STATE OF MICHIGAN
DEPARTMENT OF CONSERVATION
GEOLOGICAL SURVEY DIVISION

Publication 40. Geological Series 34.
OCCASIONAL PAPERS
ON THE
GEOLOGY OF MICHIGAN

PREPARED UNDER THE DIRECTION OF
R. A. SMITH, State Geologist

PUBLISHED AS A PART OF THE ANNUAL REPORT OF THE GEOLOGICAL SURVEY DIVISION FOR 1936.

Franklin DeKleine Company, Printers, Lithographers, Bookbinders, Lansing

Contents

Contents **1**

Illustrations **1**

Plates *1*
Tables *1*
Figures *1*

PART II. THE PENNSYLVANIAN SYSTEM OF MICHIGAN **2**

Chapter III **2**

SAGINAW GROUP **2**

NAME *2*
SOURCES OF STUDY *2*
STRATIGRAPHIC RELATIONS *2*
LITHOLOGIC AND OTHER CHARACTERS *2*
THICKNESS *3*
CORRELATION *3*
TYPE SECTION Grand Ledge, Eaton County *4*
Eaton County 4
*LOCAL DETAILS** *7*
Arenac County 7
Bay County 7
Saginaw County 9
Tuscola County 10
Genesee County 10
Shiawassee County 11
Clinton County 13
Eaton County 13
Ingham County 14
Jackson County 16
Other Counties 17

Chapter IV **17**

GRAND RIVER GROUP **17**

NAME *17*
EATON SANDSTONE 18
IONIA SANDSTONE 18
SOURCES OF STUDY *18*
STRATIGRAPHIC RELATIONS *18*
LITHOLOGIC AND OTHER CHARACTERS *18*
THICKNESS *19*
CORRELATION *19*
WOODVILLE SANDSTONE *19*
Jackson County 19
EATON SANDSTONE *19*
Eaton County 19
IONIA SANDSTONE *20*
Ionia County 20
Shiawassee County 20
Other Counties 20

STRUCTURE **21**

REGISTER OF LOCALITIES GIVEN IN FIGURE 2 AND TABLE 2 ..... **21**

REGISTER OF LOCALITIES GIVEN IN FIGURE 2 AND TABLE 3 ..... **22**

BIBLIOGRAPHY **22**

Illustrations

Plates

Plate I. *Maps of Southern Peninsula of Michigan showing the distribution of Pennsylvanian strata according to Winchell, Rominger, Lane, Allen.* ..... **Error! Bookmark not defined.**

Plate II. *Map of Pennsylvanian distribution in the Southern Peninsula of Michigan after Newcombe.* **Error! Bookmark not defined.**

Plate III. *View of the Grand Ledge coal and its associated underclay.* 3

Plate IV. *View of typical exposure of beds of the Saginaw Group near Grand Ledge.* 4

Plate V. *Conglomeratic zone at base of the Eaton sandstone* 18

Plate VI. *Shale boulder at the base of the Eaton sandstone* 20

Tables

Table 1. *Pennsylvanian nomenclature in Michigan.* ..... **Error! Bookmark not defined.**

Figures

Figure 2. *Map showing significant outcrops and mine localities of the Saginaw and Grand River Groups of Michigan* ..... **Error! Bookmark not defined.**

Figure 3. *Map of the area geology of Grand Ledge, Eaton County, and vicinity.* 5

Figure 4. *Columnar sections representing the general indication of the Verne member towards the extension of the axis of Saginaw Bay.* 6

Figure 5. *Columnar sections showing the regional dip of beds of the Saginaw Group.* 7

Figure 6. *Map showing Pennsylvanian exposures near Corunna, Shiawassee County* 12

Figure 7. *Columnar sections measured near Corunna.* 13

Figure 8. *Map showing Pennsylvanian exposures near Chester, Eaton County.* 14

Figure 9. *Map showing Pennsylvania exposures near Williamston, Ingham County.* 14

Figure 10. *Columnar sections near Williamston* 15

PART II. THE PENNSYLVANIAN SYSTEM OF MICHIGAN

by
W. A. Kelly, Ph.D.
Michigan State College

Published as a part of the Annual Report of the Michigan Geological Survey Division, Department of Conservation for 1936.

Chapter III

SAGINAW GROUP

NAME

The name Saginaw formation was originally suggested by A. C. Lane (1901), a former State Geologist of Michigan, to replace the term "Jackson" as applied to the coal series of Michigan. The name "Jackson" had in turn displaced "Coal Measures," the term by which the group was originally known.

SOURCES OF STUDY

No natural exposure exists in the Saginaw Valley, the type locality, but geologic sections exposed along the sides of numerous coal shafts furnished workers in the past with adequate information concerning the strata of the upper beds of this formation. I have had an opportunity to examine some specimens taken from mines within the "type locality" at the time the shafts were sunk, but have had to depend mainly upon outcrop localities to get an adequate conception of Pennsylvanian stratigraphy.

The chief outcrop localities of the Saginaw group are to be found near Grand Ledge, Eaton County, and these are described as a specific example to illustrate the general characters of the Saginaw rocks in Michigan.

STRATIGRAPHIC RELATIONS

The Saginaw group directly overlies the Parma sandstone wherever that formation is present. The contact between the two formations has already been referred to in the discussion of the stratigraphic relations of the Parma. The Saginaw group sometimes directly overlies the Bayport formation, as in the area immediately north of Jackson. In several localities the Saginaw may rest directly upon the Napoleon sandstone (Lane, 1909, p. 83).

LITHOLOGIC AND OTHER CHARACTERS

The Saginaw group is composed of material of fresh water, brackish water, and marine origin, and consists of sandstones, shales, coal, and limestones. It is true that the individual strata vary in character and thickness within relatively short distances, as stated by Smith (1912, p. 258), and others, but a detailed study of these variations indicates that many of them are abrupt and due to cut-offs or unconformities. This fact is cited by Smith (1912, p. 258) and an illustration of a similar condition is indicated on the areal map and sections accompanying a report on the Grand Ledge District (Kelly 1933). If proper significance is attached to the many unconformities within the Saginaw group, the apparently heterogeneous association of beds may be reduced to some order, and referred to cyclical sedimentation. The working hypothesis of cyclical sedimentation developed by Weller (1930, pp. 97-135) explains most clearly the stratigraphic succession of beds in the Grand Ledge district. The typical cyclical formation consists of a basal sandstone overlain successively by sandy shale, gray shale, underclay, coal, black shale, and limestone. Frequently the upper beds of the formation are missing and the basal beds are sandy shale rather than sandstone. The most characteristic bed, the underclay, is usually present unless the entire formation has been removed by erosion. In general the cyclical formations are incomplete, an unconformity cutting off the upper members, or even beds belonging to several different cyclical formations. The inclinations of the old surfaces affected the inclination of the beds which were later deposited above them. This is well illustrated in the Grand Ledge district where strata of the Verne cycle, directly superimposed above strata of an earlier cycle, are inclined in opposite directions. This indicates clearly that in certain places regional and local dips do not correspond.

