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By

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## INTRODUCTION

FROM THE PAST arise fond memories of the times spent, summer after summer, with George Marion Ehlers in the Northern Peninsula of Michigan -- reworking exposures of the Silurian rocks, adding to our already extensive fossil collection at each locality, and from time to time correcting little squiggles in the formational contacts on our detailed county maps. It is with mixed emotions, therefore, that I find it necessary to correct a stratigraphic error in our work. Yet -- as I look back, it is hard to conceive how we could have reached any other decision from the information we possessed.

Whatever my own bitter-sweet feelings, the Moss Lake Formation must be deactivated. The formation which we so proudly named in 1957 is only a junior synonym of the Manitoulin Dolomite. Perhaps Jim and I should have been alerted when we identified some of the poorly preserved fossils from the Moss Lake type locality as "Platystrophia sp. aff. P. daytonensis (Foerste)" on page 7 of our guidebook, the identical term we had applied on page 5 to some fossils from the Manitoulin Dolomite in a small quarry less than 50 miles to the northeast.

Furthermore, our error in calling the Moss Lake exposures a new formation led to another error. The rocks which we identified as Cabot Head Shale at the quarry on Mormom Creek Truck Trail are actually Ordovician and belong to an unnamed formation. Below them but nowhere exposed, to my knowledge, are more Ordovician strata that are best known from the core of the Cooks well.

A new interpretation is presented for the formations involved in the interval between the Ordovician Big Hill Formation and the Silurian Lime Island Dolomite.

## PREVIOUS WORK

Even before 1920, George Marion Ehlers had studied the then-known exposures of Silurian rocks in the Northern Peninsula. His stratigraphic terminology was adopted by the Michigan Geological Survey and later used on state geologic maps. For one reason or another, his work became a continuing project for many years, with additions and corrections being added on occasion. Finally, in 1973 I edited his material and saw it through publication as No. 3 in the Papers on Paleontology issued by the Museum of Paleontology.

In this "Stratigraphy of the Niagaran Series of the Northern Peninsula of Michigan," Ehlers directs attention to the pioneer work by Bigsby (1821), Houghton (1840), de Castelnau (1843), James Hall (1851), Whittlesey (1851), Winchell (1861), and others. Briefly, these early workers did little more than identify the major divisions of the Silurian in Michigan, and need not be considered further.

In 1920 Ehlers presented a paper on "Niagaran rocks of the Northern Peninsula of Michigan" before the Paleontological Society in Chicago. Unfortunately, only an abstract was published in the Bulletin of the Geological Society of America the following year. Nevertheless, his classification of strata was followed by Ulrich & Bassler in 1923 and by Ver Wiebe in 1928. Other geologists accepted Ehlers' stratigraphic interpretation, and awaited the publication of his extensive labors on measured sections, fossils, and correlation.

This is how the Michigan Silurian was classified by 1956:

| | | |
|---|---|---|
| Lockport Group | Engadine Dolomite | |
| Clinton Group | Manistique Dolomite | Cordell Member |
| | | Schoolcraft Member |
| | Burnt Bluff Limestone + Dolomite | Hendricks Member |
| | | Byron Member |
| | Mayville Dolomite | |

Meanwhile, in nearby parts of Ontario, the Canadian geologists were making rapid progress on classification of Silurian strata, particularly on Manitoulin Island. Publications included T. E. Bolton's (1953) "Silurian formations of the Niagaran escarpment in Ontario," his (1954) "Silurian of Manitoulin Island," Fisher's (1954) "Stratigraphy of Medina Group, New York and Ontario," and Liberty & Bolton's (1956) "Early Silurian stratigraphy of Ontario, Canada."

The 1957 guidebook. -- Around 1956, Ehlers and I began organization of the material to be presented during the annual excursion of the Michigan Geological Society the following year. We sought new exposures and attempted to trace the Alexandrian formations of Manitoulin Island into Michigan. In particular, we were impressed by:

(1) Strata exposed in a small quarry about 0.1 mile north of Highway 98 and 1 mile north of Manistique Lake, Luce County. The lithology and fossils led us to believe that this lowest part of the old "Mayville Dolomite" was actually equivalent to the Manitoulin Dolomite. Thus, we extended the formation over 125 miles to the west of Manitoulin Island.

(2) Stream bank exposure at Ten Mile Rapids on Sturgeon River, near Highway 13 about 4 miles north of US 2. This is the northernmost exposure known of the Upper Ordovician Big Hill Formation, definitely identifiable by Halysites gracilis and Palaeophyllum stokesi.

(3) Evaporites and shales exposed in a small roadside quarry on the north side of the Mormon Creek Truck Trail, just 3/4 mile south and 2 3/4 miles east of the Big Hill exposure on Sturgeon River. These beds were lithologically similar to those that had been described in Ontario for the Cabot Head Shale, and we thus classified them. The drift-covered interval between this quarry and the Sturgeon River outcrop (nearly 3 miles), we thought, was ample space to accommodate the 25 to 45 feet of dipping Manitoulin Dolomite.

(4) Records of four wells in Schoolcraft County: the Alphonse Vershure No. 1, Manistique Municipal Deep Well, Schoolcraft Development Syndicate No. 2, and the Blaney Park Resort Well. All these wells showed that the typical Big Hill lithology and fossils were succeeded by two cycles of strata, each with dolomite (below) and shales and evaporites (above).

At that time it was generally assumed that the Big Hill strata reached the top of the Ordovician section. Wells showed that the next interval was 25 to 45 feet of dolomite; this we accounted to be the Manitoulin Dolomite. This was overlain by 85 to 95 feet of impure dolomites, shales, and evaporites; these we thought were the strata of Cabot Head Shale, as were the beds cropping out alongside the Mormon Creek Truck Trail in the small quarry. Above was a cycle of dolomite and shale-evaporites that we regarded as unnamed beds.

(5) Strata exposed in a ditch on the east side of Moss Lake, about $1\frac{1}{2}$ miles west of Isabella, Delta County. About 14 feet of dolomite beds were measured there. We presumed that these represented the unnamed strata between our Cabot Head Shale (as seen in the Mormon Creek quarry) and the overlying dolomite unit with Virgiana decussata.

(6) Strata exposed on the west side of Lime Island. These beds contained abundant Virgiana decussata and were previously used to identify the top of the Mayville Dolomite. The lithology and fauna were identical to those of the Dyer Bay Formation of Manitoulin Island and the Fisher Branch Dolomite of the Interlake area of Manitoba. We named it the Lime Island Dolomite and placed it at the base of the Burnt Bluff Group. Blocks of this dolomite were discovered north of Cooks on the boundary line between Schoolcraft and Delta Counties.

Thus, in Schoolcraft County and the eastern part of Delta County, our stratigraphic column was, in part:

| Series | Group | Formation | Thick. |
|---|---|---|---|
| Niagaran | Burnt Bluff | Lime Isl. Dol. | 15-35 |
| Alexandrian | Cataract | Moss Lake Fm. | 125-150 |
| | | Cabot Head Sh. | 75-100 |
| | | Manitoulin Dol. | 25-50 |
| Richmond | | Big Hill Formation | |

It did occur to us to question whether, of the two dolomites between the Big Hill Formation and the Lime Island Dolomite, the Manitoulin Dolomite was the lower or the upper. Two factors led us to favor the former. (1) If, as we concluded at that time, the Cabot Head Shale was exposed at the Mormon Creek Truck Trail quarry within 3 miles of the Big Hill Formation, then as much as 50 feet of the dolomite thought to be the Manitoulin Dolomite might well be present below the shallow cover of drift in the interval; but if the Cabot Head Shale at the little quarry was accounted to be the upper shale-evaporite unit, then the interval of 3 miles would have to accommodate nearly 200 feet of strata -- which seemed highly unlikely with the average regional dip of slightly over 50 feet per mile. (2) With two cycles of dolomite and shale-evaporites, one would expect that both cycles would occur within the same system -- not one cycle at the close of Ordovician and another like it at the beginning of Silurian. So, Ehlers and I felt assured that our discovery of dolomite beds at Moss Lake was the first exposure of a new formation, embracing the sequence of dolomites and shale-evaporites shown in nearby wells.

The Cooks well. -- The Cleveland-Cliffs Iron Company drilled an exploratory test hole about 1 mile northwest of the village of Cooks, in the SW$\frac{1}{4}$ sec. 19, T 41 N, R 17 W, Schoolcraft County. The core, remarkably complete, was given to the Michigan Geological Survey. Ehlers and I met with Arthur Slaughter of the Survey at Escanaba in 1958 and made notes on the lithology. Our observations were published later in a joint paper (1967). We followed the terminology and sequence of formations used in the 1957 guidebook. It is not necessary to repeat all of the log of this well, but pertinent sections bear directly upon the problem (1967, p. 222-225):

NIAGARAN SERIES

BURNT BLUFF GROUP

LIME ISLAND DOLOMITE

| | Ft. |
|---|---|
| 37. Dolomite, buff, medium to coarsely crystalline, vuggy, with few chert nodules; Virgiana sp. (probably V. decussata) and Favosites ..... | 27.7 |

ALEXANDRIAN SERIES

CATARACT GROUP

MOSS LAKE FORMATION

| | |
|---|---|
| 36. Shale, bluish-gray, with thin beds of dolomite ..... | 1.8 |
| 35. Dolomite, argillaceous, steel-gray . | 4.6 |
| 34. Shale, bluish-gray ..... | 13.9 |
| 33. Dolomite, argillaceous, gray, fine-grained, with some vugs and shale partings ..... | 43.5 |
| 32. Dolomite, buff-gray to gray, very finely to medium crystalline, with some cherty partings ..... | 8.3 |
| 31. Dolomite, buff-gray, finely crystalline, with carbonaceous partings and a few very small vugs filled with gypsum ..... | 2.8 |
| 30. Dolomite, gray to bluish-gray, fine-grained, with numerous chert nodules ..... | 25.0 |
| 29. Dolomite, brownish-gray, fine-grained, with white chert nodules; fractured dolomite along some bedding planes re-cemented with transparent gypsum; nodules of gypsum, some thin shale layers and shale fragments also present in the dolomite ..... | 10.2 |
| 28. Dolomite, argillaceous, gray to buff-gray banded with gray, fine-grained, with few nodules of gypsum ..... | 11.1 |

CABOT HEAD SHALE

| | |
|---|---|
| 27. Dolomite, gray to buff-gray with dark-gray bands, very finely crystalline, with layers of gray satin | |

spar 1/8 to 2 inches thick ..... 6.9

26. Dolomite, alternating beds of buff and gray, with a few bluish-gray shale layers $\frac{1}{4}$ to several inches thick and a few thin partings of white gypsum; layer with external molds of Leperditia sp. found at 246.8 feet ..... 12.1
25. Shale, medium-gray to dark-gray, a few thin beds of finely crystalline buff-gray dolomite and numerous beds of gypsum occurring as alabaster, selenite, and satin spar in beds, pebbles, fracture fillings, and expansion joints; white satin spar along fractures and bedding planes and in layers 1/8 to 4 inches thick; reddish gypsum (selenite and alabaster) bedded or in pebbles; gray selenite bedded and in disseminated crystals in the dolomite ..... 39.9
24. Dolomite, light-buff to buff-gray, very fine-grained with dark gray argillaceous bands ..... 2.8
23. Shale, dolomitic, dark-gray, with a few satin spar deposits along bedding planes; fossiliferous, with brachiopods and algal (?) debris ... 10.7
22. Dolomite, grayish-buff, very finely crystalline with dark-gray to brown-gray shale bands very numerous, thin satin spar layers 1/8 to 3/4 inches thick; four-inch bed of brown selenite near the base ..... 8.4
21. Dolomite, buff-gray, very finely crystalline, with bluish-gray mottling ..... 1.4
20. Dolomite, buff-gray, very finely crystalline, with many dark blue-gray argillaceous bands; a few satin spar fillings in fissures and along bedding planes ..... 5.1

MANITOULIN DOLOMITE

19. Dolomite, buff-gray, very finely crystalline, with bluish-gray local mottling, banded with argillaceous beds; a few bryozoa (?) ..... 11.2
18. Highly argillaceous dolomite, dark-gray to medium-gray, finely to medium crystalline; some fossils, mostly brachiopods and bryozoa ... 12.1

ORDOVICIAN

CINCINNATIAN SERIES

RICHMOND GROUP

BIG HILL FORMATION

17. Dolomite, buff-gray, medium to finely crystalline, very fossiliferous; Palaeophyllum stokesi and some Halysites ..... 17.7
16. Dolomite, buff-gray to greenish-gray and gray, medium crystalline; contorted shale laminae, locally mottled with light-gray; argillaceous dolomite and shale partings; cup corals, large lobate to digitate bryozoa filled with dolomite crystals ..... 107.3
15. Dolomite, gray, very finely crystalline, very large trepostomatous bryozoa at base of unit ..... 5.6

We can simplify this log for easier discussion later:

Lime Island Dolomite

37. Dolomite, buff, coarsely crystalline, with vugs and Virgiana ..... 27.7

Moss Lake Formation

33-36. Argillaceous dolomites and bluish-gray shales ..... 63.8
29-32. Dolomite with some chert; gypsum in nodules and along bedding planes, concentrated in lower part of unit ..... 46.3
28. Argillaceous dolomite with some gypsum nodules ..... 11.1

Cabot Head Shale

26-27. Dolomite banded with gypsum and shale, Leperditia ..... 19.0
25. Shale with layers of gypsum ..... 39.9
24. Dolomite with argillaceous bands ... 2.8
23. Dolomitic shale with gypsum, brachiopods ..... 10.7
20-22. Dolomite with argillaceous bands at base and gypsum and shale bands at top ..... 14.9

Manitoulin Dolomite
18-19. Dolomite, argillaceous at base, brachiopods and bryozoa ..... 23.3

Big Hill Formation

The conodonts from the Cooks well. -- In the late 1950's, Carl B. Rexroad obtained samples from the core of the well described above. In 1970, Pollock, Rexroad, & Nicoll described the conodonts from these and other Silurian samples from Michigan and Ontario. Their faunal analysis indicated that the Ordovician-Silurian boundary in the Cooks well core should be placed at a depth of 228.3 feet, at the base of unit 29. They also found Ordovician conodonts in samples from the Mormon Creek Truck Trail Quarry, and they also found that the Silurian conodont fauna from the type locality of the Moss Lake Formation was the same as that from the Manitoulin Dolomite in the small quarry near Manistique Lake, as well as that from the Manitoulin Dolomite on Manitoulin Island and in the Owen Sound region of Ontario. They stated (1970, p. 744):

> The type section of the Moss Lake ... overlies Ordovician rather than Cabot Head strata and occupies the same stratigraphic position as does the Manitoulin. For this reason and because the lithology and conodonts of the type section of the Moss Lake and the Manitoulin are the same, the Moss Lake is not regarded as a valid unit.

