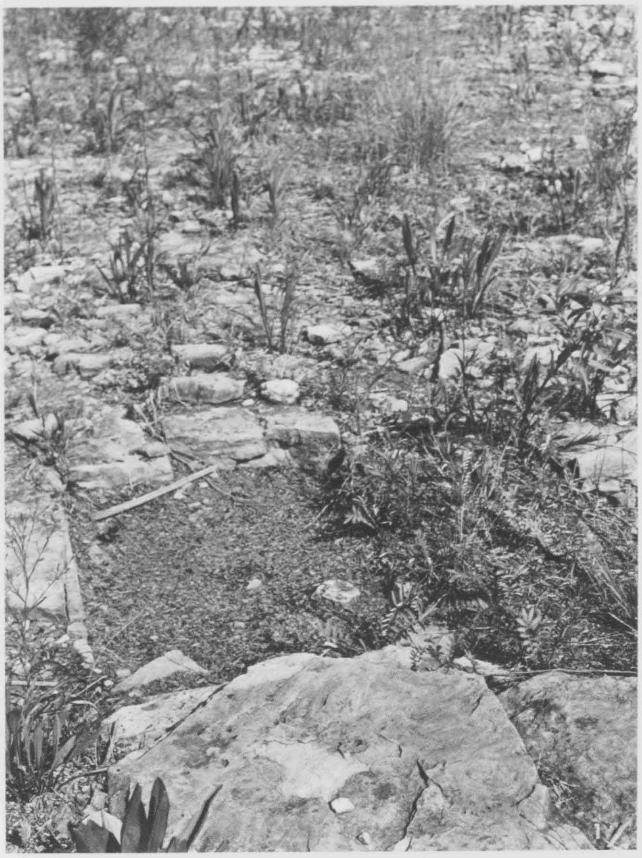
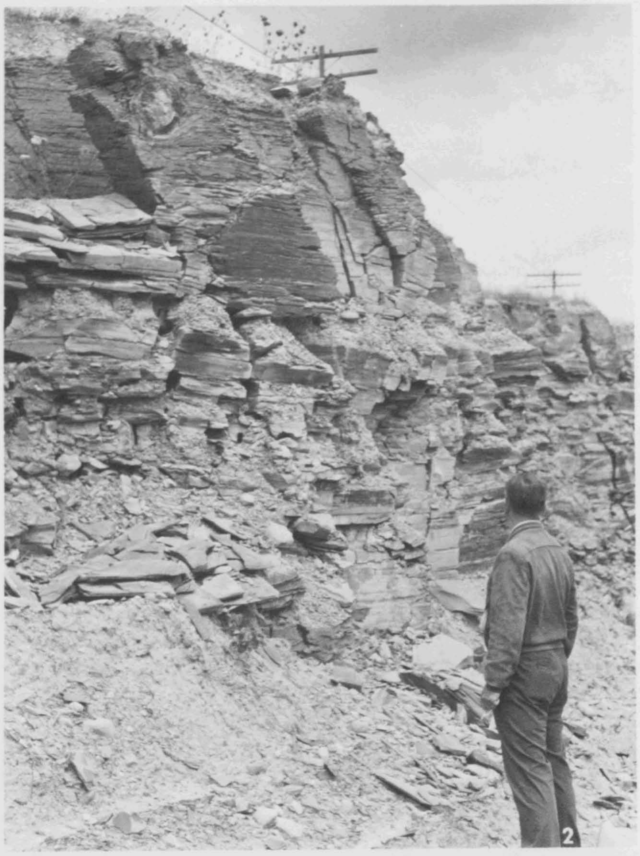


PLATE 6





Presque Isle County

33-6-4 NW: Roadside exposure just S of intersection of Hincka Road and Metz Highway, about $2\frac{1}{4}$ miles NNW of Posen, Presque Isle County. Genshaw Formation, numerous small Athyris.

33-6-8 NW: Ditch exposures from near intersections of Grand Lake Road and Leer Road extending about $\frac{1}{4}$ mile E of discontinuous spots, about $2\frac{1}{4}$ miles WNW of Posen, Presque Isle County. Alpena Limestone, Longispina aff. L. emmetensis.

33-6-9 NW: Roadside exposures at intersection of Hincka and Grand Lake Roads, about $1\frac{1}{4}$ miles NW of Posen, Presque Isle County. Genshaw Formation, above Killians Mbr., many small Athyris.

33-6-9 NNW: Exposure beside Grand Lake Road, less than $\frac{1}{4}$ mile E of Hincka Road, Presque Isle County. Genshaw Formation, Killians Member, black shaly limestone, large crushed Mucrospirifer.

33-6-9 N: Exposure along Grand Lake Road, nearly 0.7 mile W of M 65, Presque Isle County. Genshaw Formation, Cyrtina alpenensis bed.

33-6-10 SW: Exposures along M 65 just N of Posen, near center of W line SW$\frac{1}{4}$ sec. 10, Presque Isle County. Alpena Limestone (reported by Grabau and Hindshaw).

33-6-14 NW: Ditch and field exposure on CO 634 about 1/8 mile W of junction with Maple Road, about 1 mile E of Posen, Presque Isle County. Newton Creek Limestone, dark, irregularly bedded limestone weathering light gray, with strong petroliferous odor.

33-6-15 NW: Roadside exposure just E of Posen, on CO 634 about $\frac{1}{4}$ mile E of M 65, Presque Isle County. Alpena Limestone.

33-6-16 NW: Road cut about 3/4 mile W of Posen, on CO 634, Presque Isle County. Newton Creek Limestone.

33-6-17 NE: Ditches along CO 634 about $1\frac{1}{4}$ miles W of Posen, just E of junction with Spud Road, Presque Isle County. Alpena Limestone, beds with numerous cephalopods; possibly flank of bioherm. Gray shale interfingered with limestone layers.

33-6-31 E: Road cut on Leer Road less than $\frac{1}{4}$ mile S of Elowski Highway, about 5/8 mile N of Alpena County, southern Presque Isle County. Alpena Limestone, upper part, steeply dipping beds probably flank of bioherm.

33-6-32 C: Sinkhole and ledges at Sunken Lake, F. W. Fletcher State Park, near center of sec. 32, about $\frac{1}{2}$ mile north of county line, Presque Isle County. Survey Loc. 97. Alpena Limestone.

33-7-30 SE: Exposure along Long Lake Road, about 1 3/4 miles E of intersection with Polaski Road, southern Presque Isle County. Newton Creek Limestone.

33-7-36 NW: Exposure on S side of Long Lake Road (CO 634) near curve in road, near N end of Long Lake, Presque Isle County. Genshaw Formation, Killians Member.

33-7-36 N: Roadside exposure on Long Lake Road (CO 634), about $\frac{1}{4}$ mile W of Leroy resort, near center W$\frac{1}{2}$ NE$\frac{1}{4}$ sec. 36, Presque Isle County. Genshaw Formation, Killians Member.

33-8-2: Quarry of Presque Isle Corporation (formerly Lake-of-the-Woods Quarry), eastern Presque Isle County. Dundee Limestone (crusher pit), Rogers City Limestone, and Bell Shale.

33-8-8 S: Road cut on US 23 at S end of big road fill on W side of Grand Lake, 4.8 miles N of Alpena County by road, near S line of sec. 8, about 7/10 mile N of 33-8-17 E, Presque Isle County. Survey Loc. 87. Rockport Quarry Limestone.

33-8-10 E: Trails on NE side of hill just E of East Grand Lake Road (CO 405) about 1 mile SE of Fireside Inn, near center of line between secs. 10 and 11, Presque Isle County. Survey Loc. 102.

PLATE 6

1 - Squaw Bay Limestone type locality, showing scabby flat exposures along beach. Loc. 30-8-11 SW.
2 - Antrim Shale at Paxton Quarry; note large concretion near top of face. Loc. 31-7-30 NE.
3 - Thunder Bay Limestone type locality. Loc. 30-8-11 SE.

Rockport Quarry Limestone (capping the hill); Bell Shale (reported on logging trail down E side of the hill).

33-8-11 SW: Shallow abandoned clay pits on S side of East Grand Lake Road (CO 405) about $1\frac{1}{2}$ miles SE of Fireside Inn, Presque Isle County. Survey Loc. 101. Bell Shale, type locality. (Some doubt arises about the exact location of the old village, inasmuch as some of the buildings were reportedly moved to the head of the inlet S of False Presque Isle. There are no buildings standing at the site of the old village where the Bell Shale was discovered and named.)

33-8-17 E: Road cut and ditches on US 23 a short distance N of Warren Creek (entering SW corner of Grand Lake), near center of $E\frac{1}{2}$ sec. 17, Presque Isle County. Survey Loc. 86. Rockport Quarry Limestone (shaly bryozoan beds).

33-8-24 SW: Cut on abandoned Kelley's Island Lime & Transport Company railway, formerly running N from Rockport Quarry, Presque Isle County, locality now best reached by secondary road from East Grand Lake Road (CO 405). Survey Loc. 55. Bell Shale (strata below those exposed in Kelley's Island L. & T. Co. Quarry at Rockport).

33-8-29 NE: Road cut and ditches on US 23 just N of Big Gravelly Point at northeast corner of Long Lake, E line near N corner sec. 29, Presque Isle County. Survey Loc. 85. Genshaw Formation.

33-8-31 E: Exposures along West Long Lake Road (CO 634), 3/10 mile N of Alpena County, on N-S section of road, about $\frac{1}{4}$ mile SE of Orchard Point resort, near entrance to Martin's Resort, Presque Isle County. This is probably Survey Loc. 82, although this was described as $\frac{1}{4}$ mile SE of LeRoy Resort, in $S\frac{1}{2}$ $NE\frac{1}{4}$ sec. 31. Genshaw Formation (Cyrtina alpenensis bed and base of Killians Member).

33-8-34 SE: Cut on East Grand Lake Road (CO 405) about $\frac{1}{4}$ mile north of Alpena County line, along line between secs. 34 and 35, Presque Isle County. Survey Loc. 104. Genshaw Formation (lower strata, containing Sieberella romingeri).

33-8-35 NW: Outcrops on Rabiteau farm, on East Grand Lake Road (CO 405), about 0.2 mile S of NW corner sec. 35, southeastern Presque Isle County. Genshaw Formation (lower part, Sieberella romingeri zone).

33-9-18 C: Exposures along shore of Lake Huron, extending along E shore of False Presque Isle into sec. 7. Rogers City Limestone, beds with wide-frilled Atrypa.

33-9-31 SW: Beach exposures on Lake Huron about 1/8 to $\frac{1}{2}$ mile N of Alpena County line, not far from N end of Kelley's Island Quarry at Rockport and reached by bed of abandoned R.R. leading N from quarry, Presque Isle County. Survey Loc. 39. Rogers City Limestone.

34-2-5 N: Outcrops and small quarries on both sides of M 211 operated by the Onaway Stone Company, adjacent to Onaway Airport and N of Detroit & Mackinac R.R., western Presque Isle County. Onaway beds, thin, irregularly bedded limestone strata, sparsely fossiliferous and probably lagoonal deposits.

34-5-7 S: Exposure reported as good collecting site by H. H. Hindshaw. Genshaw Formation (Killians Member).

34-5-8 NW: Road cut on E-W road about 3/4 mile W of CO 451, about 3/10 mile E of NW corner sec. 8, about 5 miles SW of Rogers City, Presque Isle County; continuous cliff to 34-5-8 E. Survey Loc. 84. Genshaw Formation.

34-5-8 E: Road cut in cliff on CO 451 about 5 miles S of Rogers City, about $\frac{1}{4}$ mile N of SE corner sec. 8, cliff continuous to 34-5-8 NW, Presque Isle County. Survey Loc. 33. Genshaw Formation (below Killians Member).

34-5-8 SE: Road cut about 100 yards W of corner of CO 451 and E-W road, about 3/8 mile SW of 35-5-8 E, about $5\frac{1}{2}$ miles SSW of Rogers City, Presque Isle County. Survey Loc. 83. Genshaw Formation (Killians Member); compressed Mucrospirifer and Cyrtina alpenensis.

34-5-20 NE: Exposure along CO 638 just W of Belknap, near NE corner sec. 20, Presque Isle County. Genshaw Formation (Killians Member).

34-6-14 SE: Road cut on US 23 about 1 mile E of Trout River and 4 miles due E of Liske, S line of $SE\frac{1}{4}$ sec. 14, Presque Isle County. Survey Loc. 80b. Rockport Quarry Limestone (black coral beds).

34-6-15 C: Road cut on US 23 $\frac{1}{2}$ mile W of Trout Creek (Little Trout River; there is another Trout Creek or River west of Rogers City in the county), in $E\frac{1}{2}$ $SW\frac{1}{4}$ sec. 15, Presque Isle County.

Survey Loc. 80a. Rockport Quarry Limestone (black coral beds).

34-6-15 SW: Roadside exposures extending short distance S of junction of US 23 and M 65, Presque Isle County. Ferron Point Formation (lower part).

34-6-16 C: Road cut and ditch on US 23, 1 3/4 miles E of Swan Creek and 1 mile W of Trout Creek, about $\frac{1}{4}$ mile E of center of sec. 16, Presque Isle County. Survey Loc. 79. Ferron Point Formation (lower beds).

34-6-16 E: Outcrops and ditches a short distance west of junction of US 23 and M 65, in E$\frac{1}{4}$ sec. 16; shale exposure on N side of US 23 and beyond right-of-way contains excellent Hexagonaria; Presque Isle County. Ferron Point Formation (lower part).

34-6-17 NW: Ledges on banks and strata in bed of Swan Creek and cut on US 23 about 1/10 mile E of creek, about 6$\frac{1}{2}$ miles SE of Rogers City, Presque Isle County. Survey Loc. 77. Genshaw Formation (lower part). Topographically, this exposure much lower than outcrops of Rockport Quarry Limestone up the hill to the east.

34-6-24 NE: Bluff and cut on S side of US 23 1.8 miles E of Trout River, 1.2 miles W of junction with CO 427, and about 4.8 miles E of Liske, Presque Isle County. Survey Loc. 81. Rockport Quarry Limestone (black shaly bryozoan beds).

34-6-33 NE: Ledge and cut along M 65 2.3 miles S of US 23 and 2.9 miles N of Detroit & Mackinac R.R. crossing in Posen, from intersection of Augusta Highway to about 0.1 mile S, Presque Isle County. Genshaw Formation (lower part, Sieberella romingeri beds).

34-8-31 S: Bluffs and shore ledges near the middle of western shore of Grand Lake, near center SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 31, Presque Isle County. Survey Loc. 106. Rockport Quarry Limestone (lower part); Bell Shale crops out a short distance from the Rockport Quarry exposure and in the bed of Grand Lake nearby.

35-2-7 NW: Abandoned quarry of Onaway Limestone Company on shore of Black Lake, NW$\frac{1}{4}$ sec. 7, Presque Isle County. Survey Loc. 29. Rockport Quarry Limestone and Ferron Point Shale; Genshaw Formation exposed on slope above the quarry.

35-2-20 SW: Exposures along Stoney Creek near intersection of M 211 and Hutchinson Highway, about midway between Blask Lake and Onaway, western Presque Isle County. Ferron Point Formation.

35-2-21 NE: Road cut on Allis Road about 5$\frac{1}{4}$ miles W of Ocqueoc, $\frac{1}{4}$ mile W of NE corner sec. 21, Presque Isle County. Survey Loc. 62. Genshaw Formation.

35-2-26 S: Along Rainy River less than $\frac{1}{4}$ mile below Rainy River Falls, about 3$\frac{1}{2}$ miles E of Rowe School and about midway between Ocqueoc and Onaway, reached by Vermilya "Highway" off Porter Road, western Presque Isle County. Ferron Point and Genshaw Formations.

35-3-20 E: Road cut about $\frac{1}{2}$ mile S of Ocqueoc and 4/10 mile N of SE corner sec. 20, near King Tower and Assembly of God Church, Presque Isle County. Survey Loc. 61. Genshaw Formation.

35-3-22 S: Exposures along Ocqueoc River at Ocqueoc Falls just N of Ocqueoc Falls Highway (M 68), 4$\frac{1}{2}$ miles N of Millersburg, at Ocqueoc Falls Forest Campground, near center S$\frac{1}{4}$ sec. 22, Presque Isle County. Survey Loc. 30. Rockport Quarry Limestone.

35-3-24 S: Road cut on Ocqueoc Falls Highway (M 68), just E of Little Ocqueoc River and 1 3/4 miles E of Ocqueoc Falls, W of center of S line of sec. 24, Presque Isle County. Survey Loc. 60. Genshaw Formation.

35-3-27 C: Exposures along Ocqueoc River $\frac{1}{2}$ mile above the falls, not far W of curved junction of Ocqueoc Falls Highway and Millersburg Road (both roads part of M 68), Presque Isle County. Ferron Point Formation; Rockport Quarry Limestone downstream and Genshaw Formation upstream.

35-3-33 NW: Road cut on Ocqueoc Road about 2 miles S of Ocqueoc, $\frac{1}{4}$ mile S of NW corner sec. 33, Presque Isle County. Survey Loc. 59. Genshaw Formation.

35-5-20 SW: Small quarry N of M 68 (Onaway Road or Ocqueoc Falls Highway), about 2$\frac{1}{2}$ miles WSW of Rogers City, Presque Isle County. Rogers City Limestone, westernmost outcrop.

35-5-22 SW: Exposures along roads bounding small triangle 1 mile S of Rogers City (CO 451, US 23, and Airport Highway), Presque Isle County. Dundee Limestone.

35-5-23 SE: Calcite Quarry of Michigan Limestone Operations of the US Steel Corporation at Calcite, SSE of Rogers City, formerly site of Crawford's Marble Quarry; quarry now extends into R6E, the largest limestone quarry in the world; Presque Isle County. Survey Loc. 31. Dundee Limestone, Rogers City Limestone, and Bell Shale (lower part). Detroit River Dolomite in small part of quarry.

35-5-29 N: Road cut of M 68 (Onaway Road) about 2½ miles W of Rogers City, 3/10 mile E of NW corner sec. 29, Presque Isle County. Survey Loc. 57. Rogers City Limestone.

35-5-35 SW: Exposures at road corner of old Hagensville Road about 3 miles SSE of Rogers City, now just S of junction of US 23 and US 23A at Heythayler Highway, in SW corner sec. 35, Presque Isle County. Survey Loc. 32. Rockport Quarry Limestone.

35-6-21: Adams Point Quarry of Michigan Limestone Operations Division of US Steel Corporation, about 1 mile NE of Swan Lake on shore of Lake Huron, about 3½ miles due E of crusher and docks at Calcite, Presque Isle County. Dundee Limestone and Rogers City Limestone.

30-8-24: Sulphur Island, outcrops along shore, 5½ miles S of Alpena in Thunder Bay, Alpena County. Antrim Shale.

33-9-18 NE: Exposures along Lake Huron beach on False Presque Isle about ½ mile S of Knight Bay in W½ NE¼ sec 18, Presque Isle County. Locality 115A. Rogers City Limestone, units 3 and 4; two species of Atrypa, numerous specimens of A. arctica and a small species with coarse ribbing.

33-9-7E: Exposures along Lake Huron beach on False Presque Isle about ½ mile N of Knight Bay near C of E½ sec. 7, Presque Isle County. Locality 116A. Rogers City Limestone, top of unit 2 or base of unit 3.

33-9-7 SE: Exposures along Lake Huron beach on False Presque Isle about ¼ mile N of Knight Bay, Presque Isle County. Locality 115B. Rogers City Limestone, unit 4, possibly top of unit 3; beds with Gypidula and large Atrypa.

33-9-7 ENE: Exposures along Lake Huron beach on False Presque Isle about ½ mile N of Knight Bay, Presque Isle County. Locality 116B. Rogers City Limestone, unit 2.

33-9-7 NE: Exposures along Lake Huron beach on False Presque Isle about 3/4 mile N of Knight Bay, Presque Isle County. Locality 116C. Rogers City Limestone, unit 1.

33-9-7 NNE: Exposures along Lake Huron beach on False Presque Isle, near section line between secs. 6-7, Presque Isle County. Locality 116D. Rogers City Limestone, unit 1.

Pre-Traverse Group Formations

ROGERS CITY LIMESTONE

Name. - The Rogers City Limestone was named and described by George M. Ehlers and Robert E. Radabaugh at the 1937 meeting of the Michigan Academy of Science, Arts, and Letters and published in the "Papers" of the Academy in 1938 (p. 441-445, 2 Pls.). The name was derived from the town of Rogers City located about one mile west of the western boundary of the "Calcite Quarry," owned by the Michigan Limestone Operations of the United States Corporation.

Previous to 1938, the Rogers City Limestone was recognized as the upper part of the Dundee Limestone. The reasons for renaming this part of the Dundee are based on distinct faunal and lithological differences. The contact between the Rogers City Limestone and the Bell Shale is marked by a disconformity. That between the Rogers City and the underlying Dundee is also disconformable but not easily recognized.

Exposures. - The strata of the Rogers City and Dundee Limestones are best exposed in the Calcite Quarry. The thickness, lithology, and characteristic of the strata are indicated in the following description:

Dundee Limestone — PLATE 7 — Figures x 1 except as noted

Hexagonaria tabulata; 1, 2 #24187. Brevispirifer lucasensis; 3, #15145; 17, #57640. Panenka grandis; 4, #15266. Phenacocylas pohli; 5-8, #24403; 9-12, #24402. Atrypa ehlersi; 13, 14, #15185. A. costata; 15, #15197; 16, #15190. A. elegans; 20-22, #57680; 23-25, #57681. Paracyclas proavia; 18, 19, #24427.

PLATE 7

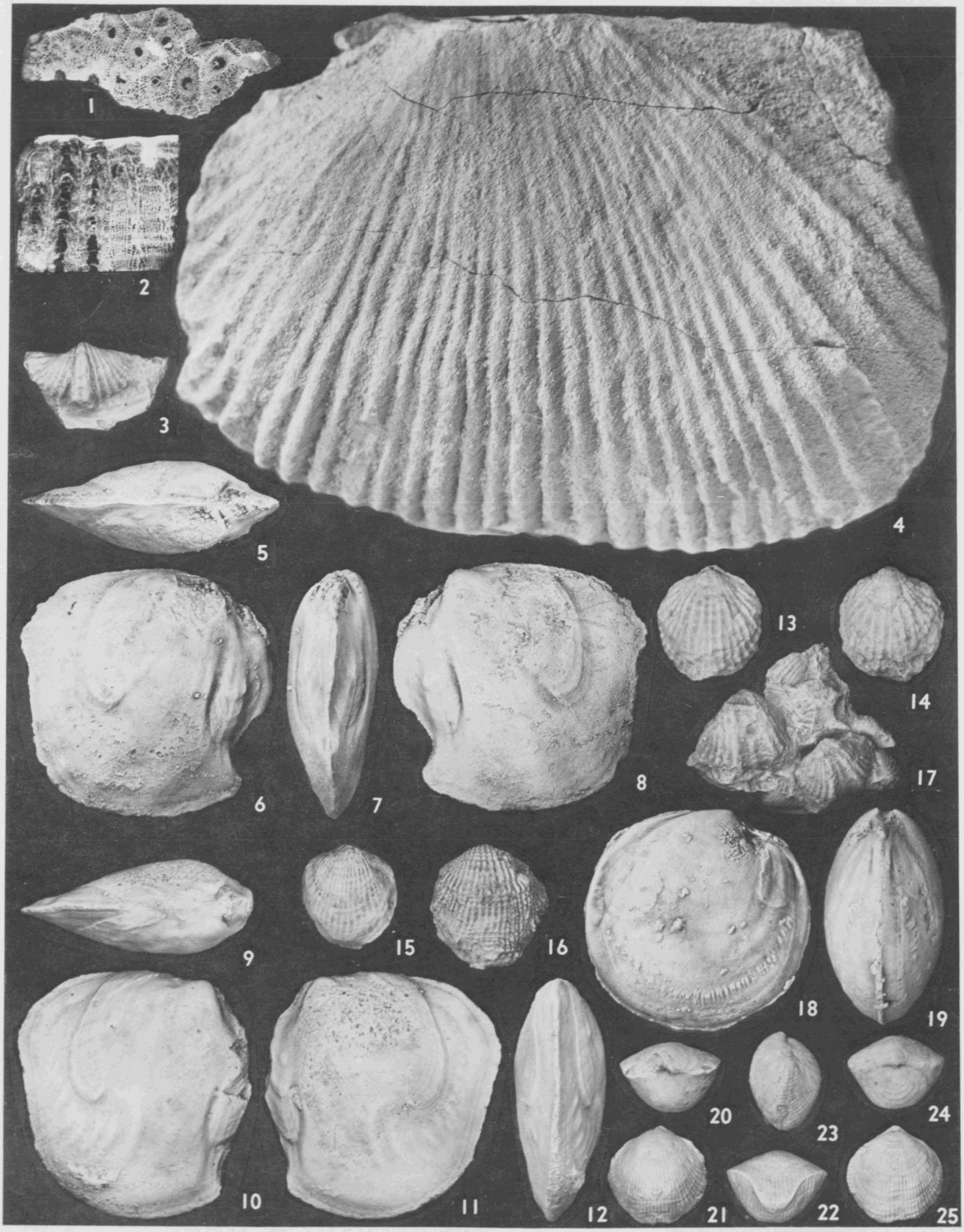
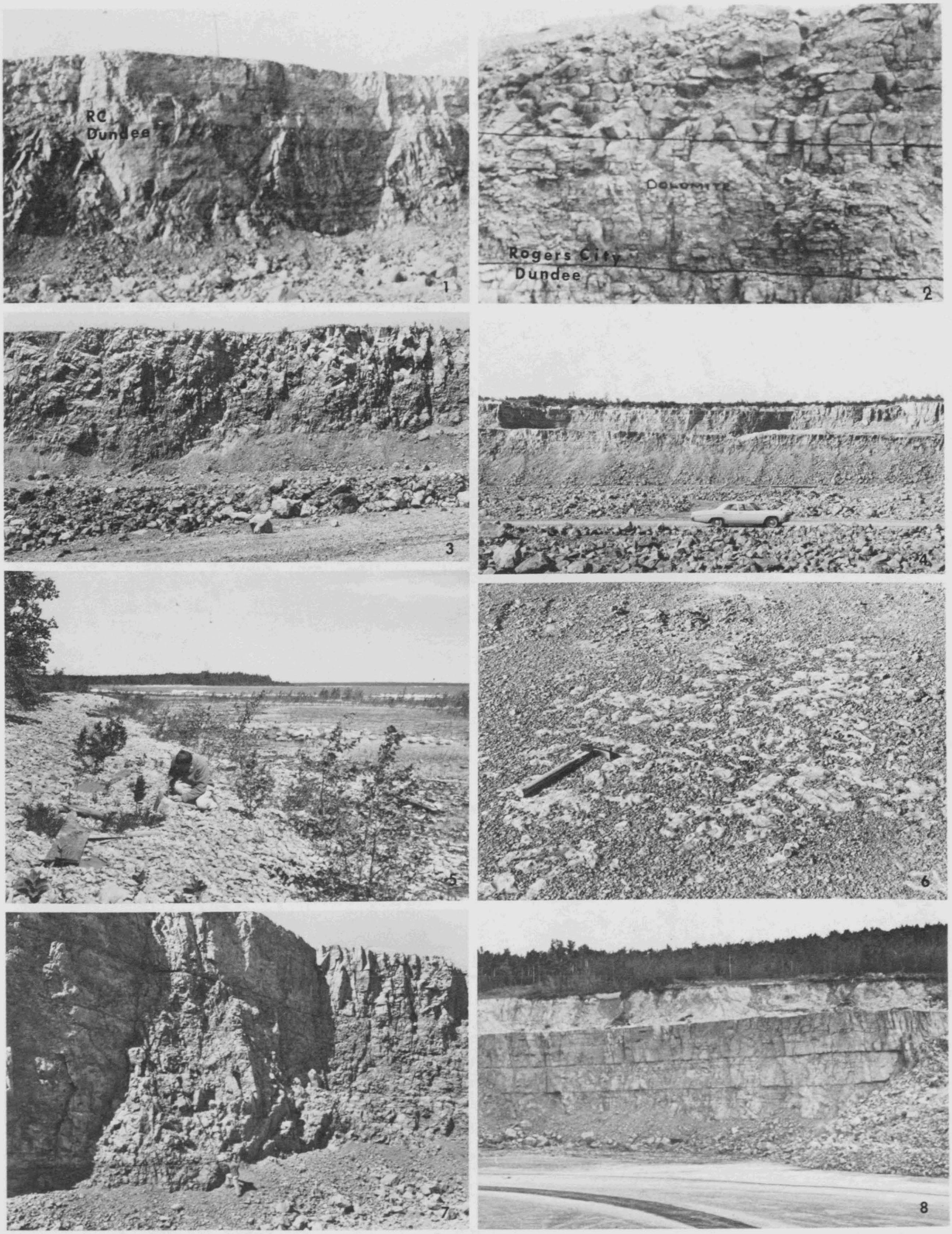
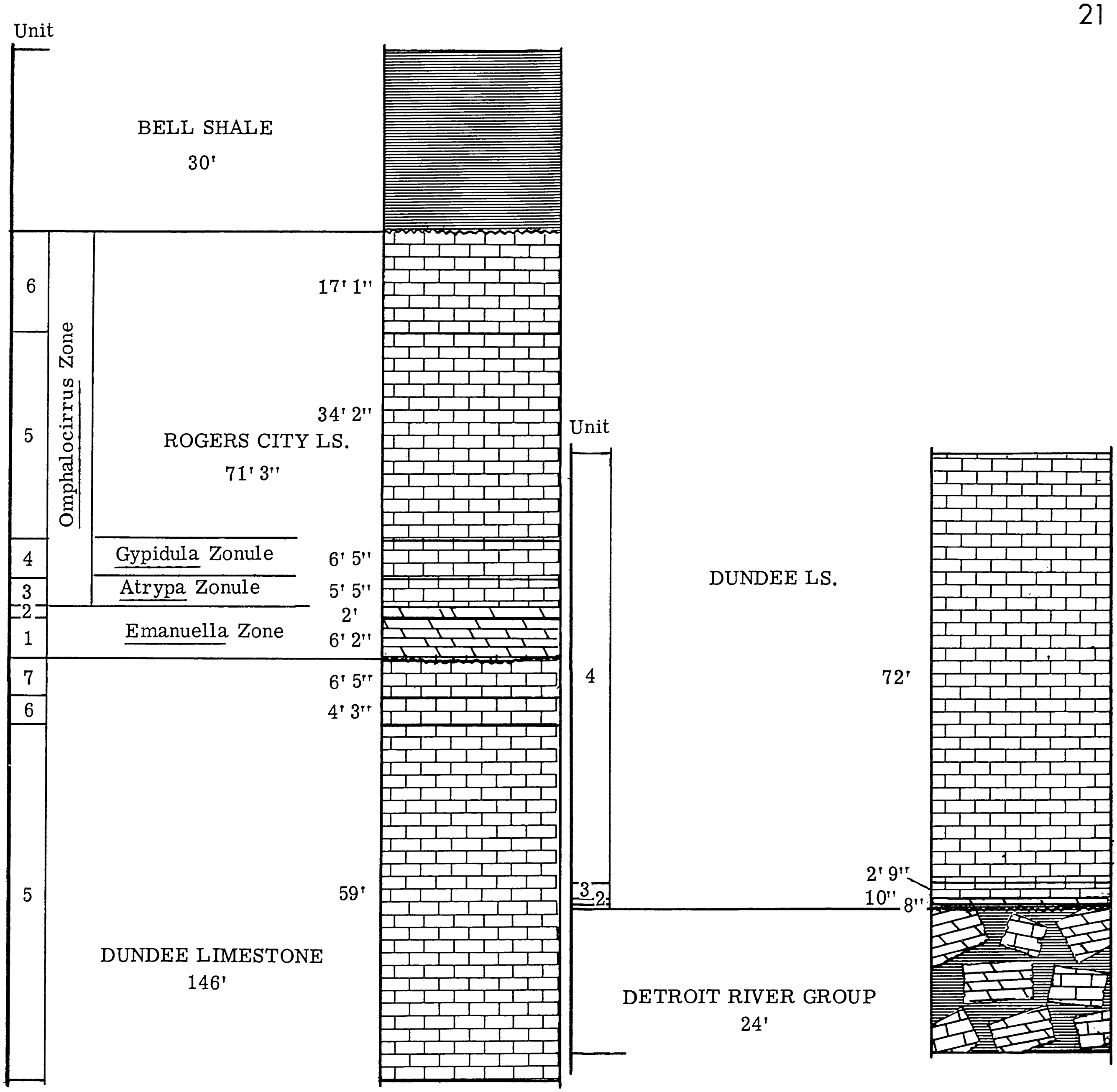


PLATE 8





TEXT-FIG. 1 -- Stratigraphic column of Devonian rocks exposed in Presque Isle County, Michigan, below the Traverse Group. Lithology somewhat simplified.

PLATE 8

1, 2 - Dundee-Rogers City Limestones contact, Calcite Quarry. Loc. 35-5-23 SE, photographed about 1935.
3 - Dundee Limestone, west wall of Calcite Quarry; dark beds are unit 6, light upper beds are units 7 and 8.
4 - Dundee-Rogers City contact at ledge in south wall of Calcite Quarry.
5 - Rogers City Limestone, unit 5, with Ferron Point peninsula in background. Loc. 33-9-31 SW.
6 - Dundee Limestone, top surface, showing erosion, partly by stylolitic solution, and 1 to 1½ inches of overlying dark soil, Calcite Quarry.
7 - Rogers City Limestone, units 4-6; man's hand at contact of units 4 and 5; prominent dark line is contact of units 5 and 6; south wall of Calcite Quarry.
8 - Rogers City Limestone-Bell Shale contact; south wall of Calcite Quarry.

Strata Exposed in Calcite Quarry of Michigan Limestone Operations of U.S. Steel Corporation near Rogers City, Michigan
(Locality 35-5-23 SE)

Traverse Group (Bell Shale)

Unit		Feet	Inches
1.	Shale, largely clay-shale, bluish-gray, very few impressions of Paracyclas sp. ...	30	
	Drill cores indicate that 35 to 40 feet of calcareous shale with thin layers of argillaceous limestone overlie the clay shale.		
	Total exposed	30	

Disconformity

Rogers City Limestone

Omphalocirrus Zone

Unit		Feet	Inches
6.	Limestone, buff, mottled with darker brown, slightly porous, thick-bedded, two sets of vertical joints, and numerous stylolitic seams; the corals Hexagonaria and Favosites, a costellate Atrypa and other brachiopods, Omphalocirrus manitobensis (Whiteaves), Bücheliа tyrrellii (Whiteaves) and other gastropods. Upper part of unit contains many large stromatoporoids and massive types of trepostomatous bryozoa	17	1
5.	Limestone, buff-gray to buff, slightly mottled, medium grained, porous, less thick bedded than unit 6, and numerous stylolitic seams; many corals, brachiopods and gastropods, including Büchelia tyrrellii (Whiteaves), Longstaffia speciosa (Whiteaves), Mastigospira ingens La Rocque and M. intermedia La Rocque, Strobeus pulchellus (Whiteaves), and Omphalocirrus manitobensis (Whiteaves). Liromytilus attenuatus (Whiteaves) is characteristic of Unit 5 and is the largest pelecypod of the Rogers City Limestone. Hexagonaria borealis Stumm in lower part of unit	34	2

Gypidula Zonule

Unit		Feet	Inches
4.	Limestone, dark grayish-brown, slightly mottled, finely crystalline and thick bedded, with many stylolitic seams; very many specimens of Gypidula sp. and a smaller number of costellate Atrypa arctica Warren, Subrensselandia sp., Omphalocirrus manitobensis (Whiteaves), Büchelia tyrrellii (Whiteaves) and other gastropods. Hexagonaria borealis Stumm rare in unit	6	5

Atrypa Zonule

Unit		Feet	Inches
3.	Limestone, buff-gray, slightly mottled, medium grained, porous, even bedded, containing many specimens of Atrypa arctica Warren, a smaller number of Gypidula sp., Omphalocirrus manitobensis (Whiteaves), Büchelia tyrrellii (Whiteaves), bellerophontid gastropods..........	5	5

Emanuella Zone

Unit		Feet	Inches
2.	Magnesian limestone, irregularly mottled buff and dark gray, finely crystalline, thicker bedded and less magnesian than Unit 1, transitional in lithology and chemical composition between Unit 1 and 3..........	2	0
1.	Magnesian limestone, finely crystalline, thin bedded, each bed with discontinuous, alternating bands of dark brownish gray and light buff arranged parallel to the bedding planes. Limestone cut by two sets of closely spaced joints; weathers into blocks or thin slabs that become light yellow in a few years. Emanuella sp. aff. E. meristoides (Meek) abundant; Carinatina dysmorphostrota		

Dundee - Rogers City | PLATE 9 | Figures x 1 except as noted

Dundee: Hexagonaria aff. coalita; 1, 2 #24189. H. parva; 3-5, #24186. H. alternata; 6, 7, #24184. Diphyphyllum rectiseptatum; 8, 9, #14378a; 14, #14305. Placophyllum ? sp.; 10, #57638. Chonophyllum ? sp.; 11, #57637. Platyceras sp.; 12, 13, #57639. Rogers City: Atrypa arctica; 15, #57682 (from Manitoba); 16, #57684 (from Michigan).

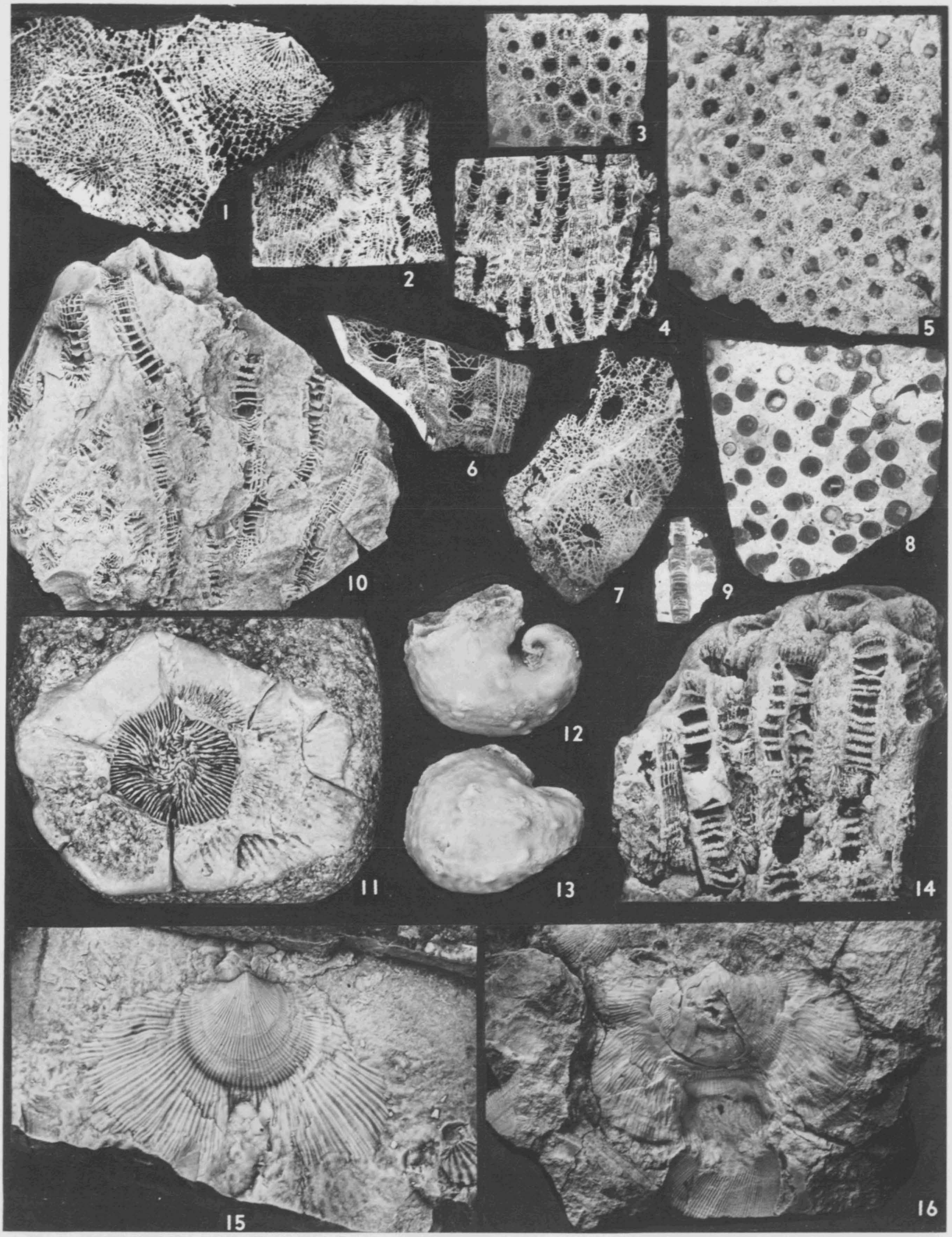

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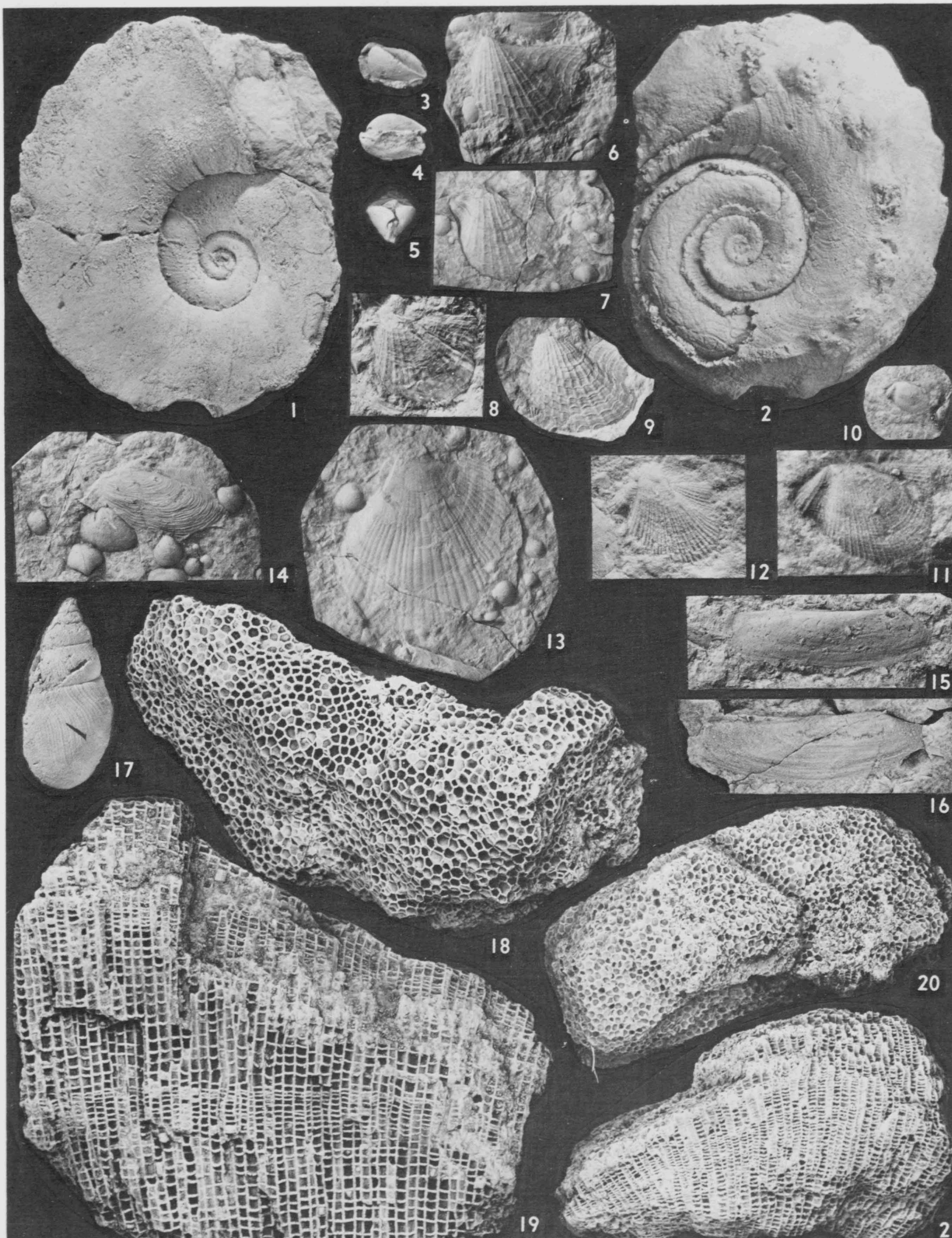
PLATE 10



Unit		Feet	Inches
	(Crickmay) and a productid relatively common. Specimens of the pelecypods Actinopterella calliotis LaRocque and A. peninsularis La Rocque, Leptodesma furcistria La Rocque, Limoptera (sec. Myalinodonta?) mygrans La Rocque characteristic of the unit.	6	2
	Total exposed	71	3

Disconformity

Dundee Limestone

Unit		Feet	Inches
7.	Limestone, gray, weathering to a buff-gray, composed of numerous shells of brachiopods and a smaller number of other invertebrates. Characteristic fossils are Hexagonaria sp., Atrypa costata Bassett, A. ehlersi Bassett, Brevispirifer lucasensis (Stauffer), Etheridgina? spinosa Bassett, Productella spinulocosta Hall, and a species of Athyris identical with a species in the Dundee Limestone of southeastern Michigan.	6	5
6.	Limestone, gray, weathering buff-gray, with few chert nodules and specimens of Hexagonaria sp., Atrypa costata Bassett, A. ehlersi Bassett, and other fossils.	4	3
5.	Limestone, buff-gray to buff, weathering to brown, and thick-bedded, with Hexagonaria parva Stumm, Atrypa costata Bassett, and A. ehlersi Bassett.	59	
4.	Limestone, buff-gray to gray, mottled, dense, slightly dolomitic in lower part, containing Acinophyllum? rectiseptatum (Rominger) (See D. J. McLaren, 1959), Atrypa elegans Grabau, A. costata Bassett, Pentamerella sp. cf. P. parva Bassett, and numerous specimens of Paracyclus proavia (Goldfuss) and Phenacocyclas pohli (La Rocque).	72	
3.	Limestone, slightly magnesian, dark buff gray to chocolate-colored, thin- and even-bedded with carbonaceous material on bedding planes, very finely crystalline; weathers into layers $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness.	2	9
2.	Dolostone, buff, with some carbonaceous laminae in upper 2 inches.		10
1.	Shale, buff-gray, mottled with brown. Shale is thickest in the lower part of a small shallow pre-Dundee limestone erosion channel carved in a breccia of the underlying Detroit River Group.		8

Total exposed 144' 8" -- 143' 8"

Disconformity

Detroit River Group

Unit		Feet	Inches
1	Breccia, composed of small and large angular blocks of buff dolomite and thin-bedded to laminated dark bluish gray limestone in a matrix of dark bluish gray shale and comminuted limestone; small light purple crystals		

Rogers City Limestone PLATE 10 Figures x 1 except as noted

Omphalocirrus manitobensis; 1, 2, #22379. Goniophora nucella; 3-5, #24592. Actinopterella peninsularis, 6, #24544; 7, #24549; 8, #24546; 9, #24545. A. calliotis; 10, 11, #24556 (11, x3); 12, #24558. Limoptera (Myalinodonta ?) migrans; 13, #24560. Leptodesma furcistriata; 14, #24564. Solenomorpha peninsularis; 15, #24598; 16, #24597. Strobeus subcostatus; 17. Favosites sp. A; 18, 19, #57636. F. sp. B; 20, 21, #57635.

	Feet	Inches
of fluorite present in few blocks of buff dolomite. The breccia was visible in a large test pit a short distance southeast of the large crusher receiving the limestone from the quarry trains. About ten years ago the pit was completely filled with overburden. See description by G. M. Ehlers (1945, p. 115)..	24	

There are eight exposures of the Rogers City Limestone in Michigan. The previously mentioned Calcite Quarry, containing the holotype section of the the formation, is believed to be the largest limestone quarry in the world. The average thickness of the section is 70 feet; when quarrying operations move the wall to the south, the section is likely to show a thickness of 100 feet. The second exposure of the Rogers City Limestone is adjacent to Adam's Point on Lake Huron about 2 miles northeast of the eastern end of the Calcite Quarry. It was named the Adam's Point Quarry by the Michigan Operations of the U.S. Steel Corporation after the point of land on Lake Huron. The quarry, which is situated on a dome structure, is now closed. The yellowish-gray blocks of magnesian limestone strewn over the floor of the abandoned quarry are derived from 8 feet of rock composing the lowest part of Rogers City Limestone. The third exposure consists of small areas of limestone located at the sides of Michigan Highway 82 about 2½ miles southwest of Rogers City; areas are larger in the low land on the north side of the road than on the south side. Exposure is about ¼ mile east of the NW corner of sec. 29, T35N, R5E.

The fourth exposure is the limestone quarry of the Presque Isle Corporation in section 2, T33N, R8E, in eastern Presque Isle County. The quarry shows the complete section of the Rogers City Limestone; about 12 to 15 feet of Bell Shale rest on the Rogers City Limestone in the southwest wall of the quarry. The fifth exposure is at the surface of False Presque Isle, the north end of which is about 2 miles southeast of the office of the Presque Isle Corporation. The sixth exposure is along the shore of Lake Huron between points about one-quarter and three-quarters mile south of Ferron Point in southeastern Presque Isle County; the rock crops out only at low level of Lake Huron. The seventh exposure is on Middle Island, Lake Huron, about 2½ miles southeast of the southeast corner of Presque Isle County. The limestone strata are only a few feet above Lake Huron and belong to the lower part of the formation. The eighth exposure is composed of a few small outcrops on the shore of the North Point peninsula, north of Presque Isle Harbor on Lake Huron.

DUNDEE LIMESTONE

Name. - The Dundee Limestone was named by Alfred C. Lane in a report by M. E. Wadsworth (1893, p. 66) for strata formerly exposed in the abandoned Pulver quarry located in the city of Dundee, Monroe County. The precise location of the quarry was on the north bank of the Raisin River back of the National Hotel. See W. H. Sherzer (1900, p. 77, 78) and Charles F. Bassett (1935, p. 433).

Alfred C. Lane (1895, p. 24-27, 42, 81-82) recognized the presence of the Dundee Limestone in the "... northern end of the Lower Peninsula to Mackinac City," and its stratigraphic position between the overlying Traverse group and the Monroe beds (upper beds), now recognized as part of the Detroit River Group (see M. Grace Wilmarth, 1938, p. 1401). The presently designated Dundee Limestone and the Rogers City Limestone, which was erroneously considered as the upper part of the Dundee, are exposed in small areas near the south and west of Rogers City. West of these areas, the two limestones are covered with Pleistocene drift.

CORRELATION OF ROGERS CITY AND DUNDEE LIMESTONES AND UNDERLYING DEVONIAN FORMATIONS

Rogers City Limestone. - The identification of the fossils of the recently described Miami Bend Formation of the Logansport, Indiana, region by G. Arthur Cooper & Thomas Phelan (1966, p. 1-20, 5 pls.) adds to the evidence that in Middle Devonian time a seaway spread southward from the Arctic Ocean to northern Indiana. The fossils of the Miami Bend Formation noted by Cooper & Phelan (1966) are (1) corals, large stromatopores, and one stick-like stromatopore Amphipora, which are present in the upper part of the

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Rogers City Limestone — PLATE 11 — Figures x 1 except as noted

Hexagonaria borealis; 1-3, #24213. Phenacocylas pohli; 4, 5, #24404. Leptodesma furcistriata; 6, #24567. Dechenella (D.) valentini; 7, 8, #29775 (8, x3); 9, 10, #20776 (10, x3). Atrypa arctica; 11, #57685. Carinatina dysmorphostrata; 12, #57686. Nuculoidea ? sp.; 13, 14, #24626. "Productella" sp.; 15, #57686. Omphalocirrus manitobensis; 16-18, #22377. Büchelia tyrrellii; 19, 20, U.S. Nat. Mus. #102935a.