The sandstones of the Saginaw group are frequently lenticular, and non-persistent, and possess irregular bedding. Most of the beds exposed at the surface are less than ten feet thick. In certain sections sandstone beds are of greater relative importance. Examples of such are to be noted in the vicinity of Lansing, where beds of sandstone over one hundred feet thick are reported from several wells. The texture of the sandstones is usually fine, although thin conglomeratic layers have been observed at the base of individual lentils. Red colors are not characteristic. Quartz is the principal constituent, but is associated at times with some decomposed feldspar, and usually with abundant white mica. The mica flakes are arranged with their cleavage surfaces along bedding planes. The sandstones contain less than one percent of heavy minerals. Tourmaline and zircon are the most common heavy minerals. Both well formed crystals and slightly

rounded fragments occur. Fossils in the sandstones are limited to plant fragments. These various characteristics taken together point to a terrestrial origin of the sand, in which shifting currents with rapidly alternating erosion and deposition played a major part.

The shales of the Saginaw fall roughly into three groups: (a) Shales with considerable sandy material, and (b) shales with little or no sandy material, and (c) underclays. The sandy shales possess many characteristics in common with the sandstones, and examples exist where a cursory examination might readily class a given bed as a sandy shale at one time, and a shaly sandstone at another time. Plant fossils are often found in these shales, fern-like fronds, isolated pinnules, and stem fragments being the most common. Like the sandstones, these shales probably had a terrestrial origin.

The shales of the second group are ordinarily dark in color. They may, or may not, be limy. The limy shales are regularly bedded and judging from fossil evidence are closely allied in origin to the shaly limestones. The non-limy shales vary in structure from very fissile to almost structureless layers up to three feet or more in thickness. The structureless beds frequently contain nodular masses, the boundaries of which are slickensided. The center of a nodular mass often contains a plant fragment, and it is thought that the local slickenside resulted as the mud about the plant compacted. The common fossils of the structureless shales are the brachiopod *Lingula*, and foraminifera including *Glomospira*, *Trochammina*, and *Hyperammina*. The fissile and other stratified shales are non-fossiliferous, or else contain macerated shells of the pelecypod *Anthracomya*. It is probable that the "Lingula" shales accumulated in quiet areas of marine or brackish water. In the Grand Ledge district Anthracomya beds succeed plant bearing shales and are followed by beds containing a normal marine fauna suggesting a stage in progressive submergence.

Shales of the third group, the underclays, are structureless, white to light gray beds of claylike or sandy texture. They commonly contain irregular nodules of iron carbonate a few feet from the top, and are often below coal seams.

The coal beds of Michigan are ordinarily thin. Little opportunity is afforded to trace the beds over great distances. Evidence exists, and has been cited in the discussion of the sandstones, that coal beds are frequently cut off by unconformities within the Saginaw group itself. It is highly probable, therefore, that individual coal beds originally had a greater lateral extent than they now possess. This viewpoint is supported by the relatively great extent over which the 18-inch coal seam of cycle 15 has been traced in the Grand Ledge area. (Pl. III). Bartlett (1927) has subjected some of the coals to a macerating process and has found identifiable spore cases in a few samples. The discovery is of value since it may provide a method for the correlation of coal seams.

The Pennsylvanian limestones of Michigan are impure, since they contain a high percentage of shaly consituents. They have been reported from the mines of the Saginaw valley and from Grand Ledge. The beds are thin and exhibit intergradations with black limy shales. In places where the top of the limestone is cut by an unconformity and is directly overlain by sandstone, a pronounced cone-in-cone structure is developed, seeming to indicate a relationship between such a structure and the circulation of ground water. Most of the limestones and limy shales are fossiliferous, and contain invertebrate fossils in greater abundance than other Pennsylvanian formations. Isolated fragments of plant stems are also found. Pyrite frequently replaces the shell material and, together with the abundant shaly material, suggests an origin for these beds in some partially land-locked embayment having poor vertical circulation.

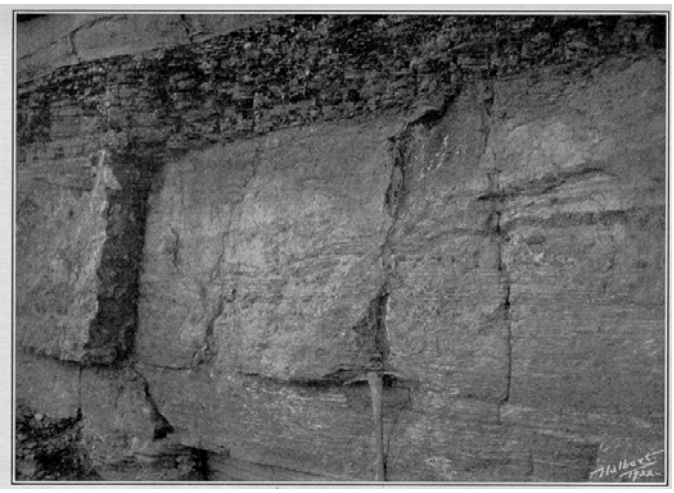

Plate III. View of the Grand Ledge coal and its associated underclays. The pick shown is about 17 inches long. The nodular zone is about midway between the pick and the coal.

THICKNESS

The average thickness given for the Saginaw group is 400 feet, and the maximum reported is 535 feet (Newcombe, 1928, p. 156). The formation is extremely variable since pre-glacial and rarely post-glacial erosion removed a considerable part of the upper beds. Apparent variations are also due to the difficulty in drawing the boundary between the Parma and the Saginaw, and the Saginaw and the overlying sandstones of the Grand River Group.

CORRELATION

The Pennsylvanian age of the shales, sandstones, and associated coal seams underlying the central part of the Southern Peninsula of Michigan was recognized as early as 1838 by Douglass Houghton (1838) who referred the strata to the Coal Measures.

About 1900 David White, after examining plant fossils collected from several mines within the State, compared the flora to the Pottsville group of West Virginia,

Pennsylvania, and Ohio (Lane, 1902, footnote to p. 44). Recent work by Arnold (1933) has led him to the conclusion that the Michigan Pennsylvanian agrees in age with the Yorkian of Great Britain. The Yorkian corresponds approximately with Middle Pennsylvanian, thus making the Michigan floras late Pottsville or early Alleghany.

The invertebrate fossils (Table 3) from the Saginaw group are confined to relatively few strata. Early determinations were made by Dr. G. H. Girty, who has since kindly lent me material collected from mines which are now abandoned. A complete list of all fossils determined to date is now on file in the Michigan Geological Survey. (Tables 2 and 3). The evidences regarding the age of the Saginaw group has already been summed up in an earlier paper (Kelly, 1930, p. 135). The conclusion reached at the time, that the invertebrate fossils indicated a Lower Pennsylvanian age, has been confirmed by later work.

A study of the fossil list (Tables 2 and 3) indicates that most of the fossils came from the limestone member outcropping in the vicinity of Grand Ledge. It is significant that many of the forms collected there are also found in the limestone overlying Lane's Lower Verne coal and that in any locality in Michigan similar faunas are known to occur only in one stratum, a limestone or calcareous shale member. The persistence of thin beds in other regions has been noted (Weller, 1930, p. 107) and it is probable, therefore, that the marine member of the Verne cyclical formation may also be persistent. On the evidence submitted above I make a tentative correlation of all the fossiliferous and calcareous shales, and have revived the term Verne to designate them. The embayment in which the Verne marine member was deposited originally extended from at least the vicinity of Bay City south-westward in a direction approximating the long axis of Saginaw Bay. The extension of the embayment outside the State of Michigan was towards Indiana, Illinois, and Iowa rather than towards Ohio.