Now the stratigraphy became clear. Of the two sequences of a dolomite overlain by a shale with evaporites, it was the upper sequence which was the Manitoulin Dolomite and Cabot Head Shale, not the lower sequence as we had believed. Here is the picture: →

| Ehlers, Kesling, & Slaughter (1967) | Beds | Actual age |
|---|---|---|
| Lime Island Dolomite | 37. Buff coarse dolomite | Lime Island Dolomite |
| Moss Lake Formation | 33-36. Dolomite and shales | Cabot Head |
| | 29-32. Dolomite with chert | Manitoulin Dolomite |
| | 28. Argillaceous dolo. w gypsum | Ordovician (top) |
| | 26-27. Dolomite, gyp., shales<br>25. Shale w gypsum | Mormon Cr. Quarry exposures |
| Cabot Head Shale | 20-24. Dolomite, arg., gypsum | Beds not exposed in outcrop |
| Manitoulin Dolomite | 18-19. Dolomite, arg., fossils | |
| Big Hill Fm. | | Big Hill Fm. |

## MORMON CREEK, NEW FORMATION

The Mormon Creek Formation is proposed for Upper Ordovician strata in the Northern Peninsula of Michigan which lie above the Big Hill Formation and below the Silurian Manitoulin Dolomite. It is characterized by thin-bedded dolomites alternating with bands of shale and containing evaporites. The fauna consists of a species of ostracod, probably Leperditia, which occurs in profusion on certain bedding planes but always preserved as molds. Some units show "fucoids," which are probably the tracks and trails of some worm-like organism.

Name. -- The formation is named for the truck trail which passes the type locality, the Mormon Creek Truck Trail. This trail is now referred to on land plat maps as US Forest Service Highway 2231. The old familiar name was given to the truck trail because it was near and nearly parallel to Mormon Creek for part of its extent. Mormon Creek begins in the NE$\frac{1}{4}$ sec. 13, T 41 N, R 20 W and joins the Sturgeon River in the SE$\frac{1}{4}$ sec. 17, T 41 N, R 19 W; thus the creek flows eastward and is a little over two miles long. The mouth of Mormon Creek is slightly over two miles due west of the type locality of the formation.

Type locality. -- The type locality and only known exposure of the formation is a small quarry on the north side of Mormon Creek Truck Trail in the SE$\frac{1}{4}$ sec. 15, T. 41 N, R 19 W, between Sturgeon River and the Southwest Branch of Fishdam Creek. It is on federal land in the

Hiawatha National Forest, in Nahma Twp., Delta County, Michigan. At the time of my visit in August of 1974, with Harry O. Sorensen and Al Johnson, the quarry appeared to be the same size as when I last saw it in 1957. Nevertheless, it was remarkably free of weeds and young shrubs and still displayed the evaporite minerals in fine preservation.

In the 1957 guidebook, Ehlers and I described the strata at this quarry as follows:

| Unit | Ft. | In. |
|---|---|---|
| 4. Dolomite, argillaceous, gray to light buff-gray, layers 2 to 4 inches thick, containing "fucoids" ... | 2-3 | |
| 3. Dolomite, argillaceous, steel-gray, fissile, with numerous specimens of Leperditia in lower part ..... | 3 | 9 |
| 2. Dolomite, argillaceous, steel-gray, fissile, with conchoidal fracture, beds averaging 2 inches in thickness ..... | 2-6 | |
| 1. Gypsum, brown selenite, with thin discontinuous seams and irregularly shaped masses of dark-gray shale; bands of white satin spar 2 to 3 inches thick. Dolomites of overlying units domed by force of crystallization of gypsum ..... | 5 | 6 |
| Total thickness ..... | 13'3" to 18'3" | |

Stratigraphic extent. -- Nowhere is a complete section of the Mormon Creek Formation exposed. From the core of the Cooks well the stratigraphic limits of the formation can be established. In the log presented above, the strata at the type locality seem to correlate with units 25 to 27; the thick gypsum layer in the bottom of the quarry is probably in the upper part of unit 25, and the uppermost beds in the quarry may be as high as the lower part of unit 27.

The outstanding characteristic of the new formation is the presence of evaporites, which continue over a considerable area in subsurface in the Northern Peninsula. In contrast to the underlying Big Hill Formation, with its abundant corals and other normal marine fauna, the brine of the Mormon Creek sea was too concentrated to permit any other kind of animal to live in it except a species of ostracod, thought to be Leperditia. Ostracods, distant relatives of the brine shrimp, are noted for their tolerance of high salinity, low oxygen, and unusual temperatures. For example, in the Devonian Gravel Point Formation in Cheboygan County, Michigan, a lagoonal deposit of highly petroliferous limestone is called the Welleria aftonensis zone because it contains myriads of this species of ostracod and no other kind of fossil (Kesling & Soronen, 1957). For another example, in the Devonian Meadow Lake Beds of the Elk Point Group in subsurface of western Saskatchewan, Canada, a feeder channel into the evaporite basin contains only one kind of fossil, the ostracod Welleria meadowlakensis -- many of them preserved in pure, transparent halite (Kesling & Takagi, 1961). I am convinced that the ostracods inhabited the restricted basin in which the Mormon Creek Formation was deposited, for if they were normal marine creatures surely other normal marine forms would have been washed into the basin along with the numerous specimens of ostracods.

The termination of Mormon Creek conditions is marked by the return of normal marine faunas in the overlying Manitoulin Dolomite. Inasmuch as the contact is nowhere exposed, it is impossible to say whether the contact is conformable.

Using the presence of evaporites as the critical criterion for the Mormon Creek Formation, the lower limit in the Cooks well core is placed at the base of unit 20 (the first unit with gypsum and lacking normal marine fauna) and the upper limit is placed at the top of unit 28 (based on the conodont work of Pollack, Rexroad, & Nicoll, 1970). The overlying unit, 29, is the first appearance of chert, which is prevalent in units of the Manitoulin Dolomite. Thus, in the Cooks well, the Mormon Creek Formation is 98.4 feet thick.

The occurrence of gypsum in well cores, I realize, is not always an accurate indicator of the original environment of the strata. In the course of changes after formation -- from gyp-

sum to anhydrite and back to gypsum -- the $CaSO_4$ minerals may be dissolved and migrate into beds that were deposited in normal salinity. However, the frequency of normal marine fauna in the formation below and the formation above can provide a check on the limits of the new formation.

Evaporites. -- Evaporite minerals are seldom present in exposures in Michigan. They dissolve readily upon weathering. At the type locality of the formation, several forms of gypsum are present. White satin spar is most common in the thicker layers. It also penetrates into fractures. White alabaster is also present in layers and in fillings, but usually in thinner layers than the satin spar. Some of the alabaster is impure, as shown by coloration of gray and pale reddish tints. Almost all of the selenite is brownish, presumably incorporating considerable weathering products from the matrix. Some of the selenite is irregularly distributed within individual beds of the exposure. No gypsum pebbles were noted in the quarry, although some were seen in units 25 and 28 in the Cooks well.

The rocks in the quarry contain physical evidence that the brine from which the gypsum was precipitated became further concentrated, at times, to precipitate NaCl. Now and then a "hopper-shaped" cavity can be found in the upper beds of the quarry, the mold left after solution of a halite crystal. These crystals were shaped like a miniature Aztec pyramid, with numerous "steps" between base and tip. Some exceed two cm in diameter, although most are much smaller.

Intraformation deformation. -- The strata in the quarry are domed to form numerous mounds, some of which are several feet across. Between these irregularly spaced mounds, the strata show effects of lateral compression. It is difficult to estimate the original thickness of many units; in intermound areas, units of argillaceous dolomite appear to reach two or three times their thickness in the mounds themselves. No regularity of spacing or size of the mounds can be detected.

The area just across the road from the quarry is hummocky, presumably from the subsurface localized doming below shallow cover of sand.

It is quite impossible to determine the regional dip from the strata in the quarry, for the rocks dip in all directions and from level to several degrees.

It is also quite impossible to determine the original thickness or area of individual evaporite layers. Now they appear to be squeezed into much greater thicknesses in the mounds. From the lateral extent of evaporites in the formation, as shown in well cores, I presume that the individual layers were originally also widespread, but I cannot be sure.

Deformation seems to have been caused, in part at least, by the change from anhydrite to gypsum. Such a change involves hydration with as much as 38% increase in solid volume. The reaction can take place only where water is available in the sediment, and this may account for some of the irregular spacing of the domes.

An unusual feature can be revealed by careful excavation through the small domes to make a cross section. The gypsum in the center of the small dome contains a hollow lens-shaped cavity. Such a void may represent a late reduction in the quantity of water chemically bound to the sulfate minerals.

Possibly, some squeezing and distortion may date from the time when the originally precipitated gypsum was deeply buried under younger formations and altered to anhydrite. Blatt, Middleton, & Murray (1972, p. 504, 505) report:

> If the deposit is now anhydrite but began as gypsum, then there should have been a 38% reduction in the solid volume at the time of the replacement of the gypsum by anhydrite. Such a significant loss of solid volume has several consequences. An abnormally high fluid pressure results in the pore space because the volume of water plus anhydrite is greater than the volume of gypsum and because the 38% loss of solid volume should produce a nongrain-supported material. This fluid pressure may approach the lithostatic pressure if the permeability is insuffic-

> ient to permit the brine to dissipate. Such high fluid pressure may permit the sediment to flow and thus create deformation structures within individual beds... At the time of replacement of gypsum by anhydrite, the flow of brine that was induced by the abnormal fluid pressure may cause brine to move out into surrounding sediment or rock and precipitate anhydrite in associated rocks that originally were devoid of evaporite minerals and were not deposited under evaporite conditions.

## LOCALITIES

From the following localities, it is possible to improve the maps of Silurian and Upper Ordovician formations in Delta, Schoolcraft, Luce, and Mackinac Counties. Some localities are new, some are from Hussey (1926), and others are from Ehlers (1973). Additional field work was done in August, 1974, in company with Harry O. Sorensen of the Michigan Geological Survey and Al Johnson of Michigan Technological University.

In particular, the distribution of the Big Hill, Mormon Creek, Manitoulin, and Cabot Head formations stand in need of revised mapping in the western part of the area. Difficulties arise from the close resemblance of some strata of the Manitoulin and Cabot Head formations; both formations include some thin-bedded dolomites, unfossiliferous, which cannot be distinguished in small areal exposures. Only in the occurrence of evaporites does the Cabot Head sequence differ significantly from parts of the Manitoulin Dolomite. Similarly, as can be seen in the Cooks well core, certain units of the Mormon Creek are also thin-bedded dolomites.

Toward the east of the area included in the maps, the unfossiliferous beds of the upper part of the Burnt Bluff Group (where dolomitized) are remarkably like some of the lower beds in the Manistique Group (above the Pentamerus zones); and certain beds of the upper part of the Manistique Group may be hard, resistant dolomites much like those of the lower part of the Engadine.

Much of the identification of formations in the area depends upon fossils, and where these are absent, the geologist must rely upon the sequence of strata in outcrop. The problem of mapping is further complicated by the local changes in dip direction and steepness and by the influence of topography on the geologic distribution of outcrops. With the accumulated work that has been done over more than a century, significantly large areas are still unknown, their "outcrops" concealed beneath glacial drift.

BIG HILL FORMATION

1. Northeast shore of West Wilsey Bay, about 3 miles north-northeast of Peninsula Point on Stonington Peninsula, W$\frac{1}{2}$ sec. 8, T 38 N, R 21 W, Bay de Noc Twp., Delta Co.
2. Exposure "in front of home of Andrew H. Leadman" (Hussey, 1926), probably on farm now owned by Richard G. Smith, SE corner sec. 21, T 39 N, R 21 W, Bay de Noc Twp., Delta Co.
3. Big Hill, or Hinkin's Hill, type locality of the formation, exposed along Co. Hwy. 511 and in wooded areas atop the hill and in fields to the south, center S$\frac{1}{2}$ sec. 11, T 39 N, R 21 W, Bay de Noc Twp., Delta Co.
4. Federal Forest Quarry No. 2, west of Co. Hwy. 511 and on south slope of Big Hill, SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 11, T 39 N, R 21 W, Bay de Noc Twp., Delta Co.
5. Intermittent exposures along Co. Hwy. 511 from Big Hill north to the east end of Maywood Road, along north-south centerlines of secs. 2 and 11, T 39 N, and secs. 35 and 26, T 40 N, R 21 W, Bay de Noc and Ensign Twps., Delta Co.
6. Exposures at eastern end of Maywood Road (now J-22) and along north side of road for $\frac{1}{4}$ mile west of the corner, S line SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 23, T 40 N, R 21 W, Ensign Twp., Delta Co.
7. Exposures along east-west section of Co. Hwy. 511, near center SE$\frac{1}{4}$ sec. 15, T 40 N, R 21 W, Ensign Twp., Delta Co.
8. Lloyd Brannstrom Quarry, about 7/8 mile south of US 2, SW$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 6, T 40 N, R 20 W, Ensign Twp., Delta Co.
9. Outcrop on Ogontz Creek "beneath a little bridge" and "about 2 miles northwest of Og-

PLATE 1


EXPLANATION OF PLATE 1
Big Hill and Mormon Creek Formations

FIG. 1 -- Big Hill Formation exposed on east side of Forest Hwy. 13 (loc. 10). FIG. 2 -- Big Hill exposure in Lloyd Brannstrom Quarry (loc. 8). FIGS. 3, 4 -- Big Hill strata in Federal Forest Quarry No. 2 (loc. 4), near type locality of the formation. FIG. 5 -- Mormon Creek Formation at type locality. FIG. 6 -- Thin dolomites southeast of Chicago Lake, probably Mormon Creek Formation (loc. 2), but lacking the evaporites exposed at the type locality.