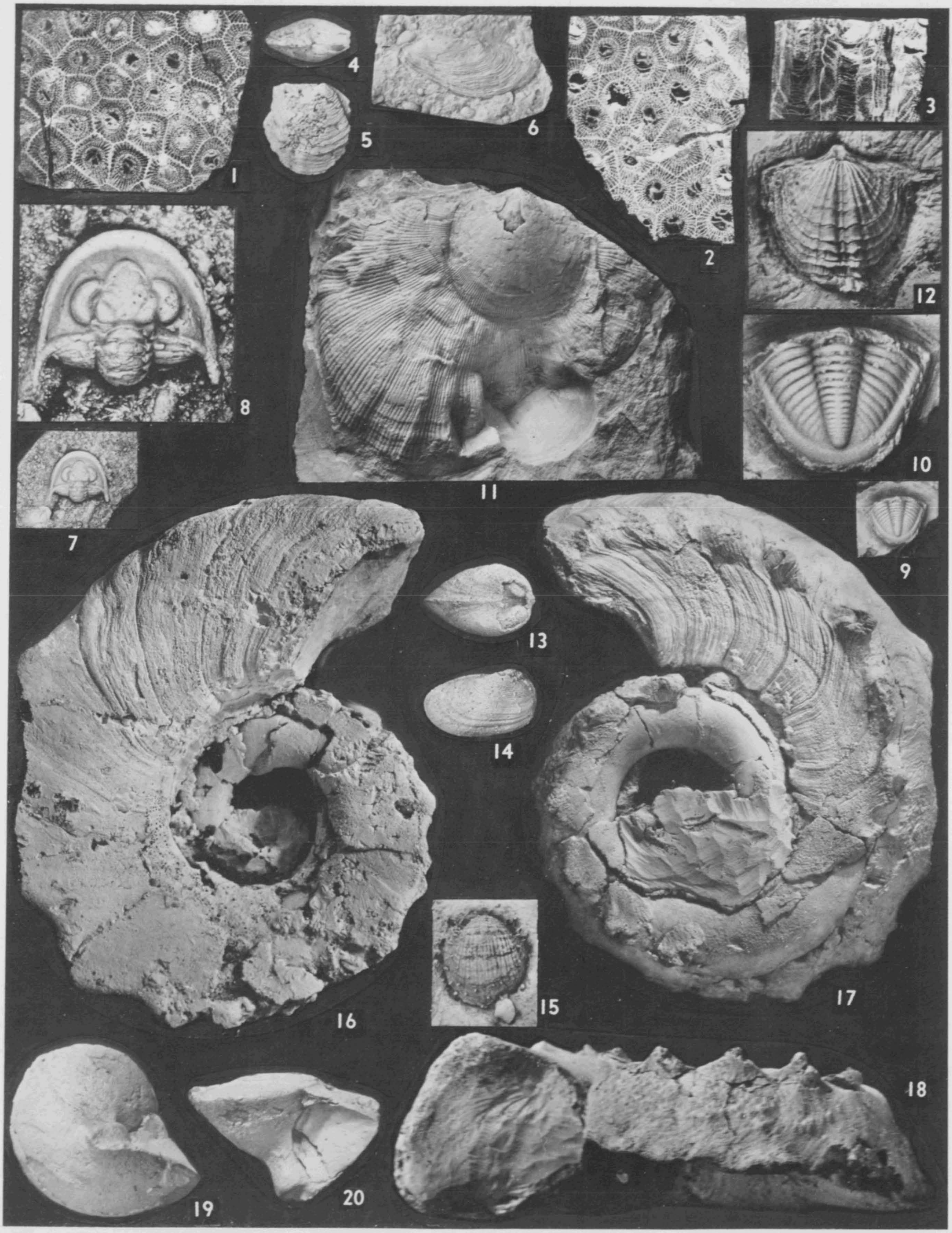
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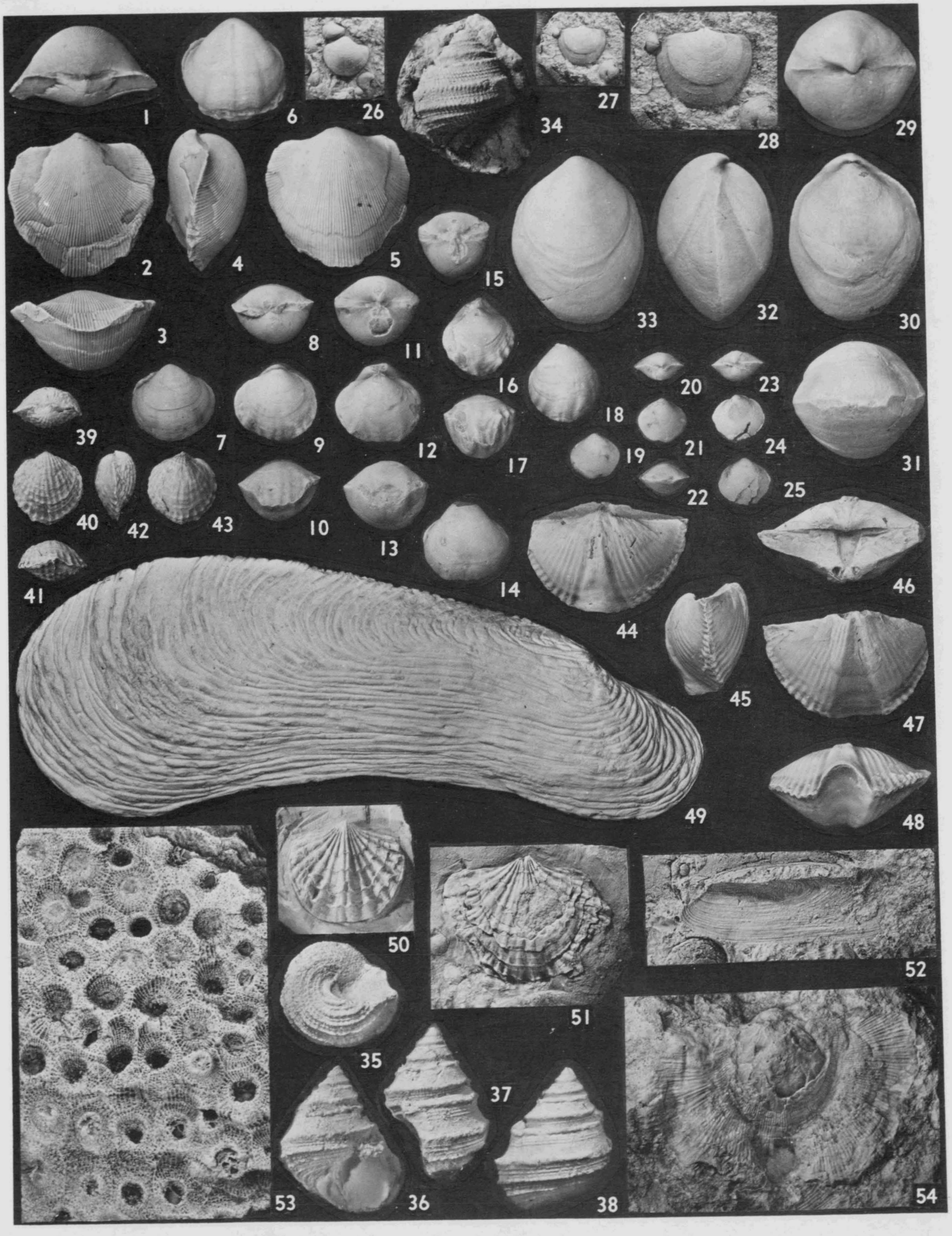
PLATE 12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formation; (2) Stringocephalus, species A, and S., species B (1966, p. 13-16), at the top of the formation; (3) Subrensselandia subpyriformis Cooper & Phelan (1966, p. 11-13), below the level of Stringocephalus, species A and B; (4) pelecypods Paracyclas sp. and Liromytilus attenuatus (Whiteaves) (see La Rocque, 1949, p. 295-298, pls. 7-10), below the level of Stringocephalus, species A and B; and (5) gastropods, Buechelia tyrrellii (Whiteaves), Mastigospira sp. and Omphalocirrus manitobensis (Whiteaves).

The relationship of the Rogers City Limestone to the Miami Bend Formation is well indicated by Cooper & Phelan (1966, p. 9-10). Apparently the Emanuella zone of the Rogers City Limestone (units 1 and 2 of the above description of the limestone), the Atrypa zonule (unit 3, etc.) and the Gypidula zonule (unit 4, etc.) are not present in exposures of the Miami Bend Formation.

The occurrence of many specimens of Atrypa arctica Warren or a closely related species in units 3 and 4 suggest that these units and possibly units 1 and 2 are correlatives of the Elk Point Group of the Lake Manitoba-Lake Winnipegosis area. The strata, designated units 5 and 6 of the Rogers City Limestone of the Calcite Quarry, have numerous remains of gastropods; only the few species listed in this guidebook and in the publication by Cooper & Phelan are sufficient to correlate units 5 and 6 and the Miami Bend Formation with the Winnipegosis Limestone of Manitoba.

The stratigraphic occurrence of two brachiopods in the Rogers City Limestone is of considerable interest. One of these, Carinatina dysmorphostrota (Crickmay) was originally described by Crickmay as Spinatrypa dysmorphostrota and assigned to his "verrilli zone" (Crickmay 1960, p. 2, 13-14, pl. 9, figs. 1-5). D. J. McLaren & A. W. Norris (1962, p. 18, pl. 8, figs. 22-24) illustrated hypotypes of Carinatina dysmorphostrota from the "Gayna River about 9 miles from mouth. District of Mackenzie" and assigned the species to the Hume Formation. A. W. Norris (1968, p. 34-35) included Carinatina dysmorphostrota in "a composite list of all species from the complete Hume Formation exposed immediately west of the Arctic Red River (section 2; Norris, 1967)." The list also records the existence of Atrypa arctica Warren, a species which is characteristic of the Elk Point Group of Manitoba as well as the Hume Formation. The occurrence of external molds of two valves of Atrypa arctica in association with specimens of Carinatina dysmorphostrota on a recently found slab of the magnesian limestone of unit 2 of the Rogers City Limestone supports the correlation of the strata of units 1 to 4 inclusive with the Elk Point and Hume deposits. A second brachiopod, an undescribed species of Subrensellandia, occurs in unit 4 of the Rogers City Limestone in association with Atrypa arctica and a few shells of gastropods that are abundantly represented in units 5 and 6. Although imperfect, the few specimens of the Subrensellandia are sufficiently well preserved to demonstrate that this brachiopod is different from Subrensellandia subpyriformis Cooper & Phelan of the Miami Bend Formation.

The occurrence of Stringocephalus in the Miami Bend Formation is an important discovery. Although no specimens of Stringocephalus have been found in the Rogers City Limestone, it is likely that specimens may be found either in the upper part of unit 6 of the limestone now exposed in the Calcite Quarry or in the 20 feet of limestone known to overlie unit 6 but not available for study until laid bare by future quarrying.

After reading the three previous paragraphs the reader will believe and perhaps be amazed that a Middle Devonian Arctic Ocean spread southward to Michigan, northern Indiana, and a small part of eastern Wisconsin where the brachiopod Carinatina has been recognized by Cooper & Phelan (1966, p. 9). The authors of this guidebook hope that our Canadian friends will cut Y-shaped maple dowsers and use them to locate the shores of the seaway. If the common types of maple trees do not work, try branches from the maple trees on Vancouver Island that have leaves 1 foot in diameter (no kidding). They should do the trick; some people say a single tree yields 1 barrel of sugar sap per hour.

Dundee Limestone. - On the second day of this field conference, members will have a fair time for examination of the Dundee Limestone. To see the formations below the Dundee we would have to visit regions on the north and south sides of the Mackinac Straits. The Michigan members of this Society welcome you to visit the Mackinac Straits at a later field conference.

In presenting the published views regarding the correlation of the Dundee and underlying Michigan Devonian formations, this guidebook will first consider the opinions of the B. V. Sandford, A. W. Norris, & H. H. Bostock (1968) in their recent important work on the Hudson Bay Lowlands (Operation Winick). According to these authors (1968, p. 34, 35), "The Murray Island Formation contains Atrypa arctica Warren and other brachiopods that suggest correlation with the Elm Point Formation of southern Manitoba.

Rogers City Limestone — PLATE 12 — Figures x 1 except as noted

Atrypa arctica; 1-5, #57689; 54, #57683. Gypidula sp.; 6, #57688f; 7-10, #57688d; 11-14, #57688e; 15-18, #57688c; 19-22, #57688f; 23-25, #57688a. Emanuella sp.; 26, #57695; 27,28, #57694 (28, x2). Rensselandia aff. laevis; 29-33, #57691. Longstaffia speciosa; 34; 35-38, #22327. Spinatrypa borealis; 39-43, #57690. Brachyspirifer sp.; 44-48, #57692. Liromytilus attenuatus; 49, #23919. Carinatina dysmorphostrota; 50, #57687; 51, #57693. Solenomorpha peninsularis; 52, #24600. Hexagonaria sp.; 53, #57634.

It is remarkably similar in lithological character to the Dundee Formation of southwestern Ontario and Michigan with which it is tentatively correlated." These geologists in their Introduction (1968, p. 1, 2) state that "Only a few of the fossil collections have been examined and identified at time of writing, consequently, conclusions presented in this paper are tentative." Atrypa arctica Warren is characteristic of the Elk Point Formation and lower part of the Rogers City Limestone, but does not occur in the Dundee Limestone of Michigan. Further examination of fossils may determine whether typical species of the Dundee Limestone are present in the Murray Island Formation. G. Arthur Cooper & Thomas Phelan (1966, p. 10) state that "The Rogers City is underlain by the Dundee Limestone (Brevispirifer lucasensis zone) which for years has been correlated with the Delaware Limestone of Ontario and Ohio and via that formation to the Marcellus of New York. Thus, the base on which the Rogers City rests is Marcellus." The discovery of diagnostic fossils of the Dundee Limestone in the Marcellus as indicated for the Murray Island Formation will not only obtain precise correlation but indicate the direction of seaways into Michigan and Canada.

Detroit River Group. - Sandford & Norris (1968, p. 33) state that "Although the Moose River Formation is unfossiliferous, its stratigraphic position suggests that it is roughly equivalent to the Middle Devonian Lucas Formation of Michigan and southwestern Ontario." The Moose River Formation consists of gypsum beds and associated unfossiliferous (see Sanford, 1968, p. 31, 32) and may partly be correlative of the evaporite beds of the Detroit River group.

The Anderdon Limestone, the uppermost formation of the Detroit River Group, is known only (1) in Anderdon Township, Essex County, Ontario, (2) in the abandoned Solway Process Company's quarry at Sibley, about three miles north of Trenton, Wayne County, Michigan, and (3) in the West quarry of the France Stone Company, and the "South" and "North Quarries" of the Medusa Portland Cement Company about 2½ miles west of Sylvania, Lucas County, Ohio. In a recent, very important publication on the gastropods of the Anderdon Limestone by Robert M. Linsley (1968, p. 346-351) there is information suggesting the existence of the Anderdon formation in the James Bay Lowland. Every person interested in the stratigraphy and paleontology of the Middle Devonian should read R. M. Linsley's publication. (P.S. For my Canadian friends: Read bottom paragraph on page 350 of Lindsley's paper, especially in regard to finding Anderdon species of gastropods -- Best wishes, G. M. Ehlers.)

Sandford & Norris (1968, p. 31) state that "on the basis of its rich coral fauna, the Kwataboahegan [Formation] is believed to be correlative with the early Middle Devonian Amherstburg Formation of Michigan and southwestern Ontario, and the Edgecliff Member of the Onondaga Formation of New York State and Niagara peninsula region of southwestern Ontario." Study of additional fossils from the Kwataboahegan Formation and also from the Amherstburg Formation would probably prove the correlations indicated.

Sandford & Norris (1968, p. 31) state that "the Stooping River [Formation] contains a Lower Devonian fauna which when studied is expected to provide a correlation with the Bois Blanc Formation of Michigan and southwestern Ontario." In a description of the Sextant Formation they (1968, p. 29) state that "Plant remains are locally abundant and indicate a continental environment of deposition. Spores from the Sextant Formation identified by D. C. McGregor suggest a late Lower Devonian (Emsian) age, which coincides with its lateral marine equivalent, the Stooping River Formation. The Sextant may therefore in turn be considered roughly equivalent to the Lower Devonian Bois Blanc Formation of Michigan and southwestern Ontario." In describing the Stooping River Formation, they say (1968, p. 30) that "Whereas lower Stooping River beds change southward to continental deposits of the Sextant, its uppermost strata transgressively overlap that formation (45 feet at Coral Rapids) to onlap the Precambrian Shield at various localities. The Stooping River Formation is disconformably overlain by massive coral limestones of the Kwataboahegan Formation." The stratigraphic relationship of the Sextant and Stooping River Formations to the Bois Blanc Formation is of considerable interest. Some fossils from the Stooping River and Sextant strata have counterpart species of the Bois Blanc strata; additional fossils would probably clinch the correlation of the formation.

The oldest known Devonian strata in the Michigan Basin comprise the Garden Island Formation (see Ehlers, 1945, p. 73-80). The formation is represented by a small outcrop on the shore of Garden Island, located in the northern part of Lake Michigan; it contains an Oriskany fauna and occupies a position between the Bois Blanc Formation and the underlying Upper Silurian St. Ignace Formation. Any chance of finding Oriskany fossils beneath the Stooping River or Sextant Formations, the correlatives of the Bois Blanc?

The closing question in this part of the guidebook is: Why did the fauna of the Rogers City Limestone of the Michigan Basin come by a long seaway from northwest Canada instead of by a much shorter waterway from the Hudson Bay region?

Traverse Group Formations

The Traverse Group of Michigan includes rocks which are equivalent to the Hamilton Group of New York, but it also includes beds which are unquestionably Upper Devonian in age. It comprises a series of rather thin formations of shales and limestones, and we follow other workers in retaining the group without separating off the Upper Devonian part. The formations are (from base upward): Bell Shale, Rockport Quarry Limestone, Ferron Point Formation, Genshaw Formation, Newton Creek Limestone, Alpena Limestone, Four Mile Dam Formation, Norway Point Formation, Potter Farm Formation, Thunder Bay Limestone, and Squaw Bay Limestone.

Thickness of Formations in the Traverse Group

Only three of the eleven formations included in the Traverse Group are exposed in their entirety, the thickness of another one is established by well cores, and the remainder are known from composite sections and interpretation of various well records.

The Rockport Quarry Limestone is exposed at its type locality at the abandoned Kelley's Island Lime & Transport Company Quarry near Rockport (Locality 32-9-6 NW), where the contacts with the underlying Bell Shale and the overlying Ferron Point Formation are distinct. It measures 42 feet thick. Both the Newton Creek Limestone and the Alpena Limestone have complete sections available in the Huron Portland Cement Company Quarry and the nearby abandoned Thunder Bay Quarry (Localities 31-8-13 W and 31-8-14 SE), the two formations extending stratigraphically between their exposed contacts with the Genshaw Formation and the Four Mile Dam Formation. The Newton Creek is 25 feet thick and the Alpena Limestone 79 feet thick.

Well cores taken at Locality 32-9-6 NW begin in the Rockport Quarry Limestone and terminate in the Rogers City Limestone, penetrating the entire Bell Shale. At this place the Bell is about 68 feet thick.

The lower part of the Ferron Point Formation is seen above the Rockport Quarry Limestone at Locality 32-9-6 NW, and the upper part is exposed below the Genshaw Formation at Locality 32-9-18 SE. The extent of the covered interval has been variously estimated.

The basal beds of the Genshaw Formation are exposed as mentioned, the upper beds are seen below the Newton Creek, and various other exposures show a few feet of strata here and there in the belt of outcrop in the two counties. From a composite section measured at four places, Warthin & Cooper (1943, p. 583) estimated the thickness to be about 117 feet.

The lower part of the Four Mile Dam Limestone is known as the Dock Street Clay. This member is in contact with the underlying Alpena Limestone at Locality 31-8-14 SE. The top of a bioherm in the Four Mile Dam Limestone is exposed below Norway Point strata at Locality 31-8-7 C. The intervening beds are unknown, and the "normal" thickness of the formation in the area is in further doubt because of the biohermal nature of the type locality. Many of the middle beds of the Norway Point Formation are also not exposed. The same may be said of the thick Potter Farm Formation, of which the upper contact is concealed. The lower extent of the Thunder Bay Limestone is open to question, and the exact thickness of the Squaw Bay is a matter of interpretation.

With these uncertainties in thickness, partial answers have been sought in well records and in correlation of key units. Estimates by Grabau (1902), Smith (1916), Ver Wiebe (1927), and Warthin & Cooper (1943) show appreciable differences, depending on the method of estimating the covered intervals.

One of the old well records which has been considered by Grabau and others is that of the so-called Churchill Well, drilled in Alpena near the shore of Thunder Bay in 1891. It was not the first deep well drilled in the vicinity, since Rominger (1895, pt. 2, p. 46-47) mentioned others (one earlier than 1866) and presented a very simplified log of one. From depth of 1267 to 1278 feet the Churchill well penetrated salt and terminated. The log of the well, as given by Grabau (1902, p. 169):

Bed		Ft.	Depth
1.	Sand and boulders	41	41
2.	Hard white (light colored) limestone	25	66
3.	Shale	9	75
4.	Very hard white limestone	$49\frac{1}{2}$	$124\frac{1}{2}$
5.	Shale	$2\frac{1}{2}$	127
6.	Extra hard gray limestone	40	167
7.	Blue shale	20	187
8.	Hard white limestone	34	221
9.	Shale, 7 feet white and slimy, possibly gypsum (?)	18	239
10.	Hard white limestone	23	262
11.	Very sticky blue shale	27	289
12.	Hard white limestone	32	321
13.	Shale	3	324
14.	Hard white limestone, upper two-thirds extra hard	39	363
15.	Shale	24	387
16.	Hard white limestone	5	392
17.	Shale, mostly blue	52	444
18.	Hard white and gray limestone, mostly extra hard	60	504
19.	Extremely hard (flinty) limestone	39	543
20.	Shale	25	568
21.	Hard gray and white limestone	103	671
22.	Shale	20	691
23.	Hard white limestone	86	777
24.	Sandy lime and shale	10	787
25.	Hard white limestone	480	1267
26.	Salt	11	1278

In the Churchill well, Grabau correctly inferred that beds 15-17 constituted the Bell Shale; in his cross section (1902, pl. 7), however, he correlated the limestone of unit 2 with outcrops of the Alpena Limestone, and thereby distributed the units incorrectly above the Bell Shale. Our text-figure 3 is a correction of this cross section.

From the measured thicknesses of beds in outcrop, the known sequence of strata, and the areal distribution of formations, it is possible to identify certain key beds in the Churchill well and use the others to establish thickness of other formations. Just above the definite Bell Shale in beds 15-17 is a hard white limestone 39 feet thick; this compares very well with the 42-feet thick Rockport Quarry Limestone exposed at the type locality.

Exposures of the Ferron Point Formation show soft shales and thin limestones in the lower part and, at another place, soft shales in the uppermost part. Further, the lower three units of the Genshaw Formation are soft shales with a thin middle stratum of argillaceous limestone; above the Rockport Quarry Limestone, therefore, the first resistant bed is unit 4 of the Genshaw, a massive 3-feet thick argillaceous limestone. This is the interval recorded in the well as beds 11-13, ending at the top with 32 feet of "very sticky blue shale." If we subtract $19\frac{1}{2}$ feet, the known thickness of the lower 3 units of the Genshaw, we get $42\frac{1}{2}$ feet for the total thickness of the Ferron Point Formation. Between the lower $18\frac{1}{2}$ feet of Ferron Point exposed above the Rockport Quarry Limestone at Locality 32-9-6 NW and the upper 19 feet exposed below the Genshaw Formation at Locality 32-9-18 SE, there are only 5 feet of strata covered, evidently hard calcareous beds logged as bed 12 in the Churchill well.

Bed 6 of the well is obviously the Newton Creek Limestone and the lower part of the Alpena Limestone. Ver Wiebe (1927, p. 185) drew the base of his Alpena division, which included strata later made into the Newton Creek, at the bottom of bed 6 in the Churchill well. The logged thickness of 40 feet is somewhat less than the 46 feet of combined Newton Creek and lower Alpena limestones exposed in the Huron Portland Cement Quarry not far away, but falls within the range to be expected. Thus the Genshaw Formation is represented in the well by beds 7-10 and, as explained above, $19\frac{1}{2}$ feet at the top of bed 11. The logged thickness of the Genshaw is therefore $114\frac{1}{2}$ feet, which compares excellently with the $116\frac{1}{2}$ feet given by Warthin & Cooper (1943, p. 583) in their composite section. Bed 8 includes the resistant Killians Member.

The shale in bed 5 is correlated with unit 3 of the Alpena Limestone at the Huron Portland Quarry; the $2\frac{1}{2}$ feet in the well is greater than the 1 foot exposed in the quarry, but falls within the expected variation in lithologic units. Bed 4 is the limestone in unit 4 of the Alpena Limestone at the quarry, although somewhat thinner; possibly, the section penetrated by the well was more distant from bioherms.

The shale encountered in bed 3 is the Dock Street Clay. The 25 feet of hard limestone in bed 2 is probably all Four Mile Dam Formation, and the "sand and boulders" in bed 1 may be some soft Norway Point beds as well as glacial drift.

Unfortunately, there are no reliable cores and records available in this area which penetrate the Squaw Bay, Thunder Bay, Potter Farm, and Norway Point formations. The thicknesses of these beds are based on composite sections and estimated covered intervals.

The final results, based in part on estimated intervals, are shown in the simplified column in text-figure 3. The total thickness of the Traverse Group is placed conservatively at about 565 feet.

Paleoecology and Sedimentation of the Traverse Group

Sediments. -- It has been estimated that the total geologic record contains five times as much shale as limestone. The Traverse Group section is far from average, with about twice as much limestone as shale. Except for the Bell Shale, the upper Ferron Point, the Dock Street Clay, and the Norway Point Formation, the Traverse Group rocks are limestones of varying purity. Some are strongly argillaceous, just over the border from calcareous shale; very few beds approach the 98% purity desired by the steel industry. The strata include no conglomerates or sandstones, although the fractured, broken, and wave-rounded fragments of stromatoporoids and other fossils might technically qualify as conglomerate, and the coarse grains of calcium carbonate incorporated in some beds fall within the size interval of sand.

The absence of quartz sand and the plentiful supply of clay indicates a generally low topography in the source area. Much of the clay was carried by wave and current action to the deeper parts of the basin, as in the formation of the Bell Shale. Transportation was irregular and incomplete, however, and a considerable quantity settled out with the carbonate before reaching the deeps, forming impure limestones, as in the Genshaw Formation, the Potter Farm Formation, or the Thunder Bay Limestone.

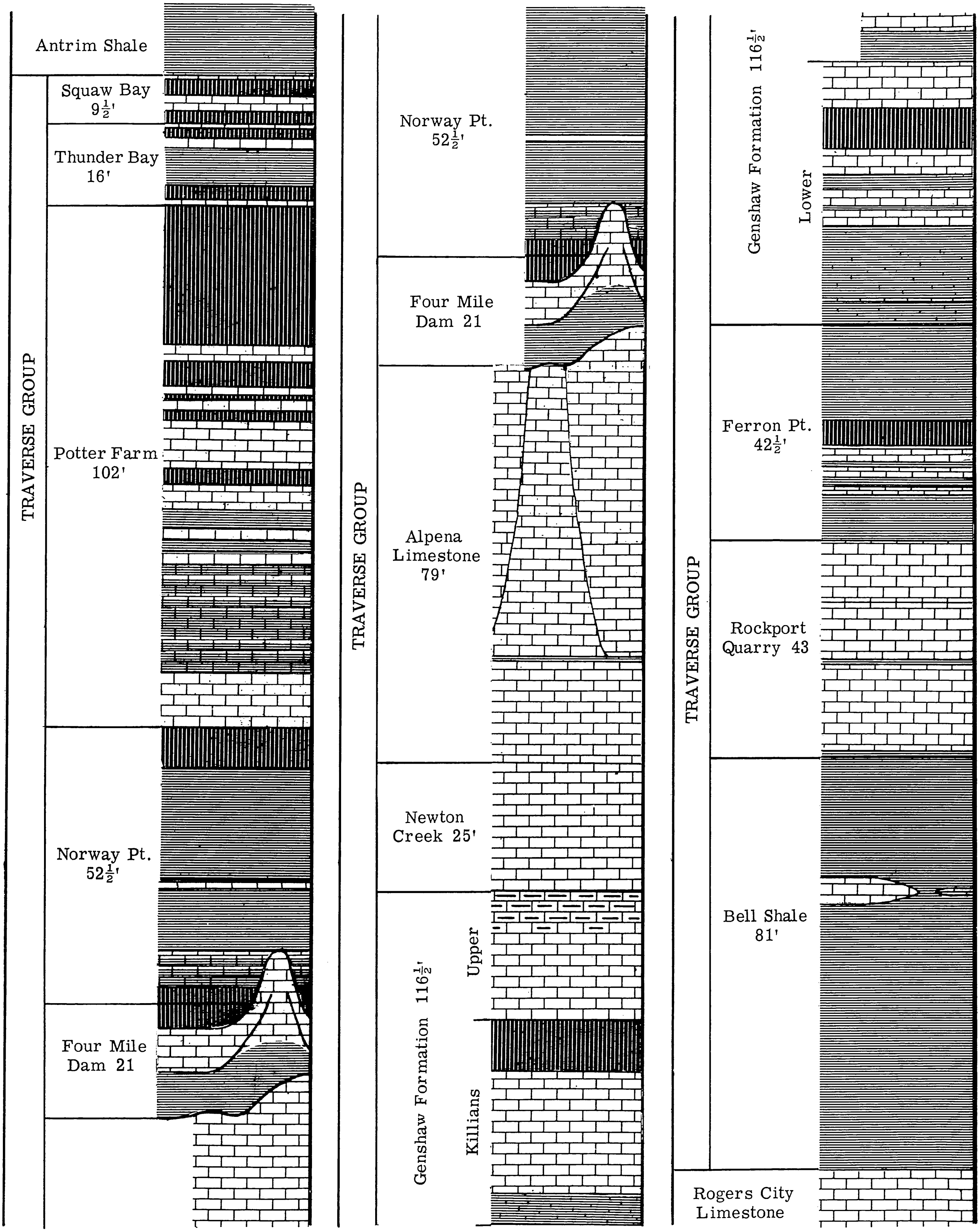
In the Middle Devonian seas of Michigan, as elsewhere, limestones originated in shallow water. The warm surface layer of the sea was essentially saturated with calcium carbonate and low in carbon dioxide. The concentration was particularly great in shoal areas. Any further decrease in the carbon dioxide content brought about carbonate precipitation. Chemical metabolism of stromatoporoids and corals, which nearly covered some areas, readily precipitated calcium carbonate; the animals incorporated great quantities in their skeletal structures. These Devonian stromatoporoids performed much the same role that algae now play on the Bahama Banks. Other lime-secreting organisms contributed minor amounts, but by actual tonnage the stromatoporoids were responsible for perhaps three-fourths of all calcium carbonate in Traverse Group fossils.

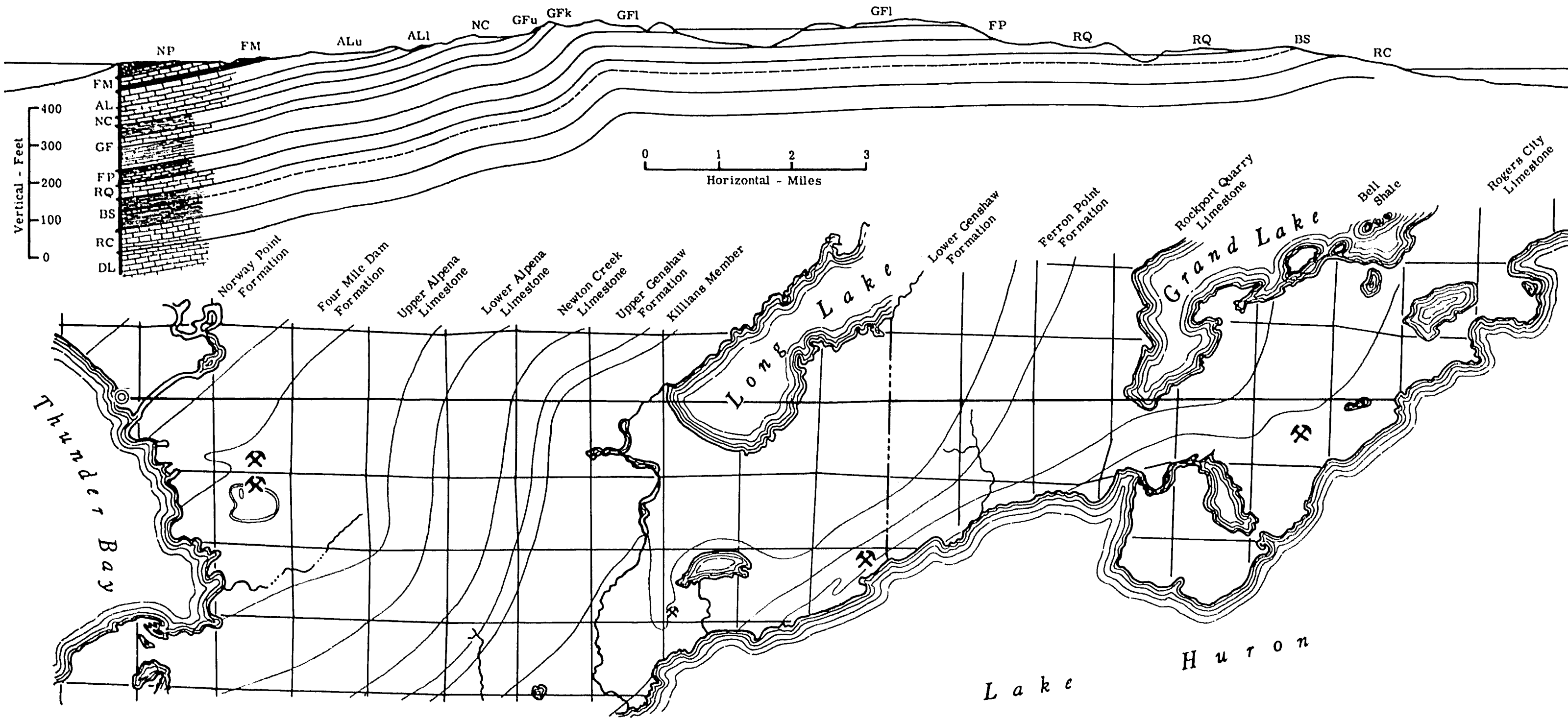
Zones of deposition. -- Several years ago we had the opportunity and pleasure of studying this region with Professor Marius Lecompte of the University of Liege, Belgium. Although we were quite familiar with all the exposures, Lecompte's keen observation and his astute analysis brought us a new insight into the geologic history of Alpena and Presque Isle Counties and fresh enthusiasm for field work. He, in turn, was delighted to find the sediments and their faunas in the Devonian of Michigan to be strikingly similar to those which he had investigated for years in Europe. From our discussions, one point of agreement stands out: strata cannot be understood without consideration of the faunas, the fossils cannot be fully interpreted without reference to the sediments, and both must be studied in the field.

Several factors can be used to infer conditions in this area during deposition of the Middle Devonian rocks: kinds of fossils and their adaptive morphology, diversity of fauna, burial attitudes of the fossils, composition of the sediments, small scale inorganic and biogenic sedimentary structures, and the nature of fossilization. Careful field observations are essential. They form the basis for much of the research that follows. From them one can attain sound and reasonable conclusions about the conditions which produced the stratofabric and influenced the habitat of the fossilized animals.

TEXT-FIG. 2 -- Stratigraphic column of rocks included in the Traverse Group. Vertical hatching represents covered intervals. Indented parts of columns are repeated in the next column. Lithology somewhat simplified.

(next page)


Antrim Shale
TRAVERSE GROUP
Squaw Bay 9½'
Thunder Bay 16'
Potter Farm 102'
Norway Pt. 52½'
Four Mile Dam 21
TRAVERSE GROUP
Norway Pt. 52½'
Four Mile Dam 21
Alpena Limestone 79'
Newton Creek 25'
Genshaw Formation 116½'
Upper
Killians
TRAVERSE GROUP
Genshaw Formation 116½'
Lower
Ferron Pt. 42½'
Rockport Quarry 43
Bell Shale 81'
Rogers City Limestone



TEXT-FIG. 3 -- Map and north-south geologic cross section through eastern Alpena and Presque Isle Counties, extending north from the site of the Churchill well in Alpena. Topographic control from stations reported by Grabau (1902), who traversed the area with aneroid barometer at the turn of the century. His elevations are still the most accurate available. The section passes from Thunder Bay through the southeastern ends of both Long Lake and Grand Lake and terminates at Lake Huron. In the cross section, a dashed line represents the thin limestone unit in the Bell Shale; the Genshaw Formation is divided into the lower (GFl), Killians (GFk), and upper (GFu) parts; and the Alpena Limestone is divided into lower and upper parts at the 1-foot shale bed (unit 3). The cross section reveals a rather sharp flexure just south of Long Lake and nearly flat-lying beds for some miles to the north.

As Lecompte suggested, beds of the Traverse Group contain abundant evidence for paleoecologic interpretation. They readily fall into distinctive zones of deposition:

I. Zone of turbulence. These units, formed in the high-energy environment near shore, contain overturned heads of corals and stromatoporoids, many of them over one foot in diameter. Numerous fossil fragments are seen in helter-skelter burial attitudes. The matrix is a clastic limestone, essentially a consolidated lime sand, incorporating a breccia of wave-broken and eroded fragments of stroms and corals. Some of the accumulated shell breccia in Michigan may be the result of some placer action from older deposits, such as Cooper (1957, p. 277) suggested for the Centerfield and Hungry Hollow Formations to the east. Sorting is poor in some units which have been examined, with considerable clay mixed in with the calcareous matrix.

Stromatoporoids dominate this near-shore zone, in number, in quantity, and in space competition. Many of the stroms grew outward as a smothering blanket over the corals; in this agitated and well-aerated zone, the fight for space amounted to the fight for life.

Examples of the zone of turbulence can be found in beds of the Rockport Quarry Limestone and the Genshaw Formation.

II. Stromatoporoid-coral zone. Faunally like zone I, this zone is generally below the violent turbulence. The dominance of the fauna by a few species of stromatoporoids and corals recalls the distribution of recent foraminifers in the Gulf of Mexico in which Walton (1964, p. 217) found that all faunas with less than 20 species occurred in water shallower than 10 fathoms. In certain beds of the Traverse Group this zone is expressed as a biostrome. Units in the middle part of the Rockport Quarry Limestone are good examples.

It seems significant that among Bryozoa, which were competently investigated by Deiss (1932), McNair (1937), Bassler (1939), and Duncan (1939), none are recorded from the Rockport Quarry Limestone, although 21 genera are known from the underlying Bell Shale and 19 genera from the overlying Ferron Point Formation (Appendix 3). Another interesting fact concerns the total number of invertebrate genera: only 22 for all of the Rockport Quarry Limestone as compared to 81 for the upper part of the Bell Shale and 61 for the Ferron Point (Appendix 3). Also, the Ferron Point has more genera in common with the Bell Shale than with the adjacent Rockport Quarry Limestone (Appendix 2). We can conclude that strata of zone II contain few kinds of fossils, and that these are markedly different from those of either zone III (much of the Ferron Point) or zone IV (upper part of the Bell Shale).

III. Coral-brachiopod zone. This zone includes most of the limestones of the Traverse Group. Beds in the upper part of this zone are dominated by corals and large brachiopods, such as the basal unit of the Genshaw Formation with numerous *Cystiphylloides*, *Heterophrentis*, large *Atrypa*, and *Sieberella*. The beds are argillaceous medium- to fine-grained limestone. In the beds in the deeper part of this zone, the fauna becomes more diverse and the rock changes to a calcareous shale. In the Genshaw Formation, these beds are marked by smaller brachiopods, bryozoa, and tabulate corals, as well as ostracods.

Blastoids, cystoids, and inadunate crinoids occur near the boundary between zones III and IV, as in the Thunder Bay Limestone (Appendix 1).

This zone contains the lower limit of stromatoporoids, and these deeper-water forms seem to be specialized. In the basal unit of the Genshaw, stroms form spherical balls around a nucleus of a large brachiopod (usually *Atrypa*); it seems to us that such a "cannon-ball" shape could only develop in the presence of rather consistent longshore currents.

Good circulation in zone III is attested by the abundance of normal marine species. From time to time there may have been somewhat stronger currents, for some of the larger invertebrates have bryozoa attached to opposite sides; presumably, these specimens must have rolled over to enable the bryozoa to grow on the upper surface, but whether the rolling was by agitated currents or by undercutting of the loose mud on one side cannot be determined.

IV. Diverse fauna zone. Deep mud flats represent the final transport of clay particles seaward. The calcareous content is low, possibly because of the lower temperature and the higher carbon dioxide content at depth (increasing the amount of carbonate in solution) and the absence of any stromatoporoids. The Bell Shale, Ferron Point Formation, and Norway Point Formation are mostly claystones or soft shales. They contain many kinds of bryozoa, articulate brachiopods, and ostracods (Appendix 3). The soft shale of the upper Ferron Point is noted for its profusion of *Chonetes*, several of which have been found with attached edrioasteroids. The trilobites *Dechenella* and *Phacops* also dwelled on the mud flats.

Tetracorals consist mostly of large, excellently preserved heads of *Hexagonaria*. If we presume that these corals, like the reef-type corals living today, were restricted to the sunlit, warm, aerated waters above 150 feet, we may set that depth as the approximate lower limit of the Traverse Group deposits. Several of the Bell Shale *Hexagonaria* specimens show evidence of regeneration of some corallites at a level in the colony at which others terminate; this apparently signifies an exceptional influx of mud, which smothered many of the animals and permitted only a fraction of the population to survive and start repairs to the colony's housing.

V. Bioherm. For the most part, the cores of the Devonian reefs are like zones I and II in fauna and sediment. Corals, both compound and horn types, as well as other large invertebrates were laced together and at times overgrown by stromatoporoids. The resulting stratofabric is strong but not dense or solid; irregular interstices are found filled with clay or impure lime. The overall appearance of the core is massive, with little or no stratification.

It was probably in the protected niches that some of the unusual invertebrates made their home. The bioherms of the Michigan Devonian are in need of further collecting and taxonomy. The abundance of life on the reef top was accompanied by an abundance of death, and some of the scavengers found protection among the corals and stroms and plenty of food at all times.

Around the edges of the bioherm was a habitat not duplicated in zones I and II. The steep sides extended below the level at which corals and stroms flourished best but still in a well-aerated, well-lighted zone. Here some of the camerate crinoids found suitable attachment and food supply. After blasting in the Huron Portland Cement Quarry in Alpena (locality 31-8-13 W), numerous heads of *Dolatocrinus* can be found from bioherms in the Alpena Limestone.

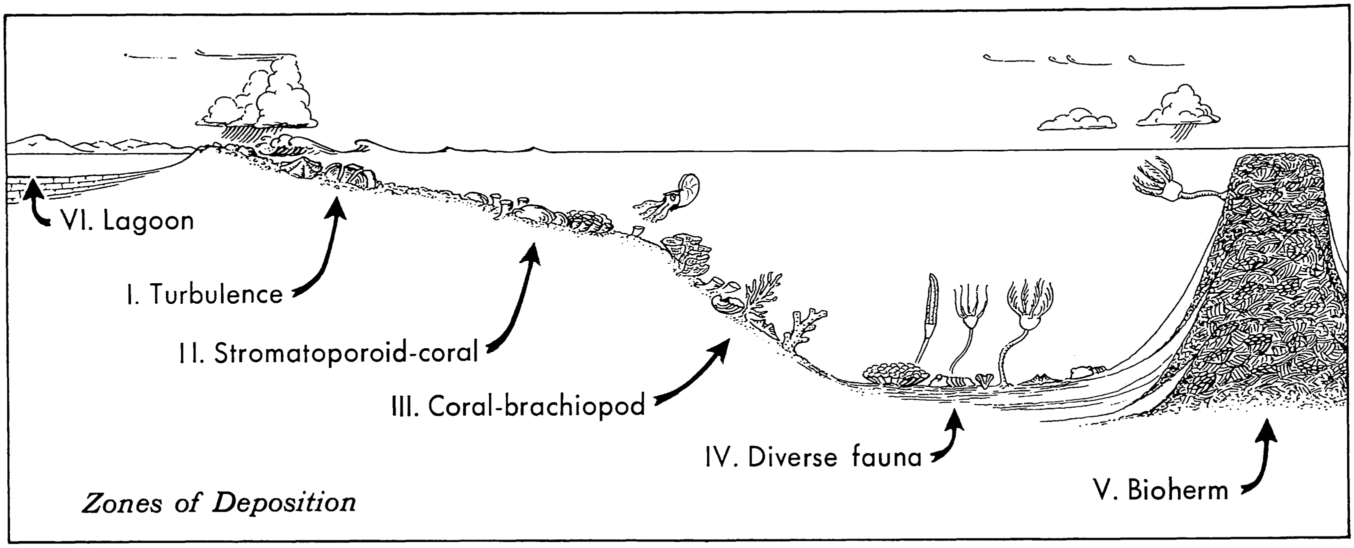
Flank beds of the bioherms slope down into zone III and finally into zone IV. They contain the same faunas and general composition.

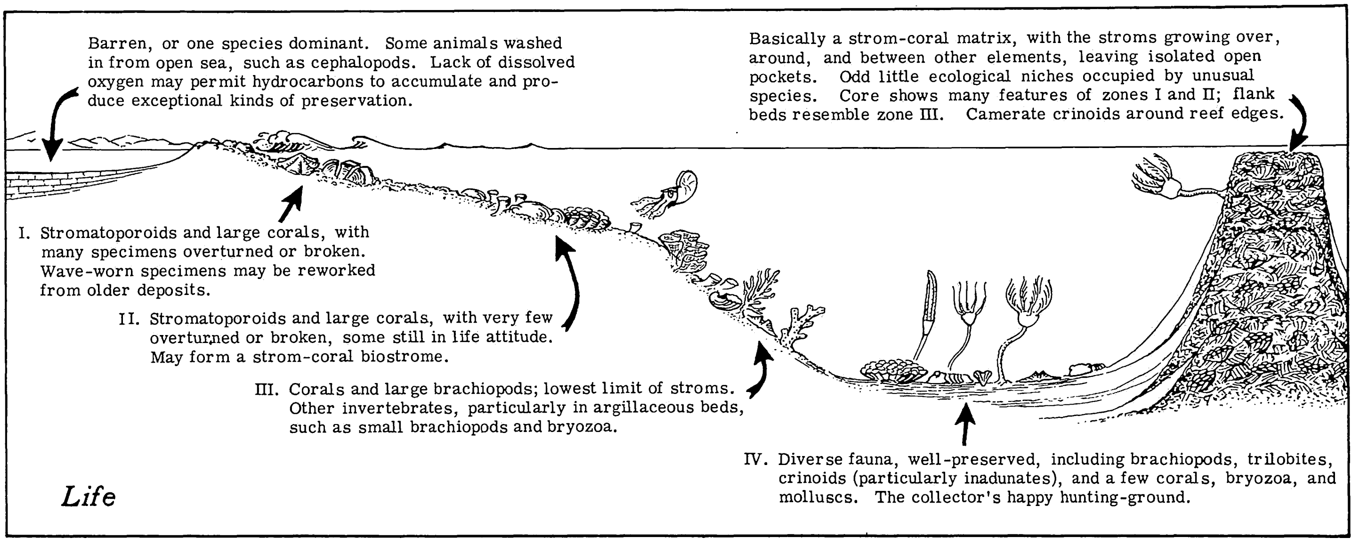
A good explanation of the bioherm deposits was offered back in 1902 by Amadeus W. Grabau, who wrote (p. 177):

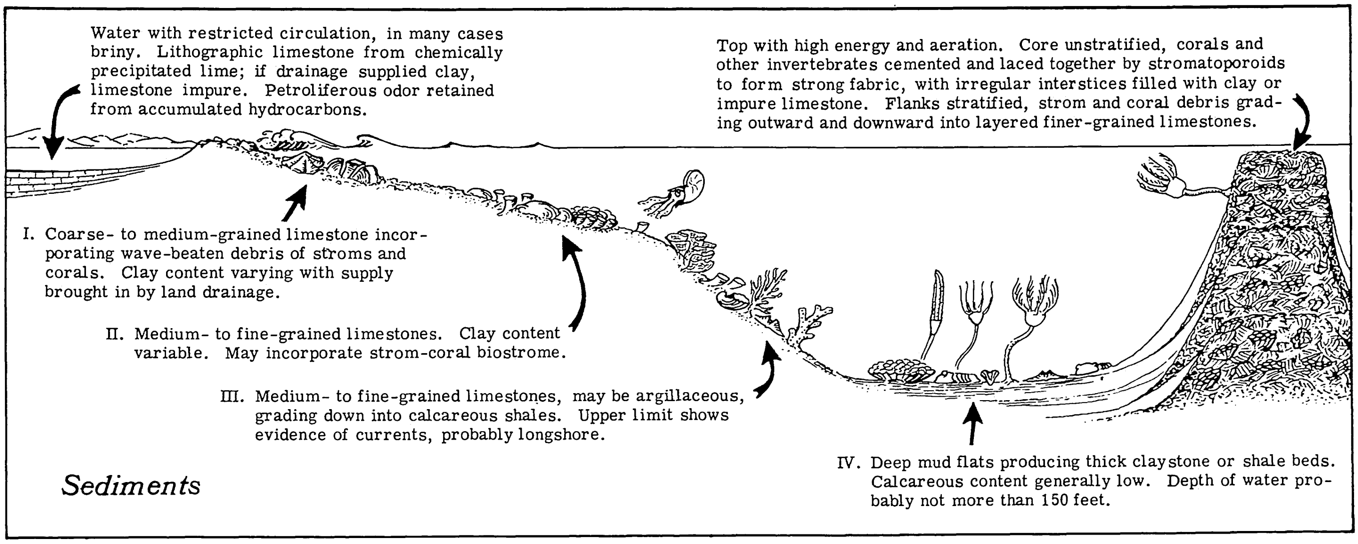
> In the Devonic sea of this region, the luxuriant growth of corals and other lime-secreting organisms produced isolated reefs, which rose to within the sphere of wave activity. Being subject to the continued attack of the waves, these reefs were destroyed wherever the vitality of the polyps was insufficient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

VI. Lagoon. This may not be an appropriate term for all occurrences of these unusual habitats, for they may vary from concentrated to dilute in salinity and they may cover an extensive area instead of a few square miles. Because of the restricted circulation with the open sea, these places had poor aeration. Evaporation in some led to concentrated brine, whereas in others the inflow of streams seems to have produced brackish swamps.

In general, these bodies of water were inimical to marine life. Some are unfossiliferous. Others abound in one (or two) species, which were able to adapt to the excess salinity and reduced oxygen. To the west of this region in Michigan is a Devonian bed known as the *Welleria* zone. The water teemed with *Welleria aftonensis* Warthin so that certain horizons constitute an ostracod coquina; presumably there were also soft-bodied organisms on which these animals fed. The sediment in the *Welleria* zone is an impure limestone containing microscopic clay chips that appear to be remnants of thin sun-cracked mud from along the nearby shore; the whole rock is saturated with oil, which seeps from some laminae on freshly broken surfaces.


VI. Lagoon
I. Turbulence
II. Stromatoporoid-coral
III. Coral-brachiopod
IV. Diverse fauna
V. Bioherm
Zones of Deposition


Barren, or one species dominant. Some animals washed in from open sea, such as cephalopods. Lack of dissolved oxygen may permit hydrocarbons to accumulate and produce exceptional kinds of preservation.
Basically a strom-coral matrix, with the stroms growing over, around, and between other elements, leaving isolated open pockets. Odd little ecological niches occupied by unusual species. Core shows many features of zones I and II; flank beds resemble zone III. Camerate crinoids around reef edges.
I. Stromatoporoids and large corals, with many specimens overturned or broken. Wave-worn specimens may be reworked from older deposits.
II. Stromatoporoids and large corals, with very few overturned or broken, some still in life attitude. May form a strom-coral biostrome.
III. Corals and large brachiopods; lowest limit of stroms. Other invertebrates, particularly in argillaceous beds, such as small brachiopods and bryozoa.
IV. Diverse fauna, well-preserved, including brachiopods, trilobites, crinoids (particularly inadunates), and a few corals, bryozoa, and molluscs. The collector's happy hunting-ground.
Life


Water with restricted circulation, in many cases briny. Lithographic limestone from chemically precipitated lime; if drainage supplied clay, limestone impure. Petroliferous odor retained from accumulated hydrocarbons.
Top with high energy and aeration. Core unstratified, corals and other invertebrates cemented and laced together by stromatoporoids to form strong fabric, with irregular interstices filled with clay or impure limestone. Flanks stratified, strom and coral debris grading outward and downward into layered finer-grained limestones.
I. Coarse- to medium-grained limestone incorporating wave-beaten debris of stroms and corals. Clay content varying with supply brought in by land drainage.
II. Medium- to fine-grained limestones. Clay content variable. May incorporate strom-coral biostrome.
III. Medium- to fine-grained limestones, may be argillaceous, grading down into calcareous shales. Upper limit shows evidence of currents, probably longshore.
IV. Deep mud flats producing thick claystone or shale beds. Calcareous content generally low. Depth of water probably not more than 150 feet.
Sediments

One of the rocks typically associated with this zone is lithographic limestone, such as that found in the upper unit of the Rockport Quarry Limestone. The saturated calcium carbonate in the upper marine water was chemically precipitated by the escape of carbon dioxide caused by the increased temperature in the sun-warmed, uncirculated water of the lagoon. This unit of the Rockport Quarry is unfossiliferous except for ostracods, which are notorious for invading all kinds of aqueous environments irregardless of salinity, temperature, or dissolved oxygen.

At times nektonic and benthonic marine creatures were able to adapt to rather foul bottom conditions. The immigrants may have come into lagoons during storms, exceptionally high tides, or strong on-shore winds and currents that swept them over the barrier; or they may have arrived by narrow channels connecting to the open sea. Undoubtedly, many species died in certain lagoonal situations, suffocating in the oxygen-deficient water or becoming pickled in the brine; some that did not succumb to these hazards may have starved from the lack of suitable food supply. A few hardy species were able to survive, often concentrated on certain areas of the sea floor. The Newton Creek Limestone is an example. Only 13 genera of invertebrates have been recorded from this formation, as compared with 83 in the underlying Genshaw Formation and 47 in the overlying Alpena Limestone (Appendix 3). Some genera found in the Newton Creek were actual inhabitants of the environment; others may not have been. Because of the oxygen deficiency and perhaps high salinity in the Newton Creek sea, hydrocarbons accumulated on the bottom and the rock still retains a strong petroliferous odor upon breakage. The presence of oily hydrocarbons may account for the unusual preservation of color markings in some of the brachiopods and cephalopods on the Newton Creek, as recorded by Foerste (1930).

Another unusual fauna occurs in the Squaw Bay Limestone at the top of the Traverse Group. It consists entirely of molluscs and fossilized wood. They are embedded in a layered limestone. The unbalanced fauna and the presence of wood suggests a brackish-water swamp behind a barrier beach, across which some of the molluscs were probably cast during high tides or storms. Most of the fossils are cephalopods. Aside from the 3 genera of cephalopods from the Squaw Bay Limestone and the 4 from the Newton Creek, only four other generic occurrences have been listed for the whole Traverse Group (Appendix 1).

The generally shallow seas, low land mass, and development of bioherms in the Middle Devonian of Michigan undoubtedly contributed to the frequency and extensive size of the lagoonal deposition zones. With only a slight emergence, large areas of the sea could be cut off. An alternation of restricted and free circulation appears to have taken place during part of Rockport Quarry time. Stromatoporoid-coral biostromes are irregularly stratified and admixed with black bituminous material. The bituminous substance is entirely foreign to the stromatoporoid-coral association, as demonstrated by its absence in other deposits of the zones I and II type. It may be inferred that the bituminous content was an accumulation at those times when the area was cut off from open sea circulation and stagnated, perhaps in subaerial strom- and coral-studded flats, and that the fauna revived or re-established itself at those times when the area once again became part of the near-shore open marine environment. This alternation occurred many times during Rockport Quarry deposition.

In 1957 (p. 250) G. Arthur Cooper wrote: "At the present time paleoecology is of limited scope only. Many of the relationships portrayed between animals and plants or animals and animals cannot be pictured with assurance. Some of the intimate relationships cannot be deduced from dead shells or seams of carbonized vegetable matter. But the dead shells and plant fossils of the Devonian do suggest certain ecological conditions that must have existed, and it can be assumed that they did. The principle that is perhaps the most fundamental in geology has proved a sound one: that the present is a key to the past. So it is with paleoecology." All of this declaration still applies to the rocks of the Traverse Group.

TEXT-FIG. 4 -- Zones of deposition and their paleoecological and sedimentational interpretations as suggested by Lecompte. In the consideration of zones, it should be emphasized that each extended over a considerable area. For example, in width most units extend through the two counties studied here and some appear to be unchanged as far away as the Thedford region in Ontario; in length, along or parallel to the old shore line, they may extend for hundreds of miles (the Thunder Bay Limestone seems to be the direct extension of the Cedar Valley Limestone of Iowa). On the other hand, only a few tens of feet change in depth completely altered the kinds of deposits and the kinds of animals suited to live on them. In other words, because of the gradual slope of the Middle Devonian sea floor and the rather uniform supply of sediment, each zone produced a widespread rock unit characterized by certain fossils. It is estimated that the many alternations of limestones and shales in the Traverse Group did not involve great changes in depth.