Fossiliferous marine strata, other than the Verne are known. These are the so-called "Lingula" shales. Three of these Lingula shales underlie the Verne at Grand Ledge, another Lingula shale has been reported above the Verne limestone member (Lane, 1902, p. 43, and Cooper, 1906, p. 185). Of far more significance than the brachiopod Lingula are the foraminifera which have been found in some of these shales (Cushman, J. A. and Waters, J. A., 1927, pp. 107-10). Considered with the cyclical repetition of beds, and the lithologic characters of the underclays, the presence of these fossiliferous members have proved of distinct value in working out the stratigraphic succession in the Grand Ledge district, and should prove serviceable in other areas.

TYPE SECTION Grand Ledge, Eaton County

Eaton County—The outcrops exposed in the vicinity of Grand Ledge (Fig. 3) are the most extensive of the Pennsylvanian exposures within the State. Excluding the capping Eaton sandstone, which is assigned to the Grand River group, the strata have an estimated thickness of about 90 feet. The different parts of the section with their overlapping units may be observed along the bluffs of the Grand River (PI. Ill, PI. IV) and two small tributaries, and also in the shale pits operated by the American Vitrified Company, the Grand Ledge Clay Products Company, and the Grand Ledge Face Brick Company. The district is in the northwest part of T. 4 N., R. 5 W. The stratigraphy is described in detail elsewhere (Kelly, 1935).

The Grand Ledge district illustrates the difficulties which are encountered in tracing any bed from one locality to another. It is probably typical of many other areas in Michigan, and since these do not possess the extensive exposures of Grand Ledge, they may present insurmountable correlation problems unless a program of shallow drilling or careful examination of the beds exposed in shafts and drifts is undertaken.

Plate IV. View of typical exposure of beds of the Saginaw Group near Grand Ledge, Michigan. Cyclical formations B and D are exposed, formation C being replaced by D. The coal seam is the “Grand Ledge” seam shown on Plate III.

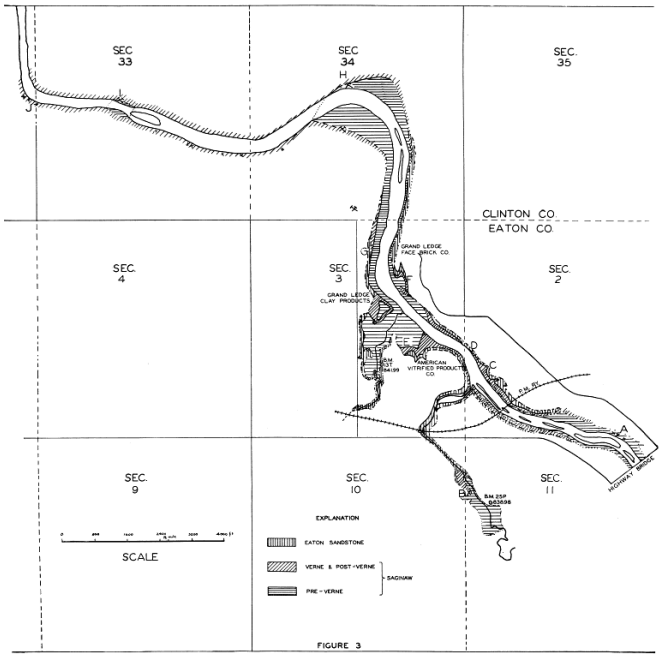

FIGURE 3

Figure 3. Map of the area geology of Grand Ledge, Eaton County, and vicinity.

A composite section of the Grand Ledge district is given below in order to illustrate the types of rocks, their thickness, and the number of repetitions which occur in one part of the coal measures.

Cyclical Formation	*Description*	*Average Thickness*
Overlying bed	Eaton Sandstone of the Grand River Group	
G	Buff-colored, cross-bedded micaceous shales, containing numerous remains of *Cordaites*. Beds of this formation found in scattered localities in what appear to be channels excavated in the underlying formations.	15 feet
F	White to light gray, medium grained micaceous sandstone lentil, shales and underclay of irregular thickness, followed by coal and carbonaceous shale with third *Lingula*. On the north side of the river the formation is represented by plant bearing shales, and *Anthracomya* shale member, and an argillaceous limestone containing a Verne fauna. This formation is imperfectly represented usually, although of wide distribution. Two cycles may also be represented.	15 feet
E	Sandstone lentil and sandy shale passing into white plastic underclay, sometimes overlain by coal seam. Capping bed a black highly plastic shale containing *Lingula carbonaria* and the foraminifera, *Psammophis* sp. and *Lituotuba* sp., and also characterized by elliptical nodules. The "*Lingula*" bed of this cyclical formation observed only on south side of the Grand River.	10 feet
D	Sandstone lentils, hard sandy underclay weathering dark gray, followed by friable nodular sandy underclay overlain by thin coal seam followed by shale member containing *Anthracomya*. Formation imperfectly represented in single sections.	5 feet
C	Gray to white, structureless soft underclay followed by thin coal seam. This cyclical formation recognized for certain only in the quarry of the Grand Ledge Face Brick Company.	5 feet

B	Irregularly laminated sandy shales followed by thick, sandy underclay containing abundant irregular iron-stained, non-calcareous nodules. Persistent coal seam, the Grand Ledge seam, about one and one-half feet thick at the top. This formation is remarkably uniform in thickness, and has been observed over the western part of the area.	12 feet
A	Non-micaceous sandstone overlain by sandy shales, a thin underclay, and shales with plant bearing, clay-ironstone nodules, capped by a black, highly plastic shale containing *Lingula carbonaria* and the foraminifera, *Glomospira pusilla* and *Ammobaculities compressa*. Area underlain by this cyclical formation co-extensive with strata of formation B.	5 feet

Strata thought to be older than any seen in the quarry sections, occur as isolated outcrops just west of the traffic bridge at Grand Ledge. At least two cyclical formations may be observed at the crest of a low anticlinal structure (Fig. 7, column E). The sandstone at the top of the section is similar in appearance and lithology to a sandstone occurring below the lower Lingula bed (Kelly, 1933, p. 80).

Only three of the cyclical formations, A, E, and F are known to have ended with a marine invasion and three of them, B, E, and F have coal seams which locally, at least, are a foot thick. A list of 58 species of fossils, comparatively few of which are common, has been collected from the limestone of cycle F, from which it has been possible to make comparisons with some of the local fossil-bearing beds found in the mine shafts of Shiawassee, Saginaw, and Bay counties.