PLATE 2


EXPLANATION OF PLATE 2
Mormon Creek Formation, type locality

FIGS. 1-4 -- Photos in 1974, showing irregular doming above evaporites and close-ups of the evaporite minerals; note (fig. 4) the void below a small dome involving satinspar. FIG. 5 -- Photo in 1956 of author on argillaceous dolomites above the evaporites, in ostracod zone.

ontz" (Hussey, 1926, p. 145); Ogontz has been located on an old map (having since disappeared) at the head of Ogontz Bay, and the bridge is probably for Co. Hwy. 503, SW¼ NW¼ sec. 4, T 40 N, R 20 W, Ensign Twp., Delta Co.

10. Exposure on banks and bed of Mormon Creek where it is crossed by the Nahma-Munising Hwy. (now Forest Hwy. 13), on east side of highway about 1/3 mile north of junction with Mormon Creek Truck Trail (now USFS Hwy. 2231), near center sec. 17, T 41 N, R 19 W, Nahma Twp., Delta Co.
11. "Eight-mile rapids" on Sturgeon River, not far from loc. 10, E½ sec. 17, T 41 N, R 19 W, Nahma Twp., Delta Co.
12. "Twelve-mile rapids" on Sturgeon River, near junction with Eighteen Mile Creek, near center sec. 29, T 42 N, R 19 W, Nahma Twp., Delta Co.

MORMON CREEK FORMATION

1. Mormon Creek Truck Trail Quarry, type locality of the formation, just north of Mormon Creek Truck Trail (now USFS Hwy. 2231) and about 2¼ miles east of Big Hill loc. 10, NE¼ SE¼ sec. 15, T 41 N, R 19 W, Nahma Twp., Delta Co.

2(?). Clearings about 1 mile south-southeast of Chicago Lake and 3/4 mile east of Mahskeekee Lake, about 3/8 to 1/2 mile southeast of corner where Co. Hwy. 442 turns northward, SE¼ sec. 19, T 42 N, R 18 W, Garden Twp., Delta Co. The scabby dolomite outcrops by their position probably lie in the Mormon Creek Formation, but they could possibly be an outlier of the Manitoulin Dolomite.

MANITOULIN DOLOMITE

1. Shore of Stony Point, Nahma Peninsula, nearly 4 miles south of Moss Lake, NE¼ sec. 28 and NW¼ sec. 27, T 40 N, R 19 W, Nahma Twp., Delta Co.
2. Rock pavement exposed along secondary road about ½ mile north of Co. Hwy. 495, NE¼ sec. 21, T 40 N, R 19 W, Nahma Twp., Delta Co.
3. American Playground Device Company Quarry, about 1 mile north of Co. Hwy. 495, center N½ SE¼ sec. 16, T 40 N, R 19 W, Nahma Twp., Delta Co.
4. Field exposures bordering both sides of Nahma-Isabella road (Co. Hwy. 495), about 2 miles northeast of Nahma, central and southern parts sec. 15, T 40 N, R 19 W, Nahma Twp., Delta Co.
5. Thornton Quarry, just south of US 2 and ½ mile south of Moss Lake, NE¼ SE¼ sec. 4, T 40 N, R 19 W, Nahma Twp., Delta Co.
6. Low (10 to 15 feet) westward-facing escarpment around east side of Moss Lake, from just south of N line SW¼ sec. 3, T 40 N, R 19 W, to just west of center E line sec. 35, T 41 N, R 19 W, with gentle slopes southward for additional 3/4 mile to center E line sec. 9 and northward to near center E line sec. 26. Includes some localities below.
7. Exposure of 8 feet of dolomite near southeast corner of Moss Lake and a few yards north of tracks of Minneapolis, St. Paul, & Sault Ste. Marie Railroad, near center sec. 3, T 40 N, R 19 W, Nahma Twp., Delta Co.
8. Railroad cut a short distance east of loc. 7, exposing 3 feet of siliceous dolomite, near center sec. 3, T 40 N, R 19 W.
9. Small road quarry in top of escarpment, exposing 3 feet of dolomite with chert, beside little-used north-south road and 2/3 mile north of railroad, probably SW¼ sec. 36, T 41 N, R 19 W, Nahma Twp., Delta Co.
10. Ditch on north side of road just west of SE corner sec. 35, T 41 N, R 19 W, Nahma Twp., Delta Co. Type locality for "Moss Lake" Formation.
11. Exposure (2 feet of dolomite) on slope a short distance southeast of center E line sec. 26, T 41 N, R 19 W, Nahma Twp., Delta Co., northeast of Moss Lake.
12. Bottom of spring a short distance east of loc. 11, W part sec. 25, T 41 N, R 19 W.
13. Bottom of spring about ½ mile north of loc. 12, NW¼ NW¼ sec. 25, T 41 N, R 19 W, Nahma Twp., Delta Co.
14. Bottom of spring in NE¼ sec. 24, T 41 N, R 19 W, Nahma Twp., Delta Co.
15. Surface exposure of 4 to 5 acres just east of branch of the Nahma & Northern Railroad (now disappeared), about 2 miles northeast of type locality of Mormon Creek Formation, NE¼ SW¼ sec. 13, T 41 N, R 19 W, Nahma

Twp., Delta Co.

16. North shore of Manistique Lake adjoining SW¼ sec. 29, T 45 N, R 12 W, Lake Twp., Luce Co.
17. Small exposure on east side of East Branch Fox River, about 1 mile north of loc. 16, SE¼ SE¼ sec. 19, T 45 N, R 12 W, Lake Twp., Luce Co.
18. Small abandoned quarry about 1/10 mile north of Co. Hwy. 98 and 1 1/4 miles east of county line, SW¼ sec. 20, T 45 N, R 12 W, Lake Twp., Luce Co.

CABOT HEAD SHALE

1(?). Pavement beside Nahma-Isabella road (Co. Hwy. 495) about 1½ miles south of Isabella, NW¼ sec. 11, T 40 N, R 19 W, Nahma Twp., Delta Co. By position geographically, these rocks should be strata within the Cabot Head; but by unsuspected local structure, they could be Manitoulin Dolomite.

2 (?). Abandoned quarry, test pit, and lime-kiln about ½ mile south of Isabella, exposing 9 feet of dolomite, SE¼ sec. 2, T 40 N, R 19 W, Nahma Twp., Delta Co. See remark for loc. 1 above.

LIME ISLAND DOLOMITE

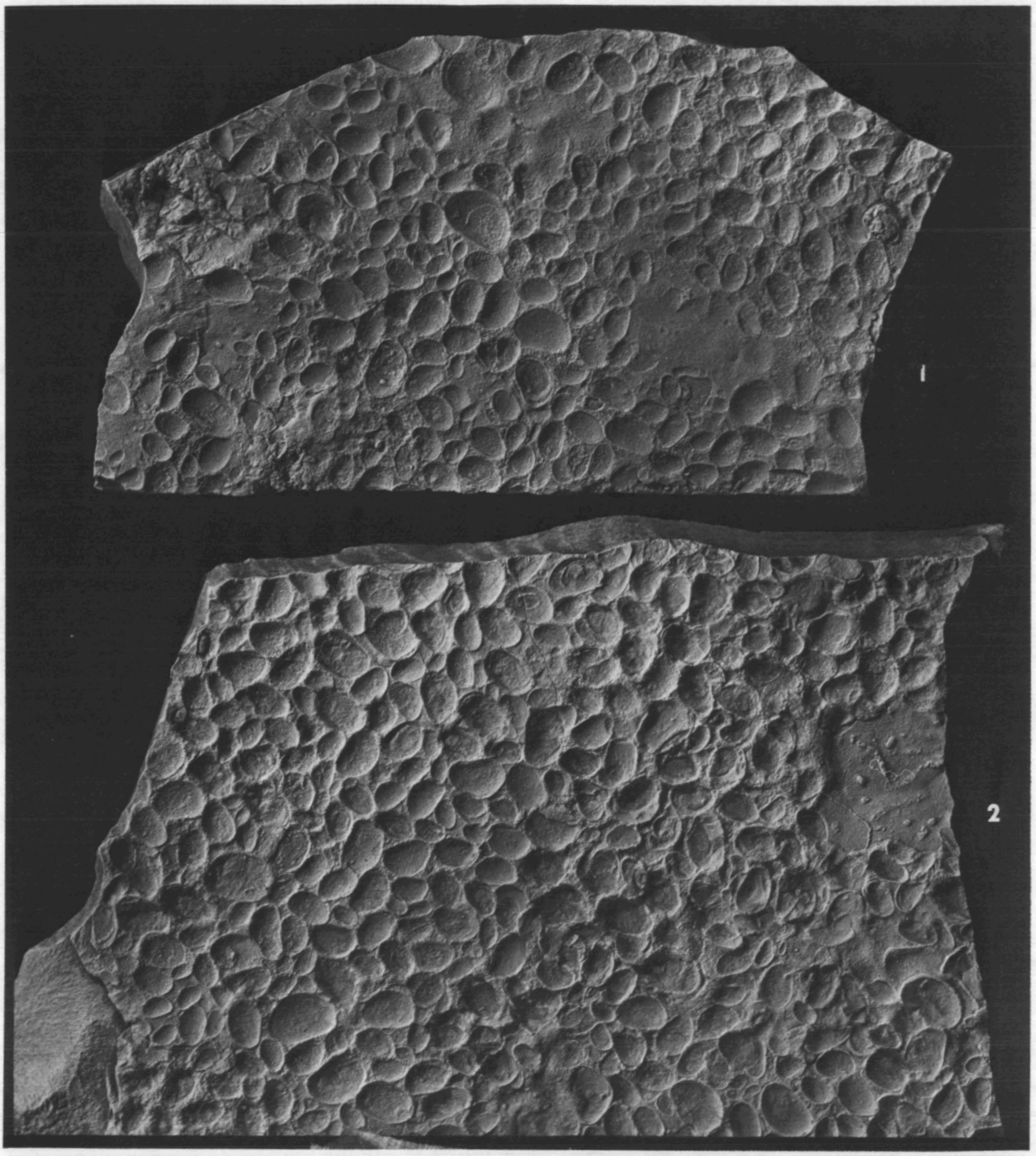
Although blocks are large and numerous in the drift at several localities, no actual exposure of the formation is known in this area. Well cores show conclusively, however, that it is present and consistently about 28 to 30 feet thick.

BURNT BLUFF GROUP

The Byron Dolomite and Hendricks Dolomite are mapped together here as the Burnt Bluff Group (excluding the Lime Island Dolomite). Most exposures are of the Hendricks.

1. Middle Bluff and abandoned quarry in the south end of the bluff near Fayette, facing Big Bay de Noc, SW¼ sec. 33, T 39 N, R 19 W, and NW¼ sec. 4, T 38 N, R 19 W, Fairbanks Twp., Delta Co. 113 feet of Hendricks dolomites; CONTACT; 22 feet of Manistique with Pentamerus.
2. Wooded cliff extending north-south along east side of South River Bay, exposing Hendricks strata from 40 to 125 feet above the bay, SW¼ sec. 23, T 39 N, R 19 W, Fairbanks Twp., Delta Co.
3. Abandoned quarry about 3/4 mile east of Garden Bluff, near shore of Goulley's Harbor, N part sec. 14, T 39 N, R 19 W, Fairbanks Twp., Delta Co. Hendricks; lower Manistique with Pentamerus a short distance back from bluff.
4. Garden Bluff, facing Big Bay de Noc and exposing Hendricks strata, secs. 10, 11, and 15, T 39 N, R 19 W, Fairbanks Twp., Delta Co.
5. Cliff a short distance northwest of Vans Harbor, near center sec. 7, T 39 N, R 18 W, Garden Twp., Delta Co. CONTACT with the Manistique Dolomite.
6. Exposures along shore from loc. 5 for about 1 mile, past Ansel's Point, Garden Peninsula, secs. 7 and 6, T 39 N, R 18 W, Garden Twp., Delta Co. Lower part of Hendricks Dolomite.
7. "Eleven-mile Bluff" about 11 miles northeast of Burnt Bluff, about 3 miles north of Garden and just north of Kates Bay, exposing 82 feet of Hendricks, NW¼ sec. 32, T 40 N, R 18 W, Garden Twp., Delta Co.
8. Sink exposing Hendricks strata, SW¼ sec. 22, T 40 N, R 18 W, Garden Twp., Delta Co.
9. William K. Haindl Quarry, just east of Co. Hwy. 442, SW corner sec. 17, T 41 N, R 17 W, Inwood Twp., Schoolcraft Co.
10. Field on north side of road near center S line sec. 7, T 41 N, R 17 W, Inwood Twp., Schoolcraft Co.
11. Roadside exposures of about 6 feet of dolomite, about 100 feet east of SW corner sec. 8, T 41 N, R 17 W, Inwood Twp., Schoolcraft Co.
12. Low ridge of about 3 feet of dolomite crossing Co. Hwy. 442 near center S line SW¼ sec. 8, T 41 N, R 17 W, Inwood Twp., Schoolcraft Co.
13. Robert Glatus Quarry for dolomite building stone, about 25 yards west of Co. Hwy. 437, NE¼ SE¼ SE¼ sec. 8, T 41 N, R 17 W, Inwood Twp., Schoolcraft Co.
14. Roadside and nearby field exposures of beds with Trimerella, SW corner sec. 9, T 41 N, R 17 W, and north of this corner, Inwood Twp., Schoolcraft Co.
15. Small quarry for road metal in small hill on north side of Co. Hwy. 442, exposing about