Bell Shale

Name. -- The Bell Shale was officially named by Grabau in 1901 (p. 191) for bluish shale dug in the clay pits north of the village of Bell and used to make bricks; at the time of his writing, the pits had been long abandoned and were filled with water. This was not, however, the first study of the formation. In 1876, Rominger had seen outcrops at the present site of the abandoned Kelley's Island Lime & Transport Company Quarry at Locality 32-9-6 NW, where it lay below the Rockport Quarry Limestone. At that time, he mentioned (p. 50) blue shales at the foot of the limestone bluffs, and presented a list of fossils identified from them. Rominger (1876, p. 63) was also familiar with an exploring shaft sunk in connection with a proposed "marble quarry" (a project abandoned some time before 1876), which dug into 50 feet of blue shale under the limestone bluffs in section 6.

Just where the village of Bell was located is somewhat uncertain. Grabau described the pits (1902, p. 191) as "north of Bell." On his Plate VII, Bell is situated just east of the south end of Grand Lake near the Lake Huron Shore (about in SE$\frac{1}{4}$ sec. 14, T 33 N, R 8 E). Warthin & Cooper (1943, p. 578) reported that H. H. Hindshaw, an old-time collector in the region, told them that the settlement of Bell was on False Presque Isle Harbor in section 13, and that the pits were in the SE$\frac{1}{4}$ sec. 11. They further located the site of the Bell post office as in the SE corner of NE$\frac{1}{4}$ sec. 34. Presently, we have found Bell School in the SE corner of sec. 27 and pits which we believe to be the long abandoned brick works near the county road in the SW$\frac{1}{4}$ of section 11.

Exposures. -- Because of its softness and quick yielding to weathering, few natural exposures of the Bell Shale exist. As mentioned above, Rominger saw it cropping out below the limestones near Rockport in 1876. Twenty-six years later, Grabau studied the same exposure, but selected the type locality in the clay pits near Bell. He also wrote about a dozen sinkholes in the SW$\frac{1}{4}$ sec. 36, T 33 N, R 8 E, just over the county line from the bluffs in section 6. These sinkholes, strung in a NW-SE line, developed in the Rockport Quarry Limestone. In the largest, Grabau noted (1902, p. 190):

> The great "bottomless" sink has vertical sides of overhanging cliffs on all sides, and has a depth to the water surface of about 50 feet (estimated). The water in the bottom has a similar or greater depth. The upper 20 feet or more of the wall consist of limestones, the basal beds of the Long lake series, which form a vertical cliff. Below these are the blue Bell shales, which weather back, leaving the limestone cliffs overhanging.

Grabau correctly assumed that the Bell Shale lay under Grand Lake, but could find no exposures.

Most knowledge of the Bell Shale extent comes from well records. In the Churchill well at Alpena, studied by Grabau in 1902 (p. 169), his units 15-17 (his numbering proceeded from the surface) constitute the Bell Shale:

15.	Shale.................	24 ft
16.	Hard white limestone...	5
17.	Shale, mostly blue.....	52
	Total	81

Through the courtesy of the late Ned Andrix, we have looked at a complete core through the Bell Shale. The following section is based for the most part on that material:

Section of Bell Shale at abandoned Kelley's Island Lime & Transport Company Quarry at Rockport, Locality 32-9-6 NW

(Upper 11 feet of Bell Shale exposed on bank of drainage ditch about $\frac{1}{4}$ mile WNW of quarry buildings; complete section encountered in core from Rockport Quarry Crusher #1 test hole drilled by Paul F. Gunia on 30 August 1946 for Ohio Mineral Resources Consultants, Inc.)

Rockport Quarry Limestone	Feet
2. Limestone, brown, bituminous, fossiliferous with stromatoporoids and corals; broken during quarry blasting, too shattered to core..............................	2.1

Bell Shale PLATE 13 Figures x 2 except as noted

Gennaeocrinus variabilis; 1-4, #37854; 5-8, #40531; 9-12, #40530; 13-16, #40521; 17-19 (old individual), #40536; 20-23, #40526; 24-27, #40528; 35-38, #40523; 39-41, #40532; 42-45, #37853. G. goldringae; dorsal cup, 30-32, #30505; old tegminal spine, 33, 34, #49428; young tegminal spines, 56, #49203; 57, #49202; cup plates, 50, #49388; 51, #49373; 52, 53, #49380; 54, 55, #49390; young dorsal cup, 46-49, #9434; columnal section, 58, #49200. Melocrinites michiganensis, 28, 29, #48206, x 1 3/4.

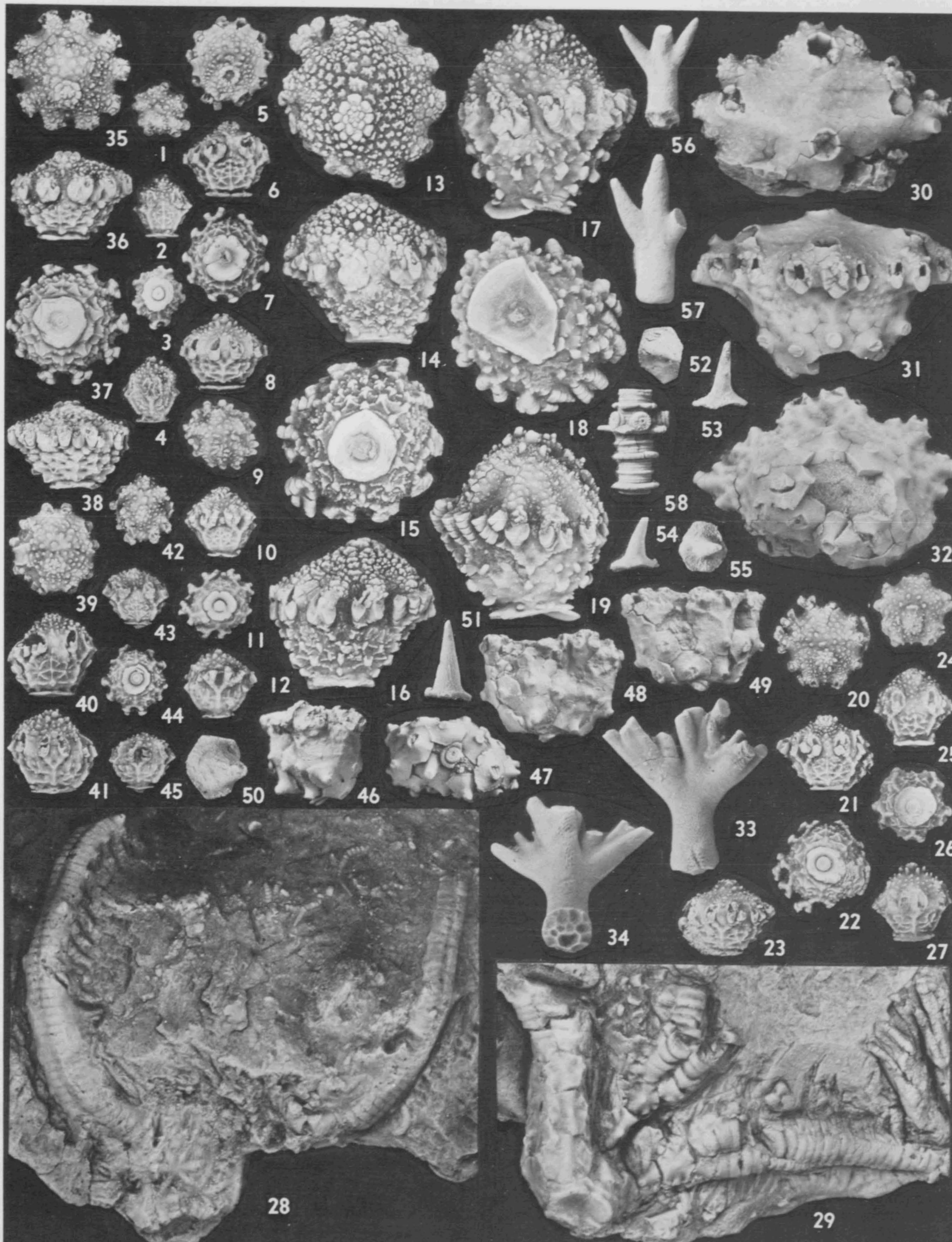

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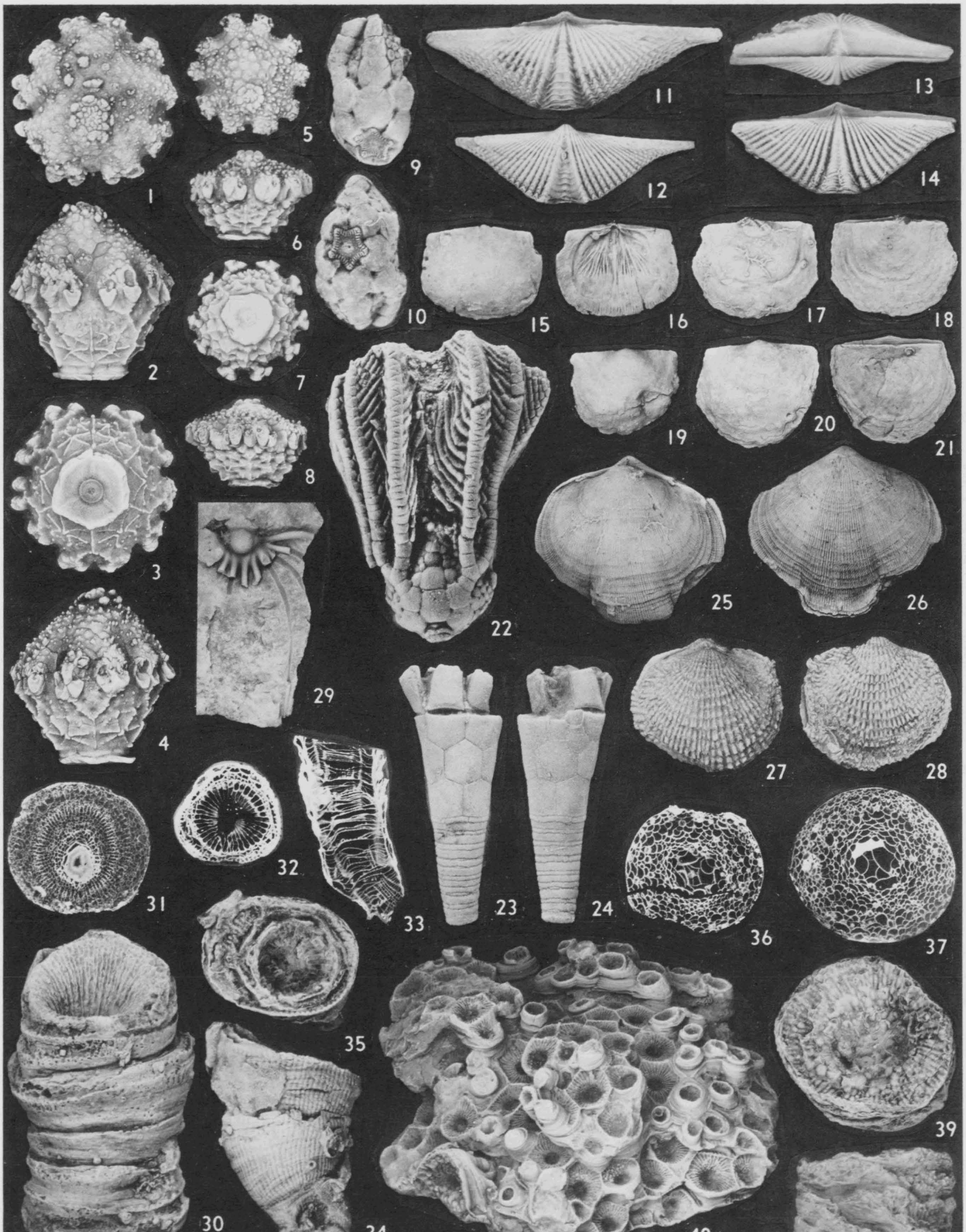
PLATE 14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1. Limestone, argillaceous, grading downward into calcareous shale, weathering with limonitic stains and alum efflorescence; fossiliferous, some Atrypa valves showing wear near base of unit 1.4

Bell Shale

8. Clay shale, soft, readily disintegrating, gray-blue, fossiliferous with small brachiopods, crinoid columnals, and other invertebrates 3.2

7. Clay shale, medium soft, blue-gray, fossiliferous 1.9

6. Clay shale, soft, blue, slightly fissle in core, fossiliferous, with Gennaeocrinus variabilis Kesling & Smith, Logocrinus conicus Kesling, and species of the brachiopods Atrypa, Chonetes, Longispina, Cryptonella, Mucrospirifer, Pholidostrophia, Schizophoria, and Strophodonta (probably including most of the species listed in Appendix 4) 5.5

5. Shale, medium hard, calcareous, containing numerous well-preserved valves of a large Atrypa showing muscle scars; other fossils include a small inadunate crinoid, Pleurodictyum (Procteria) cornu Stumm, and numerous bryozoa 0.5

4. Clay shale, very soft, blue; lower 2 inches calcareous; readily disintegrates when wet 7.0

3. Limestone, medium hard, gray 0.5

2. Shale, soft, gray-blue; thin limestone layer 1.3 feet below the top; pyrite noted 21 feet below top; fossils at 16.5 and at 30.3 feet below top; lower 10 feet very brittle 48.3

1. Clay shale, soft, calcareous, dark, extremely fossiliferous with crinoid columnals ... 1.4

Total thickness 68.3

Rogers City Limestone

Limestone, crystalline, hard, brown 13.5

In three quarries the Bell Shale is exposed and can be studied in detail. Inasmuch as the shale has no economic value at present, its presence is most unwelcome, particularly where solution in the high-calcium stone of the Rogers City Limestone has formed large sinkholes filled with collapsed and jumbled Bell Shale material. Therefore, no effort is made to extend the exposure of Bell by quarrying.

In the large quarry of the U.S. Steel Corporation at Rogers City, about 15 feet of the lower strata can be seen above the contact with the Rogers City; and at the Presque Isle Corporation Quarry (Locality 33-8-2) about 20 feet of the lower shale is exposed at the same position. At both these quarries, the basal unit of the Bell Shale was laid down on a weathered and eroded surface of the Rogers City Limestone. The top of the Rogers City is slightly undulating stratigraphically and heavily stained with iron residues from the oxidation of pyrite; its fossils are beveled off flush with the general surface of the rock so that many show naturally made cross sections. The lower unit is the same as that in the well core described above: a crinoidal hash that was produced by strong turbulence, evidently the lag residue from some shale unit that is not known in its uneroded state. Above this 1-foot bed are soft gray shales that contain few fossils, mostly small molds of pelecypods.

At the abandoned Kelley's Island Quarry at Locality 32-9-6 NW, the upper Bell Shale is exposed below the contact with the Rockport Quarry Limestone along a drainage ditch. The strata exposed here include units 5-8. They weather readily and produce a remarkable supply of well-preserved invertebrates. Most of the Bell fossils described came from this place.

Another exposure was made in a railway cut, long abandoned, of a spur line from the Rockport Quarry (Loc. 32-9-6 NW) to the old Lake-of-the-Woods Quarry (Loc. 33-8-2). Here at Locality 33-8-24 SW, the contacts of the Bell are not exposed, and the beds are considered to be slightly older than those at the Kelley's Island Quarry, possibly unit 4.

Bell Shale — PLATE 14 — Figures x 1 except as noted

Gennaeocrinus variabilis; 1-4, #40535, x2; 5-8, #40523, x2. Opsiocrinus mariae; 9, 10, #47095, x5; 22, #27682, x5. Mucrospirifer alpenensis; 11, #31667. M. prolifucus; 12, #33315; 13, 14, #31666. Pholidostrophia gracilis gracilis; 15, 16, #57627b; 17, 18, #57627c; 19, #57627d; 20, 21, #57627a. Logocrinus conicus; 23, 24, #57221, x4. Schizophoria ferronensis; 25, 26, #57624a. Atrypa sp.; 27, 28, #57623a. Ancyropyge romingeri (Gravel Point); 29, #4934. Atelophyllum subcylindricum; 30, 31, #35173. Tabulophyllum elongatum; 32, 33, #44758; 34, 35, #44759. Cystiphylloides americanum bellense; 36, #35168; 37, #35171; 38, 39, #35177. Hexagonaria sp. (regeneration); 40, #57593.

Composition. -- Because it lacks commercial value, little has been done with analyzing the Bell Shale. From a test hole drilled near the NW corner of section 6 at Locality 32-9-6 NW, the bottom sample probably includes the top of the Bell Shale (possibly with admixed unit 1 of the Rockport Quarry):

Depth (ft.)	$CaCO_3$	$MgCO_3$	SiO_2	Notes
3	94.80	1.30	.70	Unit 4, definitely below unit 5
4	93.40	1.45	1.02	
5	91.20	1.36	1.88	
6	88.18	.78	3.16	
7	88.84	.80	3.30	
8	81.50	1.74	7.12	About base of unit 4
9	83.32	.94	8.68	Unit 3
10	93.30	1.35	.76	Top unit 2
11	95.58	--	.28	
14	92.40	3.45	.38	
15	95.03	--	.04	
17	96.80	--	--	
18	95.00	2.33	.56	
20	96.69	--	.16	
21	91.90	4.38	1.08	
23	97.40	1.09	.28	
29	97.00	--	.52	
30	96.70	1.74	.20	
31	91.25	--	.78	About unit 1, Rockport Quarry Ls.
32	77.90	4.80	10.50	Top of Bell Shale, ? some Rockport.

It would appear, from this one analysis, that the Bell contains more silica than clay in the uppermost unit.

Fauna. -- The diverse fauna which characterizes the Bell Shale is concentrated in the upper units. Good collecting is available at the Kelley's Island Quarry or at places in the Rogers City Quarry where the upper Bell beds have slumped down into sinkholes in the Rogers City Limestone.

As in other Traverse Group formations, the fossils recorded do not accurately portray the whole fauna, being subject to the particular interests of paleontologists studying them. Nevertheless, some of the diversity is indicated in the 81 genera reported from the Bell (Appendix 3). These include (Appendix 1) 9 tetracorals, 8 tabulates, 16 brachiopods, 21 bryozoa, 4 trilobites, 15 ostracods, 1 blastoid, and 5 crinoids; many of these genera contain more than 1 species in the Bell Shale. Much paleontological work remains to be done on the Bell fauna; eventually, twice this many genera may be known.

To date 45 species of macrofossils have been given names from the formation. Of these (Appendix 5), only 8 are known to occur in the overlying Rockport Quarry Limestone, whereas 14 are recorded from the Ferron Point shales above the Rockport. This supports the hypothesis that in the Middle Devonian deposits of this region, the zone of deposition played a more significant role than did elapsed time. This theme of recurrent faunas has been long discussed and explored, but the examples are still exciting.

Deposition. -- Rogers City limestone deposition was interrupted and the top of the formation worn and beveled. From the amount of pyrite on the surface, the exposure may have lasted for appreciable time. After this, crinoids became established on zone IV mud flats; the first beds of Bell time in this region seem to have been crinoid-rich, fairly deep water shale. These beds were then subjected to shallow-water turbulence, in which wave action ground up the soft shale, moved all but the heavy crinoid debris into deeper water, and left behind a lag deposit of worn columnals and plates as the first record of Bell Shale sediments. Probably, during the turbulent destruction of the crinoid shale the top of the Rogers City Limestone was subjected to scouring action.

Bell Shale - Rockport Quarry Limestone PLATE 15 All figures x 1

Bell Shale: Atrypa sp.; 1, 2, #57623b; 3, #57623c. Strophodonta extenuata bellensis; 4, #42181c; 16, #42181b. Schizophoria ferronensis; 5, 6, #57624b; 10, 11, #57624c; 17, 18, #57624d; 19, #57622a; 20, #57622b; 21, #57622c. Pholidostrophia gracilis gracilis; 7, #57627e. P. gracilis nanus; 13, #57626a; 14, #57626b; 15, #57626c. Chonetes mediolatus; 8, 57625b; 9, #57625c; 12, #57625a. Tabulophyllum curtum; 22, 23, #35235; 29, 30, #35158. Heliophyllum halli bellense; 24, 27, 28, #35156. Heterophrentis ferronensis; 31, 32, #35155. Atelophyllum subcylindricum; 33, #35172. Autocystis multicystosa; 34, #34921.

Rockport Quarry Limestone: Billingsastrea rockportensis; 25, 26, #18803. Heterophrentis gregaria; 35, 36, #5174a; 40, #5174b. Cylindrophyllum delicatulum; 37-39, #25707. Spongophyllum romingeri; 41-43, #24832.

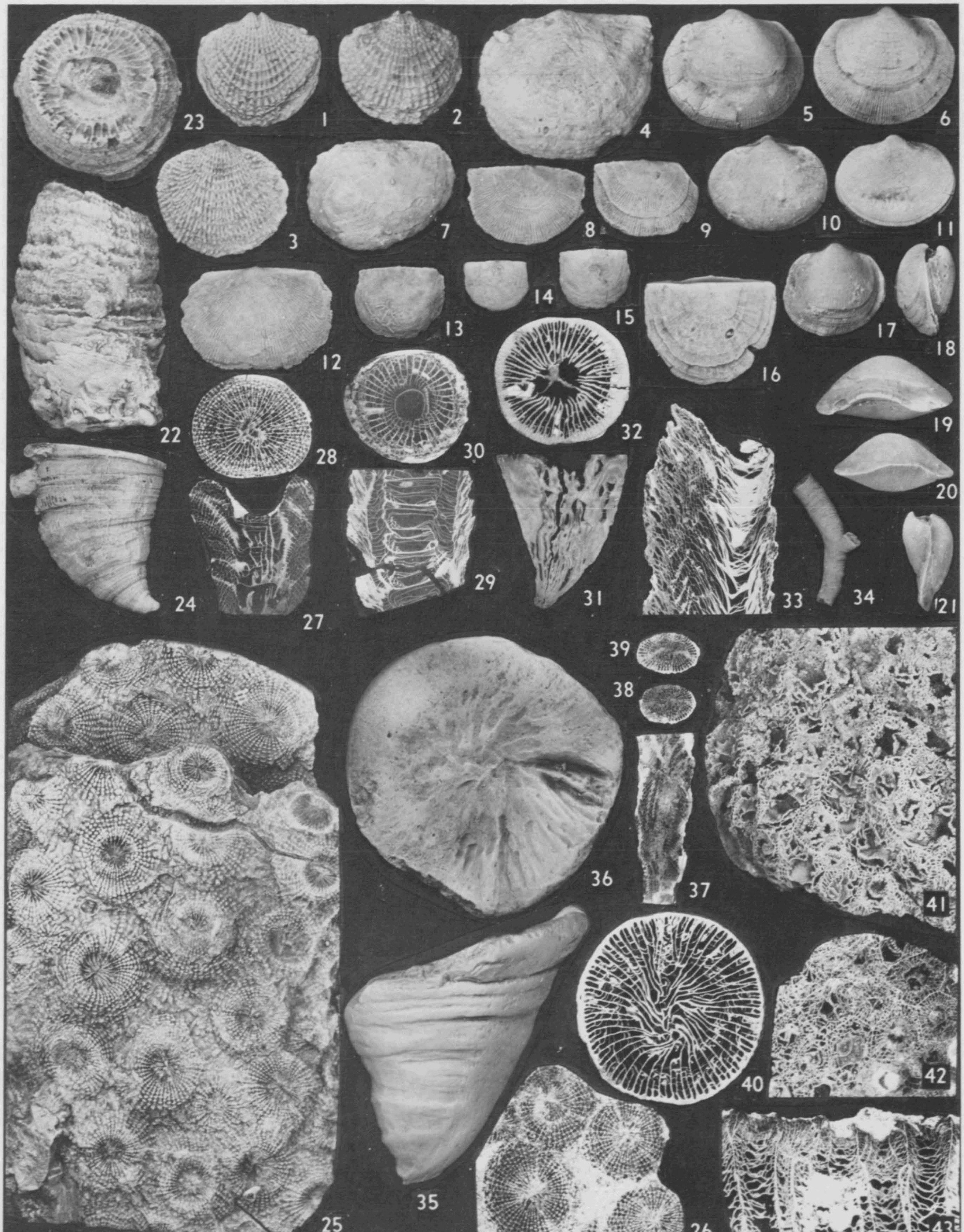
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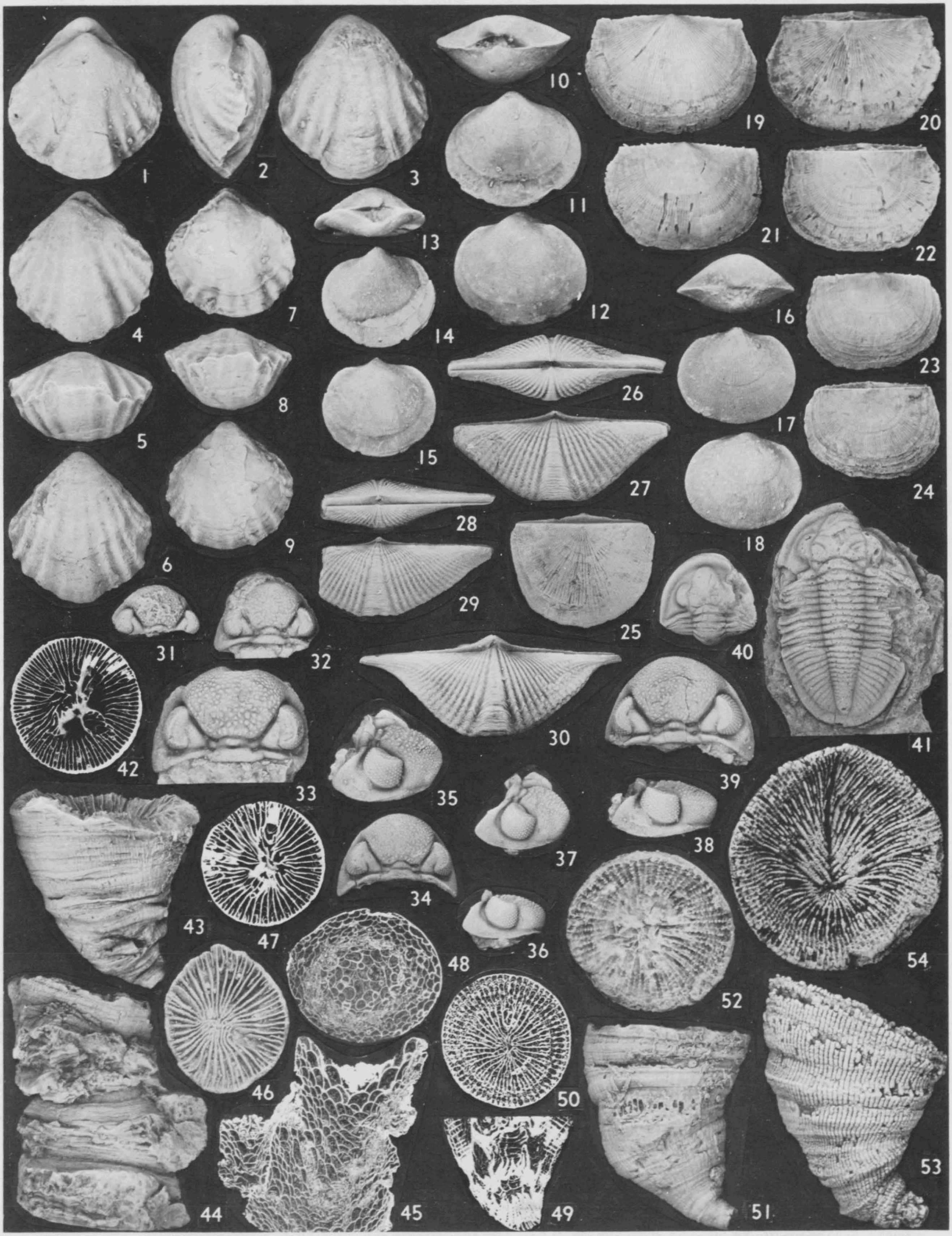
PLATE 16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This violent interval was followed by deeper and much quieter water. Some time elapsed before the marine animals found their way back into the area, for the overlying shale in unit 2 contains only a few molds of clams in the megafauna.

Except for cores, little can be learned about the abundance of invertebrates in the upper part of unit 2 or in unit 3. The exposure along the old railway cut at Locality 33-8-24 SW contains abundant corals and many calyx plates of Gennaeocrinus goldringae Ehlers. The fauna does not quite match with that at the Kelley's Island Quarry, and the geographic location of the outcrop suggests that the strata are probably unit 4.

The diverse fauna of the uppermost beds has already been mentioned. These soft shales were evidently deposited in very quiet water in zone IV. The occurrence of Gennaeocrinus variabilis Kesling & Smith at the quarry incites speculation. The crinoids are found in clusters containing up to twenty individual heads, the stems intertwined in a mass. It would appear that the crinoid gardens were occasionally affected by storms of exceptional intensity, which broke them free from their anchoring bases, swept them together and tangled their trailing stems, and rolled them along the bottom until quiet again prevailed and they came to rest. Other fossils in the upper units include thin-shelled brachiopods such as Chonetes in perfect preservation and Mucrospirifer with the fragile wing tips intact. Both microfauna and macrofauna contain highly ornamented forms in excellent condition.

Lithologically, the transition from Bell into Rockport Quarry was gradual, going from a shale through an argillaceous limestone to a purer limestone. However, as Warthin & Cooper have noted (1943, p. 580), the basal unit of the Rockport Quarry contains stromatoporoids like the beds above; and the Atrypa specimens have badly wave-worn valves, as though they had been reworked from the upper part of the original Bell succession. These are strong indications that the Bell interval terminated with a temporary retreat of the sea (or uplift of the sea bottom) which subjected the top layers to some degree of erosion. Whether the differences in thickness of the Bell Shale encountered in well drillings in Alpena and Presque Isle Counties resulted from different rates of deposition or from some terminal erosion has not been investigated.

Rockport Quarry Limestone

Name. -- In 1876 Dr. Carl Rominger, State Geologist, published his masterful work on the geology of the lower peninsula, which included a chapter on the Hamilton Group. In it (p. 49-50) he described the natural outcrops of this formation "directly west of Middle Island, on the side of a small creek flowing southeastward into Lake Huron," where they formed a chain of bluffs about 16 feet high beginning about half a mile from the shore. He described the strata as "nodular, unhomogeneous beds of limestones, interstratified with thin seams of shaly substance of black color" underlain by "blue shales" containing many fossils. From the list of fossils which he identified, it is certain that Dr. Rominger visited the type locality before it became a quarry.

On his visits to the region, Grabau did not visit the bluffs described by Rominger, although he correctly inferred that they were the same rock strata as those exposed on the southwest shore of Grand Lake, where they formed ledges rising to about 40 feet above the lake, and in the walls of "great bottomless sink" in section 36 just northwest of the type locality. He classified the strata (1902, p. 184-191) as the lowermost part of his "Long lake shales and limestones" of the "Lower Traverse series."

R. A. Smith (1916, p. 175), after studying the exposures in the recently opened quarry of the Great Lakes Stone & Lime Company, named the formation the "Rockport Limestone." The site at Locality 32-9-6 NW thus became the type locality. The name was changed, because it was thrice preoccupied, by Cooper & Warthin (1941, p. 260) to the Rockport Quarry Limestone, who designated the type locality to be the quarry of the "Kelly Island Rock and Transport Company at Rockport in the northeast corner of Alpena County, Mich."

Ferron Point — PLATE 16 — Figures x 1 except as noted

Pentamerella lingua; 1-3, #42144c; 4-6, #42144b; 7-9, #42144a. Schizophoria ferronensis; 10-12, #57622a; 13-15, #57622b; 16-18, #57622c. Chonetes nateforma; 19, 20, #57621b; 21, 22, #57621c; 23, 24, #57621a. Strophondonta extenuata ferronensis; 25, #33731a. Mucrospirifer mucronatus; 26, 27, #44121; 28, 29, #44089. M. alpenensis; 30, #31648. Phacops rana; 31, #25530c; 32, #25530b; 33, #25530a. P. milleri; 35, 38, 39, #25518a; 34, 36, 37, #25518b. Dechenella alpenensis; 40, #27077; 41, #51982. Heterophrentis ferronensis; 42, 47, #35204; 43, #44596; 46, #44595. Cystiphylloides phacelliforme; 44, 45, 48, #35289. Heliophyllum ferronense; 49, 50, #21085; 51, 52, #35198. Aulacophyllum scyphus; 53, 54, #8568.

Exposures. -- Natural outcrops of the Rockport Quarry Limestone can be found as low bluffs here and there in this region. These outcrops develop not so much from the resistant composition and structure of the formation, but rather from its stratigraphic position, sandwiched between the very soft Bell Shale below and Ferron Point Formation above. The northern part of Grand Lake, its bed gouged from the Bell Shale, has a series of exposures of the Rockport Quarry Limestone facing its western shore.

Outcrops on Thunder Bay Island and Sugar Island (east-southeast of Alpena in T 31 N, R 10 E) were studied by Rominger, who reported (1876, p. 47) "an alternation of limestones, partly of gray, partly of black color, with interstratified seams of shales, which are also black or dark gray." The strata on these islands are probably in the lower part of the Rockport Quarry Limestone, and may crop out on the lake bottom nearby, where Rominger recorded (1876, p. 47):

> The exuberance of fossils in the strata is most beautifully exhibited in the shoals of the lake north of Thunder Bay Island, where any one sailing over them can see for miles the whole bottom paved with corals in convex lumps, from a few inches to some feet in diameter, their white, sparry substance contrasting beautifully with the dark limestone which incloses them.

At a few places between the type locality and South Nine Mile Point along the northeastern shore of Alpena County the Rockport Quarry Limestone crops out.

Some excellent exposures for collecting Rockport Quarry fossils are road cuts along US 23 from the northern half of Grand Lake to the intersection with M 65. Here for a distance of over 11 miles the highway is on Rockport Quarry Limestone, and cuts intersect various beds within the formation, each with a slightly different fauna.

The only place where the entire thickness of the formation can be studied in exposure is still the type locality in the abandoned Kelley's Island Lime & Transport Company Quarry at Rockport, where 42 feet of strata lie between the shales of the Bell and Ferron Point:

Section of Rockport Quarry Limestone exposed in quarry at Rockport
(Kelley's Island Lime & Transport Company quarry, now abandoned, at Locality 32-9-6 NW; section modified after Ver Wiebe, 1926, and Warthin & Cooper, 1943)

	Feet	
Ferron Point Formation		
Clay shale, bluish gray, alternating with thin beds and lenses of limestone; fossiliferous, yielding excellent heads of *Hexagonaria*, other tetracorals, and brachiopods, as well as microfossils in washings	9	
Rockport Quarry Limestone		
5. Limestone, gray, sublithographic, specks of yellow calcite; conspicuously lighter in color than rest of formation; unfossiliferous; weathers into rectangular blocks	12	
4. Limestone, gray, with irregular bituminous streaks and inclusions; highly fossiliferous with large masses of stromatoporoids and corals	11	
3. Shale, brown to black, bituminous, hard	1	
2. Limestone, brown, irregularly bedded white, bluish, and gray limestone layers separated by bituminous partings; pyrite weathering to limonite stains; highly fossiliferous but without diverse fauna, consisting mostly of stromatoporoids and corals	17	
1. Shale, with strong limonite stains and alum efflorescence; fossiliferous, containing many worn fossils, particularly *Atrypa* valves, as well as many other brachiopods, an undescribed blastoid, and a few stromatoporoids	0	8"
Total thickness about	42	8"

Ferron Point - Genshaw — PLATE 17 — Figures x 1 except as noted

Ferron Point: *Schuchertella crassa*; 1-3, #42145. *Strophodonta extenuata ferronensis*; 4, 5, #33731b; 6, #42181c; 7, #33731d; 8, 42181b; 9, #33731c; 10, 11, #33731a. *Mucrospirifer mucronatus*; 12, 13, #44090. *Aulocystis magnispina*; 14, #34926. *Aulacophyllum hemicrassatum*; 15, 16, #45099.
Genshaw: *Billingsastrea romingeri*; 17-19, #27000. *B. pauciseptata*; 20, 23, #27001; 21, 22, #22952; 24, #26387.

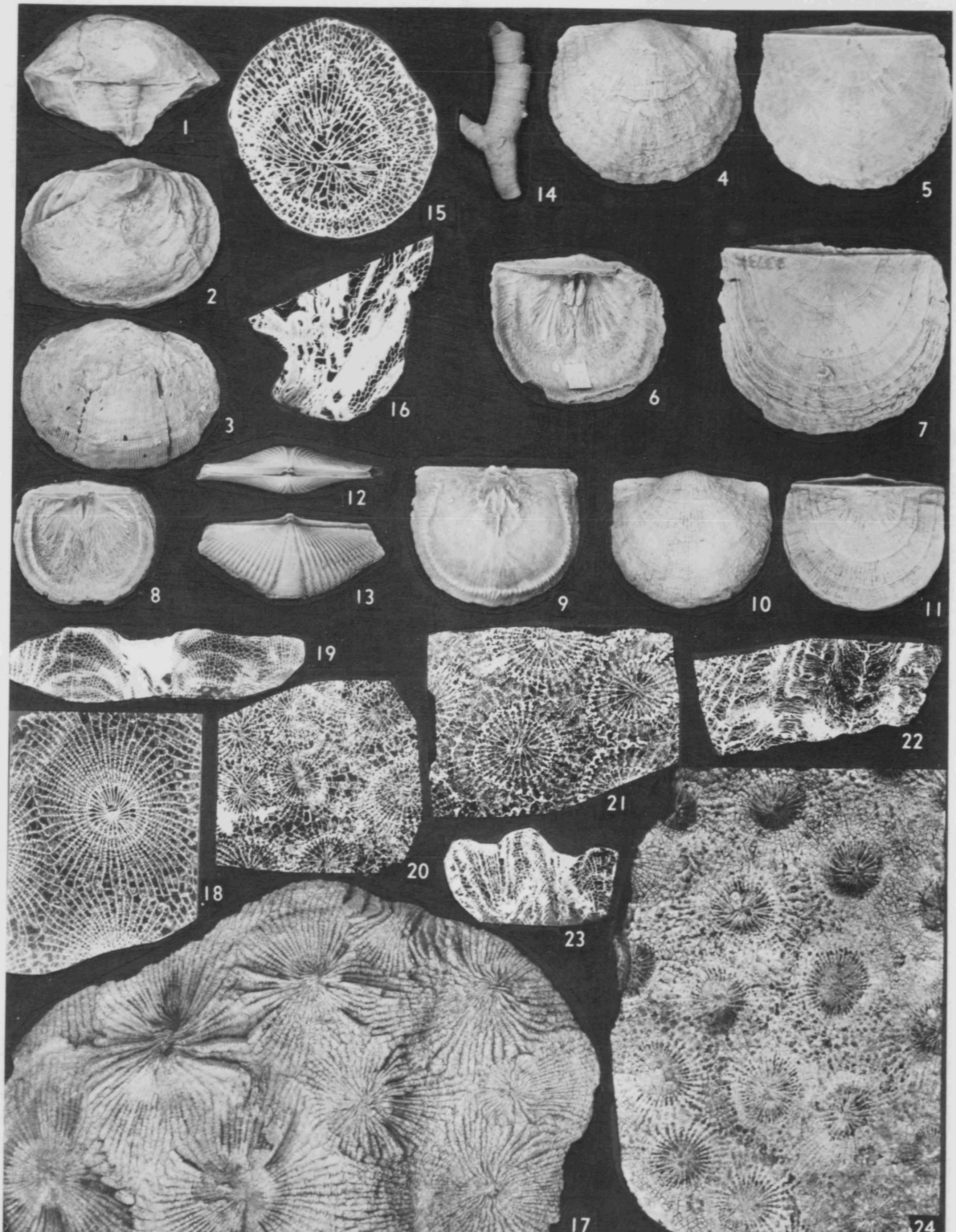
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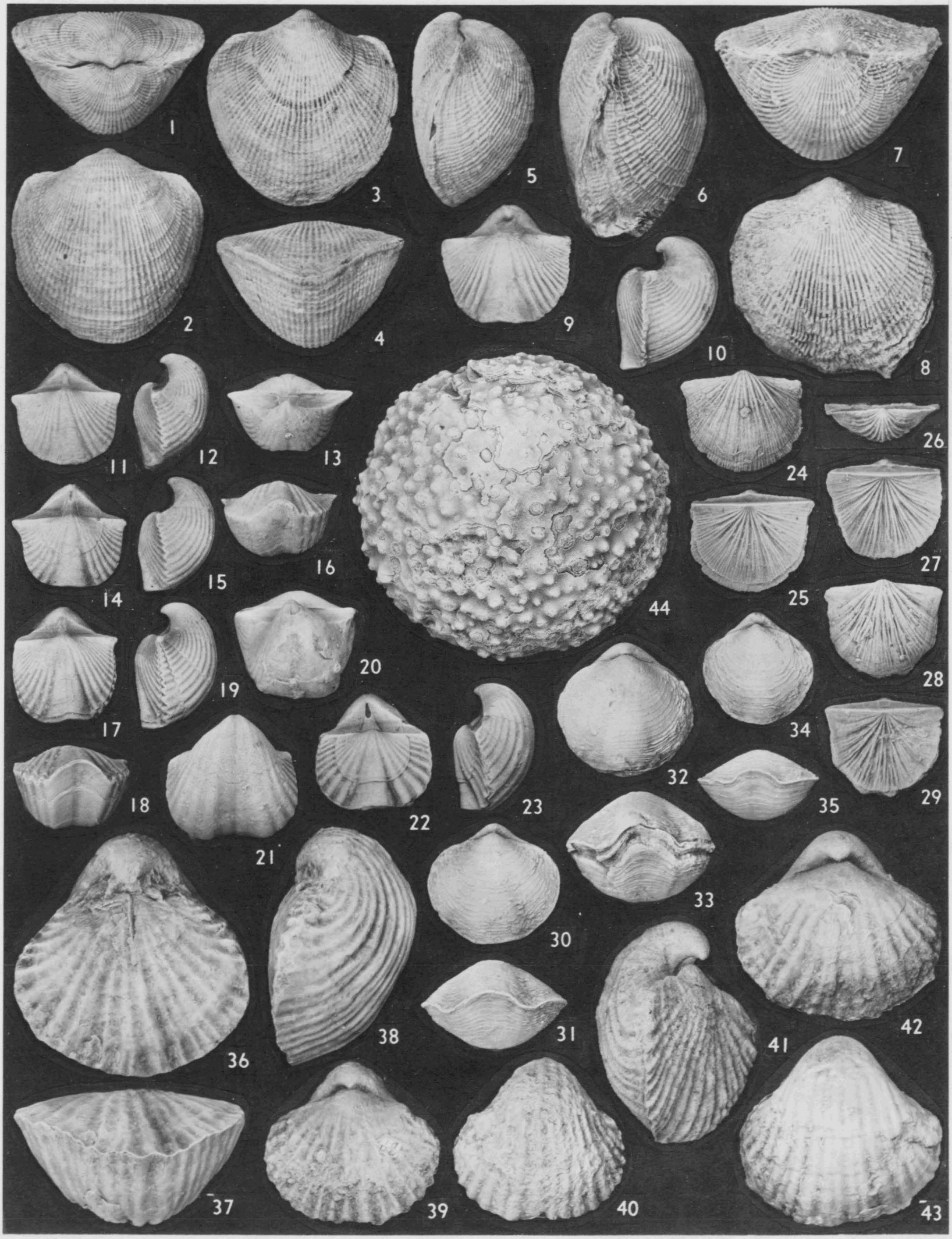
PLATE 18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Bell Shale

Mudstone or shale, very soft, dark bluish gray weathering to light gray; very fossiliferous with crinoids Gennaeocrinus, Gilbertsocrinus, Logocrinus, and others, brachiopods Chonetes, Longispina, Mucrospirifer, &c, and other taxa.	11

As in the Rogers City Limestone and the Alpena Limestone, the purity of the Rockport Quarry Limestone has promoted localized solution. Sinkholes are intersected in the walls of the quarry at the type locality. The largest is over 100 feet in diameter; in it, the Ferron Point and lower Genshaw beds have collapsed from above and lie as blocks or chunks in some disarray. On the quarry walls, the edges of the Rockport Quarry Limestone are upturned at their junction with the sink filling, suggesting that solution was able to start along vertical cracks developed at the centers of low folds in the strata. Partly because the downward extension of solution is blocked by the thick impervious Bell Shale below and partly because cavities are readily filled with collapse of the soft Ferron Point shales and thin limy beds from above, the sinkholes in the Rockport Quarry Limestone do not have conspicuous topographic expression; undoubtedly, there are many sinkholes that have not been discovered.

The sinkholes at Locality 33-8-36 SW, including the "great bottomless sink" studied by Grabau, have been mentioned above. From the occurrence of Bell Shale in the walls, it is possible, as Warthin & Cooper suggested (1943, p. 576), that the major solution occurred in the Rogers City Limestone, leading to collapse of both Bell and Rockport Quarry rocks.

The limestone also outcrops at Ocqueoc Falls (Locality 35-3-22 S), where it can be seen in the bed of Ocqueoc River and on the banks lining the falls and rapids. Here Smith (1916, p. 259) described the following section:

Section of Rockport Quarry Limestone at Ocqueoc Falls

Bed		Feet
1.	Gray crystalline magnesium limestone.	6
2.	A mass of cup corals and Stromatopora in a matrix of dark bituminous limestone.	1
3.	Massive dark crystalline and bituminous magnesium limestone.	$3\frac{1}{2}$
4.	Banded dark bituminous and crystalline magnesium limestone with Acervularia near the top...	4
5.	Banded dark bituminous and mottled and streaked magnesium limestone with numerous cavities, very fossiliferous in the upper portion.	8
	Total exposed	$22\frac{1}{2}$

A set of samples analyzed from the falls gave 34.74% of $MgCO_3$ (Smith, 1916, p. 259).

At Locality 35-2-7 NW, on the shore of Black Lake in western Presque Isle County, a small quarry was operated many years ago by the Onaway Limestone Quarry. Smith (1916, p. 201) measured the section, which he described as:

Section of Rockport Quarry Limestone at Black Lake Quarry

Bed		Feet
1.	Dark bituminous, crystalline, and very fossiliferous beds, containing masses of corals and an abundance of brachiopods. The beds are present only at the east end of the quarry.	6
2.	Light gray dense grained limestone with small disseminated calcite crystals.	8
3.	Dense grained gray limestone with but few crystals of calcite.	7

Genshaw — PLATE 18 — Figures x 1 except as noted

Atrypa sp.; 1-5, #57602; 6-8, #57598. Cyrtina umbonata alpenensis; 9, 10, #57597f; 11, 12, 16, #57597b; 13-15, #57597d; 17-19, #57597e; 20, #57597a; 21-23, #57597c. Strophodonta acris; 24, 25, #57600a; 26, 27, #57600b; 28, 29, #57600c. Athyris sp.; 30, 31, #37409b; 32, 33, #37409a; 34, 35, #37409c. Sieberella romingeri; 36-38, #4287; 39, 40, #57595; 41, 42178a; 42, 43, #57594. Stromatoporoid; 44, #57592.

4. Gray dense grained limestone with many small calcite crystals.......... 9
5. Dense grained gray to lithographic limestone with many small crystals of calcite. Lighter than beds 3 and 4.......... 4
6. Very fine grained, dark bituminous limestone.......... 1
7. Dense grained gray to lithographic limestone similar to 5.......... 4
8. Dense grained limestone with bituminous bands.......... 1½
9. Dense grained limestone with calcite crystals and dense cavities.......... 1
10. Dark argillaceous bituminous and fossiliferous limestone with druse cavities. Apparently the top of the Long Lake series.......... 1

Total exposed 42½

The beds weather to a buff or brown, with some iron stains on the old quarry walls. Essentially, the strata at Black Lake consist of about 35 feet of bituminous lithographic limestone between fossiliferous beds. This thick middle section shows strong genetic similarity to the uppermost unit at Rockport. According to Kelly & Smith (1947, p. 449) these lithographic limestones are stylolitic. Kelly (1949) noted an alternation of brown and light gray colors in the limestone, which he interpreted as possible cyclic sedimentation.

Composition. -- Although the limestone has not been quarried for many years at Rockport Quarry, some old chemical analyses collected below show the variations in the composition of the units:

Unit	Sample	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	SiO_2	S
5	Random	95.78	1.21	.60	.74	Tr
5	Random	96.96	1.17	.50	.54	Tr
5	Random	96.54	1.30	.44	.78	Tr
5	Random	95.24	2.22	.52	1.14	Tr
5	Average of 7	96.29	1.36	.49	.79	Tr
4	Random	95.30	1.55	1.14	.90	.46
4	Random	86.48	1.88	2.80	3.12	.98
4	Random	88.08	1.63	2.48	2.20	.60
4	Random	90.92	1.63	1.66	1.04	.68
4	Random	93.08	1.59	1.28	.56	.54
4	Average of 20	91.76	1.81	1.57	1.28	.53
3	Random	93.84	1.92	.94	.36	.18
3	Random	93.00	2.59	1.18	.78	.20
3	Random	92.54	1.59	1.44	1.40	.40
3	Average of 5	93.20	1.91	1.20	.80	.27
2	Random	94.50	2.68	.94	.50	.14
2	Random	95.76	1.42	1.06	.48	.39
2	Random	88.32	1.59	2.64	2.20	.95
2	Random	87.24	1.63	2.82	4.54	.59
2	Random	90.48	1.21	1.64	.68	.78
2	Random	93.00	2.59	1.18	.78	.20
2	Average of 26	91.74	1.72	1.60	1.32	.54

PLATE 19

1, 2 - Rockport Quarry Limestone exposed at Ocqueoc Falls and in valley just below falls. Loc. 35-3-22 S.

3, 4 - Rockport Quarry Limestone (unit 5) at type locality and overlying Ferron Point Formation (units 1-7) in wall of old Kelley's Island Quarry; photographs taken many years ago (probably in late 1920's) and recently showing changes wrought by slump and vegetation. Loc. 32-9-6 NW.


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PLATE 20

These analyses demonstrate the high-calcium stone that was produced from the upper unit at the quarry. The stone from the other two thick units (2 and 4) was inferior in having low calcium, high clay, occasional silica, and sulphur.

Samples collected by R. A. Smith from the Black Lake Quarry in 1914 yielded the following analysis (Smith, 1916, p. 280-281):

$CaCO_3$	$MgCO_3$	Al_2O_3, Fe_2O_3	SiO_2
96.84	2.03	.52	.39

This composition closely resembles that of unit 5 at Rockport, but has even less silica. Although it is situated inland, this still looks like a good reserve of high-calcium low-impurity stone.

Fossils. -- If the Rockport Quarry Limestone is fossiliferous at all, most strata contain a profusion of stromatoporoids and corals. There are two distinct major facies, one non-fossiliferous and the other a biostrome. It is curious that the fauna recorded from this formation (Appendix 3) includes no echinoderms, molluscs, bryozoa, nor trilobites, and only 8 genera of brachiopods. In part this published record is biased, inasmuch as the excellent exposures along US 23 were created only in the last twenty years. At Locality 34-8-31 S, for example, the strata belong to a different zone of deposition from those at the type locality and bryozoa and other quieter water invertebrates are plentiful. Most of the fossils known in literature are tetracorals and tabulates, and there are numerous stromatoporoids which remain to be studied. The Bell Shale and Ferron Point Formations, which bound the Rockport Quarry, have more genera and species in common (Appendices 2 and 5) than either formation shares with the Rockport Quarry.

This formation has some macrofossils that have not been found in other strata of the Traverse Group, including the following (Appendix 4):

Billingsastrea rockportensis Ehlers & Stumm
Cylindrophyllum delicatulum Ehlers & Stumm
Heterophrentis gregaria (Rominger)
Spongophyllum romingeri Ehlers & Stumm
Favosites alpenensis kellyi Swann
Trachypora rockportensis Stumm & Hunt
Longispina pelta Imbrie
Strophodonta extenuata rockportensis Imbrie.

Deposition. -- Two major depositional realms are indicated at the type locality. First, the biostromal limestone in units 2 and 4 is heavily admixed with bituminous residue. The combination of profuse stromatoporoids and corals with bituminous matter is somewhat enigmatic, for the former indicates strong aeration and the latter indicates little or no aeration. The occurrence suggests that insignificant little changes in sea level could temporarily cut off areas of the active strom-coral community and lead to stagnating conditions, inhibiting life and permitting the accumulation of hydrocarbons. With slight erosion or transgression, such areas could return again to the near-shore open-sea zones favoring growth of stromatoporoids and corals. In the shallow water postulated for these strata, such fluctuations, each of very little magnitude, must have happened time and again during this part of Rockport Quarry time.

The second major realm is recorded by the almost unfossiliferous lithographic limestone, which yields only small ostracods. The rock of unit 5 at the type locality seems to be chemically precipitated calcium carbonate in a quiet lagoon. The high calcium content shown in the chemical analyses attests the minimal amount of mud contributed to the basin of deposition. The concept of lagoonal deposition for the

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PLATE 20

1 - West wall of old Kelley's Island Quarry, showing Ferron Point and Genshaw Formation slump (left) filling sinkhole developed by solution through arched beds of small anticline or dome in the Rockport Quarry Limestone. Loc. 32-9-6 NW.

2 - Ferron Point Formation (upper part, units 9, 10) and overlying basal Genshaw Formation units 1-6, at abandoned shale pit of Alpena Portland Cement Company Quarry; former owner Mr. Worline. Loc. 32-9-18 SE.

lithographic strata is not new here. For strata of this kind at the Black Lake Quarry, where they form the major part of the exposed Rockport Quarry Limestone, W. A. Kelly (1949) suggested deposition in a lagoon; he stated that "reef-like barriers probably existed to the south." The different positions and thicknesses of the sublithographic phase may be interpreted as evidence of quiet lagoons forming here and there throughout the region, each with its particular extent and duration.

The strata exposed along US 23 at Grand Lake, Locality 34-8-31 S, contain few stromatoporoids and many small brachiopods, bryozoa, and other invertebrates. This lower part of the formation here is typical of the deeper part of zone III.

Ferron Point Formation

Name. -- Because it contains a large percentage of shales and argillaceous limestones, the Ferron Point Formation has only a few sporadic natural exposures. By 1902 when Grabau described the stratigraphy of the Traverse Group, the shale pits of the Alpena Portland Cement Company were already in operation at Locality 32-9-18 SE; he listed (p. 188-189) fossils from the Ferron Point and Genshaw Formations at that locality. It is almost certain that the well studied by Grabau and listed as "Loc. 29, Wiesey's Well" (1902, p. 188) revealed the upper Ferron Point Formation, which was described as "twenty feet of bluish clay with some calcareous beds intercalated"; the Wiesey well was probably situated in the S½ sec. 19, T 32 N, R 9 E, not very far south of Hell Creek. The strata were included in Grabau's "Long lake shales and limestones."