Ammodiscus annularis (H.B.B.)
Turritellella spirans C. & W.
Endothyra bowmanni (P.)
Lophophyllum profundum (M.E. and H.)
Delocrinus sp.
Crinoid columns
Liopora sp.
Polypora sp.
Septopora biserialis var. gracilis (M.)
Rhombopora sp.
Streblotrypa sp.
Lingula carbonaria S.
Trigonoglossa nebrascensis (M)
Orbiculoidea capuliformis (McC.)
Orbiculoidea missouriensis (S.)
Crania modesta W. & St. J.
Schizophoria resupinoides (C.)
Derbya aff. bennetti H. & C.
D. crassa (M. & W.)
Chonetes granulifer O.
Juresania nebrascensis (O.)
Juresania saginawensis (K.)
Dictyoclostus morrowensis (M.)
D. smithi (K.)
Marginifera missouriensis (G.)
Linoproductus prattenianus (N. & P.)
Spirifer occidentalis G.
Neospirifer cameratus (M.)
Punctospirifer kentuckyensis (S.)
Composita subtilita (H.)
Edmondia sp.
Pleurophorus sp.
Astartella compacta G.
Astartella sp.
Crenipecten foerstii H.
Myalina pernaformis C.
Myalina sp.
Anthracomya sp.
Capulus sp.
Igoceras sp.
Worthenia tabulata (C.)
Trepospira illinoisensis (W.)
Pleurotomaria carbonaria N. & P.
Pharkidonotus percarinatus (C.)
Macrochilina cf. regularis (C.)
M. cf. primigenius (C.)
M. sp.
Schizostoma catilloides (C.)
Naticopsis sp. a.
Naticopsis sp. b.
Conularia sp.
Orthoceras sp.
Pseudorthoceras knoxense (MeC.)
Temnocheilus sp.
Griffithides sp.
Paraparchites sp.
Amphissites sp.
Fish spines

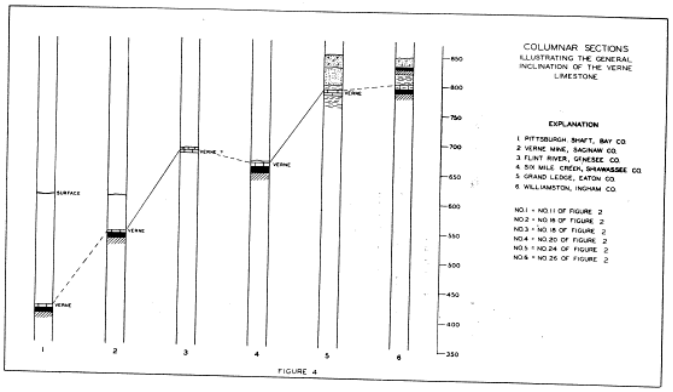

Figure 4. Columnar sections representing the general indication of the Verne member towards the extension of the axis of Saginaw Bay.

The most significant features of the stratigraphy of the district are the many breaks in sedimentation. The unconformities which end the first four cycles are of

comparatively little importance since the stratigraphic interval does not change greatly. Erosion, however, at the end of the fifth cycle of sedimentation was more profound, and more in the nature of channeling, since the beds of several cycles are sometimes cut out within a short distance. The inclination of the unconformity at the base of the sixth cyclical formation is as much as 15° to the east in the quarry of the American Vitrified Products Company and the inclination of the beds belonging to the sixth or Verne cyclical formation, accord with this dip quite closely, and thus depart considerably from the more gentle inclinations of the pre-Verne beds. In the quarry of the Grand Ledge Face Brick Company, the inclination of beds belonging to cycles A, B, C is to the east, whereas inclination of the Verne cyclical formation is strongly to the west. This illustrates the dependence of inclinations upon topography developed during pauses in sedimentation. The comparatively deep erosion of the pre-Verne cyclical formations may point to structural control, but this is an open question and would require the tracing of one of the old channels to discount or lend support to the theory. The general elevation of the Verne is in the neighborhood of 800 feet, considerably higher than in Saginaw and Bay counties. (Fig. 4, column 5).

The beds of the Verne cyclical formation are themselves overlain un-conformably by strongly cross-bedded shales which have a patchy distribution. Wherever the shales are missing beds of the Verne or earlier cycles are sharply separated from overlying sandstones of the Eaton, or from glacial drift by an erosional unconformity.

Individual beds when traced downstream from Grand Ledge show that although there are minor undulations in the strata, there is evidence that the beds have a regional dip to the northwest. Thus beds which occur at an elevation of about 780 feet at Johnston's Mine (point H on Fig. 3, and column H on Fig. 5) must have had an elevation of about 840 feet at the upper part of Sandstone Creek (point B on Fig. 3, and column B on Fig. 5). The strike of the beds, as calculated from elevations on marker horizons and the contouring of the Grand Ledge coal (cyclical formation B), is approximately northeast, and the regional dip must be in the neighborhood of one half of a degree.

LOCAL DETAILS*

Arenac County—The geology of Arenac County was reported upon by Rominger (1876, pp. 141-144) and Gregory (1902 and 1912). Pennsylvanian outcrops are almost entirely limited to sandstone, although some idea of the lithology of associated rocks may be gained from the examination of abandoned mine dumps and quarries.

Several outcrops of sandstone are in the bed of Rifle River, in the vicinity of Omer. The outcrops are described in the report by Gregory (1912, p. 37-39), who draws attention to the fact that they resemble the Parma. They are all clean white sandstones of medium grain and contain some zircon and tourmaline. A similar sandstone outcrops in a drainage ditch south of Rifle River in section 22, T. 19 N., R. 5 E. Aside from the fact that these sandstones are near the Mississippian-Pennsylvanian boundary, and are comparatively clean, there is little reason for correlating them with the Parma whose type locality is over 100 miles distant, and which has never been certainly traced across the greater part of this broad interval.

Mine and quarry sites along the Rifle River and above Omer were also visited. In all cases, the mines and quarries were filled with water, but the shale and sandstone samples collected from the dumps were more characteristic of the Saginaw group than the rocks outcropping below Omer.

Rominger (1876, p. 142) mentions the occurrence of a small Lingula which may be *L. tigti*, but this brachiopod is not a good guide fossil. No other information was obtained which would allow one to make definite correlation of the beds in Arenac County with a standard section such as that in the vicinity of Grand Ledge.

Outcrops of thinly bedded, medium grained, white sandstone are also in the bed of Pine River, north of Standish in section 35, T. 19 N., R. 4 E. This is a clean sandstone with a small amount of heavy mineral, the most common being zircon. It does not resemble a typical sandstone of the Saginaw group, but is more like the sandstones of the Parma. A correlation on general resemblances alone seems hazardous, and the beds are referred to the Saginaw, which we definitely know extends to this area.

*Descriptions of exposures proceed from the northern counties southward.

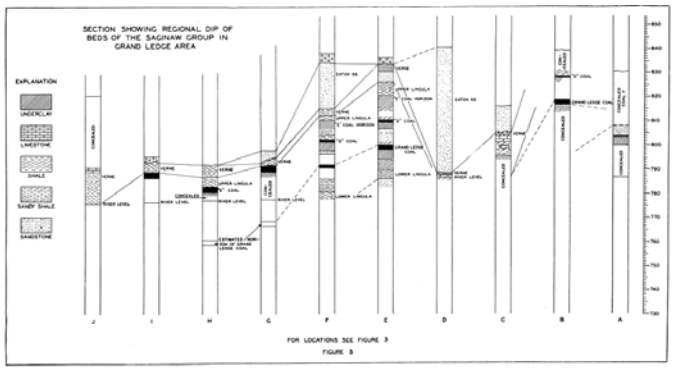

Figure 5. Columnar sections showing the regional dip of beds of the Saginaw Group.