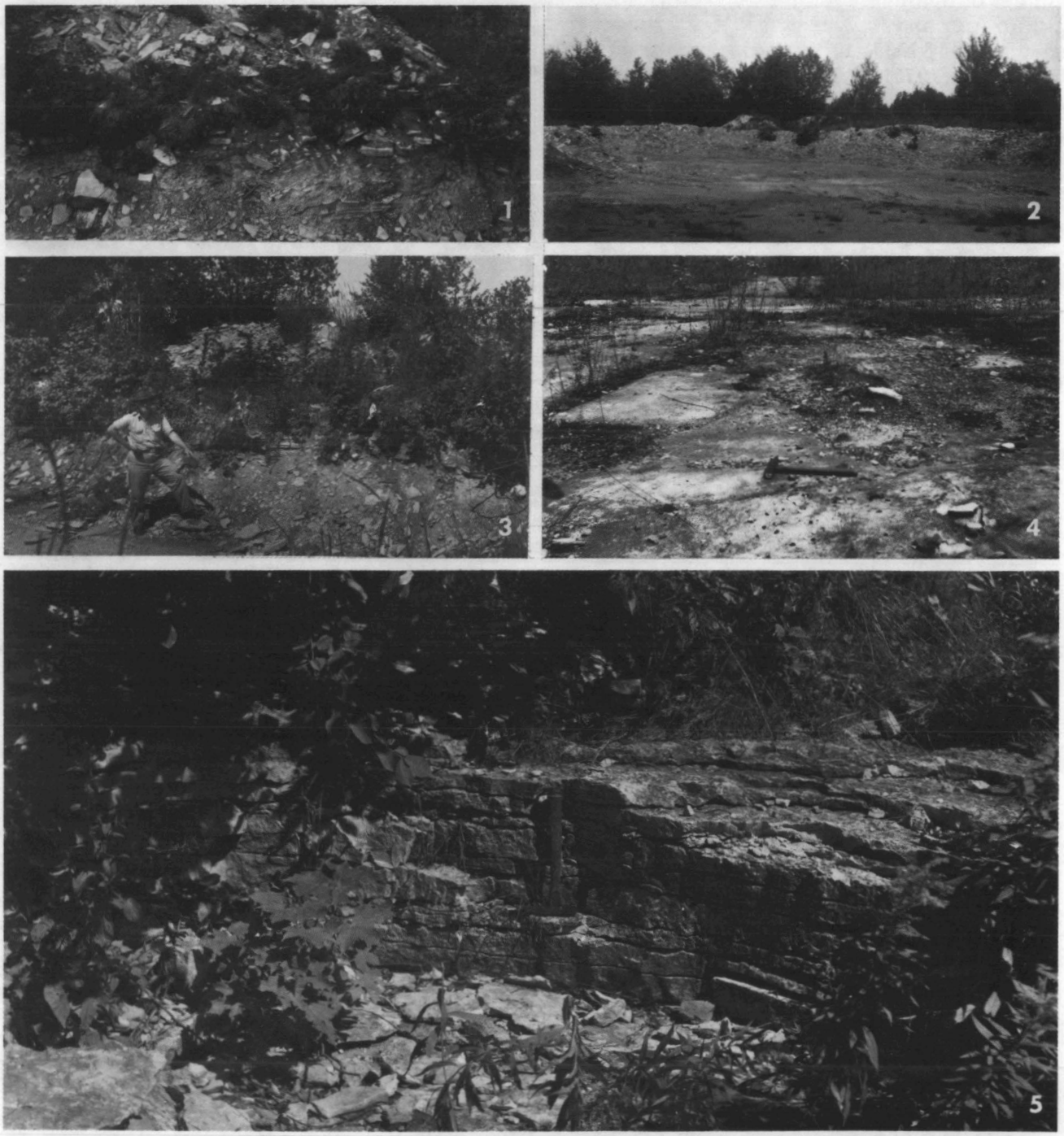
PLATE 3




EXPLANATION OF PLATE 3

Ostracods from the Mormon Creek Formation (x 2), probably a species of Leperditia. Type locality of the formation.

PLATE 4




EXPLANATION OF PLATE 4
Mormon Creek and Manitoulin Formations

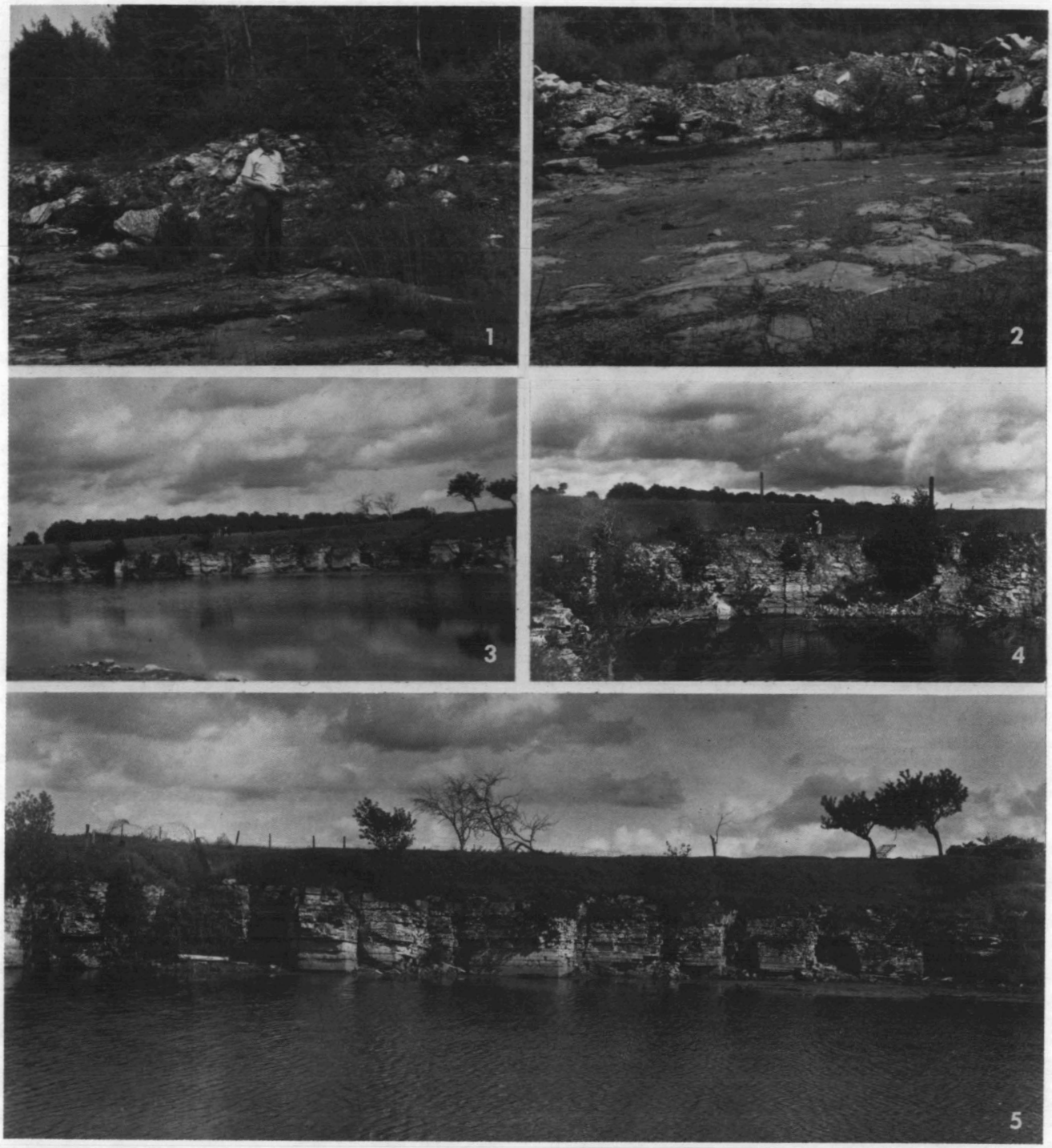
FIGS. 1-3 -- Mormon Creek Formation at type locality. FIG. 4 -- Manitoulin strata forming rock pavement in Nahma Twp. (loc. 2). FIG. 5 -- Manitoulin Dolomite exposed in ditch at the type locality of the "Moss Lake Formation" (loc. 10), typical thin-bedded dolomites.

16 feet of dolomites with Trimerella, about ½ mile east and 100 yards north of SW corner sec. 9, T 41 N, R 17 W. Quarry reported by Ehlers (1973), but could not be located in Aug 1974 by Kesling, Sorensen, and Johnson.

16. Edward H. Gray Quarry, about 1 mile west of intersection of Co. Hwys. 442 and 149 and 100 yards north of road (northeast of the owner's house); also intermittent exposures on hill behind the quarry; SE¼ SE¼ SE¼ sec. 9, T 41 N, R 17 W, Inwood Twp., Schoolcraft Co.
17. Very small quarry for road metal in side of low east-west ridge, exposing 5 to 6 feet of lowest Hendricks, SW¼ sec. 28, T 42 N, R 17 W, Inwood Twp., Schoolcraft Co.
18. Ledges on bottom of Indian River between Indian Lake and M-94 highway (old Manistique-Shingleton road), exposing Hendricks dolomite beds, secs. 34 and 35, T 42 N, and secs. 2 and 1, T 41 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
19. Surface exposures over 3 to 4 acres just north of Indian River and east of M-94; also a few small quarries excavated in area for building stone, exposing strata near top of Hendricks; NE¼ NE¼ sec. 2, T 41 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
20. Road cut on M-94, about 1/8 mile south of N line sec. 35, T 42 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
21. Escarpment north of Manistique and associated cuesta between Indian Lake and valley of Manistique River, extending from N central part sec. 27 northwestward through W central part sec. 22, thence northeastward into S parts secs. 15 and 14 (there trending E-W), thence southeastward into E central sec. 23 and southward into NE¼ sec. 26, thence east-northeastward into S part sec. 24 and continuing as low and discontinous cliff into NE¼ sec. 25, T 42 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
22. Discontinuous exposures along shore of Indian Lake and in low cliff between outlet of lake into Indian River and southwest end of escarpment in loc. 21, exposing dolomite below and limestone (probably lower than the Fiborn Member) above, secs. 34 and 27, T 42 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
23. Top of bluff about 1 mile northeast of Indian Lake, exposing Hendricks strata, center S line sec. 15, T 42 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
24. Cut on M-94 near S line sec. 14, T 42 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
25. Cut on M-94 (old Manistique-Shingleton road) through cuesta and escarpment and roadside (west of highway) quarry known as Sawheidle Quarry, exposing in all over 58 feet of fossiliferous Hendricks dolomites, about ¼ mile south of center sec. 14, T 42 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
26. Low ridge along Co. Hwy. 433 (old River Road), with roadside exposures and small abandoned quarry just south of road, dolomite beds with Trimerella, NE¼ SE¼ sec. 27, T 42 N, R 15 W, Manistique Twp., Schoolcraft Co.
27. Cut on south side of Co. Hwy. 433, exposing a few feet of dolomite, some chert, SW¼ NW¼ sec. 26, T 42 N, R 15 W, Manistique Twp.
28. "Hidden Nicholson" Quarry, situated in low swampy area in woods and not visible from any road, long abandoned but said to have been operated as one of several quarries owned by Mr. Nicholson; quarry mostly filled with water but showing steeply dipping (possibly as much as 8 degrees) strata with Trimerella; quarry can be reached by very secondary trail from road in W½ SW¼ SE¼ sec. 26 leading south; quarry on land listed in plat book of 1970 as owned by James Hubble but said by Florimand Vandewalle, a neighbor, to have been sold to Mr. Beal; W½ NE¼ sec. 35, T 42 N, R 15 W, Manistique Twp., Schoolcraft Co.
29. Low south-facing escarpment with Trimerella zone of Hendricks, about 100 yards south of NW corner sec. 30, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
30. Cut on northeast-southwest section of Co. Hwy. 433, SW¼ sec. 17, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
31. Bluff about ¼ mile north and 1/8 mile east of SW corner sec. 8, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
32. Rock pavement over S½ sec. 8, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
33. Escarpment rising 80 feet above swamp bordering Manistique River and exposing 48 feet of Hendricks at the top, NE¼ SW¼ sec. 8, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.

34. Cliff facing northwest about 3/4 mile east of loc. 33, exposing about 45 feet of dolomitized equivalent of Fiborn, NE¼ SE¼ sec. 8 and extending from NE¼ sec. 17 to SW¼ sec. 4, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
35. Spring in NW¼ NE¼ sec. 8, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
36. Exposure in NE¼ NE¼ sec. 8, not far from junctions of Co. Hwys. 433 and 436, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
37. Calvin Johnson Quarry, about 100 yards east of Co. Hwy. 432 and 1.3 miles south of Co. Hwy. 433, SW¼ NW¼ sec. 13, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
38. Outcrop on east side of Co. Hwy. 432 on farm of Calvin Johnson, about 1.1 miles south of Co. Hwy. 433, near NW corner sec. 13, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
39. Roadside exposure of 10 feet of dolomite with Trimerella alongside Co. Hwy. 432, S½ of line between secs. 11 and 12, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
40. Roadside exposure of 2 feet of limestone (below Trimerella beds) beside Co. Hwy. 433, S line near SW corner sec. 2, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
41. Exposure beside winding (more or less north-south) road, SE¼ sec. 33, T 43 N, R 14 W, Doyle Twp., Schoolcraft Co.
42. Exposures of Fiborn Limestone along north-south road leading south from Co. Hwy. 433, ¼ mile east of US 2, center N½ sec. 8, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
43. Roadside quarry in side of low west-facing bluff and field exposures just south of the quarry, exposing 11½ feet of dolomite below the Fiborn, near SW corner sec. 5, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
44. Ditch about 2 miles west of Calspar Quarry exposing 3 inches of dolomitized strata overlain by 8 inches of highly calcareous Fiborn, SE¼ SW¼ sec. 5, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co. Ditch formerly along Nicholsonville Road (now Co. Hwy. 433) and exposure somewhat changed by present location of US 2.
45. Various test pits dug south of Co. Hwy. 433, most now obscured, exposing Fiborn Limestone, N part sec. 10, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
46. Calspar Quarry, also known as Nicholsonville Quarry and to local residents as "Blaney Quarry," located at Calspar (formerly Nicholsonville) and owned by the Manistique Lime Company, then by Inland Lime & Stone Co., now abandoned and water-filled; once situated on Blaney & Southeastern Railroad, but railroad long abandoned; once exposed 44 feet of Hendricks, mostly Fiborn Limestone; NE¼ SW¼ sec. 3, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
47. Low ridge exposing dolomitized equivalent of Fiborn Limestone, crossing section line 1/8 mile north of SE corner sec. 12 and extending west-southwest, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co. Possibly the same strata as in the Calvin Johnson Quarry about 1 mile southwest.
48. Quarry for road metal, long abandoned, just southeast of old cut-off section of US 2, quarry partly filled with rubbish, but probably once exposing as much as 8 feet of strata; limestone probably stratigraphically below Trimerella beds; SW¼ NE¼ sec. 29, T 43 N, R 13 W, Mueller Twp., Schoolcraft Co.
49. Large area around Calspar (formerly Nicholsonville) exposing Fiborn Limestone as rock pavement in discontinuous patches, S½ sec. 34, S½ sec. 35, S½ sec. 36, SE¼ sec. 33, T 43 N, R 13 W; N½ sec. 1, N½ sec. 2, all sec. 3, E and S parts sec. 4, N½ sec. 8, and N½ sec. 9, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
50. Roadside exposures about 1/8 mile northeast of quarry in loc. 48, along cut-off section of old US 2, with limestone like that in quarry, NE¼ sec. 29, T 43 N, R 13 W, Mueller Twp., Schoolcraft Co.
51. Small bluff about 3/4 mile north of Calspar Quarry, exposing 2 feet of dolomite lower than the Fiborn, S part sec. 34, T 43 N, R 13 W, Mueller Twp., Schoolcraft Co.
52. Exposure of Fiborn Limestone north of Old Hunt Spur (located on Minneapolis, St. Paul, & Sault Ste. Marie Railroad), SW¼ sec. 7, T 42 N, R 12 W, Newton Twp., Mackinac Co.
53. Inland Limestone Quarry of Inland Lime & Stone Company, opened in SW¼ sec. 6, expanded into secs. 5 and 6, and recently greatly expanded toward the west; about 1 mile north