Ver Wiebe (1927, p. 182) classified the formation as his "Middle member of Long Lake series," but did not try to define the limits. Some drill holes had penetrated the whole of the formation, but no attempt was made to assign particular strata to this unit.

The formation was named and defined by Warthin & Cooper (1935, p. 526), who gave the thickness as approximately 35 feet and designated the type locality at Rockport Quarry (Locality 32-9-6 NW).

Exposures. -- The formation is still known best from the two exposures listed above. Well records from the two counties indicate that the Ferron Point Formation is present everywhere in the area except where removed by erosion in post-Devonian time. There is marked thinning toward the west.

At Black Lake in western Presque Isle County (Locality 35-2-7 NW) the formation is only 9 feet thick, and Kelly & Smith (1947, p. 451) indicate that it is even thinner nearby. In this area the soft shales are exposed in the beds and banks of Stoney Creek (Locality 35-2-20 SW), Rainy River (Locality 35-2-26 S), and Ocqueoc River (Locality 35-3-27 C), where they are identified both from lithology and fossils.

The composite section of the Ferron Point Formation in eastern Alpena County:

Section of the Ferron Point Formation
(Units 1-7 exposed at the type locality at 32-9-6 NW; units 9-10 exposed at the clay pits at Locality 32-9-18 SE; and covered interval 8 estimated from the Churchill well record)

Genshaw Formation — Feet

Units 1-6 exposed above contact, consisting of alternating soft shales and argillaceous limestones; fossiliferous with *Sieberella romingeri*, large *Atrypa*, and other brachiopods. Basal unit 5 feet of gray calcareous shale. Forms distinct bluff above softer beds of Ferron Point.

Genshaw — PLATE 21 — Figures x 1 except as noted

Schizophoria striatula traversensis; 1, 2, #26944b; 3, 4, #26944a. *Cyrtina umbonata alpenensis*; 5, #57597f; 6, 7, #57597a. *Helaspis luma crista*; 8-10, #42220a; 11-13, #42220b; 14-16, #42220c. *Athyris* sp.; 17, 18, #57599a; 19, 20, #57599b; 21, 22, #57599c. *Mucrospirifer multiplicatus*; 23, 24, #31668. *M. mucronatus*; 25, 26, #44110. M. sp.; 27, #57620a; 28, #57620b; 29, #57620c. *Basidechenella nodosa*; 30, #28678; 31, #25509. *Dechenella alpenensis*; 32, #27082. *Tabulophyllum traversense*; 33, 34, #35215. *Hexagonaria* sp.; 35, #57596. *Lythophyllum alpenense*; 36, #35213. *Heterophrentis ferronensis*; 37, 38, #44547. *Aulocystis alectiformis reptata*; 39, #34932. *Aulacophyllum scyphus*; 40, 41, #44751.

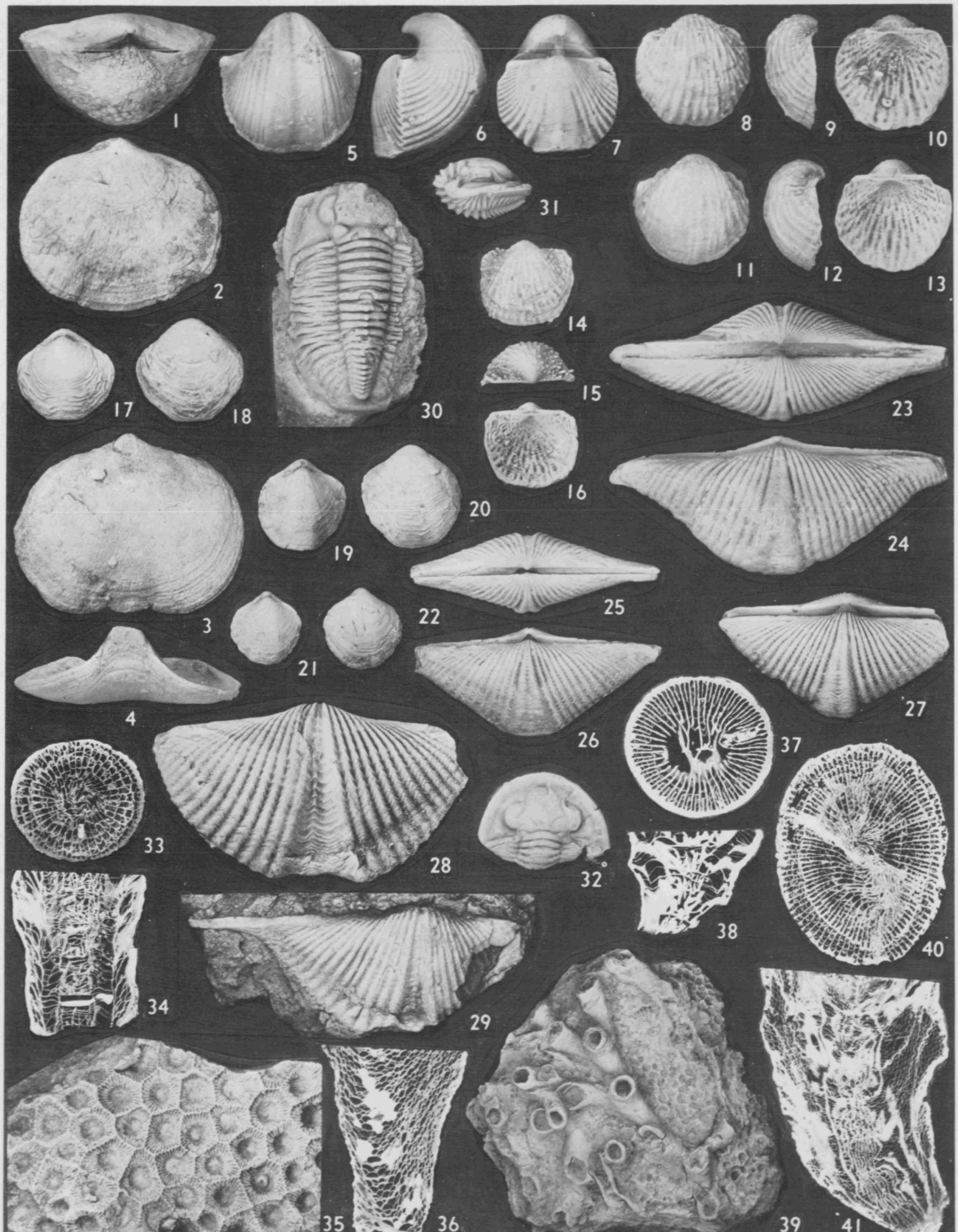
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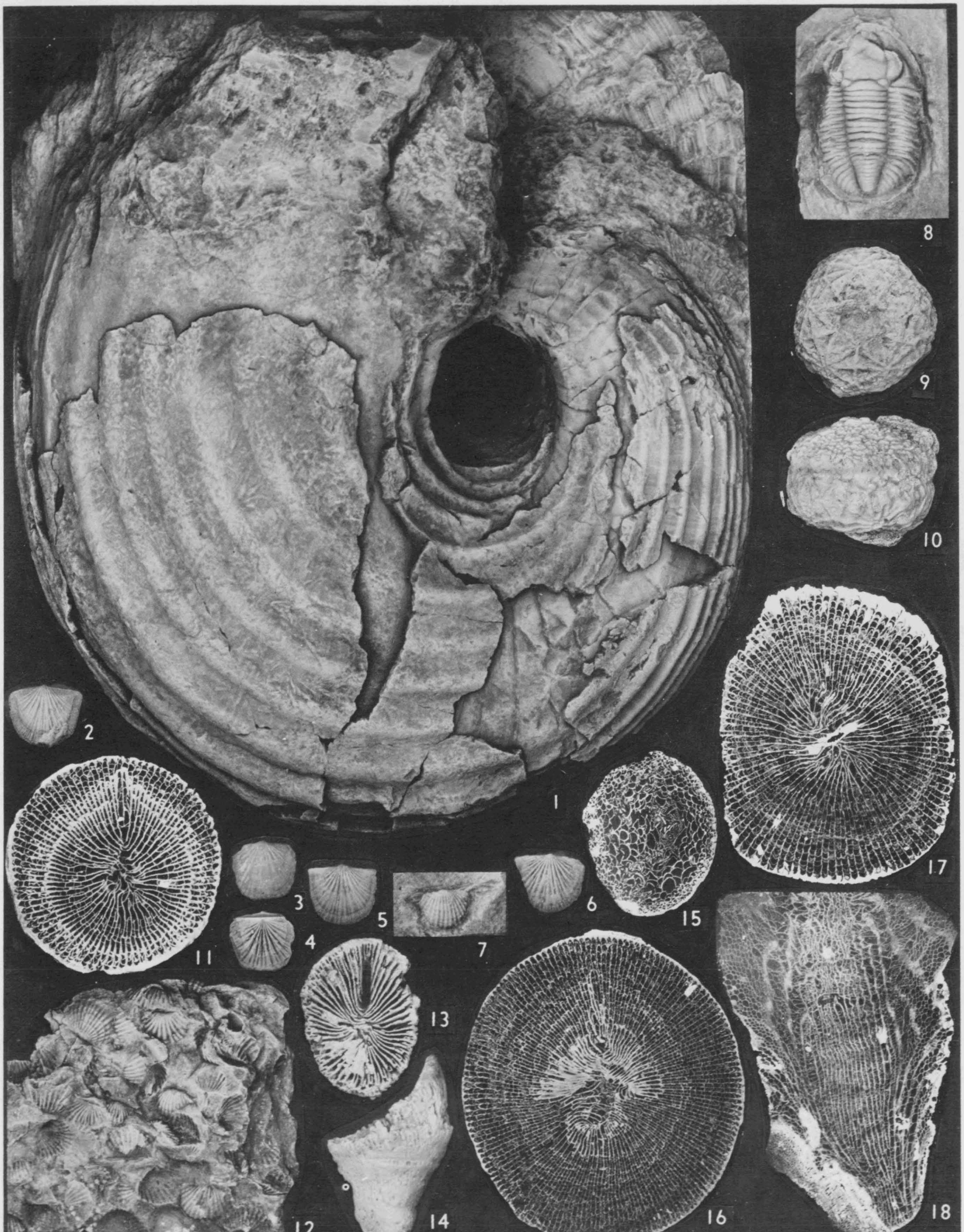
PLATE 22



Ferron Point Formation

10.	Clay, greenish gray, containing numerous Chonetes, Longispina, Mucrospirifer, Strophodonta, and other brachiopods; Chonetes prolific, forming a densely packed surface on certain exposed beds (one cannot cross without crunching hundreds underfoot), several with attached edrioasteroids	16
9.	Shale, gray, calcareous, fossiliferous, extending below water level at the outlet to the pit	3
8.	Covered	5
7.	Shale, gray, calcareous	$\frac{1}{2}$
6.	Limestone, gray	$2\frac{1}{2}$
5.	Shale, gray, calcareous, many heads of the compound coral Hexagonaria in excellent preservation	1
4.	Limestone, gray massive argillaceous bed, weathering yellowish	2
3.	Claystone, bluish gray	2
2.	Limestone, blue-gray, argillaceous	$1\frac{1}{2}$
1.	Claystone, bluish gray, with limestone lenses	9
	Total thickness	$42\frac{1}{2}$

Rockport Quarry Limestone

Limestone, gray, sublithographic, strikingly more resistant than overlying beds. Upper surface locally iron stained.

Fossils. -- The Ferron Point has the diverse mud-flat fauna typical of zone IV and the deeper part of zone III. To date, 61 genera have appeared in literature, and many groups have not received much attention. The macrofauna is particularly rich in articulate brachiopods and tetracorals, many in excellent preservation. No crinoids or blastoids have been found, in contrast to the Bell Shale. The closest generic affinity of the macrofossils (Appendix 2) is found in the overlying Genshaw Formation; and fewer genera are shared with the Rockport Quarry Limestone than with the Bell Shale.

The following species are restricted, insofar as known, to this formation (Appendix 4):

Heliophyllum ferronense Stumm & Tyler
Chonetes nateforma Imbrie (closely akin to C. coronatus)
Longispina lissohybus Imbrie
Pentamerella lingua Imbrie
Phacops rana crassituberculata Stumm
Strophodonta extenuata extenuata Imbrie
S. extenuata fascis Imbrie
S. extenuata ferronensis Imbrie
Hemicystites devonicus Bassler
Lepidodiscus alpenensis Bassler

The distribution of fossils has not been thoroughly investigated, but the following are the results of collecting when the units were not obscured by slump:

Unit	Fossils
10	Hederella, Arthroclema, Helopora inexpectata McNair, Stictoporina granulifera Stewart, Strophodonta extenuata ferronensis Imbrie, Mucrospirifer attenuatus (Grabau), Chonetes mediolatus Cooper, Cyrtina, Michelinoceras sp., Hemicystites devonicus Bassler, Lepidodiscus alpenensis Bassler, Lophonychia cf. cordata Stewart.

Genshaw Formation - Alpena PLATE 22 Figures x 1 except as noted

Genshaw Formation: Lyrioceras hindshawi; 1, #7530.
Alpena: Strophodonta proteus; 2, #57633c; 3, 4, #57633a; 5, #57633b; 6, #57633d. Longispina emmetensis (Gravel Point); 7, #49522; 12, #4134. Basidechenella witherspooni; 8, #56620. Dolatocrinus asterias; 9, 10, USNM S6023. Aulacophyllum hemicrassatum; 11, #35252. A. alpenense; 16, #35257. Heterophrentis simplex alpenensis; 13, 14, #44551. Cystiphylloides alpenense; 15, 35230. Bethanyphyllum geniculatum; 17, 18 #35256.

9 Brachiopods and corals.

6 Hexagonaria, many cup corals, some crinoid columnals.

5 Hexagonaria, Schizophoria ferronensis Imbrie.

4 Atrypa (medium-size), Hexagonaria, cup corals, massive bryozoa.

3 Mucrospirifer prolificus (Stewart), Camarotoechia, fenestellids.

2 Hexagonaria.

1 Abundant: Atrypa, Athyris, Cyrtina, Strophodonta extenuata extenuata Imbrie, Mucrospirifer, large Ceratopora, Pholidostrophia gracilis gracilis Imbrie; common: Hexagonaria, cup corals, dumose Favosites, Aulopora microbuccinata Watkins, Hederella, massive and fenestellid bryozoa, small Cyrtina, Pentamerella lingua Imbrie, Schizophoria ferronensis Imbrie, Strophodonta extenuata extenuata Imbrie; rare: Chonetes mediolatus Cooper, Camarotoechia, Schuchertella crassa Imbrie, Helaspis luma luma Imbrie.

Deposition. -- Localized iron stains atop the uppermost unit of the Rockport Quarry Limestone point to a period of exposure before the basal beds of the Ferron Point were laid down. The uplift must have proceeded evenly, for the Rockport Quarry shows a remarkably consistent thickness throughout the two counties.

No chemical analyses are available, since the Ferron Point is no longer of commercial use, but the ease of weathering suggests that the shales contain very little silica and are low in calcium carbonate. In this they differ from many units in the overlying Genshaw Formation.

Very slow accumulation in relatively clear water is indicated as the conditions for the Chonetes beds in the top unit. These very fragile brachiopods grew in abundance on the mud flats, and edrioasteroids became established upon them. Enough of the blister-like edrioasteroids are recovered in a good state of preservation to show that very little disturbance of the bottom went on during Ferron Point time.

At the termination of the Ferron Point shale deposition, the more calcareous beds of the Genshaw were formed, probably in shallower water.

Genshaw Formation

Name. -- The Genshaw Formation has passed through the throes of several stratigraphic revisions. Grabau (1902, p. 184) placed the lower beds in his "Long lake shales and limestones" and the beds of the black limestone and overlying shales in the Alpena limestone. Ver Wiebe (1927, p. 182) placed the lower units in the "Upper member of Long Lake series"; evidently, he retained the upper units in the Alpena Limestone, for he stated (1927, p. 186), "The lowest layer of the Alpena limestone division ... or the ones immediately above it, can be traced toward the northwest so as to allow a correlation with the section at Killian's ..." Pohl (1930) called the lower units the "Long Lake member of the Presque Isle stage."

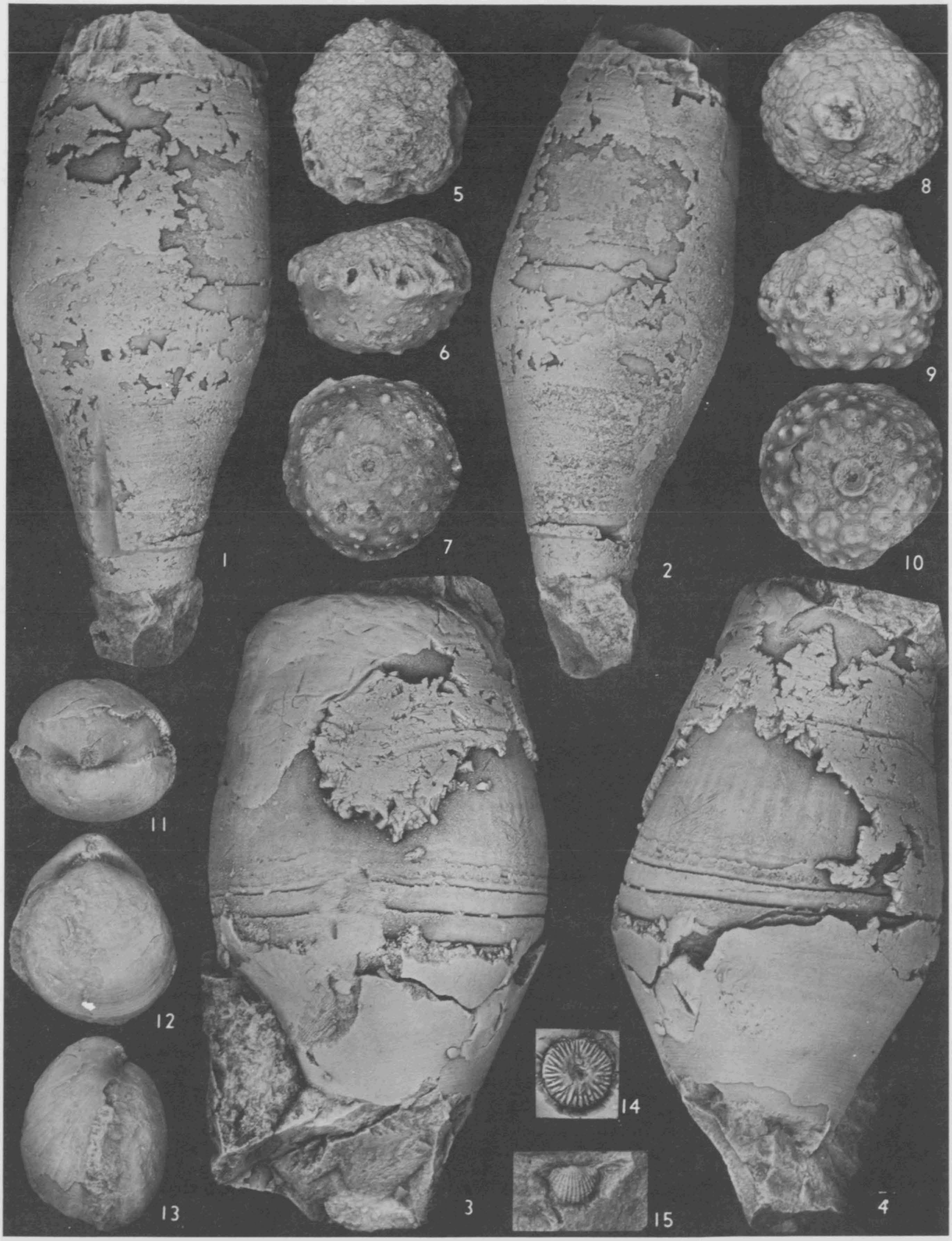
The name Genshaw Formation was created by Warthin & Cooper (1935, p. 526) for strata exposed near Genshaw School (Locality 32-8-13 SE). They included strata between the Ferron Point Formation and their new Killians Limestone. This was followed by the last revision, in which Warthin & cooper (1943, p. 583) extended the upper limit of the Genshaw to the base of the Newton Creek and reduced their Killians Limestone to the status of a member within the Genshaw Formation.

Exposures. -- The type locality is a poor place to study the formation at the present time. Even if the site of the long-vanished Genshaw School can be found, the only outcrops are small exposures in the road bed of Monaghan Point Road where road scrapers chatter the blade on more resistant strata.

Newton Creek - Alpena PLATE 23 Figures x 1 except as noted

Newton Creek: Acleistoceras casei; 1, 2, #10030. A. nummulatum; 3, 4, #10027. Cranaena casei; 11-13, #57603.

Alpena: Megistocrinus sphaeralis; 5-7, #30209b; 8-10, #30209a. Microcyclus alpenensis; 14, #25719. Longispina emmetensis; 15, #49522.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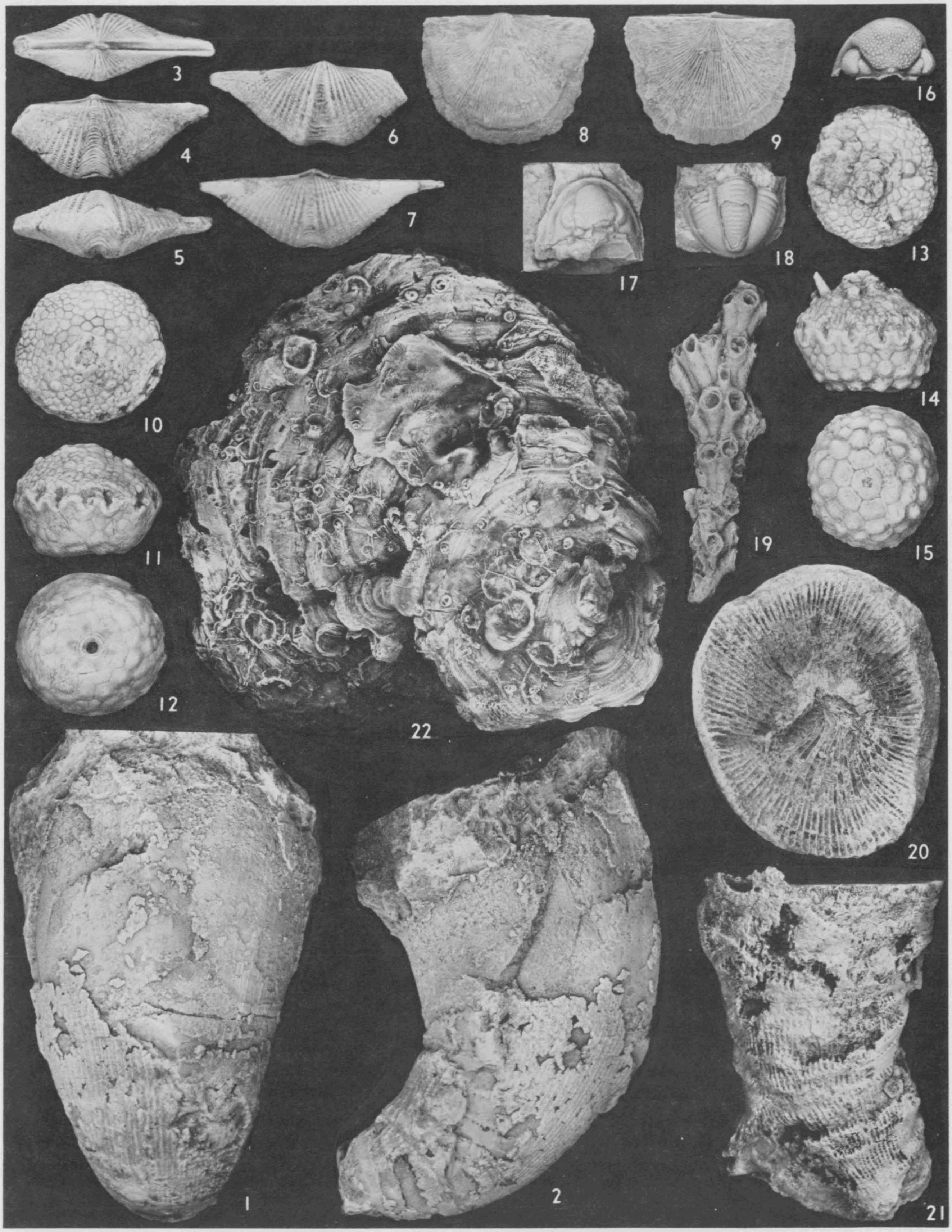
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The composite section pieced together by Warthin & Cooper (1943, p. 58) from exposures at four localities is still the best that can be made:

Section of the Genshaw Formation

(Units 1-6 exposed at the shale pit at Locality 32-9-18 SE; units 5-10 exposed along Long Lake Road at Locality 32-8-22 NE; units 8-13 exposed along French Road at Locality 32-8-8 E; and units 13-15 exposed in the quarry at 31-8-13 W)

	Feet
Newton Creek Limestone	
Limestone, dark brown, crystalline	25
Genshaw Formation	
Upper part	
15. Limestone, gray or light brown; small bioherms in places; first appearance of *Pentamerella tumida*	25
14. Limestone in test pit; not exposed	10
Killians Member	
13. Limestone, dark gray to black, with black shale layers; very resistant, forming cuesta locally but not continuous through area; large white *Mucrospirifer* conspicuous in most exposures, some cephalopods	23
12. Limestone, gray, argillaceous; first appearance of *Helaspis luma crista*	1
11. Shale, gray, calcareous; contains *Cyrtina umbonata alpenensis* and small *Athyris*	6
Lower part	
10. Limestone, gray, granular to semicrystalline	9
9. Shale, gray, calcareous, fossiliferous	8
8. Limestone, gray, granular	3
7. Shale, gray, calcareous, similar to unit 9: fauna dominated by large *Atrypa*, *Sieberella romingeri*, *Billingsastrea pauciseptata*, *B. romingeri*, *Schizophoria striatula traversensis*, *Hexagonaria* sp., and *Clathyrodictyon* cf. *retiforme*	5
6. Limestone, gray, argillaceous, massive	3
5. Shale, gray, calcareous	1
4. Limestone, gray, argillaceous, massive	3
3. Shale, gray, calcareous; first appearance of *Sieberella romingeri*	14
2. Limestone, gray, argillaceous	$\frac{1}{2}$
1. Shale, gray, slightly calcareous	5
Total thickness	116 $\frac{1}{2}$
Ferron Point Formation	
Clay, greenish gray, containing numerous *Chonetes*, some with attached edrioasteroids	16

Newton Creek - Alpena — PLATE 24 — Figures x 1 except as noted

Newton Creek: *Nephriticerina alpenensis*; 1, 2, #10029.

Alpena: *Mucrospirifer thedfordensis*; 3-6, #44112. *M. latus*; 7, #31642. *Strophodonta micropleura*; 8, 9, #57601. *Megistocrinus regularis*; 10-12, #30208a; 13-15, #30208b. *Phacops rana alpenensis*; 16, #25438. *Basidechenella pulchra*; 17, #28680. *Crassiproetus micrograntulatus*; 18, #27080. *Aulocystis fenestrata*; 19, #34936. *Tortophyllum cysticum*; 20, 21, #47097. *Leptalosia radicans*; 22, #17059.

Many other exposures are known, most of them part of the resistant Killians Member. In the eastern parts of the two counties, several outcrops occur beside Long Lake Road: lower units are found at Locality 32-8-22 NE and Locality 32-8-5 SW in ditches, and at a few places in between, as in excavations for houses; the Cyrtina bed (unit 11) is found at Locality 33-8-31 E; and the Killians black limestone at Localities 33-7-36 N and 33-7-36 NW.

The lower units (1-11) are exposed at several places: along US 23 at the southeast end of Long Lake (32-8-11 SE), on Maple Grove Road near the junction with US 23 (32-8-15 S), along US 23 near the northeast end of Long Lake (33-8-29 NE), beside East Grand Lake Road (33-8-34 SE, 33-8-35 NW and on Rabiteau Farm, 32-8-3 E), on North Point Road (31-9-16 NE), along US 23 and in bed of Swan Creek (34-6-17 NW), along Posen Road or M 65 (34-6-33 NE), in a road cut 5 miles southwest of Rogers City (34-5-8 NW), on CO 451 (34-5-8 E), and on Bloom Road (32-9-31 N). The Cyrtina bed crops out beside Grand Lake Road at Locality 33-6-9 N; they were also exposed by bulldozing and pole-hole drilling for a power line at 32-8-26 E, but the fine collecting was soon overcome by vegetation. Some exposures of the lower Genshaw are not alongside roads and require some hiking; these include the long abandoned quarry of the El Cajon Cement Company (31-9-10 NE), a test pit northeast of Lakewood (32-8-2 NE), the bottom of Devil's Lake (32-8-23 SE, exposed only in dry season), and the south shore of Hell Creek (32-8-24 NE).

Outcrops of the Killians are more conspicuous, particularly where the cuesta is cut through by a roadway. This middle part of the Genshaw is available along Bloom Road (Locality 32-8-25 SE), on Wessel Road (32-8-25 SW), on Grand Lake Road (33-6-9 NNW), on CO 638 (34-5-20 NE), south-southwest of Rogers City (34-5-8 SE and 34-5-7 S). At some of these localities the cuesta extends for some distance.

The upper units (14-15) are much softer than the Killians, but are intersected at several localities. One of the interesting exposures is in a deep hole at El Cajon Bay (Locality 31-9-15 SW); this structure is at the head of Misery Bay, formerly known as Little Thunder Bay. It was known to Rominger, who wrote in 1876 (p. 49):

> Little Thunder Bay is a deep recess in the coast ... Its entrance is very shallow, not always deep enough to admit a Mackinaw boat. The head of the recess is formed by a large sinkhole, which in the middle has a depth of 100 feet. A semicircle of rocky bluffs of from 25 to 30 feet elevation surrounds this deep pot-hole ...

Grabau (1902, p. 168) was also familiar with this feature and called it a sinkhole. As Warthin & Cooper (1943, p. 576) pointed out, however, this hole discharges a considerable volume of water, like the great springs of Florida, and may not be a true sinkhole. In this it is in sharp contrast to Devil's Lake (Locality 32-8-23 SE), which in summer can draw off all the flow from Long Lake, leaving the normal drainage channel of Hell Creek as a dry valley. Upper beds are also exposed along Hincka Road at its intersections with Grand Lake Road (33-6-9 NW) and with Metz Highway (33-6-4 NW), the latter bearing a multitude of small Athyris nicely preserved and many of a peculiar bluish cast.

In western Presque Isle County, the Genshaw reaches a thickness of 150 feet, much of the increase being in the Killians Member. Road cuts through the Genshaw in this area lie on Allis Road (35-2-21 NE), M 68 (35-3-24 S), and Ocqueoc Road (35-3-33 NW). In addition discontinuous exposures can be found along the banks of Rainy River and Ocqueoc River.

Composition. -- The Genshaw is not used commercially, but it has been explored to some degree because it lies just below the valuable Newton Creek and Alpena Limestones. Just after the turn of the century a well was drilled in section 6, T 31 N, R 9 E; the following is a chemical and stratigraphic analysis of strata from this well:

Miscellaneous Formations — PLATE 25 — Figures x 1 except as noted

Alpena: Cystiphylloides alpenense; 1, 2, #44297.
Four Mile Dam: Cylindrophyllum magnum; 3, 4, #25642. Aulacophyllum hemicrassatum; 5, #46390. Eridophyllum archiaci; 6, 7, #23861. Depasophyllum adnetum; 8, 9, #18808; 10, #26190. Heliophyllum halli; 11, 12, #35260. H. elongatum; 13, 14, #35258. Atelophyllum magnum; 15, 16, #8610. Elytha fimbriata; 17, #57611c; 18, #57611b; 19, 20, #57611a, 20 x4. Tabulophyllum traversense; 21-23, #35242.
Thunder Bay: Cylindrophyllum grabaui; 24-26, #25671. Bethanyphyllum geniculatum; 27, #8571, x0.8. Synbathocrinus cf. matutinus; 28, #57632.

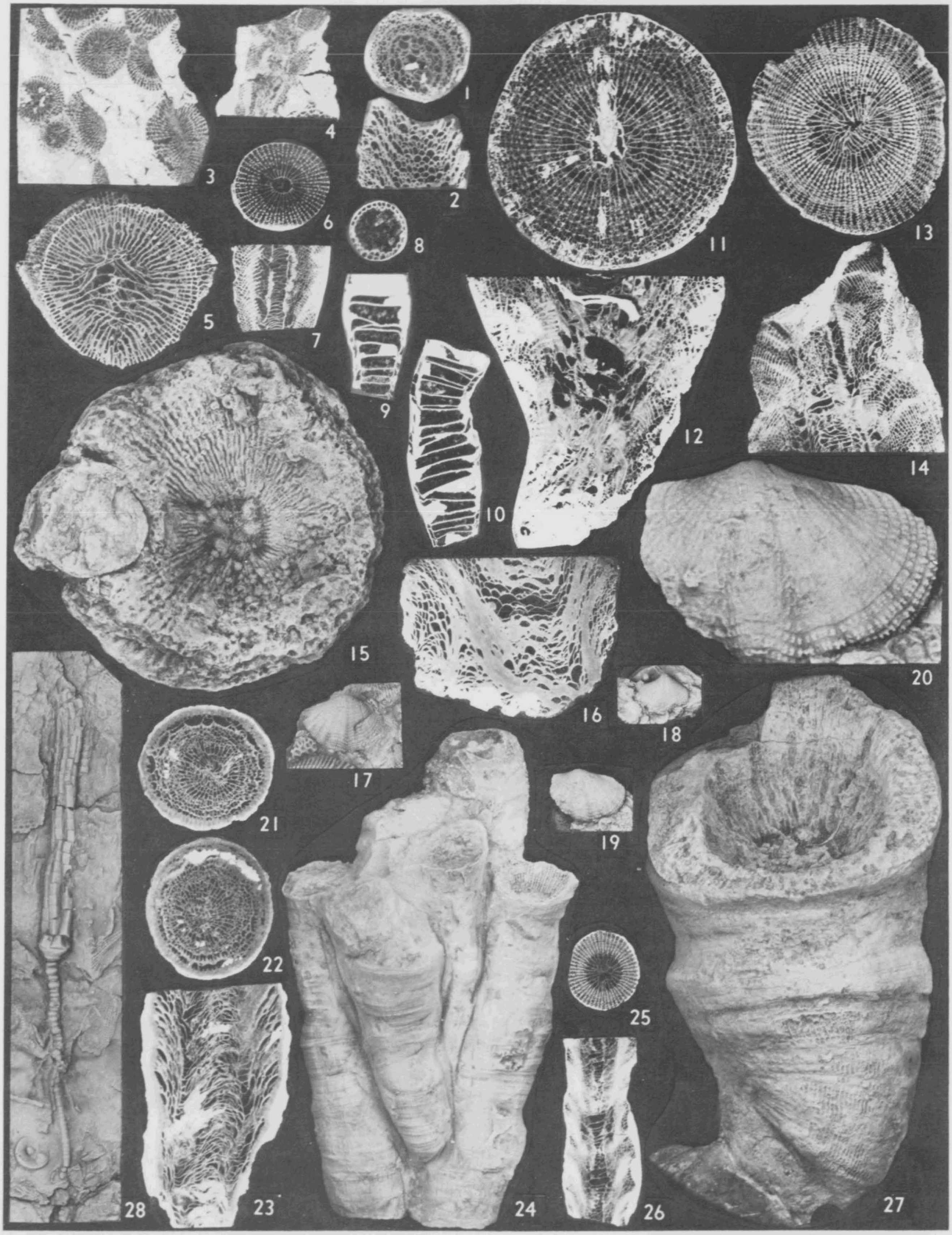
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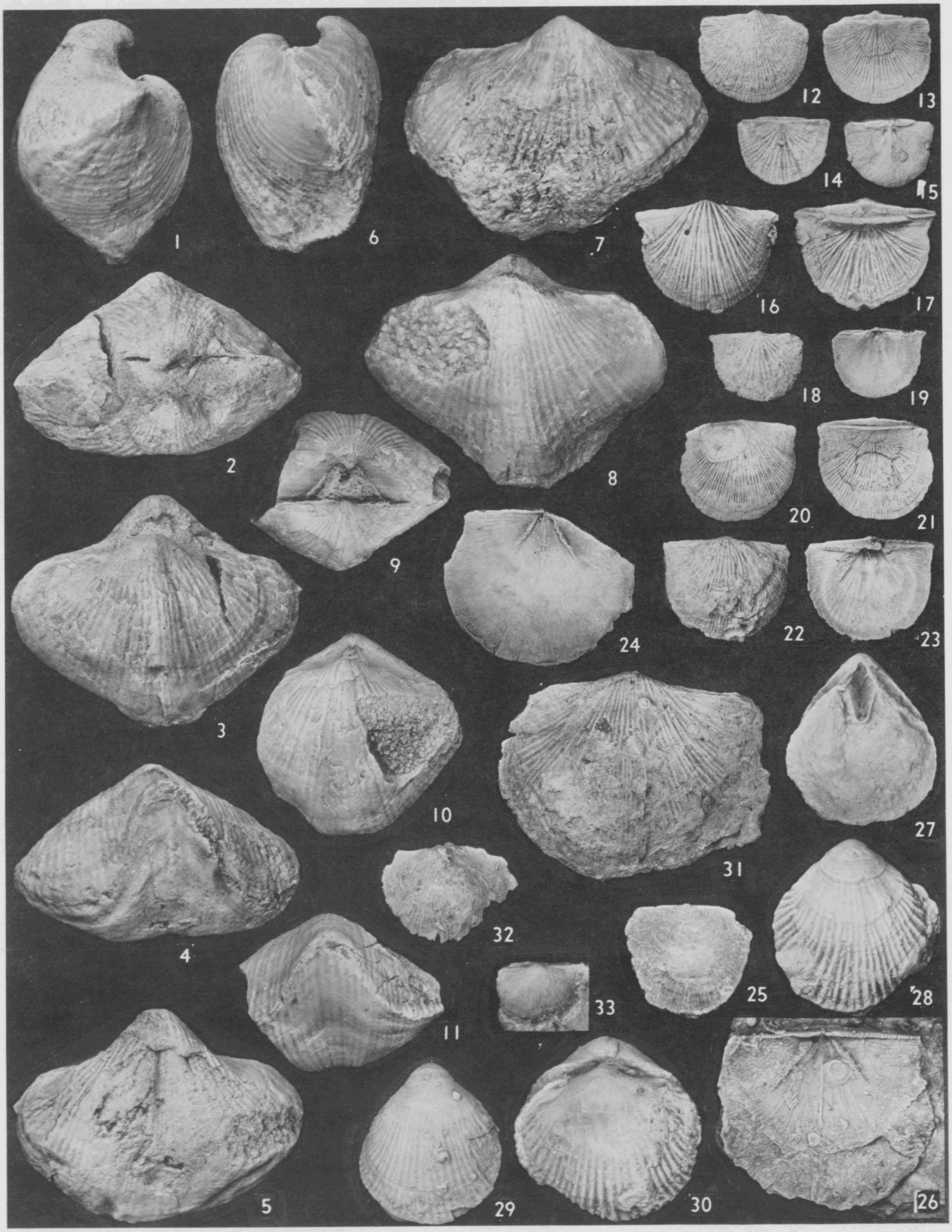
PLATE 26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Formation	Depth (feet)	$CaCO_3$	$MgCO_3$	Al_2O_3, Fe_2O_3	SiO_2	S
Lower Alpena	0-5	92.32	1.78	3.19	2.32	.100
	5-10	93.00	1.51	2.19	2.58	.083
	10-15	93.77	1.28	1.57	2.38	.086
Newton Creek	15-20	97.93	1.87	.63	.68	.152
	20-25	93.60	3.34	1.81	1.34	.146
	25-30	94.26	3.65	.90	.62	.073
	30-35	96.08	1.47	.77	.70	.072
Upper Genshaw	35-40	87.64	2.35	4.83	4.16	.140
	40-45	93.00	2.39	1.92	1.80	.141
	45-50	91.40	2.56	2.42	2.82	.121
	50-55	89.25	2.39	4.74	3.80	.135
	55-60	89.25	1.93	4.58	3.12	.127
	60-65	91.32	1.57	2.13	2.10	.140
	65-70	93.60	1.51	2.09	1.62	.123
	70-75	94.82	2.46	1.93	1.38	.109
Killians Mbr.	75-80	78.47	3.27	7.94	10.90	.148
	80-85	28.24	5.79	29.02	32.72	.150
	85-90	26.42	6.44	25.88	35.24	.229
	90-95	83.83	2.39	5.32	8.34	.207
	95-100	66.43	3.82	10.33	17.26	.204
Lower Genshaw	100-105	91.54	3.34	1.98	3.54	.208
	105-110	92.22	3.13	2.78	5.74	.131
	110-115	86.72	3.63	3.78	6.48	.133
	115-120	84.17	2.39	1.98	10.40	.138
	120-125	68.27	2.20	5.41	21.98	.162
	125-130	59.07	2.39	8.71	27.54	.206
	130-135	56.92	2.94	9.52	26.44	.193
	135-140	67.10	3.13	7.30	22.00	.139
	140-145	72.06	2.50	5.76	19.62	.106

This analysis shows clearly that the resistant beds of the Killians contain remarkable amounts of both clay and silica; in fact, the silica exceeds the calcium carbonate, casting some doubt on the use of the term "limestone" for this lithology. The soft upper beds begin with a sudden decrease in silica and clay, and the Newton Creek shows further decrease in these constituents. Not all of the lower Genshaw units were penetrated by this well, and the section evidently ends somewhere in unit 3. The lower Genshaw has a surprising amount of silica, considering its susceptibility to erosion; the chief difference between some of the beds in about units 4-8 and the Killians limestone is in the greater percentage of clay in the latter. Evidently, the combination of low-calcium, high-clay, and high-silica produces a resistant rock.

Fossils. -- More than any formation yet discussed, the Genshaw Formation can be divided into faunal zones. The first may be termed the Sieberella romingeri-large Atrypa zone; it attains its best development in unit 7. In the lower part of the zone, Billingsastrea pauciseptata and B. romingeri are conspicuous but not numerous elements. A stromatoporoid Clathyrodictyon cf. retiforme occurs in the zone, normally encrusting brachiopods (particularly the rotund Atrypa) to form a subspherical "cannon ball." The large Schizophoria striatula traversensis is another part of this fauna. The brachiopods are associated with large solitary corals at several localities.

Four Mile Dam — PLATE 26 — Figures x 1 except as noted

Fimbrispirifer venustus; 1-5, #26334 (Hungry Hollow); 6-8, #57619a; 9-11, #57619b. Strophodonta sp.; 12, 13, #57612e; 14, 15, #57612c; 16, 17, #57612a; 18, 19, #57612d; 20, 21, #57612f; 22, 23, #57612b. Protoleptostrophia lirella; 24, #57617b; 25, #57617c; 26, #57617a. Pentamerella alpenensis; 27, #57614c; 28, #57614a; 29, #57614d; 30, #57614b. Megastrophia gibbosa; 31, #57616. Schuchertella anomala; 32, #57618. Douvillina distans; 33, #57613.

The second faunal zone is the Cyrtina umbonata alpenensis zone, restricted to unit 11. In this readily weathered shale, great numbers of "perfect" specimens can be collected. A small Athyris also occurs in appreciable quantity, and a few other brachiopods are present. The third is the big Mucrospirifer zone, limited to the Killians Member. In this zone the fossils show up as shiny white against the black matrix, but closer inspection reveals that the preservation leaves much to be desired. Imbrie reported (1959) that Helaspis luma crista occurs in the transition beds below and in the black limestone. In the western area, around Black Lake, Kelly & Smith (1947, p. 453) reported that the big Mucrospirifer appeared first in the transition strata and that a breviconic cephalopod (provisionally assigned to Gomphoceras) was associated with it in the hard black Killians beds.

The fourth zone, not yet identified in the Black Lake region, is the Pentamerella tumida zone. This brachiopod continues upward into the Newton Creek Limestone. In the soft argillaceous limestones of units 14 and 15, the Pentamerella is found with some other brachiopods as well as other kinds of invertebrates.

Over all, to judge from published articles, the Genshaw has the most prolific fauna of any Traverse Group formation -- 83 genera. These are dominated by corals and brachiopods, with a few molluscs and echinoderms present. Of the 43 species which have been identified, the following are found in no other Traverse Group formation:

Billingsastrea pauciseptata Ehlers & Stumm
B. romingeri Ehlers & Stumm
Lythophyllum alpenense Stumm
Aulocystis alectiformis reptata Watkins
A. fenestrata problematica Watkins
Favosites alpenensis hindshawi Swann
F. alpenensis killiansensis Swann
Cyrtina umbonata alpenensis Hall & Clarke
Helaspis luma crista Imbrie
Mucrospirifer multiplicatus (Grabau)
Schizophoria striatula delta Grabau
S. striatula traversensis Grabau
Schuchertella cornucopia Imbrie
Sieberella romingeri (Hall & Clarke)
Strophodonta acris Imbrie
S. extenuata Imbrie
S. extenuata genshawensis Imbrie
S. titan costella Imbrie
Lyrioceras hindshawi (Ehlers & Hussey)
Pentremitidea ovalis michiganensis Reimann
P. preciosa Reimann.

The following species are known to occur in the assigned units:

Unit	Fossils
13.	Mucrospirifer (large), Stromatopora (smooth), Favosites alpenensis killiansensis Swann, F. digitatus Rominger, Strophodonta cf. erratica Winchell, Pholidostrophia gracilis gracilis Imbrie, Dentalium (3-inch), Lyrioceras hindshawi (Ehlers & Hussey)
11.	Cyrtina umbonata alpenensis Hall & Clarke, Mucrospirifer (large), Strophodonta cf. erratica Winchell, Sieberella romingeri (Hall & Clarke), Strophodonta cf. extenuata Imbrie, Helaspis luma crista Imbrie, Atrypa (large), Athyris (small)
10.	Atrypa (large), Cyrtina umbonata alpenensis Hall & Clarke, Sieberella romingeri (Hall & Clarke), Atrypa (small, cf. A. reticularis, numerous), Athyris
9.	Aulopora gregaria Watkins, Hexagonaria, Favosites alpenensis hindshawi Swann, Cyathophyllum, Atrypa (large), Sieberella romingeri (Hall & Clarke), Spinocyrtia, Athyris cf. fultonensis (Swallow), Schizophoria traversensis Grabau, Cyrtina umbonata alpenensis Hall & Clarke, Strophodonta acris Imbrie, Helaspis luma crista Imbrie, Schuchertella cornucopia Imbrie
8.	Hexagonaria (large, thin coralla), Pholidostrophia gracilis gracilis Imbrie, Atrypa (large), Schizophoria traversensis Grabau, Helaspis luma crista Imbrie, Spinocyrtia
7.	Sieberella romingeri (Hall & Clarke), Hexagonaria, Billingsastrea pauciseptata Ehlers & Stumm, Atrypa (large), Schizophoria traversensis Grabau, Clathyrodictyon
6.	Hexagonaria (large, thin coralla), Atrypa, Schizophoria traversensis Grabau, Sieberella romingeri (Hall & Clarke), Schuchertella cornucopia Imbrie
5.	Atrypa (large), Mucrospirifer, Strophodonta extenuata genshawensis Imbrie, Pholidostrophia gracilis gracilis Imbrie
4.	Hexagonaria, Atrypa (large), Sieberella romingeri (Hall & Clarke), Helaspis luma crista Imbrie, Pholidostrophia gracilis gracilis Imbrie
3.	Atrypa (large), Sieberella romingeri (Hall & Clarke), Spinocyrtia, Cyrtina, Pholidostrophia gracilis gracilis Imbrie, Schuchertella cornucopia Imbrie, Pterinea, Arthroclema.

Deposition. -- The Genshaw Formation contains examples of more types of deposition zones than any other Traverse Group formation, although this is not apparent with the first glance at exposures. The lower eleven units are a series of alternating calcareous shales and argillaceous limestones of varying composition and hardness. They were deposited under several depths of water. While inspecting an outcrop freshly exposed by ditching along M 65, Professor Lecompte pointed out one bed in which the large corals were overturned in place and specimens were broken and worn; he pronounced it an excellent example of his zone of turbulence. Such beds are rarely seen in the Genshaw, however, and most show evidence of deeper and quieter water.

The Sieberella romingeri-large Atrypa zone is typical of the upper limit of zone III. In addition to large brachiopods, there are some corals. This is nearly the lower limit of the stromatoporoids, and the Clathrodictyon grows in small bodies, often forming spheres around the nucleus of a brachiopod. These "cannon balls" probably attained their shape by current movement. Some beds contain more clay and produce a more diverse fauna with bryozoa taking the place of the corals.

The Cyrtina umbonata alpenensis zone is found in a soft shale. The abundance of small brachiopods is typical of zone IV.

Several features of the black Killians Member need interpretation, especially as they occur in combination: low calcium, high silica, high carbon, considerable clay, and invertebrate fauna. The silica and aluminum oxide are both very high as compared with the underlying and overlying beds; inasmuch as we cannot find chert or quartz sand in the rock, it seems that the silica is incorporated in siliceous clay. The proportions of aluminum oxide and silica suggest that the clay element is beidellite, one of the common siliceous clays in marine shales. Such clays form today under conditions of prolonged decomposition, which also favor leaching of calcium; common source areas are low-lying land areas.

Black shales are considered indicative of tranquil water, poor circulation, and oxygen deficiency. In such currentless Paleozoic seas, stagnation appears to have precluded marine life or to have produced dwarfed faunas. Yet the brachiopods in the Killians are so widespread and disseminated through the unit that they must be regarded as inhabitants of the environment; they do not show dwarfing, but the fauna is limited to few species. Evidently, some brachiopods could adapt to the inhospitable conditions in the cul de sac of the sea in which Killians black siliceous clay was being deposited. The situation may have been comparable to that in which the Antrim Shale was laid down, but with enough oxygen present to support certain brachiopods. In terms of zones of deposition, this seems to have been a variety of the lagoonal. The carbon may have been brought in by drainage from extensive low swampy regions and deposited not far from shore.

It is possible that the siliceous fraction in the Killians beds was not in the form of a siliceous clay when it was transported. In his Treatise on Sedimentation (1932, p. 512) Twenhofel stated, "Studies of river waters have shown that rivers high in silica are also high in organic matter; ... this seems to be caused by the organic matter serving as a stabilizer to prevent the silica from being precipitated ... Evidently the silica contributed by streams is precipitated almost immediately on arriving at the sea, where it becomes mingled with sediments of all kinds, thus entering into shales, limestones, etc."

Conditions leading to the resistant beds built up gradually, for the beds below show progressive increase in darkness of color. The end of Killians sedimentation was not marked by any distinguishable unconformity, and the greater thickness of this member toward the west may be attributed to more rapid deposition. The upper Genshaw strata are generally like those of the lower part of the formation in lithology and in general kinds of animals in the fauna, although there was an introduction of some new species and disappearance of old ones. The upper units, 14 and 15, seem to be products of increased circulation and aeration; the carbonaceous matter was either eliminated from the supply of sediment or oxidized in the zone of deposition.

Newton Creek Limestone

Name. -- In 1941 (p. 260) Cooper & Warthin proposed the name for the brown, bituminous, crystalline limestone exposed near the base of the Michigan Alkali Company Quarry at Alpena. They stated that "The formation abounds in large brachiopods: Cranaena, Pentamerella, Camerophoria, and Charionella." Previously this 25-foot bed had been included in the Alpena Limestone, as is discussed below under that formation. Newton Creek is a small stream flowing across section 13, in which the type section is exposed in the quarry.

Later, Warthin & Cooper (1943, p. 584) discussed the strata from the base of the Killians to the top of the Alpena Limestone. They stated, "On gross lithology alone it would be desirable to place this mass under a single formation name, but since it contains three distinct units with different faunas and geographic distribution such a correlation would lead only to confusion." Their decision to set off the Newton Creek from the underlying Genshaw and the overlying Alpena Limestone was wise, for it is not related to them genetically. They are open sea deposits in normal aerated marine waters, whereas the Newton Creek is a lagoonal limestone deposited in waters of little or no circulation.

Exposures. -- Outcrops of this formation are rather limited because it does not stand up under weathering. Nevertheless, the Newton Creek has been identified by its peculiar lithology as far west as Cheboygan County, Michigan.

Knowledge of the vertical extent of this limestone has been gained at the type exposure, where the following section is seen in the walls of the Huron Portland Cement Company Quarry:

Section of Newton Creek Limestone at the Type Locality in the Huron Portland Cement Company Quarry, Locality 31-8-13 W

	Feet
Alpena Limestone	
2. Limestone, white to light gray, massive	20
1. Shale, black, bituminous, not continuous in quarry	1
Newton Creek Limestone	
Limestone, dark brown, crystalline, petroliferous odor when freshly broken; fossils scattered through formation, consisting of large brachiopods and cephalopods, some with color markings	25
Genshaw Formation	
Limestone (above Killians Member), gray to buff; some small bioherms reported; forms floor of part of quarry and is exposed in drainage ditch near crusher	25

The Newton Creek is very conspicuous in the quarry walls, its very dark color in sharp contrast to the white limestone above. It is notably uniform from base to top.

Small exposures occur just east of the quarry. At Locality 31-9-6 SE, the beds are near the top of the formation and the Alpena Limestone outcrops nearby. Another small roadside outcrops at 31-9-5W, stratigraphically near the middle of the formation.

In northern Alpena County, near the junctions of Melville and Maple Lane Roads, at Locality 32-7-11 NW, the largest sinkhole complex shows the contact of the Newton Creek and Alpena Limestones. The lower strata around the edges of the sink produce a strong petroliferous odor when struck with a hammer; the upper strata do not.

Presque Isle County contains three exposures. The most extensive is about one mile east of Posen, at Locality 33-6-14 NW, where strata outcrop in an open field and in roadside ditches. Here the Newton Creek can be recognized by the strong petroliferous odor. Weathering has leached the rock to a light gray, but the interior of each piece still retains the brown color typical of the strata at the type locality. The exposure consists of an estimated 2 feet of irregularly bedded limestone.

Other exposures, less leached, occur about 3/4 mile west of Posen at Locality 33-6-16 NE and along Long Lake Road at Locality 33-7-30 SE.

Composition. -- For many years the Michigan Alkali Company quarried the Newton Creek Limestone and the lower limestone of the Alpena as one unit and the upper limestone of the Alpena as another, utilizing the 1-foot shale unit as a natural zone of separation and scraping a ledge top in this soft stratum. Now the Huron Portland Cement Company, which uses all of their output for cement, has abandoned this selective quarrying and blasts the wall through both Newton Creek and Alpena Limestones. As the following four analyses show, the Newton Creek Limestone is markedly low in silica and in iron and aluminum oxides, in contrast to the overlying beds of the Alpena Limestone:

	Locality	$CaCO_3$	$MgCO_3$	Al_2O_3, Fe_2O_3	SiO_2	S
5 ft. below top	31-8-13 W	95.40	1.44	.60	.70	.23
12 ft. below top	31-8-13 W	97.62	.58	.66	.18	.22
Near middle	31-9-5 W	97.62	.60	.42	.38	.06
Near top	31-9-6 SE	97.01	.65	.62	.88	.13
Average		96.91	.82	.58	.54	.16

Fauna. -- The recorded Newton Creek invertebrates are rather few, consisting of one genus of tetracoral, 2 genera of tabulate corals, 5 of brachiopods, 1 trilobite, and 4 genera of molluscs (Appendix 1). Few genera are shared with other Traverse Group formations (Appendix 2); in fact, the underlying Genshaw Formation has only 8 genera in common with the Newton Creek, but has 26 in common with the Alpena Limestone. Most of the fossils consist of cephalopods and large brachiopods. The cephalopods were described many years ago by Foerste.