Bay County—Although no outcrops are known in this county, some of the specimens collected from the old mines were deposited in the Museum of Paleontology of the University of Michigan and made available for study. Determinations of their fossil contents were made and are given below.

The localities are listed as from north to south and west to east in order that any relationship between the strata and the faunas found in the mine sections may be more apparent.

WENONA BEACH MINE, SECTION 33 OR 34, T. 15 N., R. 5 E.

This locality is represented by a fauna consisting of eleven species, determinations of which follow:

Lingula carbonaria S.
L. sp.
Orbiculoidea sp.
Chonetes granulifer O.
Chonetina flemingi (N. & P.)
Dictyoclostus smithi (K).
Juresiania saginawensis (K).
Pleurophorus oblongus M.
Plagiostoma? acosta (C).
Trepospira illinoisensis (W).
Pseudorthoceras knoxense (McC)

The collection above was lent to me by Dr. G. H. Girty. The brachiopod *Lingula* is in a black, carbonaceous shale; the remainder of the fauna is in a calcareous shale. Lane (1902, p. 42) mentioned the "*Lingula*" fauna from the Wenona Mine, but does not mention the other forms. Some mixing of specimens may have occurred, and the fauna above may include specimens from the Michigan mine, Bay County, which were sent to Dr. Girty for identification.

LOCALITY 18978. WOLVERINE MINE NO. 3, SE. CORNER NE. QUARTER, SECTION 12, T. 14 N, R. 3 E.

I did not see any samples from this locality. A small flora is reported from the mine, however:

Lepididendron aculeatum Sternb.
Lepidostrobus variabilis.
Neuropteris desorii group Lx.

The determinations are by David White, (Lane, 1908, p. 19.)

LOCALITY 18999. UNITED CITY COAL MINE. SECTION 17, T. 14 N., R. 5. E.

This locality is a little over one mile southwest of the Wenona Beach Mine. Abundant specimens of *Lingula carbonaria* associated with a small ovate Lingula occur in a black compact shale. The collector and horizon are not given on the label accompanying the specimens.

LOCALITY 18993. MONITOR SHAFT. SW. CORNER, SE. QUARTER, SECTION 28, T. 14 N., R. 4 E.

This locality is about two miles southwest of locality 18999. It is represented by four species, which are listed below:

Lingula carbonaria S
Juresania saginawensis (K.)
Linoproductus prattenianus (N. & P.)
Naiadites ohioense (M.)

The material was collected by W. F. Cooper who states that it came from above the "Upper Verne" coal. Two distinct types of rock are represented, however. One of the types is a black, compact shale containing abundant specimens of Lingula, and also a pyritous nodule in which a small pelecypod resembling Naiadites ohioense is present. The other type is a black, slightly calcareous shale containing the two Productidae, *Juresania* and *Linoproductus*. It is believed that two horizons are indicated here, and that the slightly calcareous shale represents the Verne horizon.

A small collection of fossils obtained about one and one-half miles east of locality No. 18993 was lent to me by Dr. Girty. The exact locality given is:

MICHIGAN STANDARD COAL AND MINING CO., SECTION 25, T. 14 N., R. 4 E.

Chonetes granulifer O.
Dictyoclostus smithi (K.)
Linoproductus prattenianus (N. & P.)

The matrix is a black, calcareous shale. The horizon is probably the Verne.

CENTRAL COAL AND MINING CO., SECTION 30, T. 14 N., R. 5 E.

This locality is a short distance east of the Michigan Standard Mine. It contains specimens of *Lingula carbonaria* and a small ovate *Lingula*, like that occurring at the Wenona Beach Mine about six miles to the northeast. The collection was lent to me by Dr. G. H. Girty.

LOCALITY 18994. CENTRAL MINE SHAFT. SE CORNER, SE QUARTER, SECTION 25, T. 14 N., R. 4 E.

Abundant specimens of *Lingula carbonaria* occur in a black, brittle, carbonaceous shale, identical with the *Lingula* shale of the locality given above. The collector, W. F. Cooper, states that it came from the "Upper Verne" coal.

LOCALITY 18995-6. MICHIGAN COAL AND MINING CO., SE QUARTER, SECTION 25, T. 14 N., R. 4 E.

Lingula carbonaria S.
Dictyoclostus smithi (K.)
Marginifera missouriensis (G.)
Neospirifer cameratus (M.)
Composita subtilita (H.)

The fossils with the exception of the *Lingula*, are in a black, compact highly argillaceous limestone, No. 18995, which strongly resembles the Verne limestone member from the Verne Mine in Saginaw County. Cooper, the collector, states that it came from above the "Lower Verne" coal. The *Lingula* shale, numbered 18996, is like the Lingula shales from the Wenona Beach and Monitor mines. Cooper states that it comes from above the "Upper Verne" coal, that is stratigraphically higher than the other fossils from the same mine.

Localities 18995 and 18996 are possibly from one mine, the numbers indicating different horizons. Like locality 18994, they are very close to the Michigan Standard Mine.

A collection from a locality about one mile south of the Monitor Shaft, or about one and one-half miles southwest of the Michigan Coal and Mining Company shaft, contains the fossils listed below. The locality given on the label is:

LOCALITY 18998. BAY COAL SHAFT NO. 2, SE QUARTER, SECTION 4, T. 13 N., R. 4 E.

Calamites sp.
Derbya crassa (M.&W.)
Dictyoclostus morrowensis (M.)
Linoproductus prattenianus (N.&P.)
Neospirifer cameratus (M.)

The fossils are in a black, carbonaceous and slightly calcareous shale similar to the shales from the Monitor, Michigan Standard and Michigan Coal and Mining shafts. Cooper's label states the name of the rock to be the "Lingula black shale." However, I found no specimen of *Lingula* and the horizon very probably represents the Verne.

LOCALITY 18992. VALLEY COAL MINING COMPANY, SE CORNER, NE QUARTER SECTION 1, T.13 N., R. 4 E.

This locality is about one and one-half miles east of the last. The fauna present is listed below:

Rhombopora sp. undt.
Lingula carbonaria S.
Derbya crassa (M.&W.)
Juresania saginawensis (K.)
Dictyoclostus morrowensis (M.)
D. smithi (K.)
Spirifer occidentalis G.
Punctospirifer kentuckyensis (S).
Rhadianichthys sp.

The fossils were collected by W. F. Cooper, who states that the horizon of the cap rock is the "Upper Verne" coal. However, the specimens in the collection of the Museum of Paleontology of the University of Michigan show two different kinds of rock similar to those observed in specimens from the Michigan Coal and Mining Company shaft, about one mile to the north. One type, the black, brittle carbonaceous shale contains only specimens of *Lingula carbonaria*. The other, a black, slightly calcareous shale, contains the more varied Verne fauna.

LOCALITY 18997. PITTSBURGH SHAFT, QUARTER LINE, SECTION 15, T. 13 N., R. 4 E.

This locality is about one mile southwest of the last. The flora and fauna follow:

Cordaites sp. undt.
Rhombopora sp. undt.
Orbiculoidea capuliformis (McC.)
O. missouriensis (S.)
Derbya crassa (M. & W.)
Chonetes granulifer O.
Dictyoclostus morrowensis (M.)
D. smithi (K.)
D. sp. undt.
Marginifera missouriensis (G.)
Linoproductus prattenianus (N.&P.)
Punctospirifer kentuckyensis (S.)