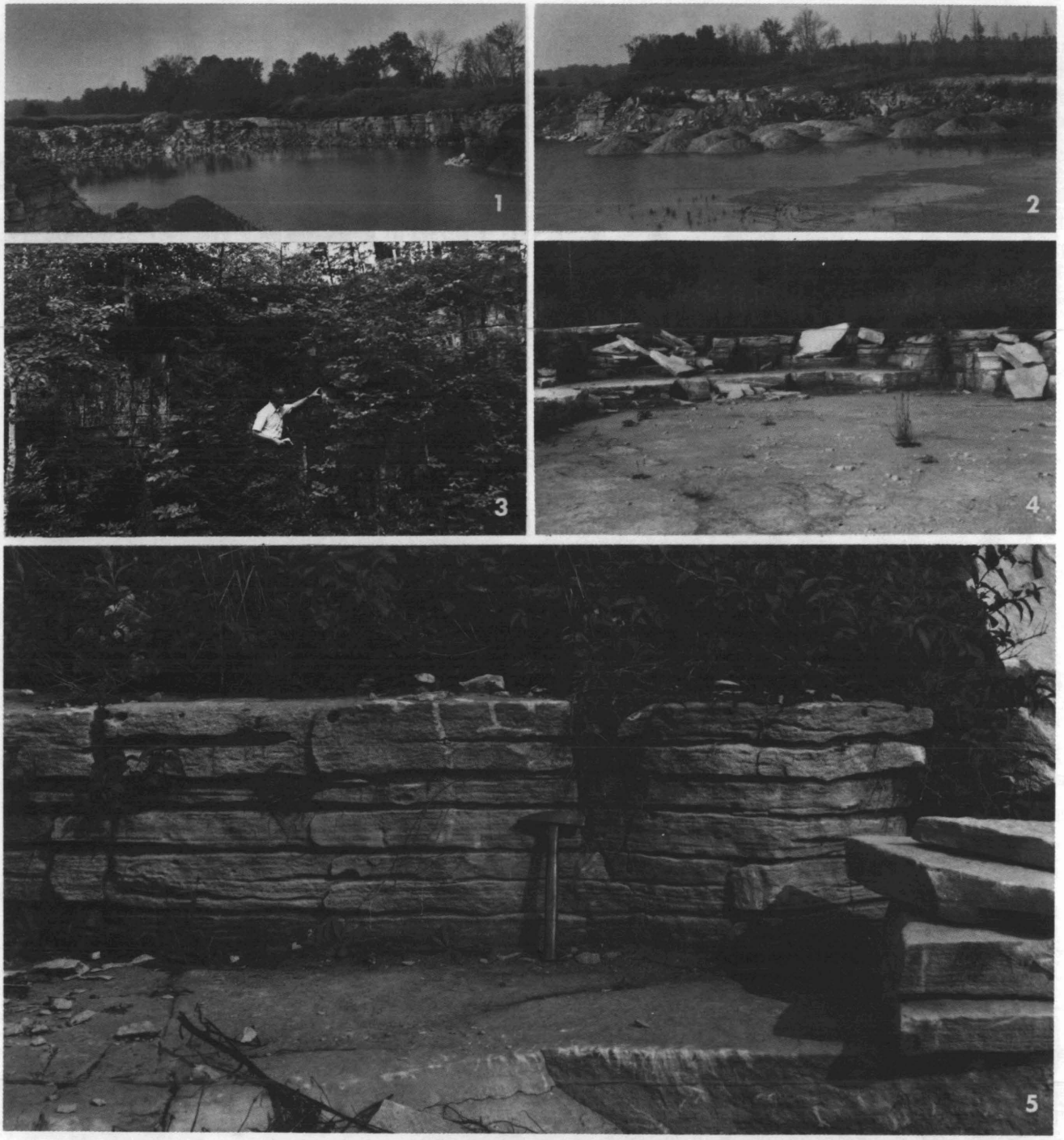
PLATE 5




EXPLANATION OF PLATE 5
Manitoulin Dolomite

FIGS. 1, 2 -- American Playground Device Company Quarry (loc. 3). FIGS. 3-5 -- Small abandoned quarry north of Manistique Lake, Luce Co. (loc. 18).

PLATE 6




EXPLANATION OF PLATE 6
Manitoulin Dolomite and Burnt Bluff Group

FIGS. 1, 2 -- Manitoulin Dolomite in Thornton Quarry, south of Moss Lake (loc. 5). FIG. 3 -- Hendricks Dolomite in William K. Haindl Quarry (loc. 9). FIGS. 4, 5 -- Hendricks Dolomite in Robert Glatus Quarry (loc. 13), even-bedded coarsely crystalline dolomite building stone.

of Old Hunt Spur and about 7 miles north-northeast of Port Inland; thickest section of Fiborn Limestone about 50 feet; T 42 N, R 12 W, Newton Twp., Mackinac Co., and T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.

54. Surface exposures of Fiborn Limestone over extensive area north of Old Hunt Spur, continuous with similar exposures at loc. 49 in Schoolcraft Co., covering unquarried parts of sec. 6 and NE$\frac{1}{4}$ sec. 5, T 42 N, R 12 W, and S$\frac{1}{2}$ sec. 31 and SW$\frac{1}{4}$ sec. 32, T 43 N, R 12 W, Newton Twp., Mackinac Co.
55. Surface exposures of Fiborn Limestone and overlying magnesian-limestone, about $\frac{1}{4}$ mile northwest of Gould City and extending into S parts secs. 19 and 20 and N parts secs. 29 and 30, on both sides of US 2, T 43 N, R 11 W, Newton Twp., Mackinac Co.
56. Roadside exposures of limestone along North Gould City Road, about 4 miles north of Gould City, on line between secs. 4 and 5, T 43 N, R 11 W, Newton Twp., Mackinac Co.

MANISTIQUE GROUP

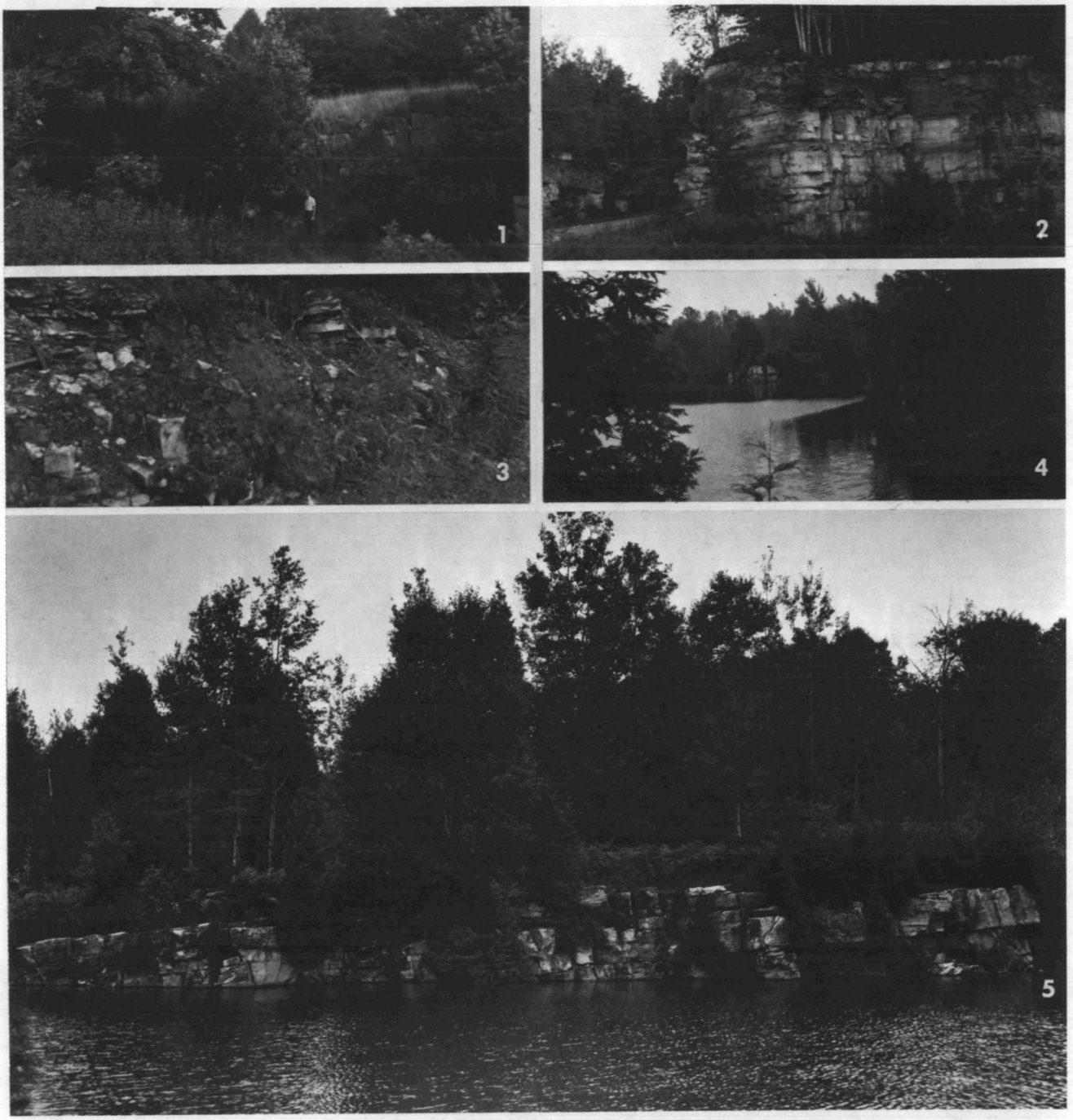
The Schoolcraft Dolomite and Cordell Dolomite are mapped together for most of the extent of the Manistique Group. In the mapped area, the Schoolcraft is about 50 feet thick and the Cordell is much thicker, reaching 150 feet at some places.

1. Exposures along roads in and near Garden and in W$\frac{1}{2}$ sec. 18, T 39 N, R 18 W, Garden Twp., Delta Co.
2. Middle Bluff near Fayette and facing Big Bay de Noc, SW$\frac{1}{4}$ sec. 33, T 39 N, R 19 W, and NW$\frac{1}{4}$ sec. 4, T 38 N, R 19 W, Fairbanks Twp., Delta Co. 22 feet of dolomite with Pentamerus in CONTACT with 113-foot cliff of Hendricks Dolomite.
3. Abandoned quarry about 3/4 mile east of Garden Bluff, near shore of Goulley's Harbor, N part sec. 14, T 39 N, R 19 W, Fairbanks Twp., Delta Co. Pentamerus beds in CONTACT with Hendricks Dolomite.
4. Cliff a short distance northwest of Vans Harbor, near center sec. 7, T 39 N, R 18 W, Garden Twp., Delta Co. CONTACT with the underlying Burnt Bluff Group.
5. Rock fragments cast up from bottom of Lake Michigan onto point between Manistique and Thompson, in the southern part of general area included in Stoney Point, sec. 27, T 41 N, R 16 W, Thompson Twp., Schoolcraft Co. Beds identified as upper Pentamerus dolomite.
6. Outcrops in town of Manistique along Manistique River, east of the river from its mouth to Charcoal Iron Company and along course of flume for Manistique Paper Company, extending nearly 1 mile above river mouth and also along nearby shore of Lake Michigan.
7. White Marble Quarry in Manistique, now abandoned and partly water-filled, and more elevated nearby sections of town nearby; quarry is located east of the turn of US 2 from Maple Street (N-S) onto Elk Street (E-W), and northeast of the High School Athletic Field and Softball Diamonds; quarry exposed 56 feet of Schoolcraft from basal lower Pentamerus dolomite to top of the formation; nearby, east of the athletic fields, 19 feet of Cordell are exposed at one place or another.
8. Small quarry recently opened, probably for road metal, east of White Marble Quarry and not visible from it because of high intervening sand hill, just west of Lakeside Road between Cherry and Elm Streets, a short distance north-northeast of Lakeview Cemetery; Cordell cherty dolomites.
9. Exposures along M-94 less than $\frac{1}{4}$ mile south of Indian River, probably lower Pentamerus dolomite, near center W$\frac{1}{2}$ sec. 2, T 41 N, R 16 W, Hiawatha Twp., Schoolcraft Co.
10. Road cut of US 2 by-passing old corner, exposing mostly Cordell but with underlying Schoolcraft Dolomite exposed along cut-off section of road to the northwest; strata dipping steeply and faulted with small displacement; exposures here separated from Marblehead Quarry to the west by small stream draining Marblehead Lake; SW$\frac{1}{4}$ sec. 36, T 42 N, R 15 W, Manistique Twp., Schoolcraft Co.
11. York Anderson Quarry, just south of loc. 10 and south of US 2, exposing cherty beds of Cordell Dolomite, SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 36, T 42 N, R 15 W, Manistique Twp., Schoolcraft Co.
12. Exposure on south side of US 2 about $\frac{1}{2}$ mile east of Marblehead Quarry, showing

contact between Cordell and Schoolcraft formations, SE¼ sec. 36, T 42 N, R 15 W, Manistique Twp., Schoolcraft Co.