Although specimens are not plentiful, the Newton Creek Limestone has yielded color-marked individuals of the cephalopod Michelinoceras anguliferum alpenense (Foerste) and the brachiopod Cranaena casei Foerste. The cephalopod was marked with red stripes in a sharply zig-zag pattern, and the brachiopod with dark concentric bands.

Deposition. --- Poor circulation of water is indicated by the retention of hydrocarbons in the rock. These produce a strong petroliferous odor when the rock is broken, as stated above, and form an oily film on some of the specimens obtained from the formation. The Newton Creek was laid down with much less clay and silica than either the underlying Genshaw or the overlying Alpena Limestone. It seems inescapable that the limestone was deposited in a body of water cut off from active circulation with the open sea; in other words, it represents sediments in a lagoon.

In 1932, when he described the color markings mentioned above, Foerste made some observations which were remarkable for that time and still contribute to our understanding of paleoecology. He wrote (p. 145-146):

> ... there evidently is an intimate connection between the presence of color markings on shells and their access to light during the life of the animal... [In] shallow waters shells present more varied colors and more distinct color designs. At greater depths the colors tend to become uniform over the entire surface of the shell, so that color patterns disappear... In the Mediterranean only 1 out of 18 shells showed colors below the 100-fathom line; ... at depths of only 2 fathoms or less, more than half [showed color markings] ... It seems probable that the portion of the Alpena limestone [now Newton Creek] which retained color markings in a species of cephalopod and also in a species of brachiopod was deposited in relatively shallow waters.

Alpena Limestone

Name. -- The Alpena Limestone was named by Grabau in 1902 (p. 175), who termed it the "Traverse middle limestone." The sections studied by Grabau were in the neighboring quarries of Owen Fox and Richard Collins. There is some question about the exact location of these small quarries, operated for a short time to burn lime. According to Warthin & Cooper (1943, p. 585), the first was superseded by the Thunder Bay Quarries Company workings, now abandoned, at Locality 31-8-14NE; and the second was greatly expanded by the Michigan Alkali Company (now operated by the Huron Portland Cement Company) at Locality 31-8-13 W. This does not agree with the statements by R. A. Smith (1916, p. 179), who described the Richard Collins Quarry as "a small quarry operated for lime burning about two miles north of the Michigan Alkali Company's quarry. The opening is in dense, light gray, fragmental reef-limestone ..."; he further placed this quarry (p. 272) in sec. 12, T 31 N, R 8 E. If the distance and location are correct, the Collins Quarry was in the NW$\frac{1}{4}$ of section 12. Smith also described Owen Fox's Quarry (p. 179) as located about 2 miles north and slightly west of the Michigan Alkali Company Quarry, stating that the general dip is 4 degrees to the south, with steeper dips at the eastern end of the quarry where abundant corals indicate nearness to a reef; he located the Owen Fox Quarry further (p. 272) as "across road from Collins quarry." The general dip reported by Smith would favor the location of the Owen Fox Quarry in the NE$\frac{1}{4}$ of section 11. Wherever the old quarries were situated, most of our information on the Alpena Limestone is derived from the rocks exposed in the Huron Portland Cement Company Quarry and the abandoned Thunder Bay Quarry. These large quarries lie on the eastern edge of Alpena, where Wessel Road is left as an unquarried high backbone between them.

When Crabau named the formation, only 25 to 35 feet of the section were exposed. At the same time (1902, p. 192), he named the overlying strata the Dock Street Clay.

Through the years the limits of the Alpena were extended above and below. Ver Wiebe redefined the Alpena in 1926 (p. 185-187), extending it down to include a hard black limestone which is now classed as the Killians Member of the Genshaw Formation. In the stratigraphic revisions of Warthin & Cooper in 1935, they set off the black limestone as the Killians Limestone, which lay above their new Genshaw Formation; but regarding the upper limit of the Alpena, they stated (p. 526), "The Dock Street clay of Grabau is a local clay facies of the upper Alpena horizon." Thus the Alpena at that time came to include all strata between the Killians Member of the Genshaw and the limestones above the Dock Street Clay Member of the Four Mile Dam.

The next important changes came in the publication of Cooper & Warthin in 1941. For the brown bituminous limestone in the lower part of the big quarry (then the Michigan Alkali Quarry) they proposed the name Newton Creek Limestone. They did not, however, make any disposition of the strata between their earlier Killians Limestone and their new Newton Creek Limestone. In the same paper they created the Four Mile Dam Limestone for the bioherm just under the Norway Point Formation, but did not include the Dock Street Clay in it.

The present classification of the Alpena Limestone dates from the work by Warthin & Cooper in 1943. The significant revision was the removal of the Dock Street Clay to be a member of the Four Mile Dam Formation (p. 588). Thus, through expanded and reduced coverage, the Alpena Limestone has come to apply to 79 feet of strata in the type section.

Exposures. -- The type section in the Huron Portland Cement Company Quarry is still the only complete section available. The limestone is reported here and there in the western part of the area included in this guidebook, where it occurs in the walls of sinkholes. Of the numerous exposures in the eastern part of the area, most occur as low mounds over bioherms.

Another quarry, abandoned before 1915, which utilized the Alpena Limestone was the M. J. Griffin quarry at Locality 32-7-5 SW. Actually, this was several small pits in close proximity. The exposed strata measure only about 8 feet. The lower beds are dark and argillaceous. They are overlain by a 6-inch bed of densely packed brachiopods. The top is crinoidal, light-colored, and yielding numbers of large camerate crinoids. The rocks appear to be flank beds close to a bioherm.

Two other small quarries, abandoned when mentioned by R. A. Smith in 1916, lie just east of the Huron Portland Cement Company Quarry east of Alpena. The larger, the Alpena Portland Cement Quarry (water-filled in 1915), is at Locality 31-9-18 SW; a bioherm was exposed on the south wall, and other strata dipped away from it. The smaller, the Gilbert Olson Quarry, is at Locality 31-9-18 S; it likewise involved biohermal limestone.

Section of the Alpena Limestone at the Type Locality in the Huron Portland Cement Company Quarry, Locality 31-8-13 W

	Feet
Four Mile Dam Formation	
Dock Street Clay Member, mudstone, bluish gray, calcareous, fossiliferous with Depasophyllum adnetum Grabau, the crinoids Dolatocrinus, Megistocrinus, Halysiocrinus, Synbathocrinus, and an undescribed Gennaeocrinus, as well as excellently preserved brachiopods, including many of the genera listed in Appendix 1.	7
Alpena Limestone	
4. Limestone, white, light gray, or light brown, containing many bioherms; extremely variable composition; crinoids Dolatocrinus and Megistocrinus abundant only at bioherm edges; brachiopod-coral fauna in inter-bioherm facies. . . .	57

PLATE 27

1, 2 - Alpena Limestone, bioherm edge showing steeply inclined and pinching flank beds and irregular and discontinuous traces of bedding in core rock; old Michigan Alkali Quarry. Loc. 31-8-13 W.

3, 4 - Newton Creek and Alpena Limestones in quarry walls and upper Genshaw Formation on floor and in drainage ditch of Huron Portland Cement Company Quarry; 3, view from Wessel Road; 4, view from within the quarry. Same locality.

5 - Alpena Limestone at old Bolton Quarry; white spots are crinoid heads. Loc. 32-7-5 SW.

PLATE 27

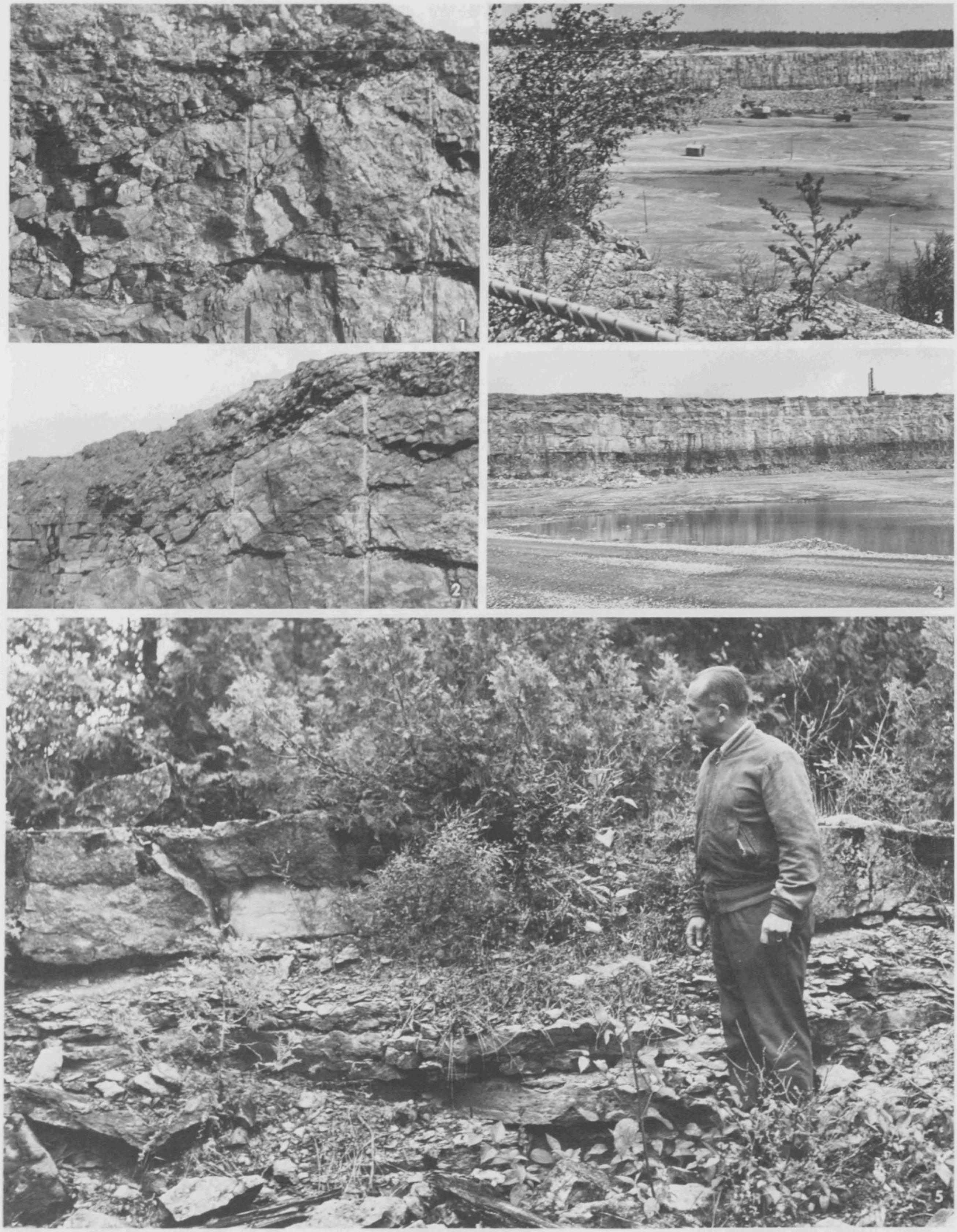
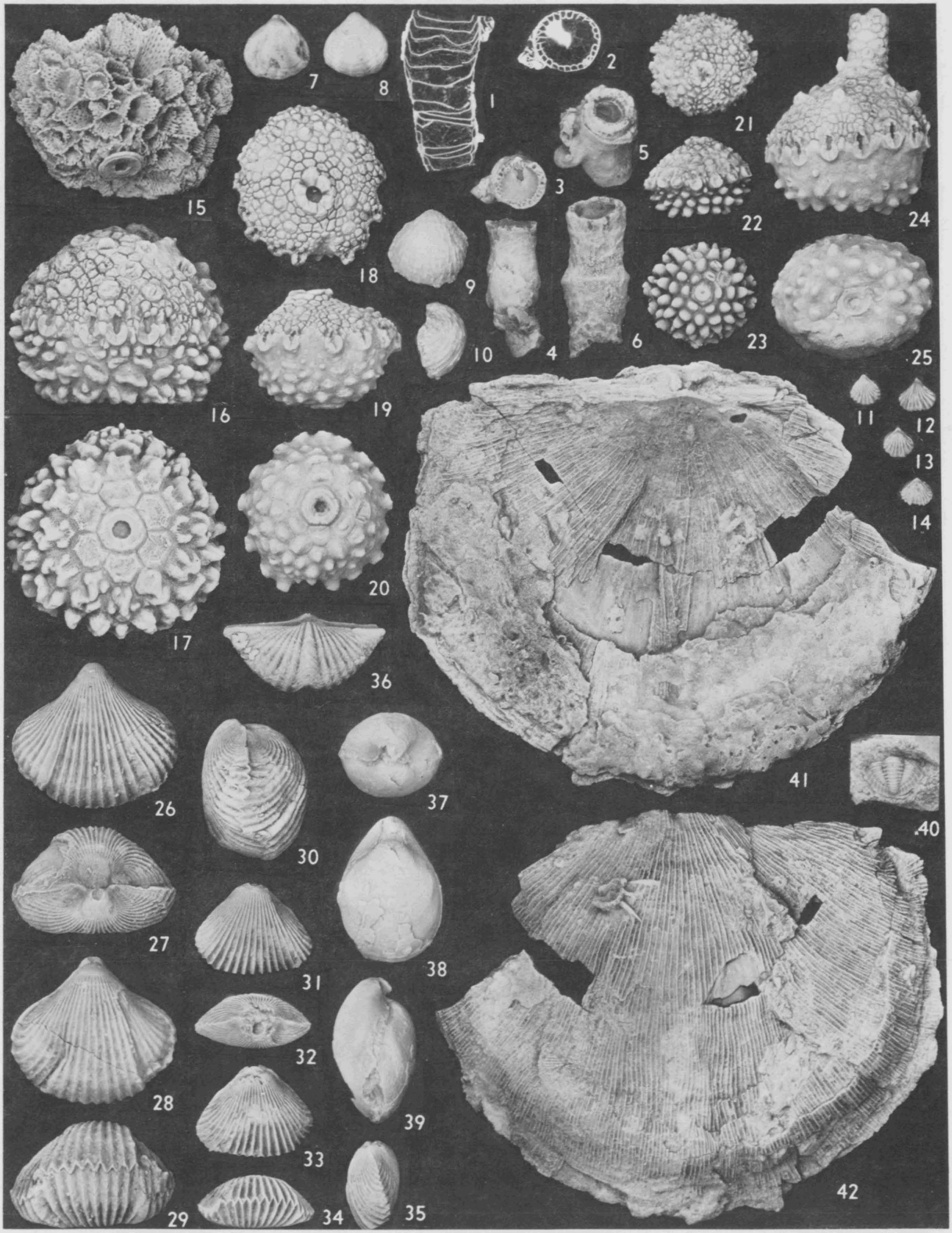


PLATE 28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3. Shale, bluish gray, highly calcareous and fossiliferous, containing well-preserved brachiopods, trilobites, and bryozoa	1
2. Limestone, white to light gray, massive	20
1. Shale, black, bituminous	1
Total thickness	79

Newton Creek Limestone — Feet

Limestone, dark brown, crystalline, petroliferous odor when freshly broken	25

A more detailed section was recorded by R. A. Smith (1916, p. 177-178):

Bed	Description	Thickness (ft.)
"Upper Quarry"		
1.	Hard buff crystalline limestone ($CaCO_3$ = 90.43%, $MgCO_3$ = 8.31%)	4
2.	Grayish buff crystalline limestone ($CaCO_3$ = 90.43%, $MgCO_3$ = 8.31%)	2
3.	Hard grayish buff crystalline limestone with some bituminous streaks ($CaCO_3$ = 94.54%, $MgCO_3$ = 2.61%)	9
4.	Shaly and cherty limestone	2
5.	Dark gray crystalline limestone with bituminous streaks ($CaCO_3$ = 92.38%, SiO_2 = 4.03%)	4
6.	Shaly, fossiliferous, and cherty limestone. Much soft shale	3
7.	Light buff crystalline limestone ($CaCO_3$ = 95.58%)	3
8.	Dark gray crystalline limestone with shaly streaks and chert nodules	4
9.	Buff crystalline limestone	2
10.	Grayish buff crystalline similar to No. 2 ($CaCO_3$ = 94.78%)	6
	Missing	6
"Lower Quarry"		
11.	Dark crystalline and crinoidal limestone	3
12.	Dark bituminous limestone with interbedded coral masses	7
13.	Dark gray massive limestone with scattered heads of coral	8
14.	Crystalline limestone, with stylolitic structure ($CaCO_3$ = 96.40%)	5
15.	Dark fine grained bituminous limestone	4
16.	Argillaceous (?) limestone or limestone of inferior quality	

Four Mile Dam — PLATE 28 — Figures x 1 except as noted

Depasophyllum adnetum; 1, 2, #25702; 3-6, #25704. Stenoscisma illinoisensis; 7, 8, #47254. Spinulicosta mutocosta; 9, 10, #47247. Camarotoechia thedfordensis; 11-14, #37916. Antholites bridghami; 15, #26400. Megistocrinus cf. rugosus; 16, 17, #23878. M. sp.; 18-20, #23880; 21-23, #23882; 24, 25, #23884. Callipleura nobilis; (Hungry Hollow), 26-30, #17807a; 31-35, #17807b. Mucrospirifer grabaui; 36, #31654. Cranaena romingeri; 37-39, #47274. Mystrocephala rara; 40, #47296a. Megastrophia sp.; 41, 42, #57615.

It is easy to correlate this section with that given above: unit 4 is represented in Smith's section by beds 1-5, unit 3 by his bed 6, unit 2 by his beds 7-10 and the missing beds, unit 1 by his bed 11, and the Newton Creek by his units 12-15.

Strata. -- As can be seen in the description of the type section, the Alpena Limestone can be readily divided into a "lower limestone" and an "upper limestone," which are separated by a thin shale bed. The two limestones have somewhat different lithologies. The upper limestone is characterized by numerous bioherms; no bioherms are seen in the lower limestone exposed in quarries; however, Warthin & Cooper (1943, p. 585) suggest that the exposure at Locality 31-8-13 SW is a bioherm in the lower unit.

Unit 1, a black bituminous shale, is not continuous over the quarry at the type locality. It was probably a reworking of some upper Newton Creek deposits following a brief interruption of sedimentation. The bituminous content seems to have had its source in the Newton Creek environment.

Unit 2, a massive light-colored limestone, was deposited in clear, quiet, normal marine sea water. It is typical of zone III, with only slight variations in the kinds of supplied detritus (siliceous and argillaceous), which were thoroughly admixed and laid down with the calcium carbonate.

Unit 3, the 1-foot calcareous shale bed, is in sharp contrast to the limestones above and below. It is highly fossiliferous; because of the ease with which specimens can be cleaned of this matrix, most of the brachiopods and trilobites, and many of the corals, which have been described from the Alpena Limestone, actually came from this thin shale unit. Faunally, it fits somewhere near the border of zones III and IV.

Unit 4, the thick upper limestone, is noted for its bioherms. These strom-coral concentrations rise as steep mounds above the 1-foot shale, with sloping flank beds which gradually merge into the inter-biostrom facies. Because of the various zones involved in the deposition of this unit, the composition of the limestone varies greatly.

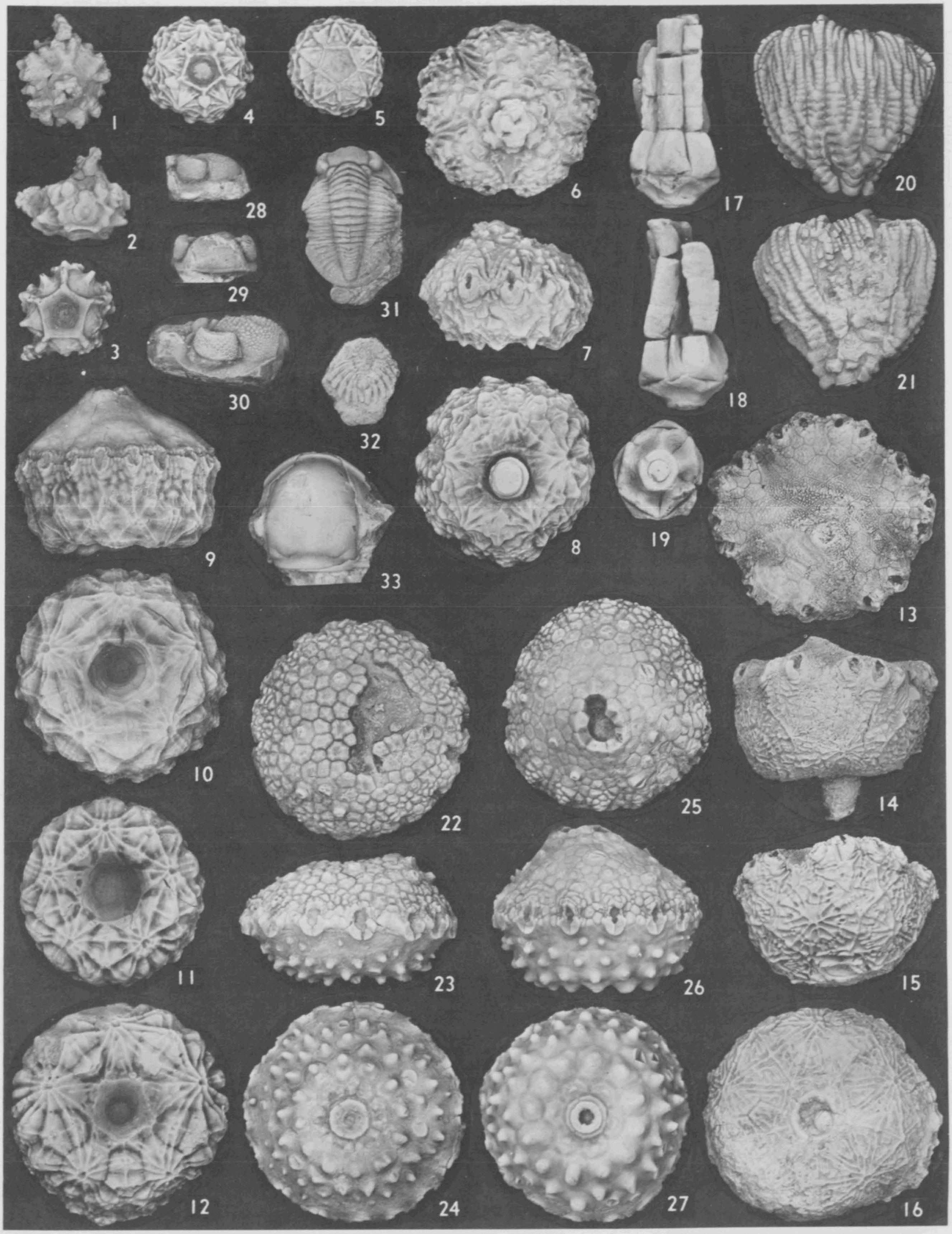
Just why the bioherm-producing strom-coral colonies were localized at their inception has been a matter for speculation. It should be noted that these reefs can not be studied except in cross sections, and that the extent of a particular reef can only be established by following quarrying operations over a span of time. For several years operations in the type locality quarry were removing limestone in one reef; although this structure was only some tens of yards in width, it extended for hundreds of yards, perhaps over a quarter of a mile. On the other hand, some of the bioherm cores, which seem to have been more resistant than the rest of the limestone, form low surface exposures in the Alpena region, some of which appear to be domes rather than ridges. It has been suggested that slight warps uplifted local areas enough to bring the bottom into the shallow, well-aerated zones where the stroms and corals could establish themselves. Or that of the original inhabitants of the shallow zones, most died off when the waters became too deep and only a few fortunate patches of the strom-coral garden survived; these multiplied at the same pace as subsidence, so that they were always in the shallow zones I and II. Possibly a combination of warping and fortuitous survival gave the start to the Alpena Limestone bioherms.

The reef cores are fairly high calcium limestone, in places reaching 99%. This stone was generally free of dolomite, but where circulating ground water invaded the core locally it replaced the calcium with magnesium. This increased the volume of stone, causing dome-shaped swellings which can be seen at some surface outcrops. Quarrymen refer to these high-magnesium parts of the core as "dolomite chimneys" or "magnesian chimneys." At one time, this yellowish, iron-stained, porous, spongy stone was in great demand by the paper industry, where it was used in the sulphite method (Smith, 1916, p. 178).

The beds dip away from the bioherms at rather steep angles, but within a short distance become practically horizontal. The interbiohermal limestone varies greatly in the amount of clay, silica, dolomite, and sulphur. In the south wall of the quarry near the southwest corner, a section of the inter-reef upper limestone has abundant chert.

Four Mile Dam — PLATE 29 — Figures x 1 except as noted

Dolatocrinus bulbaceous; 1-3, #45078. D. michiganensis; 4, #44994; 6-8, #23890. D. sp.; 5, #44989. D. stellifer; 9, 10, Buffalo Mus. #E11930; 11, #45012; 12, #45016. D. liratus; 13, 14, #44978; 15, #44983; 16, #44986. Synbathocrinus michiganensis; 17-19, Buffalo Mus. #E16581a. Euryocrinus barrisi; 20, 21, #23876. Megistocrinus sp.; 22-24, #23885. M. cf. spinulosus; 25-27, #23881. Phacops rana; 28, #25530b; 29, #25530c; 30, #25530a. Basidechenella pulchra; 31, #28681. Greenops aequituberculatus; 32, #27083. Crassiproetus traversensis; 33, #28673.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In spite of the great differences in chemical composition (see below), for many years the Michigan Alkali Company was able by selective quarrying to produce exceptionally high calcium stone for chemical use. The stone with higher percentages of magnesium carbonate was used in the manufacture of cement.

Composition. -- Random samples from the Alpena Limestone in the abandoned Thunder Bay Quarry at Locality 31-8-14 NE yielded the following chemical analyses:

$CaCO_3$	$MgCO_3$	Al_2O_3, Fe_2O_3	SiO_2	S	$CaCO_3$	$MgCO_3$	Al_2O_3, Fe_2O_3	SiO_2	S
98.57	.84	.08	.38	.01	98.03	1.02	.58	.28	.03
70.20	1.78	10.36	16.42	.49	95.00	.76	2.96	1.06	.02
97.68	.76	1.44	.22	.02	89.01	9.60	1.14	.18	.02
87.10	11.38	1.02	.34	.03	98.84	.69	.40	.02	.00
98.03	1.00	.60	.24	.02	98.21	.94	.50	.22	.02
98.21	1.21	.36	.06	.01	98.03	.80	.44	.68	.01
98.84	.74	.24	.04	.02	84.60	13.78	1.26	.20	.05
89.64	8.61	1.20	.54	.02	94.82	1.38	1.30	2.42	.03
98.57	.92	.16	.30	.01	84.00	3.22	.98	1.68	.05
94.02	3.67	1.90	.32	.03	76.20	20.60	1.05	2.18	.45
96.78	1.11	.80	1.14	.07					
				Average	92.58	4.03	1.36	1.38	.06

Other analyses of the Alpena at and near the type locality show that the calcium carbonate tends to run higher in the upper limestone:

Position	Locality	$CaCO_3$	$MgCO_3$	Fe_2O_3, Al_2O_3	SiO_2	S
Upper	31-9-18 NW	97.62	.40	.54	.80	.03
Upper	31-9-18 N	95.40	.98	.82	2.32	.01
8 ft. above shale	31-8-13 W	97.82	.76	.52	.78	.03
5 ft. above shale	31-8-13 W	95.60	.57	.68	2.26	.04
Lower	31-9-7 NW	92.18	.81	1.16	4.56	.05
Lower	31-9-7 S	94.39	.73	1.14	2.72	.05
Lower	31-9-6 S	95.60	.66	.80	2.18	.04
Lower	31-9-6 SE	94.60	.54	.94	3.16	.04
16 ft. above base	31-8-13 W	92.38	1.00	1.32	4.04	.14
6 ft. above base	31-8-13 W	93.59	.85	.98	3.00	.13

A siliceous phase between bioherms in the Alpena Limestone which necessitated selective quarrying in the old Michigan Alkali Quarry is shown in analyses of a drill core taken many years ago near Wessel Road north of the present quarries:

	Depth (ft.)	$CaCO_3$	$MgCO_3$	Al_2O_3 Fe_2O_3	SiO_2	S
Upper Alpena	0-5	92.27	2.67	1.44	3.38	.050
	5-10	92.27	1.45	1.08	4.68	.126
	10-15	89.45	1.37	2.09	6.28	.126
	15-20	88.34	2.42	3.15	5.60	.225
	20-25	92.27	2.27	1.19	3.60	.160
	25-30	91.66	2.23	.99	4.24	.087
	30-35	93.05	2.88	.62	2.64	.123
Lower Alpena	35-40	89.80	2.35	2.97	4.20	.197
	40-45	90.54	2.73	2.87	3.06	.177
	45-50	90.88	2.69	2.09	3.80	.180
	50-55	94.14	2.12	1.16	2.20	.130

For a composite sample of the strata in the Griffin Quarry at Locality 32-7-5 SW, Smith (1916, p. 272) gave the following analysis:

$CaCO_3$	$MgCO_3$	Al_2O_3, Fe_2O_3	Silica
95.02	2.27	1.21	1.11

Fauna. -- The recorded genera and species from the Alpena may not accurately reflect the total fauna because most specimens studied came from the soft 1-foot shale unit between the hard lower and upper limestones. For several years in the past, quarrying operations used the soft shale layer to separate the two limestones (with different composition, as stated above), leaving wide areas atop the bench on unit 2 where the shale unit 3 was exposed to weathering. This wonderful collecting ground is no more, as the quarrying method now in use leaves a sheer face through the whole of the Newton Creek and Alpena Limestones.

What is published, however, shows a normal balance for the Traverse Group: 9 genera of tetracorals, 7 of tabulates, 15 of brachiopods, 7 bryozoa, 3 trilobites, 1 cystoid, and 2 genera of crinoids. If the microfauna from the shale was studied intensively, it would probably amount to 20 or more genera. Like most other formations of the group, the Alpena Limestone is deficient in molluscs, although there are some undescribed cephalopods in the bed exposed at Locality 33-6-17 NE.

The species named from the Alpena Limestone (Appendix 4) include some which have to date been recorded only from that formation in the Traverse Group. These are the tetracorals Aulacophyllum alpenense Stumm, Heterophrentis simplex alpenensis Stumm, Microcyclus alpenensis Stumm, and Naos ponderosus (Rominger), the tabulates Alveolites goldfussi Billings, Aulocystis alectiformis (Winchell), A. fenestrata (Winchell), Favosites nitellus Winchell, F. romingeri saetigera Swann, F. turbinatus Billings, and Trachypora alpenensis Stumm & Hunt, the brachiopods Hercostrophia alpenensis Williams, Pholidostrophia geniculata Imbrie, Strophodonta discus Imbrie, S. leptoidema Imbrie, S. micropleura Imbrie, S. proetus Imbrie, and S. titan titan Imbrie, the trilobites Crassiproetus microgranulatus Stumm and Phacops rana alpenensis Stumm, the cystoid Pothocrinus cooperi Kirk, and the crinoids Dolatocrinus incisus Springer, Megistocrinus expansus Miller & Gurley, M. regularis Wood, and M. sphaeralis Wood. Nevertheless, the fauna is not all unique, for from a total of 60 named species, 35 are shared with other formations of the group (Appendix 5); of these, 11 are in common with the Genshaw Formation, only 3 with the Newton Creek, and 24 with the overlying Four Mile Dam Formation. Even if future investigations and revisions should change these figures somewhat, they appear to constitute a gauge to the Alpena fauna and its affinities.

Two features stand out in the lists. First, the Alpena Limestone fauna has little relationship to that of the underlying Newton Creek fauna, being more like that of the older Genshaw Formation. Second, the Alpena invertebrates were the direct ancestors of many of those found in the Four Mile Dam Formation.

Deposition. -- The Alpena began with an interval, probably brief, of erosion and reworking of the uppermost Newton Creek; this is recorded in the discontinuous black shale at the base. It may be assumed that this turbulent action followed after the removal by erosion of whatever barrier shut off the Newton Creek waters from the open sea.

Except for the bioherms, the Alpena Limestone contains no well-developed stromatoporoid-coral concentrations like those typical of zones I and II; and except for the thin unit 3, there is no reduction of calcium carbonate in favor of clay like that typical of zone IV. It would appear from both fauna and sediment that the lower and upper limestones were laid down in zone III, removed from the zone of turbulence. Unit 2, the massive limestone, was deposited under uniform conditions, the carbonate supply uninterrupted by any changes in sea depth.

Unit 3, with a diverse fauna and increased argillaceous content, shows greater similarity to zone IV. It probably represents an interval of deeper water rather than a temporary influx of argillaceous mud from the land drainage, for the invertebrates increased both in numbers and in kinds.

Unit 4 shows a return to the generally quiet, slightly shallower water under which unit 2 was deposited. Only from chemical analyses is it clear that the supply of sediment for this unit varied considerably in the clay (Al_2O_3 in analyses) and siliceous content from time to time. The dissolved silica evidently reached the critical concentration to precipitate syngenetic chert. The localization of chert nodules in the Huron Portland Cement Company Quarry may be the result of slight eddying currents which brought the silica gel masses together on a small area of the sea floor.

After Alpena deposition, the sea regressed from the area and the exposed surface was weathered for some time. Along the western edges of the Thunder Bay Quarry, the top of Alpena was exposed at one time, showing appreciable rutting and irregularity as well as iron-staining. In this and the Huron Portland Quarry across the road, in the days when bioherms were being quarried, none of the bioherms were known to project up much above the rest of the formation. In other words, the Dock Street Clay was not seen to pinch out against the flanks of the reefs. This suggests that the period of emergent weathering was rather long, sufficient in duration for the reef tops to be eroded down to the general surface level.

The return of the sea brought with it a faunal assemblage markedly different from that which lived here previously. On the soft gray mud of the Dock Street Clay, new kinds of invertebrates became established and in a few favored sites started a new set of reefs.

KOEHLER LIMESTONE

Name. -- The Koehler Limestone was named by Kelly & Smith in 1947 (p. 454) for "gray, bedded, dense limestones of sub-lithographic texture, which are known to overlie the Killians black limestone member, and underlie, uncomformably, the Gravel Point crystalline and shaly limestone strata." At the time of description Kelly & Smith stated that the most eastern exposure was in sec. 5, T 34 N, R 1 E, west of Tower, Cheboygan County; their map (1947, fig. 1) showed Onaway and the area for two miles north to be underlain by "Killians Member." Two years later, in the 1949 guidebook of the Michigan Geological Society, Kelly showed in his Map No. 2 the area just north of Onaway to be underlain by Koehler Limestone.

Exposures. -- Although this field trip is not planned to study the strata at Onaway (Locality 34-2-5N), they are interesting as possible equivalents of formations to the east. At Onaway, particular rock layers are quarried which have consistent thickness and break readily into brick-like rectangles upon scoring. The building stones are sold for facing and may be seen on some stores in Rogers City, set in mortar-like bricks. The colors range from light tan to brown. The quarries have produced no invertebrate fossils preserved well enough for identification, only comminuted small fragments. A few years ago armor plates of a fossil fish were found on one slab, but extensive searches failed to produce other specimens. The thin unfossiliferous beds of dense limestone definitely appear to be lagoonal.

At the type locality in the old Campbell Stone Quarry in the E$\frac{1}{2}$ sec. 36, T 35 N, R 2 W, the Koehler Limestone forms the floor of the quarry. Ten feet above the floor, a 2-foot bed contains the corals Heterophrentis and Hexagonaria. This is overlain by a 1-foot clay seam with chert concretions; this weathering residue appears to have accumulated from a long period of exposure.

Longispina emmetensis (Winchell) is recorded in the Alpena Limestone and in the Gravel Point Formation (above the Koehler) in Cheboygan County. Since the Koehler Limestone lies above the Killians Member of the Genshaw Formation, there is some evidence to correlate the Koehler with the Newton Creek Limestone and/or the lower part of the Alpena Limestone. The formation, therefore, may be a westward extension of the Newton Creek lagoon, or it may be a lagoonal facies of the Alpena.

Four Mile Dam Formation

Name. -- Appreciable doubt persists about the extent of this formation. The base is at one locality and the top at another. Since the upper beds are in the form of a bioherm, which obviously cuts out some of the lower units of the overlying Norway Point Formation, we cannot determine what the "normal" or average thickness of the formation may be.

One good locality was known to Rominger (1876, p. 44), who wrote that limestone layers "interlaminated with soft, soap-like, whitish green clay are uncovered in the race of Mr. Boadwell's saw mill on Thunder Bay River. The clay incloses a profusion of splendidly preserved Bryozoa and corals, also some Crinoids (Dolatocrinus) and Brachiopods ... A bubble-like upheaval of the beds has its centre in the river

PLATE 30

1 - Alpena Limestone, bioherm in old Thunder Bay Quarry in Alpena. Loc. 31-8-14 SE. Flank beds dip away from reef core.

2 - Four Mile Dam Formation and overlying basal beds of Norway Point Formation; reef core of Four Mile Dam poorly bedded and strata of Norway Point thin-bedded. Loc. 31-8-7 C.

PLATE 30

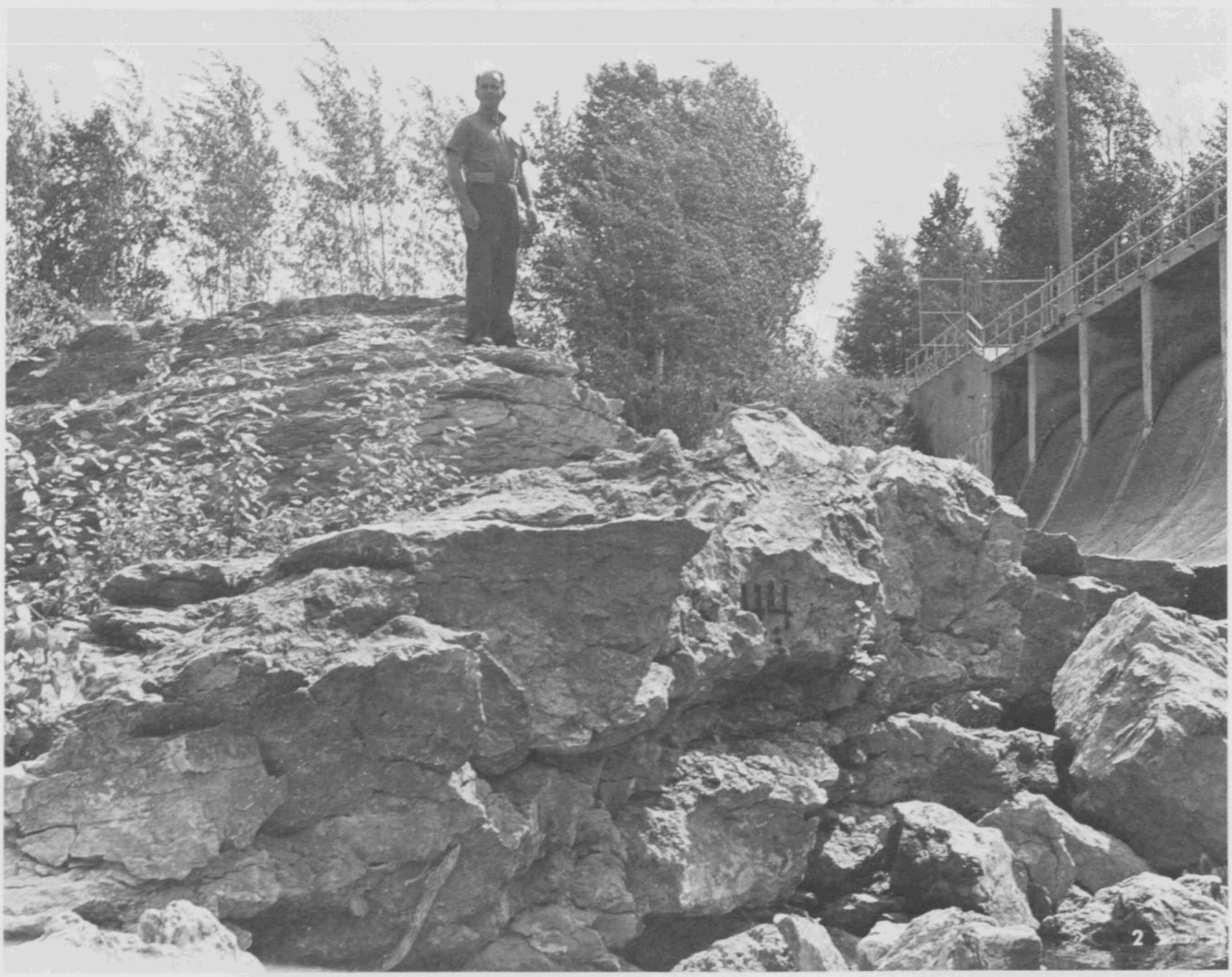
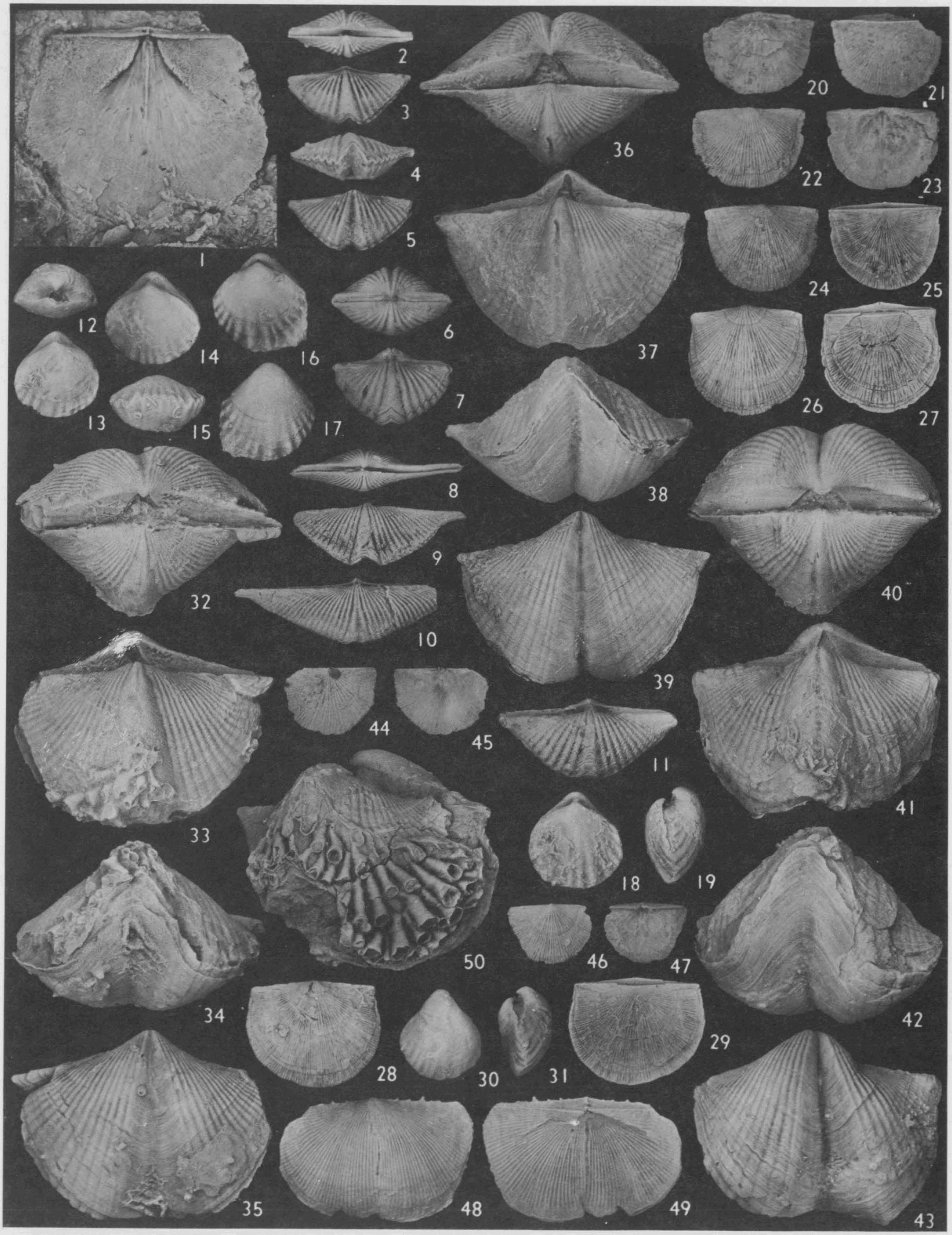


PLATE 31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bottom and by the dam thrown across the river -- the most instructive portions of the section are thus set under water."

Grabau (1902, p. 192) also knew the locality, which by that time was called Fletcher dam and operated by the Fletcher pulp and paper mill. He described the beds and listed fossils found in them. In his and other accounts, there is some confusion in the relative position of strata, inasmuch as the younger shaly beds lap against the sides of the bioherm core.

The type locality can be studied in somewhat better fashion because erosion has exposed much of the core rock and the attitude of the adjacent beds is clearly revealed. Cooper & Warthin (1941, p. 260) named the formation the Four Mile Dam Limestone, for "part of a reef of uncertain thickness overlain unconformably by the Norway Point formation." They had previously (Warthin & Cooper, 1935, p. 526) included the Dock Street clay of Grabau (1902, p. 192) in the "upper Alpena horizon."

In their last work on the stratigraphy of this region, Warthin & Cooper (1943, p. 588) made the Dock Street Clay a member of the Four Mile Dam Formation.

Exposures. -- The Dock Street Clay is still known only from the quarry (abandoned for years) of the Thunder Bay Quarries Company at Locality 31-8-14 NE, and the bioherm top is known only from the outcrop in Thunder Bay River at Four Mile Dam (Locality 31-8-7C). With no other outcrops showing upper or lower contacts, the extent of strata to be included must be based on well records (and in part on the relative width of outcrop area between the base of Norway Point Formation and the top of the Alpena Limestone). The "normal" thickness of the formation, where reefs are absent, is best estimated from the exposures in the abandoned Thunder Bay Quarry along a cut that formerly accommodated the railroad leading south from the quarry to the loading dock on Thunder Bay:

Section of the Four Mile Dam Formation at Abandoned Thunder Bay Quarry
(Locality 31-8-14 NE)

	Feet
Norway Point Formation	
Lower stratigraphic units known only from exposures at Four Mile Dam (Locality 31-8-7 C) and Seven Mile Dam (Locality 31-7-12 NE), where they consist of shaly limestones of varying resistance to erosion. The exposures nearest to the Thunder Bay Quarry are thin scabby outcrops at Locality 31-8-16 SE.	
Four Mile Dam Formation	
4. Covered. Estimated from the areal distribution of the formation between the site of the Foxton brothers quarry (Locality 31-8-15 C), where the Dock Street Clay lies atop the Alpena Limestone, and the Norway Point Formation outcrops on US 23 at Locality 31-8-16 SE	5
3. Limestone, brownish gray, with sandy shale partings	6
2. Limestone, gray, crystalline, with Fimbrispirifer venustus	2 ½
1. Dock Street Clay Member, mudstone, calcareous, bluish gray, soft, producing numerous crinoids including Megistocrinus and Dolatocrinus, the coral Depasophyllum adnetum, several brachiopods, and other corals and crinoids	7 ½
Total thickness about	21

Norway Point — PLATE 31 — Figures x 1 except as noted

Protoleptostrophia lirella; 1, #57609. Mucrospirifer thedfordensis; 2-5, #44118. M. profundus; 6,7, #31659. M. latus; 8, 9, #31649a; 11, #31649b. M. attenuatus; 10, #31657. Pentamerella pericosta; 12, 13, #57607c; 14, 15, #57607d; 16, 17, #57607a; 18, 19, #57607b; 30, 31, #57607f. Strophodonta sp.; 20, 21, #57606a; 22, 23, #57606b; 44, 45, #57606d; 46, 47, #57606c. Chonetes pachyactis; 48, 49, #57605. Strophodonta alpenensis; 24, 25, #57608f; 26, 27, #57608a; 28, 29, #57608b. Spinocyrtia cf. granulosa; 32-35, #57604b; 36-39, #57604c; 40-43, #57604a. Aulocystis commensalis; 50, #34969.

Unconformity

Alpena Limestone

Limestone, white, light gray, or light brown, containing numerous bioherms; fossiliferous. Upper surface - beveled and sculptured by erosion, iron-stained.

The strata exposed at the type locality appear to indicate a thinner section, apart from the reef core, than that in the above section. In the reef at Four Mile Dam, Depasophyllum adnetum occurs below the level of Fimbrispirifer venustus, suggesting by their positions that the reef core is correlated in part with units 1 and 2 of the Thunder Bay Quarry section. Inasmuch as units 1-7 of the Norway Point Formation (totaling an estimated 9 feet), pinch out on the flanks of the bioherm and unit 8 rests directly on the top of the bioherm, the projection of the reef into Norway Point strata must be about 9 feet. The total exposure of reef core is only about 8 feet; obviously, if the lower part of the reef is correlated with the Dock Street Clay on the occurrence of Depasophyllum adnetum, then the Four Mile Dam strata just off the flanks of the reef are considerably thinner than those to the east at the Thunder Bay Quarry.

Section of the Four Mile Dam Formation at the Type Locality
(Locality 31-8-7 C)

		Feet
Norway Point Formation		
8.	Shale, gray, calcareous and arenaceous, irregularly bedded; lies directly atop the bioherm of Four Mile Dam Formation	12
5-7.	Limestone, dark gray, shaly; crinoid columnals, Mucrospirifer, Atrypa, Cyrtina	4½
	Unconformity	
Four Mile Dam Formation (at reef core)		
2.	Limestone, light to medium brown, massive; encrinal, fossiliferous; at upper surface, fossils truncated by erosion	4
1.	Limestone, argillaceous, medium to dark gray, massive, fine-grained matrix; fossiliferous, locally Depasophyllum adnetum constituting about 60 per cent of the volume of the rock; clay locally concentrated to fill voids in the main limestone mass, usually lighter in color than the latter; irregular (eroded?) contact with overlying unit. Base of unit not seen	5
	Maximum thickness exposed	9

There is some doubt as to whether all the strata in bed 2 of the Churchill well record are part of the Four Mile Dam or are shared between the Four Mile Dam and the Norway Point; or it is conceivable that the Four Mile Dam limestones were even thicker than 25 feet, since this reaches to the upper limit of bed rock in the well. Further doubt exists as to whether the section penetrated by the Churchill was through a bioherm or an inter-reef part of the Four Mile Dam.

About half a mile northwest of the Norway Point Dam, in low cuts and ditches along Long Rapids Road, at Locality 31-7-1 S, a small bioherm is exposed which appears to fit into the Four Mile Dam Formation.

Fossils. -- Eighty genera have been listed from the formation; this is far from representative of the total fauna, particularly from the bioherm. The fossils are placed in the Centerfield fauna, also found in western New York, in the coral beds of the Hungry Hollow Formation in Ontario, the Ten Mile Creek Limestone of northern Ohio, the Logansport Limestone of northern Indiana, and in other formations as far south as Alabama (see Cooper & Warthin, 1942, New Devonian (Hamilton) Correlations: Bull. Geol. Soc. Am., v. 53).

Potter Farm — PLATE 32 — Figures x 1 except as noted

Truncalosia gibbosa; 1, 2, #57628a; 3, #57628b; 4, #57628c. Strophodonta crassa; 5, 6 #42184d; 7, 8 #42184b; 9, 10, #42184c; 11, 12 #42184e; 25, 26, #42184a. Mucrospirifer thedfordensis; 13-16, #44115. M. grabaui; 17, #33324. Tortophyllum cysticum; 18, #26254. T. magnum; 24, #35268. Aulophyllum alpenensis; 19, #7657. Hallia vesiculata; 20, 21, #45098. Heliophyllum rotatorium; 22, #44533. Cystiphylloides potterense; 23, #35266.