The fossils are in a black carbonaceous and slightly calcareous shale, similar to the shales from other localities in neighboring sections identified as the Verne. W. F. Cooper states on the accompanying label that the fossils were collected from the cap rock of the "Lower Verne" coal, 200 feet below the surface. The United States Geological Survey Bay City quadrangle gives an elevation varying from 600 to 610 feet above sea level for section 28. This would give an elevation between 400 and 410 feet above sea level for the Verne horizon (Figure 4, column 1).

In addition to the faunal lists which have been tabulated one other is given by Lane (1902, p. 42) from the Michigan mine. The exact locality of this mine is not stated, but it is probably near St. Charles. The identifications are by Girty and are reproduced here for the sake of reference. The probable present day synonomy is given in the right-hand column and occurrences are listed under these names in the complete faunal list. (Table 3, column 12). The choice of synonyms has been guided largely by common Michigan forms. Where reasonable doubt exists in my choice of synonyms the occurrence is listed as questionable:

Lingula mytiloides	Lingula carbonaria S.
Chonetes flemingi	Chonetes granulifer O.
Productus prattenianus	Linoproductus prattenianus (N.&P.)
P. (Marginifera) muricatus	Marginifera missouriensis (G.)
Avicula acosta	Plagiostoma? acosta (C.)
Pleurophorus oblongus	Pleurophorus oblongus M.
Nucula ventricosa	Nuculopsis ventricosa (H.)
Trepospira sphaerulata	Trepospira illinoisensis (W.)
Orthoceras rusheuse	Pseudorthoceras knoxense (McC.)
Large nautiloid	Metacoceras cornutum G.
Fish bone	Fish bone

Excepting the specimens from the Pittsburg Shaft in section 15, T. 13 N., R. 4 E., no data bearing on the elevation of the Verne member may be obtained from labels. However, an average elevation of 440 feet above sea level is given for the "Lower Verne" coal (Cooper, 1905, p. 184) which is just below the Verne member. We cannot be sure that the "Lower Verne" coal was always correctly identified, but if Cooper's statement has any value the Verne cyclical formation in Bay County is definitely lower than the same member in counties to the south.

Saginaw County—Many mines were formerly operated in this county, but partial records obtained when the shaft was opened are preserved only from two. Small

collections have also been obtained from a few of the mines which are still operating.

UNCLE HENRY MINE NO. 2, SECTION 6, T. 12 N., R. 6 E.

This mine is about seven miles northeast of Saginaw and is one of those being operated under normal conditions today. A collection of fossils was made from the material thrown out on the dump. Among the invertebrates were macerated specimens of large *Anthracomyas* similar to some collected from Williamston (see ante under Ingham County). The stratum from which they came is not known.

LOCALITY 18989. STANDARD MINE, SECTION 6, T. 11 N., R. 5 E.

The Standard mine is about ten miles south of the Pittsburgh mine. A calcareous shale sample showed the presence of *Marginifera muricatina* D. and C. Preservation was poor and the identification is open to question. As they are preserved, however, the fossils look more like *M. muricatina* than *M. missourensis* (Girty), the more common species in Michigan.

From the Somers Mine No. 1 near St. Charles, a black compact, carbonaceous shale yielded fish fragments. These, according to Dr. E. C. Case of the University of Michigan, should be compared with species of the genera *Rhadianicthys* and *Onychodus*.

LOCALITY 18983. VERNE MINE, SECTION 23, T. 10 N., R. 4 E.

This locality is about nine miles south of the Standard Mine. Its fauna includes:

Orbiculoidea capuliformis (McC.)
O. missouriensis (S.)
Chonetes granulifer O.
Chonetina flemingi (N.&P.)
Juresania saginawensis (K.)
Dictyoclostus morrowensis (M.)
D. smithi (K.)
Marginifera muricatina (D.&C.)
M. missouriensis (G.)
Linoproductus prattenianus (N.&P.)
Pseudorthoceras knoxense (McC.)

In addition to the above Girty (Lane, 1902, p. 42) lists *Soleniscus sp*. The small collection contains the important elements of the larger fauna from Grand Ledge. The rock in which the fossils are preserved is a black, highly argillaceous limestone very similar to limestones which are about 20 miles northward in Bay County, and at Grand Ledge, about 60 miles southwest. The mine forms the type locality for the Verne cyclical formation which includes a marine member which I believe has a persistent though interrupted extension from Bay County to Eaton County.

The label accompanying the Verne mine specimens states that they were secured at a depth of 58 feet. Since the general elevation of the area, as determined from a topographic map, is from 590 to 605 feet above sea level this depth places the Verne limestone at an elevation of 530 to 545 feet. However, the elevations of the coal bed beneath, according to Lane, (1902, pp. 175-191) indicates an elevation nearer 500 feet. In general, one might say that the Verne limestone, at least in the southern part of Saginaw County, is at a higher elevation than it is in Bay County (Figure 4, column 2.)

Tuscola County—A small exposure of shale occurs on the left bank of Cass River about one-half mile below the bridge at Tuscola in section 29, T. 11 N., R. 7 E. This is evidently the outcrop referred to by Winchell (1861, p. 120) since the Cass River does not flow in the location which he gives, namely section 29, T. 11 N., R. 9 E.

The outcrop consists of slumped shale from which a few foraminifera referred to *Ammodiscus* were obtained. Winchell also reports a *Lingula* from this locality.

Beyond suggesting the former eastern extent of the Pennsylvanian sea, this outcrop tells very little. The species of *Ammodiscus* is not identical with that occurring in the shales immediately above the Verne limestone at Grand Ledge.

Genesee County—Two outcrop localities were visited in Genesee County, one north, and the second east of the town of Flushing.

The outcrop north of Flushing is on the right bank of the river, near the center of section 22, T. 8 N., R. 5 E. The beds are exposed in a shale pit formerly worked by the Saginaw Clay Manufacturing Company. At the time of my visit the pit was filled with water. Samples were collected below the tipple on the west side of the river, and were later examined. The brackish water pelecypod, *Anthmcomya* sp. A, was found in very thinly-bedded brittle dark gray shales. A fragment of the brachiopod *Trigonoglossa* was also found in some of the shale. According to the section given by Ries (1900, p. 30) these shales are near the top, overlying a so-called fire-clay and separated from the fire-clay by a seam of coal.

A cycle of sedimentation is again illustrated here, but occurring as it does in an essentially isolated position, it seems impossible to definitely fit it into either the upper or the lower part of the Saginaw group.

The eastern outcrop is located along the banks of a small creek which joins the Flint River in the northwest quarter of section 36, T. 8 N., R. 5 E. The exposures can be observed in the bed and banks of a creek for a distance of about 900 feet. They consist entirely of sandstones having a total thickness of about five feet. The upper sandstones are thinly-bedded medium grained sandstones with abundant mica along the bedding planes. Scattered clay gallen were found in some of the layers. The lower sandstones are strongly cross-bedded, the dip of cross-bedding being about five degrees westward. Like the sandstones above, the lower sandstones also contain considerable mica.