13. Exposures between Cookson Lake and the junction of US 2 and Co. Hwy. 438, about ¼ mile from loc. 12, showing dolomites thought to be below the upper Pentamerus dolomite, SW¼ SW¼ sec. 31, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
14. Road quarry just east of Co. Hwy. 438, exposing lower Pentamerus dolomite of the Schoolcraft, possibly a small outlier, about 1/8 mile north of SW corner sec. 19, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
15. Exposures of upper Pentamerus dolomite about 2 miles northwest of Gulliver (formerly Whitedale), along north-south road with ridge crossing road at north end of exposure, from NE corner sec. 33 to NE corner sec. 28, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
16. Exposures of highly fossiliferous Cordell strata about 1 3/4 miles west of Gulliver, south of loc. 15, E½ sec. 33 and W½ sec. 34, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
17. Two outliers of Engadine Dolomite surrounded by Cordell beds in the vicinity of Gulliver (formerly Whitedale), the larger in S½ sec. 26 and extending as a ridge beyond E edge sec. 27 to the west and beyond the intersection of secs. 25, 26, 35, and 36 to the east, crossing Co. Hwy. 432, more or less extending between Gents Creek and Fernia Creek and rising above the village to the north; the smaller outlier east of Gulliver, south of US 2 and the Minneapolis, St. Paul, & Sault Ste. Marie Railroad tracks, and east of Little Muddy Lake, NE¼ sec. 36, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
18. Ridge trending northwest-southeast, about 1 mile southeast of Gulliver near Co. Hwy. 432, exposing Cordell dolomites, sec. 1, T 41 N, R 14 W, Doyle Twp., Schoolcraft Co.
19. Seul Choix Point, exposures near lighthouse and near end of Co. Hwy. 431; axis of the peninsula is the axis of a sharp anticline with Cordell strata in the middle and Engadine Dolomite dipping strongly away on both flanks; N½ sec. 27, T 41 N, R 13 W, Mueller Twp., Schoolcraft Co.
20. Exposures on south, southwest, and north shores of McDonald Lake, about 2 miles southeast of Gulliver; fossiliferous Cordell Dolomite; NE part T 41 N, R 14 W (Doyle Twp.) and NW part T 41 N, R 13 W (Mueller Twp.), Schoolcraft Co.
21. Outcrops of fossiliferous Cordell on east shore of McDonald Lake, sec. 5, T 41 N, R 13 W, and sec. 32, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
22. Exposure of dolomite presumed to be basal Manistique reported along railroad (now disappeared) about ½ mile south of Calspar (also called Nicholsonville and "Blaney") Quarry, N part sec. 10, T 42 N, R 13 W, Mueller Twp., Schoolcraft Co.
23. Field exposures of thin Cordell dolomites north of Old Hunt Spur by ¼ and ½ mile, near west line of section, SW¼ sec. 7, T 42 N, R 12 W, Newton Twp., Mackinac Co.
24. General area of exposures along South Gould City Road, from SE corner sec. 29, T 43 N, R 11 W, and SE corner sec. 17, T 42 N, R 11 W, Newton Twp., Mackinac Co. The CONTACT with the Engadine Dolomite crosses the road near SE corner sec. 17.
25. Exposure of Cordell Dolomite about ½ mile north of SE corner sec. 8, T 42 N, R 11 W, Newton Twp., Mackinac Co.
26. Exposure of Cordell near SE corner sec. 5, T 42 N, R 11 W, Newton Twp.
27. Exposure of Cordell about 1/8 mile south of NE corner sec. 5, T 42 N, R 11 W.
28. Low ridge about ½ mile southwest of Gould City, exposing at most 4 feet of fossiliferous Cordell strata, from SE¼ sec. 29 southward through east part of sec. 32 and crossing South Gould City Road on east line of sec. 32 about 1½ miles south of Gould City, T 43 N, R 11 W, Newton Twp., Mackinac Co.
29. Exposure of Cordell along Brawley Road, about 2 miles east-southeast of Gould City, about 1/8 mile north of SW corner sec. 26, T 43 N, R 11 W, Newton Twp., Mackinac Co.
30. Exposure of Cordell along north-south road connecting Hiawatha Trail and Linch Road, over 3 miles east-northeast of Gould City, about ¼ mile south of NW corner sec. 24, T 43 N, R 11 W, Newton Twp.
31. Low bluff about 1 mile north of Hazelmere (now disappeared; once a station on the Minneapolis, St. Paul, & Sault Ste. Marie Railroad), and 3 miles east-northeast of Gould

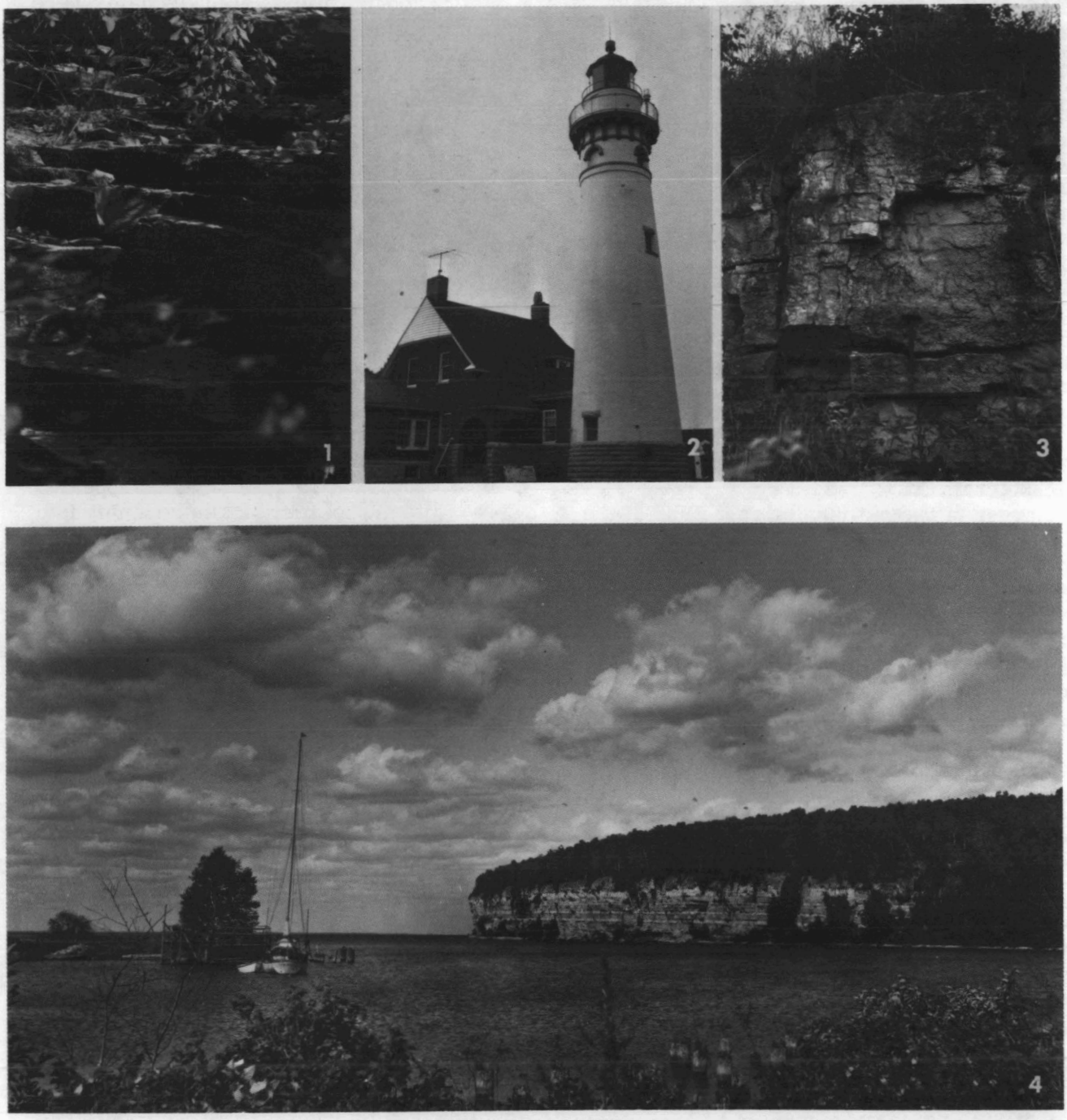
PLATE 7




EXPLANATION OF PLATE 7
Burnt Bluff Group

FIG. 1 -- Hendricks Dolomite in Edward H. Gray Quarry (loc. 16). FIG. 2 -- Hendricks Dolomite in Sawheidle Quarry (loc. 25). FIG. 3 -- Hendricks Dolomite exposed in cut on Co. Hwy. 433 (loc. 27), dolomite with some chert. FIGS. 4, 5 -- Hendricks Dolomite in "Hidden Nicholson" Quarry, Trimerella present in dolomite with steep dip, up to 8 degrees (loc. 28).

PLATE 8




EXPLANATION OF PLATE 8

FIG. 1 -- Manitoulin Dolomite at type locality of "Moss Lake Formation" (loc. 10). FIG. 2 -- Manistique Group at Seul Choix Point; lighthouse rests on Cordell Dolomite exposed on axis of the sharply defined anticline (loc. 19). FIG. 3 -- Burnt Bluff Group, Hendricks Formation in Edward H. Gray Quarry (loc. 16). FIG. 4 -- Burnt Bluff Group, Hendricks Dolomite in Middle Bluff (loc. 1), with contact with Manistique Group in wooded area above.

City; bluff is Engadine Dolomite and field exposures to the west are Cordell Dolomite; SW$\frac{1}{4}$ sec. 13 and NW$\frac{1}{4}$ sec. 24, T 43 N, R 11 W, Newton Twp., Mackinac Co.

ENGADINE DOLOMITE

1. Marblehead Quarry, formerly operated by Inland Lime & Stone Co., exposing 8 feet of hard massive dolomite beds, located northwest of US 2 and west of road cut exposures of Cordell Dolomite at Manistique Group loc. 10, topographically higher than latter; over $\frac{1}{2}$ mile southeast of "Hidden Nicholson" Quarry (Burnt Bluff Group loc. 28) with its steeply dipping Trimerella beds of Hendricks Dolomite; exposure is an outlier on the west flank of the Seul Choix Anticline, matching the two outliers on the east flank near Gulliver; SW$\frac{1}{4}$ sec. 36, T 42 N, R 15 W, Manistique Twp., Schoolcraft Co.
2. Larger of two outliers on east flank of the Seul Choix Anticline, surrounded by Cordell beds, located north of Gulliver (formerly Whitedale), forming a ridge from E edge sec. 27, through S$\frac{1}{2}$ sec. 26, and crossing Co. Hwy. 432 beyond intersection of secs. 25, 26, 35, and 36, more or less extending between Gents Creek and Fernia Creek, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
3. Smaller of two outliers on east flank of Seul Choix Anticline, located east of Gulliver and south of US 2 and Minneapolis, St. Paul, & Sault Ste. Marie Railroad tracks, east of Little Muddy Lake, NE$\frac{1}{4}$ sec. 36, T 42 N, R 14 W, Doyle Twp., Schoolcraft Co.
4. Seul Choix Point area, with axis of peninsula also the axis of the Seul Choix Anticline, with Cordell Dolomite along the middle and Engadine Dolomite dipping steeply away on both sides; on southwest flank of the anticline, the Engadine outcrops extensively onshore near Goudreau's Harbor in SE$\frac{1}{4}$ sec. 21, T 41 N, R 13 W, Mueller Twp., Schoolcraft Co.
5. Outcrops on beach and pavements in the shallows of Seul Choix Bay at various points between Seul Choix Point and the mouth of Bulldog Creek about 2 miles to the north, secs. 15 and 10, T 41 N, R 13 W, Mueller Twp., Schoolcraft Co.
6. Sam Wall Quarry, on land now owned by Chuck Barker (son-in-law of the late Sam Wall), about $\frac{1}{2}$ mile east of the dam where Bulldog Creek begins at the outlet to McDonald Lake, about $\frac{1}{4}$ mile north of Co. Hwy. 432, W$\frac{1}{2}$ SE$\frac{1}{4}$ sec. 4, T 41 N, R 13 W, Mueller Twp., Schoolcraft Co.
7. Inland Steel Dolomite Quarry, expanding and active quarry in Engadine Dolomite, north of Co. Hwy. 432, center S$\frac{1}{2}$ sec. 2, T 41 N, R 13 W, and small test pits in SE$\frac{1}{4}$ sec. 3, T 41 N, R 13 W, Mueller Twp., Schoolcraft Co.
8. Exposures of dolomite about 5$\frac{1}{2}$ miles south of Gould City along South Gould City Road, E$\frac{1}{2}$ sec. 20, W$\frac{1}{2}$ sec. 21, NW$\frac{1}{4}$ sec. 28, and NE$\frac{1}{4}$ sec. 29, T 42 N, R 11 W, Newton Twp., Mackinac Co.
9. Sinkholes in dolomite; largest, 150 feet in diameter, located $\frac{1}{4}$ mile west of SE corner sec. 20 and 500 feet north of S line of sec.; small stream from northwest disappears into this sinkhole; small sink opening into cave about 75 feet west of E line sec. 20 and 200 feet north of S line of sec., the cave containing a south-flowing underground stream; SE$\frac{1}{4}$ sec. 20, T 42 N, R 11 W, Newton Twp., Mackinac Co.
10. Exposures over area 3/4 mile wide southeast of Gould City, extending northeast for 2 miles from NE$\frac{1}{4}$ sec. 22 to W part sec. 12, T 42 N, R 11 W, Newton Twp., Mackinac Co.
11. Exposure crossing South Gould City Road showing CONTACT of Cordell Dolomite and Engadine Dolomite, near SE corner sec. 17, T 42 N, R 11 W, Newton Twp., Mackinac Co.
12. Low bluff capped by Engadine with Cordell outcrops on slope in field to the west, about 3 miles east-northeast of Gould City and 1 mile north of former site of Hazelmere, a station on the M, St. P, and SSte. M Railroad, SW$\frac{1}{4}$ sec. 13 and NW$\frac{1}{4}$ sec. 24, T 43 N, R 11 W, Newton Twp., Mackinac Co.