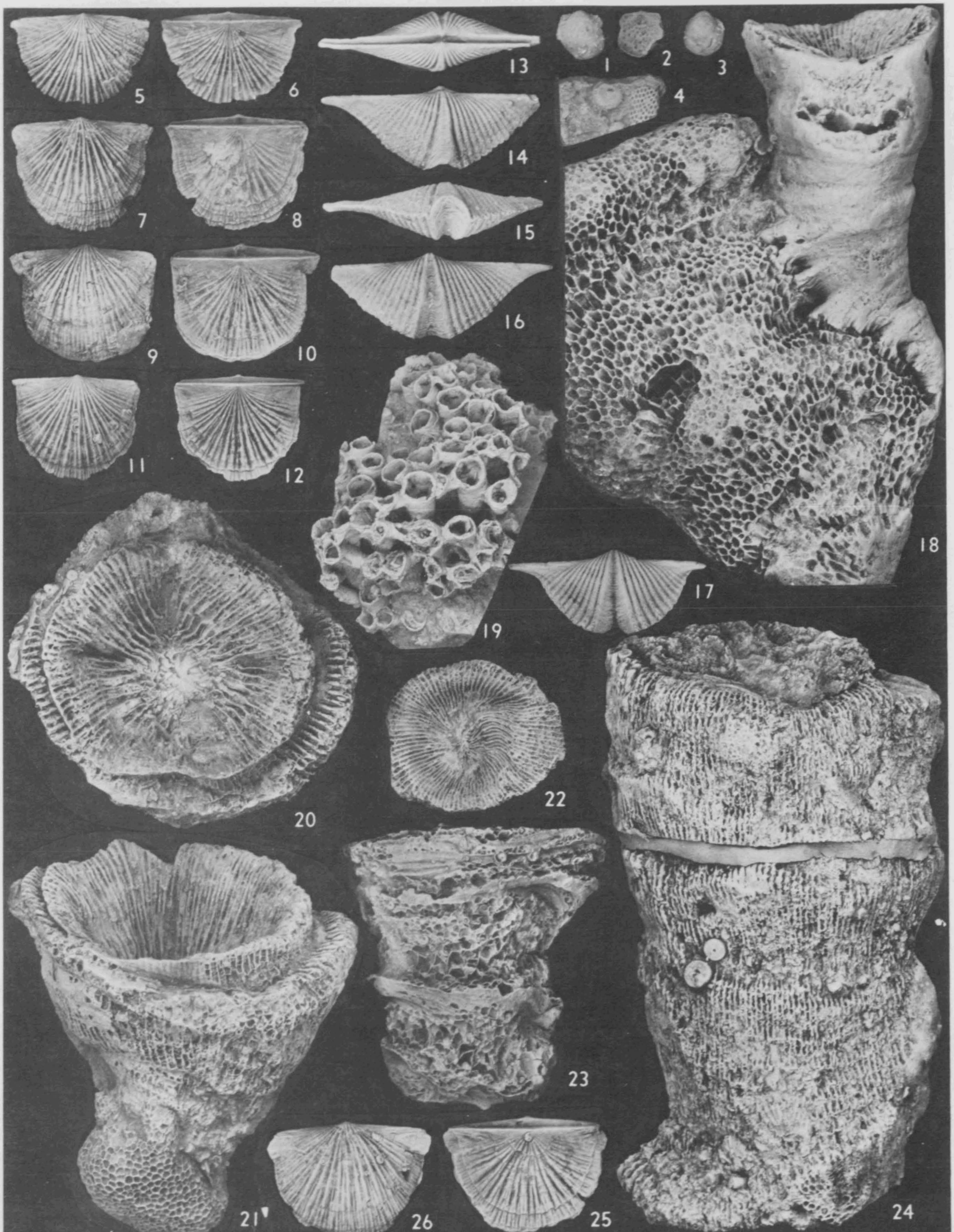
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PLATE 33

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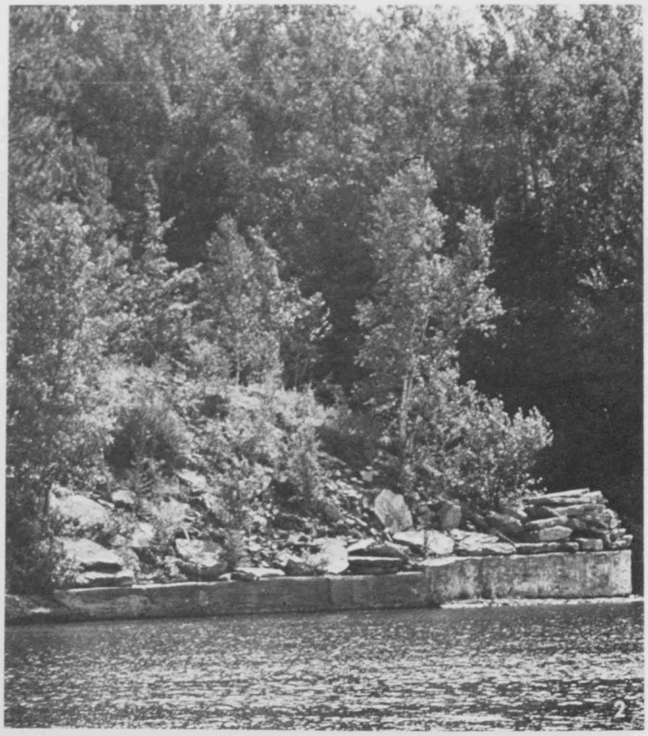

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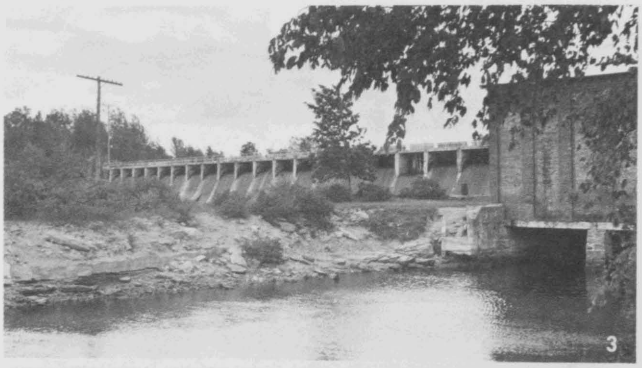

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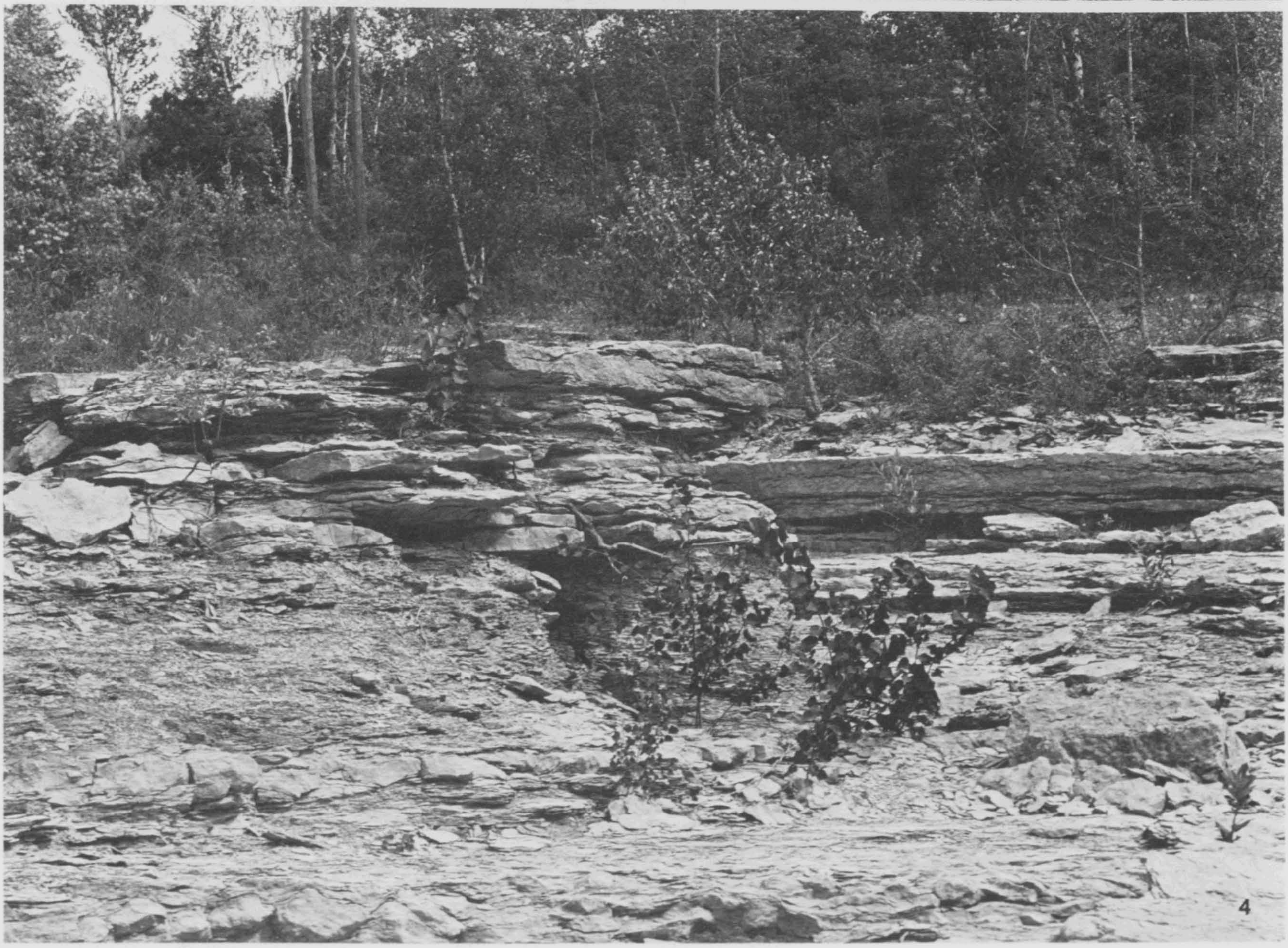

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In the Traverse Group, the following genera are restricted to the Four Mile Dam Formation (based only on published descriptions):

Depasophyllum	Elytha	Mystrocephala
Eridophyllum	Fimbrispirifer	Cyrtonella
Iowaphyllum	Oligorhachis	Exocyrtoceras
Camarospira	Parazyga	Halysiocrinus
Callipleura	Trematospira	Timeischytes
Douvillina		

Species similarly restricted to the Four Mile Dam (Appendix 4):

Atelophyllum magnum Stumm
Cylindrophyllum magnum Ehlers & Stumm
Cystiphylloides americanum Edwards & Haime
Depasophyllum adnetum Grabau
Eridophyllum archiaci (Billings)
Heliophyllum elongatum Stumm & Tyler
H. halli Edwards & Haime
H. juvene Rominger
H. tenuiseptatum traversense Stumm & Tyler
*Iowaphyllum alpenense (Rominger)
Antholites bridghami (Greene)
Aulopora serpens Goldfuss
Cladopora alpenensis Rominger
Emmonsia radiata (Rominger)
Favosites billingsi Rominger
F. clausus Rominger
F. radiciformis Rominger
F. warthini Swann
Platyaxum fischeri (Billings)
Pleurodictyum insigne (Rominger)
P. wardi (Greene)
Striatopora linneana Billings
Striatopora cf. iowensis (Owen)
Trachypora dendroidea Stumm & Hunt
Trachypora elegantula Billings
Callipleura nobilis (Hall)
*Camarotoechia thedfordensis Whiteaves
Douvillina distans Imbrie
*Elytha fimbriata (Conrad)
*Fimbrispirifer venustus (Hall)
Megastrophia gibbosa Imbrie
Mucrospirifer grabaui Stumm
Oligorhachis oligorhachis Imbrie
*Parazyga hirsuta (Hall)
Pentamerella cf. pavilionensis Hall
Rhipidomella penelope traversensis Imbrie
Schuchertella anomala (Winchell)
Strophodonta fissicosta Winchell
Basidechenella macrocephala (Hall)
B. rowi (Green)
Crassiproetus traversensis Stumm
Greenops traversensis Stumm
Mystrocephala rara (Stumm)
Cyrtonella nitella (Hall)
Exocyrtoceras reimanni Flower
Lipsanocystis magnus Stumm
L. rugosus Stumm
Timeischytes megapinacotus Ehlers & Kesling
Botryocrinus reimanni granilineatus Goldring
Dolatocrinus amplus Miller & Gurley
D. bulbaceous Miller & Gurley
D. liratus (Hall)
D. michiganensis Kesling & Mintz
Halysiocrinus barrisi (Worthen)
H. carinatus Springer
Megistocrinus rugosus Lyon & Casseday
Synbathocrinus michiganensis Kesling & Smith

In the above list, the asterisks mark species found in the Centerfield fauna in other regions. Of the 59 genera of macrofossils described from the Four Mile Dam Formation (Appendix 2), 19 or more are shared with each of the other Traverse Group formations except the Rockport Quarry Limestone, Newton Creek Limestone, and the Squaw Bay Limestone. Being in the middle of the group, the Four Mile Dam saw the last of some genera and the introduction of others. On the species level (Appendix 5), it shows close relationship only to the underlying Alpena Limestone.

In his doctoral thesis at the University of Michigan (1963), John Howard Tyler investigated the petrology, fauna, and paleoecology of the Four Mile Dam reef. His faunal lists (here modified slightly) include:

PLATE 33

1 - Norway Point Formation, lower beds exposed on north bank of Thunder Bay River in a low dome. Loc. 31-7-12 NE.
2 - Norway Point Formation, strata exposed on south bank of river; same locality.
3 - Four Mile Dam Formation, mill race on north side of Thunder Bay River. Loc. 31-8-7 C.
4 - Norway Point Formation, lower beds on south bank of river; same locality.

Unit	Fossils
2.	Stromatoporoid Anostylostroma; corals Chonophyllum, Cystiphylloides, Favosites alpenensis alpenensis Winchell, Striatopora linneana Billings, Trachypora elegantula Billings; bryozoa Fistulipora, Anastomopora, Fenestella, Sulcoretepora; brachiopods Pholidops, Pentamerella cf. pericosta Imbrie, Camarotoechia aff. compacta Cooper, Stenoscisma illinoisensis Cooper, Charionella?, Atrypa, Fimbrispirifer venustus (Hall), Brachyspirifer, Elytha fimbriata (Conrad), Megastrophia (Megastrophia), Douvillina distans Imbrie, Spinulicosta mutocosta Imbrie, Truncalosia?, Cyrtina, Parazyga, Cranaena romingeri (Hall); pelecypods Leptodesma, Plethomytilus, Cypricardinia, Lyriopecten aff. illinoisensis Cooper & Cloud, Conocardium; gastropods Palaeoscurria?, Platyceras (Orthonychia), P. (P.) erectum (Hall), Naticopsis, Trepospira (Angyomphalus), Straparollus (Philoxene), Anematina (2 sp.), Murchisonia (M.), Knightella ?, Mourlonia, Turbonopsis, 2 new genera; cephalopods Euryrizoceras, Verticoceras?; ostracod Cavellina?; trilobites Proetus (Crassiproetus) traversensis Stumm, Dechenella (Basidechenella) macrocephala (Hall), Mystrocephala rara (Stumm); and crinoid Dolatocrinus?
1.	Corals Cylindrophyllum magnum Ehlers & Stumm, Depasophyllum adnetum Grabau, Tortophyllum, Chonophyllum, Eridophyllum archiaci (Billings), Cystiphylloides, Iowaphyllum alpenense (Rominger), Xystriphyllum, Trachypora alternans (Rominger), T. dendroidea Stumm & Hunt, Favosites clausus Rominger, F. placenta Rominger, F. alpenensis alpenensis Winchell, F. warthini Swann, Aulocystis jacksoni (Grabau); bryozoa Fistulipora, Dyoidophragma serratum Duncan, Fenestrellina alpenensis McNair, F. minutiserrata Deiss, Fenestella, Polypora, Leioclema aff. alpenense Duncan; brachiopods Trematospira gibbosa (Hall), Tylothyris?, Stenoscisma illinoisensis Cooper, Pentamerella cf. pericosta Imbrie, Fimbrispirifer venustus (Hall), Cranaena romingeri (Hall), Charionella, Camarospira, Elytha fimbriata (Conrad), Camarotoechia?, Douvillina distans Imbrie, Atrypa, Cyrtina; orthoconic cephalopod; and trilobite Mystrocephala.

Deposition. -- When the last of the Alpena interval ended, the sea floor topography was irregular, with the old bioherms forming steeply rising mounds. We suspect that they were somewhat lower than the 30 to 40 feet suggested by Warthin & Cooper; nevertheless, they were high enough that the $7\frac{1}{2}$-feet bed of Dock Street Clay could fill only the interbioherm areas. We believe that the change from limestone to mudstone signifies a transgression, deepening the water appreciably and suddenly decreasing the calcium carbonate content of the sediment. There are several hints that the influx of mud was fairly rapid; most of the bryozoa colonies that succeeded were wrapped around corallites of Depasophyllum adnetum and the edrioasteroids established themselves likewise off the bottom by attaching to coral; stromatoporoids are conspicuously absent. The zone was that of diversified fauna.

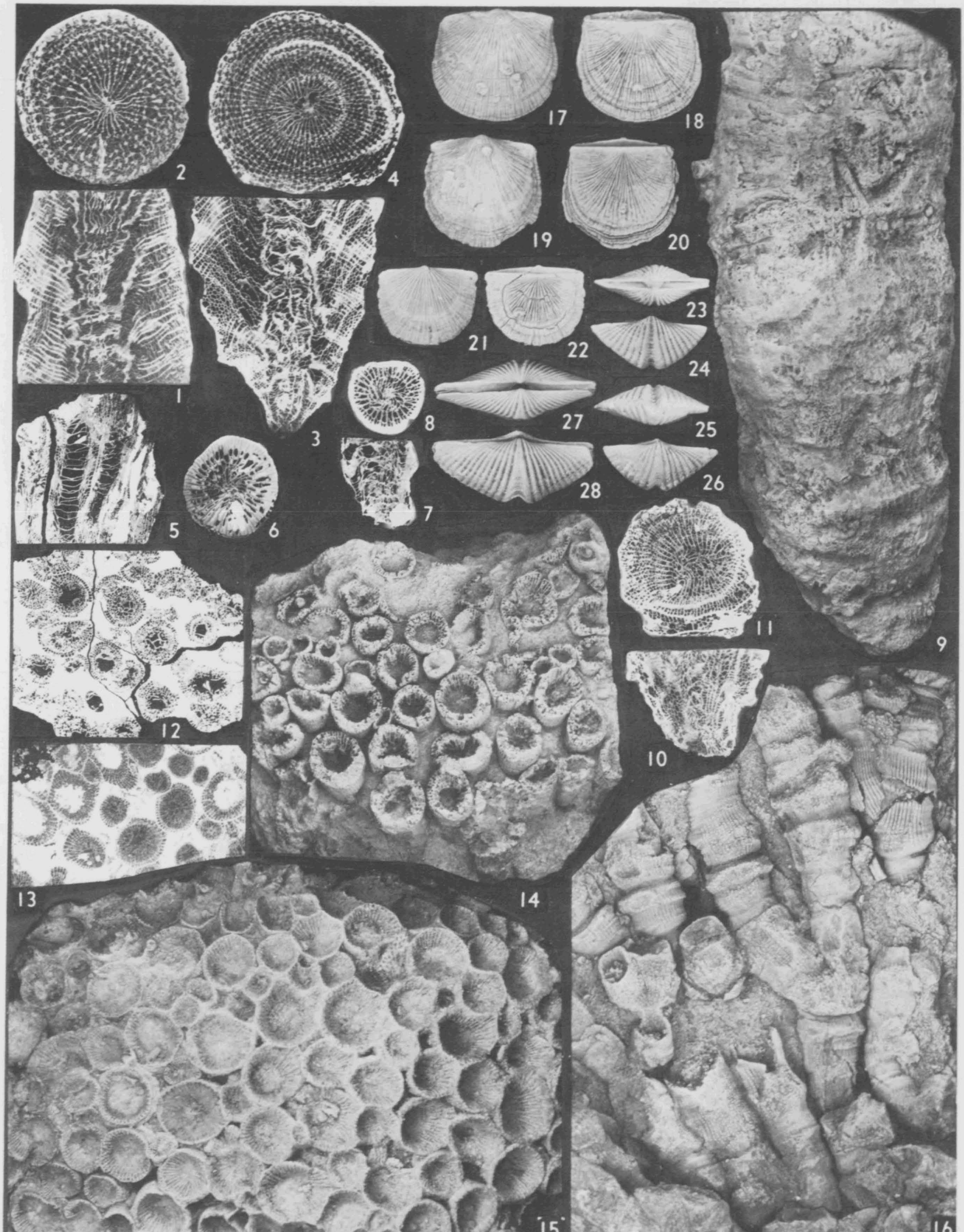
When the water became shallower and reefs were once again flourishing, they were populated by immigrants of the Centerfield type. It seems likely that such bioherms as that at the type locality were established on the tops of the dead Alpena bioherms. Perhaps because stromatoporoids played a less dominant role, the Four Mile Dam bioherm has a more diverse fauna than the bioherms of the Alpena Limestone. Little protected niches around the bioherm were inhabited by molluscs and trilobites.

Norway Point Formation

Name. -- Rominger saw the strata now placed in this formation and wrote (1876, p. 44), "The argillaceous limestones interstratified with the shales were a number of years ago used for the fabrication of hydraulic cement. Expensive kilns stand abandoned at the foot of the river bluffs. Mr. Trowbridge, their former owner, informs me that sometimes an article of very good quality was produced, but the success was so uncertain that the cement never came into reputation in the market, and after a short time he gave up the undertaking."

Potter Farm — PLATE 34 — Figures x 1 except as noted

Heliophyllum halli potterense; 1, 2, #35261; 3, 4, #35262. H. elongatum; 9, #35258. H. rotatorium; 10, 11, #44537. Disphyllum compactum; 5, 12, #25683. Heterophrentis curviseptatum; 6, #44598. Stereolasma; 7, 8, #44593. Cylindrophyllum hindshawi; 13, 15, #25684. C. panicum; 16, #14338. Disphyllum compactum; 14, #25683. Strophodonta potterensis; 17, 18, #42182b; 19, 20, #42182e; 21, 22, #42182d. Mucrospirifer thedfordensis; 23-26, #44119. M. latus; 27, 28, #31637.



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By 1902 the site had changed name from Trowbridge's mill to Boom Company's dam, at which time Grabau (p. 193) described the beds and listed the fauna. Ver Wiebe (1927, p. 188-190) included Norway Point strata in his beds 25-30 and estimated their total thickness at 36 feet 10 inches; these beds are those he described from the "upper dam." The site of Trowbridge's mill and the Boom Company dam now lie under water impounded by the new dam downstream.

The site of the type locality has been variously known as Six Mile Dam, Seven Mile Dam, and Norway Point Dam. The last name was used by Warthin & Cooper (1935, p. 525) when they named the formation for rocks below the Potter Farm Formation and above the Alpena Limestone (which then included the Four Mile Dam Formation). In 1943 (p. 579) Warthin & Cooper estimated the total thickness at 45 feet.

Exposures. -- No continuous section is available and the estimation of total thickness is complicated by the overlap of lower units against the bioherm of the Four Mile Dam Formation at its type locality. The composite section presented by Warthin & Cooper (1943, p. 589-590) was made from measured strata at the type locality (Locality 31-7-12 NE) and at Four Mile Dam (Locality 31-8-7 C).

Section of the Norway Point Formation

	Feet
Potter Farm Formation	
Limestone, crinoidal, thin bedded with shaly partings.	
Norway Point Formation	
12. Covered. Estimated by the separation of the top of unit 11 at Locality 31-8-18 E and nearby exposures of the "Silo Terrace" (unit 2) bed of the Potter Farm at Locality 31-8-18 C; probably the whole interval is occupied by the soft clay of unit 11	8
11. Clay, bluish gray, with siltstone lenses, fossiliferous; maximum thickness exposed on bank of Thunder Bay River downstream from Four Mile Dam at Locality 31-8-18 E	19
10. Shale, bluish gray, calcareous and highly fossiliferous	3
9. Limestone, gray, coarsely crystalline	1 ½
8. Shale, gray, calcareous and arenaceous, irregularly bedded. According to Warthin & Cooper (1943, p. 590), at Four Mile Dam this unit directly overlies the Four Mile Dam Formation because overlap against the flanks of the bioherm cuts out units 1-6	12
7. Limestone, gray, finely crystalline, massive	½
6. Limestone, gray, coarsely crystalline, fossiliferous	1
5. Limestone, gray, finely crystalline, fossiliferous; probably the "Cyrtina umbonata" bed of Grabau (1902, p. 193)	3
4. Limestone, brown, finely crystalline, weathered surface sandy; Grabau reported "sun-cracks" in the "shales" below the Cyrtina bed (1902, p. 193)	1
3. Limestone, brown, fossiliferous	1
2. Limestone, brown, stylolitic. Exposed on the north side of Thunder Bay River at Seven Mile Dam in a low arch; probably draped over top of bioherm not far underneath	½
1. Covered. Estimated on assumption that unit 2 is near the contact with the bioherm at Seven Mile Dam	2
Total thickness about	52 ½

According to Warthin & Cooper (1943) the maximum known thickness is 45 feet, but they conceded that the formation "may reach 55-60 feet in some parts of the region." On the south bank of Thunder Bay River exposures are intermittent from Four Mile Dam to Locality 31-8-18 C on Four Mile Dam Road, where upper beds are exposed. The thick clay unit 11 is found farther downstream at Locality 31-8-18 E, where the outcrop has suffered greatly in recent years from slumping. The "limestones" of units 2-7 are not very resistant, either at Four Mile Dam or at Seven Mile Dam.

Along the North Branch of the Thunder Bay River at Locality 32-7-29 C, soft strata in the bed and banks are Norway Point Formation, perhaps lower than unit 2. These are probably the rocks seen by Rominger (1876, p. 45): "From Trowbridge's mills, higher up the river, the strata are hidden from view for several miles; they appear again under the bridge crossing the north branch of Thunder Bay River."

Strata perhaps near the base of the formation crop out along French Road at Locality 31-8-9 NW, where the surface shows numerous silicified rhynchonellid brachiopods. Probably, the silicification is entirely secondary, just under the thin drift which gradually obscures the beds in all directions. Thin, scabby surface exposures could be seen just north of Alpena a few years ago at Locality 31-8-16 SE, but today most if not all are covered by landscaping around the Presbyterian Church, Fletcher Motel, and the Grove Tavern.

Fossils. -- The Norway Point fauna contains no stromatoporoids or tetracorals. It has, nevertheless, 79 genera of invertebrates described from it (Appendix 3). Generically (Appendix 2), the Norway Point fauna is closer allied to that in the shales of the older formations than to that in the limestones; it is also closer to the underlying Four Mile Dam Formation than to the overlying Potter Farm Formation.

Relatively few species are restricted to the Norway Point (Appendix 4); they include:

? Drymopora erecta Rominger
Drymopora nobilis Billings
Aulocystis commensalis Watkins
A. stummi Watkins
Striatopora rugosa Hall
Chonetes pachyactis Imbrie
Pentamerella pericosta Imbrie
Pholidostrophia ovata Imbrie
Schuchertella lirella Imbrie
Sphenophragmus nanus Imbrie
Strophodonta alpenensis Grabau
Greenops boothi (Green)
Pentremitidea clavatiformis Reimann
P. cooperi Reimann
P. cooperi breviceps Reimann
P. filosa Whiteaves
Atractocrinus curtus Kirk

The other 11 species that have been named from the Norway Point are shared with the adjacent formations.

The following list of fossils was collected unit by unit:

Unit	Fossils
11.	Chonetes pachyactis Imbrie, Orthonota cf. constricta, large fucoids, Dipleura
10.	Strophodonta alpenensis Grabau, Spinocyrtia cf. granulosa (Conrad), Fistulipora spinulifera (Rominger), Mucrospirifer, Cyrtina cf. hamiltonensis (Hall), fenestellids, Pentamerella pericosta Imbrie, Atrypa (small), Athyris, Chonetes pachyactis Imbrie, Greenops boothi (Green)
9.	Fucoids
6.	Chonetes pachyactis Imbrie, Strophodonta alpenensis Grabau, Pholidostrophia ovata Imbrie, Cyrtina, crinoid columnals
5.	Chonetes (small, numerous), Cyrtina, Mucrospirifer, Favosites (small)
3.	Chonetes, two spiriferoid brachiopods, Pholidostrophia ovata Imbrie, rare Camarotoechia.

Deposition. -- The Norway Point began, just as did the Four Mile Dam Formation, with deepening of the water by transgression, submerging of the bioherm tops below survival level for the fauna, and filling of the inter-reef areas with mud flats. The difference between the two is that, in the Norway Point sequence, the conditions continued for a considerable time, allowing over 50 feet of shales and soft limestones to accumulate.

It seems significant that, with the exception of the lagoonal Squaw Bay Limestone, the Norway Point is the only formation of the Traverse Group which has no tetracorals recorded from it. Stromatoporoids are absent. The fauna consists of many kinds of brachiopods, bryozoa, and ostracods, with a few tabulate corals, molluscs, trilobites, and echinoderms. The lithology and fauna are both indicative of slight alternations between zones III and IV.

Potter Farm Formation

Name. -- On the hillsides along the Thunder Bay River, Rominger (1876) saw several exposures of these beds. Both Rominger (1876) and Grabau (1902) studied the outcrops at Stony Point. The strata were incorporated in a composite section by Ver Wiebe (1927).

It was not until 1935, however, that Warthin & Cooper named the formation for exposures on the F. N. Potter farm in sections 18-20, T 31 N, R 8 E, just west of Alpena.

Exposures. -- Because the Potter Farm is more resistant than the underlying Norway Point Formation, there are more natural exposures; in particular, some resistant units form small cuestas that can be followed for short distances along the strike. The more argillaceous strata, however, are more difficult to find and the stratigraphic section has to be pieced together from several localities. The following is a composite section.

Section of the Potter Farm Formation

Thunder Bay Limestone — Feet

Limestone, bluish, argillaceous, weathering to rusty brown; exposed at water level or just below at Partridge Point (Locality 30-8-11 SE); this is separated by a short covered interval from a gray fossiliferous shale.

Potter Farm Formation

17. Covered. Estimated by Warthin & Cooper (1943) from areal distribution, dip, and strike of strata; bottom contours in Thunder Bay suggest two resistant (limestone ?) layers. Dredging for water pipes to cottages along the cliff at Partridge Point brings up 2 to 3 feet of soft, gray shale or clay containing fossils; this needs further investigation, but appears to be part of the Potter Farm rather than the Thunder Bay Limestone.... 27
16. Limestone, dark gray, argillaceous; many corals and stromatoporoids.... 3
15. Covered. Warthin & Cooper (1943) are uncertain as to whether this interval exists.. 5
14. Limestone, gray, crystalline, rusty on weathered surface, fossiliferous with corals; weathers out into flat slabs. This is bed 4 of Ver Wiebe (1927, p. 188).. 1 ½
13. Covered.... 1
12. Limestone, bluish gray, sublithographic, hard; weathers nearly white. Ver Wiebe's bed 6.... 2
11. Covered 2
10. Limestone, gray, mostly conspicuous in outcrop as a terrace; irregular bedding seen on weathered surface; contains corals and crinoids. Corresponds to Ver Wiebe's beds 8-12. Probably correlates with beds exposed at Orchard Hill.... 10
9. Covered. Probably corresponds to Ver Wiebe's beds 13-15, described as:
   Shale, calcareous, with bituminous streaks ....1'3"
   Limestone, blue, thin-bedded, many fossils.........2'
   Shale, calcareous, blue and black.................. 9"
   Thickness given by Warthin & Cooper (1943).... 3
8. Limestone, massive, porous and rusty on weathered surface.... 5
7. Shale, gray, calcareous; few fossils.... 3 ½
6. Limestone, gray, massive, finely granular, weathers to yellow or buff.... 2

Potter Farm - Thunder Bay PLATE 35 Figures x 1 except as noted

Potter Farm: Cystiphylloides amalgamatum; 1, 2, #35286. C. petoskeyense; 5, 6, #44313; 14, #44082. C. potterense; 7, #44315. Synaptophyllum crassiseptatum; 3, 4, #25680. Spongophyllum alpenense; 8, 9, #23898; 13, #24829. Bethanyphyllum geniculatum; 10, 11, #35273. Mucrospirifer profundus; 19, 20, #31653. Strophodonta potterensis; 21, 22, #42182c; 23, 24, #42182a.
Thunder Bay: Antholites alpenensis; 12, #26402. Cylindrophyllum grabaui; 15, 16, #25671. Dolatocrinus romingeri; 17, #45094. Gennaeocrinus romingeri; 18, Buffalo Museum # E16586.

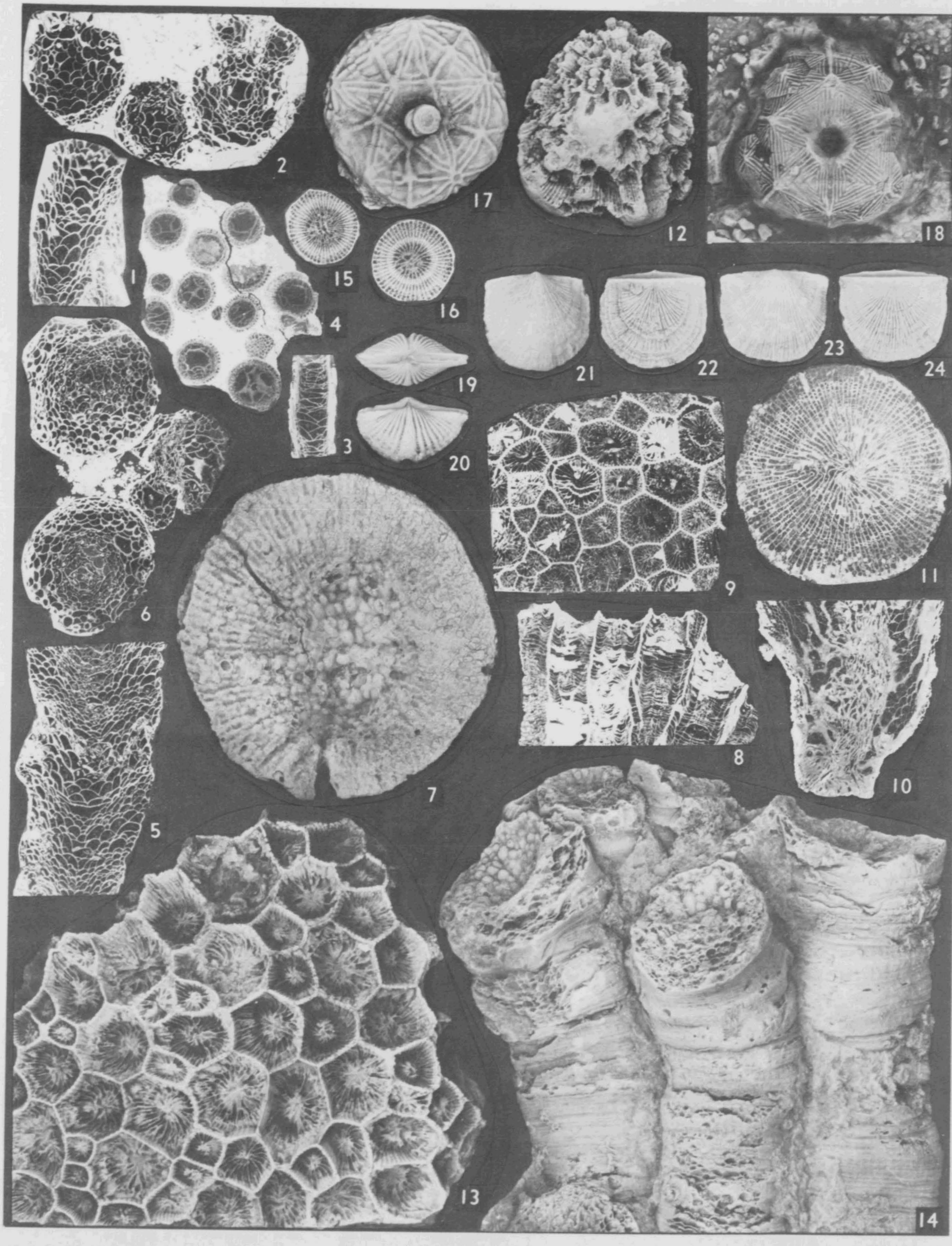
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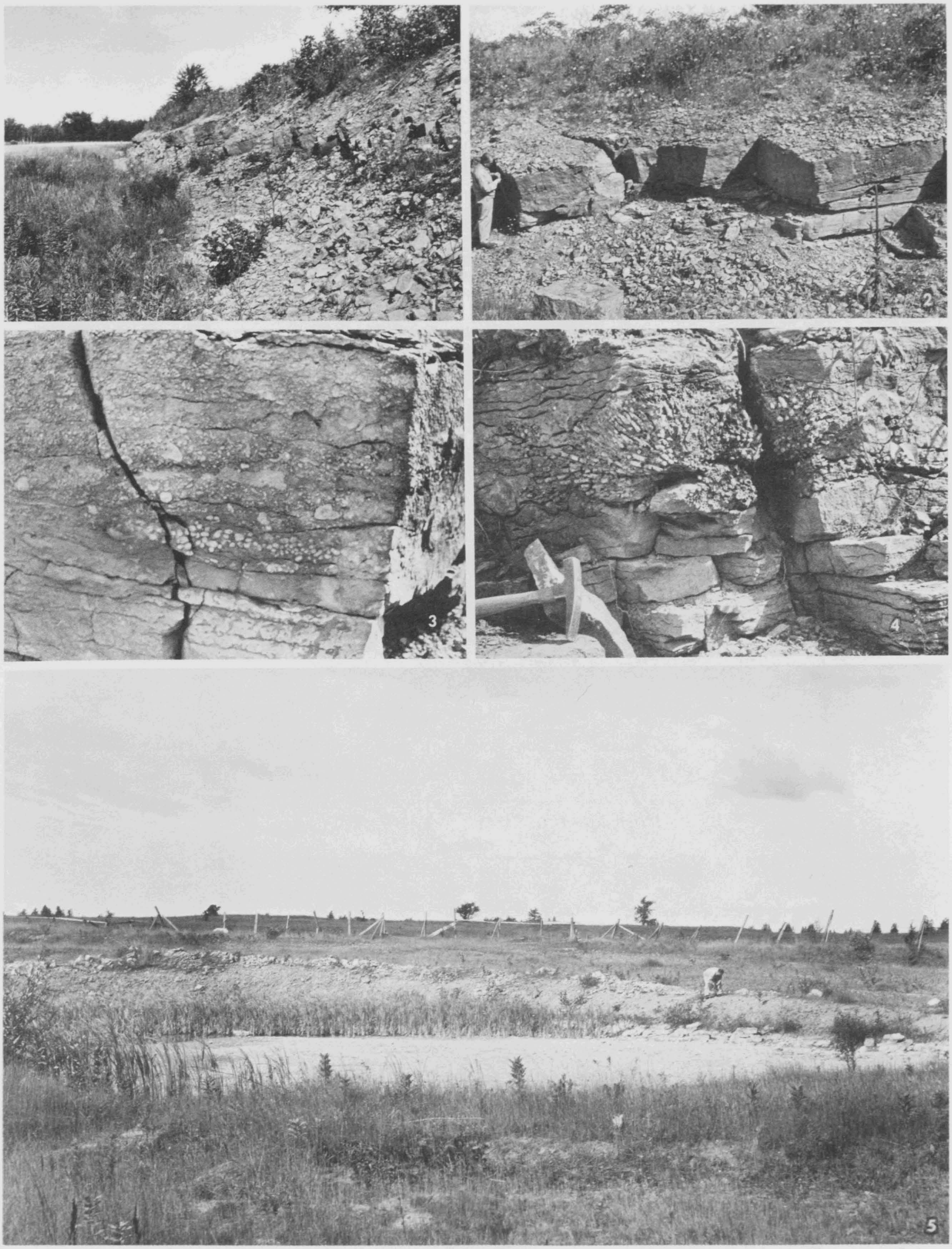
PLATE 36



5. Shale, gray, calcareous; fossils numerous, including corals and large Cranaena; rusty on exposure..	2 ½
4. Limestone, gray, argillaceous, coarsely crinoidal in lower part; top hard, buff..	2 ½
3. Limestone, interbedded with greenish clay, mostly clay in lower part, the amount of limestone increasing upward, and the top part mostly calcareous abundantly fossiliferous, described by Ver Wiebe as the "zone that offers the happy hunting-ground for the collector of fossils"......................	19
2. "Silo Terrace" bed of Ver Wiebe; limestone, gray, weathering buff, yellow, and reddish; crinoidal, massive, resistant. Forms low cuesta extending for some distance across old Potter farm in section 20...................	8
1. Limestone, crinoidal, in thin layers with shale partings........................	5
Total thickness	102

Norway Point Formation

Actual contact not exposed, but probably the uppermost Norway Point strata are an upward continuation of the soft, bluish gray shale of unit 11.

In the composite section the lower units are exposed above the Norway Point Formation on Four Mile Dam Road at Locality 31-8-18 C, and extending around the hill to the east and southeast; the middle units (from 3 to 14) are exposed in the cemetery shale pit (Locality 31-8-21 SW), extending up the hill to the west (Locality 31-8-20 SE), and in road cuts along M 32 (Locality 31-8-20 S); and unit 16 is known only from an abandoned shallow quarry on M 32 at Locality 31-8-19 SW.

Unit 2 was called the Silo Terrace by Ver Wiebe (1927) because it formed a prominent terrace on which stood a "high, hollow-tile silo, which can be seen for miles." This resistant bed can be traced almost continuously between Localities 31-8-18/20 and 31-8-18 C. It is well exposed at cuts for the abandoned Boyne City, Gaylord, & Alpena R.R. near Thunder Bay River at Locality 31-8-20 NW. Undoubtedly, this is the unit cropping out at Stony Point (Locality 31-8-34 NW), where it was examined by Rominger (1876, p. 42) and by Grabau (1902, p. 195).

The highly fossiliferous unit 3, which has yielded the majority of specimens collected from the formation, is now best available at a small shale pit at the west edge of Evergreen Cemetery in Alpena (Locality 31-8-21 SW). At one time it was also exposed at Warner's Brick Yard in Alpena (Locality 31-8-28 NE), where Grabau (1902, p. 194) identified an extensive list of fossils.

South of Orchard Hill, at Locality 32-7-31 S, beds are exposed which contain numerous gastropods; we suppose that they are below the strata exposed on the south flank of the hill along Long Rapids Road, and that they represent unit 8. Similar beds are exposed in the abandoned Nicholson Limestone Quarry at Locality 31-8-29 NE.

Orchard Hill is an unusual exposure which, because of the combination of topography and steep dips, appears on the map as a sort of inlier, surrounded or nearly so by the older Norway Point Formation. The south flank is exposed along Long Rapids Road at Locality 32-7-31 C; there the strata dip very steeply to the south. The dip must level off rather abruptly, however, for the exposures of the Thunder Bay Limestone and Squaw Bay Limestone about 3 miles to the southeast (Localities 31-7-17 NW and 31-7-17 C) show only the gentle regional inclination. The northwest side of the structure is exposed along roads at Localities 32-6-25 S and 32-7-31 NW; the dips are not as steep as on the south side. The fauna at 32-7-31 NW is particularly rich in Cystiphyllum, and an assortment of large brachiopods and corals is present on the north side of the hill at Locality 32-7-31 N. Just north of Orchard Hill are level fields with numerous piles of

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PLATE 36

1-4 - Potter Farm Formation, steeply dipping beds on south side of Orchard Hill. Loc. 32-7-31 C. 3, densely packed corals and stromatoporoids. 4, large coral head in living position.

5 - Potter Farm Formation, shale pit in Evergreen cemetery, Alpena. Loc. 31-8-21 SW.

stone gathered from the area; the only place where strata definitely crop out there is in road ditches near the hill, where brownish thinbedded layers have produced one specimen of Dolatocrinus. The Orchard Hill structure was known to Ver Wiebe, who correlated the outcrops with his beds 22-24 (units 2-4 in the section above); we think it is more likely that they correspond to unit 10 on the bases of fauna and location. Warthin & Cooper (1943, p. 591) conjectured that "the dome may be a large covered bioherm of the Alpena or Four Mile Dam limestones." This is a reasonable interpretation, but it should be emphasized that the settling of the Potter Farm beds had to be exceptional to produce the very steep dips found on the south flank of the structure.

Fossils. -- The Potter Farm fauna has not been fully explored, and may eventually prove to be the largest in the Traverse Group. Field observations suggest that intensive work will probably establish several faunal zones that can be used to extend knowledge of the section.

In contrast to the underlying Norway Point Formation, which is barren of tetracorals and stromatoporoids, the Potter Farm contains 13 genera of identified tetracorals and many stromatoporoids. On the other hand, it has only 7 genera of articulate brachiopods, as compared to 18 in the Norway Point.

Three coral genera have not been recorded in other Traverse formations (Appendix 1):

Disphyllum
Hallia
Synaptophyllum

This is not to prove that these genera are not present in other formations, but so far they have not been found in such numbers as to excite a paleontologist to publish the fact. Generically, the Potter Farm Formation shows strong relationship with all other Traverse Group formations except the Newton Creek Limestone, Norway Point Formation, and the Squaw Bay Limestone.

Enough species have been recorded only from the Potter Farm (Appendix 4) to indicate that it has a distinctive fauna:

Cylindrophyllum hindshawi Ehlers & White
C. panicum (Winchell)
Cystiphylloides cf. aggregatus (Billings)
C. (?) amalgamatum Stumm
C. petoskeyense Stumm
C. potterense Stumm
Disphyllum compactum Ehlers & Stumm
Hallia vesiculata Sloss
Heliophyllum halli potterense Stumm & Tyler
H. rotatorium Stumm & Tyler
H. tenuiseptatum tentaculum Stumm & Tyler
Heterophrentis curviseptata Stumm
Spongophyllum alpenense Ehlers & Stumm
Stereolasma petoskeyense (Sloss)
Synaptophyllum crassiseptatum Ehlers & Stumm
Tortophyllum magnum Stumm
Alveolites subramosus Rominger
Aulocystis alpenensis Watkins
A. parva Watkins
Favosites romingeri patella Swann
F. romingeri romingeri Swann
F. romingeri romingeri pisum Swann
Pachyphragma erectum (Rominger)
Chonetes ensicosta Imbrie
Cranaena aff. amygdaloidea Cooper & Cloud
Pentamerella papilla Imbrie
P. petoskeyensis (Imlay)
Strophodonta crassa Imbrie
S. elongata Imbrie
S. potterensis Imbrie
Pleurotomaria alpenensis Ehlers & Hussey
Codaster alatus Reimann
Lipsanocystis oblatus Stumm
Dolatocrinus grabaui Kirk.

Of the 55 species reported from the Potter Farm Formation, 13 are shared with the Alpena Limestone, to which it shows closest relationship.

Thunder Bay | PLATE 37 | Figures x 1 except as noted

Cystiphylloides americanum elongatum; 1, 3, #35284; 2, #35285. Aulacophyllum hemicrassatum; 4, #46392. Megistocrinus nodosus; 5-7, #13598a. M. multidecoratus; 8-10, #5945. Botryocrinus thomasi; 11-14, #47114, x2. Basidechenella reimanni; 15, #28718. Dipleura dekayi; 16, #54161, x0.6.

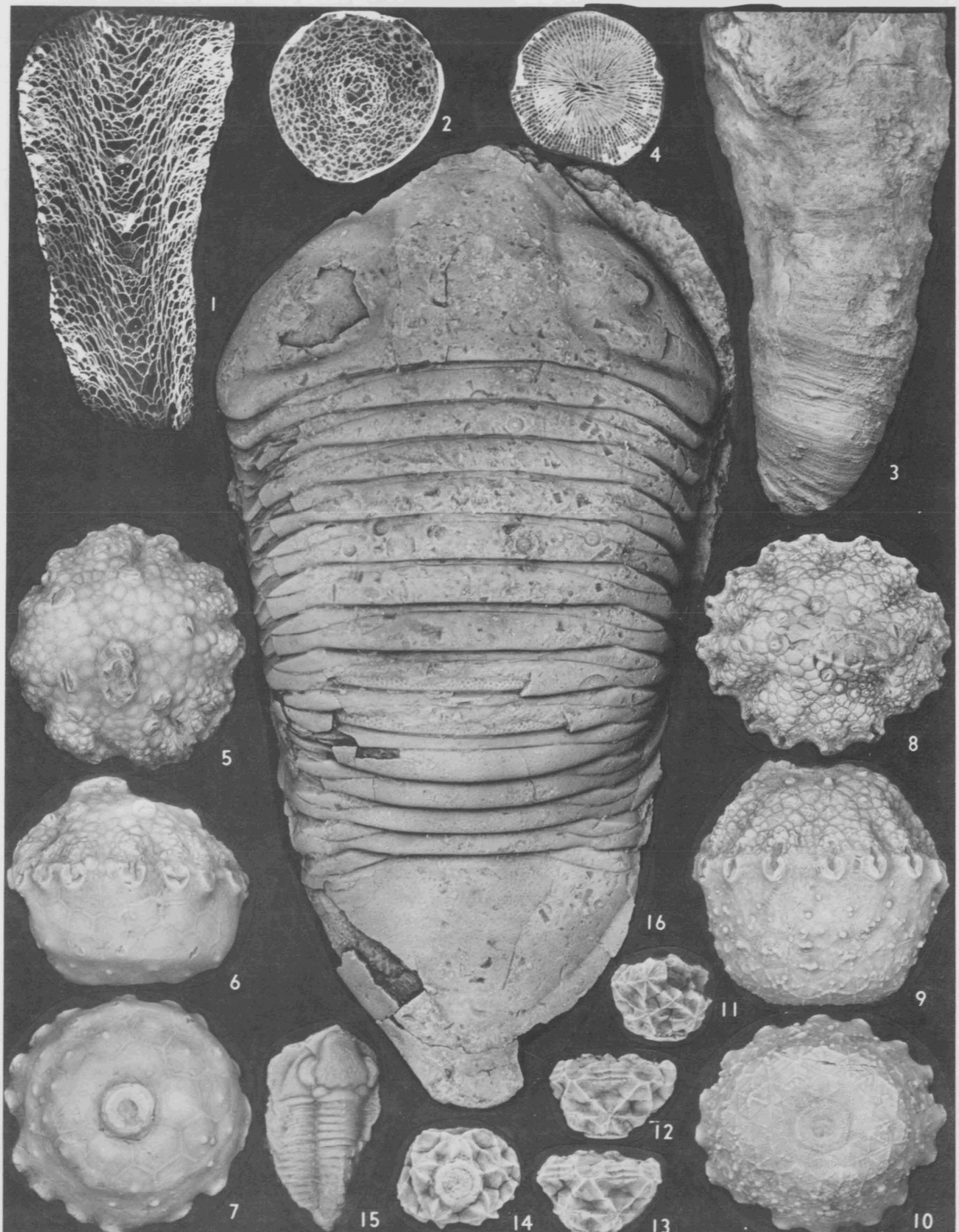
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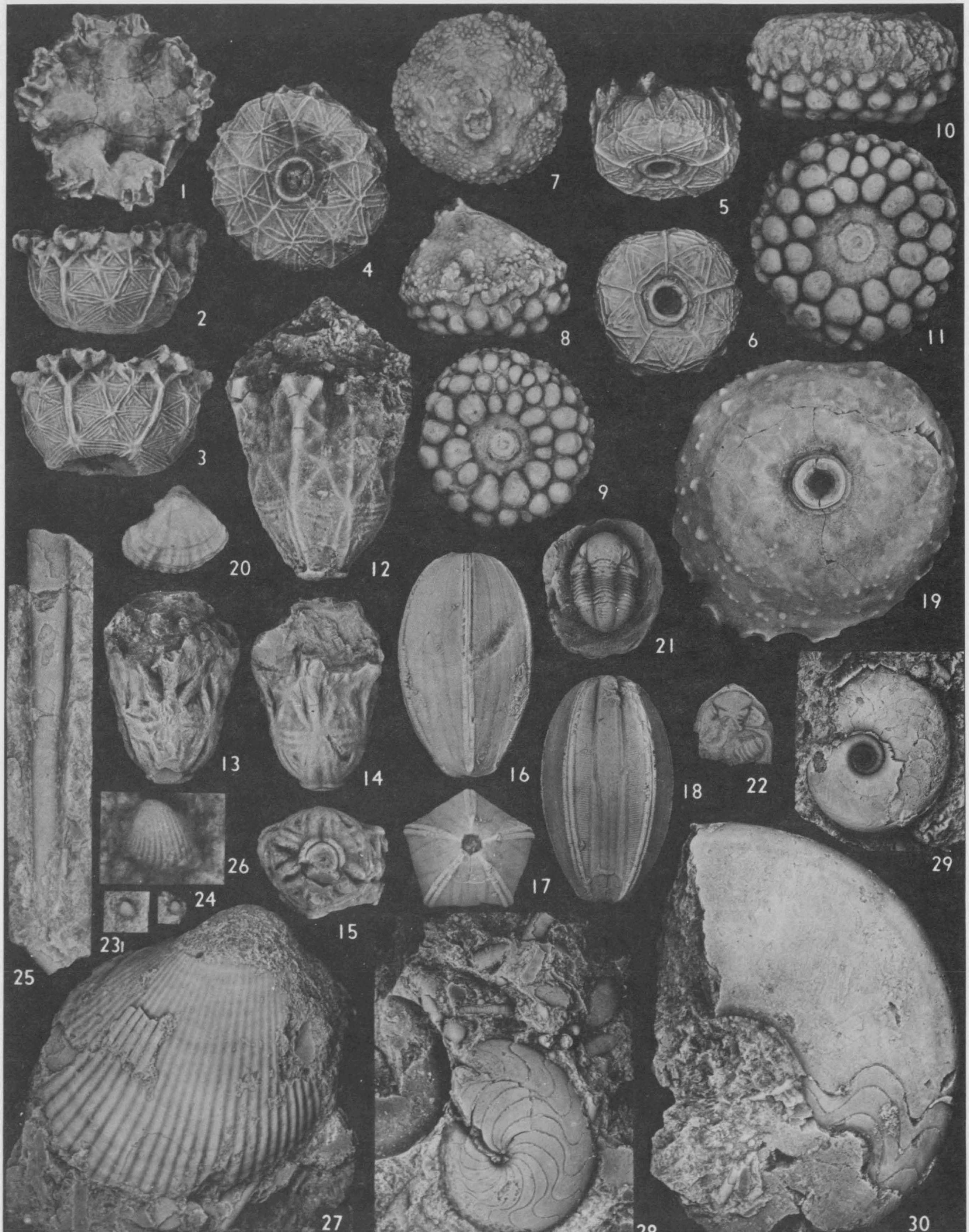
PLATE 38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The following composite section was measured and collected bed-by-bed at a time, many years ago, when beds 1-3 were exposed along the road between Four Mile Dam and Norway Point Dam and beds 3-11 along the road south from Four Mile Dam. In it, beds 1-4 correspond to unit 1, beds 5-7 correspond to unit 2, and beds 8-11 to unit 3:

Potter Farm Bed		Feet
11.	Limestone, gray, coral-stromatoporoid layer; Favosites alpenensis alpenensis Swann, Coenostroma monticulifera, Cladopora, Stromatopora pustulifera, cup corals (3 sp.), Cylindrophyllum hindshawi Ehlers & White, Strophodonta crassa Imbrie, S. potterensis Imbrie, Athyris (small), Conocardium, gastropod (large, low-spired)	2
10.	Covered	5
9.	Limestone, gray to bluish, many corals; Favosites alpenensis alpenensis Swann, Cylindrophyllum hindshawi Ehlers & White, cup corals, stromatoporoids	2
8.	Covered	8
7.	Limestone, gray, platy; Chonetes ensicosta Imbrie, Strophodonta crassa Imbrie, S. potterensis Imbrie, dwarf brachiopods and gastropods	7
6.	Limestone, crinoidal; Pentamerella papilla Imbrie	1
5.	Limestone, gray, lithographic	1
4.	Covered	3
3.	Limestone, crinoidal, fossils silicify on weathering	1
2.	Clay, blue, fossiliferous, weathering yellow; Cylindrophyllum hindshawi Ehlers & White, Alveolites, Cystiphylloides, Favosites, cup corals (3 sp.), Ceratopora, Coenostroma monticulifera, Hexagonaria (rare), Strophodonta, Atrypa (small), Athyris (small), Pentamerella papilla Imbrie, Cyrtina (small), terebratuloid brachiopod	$\frac{1}{2}$
1.	Limestone, gray, crinoidal	$\frac{1}{2}$
Norway Point		
	Shale, blue clay	1

Deposition. -- The alternating impure limestones and argillaceous shales seem to fall within the limits of zone III. The occurrence of stromatoporoids may indicate periods of somewhat shallower water. Although some beds qualify as biostromes, insofar as known no bioherms developed. It might be instructive to have chemical analyses of the various units, to see if the resistant units have about the same composition.

The change from Potter Farm to Thunder Bay deposition seems to have been accomplished with little change in lithology. The contact is not exposed and no unconformity is proved. There is a definite change in fauna, the Thunder Bay having faunal elements in common with the Cedar Valley Limestone of Iowa.