Winchell (1861, p. 118) describes a section exposed along the Flint River in section 24, T. 8 N., R. 5 E., just

north of the section line and north of the exposures described in the preceding paragraph. The locality is about 15 miles southeast of the old Verne mine. Winchell's section follows:

Superficial materials	4 feet
Black shale, containing *Lingula*, *Chonetes Smithii*, *Productus asperus* and *Spirifer cameratus*	3 feet
Sandstone tinged with iron	0 feet 7 inches
Shale	1 foot
Sandstone	0 feet 3 inches
Shale	4 feet
Sandstone	0 feet 6 inches
Shale to surface of water	0 feet 10 inches

I did not observe such complete exposures although a search was made for the reported outcrops along the river bank and the bank of the tributary creek. Fragments of black, argillaceous limestone, lithologically similar to the limestone bed in the Verne and other mines as well as at Grand Ledge, were found lying on the banks in this locality above sandstone beds. One of the limestone fragments collected by the writer yielded a small *Lingula* like that found in the Wenona and other mines. This horizon is very probably that which Winchell describes as a black shale.

Winchell's fossil list includes more than the *Lingula*, and is reproduced here for the sake of reference. The probable present day synonymy is given in the right-hand column:

Lingula	Lingula sp.
Chonetes Smithii	Chonetes granulifer
Productus asperus	Juresania nebrascensis
Spirifer cameratus	Neospirifer cameratus

All these forms are present in the black argillaceous limestone at Grand Ledge, and appear to indicate the presence of the Verne member near Flushing. The elevation of this bed is from 675 to 700 feet. (Figure 4, column 3).

Other localities have been mentioned by Winchell (1861, p. 120). He states that sandstone, not unlikely the Woodville sandstone, is found outcropping in the township of Montrose, on the borders of Saginaw County. This area is an old lake plain and showed no signs of an outcropping of sandstone. Lane (1902, p. 200) also mentions that an outcrop was reported on the river bank near the northeast corner of section 4, Flushing township. The locality was visited but no outcrop was found.

Shiawassee County—Winchell (1861, p. 123) describes outcrops along Six Mile Creek in section 18, T. 8 N., R. 3 E. about 10 miles southwest of the Verne mine and 15 miles west of the Flushing locality. The same outcrops are described by Rominger (1876, pp. 138-140). Rominger mentions a "black, shaly lime rock, visible in a thickness of four or five feet, containing numerous fossils, partly in calcified, partly in pyritous condition." I have never seen this rock outcropping in Six Mile Creek although collections of fragments answering Rominger's description have been made from the dumps of two shafts, sunk in its bed. Determinations made of specimens I have collected, and of other specimens in the Museum of Paleontology of the University of Michigan labeled New Haven township, that is T. 8 N., R. 3 E., which are believed to be from identically the same locality are given below:

Crinoid columnals
Lingula sp.
Schizophoria resupinoides (C.)
Derbya aff. Bennetti
Chonetes granulifer O.
Mesolobus mesolobus var. like euampygus (G.)*
Marginifera missouriensis (G.)
M. aff. wabashensis N. & P.*
Linoproductus prattenianus (N.&P.)
Neospirifer cameratus (M.)*
Ambocoelia sp.*
Composita subtilita (H.)
Pharkidonotus percarinatus
Trepospira illinoisensis (W.)
Meekospira paracuta
Metacoceras cornutum G.
Gastrioceras sp. nov.
Edestus minor

With the exception of the *Lingula*, which is in a black, fissile carbonaceous shale, all the forms are in either a black, argillaceous limestone, similar to the limestone at Grand Ledge and the Verne and other mines, or in a black, hard, pyritized limestone. Some forms such as *Marginifera missouriensis*, are common to both types of limestone. There seems to be little doubt that this is the Verne fauna.

Rominger (1876, p. 139) also lists a comparatively large fauna from this locality. His list is given below in the left hand column, and present

day synonyms determined from standard works, but guided by probable Michigan species are given in the right-hand column:

Zaphrentis	Lophophyllum profundum
Crinoid stems	Crinoid stems
Chonetes sp.	Chonetes granulifer
Productus manus	Marginifera missouriensis
Spirifer cameratus	Neospirifer cameratus
Spirigera sp.	Composita subtilita
Myalina sp.	Myalina sp.
Bellerophon sp.	Pharkidonotus percarinatus
Platyceras sp.	Platyceras sp.
Orthoceras sp.	Pseudorthoceras knoxense

Nautilus latus or winslowi	Temnocheilis latus or winslowi

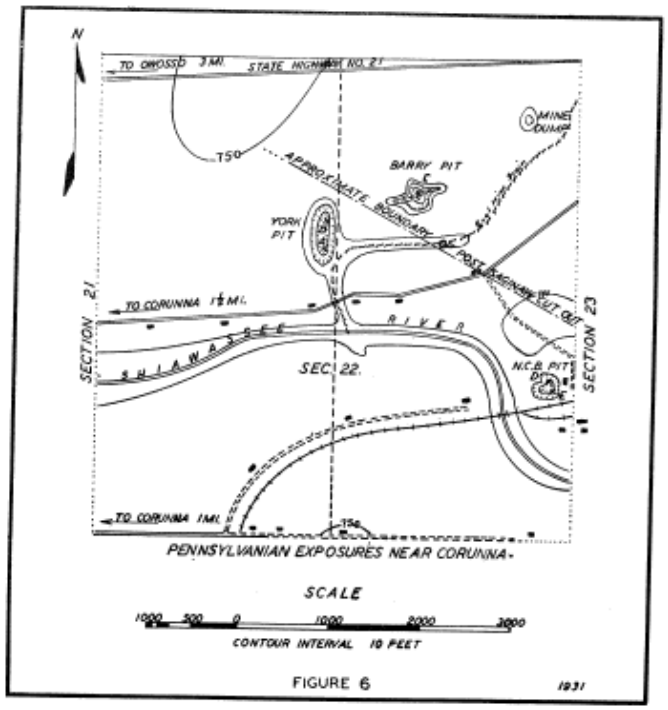

Figure 6. Map showing Pennsylvanian exposures near Corunna, Shiawassee County

The outcrops mentioned by Winchell and Rominger are now concealed, but it is probable that the limestone bed is close to the surface, giving the Verne member in this area an elevation of about 660 feet. (Figure 4, column 4).

Other outcrops of Pennsylvanian beds are mentioned by Winchell (1861, p. 124) as occurring at Chesaning, and at several places along the Shiawassee River. However, I have found none of those outcrops reported below Corunna.