Other localities used in making the maps are listed in Ehlers (1973, p. 190-200).

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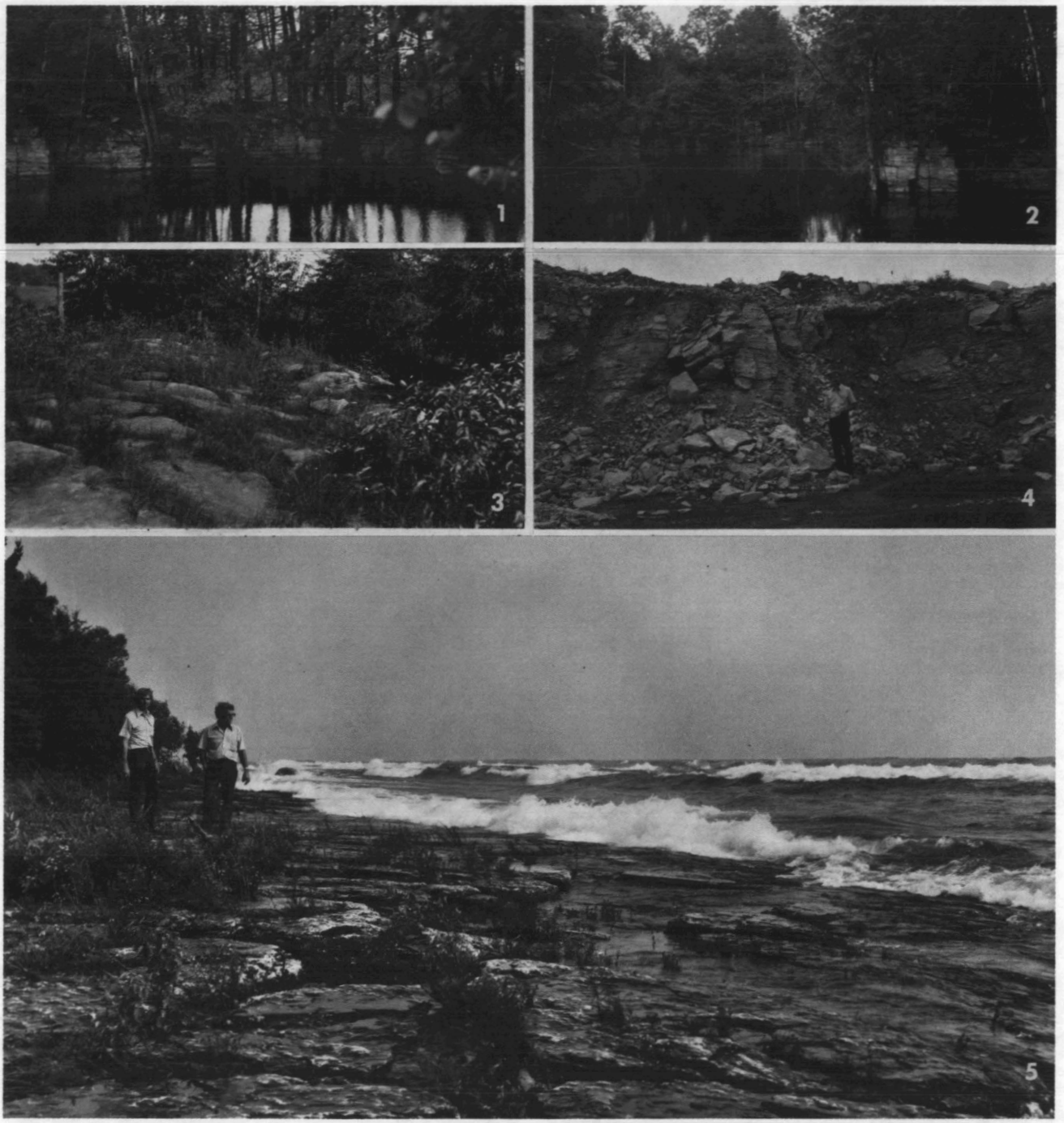
PLATE 9




EXPLANATION OF PLATE 9

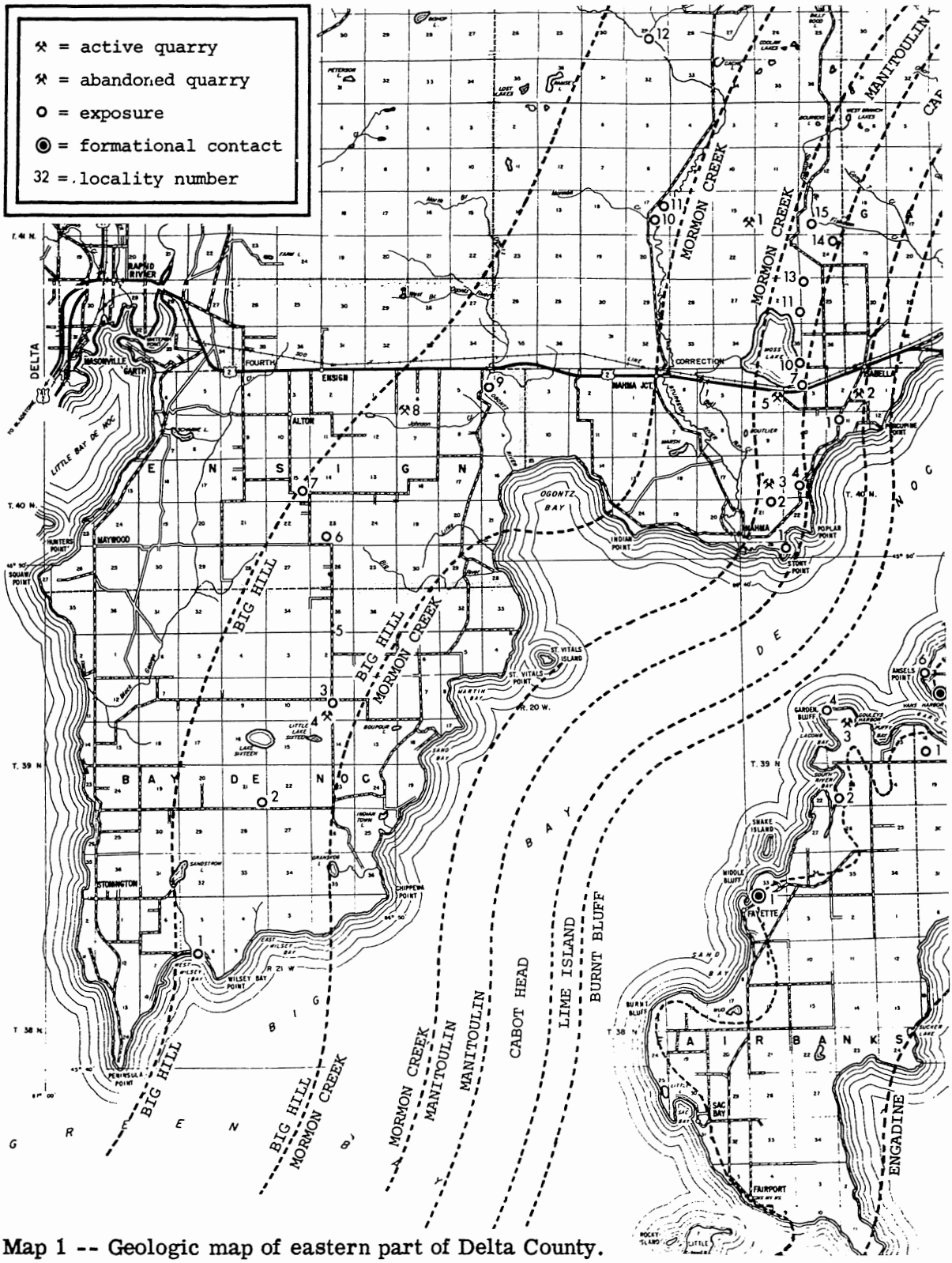
FIGS. 1, 2 -- Burnt Bluff Group, Hendricks Formation in Calvin Johnson Quarry (loc. 37), long abandoned. FIG. 3 -- Burnt Bluff Group, Hendricks Formation exposed on Calvin Johnson farm (loc. 38). FIG. 4 -- Manistique Group, Cordell Dolomite in York Anderson Quarry (loc. 11). FIG. 5 -- Engadine Dolomite at Goudreau's Harbor on southwest side of Seul Choix peninsula, showing steeply dipping resistant beds breaking the waves offshore, Aug 1974 (loc. 4).

PLATE 10


EXPLANATION OF PLATE 10
Engadine Dolomite

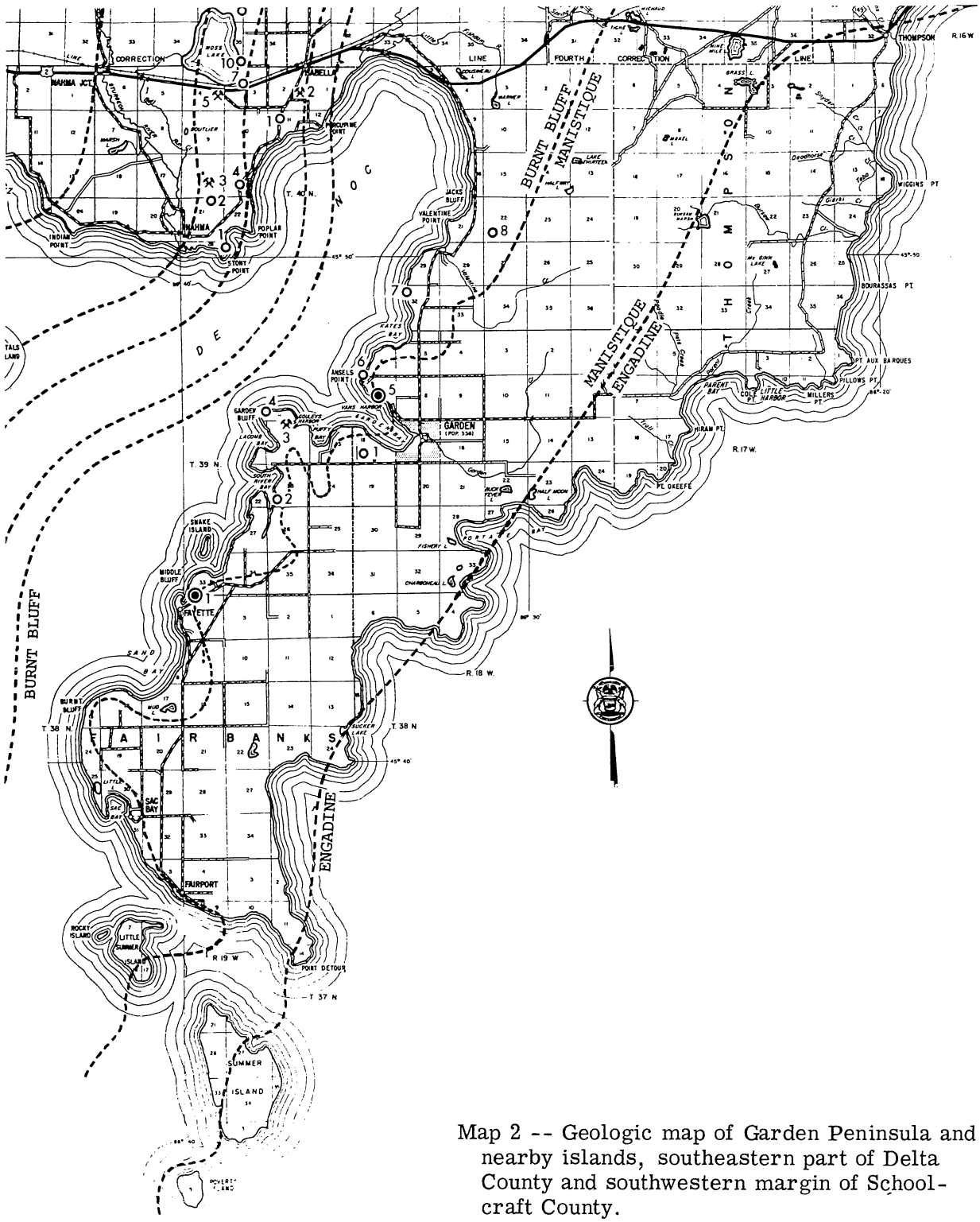
FIGS. 1-3 -- Sam Wall Quarry and adjacent rock pavement showing typical jointing of resistant thick-bedded dolomite strata (loc. 6). FIGS. 4, 5 -- Dolomite Quarry of Inland Steel Company, newly opened and active (loc. 7).