Thunder Bay - Squaw Bay — PLATE 38 — Figures x 1 except as noted

Thunder Bay: Gennaeocrinus romingeri; 1-3, #30519. Dolatocrinus barrisi; 4, #45097; 5, 6, #6018a. Megistocrinus concavus; 7-9, #5948b; 10, 11, #5948a. Corocrinus pettyesi; 12, #30529; 13-15, Buffalo Museum #E16585b. Nucleocrinus obovatus; 16-18, #1262. Megistocrinus nodosus; 19, #13598b. Pentamerella cf. matutinus; 20, #57631. Crassiproetus alpenensis; 21, #51983. Greenops alpenensis; 22, #25436. Squaw Bay: Buchiola sp.; 23, 26, #57629a, 26 x4; 24, #57629b. Bactrite warthini; 25, #20433. Paneka sp.; 27, #57630. Tornoceras (T.) uniangulare; 28, #15975e. Koenenites cooperi; 29, #13846b; 30, #13846a.

Thunder Bay Limestone

Name. -- In 1841 C. C. Douglass described strata from the "south cape of Thunder Bay" and used the name Thunder Bay for them. His work escaped the notice of Rominger (1876), Grabau (1902), and other later workers; therefore, Warthin & Cooper (1935, p. 525) proposed the name Partridge Point Formation for the beds at Partridge Point, four miles south of Alpena. Grabau (1902) had used the term Thunder Bay series for Traverse Group rocks above the Alpena Limestone and Pohl (1930) had similarly used Thunder Bay stage. In a review and revision of stratigraphy in 1943 (p. 593), Warthin & Cooper went back to Douglass' original name and conceded that "south cape" was in fact the type locality on the peninsula at Partridge Point.

Exposures. -- The type locality is still the most extensive outcrop of this formation.

Section of the Thunder Bay Limestone at the Type Locality
(Locality 30-8-11 SE)

Thunder Bay Limestone	Feet
6. Limestone, light gray, weathered to irregular slabs and pieces in ditch along Partridge Point Road near cliff	½
5. Covered, estimated	2
4. Limestone, gray, irregularly bedded, weathering buff; fossils rare	2
3. Shale, gray, calcareous, with limestone lenses, grading into granular limestone at the top	7½
2. Covered, non-resistant beds, probably a continuation of unit 3	3
1. Limestone, bluish, argillaceous, weathering to rusty brown	1
Thickness exposed	16

Covered. Dredging for water pipes to cottages along cliff brings up 2 to 3 feet of soft gray shale or clay containing fossils, possibly all belonging to the uppermost Potter Farm Formation. From a study of bottom contours in Thunder Bay, Warthin & Cooper (1943, p. 592) estimated the interval between the uppermost exposed unit of the Potter Farm Formation and the basal exposed unit of the Thunder Bay Limestone to be about 27 feet, in which there are two particularly resistant members (presumably hard limestones).

The other known exposure is along Lancaster Truck Trail at Locality 31-7-17 NW, where the upper beds of the Thunder Bay crop out in close proximity to the Squaw Bay Limestone and the Antrim Shale. They form low ledges in the fields.

Fossils. -- The fauna has definite affinities with that of the Cedar Valley Limestone. It is made up of a mass of corals, bryozoa, brachiopods, and echinoderms in each of the limy layers in unit 3. As these layers are weathered from the intervening shales, beautiful slabs are prepared by nature that show the bryozoa particularly well. Some 55 genera have been named in literature (Appendix 5), and many remain to be identified.

Unit	Fossils
4.	*Modiomorpha* cf. *mytiloides* Hall, *Homalonatus* cf. *dekayi* (Green); both rare.
3.	All megafossils listed above, plus *Dictyonema*, *Atrypa*, large syringothyroid spirifer, *Mucrospirifer*, large-spined *Platyceras*, and the bryozoa *Cyphotrypa*? *unica* Duncan, *Euspilipora serrata* Ulrich, *Fenestrellina compacta* (Deiss), *F. longispinosa* (Deiss), *F. nodicula* (Deiss),

F. variifenestrula (Deiss), Fistuliphragma spinulifera (Rominger), Fistulipora acervulosa (Rominger), F. corrugata Ulrich, F. stellifera Rominger, F. sulcata Rominger, Hederella cirrhosa Hall, H. compacta Bassler, H. delicatula Bassler, H. persimilis Bassler, H. rugosa Bassler, Lioclema incompositum Duncan, L. minutum Rominger, Polypora modesta Deiss, Scalaripora approximata Ulrich, S. separata Ulrich, Semicoscinium approximatum Deiss, and Sulcoretepora hamiltonensis (Ulrich).

1. Various fenestellid bryozoa and reworked crinoid columnals.

Among the Traverse Group formations, the following macrofossil species are recorded only from the Thunder Bay (Appendix 4):

Cylindrophyllum grabaui Ehlers & Stumm
Cystiphylloides americanum elongatum Stumm
Antholites alpenensis Stumm
Favosites romingeri gilvisquamulata Swann
Syringopora ehlersi Watkins
Trachypora perreticulata Stumm & Hunt
Cranaena lincklaeni (Hall)
Pentamerella proteus Imbrie
Basidechenella reimanni Stumm
Greenops alpenensis Stumm
Codaster gracile (Wachsmuth)
Nucleocrinus elegans ? Conrad
N. meloniformis (Barris)
N. obovatus (Barris)
Pentremitidea bassleri Reimann
P. bassleri hastula Reimann
P. milwaukeensis Weller
Lipsanocystis traversensis Ehlers & Leighly
Aorocrinus cassedayi (Lyon)
Botryocrinus thomasi Laudon
Corocrinus pettyesi Kesling
Dactylocrinus alpena Springer
D. barrisi (Wachsmuth & Springer)
D. triangulatus (Barris)
Euryocrinus barrisi Springer
Gennaeocrinus romingeri Kesling
Megistocrinus concavus Wachsmuth
M. multidecoratus (Barris)
M. novus (Wood)
M. tuberatus Wood
Synbathocrinus matutinus Hall.

More species are shared with the underlying Potter Farm Formation than with any other Traverse formation (Appendix 5).

Deposition. -- The diversity of fauna points to fairly deep water, but the presence of numerous corals and some stromatoporoids argues for shallower water. In the suggested classification, the Thunder Bay would come under zone III deposits. The echinoderms grew here in greater diversity and numbers than at any other time or place during the Traverse. It seems significant that crinoid columns are thoroughly disarticulated and the cup corals lie flat in certain layers; we may infer that some current or wave action reached the bottom, at least from time to time.

Squaw Bay Limestone

Name. -- The fossiliferous nature of these layers appears to have first been recognized by Grabau in 1908, when he mentioned the occurrence of cephalopods. They remained as part of the Thunder Bay series until 1935, when Warthin & Cooper named the formation for strata cropping out on the southwestern shore of Partridge Point.

Exposures. -- The formation is thin and non-resistant; hence, outcrops are hard to find. The best exposure is still the type locality, where an irregular pavement is exposed at low lake levels along the Squaw Bay shore.

Section of the Squaw Bay Limestone at the Type Locality

(Locality 30-8-11 SW)

	Feet
Antrim Shale	
Black, thinbedded to moderately thickbedded, some layers thin partings; small pyritiferous and large calcareous concretions ("hardheads") scattered throughout but concentrated at certain levels; relatively unfossiliferous except for conodonts.	
Squaw Bay Limestone	
4. Limestone, brown, crystalline, containing Upper Devonian cephalopods; exposed only on Lancaster Truck Trail..	$\frac{1}{2}$

3.	Covered, interval estimated from discussion by Warthin & Cooper (1943, p. 595) of total thickness	3 ½
2.	Limestone, brown, crystalline, irregularly dolomitic; fossil wood and cephalopods concentrated in certain beds, others barren; Tornoceras uniangulare (Conrad), Koenenites cooperi Miller, Bactrites warthini Miller, and Styliolina fissurella (Hall), the latter often found with long axes all parallel	3
1.	Covered, interval to unit 4 of the Thunder Bay Limestone estimated by Warthin & Cooper (1943, p. 595) at 5 feet. Some isolated shallow exposures of limestone occur in ditches along Partridge Point Road and probably belong to this formation.	2 ½
	Thickness about	9 ½

Many years ago a shaft was put down for a "gold mine" at Locality 31-6-36 SE, with sad results. Dump piles show that it penetrated through the black Antrim Shale into the Squaw Bay Limestone.

Another exposure is along Lancaster Truck Trail at Locality 31-7-17 C, at a road corner ditch, where it is near outcrops of both the underlying Thunder Bay Limestone (Locality 31-7-17 NW) and the overlying black Antrim Shale (Locality 31-7-17 S). Here it shows the typical fauna of molluscs and poorly preserved wood.

Fossils. -- The fauna consists entirely of molluscs and fossil wood, the latter in a poor state of preservation and sometimes almost macerated. The molluscs include cephalopods, pelecypods, a gastropod, and a species of pteropod:

Bactrites warthini Miller
Koenenites cooperi Miller
Tornoceras (Tornoceras) uniangulare (Conrad)
Diaphorostoma pugnus
Buchiola sp.
Paracardium sp.
Styliolina fissurella (Hall)

Deposition. -- The fossils are not evenly distributed in the layers at the type locality. Some thin beds are barren, whereas others are filled. The presence of wood and the strongly unbalanced fauna are evidence of a lagoonal type deposit, probably a brackish-water swamp isolated by a barrier beach, possibly connected with the open sea through channels from time to time. Perhaps some of the mollusca adapted to the environment, but we suspect that most or all of the specimens embedded in the limestone were cast over the low barrier during high tides or storms. On some bedding planes the Styliolina are all neatly aligned with their long axes parallel. On others, however, all faunal elements are packed in a jumbled mass. The presence of barren layers argues that few if any of the fossils were permanent inhabitants of the depositional area; instead, they were cut off or stranded there and died soon after.

Antrim Shale

Name. -- Winchell called the black shales overlying the Traverse Group the Huron Shales. Rominger (1876, p. 64) described them under the heading "Black Shales of Ohio - Genesee Shales of New-York." In 1893, M. E. Wadsworth reported that A. C. Lane stated that the St. Clair shales were deposited over the Traverse group rocks, and two years later Lane himself (Mich. Geol. Survey, v. 5) described the "St. Clair black shales." In 1901, Lane discovered that St. Clair was a preoccupied stratigraphic name, and replaced it with Antrim, "the name of the county in which the shales are exposed." Grabau (1902, p. 171) referred to the shales as the "Neo-Devonian black shale (Antrim), then as the "Black Shale" (p. 173), and again as the "black St. Clair shales" (p. 195). Some of the better descriptions of the outcrops were written by Ver Wiebe (1927, p. 190-192). Attempts have been made to introduce divisions within the black shale, but it seems best here to treat it as one formation.

It is now generally agreed that the type locality should be considered the shore exposures on Grand Traverse Bay of Lake Michigan near Norwood, Michigan.

Exposures. -- Although the Antrim is exposed at several places in the area, the best place to study it is at Locality 31-7-30 NE, the Paxton Shale Quarry:

Section of the Antrim Shale at Paxton Shale Quarry

Antrim Shale	Feet
9. Shale, black, with numerous spherical concretions	6 ½
8. Shale, alternating bands of greenish gray and black, few concretions	4
7. Shale, black, with greenish shale or mud lumps and pyrite	25 ½
6. Shale, greenish gray, calcareous (floor of quarry)	½
5. Shale, black (exposed in sump)	19
4. Shale, black, continuation of unit 5 (this and lower units known only from well drilled in quarry floor)	15 ½
3. "Limey material," cream-colored, effervesces with acid	3
2. Shale, black	21
1. "Sand," black, yielding fresh water, possibly at or very near the contact with the Squaw Bay Limestone	1 ½
Thickness	96 ½

Ver Wiebe described two kinds of concretions at Paxton Quarry. The larger consist chiefly of calcium carbonate with some clay and iron carbonate as impurities, ranging from about 8 inches to over three feet in diameter. Thousands of these spherical "hardheads" were discarded on the quarry floor, and many can be seen in rows. The central core is a bituminous calcite, anthracolite, which displays evidence of outward growth in radial structure. A few of this type have a geode center with secondary calcite, siderite, or magnesite (rarely quartz).

The second kind of concretion is smaller and much more irregular, commonly the size of a walnut and seldom exceeding that of a large apple. They are disseminated throughout the shale, but are more numerous at certain levels. The binding material is iron sulphide, likely pyrite.

Some fossils have been found in Paxton Quarry, but they are rare. The shales contain Callixylon newberryi (Dawson), Sporangites, and conodonts. A few concretions yield fish fragments assigned to Dinichthys. On the other side of the state, at the type locality, Rominger (1876, p. 66) reported wood fragments, dermal plates of Aspidichthys, and Lingula. The hardness of the spherical concretions and the scarcity of specimens insures against a large fauna being discovered.

Structure

Swan Creek Monocline. -- In addition to small-scale local folds, there are some interesting flexures of strata in this region. Two are monoclines. The more conspicuous is traversed by US 23 just east of Swan Creek. At Locality 34-6-17 NW, the Genshaw Formation is exposed in the bed of Swan Creek and at the nearby road cut on US 23. The beds contain Sieberella romingeri, Billingsastrea pauciseptata, and the large rotund Atrypa typical of the lower units of the Genshaw. From Swan Creek, the valley side rises for two miles to the east, to the junction of US 23 and M 65. Near this junction to the west, at Locality 34-6-16 E, the lower part of the Ferron Point Formation is exposed; to the east of the junction, at Locality 34-6-15 C, black coral beds of the Rockport Quarry Limestone form low ledges along US 23. These are at a much higher elevation than the exposures near Swan Creek. From the outcrop of the Rockport Quarry Limestone, the steep westerly component of the dip not only exceeds the topographic slope but also extends the whole of the Ferron Point Formation (here estimated at about 20 feet thickness) below the lowermost bed of the Genshaw before reaching Swan Creek. Eastward from Locality 34-6-15 C for nearly three miles, US 23 lies on the Rockport Quarry Limestone, which is exposed at Localities 34-6-14 SE and 34-6-24 NE. In this interval the Rockport Quarry Limestone dips gently to the south.

The rather abrupt change in dip at the Swan Creek Monocline is reflected in the strike, which is nearly east-west just west of Swan Creek and is north-south between US 23 and Posen. Along Grand Lake Highway (one mile north of Posen), the succession of exposures extends from the Cyrtina umbonata alpenensis zone of the Genshaw at Locality 33-6-9N, to the black Killians Member of the Genshaw at Locality 33-6-9 NNW, to the upper Genshaw at Locality 33-6-9 NW, to the Longispina emmetensis beds of the Alpena Limestone at Locality 33-6-8 NW. In this interval, just over 1 mile, about 100 feet of strata dip underground. The steep westerly dips change to gentle south-southwesterly dips near Posen.

Devil's Lake Monocline. -- This structure, between Alpena and Long Lake, is not as conspicuous as the Swan Creek Monocline. As shown in text-figure 3, about one mile south of Long Lake the strike of the formations becomes nearly east-west and the strata, gently dipping at Long Lake, are flexed strongly downward. Along the line of the cross section in text-figure 3, the lower Genshaw (52 feet thick) has an outcrop area $5\frac{1}{2}$ miles long, but the Killians Member, upper Genshaw, Newton Creek Limestone, and lower Alpena Limestone (totaling 111 feet) outcrop in a distance of about $1\frac{1}{2}$ miles; this is a change in dip from less than 10 feet/mile to about 74 feet/mile, not counting the extra dip component required to equal the topographic slope southward toward Thunder Bay.

Adams Point Dome. -- At Locality 35-6-21, the Adams Point Quarry of the US Steel Corporation, the strata of the Dundee Limestone dip sharply out under Lake Huron. Inasmuch as the strata dip away from a common center, the structure is a dome. Its shape can be seen on the geologic map. Because of its alignment with the Swan Creek Monocline, it may be structurally connected.

Orchard Hill Dome. -- At Localities 32-6-25 S, 32-7-30 S, 32-7-31 NW, 32-7-31 N, and 31-7-31 C, exposures of Potter Farm Formation are exposed in an east-west elongated dome, with steeper dips on the south side than on the north. The dome is almost or wholly surrounded by Norway Point Formation, and contains Potter Farm Formation in its center only because of the topographic relief. As mentioned, it has been suggested that this structure is caused by a large bioherm beneath; it is equally possible that it is entirely due to a local fold.

Rainy River Dome. -- In the bed and lower part of the banks of Rainy River in sections 22, 23, and 26, T 35 N, R 2 E, an abrupt little arch or dome exposes the Rockport Quarry Limestone and Ferron Point Formation within the outcrop area of the lower Genshaw Formation. In the SE$\frac{1}{4}$ sec. 22, the Ferron Point beds cross the river dipping about 45 feet/mile to the north, opposite to the general dip in the area.

Black Lake Trough. -- In section 8, T 35 N, R 2 E, a narrow lobe of Genshaw Formation outcrop extends to Black Lake. Much of the form of this northwestward areal extension may be attributed to the topographic effects of the valleys of Rainy River and Stony Creek; however, the constriction of the extension indicates dip components toward the axis to form a shallow trough.

Small arches or domes associated with sinkholes. -- Quarrying operations in the Calcite Quarry have exposed several sinkholes in the Rogers City Limestone, some extending down into the underlying Dundee Limestone. From the quarrymen's viewpoint, these are disgusting manifestations of Nature. They are filled with Bell Shale in most cases, but at least one contained Ferron Point strata in addition. The latter occurrence shows that collapse in some of the sinkholes occurred long ago, for erosion has now removed all the Ferron Point Formation and Rockport Quarry Limestone from the immediate vicinity and has eaten away the Ferron Point to the outcrop area, which is over a mile south of the quarry.

In each of the sinks, the edges of the Rogers City Limestone are sharply upturned. The same relationship of host rock to sink filling can be seen in the Rockport Quarry Limestone at the old Kelley's Island Quarry: wherever the strata of the Rockport Quarry are sharply upturned, the center of the small anticline or dome has been dissolved away and the space is filled with collapsed rocks from above. This suggests that the folding of these arches fractured the resistant limestones and permitted solution to progress down through the formation.

At the abandoned Kelley's Island Quarry, some of the sinkholes are filled with Ferron Point strata, but in at least one other the collapse included Genshaw Formation beds. The Rockport Quarry Limestone at this place is only 42 feet thick and the overlying Ferron Point Formation is about the same thickness. For the collapse to include Genshaw beds, solution may also have involved the Rogers City Limestone, with collapse of Bell Shale, Rockport Quarry Limestone, Ferron Point, and Genshaw Formations; or it is possible that the collapse occurred in stages, and at one time or another some Genshaw material fell down into the hole in the Rockport Quarry Limestone. Since the base of the sinkhole is not seen in the quarry, only a drill hole through the sink filling will provide an answer.

Just north of the quarry in section 36, T 33 N, R 8 E, are a number of sinkholes in the Rockport Quarry Limestone, which we have not examined. Grabau (1902, p. 190) reported at least a dozen, including the great "bottomless" sinkhole in which Bell Shale was exposed; his remarks are quoted under the Bell Shale above. We do not know whether these developed at the sites of structural arches, at joint intersections, or at random.

Small-scale folds. -- Even though each small outcrop (except near bioherms) appears to have an evenly dipping surface, the main quarry level in the Calcite Quarry (at the top of the magnesian beds of the Rogers City Limestone), stripped to a bedding plane over hundreds of acres, reveals gentle undulations with up to several feet relief.

Bioherms. -- By the mass of organic calcareous accumulation, the cores of the bioherms in the Alpena Limestone and the Four Mile Dam Formation built above the surrounding sea floor. Loose debris worked its way down the slopes on all sides and graded outward to form the dipping flanks. We have not seen evidence of settling of the massive core, but we suspect that it took place in the larger bioherms, just as it is known to have done in reefs of other regions. Most of the flank beds appear to retain their original slope in relation to the core rock. The greater hardness of the core did lead to settling of the overlying soft strata, as strikingly shown in the Four Mile Dam bioherm at the type locality, with some soft Norway Point beds draped over the top and others pinching out at their upturned edges against the old reef.

Karst features. -- The numerous sinkholes in the area of the Alpena Limestone have excited comment for many years. In some, the steep dips around them indicate that solution developed through the high-calcium core of a bioherm. In others, the extent of the solution makes the primary locus uncertain.

One of the largest of the Alpena Limestone sinkholes is Sunken Lake (Locality 33-6-32 C). Rominger wrote in 1876 (p. 46, 47):

> An interesting feature of this district are the numerous sink-holes found in it, hundreds of which may be counted along the headwaters of Thunder Bay River; some are small, funnel-shaped depressions, dry on the bottom, or containing water pools; others are narrow, vertical clefts, described to me by the woodsmen as sometimes 80 to 100 feet deep; and it is said of one which I passed that a large stream of water rushes across its bottom. A few of these sink-holes, as mentioned before, are of very large size, and form lakes. One of the latter is Sunken Lake in Township 33, R. 6, Section 32. It is about one mile and a half long, and in its widest part 500 yards. During the wet season, it is filled with water, having a depth of 90 feet; its overflow forms a branch of Thunder Bay River, which at that time is used for floating logs from the surrounding pineries to the saw mills of Alpena. During the dry summer season, the water almost totally disappears from the lake, making its escape through the rock crevices in its bottom. Formerly the water flowed off very rapidly, making a strong whirlpool. The lumbermen, in order to keep the water in the lake, threw masses of brush and even whole trees and rocks into the crevices to stop them up, and partially succeeded, but the water soon again cleared its passage through these obstructions; its efflux was retarded only, not prevented. At the time of my visit in June I found the lake 25 feet below high-water mark. At its west end a vertical rock wall about 15 feet high ascends from the water; the ledges are dolomitic limestone from 18 inches to 2 feet thick, of light gray color, separated by thin, intermediate shale seams; they contain Atrypa reticularis, Spirifer granuliferous, Strophodonta demissa, and Crinoid stems.

Rominger also recorded (1876, p. 45) another interesting sinkhole:

> In Township 32, R. 6, east, Section 34, on the farm of Mr. Marston, close to his dwelling-house, a large funnel-shaped sink-hole without an outlet attracts attention. It occupies the area of a few acres, and has a depth of about 25 feet; a strong spring issues from the side of the depression and disappears again in its bottom in crevices of the rock.

Only recently we learned from Prof. Rene L. Curl, of the Chemical and Metallurgical Engineering Department at The University of Michigan, that a cave has been known since about 1957 in the Alpena Limestone about 2½ miles south-southwest of Posen near the center of sec. 28, on the Grocholski farm. An interesting feature of the cave is known to the few speleologists that have descended into it as Bottle-Neck Pit, a vertical hole with a rather narrow entry at the top and an expanded base. The pit is approximately 100 feet deep. At times water rises in it and the muddy residue obscures the rock sides to some degree. Prof. Curl plans further exploration and study of this feature; in his descent, he noted that the floor of the pit was covered with blocks and rubble from above and that about 5 feet above the floor an 8-inch layer of soft shale had weathered back notably to form a horizontal groove around the whole of Bottle-Neck Pit. From the depth of this sinkhole and the fact that it must start within the Alpena Limestone at its top, it seems certain that the exposed walls pass through the Newton Creek Limestone and well down into the Genshaw Formation; it seems likely that the solution reached at least into the Rockport Quarry Limestone, although the record of such solution is now obscured by fill from collapsed strata. An interesting experiment with trace solutions might establish the route of the drainage from the bottom of the pit; since it begins more than 100 feet below the surface, it seems likely that it drains off into some deep valley filled with glacial till to the west.

Other karst features are developed in the thinner Rockport Quarry Limestone. The several sinkholes in section 36 north of the Kelley's Island Quarry have been mentioned. Two prominent features are found in eastern Alpena County, Devil's Lake and El Cajon Bay. Both undoubtedly involve solution in the Rockport Quarry, although the strata exposed at Devil's Lake (Locality 32-8-23 SE) are lower Genshaw Formation and those at El Cajon Bay (Locality 31-9-15 SW) are upper Genshaw Formation. Devil's Lake receives water from Long Lake. During the wet season its basin (of solid rock) overflows in rapids through Hell Creek, but in the summer dry season the water all drains through a subterranean outlet at the bottom of the basin, leaving Hell Creek as a small dry run. At El Cajon Bay at the head of Misery Bay, the deep hole discharges an appreciable volume of water, but its exact source is unknown; it is over six miles from Devil's Lake. Rominger (1876, p. 49) reported a depth of 100 feet in El Cajon Bay. The surface strata are upper Genshaw, and 100 feet would place the bottom of the hole at the middle of the Ferron Point Formation; assuming some collapse and fill, solution undoubtedly extended into Rockport Quarry Limestone and took place when Lake Huron was not there to bring the water table nearly to the top of the sinkhole.

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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 publications since 1961. Only published faunal records are incorporated. In some cases this represents a taxonomic group rather fully; in other cases, however, the sparsity of fauna indicated is only a reflection of the lack of interest by the specialists on the group. We have updated the generic assignments of some species, which we recognized at first glance, but we did not conduct an exhaustive revision of generic content. The appendices give a good summary of what is available in literature on the fossils of the Traverse Group.

APPENDIX 1

GENERA OF MACROFOSSILS RECORDED FROM FORMATIONS OF THE TRAVERSE GROUP

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
TETRACORALLA											
Atelophyllum	x						x				
Aulacophyllum			x	x		x			x	x	
Bethanyphyllum	x					x			x	x	
Billingsastrea		x		x							
Cyathophyllum		x		x							
Cylindrophyllum		x					x		x	x	
Cystiphylloides	x	x	x	x		x	x		x	x	
Depasophyllum							x				
Disphyllum									x		
Eridophyllum							x				
Hallia									x		
Heliophyllum	x		x	x			x		x		
Heterophrentis	x	x	x	x		x			x	x	
Hexagonaria	x	x	x	x	x	x	x				
Iowaphyllum							x				
Lythophyllum				x							
Microcyclus						x					
Naos	x					x					
Spongophyllum		x							x		
Stereolasma									x	x	
Synaptophyllum									x		
Tabulophyllum	x			x		x	x		x		
Tortophyllum	x					x			x		
Total 23	9	7	5	9	1	9	9	0	13	6	0
TABULATA											
Alveolites						x			x	x	
Antholites							x			x	
Aulocystis	x	x	x	x	x	x	x	x	x		
Aulopora	x		x	x		x	x	x			
Cladopora				x			x	x			
Drymopora	x			x			x	x	x	x	
Emmonsia	x	x		x		x	x		x		
Favosites	x	x	x	x	x	x	x		x	x	
Pachyphragma	x		x			x	x		x		
Platyaxum							x			x	
Pleurodictyum	x						x				
Striatopora							x	x			
Syringopora										x	
Trachypora	x	x		x		x	x	x	x	x	
Total 14	8	4	4	7	2	7	12	6	7	7	0

BRACHIOPODA - ARTICULATA

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Athyris			x	x				x		x	
Atrypa	x		x	x		x	x	x		x	
Brachyspirifer				x			x				
Callipleura							x				
Camarospira							x				
Camarotoechia							x	x		x	
Camerophoria					x		x				
Charionella					x						
Chonetes	x	x	x	x		x		x	x	x	
Cranaena			x	x	x			x	x	x	
Cryptonella	x							x			
Cyrtina			x	x		x	x	x		x	
Douvillina							x				
Elytha							x				
Fimbrispirifer							x				
Gypidula				x							
Helaspis	x		x	x							
Hercostrophia						x					
Heteralosia				x							
Leiorhynchus	x										
Leptalosia				x		x	x	x			
Leptostrophia	x										
Longispina	x	x	x	x		x	x				
Megastrophia	x					x	x	x			
Meristella			x	x							
Mucrospirifer	x		x	x		x	x	x	x	x	
Oligorhachis							x				
Parazyga							x				
Pentamerella	x	x	x	x	x	x	x	x	x		
Pholidostrophia	x	x	x	x		x		x			
Productella				x							
Protoleptostrophia				x		x	x	x			
Rhipidomella						x	x				
Schizophoria	x	x	x	x							
Schuchertella	x	x	x	x			x	x			
Sieberella				x	x						
Sphenophragmus								x			
Spinocyrtia	x		x	x		x	x	x			
Spinulicosta	x	x	x				x		x	x	
"Spirifer"				x							
Strophodonta	x	x	x	x		x	x	x	x		
Trematospira							x				
Truncalosia				x		x		x	x		
Total 43	16	8	16	24	5	15	24	18	7	10	0

CRUSTACEA - TRILOBITA

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Acidaspis (?)	x										
Ancyropyge	x										
Basidechenella			x	x		x	x	x	x	x	
Crassiproetus			x	x	x	x	x		x	x	
Dechenella	x		x	x					x		
Dipleura								x		x	
Greenops							x	x	x	x	
Mystrocephala							x				
Phacops	x		x	x		x	x	x	x	x	
Total 9	4	0	4	4	1	3	5	4	5	5	0

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
MOLLUSCA - PELECYPODA											
Buchiola											x
Cimitaria										x	
Conocardium								x			
Cornellites	x										
Grammysia	x										
Modiomorpha				x							
Paracardium											x
Plethomytilus										x	
Total 8	2	0	0	1	0	0	0	1	0	2	2
MOLLUSCA - GASTROPODA											
Cyrtonella							x				
Diaphorostoma											x
Pleurotomaria								x	x		
Styliolina											x
Tentaculites										x	
Total 5	0	0	0	0	0	0	1	1	1	1	2
MOLLUSCA - CEPHALOPODA											
Acleistoceras					x						
Alpenoceras					x						
Bactrites											x
Exocyrtoceras							x				
Gomphoceras				x							
Koenenites											x
Lyrioceras				x							
Michelinoceras				x	x						
Nephriticerina					x						
Tornoceras											x
Total 10	0	0	0	3	4	0	1	0	0	0	3
All Mollusca 25	2	0	0	4	4	0	2	2	1	3	7
ECHINODERMATA - BLASTOIDEA											
Codaster									x	x	
Nucleocrinus							x			x	
Pentremitidea	x			x				x		x	
Total 3	1	0	0	1	0	0	1	1	1	3	0
ECHINODERMATA - CRINOIDEA											
Aorocrinus										x	
Atractocrinus								x			
Botryocrinus							x			x	
Cadiscocrinus								x			
Corocrinus										x	
Dactylocrinus										x	
Dolatocrinus						x	x		x	x	
Euryocrinus										x	
Gennaeocrinus	x									x	
Gilbertsocrinus	x										
Halysiocrinus							x				
Logocrinus	x										
Megistocrinus						x	x			x	

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Melocrinites	x										
Opsiocrinus	x										
Synbathocrinus							x			x	
Total 16	5	0	0	0	0	2	5	2	1	8	0
ECHINODERMATA - CYSTOIDEA											
Lipsanocystis							x		x	x	
Pothocrinus						x					
Total 2	0	0	0	0	0	1	1	0	1	1	0
ECHINODERMATA - EDRIOASTEROIDEA											
Agelacrinites			x								
Hemicystites			x								
Lepidodiscus			x								
Timeischytes							x				
Total 4	0	0	3	0	0	0	1	0	0	0	0
All Echinodermata	6	0	3	1	0	3	8	3	3	12	0

APPENDIX 2

NUMBER OF GENERA OF MACROFOSSILS SHARED BY FORMATIONS OF THE TRAVERSE GROUP

	Total Genera	Shared in common with										
		BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Bell Shale	45	--	15	21	25	4	22	21	16	19	13	0
Rockport Quarry Ls.	19	15	--	16	16	4	12	12	4	13	8	0
Ferron Point Fm.	32	21	16	--	27	6	20	19	15	16	13	0
Genshaw Formation	49	25	16	27	--	8	26	26	22	20	21	0
Newton Creek Ls.	13	4	4	6	8	--	4	5	2	3	2	0
Alpena Limestone	37	22	12	20	26	4	--	26	17	21	15	0
Four Mile Dam Fm.	59	21	12	19	26	5	26	--	20	20	21	0
Norway Point Fm.	33	16	4	15	22	2	17	20	--	9	14	0
Potter Farm Fm.	36	19	13	16	20	3	21	20	9	--	20	0
Thunder Bay Ls.	44	13	8	13	21	2	15	21	14	20	--	0
Squaw Bay Ls.	7	0	0	0	0	0	0	0	0	0	0	0

APPENDIX 3

NUMBER OF GENERA IN EACH MAJOR TAXON
RECORDED FROM FORMATIONS OF THE TRAVERSE GROUP

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Porifera	0	0	0	0	0	0	0	0	1	0	0
Tetracoralla	9	7	5	9	1	9	9	0	13	6	0
Tabulata	8	4	4	7	2	7	12	6	7	7	0
Stromatoporoidea	0	1	0	4	0	1	0	0	5	1	0
Brachiopoda - Artic.	16	8	16	24	5	15	24	18	7	10	0
Vermes	0	0	0	1	0	0	0	0	5	0	0
Bryozoa	21	0	19	13	0	7	18	13	6	11	0

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Mollusca											
Pelecypoda	2	0	0	1	0	0	0	1	0	2	2
Gastropoda	0	0	0	0	0	0	1	1	1	1	1
Pteropoda	0	0	0	0	0	0	0	0	0	0	1
Cephalopoda	0	0	0	3	4	0	1	0	0	0	3
Crustacea											
Trilobita	4	0	4	4	1	3	5	4	5	5	0
Ostracoda	15	2	10	16	0	2	2	32	0	0	0
Echinodermata											
Cystoidea	0	0	0	0	0	1	1	0	1	1	0
Blastoidea	1	0	0	1	0	0	1	1	1	3	0
Crinoidea	5	0	0	0	0	2	5	2	1	8	0
Edrioasteroidea	0	0	3	0	0	0	1	0	0	0	0
Graptozoa	0	0	0	0	0	0	0	1	0	0	0
Invertebrates	81	22	61	83	13	47	80	79	53	55	7

APPENDIX 4

SPECIES OF MACROFOSSILS RECORDED FROM THE TRAVERSE GROUP

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
TETRACORALLA											
Atelophyllum magnum Stumm							x				
Atelophyllum subcylindricum Stumm	x										
Aulacophyllum alpenense Stumm						x					
Aulacophyllum hemicrassatum Sloss			x						x	x	
A. scyphus (Rominger)			x	x							
Bethanyphyllum bellense Stumm	x										
Bethanyphyllum geniculatum (Rominger)						x			x	x	
Billingsastrea pauciseptata Ehlers & Stumm				x							
Billingsastrea rockportensis Ehlers & Stumm		x									
Billingsastrea romingeri Ehlers & Stumm				x							
Cylindrophyllum delicatulum Ehlers & Stumm		x									
Cylindrophyllum grabaui Ehlers & Stumm										x	
Cylindrophyllum hindshawi Ehlers & White									x		
Cylindrophyllum magnum Ehlers & Stumm							x				
Cylindrophyllum panicum (Winchell)									x		
Cystiphylloides cf. aggregatum (Billings)									x		
Cystiphylloides alpenense Stumm						x	x				
Cystiphylloides (?) amalgamatum Stumm									x		
Cystiphylloides americanum Edwards & Haime							x				
Cystiphylloides americanum bellense Stumm	x	x	x								
Cystiphylloides americanum elongatum Stumm										x	
Cystiphylloides petoskeyense Stumm									x		
Cystiphylloides phacelliforme Stumm			x	x							
Cystiphylloides potterense Stumm									x		
Depasophyllum adnetum Grabau							x				
Disphyllum compactum Ehlers & Stumm									x		
Eridophyllum archiaci (Billings)							x				
Hallia vesiculata Sloss									x		
Heliophyllum elongatum Stumm & Tyler							x				
Heliophyllum ferronense Stumm & Tyler			x								
Heliophyllum halli Edwards & Haime							x				
Heliophyllum halli bellense Stumm & Tyler	x										
Heliophyllum halli potterense Stumm & Tyler									x		
Heliophyllum juvene Rominger							x				
Heliophyllum rotatorium Stumm & Tyler									x		

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Heliophyllum tenuiseptatum tentaculum Stumm & Tyler									x		
Heliophyllum tenuiseptatum traversense Stumm & Tyler							x				
Heterophrentis curviseptata Stumm									x		
Heterophrentis ferronensis Stumm	x		x	x							
Heterophrentis gregaria (Rominger)		x									
Heterophrentis simplex alpenensis Stumm						x					
Iowaphyllum alpenense (Rominger)							x				
Lythophyllum alpenense Stumm				x							
Microcyclus alpenensis Stumm						x					
Naos ovatus (Sloss)	x										
Naos ponderosus (Rominger)						x					
Spongophyllum alpenense Ehlers & Stumm									x		
Spongophyllum romingeri Ehlers & Stumm		x									
Stereolasma petoskeyense (Sloss)									x		
Synaptophyllum crassiseptatum Ehlers & Stumm									x		
Tabulophyllum curtum Stumm	x										
Tabulophyllum elongatum Stumm	x										
Tabulophyllum traversense (Winchell)				x		x	x		x		
Tortophyllum cysticum (Winchell)						x			x		
Tortophyllum magnum Stumm									x		
TABULATA											
Alveolites goldfussi Billings						x					
Alveolites subramosus Rominger									x		
Antholites alpenensis Stumm										x	
Antholites bridghami (Greene)							x				
Aulocystis alectiformis (Winchell)						x					
Aulocystis alectiformis dubia Watkins					x						
Aulocystis alectiformis reptata Watkins				x							
Aulocystis alpenensis Watkins									x		
Aulocystis commensalis Watkins								x			
Aulocystis cooperi Watkins							x		x		
Aulocystis crassimurata Watkins	x										
Aulocystis fenestrata (Winchell)						x					
Aulocystis fenestrata problematica Watkins				x							
Aulocystis jacksoni (Grabau)			x								
Aulocystis magnispina Watkins		x	x								
Aulocystis multicystosa Watkins	x										
Aulocystis parva Watkins									x		
Aulocystis stummi Watkins								x			
Aulopora conferta Winchell	x										
Aulopora gregaria Watkins				x		x	x				
Aulopora microbuccinata Watkins	x		x	x							
Aulopora "serpens" Goldfuss							x				
Cladopora alpenensis Rominger							x				
? Drymopora erecta Rominger								x			
Drymopora "nobilis" Billings								x			
Emmonsia alpenensis Stumm & Tyler	x	x		x		x			x		
Emmonsia radiata (Rominger)							x				
Favosites alpenensis alpenensis Winchell					x	x			x		
Favosites alp. bellensis Swann	x										
Favosites alp. calveri Swann				x	x	x					
Favosites alp. hindshawi Swann				x							
Favosites alp. kellyi Swann		x									
Favosites alp. killiansensis Swann				x							
Favosites alp. peninsulae Swann		x	x								
Favosites alp. tenuimuralis Swann					x	x			x		
Favosites billingsi Rominger							x				
Favosites clausus Rominger							x				
Favosites digitatus Rominger	x	x		x		x	x				
Favosites mammillatus Stumm & Tyler	x		x	x		x	x		x	x	

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Favosites nitellus Winchell						x					
Favosites placentus Rominger						x	x		x	x	
Favosites radiciformis Rominger							x				
Favosites romingeri gilvisquamulata Swann										x	
Favosites romingeri patella Swann									x		
Favosites romingeri romingeri Swann									x		
Favosites rom. romingeri pisum Swann									x		
Favosites romingeri saetigera Swann						x					
Favosites turbinatus Billings						x					
Favosites valentini Swann	x										
Favosites warthini Swann							x				
Pachyphragma concentricum Watkins			x	x		x	x				
Pachyphragma cylindricum Watkins	x		x								
Pachyphragma erectum (Rominger)									x		
Platyaxum fischeri (Billings)							x				
Pleurodictyum (Procteria) cornu Stumm	x										
Pleurodictyum insigne (Rominger)							x				
Pleurodictyum wardi (Greene)							x				
Striatopora cf. iowensis (Owen)							x				
Striatopora linneana Billings							x				
Striatopora rugosa Hall								x			
Syringopora ehlersi Watkins										x	
Trachypora alpenensis Stumm & Hunt						x					
Trachypora alternans Stumm & Hunt						x	x	x	x	x	
Trachypora dendroidea Stumm & Hunt							x				
Trachypora elegantula Billings							x				
Trachypora lineata Stumm & Hunt							x		x		
Trachypora ornata Stumm & Hunt						x	x	x	x		
Trachypora perreticulata Stumm & Hunt										x	
Trachypora proboscidialis (Rominger)						x	x		x	x	
Trachypora (?) reticulata Stumm & Hunt				x		x	x			x	
Trachypora rockportensis Stumm & Hunt		x									
BRACHIOPODA - ARTICULATA											
Callipleura nobilis (Hall)							x				
Camarotoechia thedfordensis Whiteaves							x				
Chonetes cf. coronatus (Conrad)	x										
Chonetes ensicosta Imbrie									x		
Chonetes fragilis Stewart	x										
Chonetes mediolatus Cooper	x	x	x								
Chonetes nateforma Imbrie			x								
Chonetes pachyactis Imbrie								x			
Cranaena aff. amygdaloidea Cooper & Cloud									x		
Cranaena casei Foerste					x						
Cranaena lincklaeni (Hall)										x	
Cryptonella aff. attenuata (Whiteaves)	x										
Cyrtina umbonata alpenensis Hall & Clarke				x							
Douvillina distans Imbrie							x				
Elytha fimbriata (Conrad)							x				
Fimbrispirifer venustus (Hall)							x				
Helaspis luma crista Imbrie				x							
Helaspis luma luma Imbrie			x	x							
Hercostrophia alpenensis Williams						x					
Leiorhynchus lucasi Stewart	x										
Leptalosia radicans (Winchell)				x		x	x	x			
Longispina emmetensis (Winchell)						x	x				
Longispina leionanus Imbrie	x										
Longispina lissohybus Imbrie			x								
Longispina pelta Imbrie		x									
Longispina subclava Imbrie			x	x							
Megastrophia concava Hall						x	x				
Megastrophia gibbosa Imbrie							x				

	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Mucrospirifer alpenensis (Grabau)	x		x								
Mucrospirifer attenuatus (Grabau)								x	x		
Mucrospirifer grabaui Stumm							x				
Mucrospirifer latus (Grabau)						x		x	x		
Mucrospirifer multiplicatus (Grabau)				x							
Mucrospirifer profundus (Grabau)								x	x		
Mucrospirifer prolificus (Stewart)	x		x								
Oligorhachis oligorhachis Imbrie							x				
Parazyga hirsuta (Hall)							x				
Pentamerella alpenensis Imbrie						x	x				
Pentamerella lingua Imbrie			x								
Pentamerella papilla Imbrie									x		
Pentamerella cf. pavilionensis Hall							x				
Pentamerella pericosta Imbrie								x			
Pentamerella petoskeyensis (Imlay)									x		
Pentamerella proteus Imbrie										x	
Pentamerella tumida Imbrie				x	x						
Pholidostrophia ovata Imbrie								x			
Pholidostrophia geniculata Imbrie						x					
Pholidostrophia gracilis gracilis Imbrie	x	x	x	x							
Pholidostrophia gracilis nanus Imbrie	x										
Protoleptostrophia lirella Imbrie						x	x	x			
Rhipidomella penelope traversensis Imbrie							x				
Schizophoria ferronensis Imbrie	x	x	x								
Schizophoria striatula delta Grabau				x							
Schizophoria striatula traversensis Grabau				x							
Schuchertella anomala (Winchell)							x				
Schuchertella cornucopia Imbrie				x							
Schuchertella crassa Imbrie	x	x	x								
Schuchertella lirella Imbrie				x							
Sieberella newtonensis Imbrie					x						
Sieberella romingeri (Hall & Clarke)				x							
Sphenophragmus nanus Imbrie								x			
Spinulicosta mutocosta Imbrie	x	x	x				x		x	x	
Strophodonta acris Imbrie				x							
Strophodonta alpenensis Grabau								x			
Strophodonta crassa Imbrie									x		
Strophodonta discus Imbrie						x					
Strophodonta elongata Imbrie									x		
Strophodonta erratica Winchell						x	x				
Strophodonta extenuata Imbrie				x							
Strophodonta extenuata bellensis Imbrie	x										
Strophodonta extenuata extenuata Imbrie			x								
Strophodonta extenuata ferronensis Imbrie			x								
Strophodonta extenuata genshawensis Imbrie				x							
Strophodonta extenuata rockportensis Imbrie		x									
Strophodonta fascis Imbrie			x								
Strophodonta fissicosta Winchell							x				
Strophodonta leptoidema Imbrie						x					
Strophodonta micropleura Imbrie						x					
Strophodonta nana Imbrie						x	x				
Strophodonta paula Imbrie						x	x				
Strophodonta potterensis Imbrie									x		
Strophodonta proetus Imbrie						x					
Strophodonta titan Imbrie				x		x					
Strophodonta titan costella Imbrie				x							
Strophodonta titan titan Imbrie						x					
Truncalosia gibbosa Imbrie				x		x		x	x		

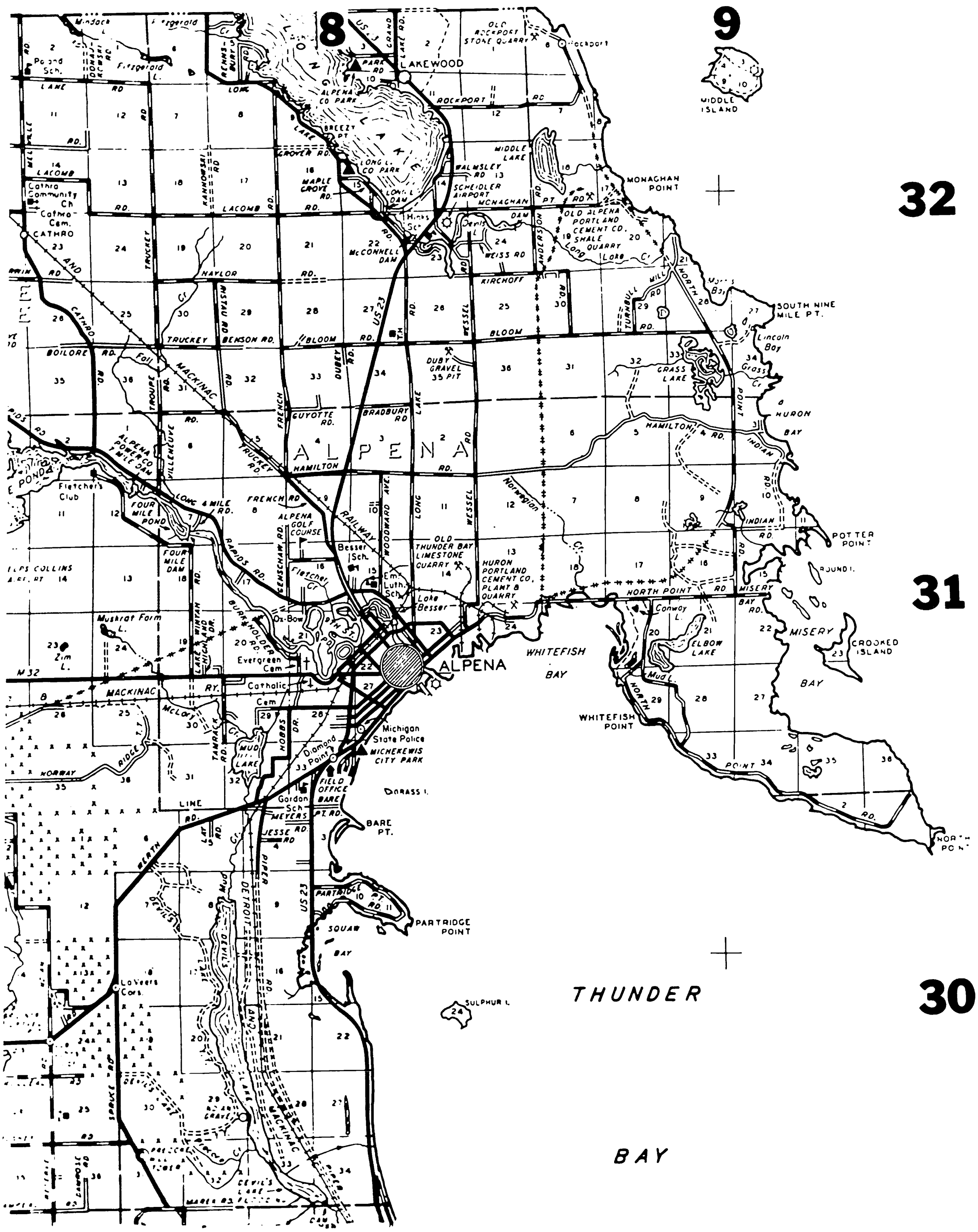
	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
CRUSTACEA - TRILOBITA											
Ancyropyge romingeri (Hall & Clarke)	x										
Basidechenella macrocephala (Hall)							x				
Basidechenella nodosa Stumm			x	x							
Basidechenella pulchra Stumm						x	x				
Basidechenella reimanni Stumm										x	
~~Basidechenella rowi (Green)~~							x				
Crassiproetus alpenensis Stumm									x	x	
Crassiproetus microgranulatus Stumm						x					
Crassiproetus traversensis Stumm							x				
Dechenella alpenensis Stumm	x		x	x							
Dipleura dekayi Green								x		x	
Greenops alpenensis Stumm										x	
Greenops boothi (Green)								x			
Greenops traversensis Stumm							x				
Mystrocephala rara (Stumm)							x				
Phacops iowensis Delo									x	x	
Phacops milleri Stewart	x		x	x							
Phacops rana (Green)						x	x	x			
Phacops rana alpenensis Stumm						x					
Phacops rana bellensis Stumm	x										
Phacops rana crassituberculata Stumm			x								
MOLLUSCA - GASTROPODA											
Cyrtonella nitella (Hall)							x				
Diaphorostoma pugnus											x
Pleurotomaria alpenensis Ehlers & Hussey									x		
MOLLUSCA - PTEROPODA											
Styliolina fissurella (Hall)											x
MOLLUSCA - CEPHALOPODA											
Acleistoceras casei Foerste					x						
Acleistoceras nummulatum Foerste					x						
Alpenoceras ulrichi Foerste					x						
Bactrites warthini Miller											x
Exocyrtoceras reimanni Flower							x				
Koenenites cooperi Miller											x
Lyrioceras hindshawi (Ehlers & Hussey)				x							
Michelinoceras anguliferum alpenense (Foerste)					x						
Nephriticerina alpenensis Foerste					x						
Tornoceras (*T.*) *uniangulare* (Conrad)											x
ECHINODERMATA - BLASTOIDEA											
Codaster alatus Reimann									x		
Codaster gracile (Wachsmuth)										x	
Nucleocrinus elegans ? Conrad										x	
Nucleocrinus meloniformis (Barris)										x	
Nucleocrinus obovatus (Barris)										x	
Pentremitidea americana Barris								x			
Pentremitidea arrecta Reimann	x										
Pentremitidea bassleri Reimann										x	
Pentremitidea bassleri hastula Reimann										x	
Pentremitidea bellatula Reimann	x										
Pentremitidea clavatiformis Reimann								x			
Pentremitidea cooperi Reimann								x			
Pentremitidea cooperi breviceps Reimann								x			
Pentremitidea filosa Whiteaves								x			
Pentremitidea milwaukeensis Weller										x	
Pentremitidea ovalis michiganense Reimann				x							
Pentremitidea preciosa Reimann				x							

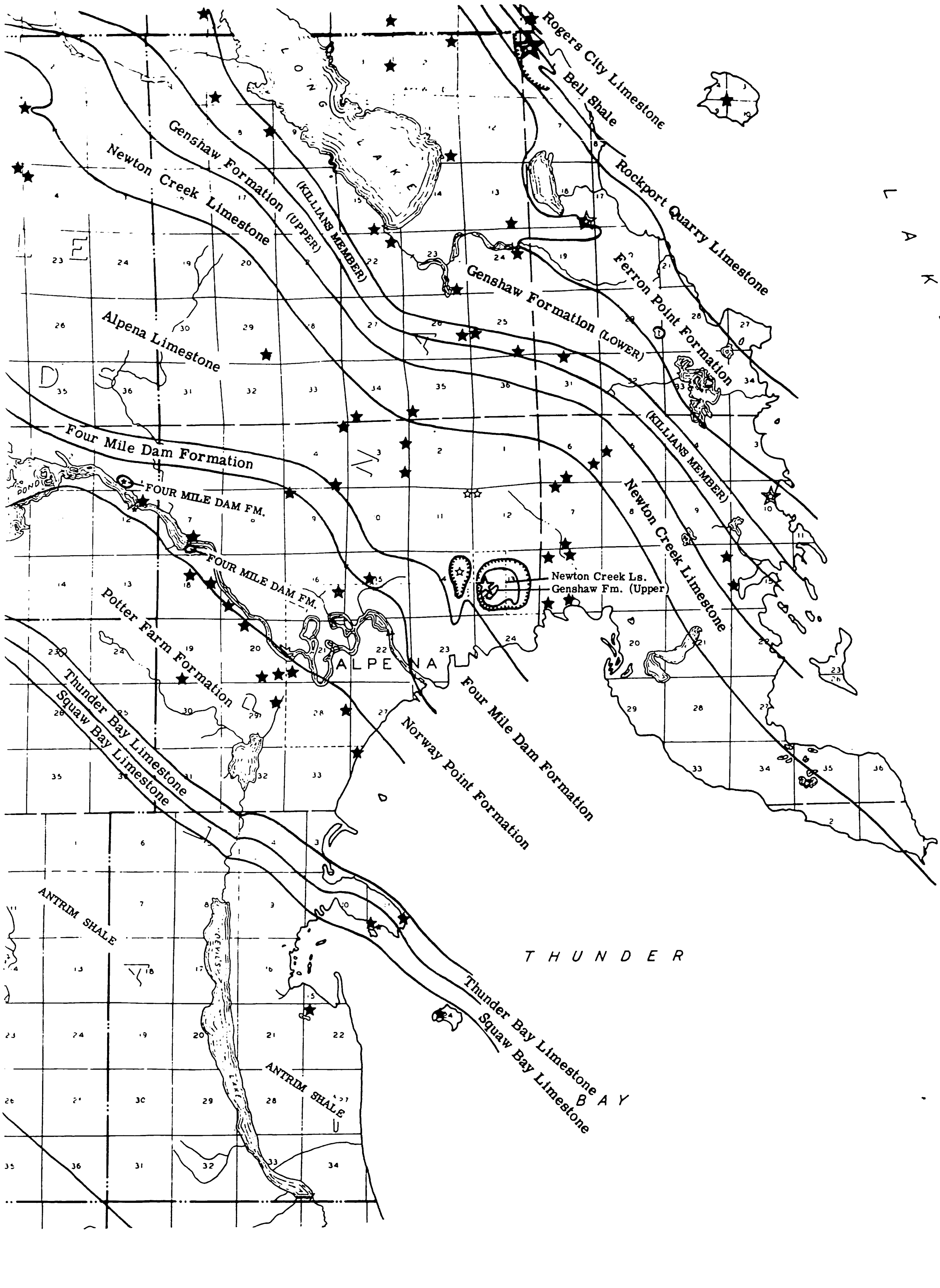
	BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
ECHINODERMATA - CYSTOIDEA											
Lipsanocystis magnus Stumm							x				
Lipsanocystis oblatus Stumm									x		
Lipsanocystis rugosus Stumm							x				
Lipsanocystis traversensis Ehlers & Leighly										x	
Pothocrinus cooperi Kirk						x					
ECHINODERMATA - EDRIOASTEROIDEA											
Hemicystites devonicus Bassler			x								
Lepidodiscus alpenensis Bassler			x								
Timeischytes megapinacotus Ehlers & Kesling							x				
ECHINODERMATA - CRINOIDEA											
Aorocrinus cassedayi (Lyon)										x	
Atractocrinus curtus Kirk								x			
Botryocrinus reimanni granilineatus Goldring							x				
Botryocrinus thomasi Laudon										x	
Corocrinus pettyesi Kesling										x	
Dactylocrinus alpena Springer										x	
Dolatocrinus amplus Miller & Gurley							x				
Dolatocrinus asterias Wood						x				x	
Dolatocrinus barrisi (Wachsmuth & Springer)										x	
Dolatocrinus bulbaceous Miller & Gurley							x				
Dolatocrinus costatus Wood						x	x				
Dolatocrinus grabaui Kirk									x		
Dolatocrinus incisus Springer						x					
Dolatocrinus liratus (Hall)							x				
Dolatocrinus michiganensis Kesling & Mintz							x				
Dolatocrinus stellifer Miller & Gurley						x	x				
Dolatocrinus triadactylus Barris							x			x	
Dolatocrinus triangulatus (Barris)										x	
Dolatocrinus venustus Miller & Gurley						x	x				
Euryocrinus barrisi Springer										x	
Gennaeocrinus goldringae Ehlers	x										
Gennaeocrinus romingeri Kesling										x	
Gennaeocrinus variabilis Kesling & Smith	x										
Gilbertsocrinus alpenensis Ehlers	x										
Halysiocrinus barrisi (Worthen)							x				
Halysiocrinus carinatus Springer							x				
Logocrinus conicus Kesling	x										
Megistocrinus concavus Wachsmuth										x	
Megistocrinus expansus Miller & Gurley						x					
Megistocrinus multidecoratus (Barris)										x	
Megistocrinus nodosus Barris						x				x	
Megistocrinus novus (Wood)										x	
Megistocrinus regularis Wood						x					
Megistocrinus rugosus Lyon & Casseday							x				
Megistocrinus sphaeralis Wood						x					
Megistocrinus tuberatus Wood										x	
Melocrinites michiganensis Kesling	x										
Opsiocrinus mariae Kier	x										
Synbathocrinus matutinus Hall										x	
Synbathocrinus michiganensis Kesling & Smith							x				