MAP 1



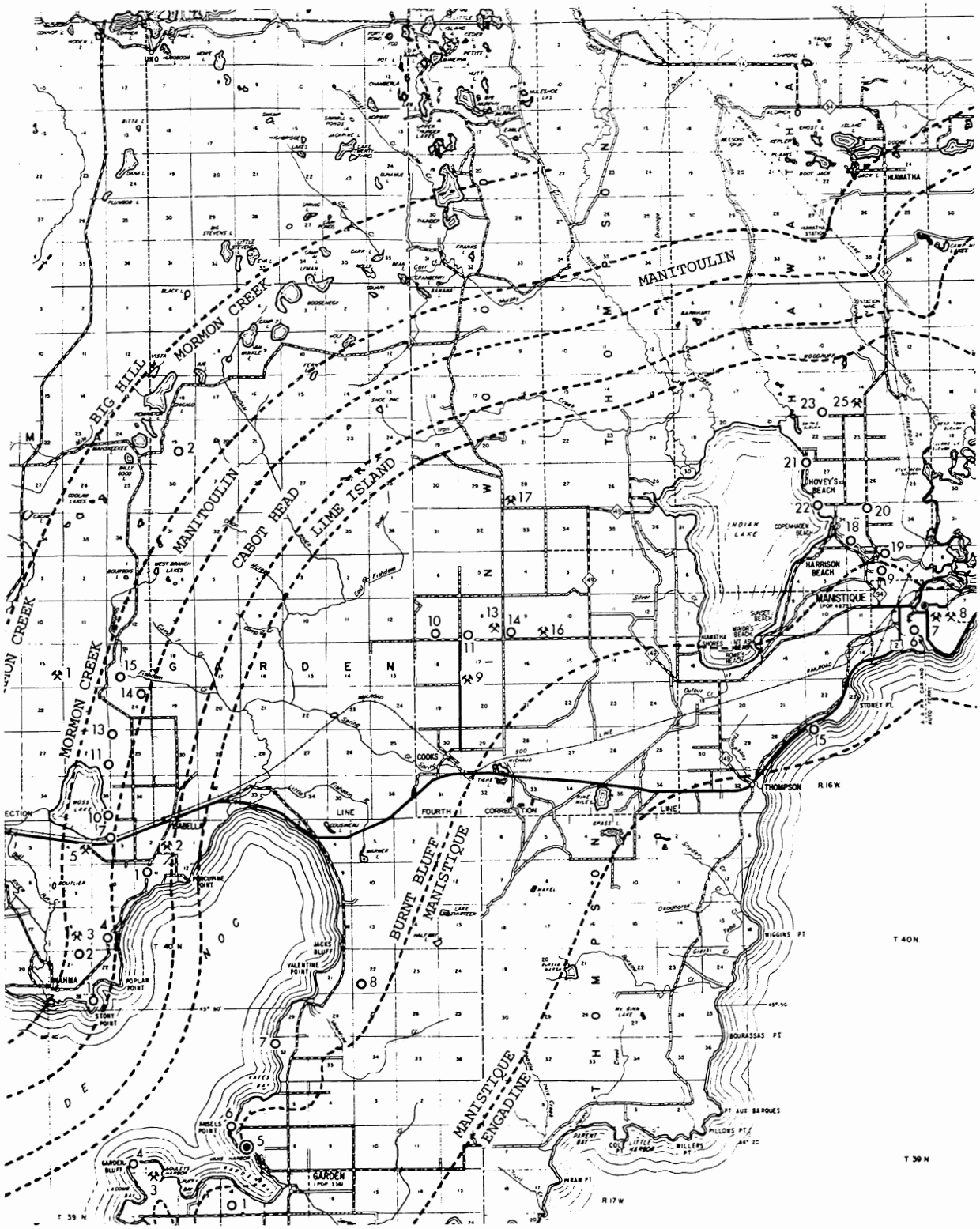

Map 1 -- Geologic map of eastern part of Delta County.

MAP 2



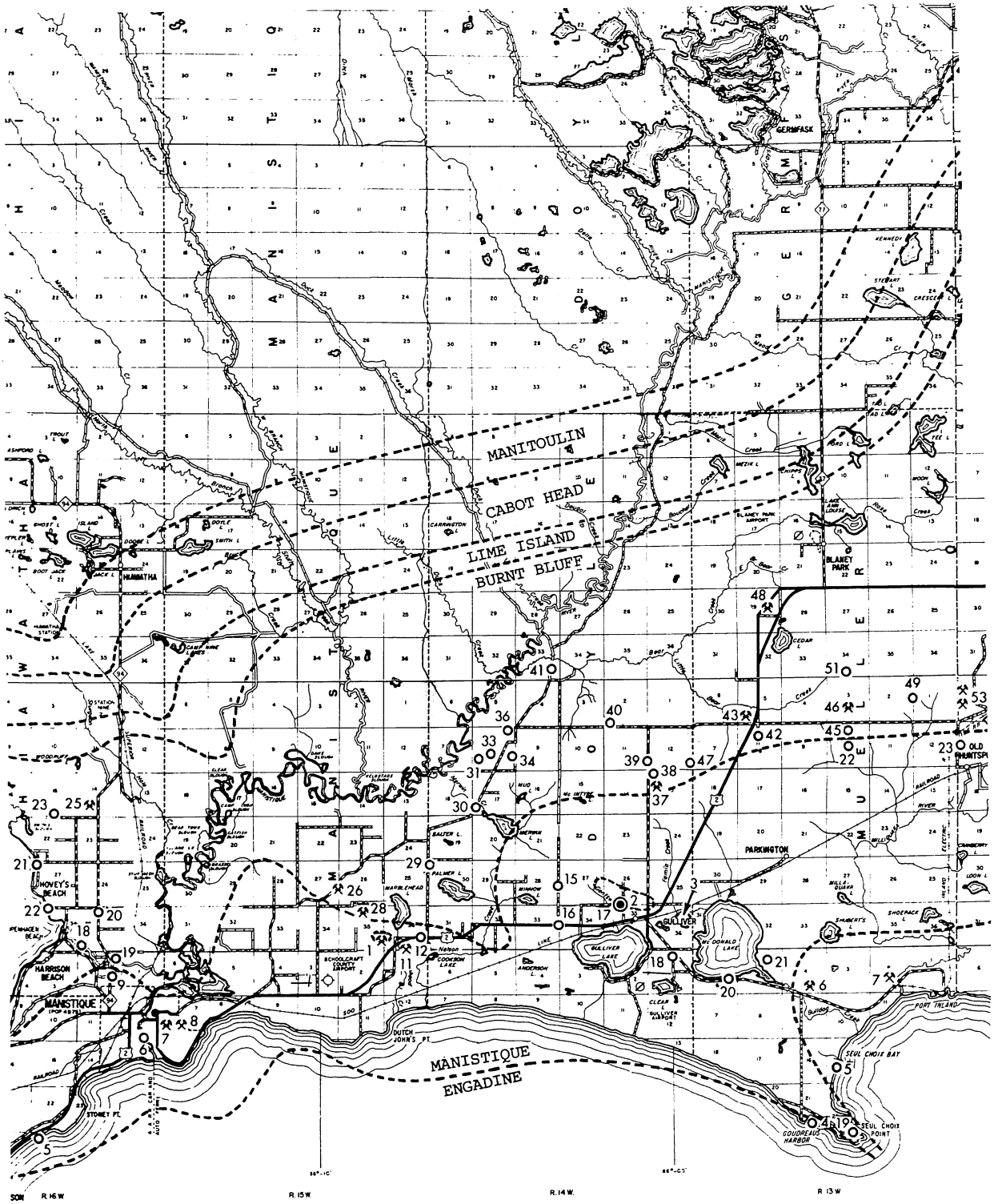

Map 2 -- Geologic map of Garden Peninsula and nearby islands, southeastern part of Delta County and southwestern margin of Schoolcraft County.

MAP 3



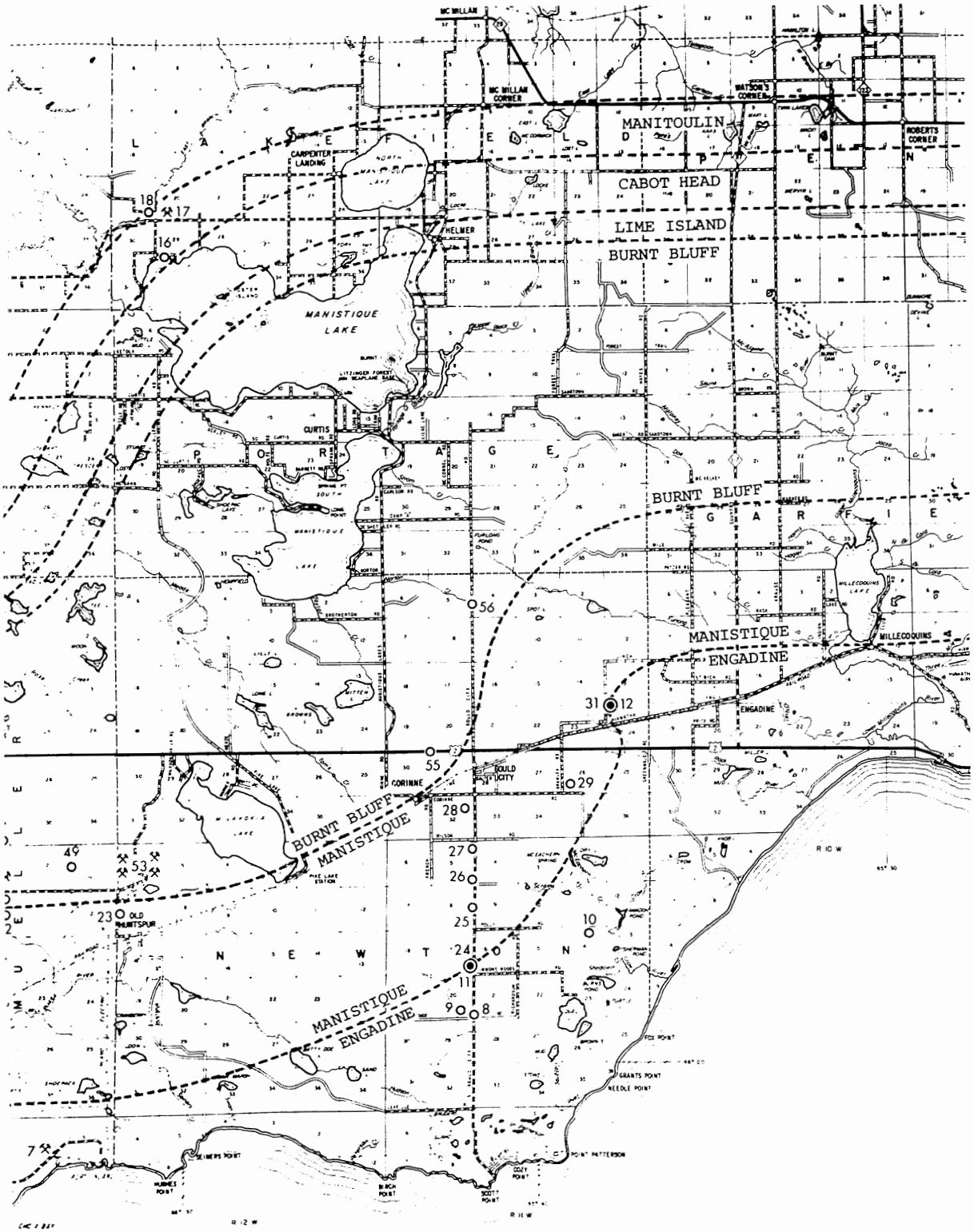

Map 3 -- Geologic map of eastern margin of Delta County and western part of Schoolcraft County.

MAP 4



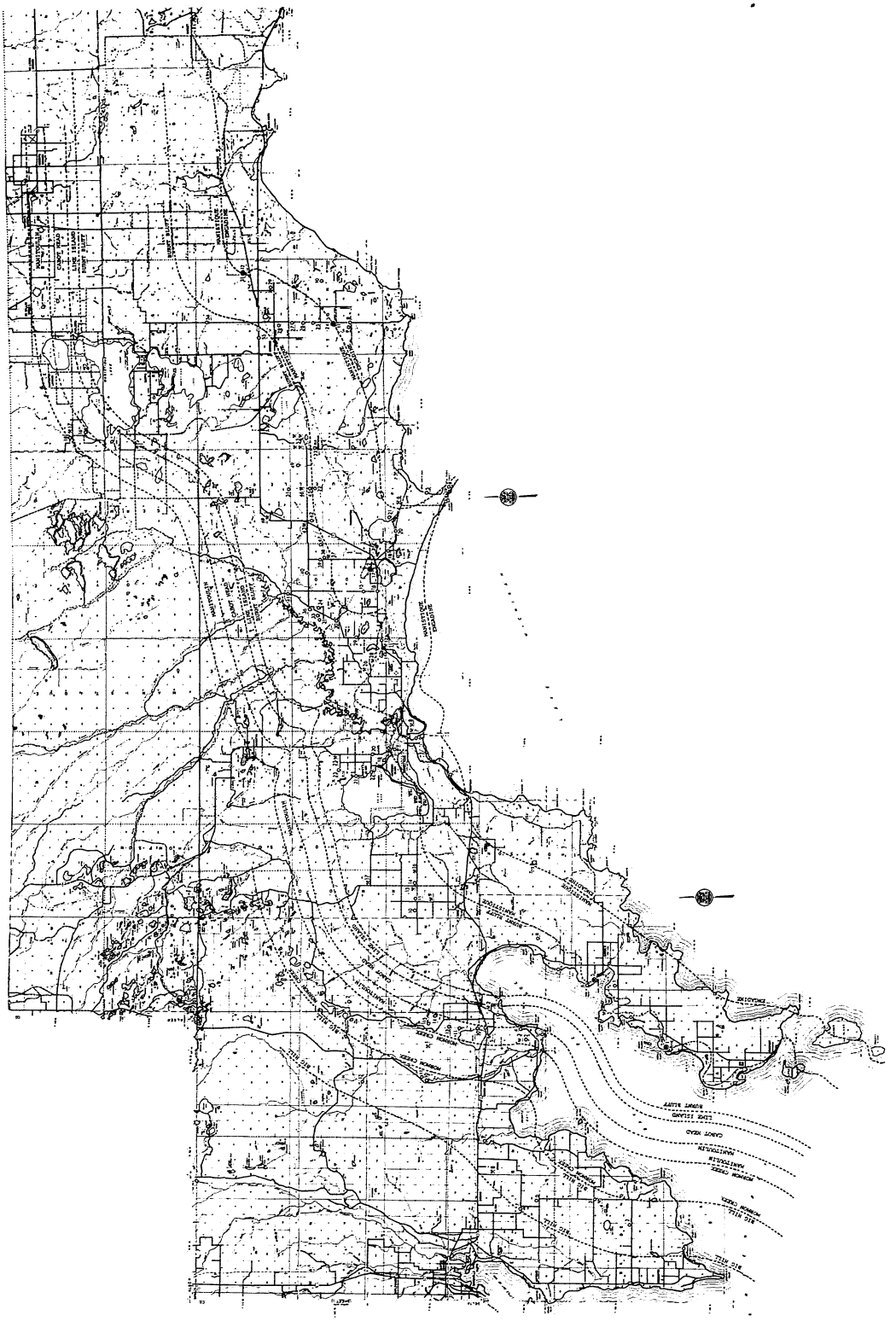

Map 4 -- Geologic map of southwestern part of Schoolcraft County, featuring the Seul Choix Point Anticline, which trends west-northwest and east-southeast through Seul Choix Point, with outliers of Engadine Dolomite at Marblehead Quarry and at Gulliver.

MAP 5




Map 5 -- Geologic map of eastern margin of Schoolcraft County, western part of Mackinac County, and southern part of Luce County.

MAP 6



Map 6 -- Geologic map of parts of Delta, Schoolcraft, Mackinac, and Luce Counties, Michigan, covering the areas shown in Maps 1-5 at expanded scale.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