APPENDIX 5

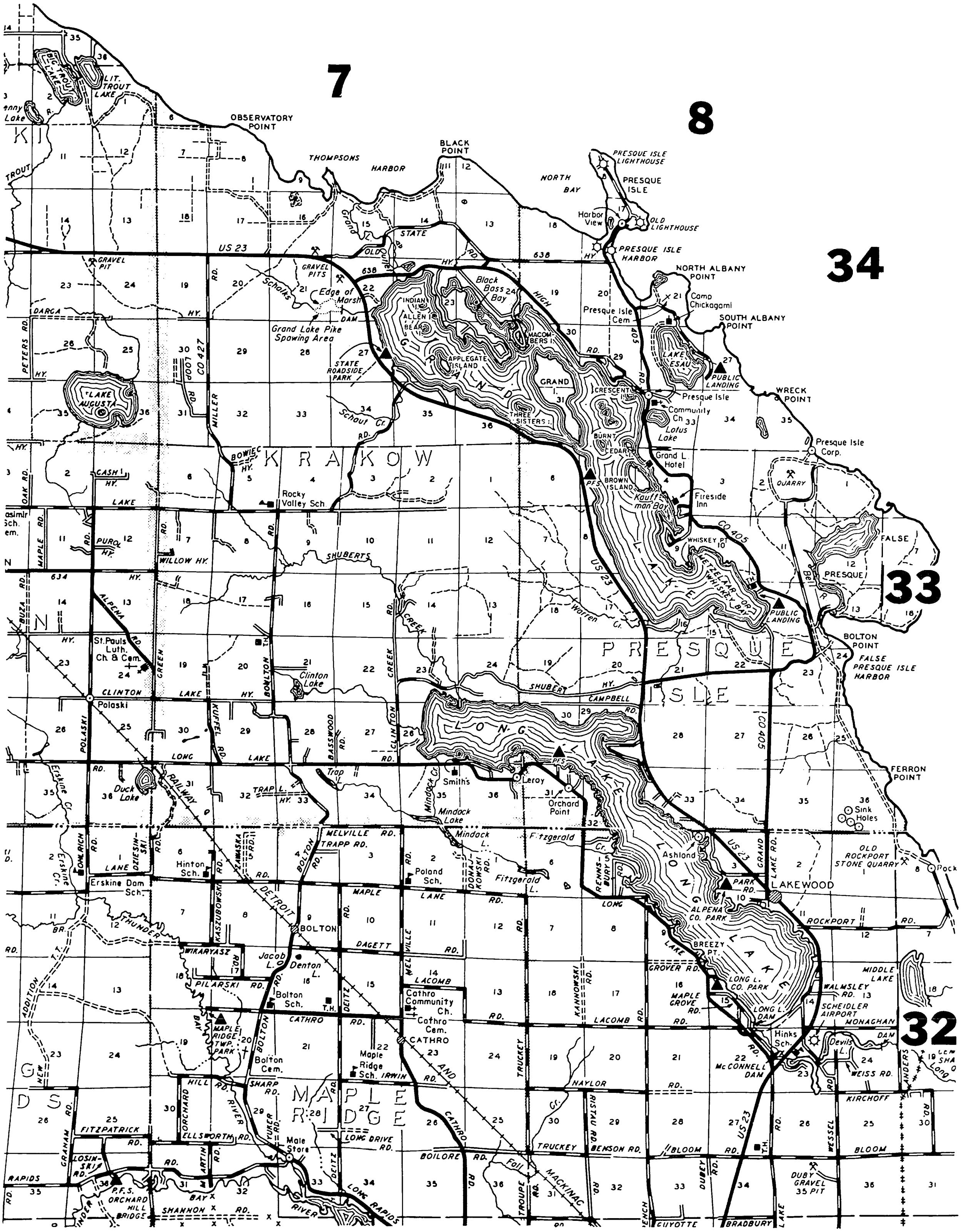
NUMBER OF SPECIES OF MACROFOSSILS SHARED BY FORMATIONS OF THE TRAVERSE GROUP

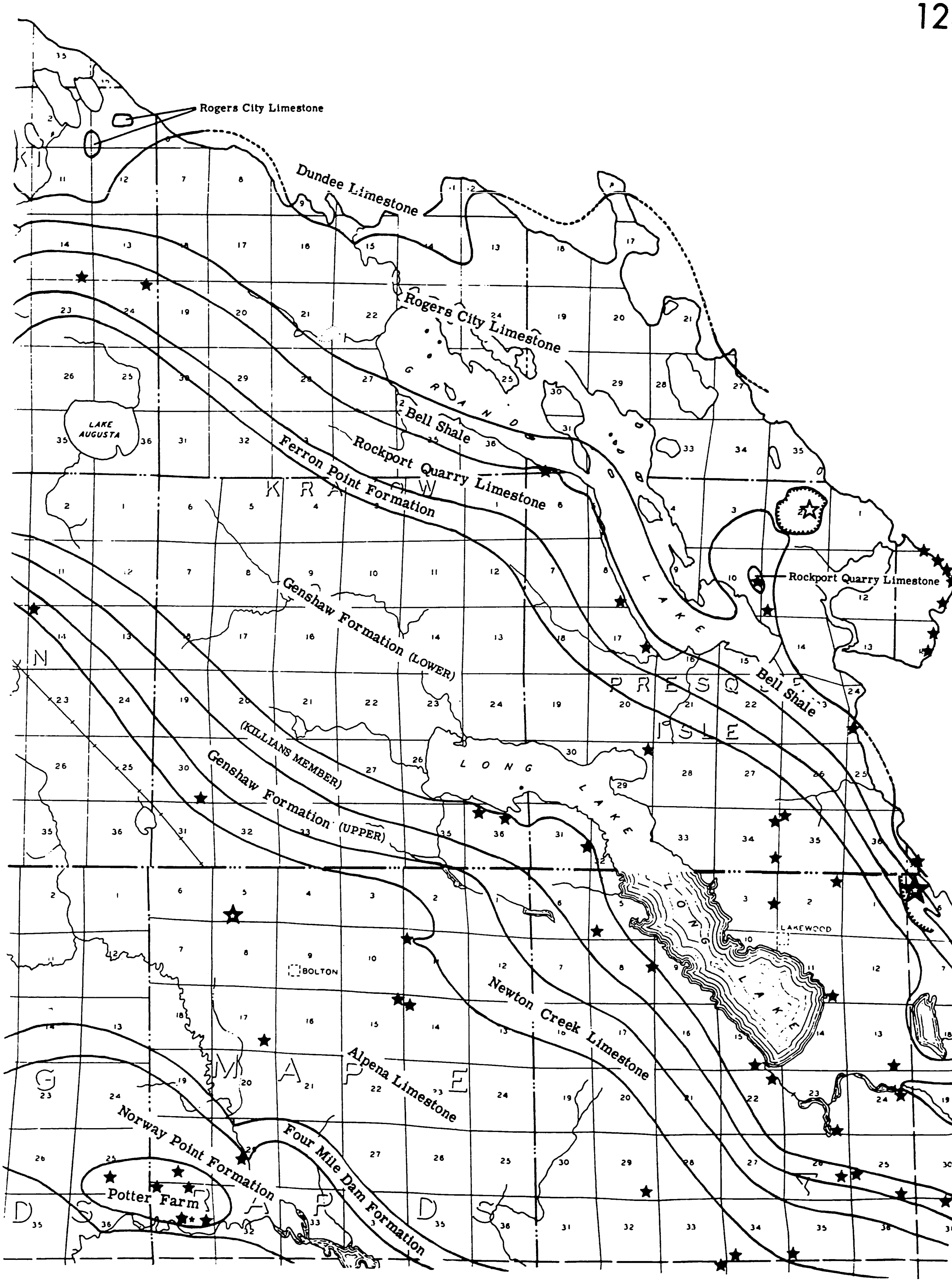
	Total Species	Shared in common with BS	RQ	FP	GF	NC	AL	FM	NP	PF	TB	SB
Bell Shale	45	--	8	14	8	0	3	3	0	3	2	0
Rockport Quarry Ls.	18	8	--	8	3	0	2	2	0	2	1	0
Ferron Point Fm.	34	14	8	--	12	0	2	4	0	3	3	0
Genshaw Formation	43	8	3	12	--	2	11	6	2	4	2	0
Newton Creek Ls.	12	0	0	0	2	--	3	0	0	2	0	0
Alpena Limestone	60	3	2	2	11	3	--	24	7	13	7	0
Four Mile Dam Fm.	86	3	2	4	6	0	24	--	5	8	7	0
Norway Point Fm.	28	0	0	0	2	0	7	5	--	6	3	0
Potter Farm Fm.	55	3	2	3	4	2	13	8	6	--	9	0
Thunder Bay Ls.	46	2	1	3	2	0	7	7	3	9	--	0
Squaw Bay Ls.	5	0	0	0	0	0	0	0	0	0	0	--

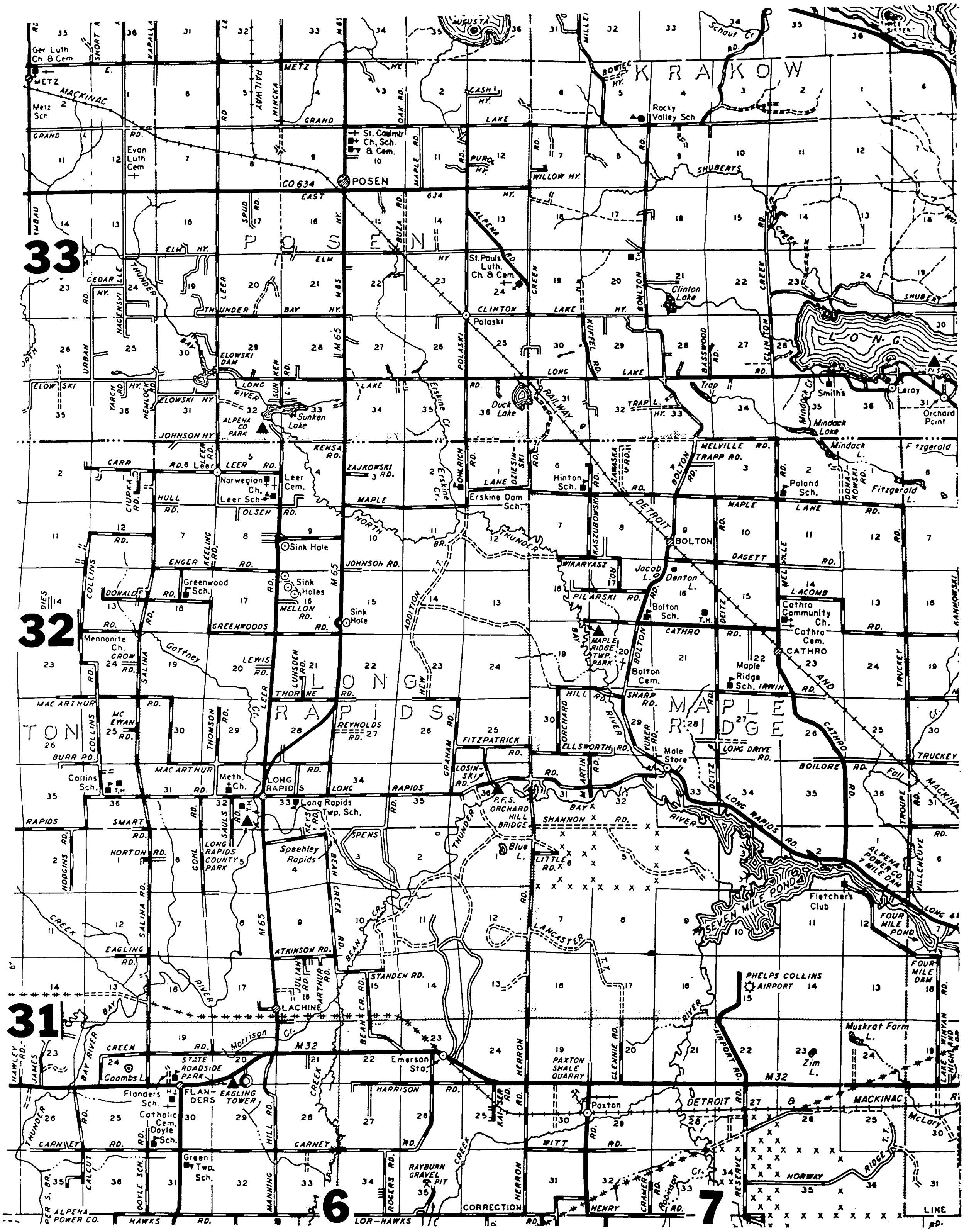

8
9
32
31
30
LAKEWOOD
MIDDLE ISLAND
OLD ROCKPORT STONE QUARRY
ROCKPORT
LONG LAKE
ALPENA CO PARK
BREEZY PT
LONG L. CO PARK
MAPLE GROVE RD.
MIDDLE LAKE
WALMSLEY RD
SCHEIDLER AIRPORT
MCNAGHAN
MONAGHAN POINT
OLD ALPENA PORTLAND CEMENT CO. SHALE QUARRY
LACOMB
Cathro Community Ch
Cathro Cem.
CATHRO
MCCONNELL DAM
NAYLOR
KIRCHOFF
WEISS RD
ANDERSON
TURNBULL
NORTH
SOUTH NINE MILE PT.
Lincoln Bay
BLOOM
TRUCKEY
BENSON RD.
BOILORE
DUBY GRAVEL
GRASS LAKE
HURON BAY
INDIAN
GUYOTTE RD.
BRADBURY RD
FRENCH
LONG LAKE
WESSEL
HAMILTON
A L P E N A
MACKINAC
ALPENA POWER CO 7 MILE DAM
VILLENEUVE
Fletchers Club
FOUR MILE POND
FOUR MILE DAM
LONG 4 MILE RD.
ALPENA GOLF COURSE
RAILWAY
WOODWARD AVE.
OLD THUNDER BAY LIMESTONE QUARRY
HURON PORTLAND CEMENT CO. PLANT & QUARRY
Norwegian
POTTER POINT
ROUND I.
NORTH POINT RD
MISERY BAY RD.
Conway L.
ELBOW LAKE
MISERY BAY
CROOKED ISLAND
Mud L.
WHITEFISH BAY
WHITEFISH POINT
POINT
NORTH POINT
Muskrat Farm L.
Zim L.
Besser Sch.
Em. Luth. Sch.
Lake Besser
Ox-Bow
Evergreen Cem.
Catholic Cem
ALPENA
M 32
MACKINAC RY.
McCloy Cr.
NORWAY
RIDGE
TAMARACK RD.
HOBBS DR.
MUD LAKE
Michigan State Police
MICHEKEWIS CITY PARK
Diamond Point
FIELD OFFICE
Gordon Sch
MEYERS PT. RD.
JESSE RD
BARE PT.
LINE RD.
PERTH
DETROIT
PIPER
US 23
PARTRIDGE PT. RD.
PARTRIDGE POINT
SQUAW BAY
LaVeers Cors.
SPRUCE RD
DEVIL'S LAKE
THUNDER
BAY
SULPHUR I.

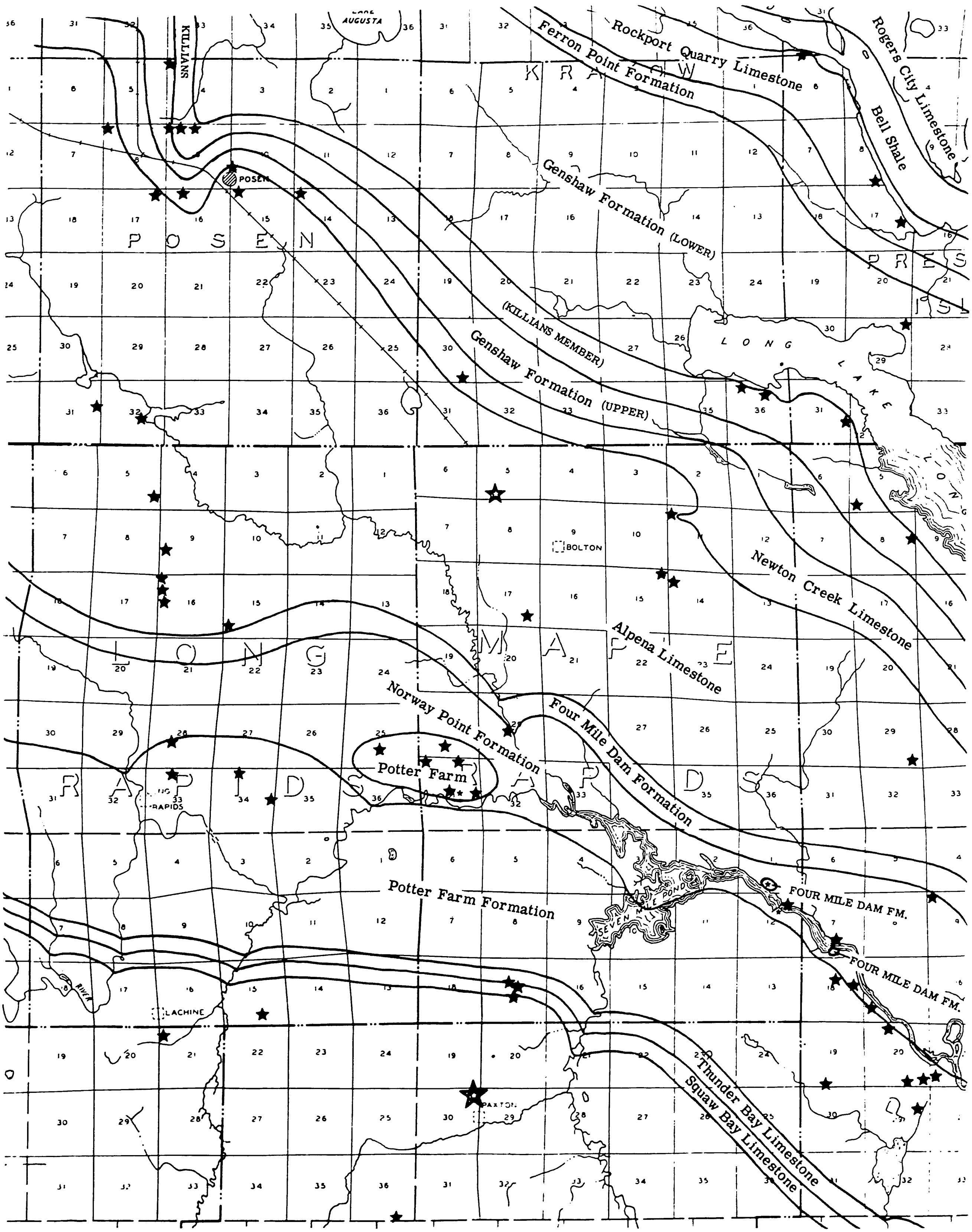


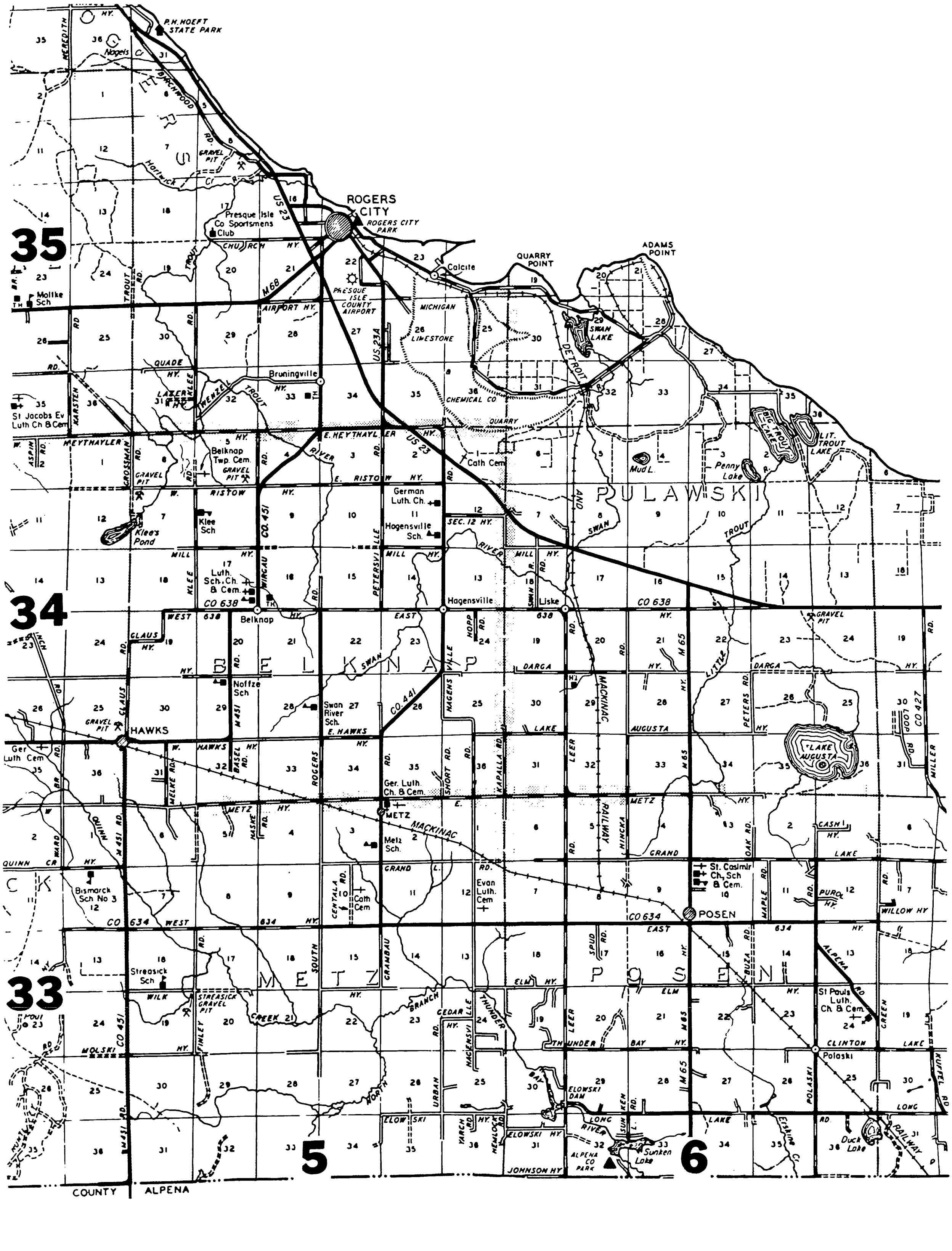
Rogers City Limestone
Bell Shale
Rockport Quarry Limestone
Ferron Point Formation
Genshaw Formation (LOWER)
(KILLIANS MEMBER)
Newton Creek Limestone
Genshaw Formation (UPPER)
(KILLIANS MEMBER)
Newton Creek Limestone
Alpena Limestone
Four Mile Dam Formation
FOUR MILE DAM FM.
FOUR MILE DAM FM.
Newton Creek Ls.
Genshaw Fm. (Upper)
Potter Farm Formation
ALPENA
Four Mile Dam Formation
Norway Point Formation
Thunder Bay Limestone
Squaw Bay Limestone
ANTRIM SHALE
ANTRIM SHALE
LONG LAKE
LAKE
THUNDER BAY
Thunder Bay Limestone
Squaw Bay Limestone

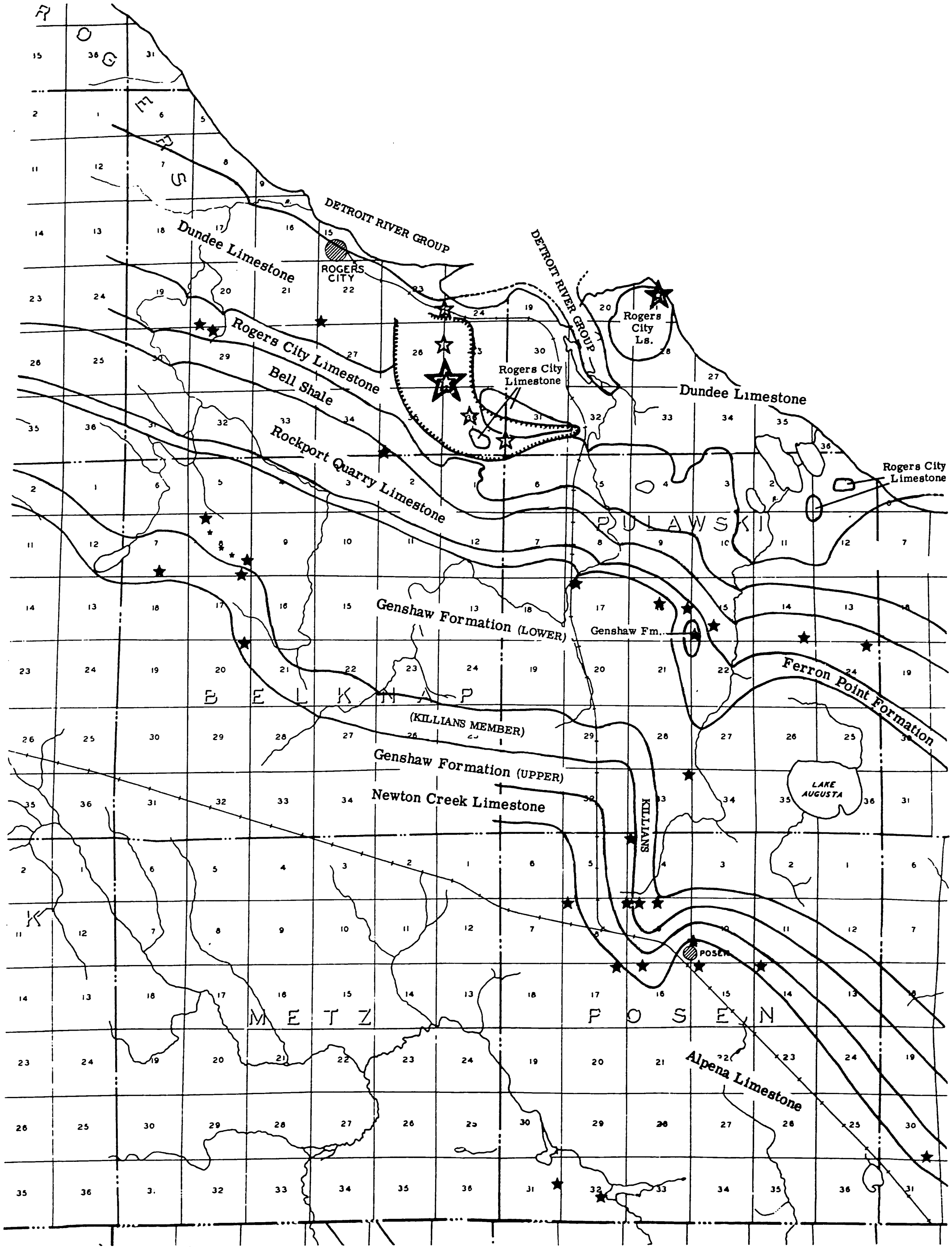

7
8
34
33
32
BIG TROUT LAKE
LIT. TROUT LAKE
OBSERVATORY POINT
THOMPSONS HARBOR
BLACK POINT
NORTH BAY
PRESQUE ISLE LIGHTHOUSE
PRESQUE ISLE
Harbor View
OLD LIGHTHOUSE
PRESQUE ISLE HARBOR
NORTH ALBANY POINT
Camp Chickagami
SOUTH ALBANY POINT
Presque Isle Cem.
LAKE ESAU
PUBLIC LANDING
WRECK POINT
Presque Isle
Community Ch.
Lotus Lake
Presque Isle Corp.
QUARRY
Grand L. Hotel
Fireside Inn
WHISKEY PT.
FALSE PRESQUE
PUBLIC LANDING
BOLTON POINT
FALSE PRESQUE ISLE HARBOR
FERRON POINT
Sink Holes
OLD ROCKPORT STONE QUARRY
Rock
MIDDLE LAKE
SCHEIDLER AIRPORT
Devils L.
US 23
638
GRAVEL PIT
GRAVEL PITS
Edge of Marsh
Grand Lake Pike Spawing Area
STATE ROADSIDE PARK
INDIAN I.
ALLEN I.
BEAR I.
Black Bass Bay
MACOMBERS I.
APPLEGATE ISLAND
GRAND L.
CRESCENT
THREE SISTERS I.
BURNT CEDAR I.
BROWN ISLAND
Kauffman Bay
PFS
CO 405
CO 427
LAKE AUGUSTA
DARGA
PETERS RD.
Schalks Cr.
Schoui Cr.
K R A K O W
BOWIEC HY.
CASH HY.
LAKE
Rocky Valley Sch.
PUROL HY.
WILLOW HY.
634
ALPENA RD.
SHUBERTS
CREEK
Warren Cr.
St. Pauls Luth. Ch. & Cem.
CLINTON
Polaski
Clinton Lake
P R E S Q U E
I S L E
SHUBERT HY.
CAMPBELL
L O N G
LONG LAKE RD.
Duck Lake
Trap L.
TRAP L. HY.
Smith's
Leroy
Orchard Point
Mindack Cr.
Mindack Lake
Fitzgerald Cr.
Fitzgerald L.
Ashland
PARK RD.
ALPENA CO. PARK
LAKEWOOD
ROCKPORT RD.
BREEZY PT.
LONG L. CO. PARK
MAPLE GROVE RD.
LONG L. DAM
WALMSLEY RD.
MONAGHAN
Hinks Sch.
McCONNELL DAM
RAILWAY
DETROIT AND MACKINAC
MELVILLE RD.
TRAPP RD.
Hinton Sch.
Poland Sch.
Erskine Dam Sch.
Erskine Cr.
THUNDER BAY RIVER
BOLTON
MAPLE LANE RD.
DAGETT RD.
LACOMB
GROVER RD.
Jacob L.
Denton L.
PILARSKI RD.
Bolton Sch.
Cathro Community Ch.
Cathro Cem.
CATHRO
CATHRO RD.
MAPLE RIDGE TWP. PARK
Bolton Cem.
Maple Ridge Sch.
HILL RD.
SHARP RD.
NAYLOR RD.
WEISS RD.
KIRCHOFF
M A P L E
R I D G E
FITZPATRICK RD.
ELLSWORTH RD.
LONG DRIVE RD.
BOILORE RD.
TRUCKEY RD.
BENSON RD.
BLOOM RD.
Male Store
Fall Cr.
DUBY GRAVEL PIT
LOSINSKI RD.
P.F.S. ORCHARD HILL BRIDGE
SHANNON RD.
RAPIDS
LONG RAPIDS RIVER
GUYOTTE
BRADBURY
LAKE RD.
WESSEL RD.

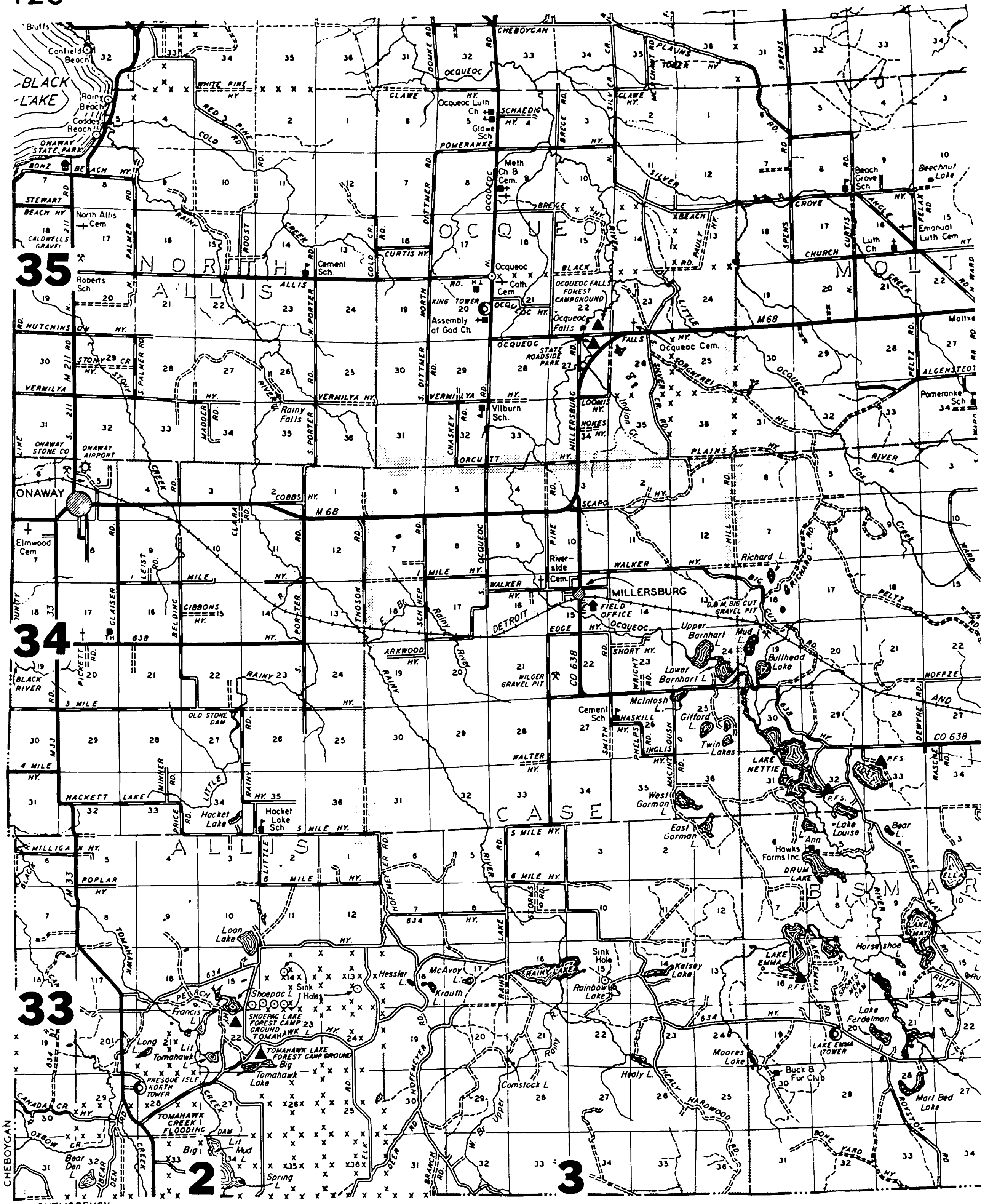

Rogers City Limestone
Dundee Limestone
Rogers City Limestone
Bell Shale
Rockport Quarry Limestone
Ferron Point Formation
Rockport Quarry Limestone
Genshaw Formation (LOWER)
Bell Shale
(KILLIANS MEMBER)
Genshaw Formation (UPPER)
LAKE AUGUSTA
GRAND LAKE
LONG LAKE
LONG LAKE
LAKEWOOD
BOLTON
Newton Creek Limestone
Alpena Limestone
Norway Point Formation
Four Mile Dam Formation
Potter Farm
KRAKOW
PRESQUE ISLE
MAPLE
RAPIDS


KRAKOW
POSEN
LONG RAPIDS
MAPLE RIDGE
33
32
31
6
7
POSEN
Metz
Polaski
Bolton
Cathro
Long Rapids
Lachine
Flanders
Paxton
Emerson Sta.
Leroy
Orchard Point
Long L.
Seven Mile Pond
Four Mile Pond
Duck Lake
Sunken Lake
Clinton Lake
Mindack Lake
Fitzgerald L.
Alpena Co. Park
Maple Ridge Twp. Park
Long Rapids County Park
State Roadside Park
Eagling Tower
Phelps Collins Airport
Paxton Shale Quarry
Rayburn Gravel Pit
Alpena Power Co. 7 Mile Dam
Four Mile Dam
Fletcher's Club
Muskrat Farm
M 65
M 32
CO 634
Thunder Bay River
Long Rapids Rd.
Detroit and Mackinac Railway
Correction Line Rd.


LAKE AUGUSTA
KILLIANS
POSEN
KRAKOW
Rockport Quarry Limestone
Ferron Point Formation
Rogers City Limestone
Bell Shale
Genshaw Formation (LOWER)
(KILLIANS MEMBER)
Genshaw Formation (UPPER)
LONG LAKE
Newton Creek Limestone
BOLTON
Alpena Limestone
LONG
Norway Point Formation
Four Mile Dam Formation
Potter Farm
RAPIDS
Potter Farm Formation
SEVEN MILE POND
FOUR MILE DAM FM.
FOUR MILE DAM FM.
RIVER
LACHINE
PAXTON
Thunder Bay Limestone
Squaw Bay Limestone


ROGERS CITY
ROGERS CITY PARK
P.H. HOEFT STATE PARK
Presque Isle Co Sportsmens Club
PRESQUE ISLE COUNTY AIRPORT
QUARRY POINT
ADAMS POINT
Calcite
SWAN LAKE
Bruningville
CHEMICAL CO
QUARRY
BIG TROUT LAKE
LIT. TROUT LAKE
Mud L.
Penny Lake
PULAWSKI
Moltke Sch
St Jacobs Ev Luth Ch & Cem
Belknap Twp. Cem.
Cath Cem
German Luth. Ch.
Hogensville Sch.
Klee Sch
Klee's Pond
Luth. Sch. Ch. & Cem.
Belknap
Hagensville
Liske
B E L K N A P
Noffze Sch
Swan River Sch.
HAWKS
Ger Luth Cem
Ger. Luth. Ch. & Cem.
METZ
Metz Sch.
LAKE AUGUSTA
St. Casimir Ch., Sch & Cem.
Evan Luth. Cem
Cath Cem
Bismarck Sch No 3
POSEN
M E T Z
P O S E N
Streasick Sch
St Pauls Luth. Ch. & Cem.
Polaski
ELOWSKI DAM
ALPENA CO PARK
Sunken Lake
Duck Lake
35
34
33
5
6
COUNTY
ALPENA
US 23
US 23A
M 68
M 65
CO 451
CO 638
CO 634
CO 441
CO 427
MACKINAC
DETROIT AND MACKINAC RAILWAY


ROGERS
DETROIT RIVER GROUP
DETROIT RIVER GROUP
ROGERS CITY
Dundee Limestone
Rogers City Ls.
Rogers City Limestone
Bell Shale
Rogers City Limestone
Dundee Limestone
Rockport Quarry Limestone
Rogers City Limestone
PULAWSKI
Genshaw Formation (LOWER)
Genshaw Fm.
Ferron Point Formation
BELKNAP
(KILLIANS MEMBER)
Genshaw Formation (UPPER)
Newton Creek Limestone
KILLIANS
LAKE AUGUSTA
POSEN
METZ
POSEN
Alpena Limestone


BLACK LAKE
Onaway State Park
NORTH ALLIS
OCQUEOC
MOLT
ALLIS
CASE
BISMAR
ONAWAY
MILLERSBURG
Ocqueoc Falls
Rainy Falls
Onaway Airport
Onaway Stone Co
Field Office
Upper Barnhart L.
Lower Barnhart L.
Bullhead Lake
Lake Nettie
Lake Louise
Drum Lake
Lake May
Lake Emma
Lake Emma Tower
Lake Ferdelman
Loon Lake
Shoepac L.
Shoepac Lake Forest Camp Ground
Tomahawk Lake Forest Camp Ground
Big Tomahawk Lake
Lit Tomahawk L.
Presque Isle North Tower
Tomahawk Creek Flooding
Rainy Lake
Rainbow Lake
Kelsey Lake
Healy L.
Moores Lake
Marl Bed Lake
Hackett Lake
Twin Lakes
Gifford L.
West Gorman L.
East Gorman L.
Comstock L.
M 68
M 33
CO 638
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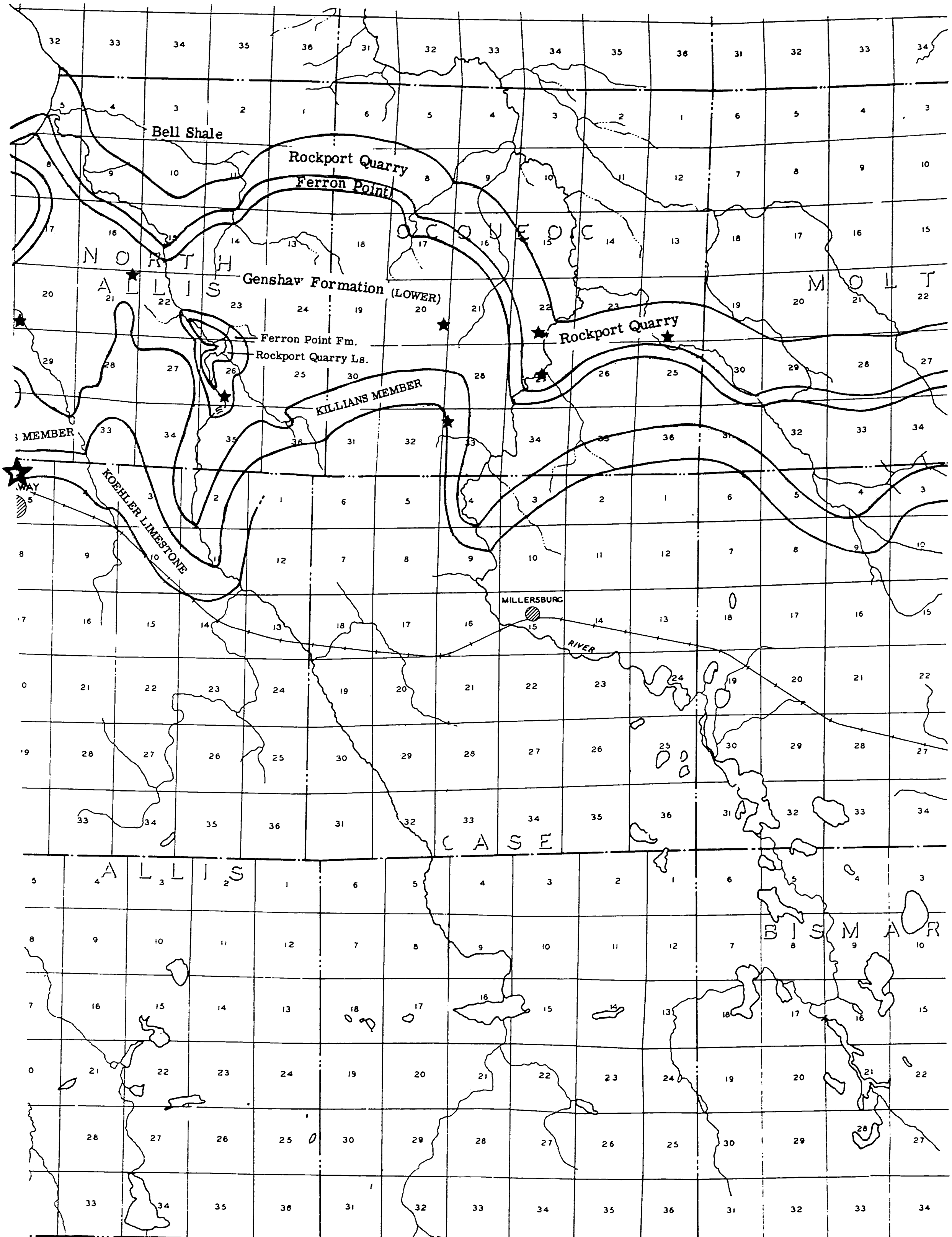
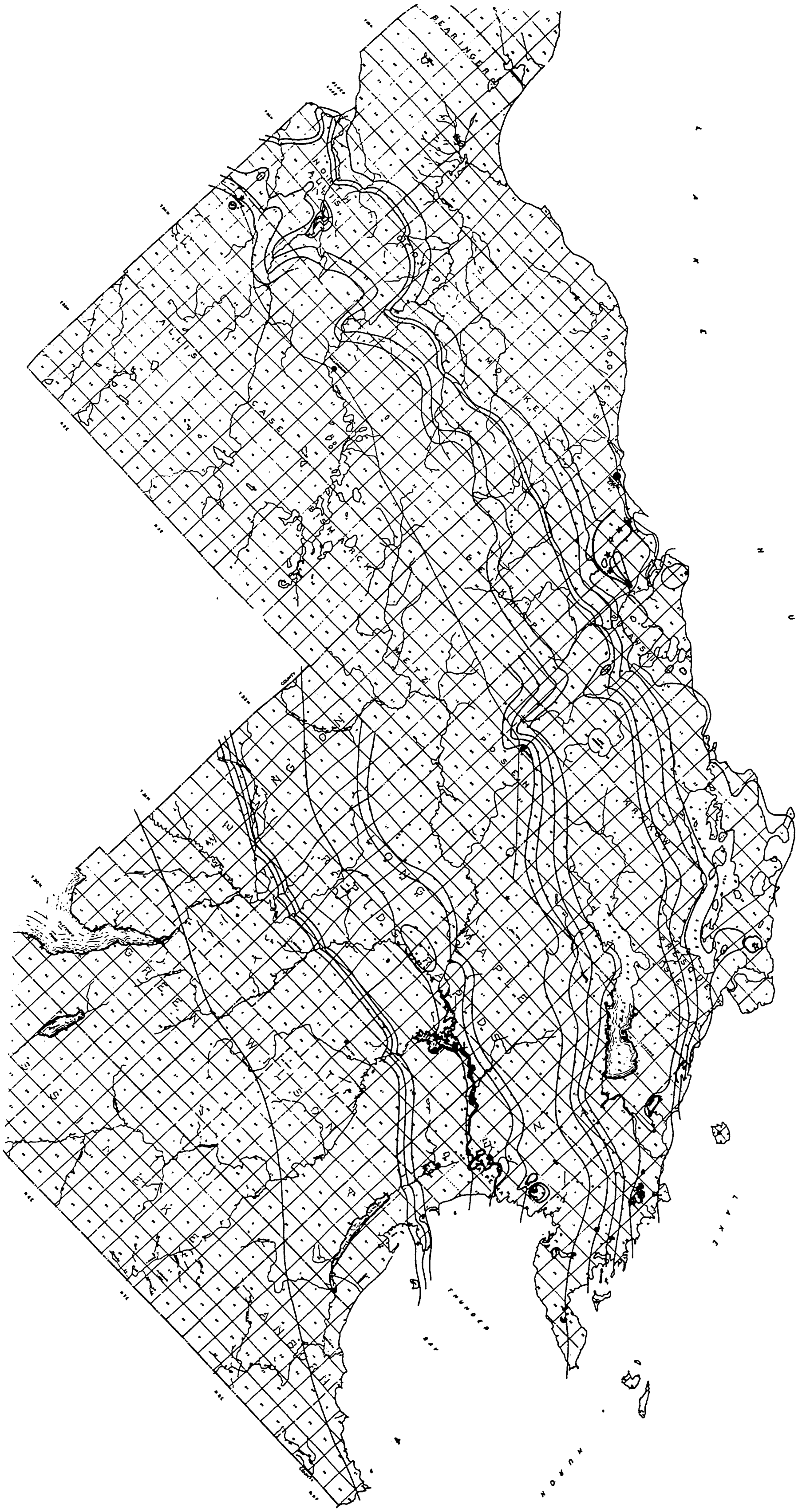
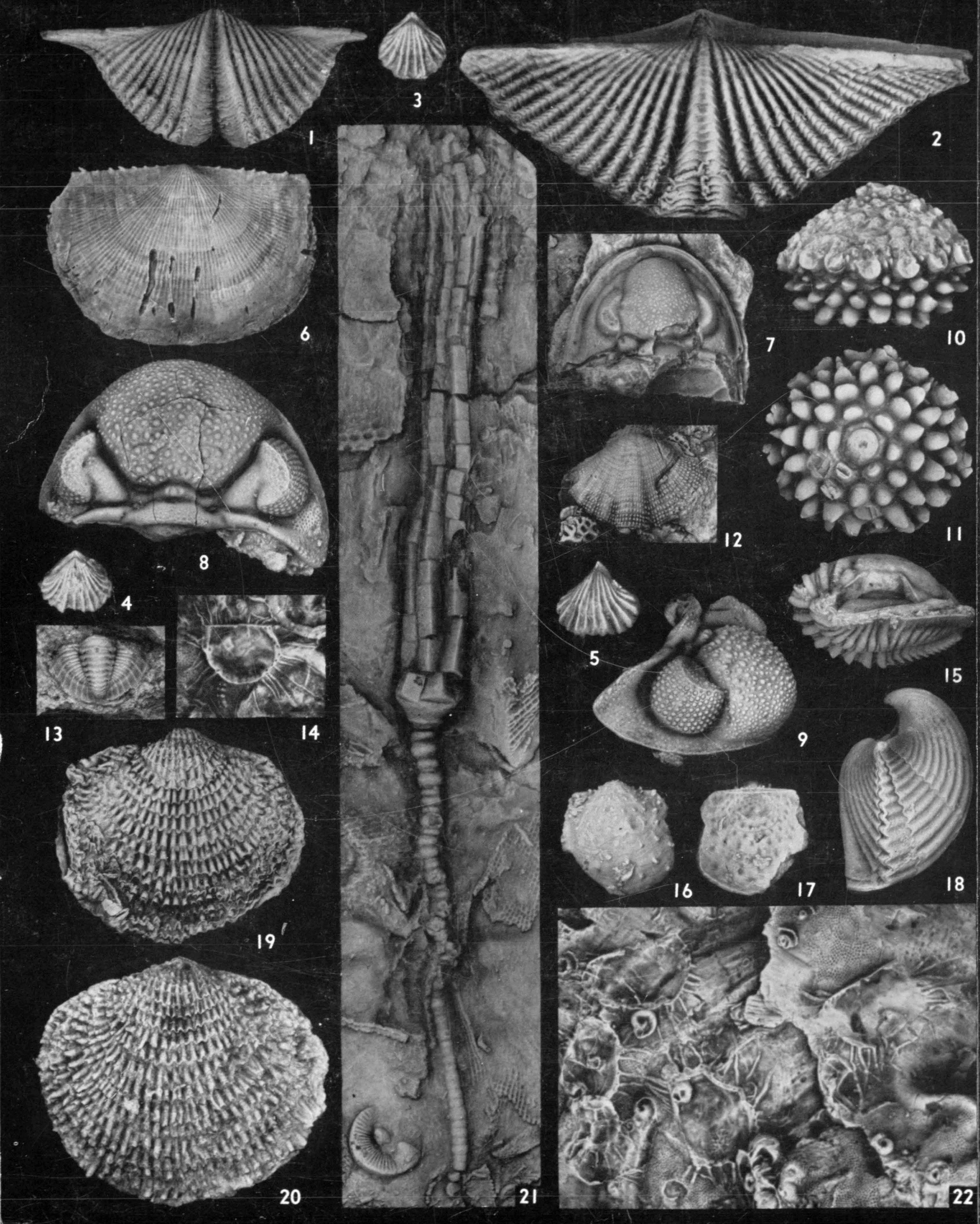
33
2
3
CHEBOYGAN
MONTMORENCY


Bell Shale
Rockport Quarry
Ferron Point
OCQUEOC
NORTH ALLIS
Genshaw Formation (LOWER)
MOLT
Ferron Point Fm.
Rockport Quarry Ls.
Rockport Quarry
KILLIANS MEMBER
MEMBER
KOEHLER LIMESTONE
MILLERSBURG
RIVER
CASE
ALLIS
BISMAR


BEARINGER
THUNDER
BAY
LAKE
HURON

Miscellaneous Traverse Group Fossils REAR COVER All figures x $2\frac{1}{2}$

Mucrospirifer grabaui, 1, #33324; Potter Farm Fm. M. prolificus, 2, #31666; Bell Shale. Camarotoechia thedfordensis, 3-5, #37916; Four Mile Dam Fm. Chonetes pachyactis, 6, #57621; Ferron Point Fm. (upper). Basidechenella pulchra, 7, #28680; Alpena Ls. Phacops milleri, 8, #25518a; 9, #25518b; Ferron Point Fm. Megistocrinus sp., 10, 11, #23882; Four Mile Dam Fm. Elytha fimbriata, 12, #57611c; Four Mile Dam Fm. Mystrocephala rara, 13, #47296a; Four Mile Dam Fm. Leptalosia radicans, 14, 22, #17059; Gravel Point Fm. (Lower Blue Shale) (also in Alpena Ls.). Basidechenella nodosa, 15, #25509; Genshaw Fm. Truncalosia gibbosa, 16, 17, #57628a; Potter Farm Fm. Cyrtina umbonata alpenensis, 18, #57597e; Genshaw Fm. Atrypa sp., 19, #57623b; 20, #57623c; Bell Shale. Synbathocrinus cf. matutinus, 21, #57632; Thunder Bay Ls.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