Exposures of the Saginaw Group may be observed in the shale pit of the New Corunna Brick Company, section 22, T. 7 N., R. 3 E., and the recent excavations made in local coal stripping operations about two miles northeast of the center of the town of Corunna. A sketch map showing the area dealt with (Figure 6) is reproduced here. The map is an enlargement made from the U. S. Geological Survey topographic sheet, Corunna quadrangle, and illustrates the level character of the district. The location of the pits is indicated. Several sections were measured, five of which are reproduced (Figure 7). The most complete sequence of strata can be seen at the south end of the shale pit of the New Corunna Brick Company (Figure 7, column E). Details of the section are given below:

Overlying Bed	Grand River Group	*Thickness*
8	Sandstone.	2.0 feet
7	Lignitic coal, lower part very shaly (overlain by "Lingula" shale at north end of pit).	2.0 feet
6	Light gray, somewhat sandy, micaceous underclay, grading downwards into sandy shales which overlie lentil of sandstone conglomeratic at base. In north end of quarry the sandstone is fine-grained and argillaceous and contains many remains of *Cordaites.*	6.5 feet
5	Thinly bedded, light colored sandy shale, containing elliptical clay ironstone septaria with calcite and gypsum veinlets. In north end of quarry a black shale, resembling shale at base of quarry, is found above the sandy shales.	6.5 feet
4	Thin stratum of reddish weathering hard calcareous sandstone containing imperfectly preserved and fragmentary fossils.	1.0 feet
3	Fissile, dark gray shales.	8.0 feet
2	Arenaceous shales overlying light gray to white micaceous, medium grained sandstone. In north end of pit, a sandstone lentil in the upper sandy shales, contains 2 species of Megalopteris.	7.0 feet
1	Black, compact plastic shale containing *Lingula carbonaria* and the foraminifera *Psammophis* sp. and *Cornuspira* sp. probably overlying coal seam mentioned by Brown (1926 p. 373).	2.0 feet

An analysis of this section shows that it may be subdivided into four cyclical formations. The upper part of the first, or *A*. formation is represented by bed 1; formation *B* includes the overlying strata of 2, 3, and 4, which have a thickness of 16 feet; formation *C* is represented by the succeeding six and a half feet of sandy shales with the black shale included in bed 5, and formation *D* includes beds 6 and 7.

The fossils found in bed 4 are mainly pelecypoda with a few gastropoda. Their imperfect preservation and fragmentary condition render even generic identifications doubtful. The genera *Astartella*, *Pleurophorus*, and *Macrochilina* may be represented.

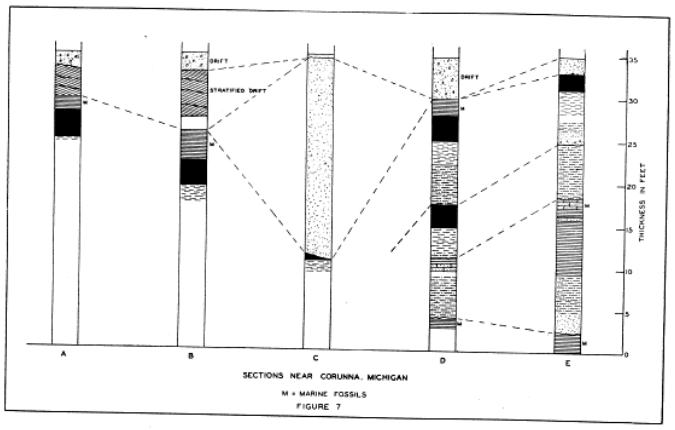

Figure 7. Columnar sections measured near Corunna.

The beds are easily traced along the east side of the shale pit from south to north. Strata of beds assigned to cycles "C" and "D" thin and disappear northward. That the disappearance is at least in part due to erosion is clearly evident in the coal beds belonging to cycle "C" and shown in column D, Figure 7. One can readily see that that seam beveled within a distance of 50 feet. The upper strata dip with the inclination of the unconformity, and at the northern end of the pit, a black shale, containing a recurrence of *Lingula carbonaria*, caps the coal of cycle "D". About 2000 feet northward, in the pit of the Barry Coal Company, the "D" coal, overlain by the *Lingula* shale and underlain by its characteristic underclay, is observed about 24 feet below the surface of the plain (Figure 7, C). A coarse grained sandstone, probably bed 8 and like it assigned provisionally to the Grand River group, unconformably overlies the coal, and farther north it overlies the underclay.

The sections in the York pit (Figure 7, columns A and B) show a rise of "D" coal from north to south. The coal at the south end of the York pit is almost at the same elevation as the same bed in the north end of the New Corunna Brick Company pit. A line drawn between these two locations gives the approximate trend of one of the valleys of Saginaw time, which appeared to influence the localization of erosion during Grand River time. A similar occurrence of superimposed unconformities is also illustrated at Grand Ledge.

The absence of an undoubted suggestion of the Verne fauna from this locality makes correlation with other sections highly speculative. The "*Lingula*" horizons are unreliable markers and of little value in inter-areal correlation since in one area, the Grand Ledge district, as many as three such horizons have been found. A plant horizon containing apparently identical species of *Megalopteris* as those found in the lowermost beds in the Grand Ledge section, however, points to general similarity in age. The lithology, particularly of beds 3 and 4, formation "B" and bed 5 of formation "C" on the other hand, is decidedly different from anything at Grand Ledge and more like that of some beds in the Williamston section.

Outcrops of sandstone also appear upstream along the banks of the Shiawassee River in section 36, T. 7 N., R. 3 E. The sandstones are flaggy, buff-weathering, and medium grained, and are about four feet thick. They contain considerable mica, and are more like the sandstones of the Saginaw than of the Grand River formation.

*Specimens labeled "New Haven township."

Clinton County. The outcrops noted in Clinton County are along both banks of the Grand River for a distance of at least two and one-half miles below the Eaton-Clinton County line. The beds can be correlated with those at Grand Ledge. From the nature of the underclay and the lithologic character and contained fauna of the black shale above the coal, the seam is assigned to the cycle E of the Grand Ledge section. (Figure 5, columns 7, 8, 9). A marked dip, perhaps only a local one, is noted. A few mines were operated in 1932, but in the past many more were worked. Coal was also dredged from the river bottom about 1000 feet north of the county line.

An outcrop of the fossiliferous limestone of the Verne cyclical formation is twelve feet above river level (Figure 5, column 10) close to the Grand River where it crosses the section line between sections 32 and 33, T. 5 N., R. 4 W.

The fauna collected includes the following species:

Marginifera missouriensis (G.)
Trepospira illinoisensis (W.)
Pseudorthoceras Knoxense (McC.)

Eaton County: In addition to the Grand Ledge exposures, already described (pp. 177-184) a few other outcrops are known in Eaton County.

Outcrops of coal along the valley of the Thornapple River in the vicinity of Chester were reported by Rominger, in his report on the Geology of the Lower Peninsula (1876, p. 130). The locality was visited in 1928 and again in 1932, at the time of active coal-stripping operations. Two exposures were observed, one near the section line between sections 14 and 23, T. 3 N., R. 5 W., and the other in the southeast quarter of section 28 of the same township (see Fig. 8).

The more northerly of the two localities is about 8 miles southwest of Grand Ledge and is on the eastern side of the Thornapple Valley. The coal averages about 3 feet in thickness, and, where observed, was overlain directly by glacial drift. The underclay is soft, and resembles somewhat the highest coal seam of the Grand Ledge section. Exposures of the coal may be seen along the road between sections 14 and 23, and also in the excavations made by coal stripping operations.

The second locality is about 1½ miles southwest, on the western side of the valley. The entire thickness of the section exposed was about eight feet. Descriptions of the beds follow:

Overlying bed	Drift	Maximum observed thickness
5	Light, slightly sandy shale.	2.0 feet
4	Black, compact plastic shale with *Lingula carbonaria*.	1.0 feet
3	Coal, canneloid at base.	1.3 feet
2	Sandy underclay with *Stigmaria* rootlets.	3.5 feet
1	Fine grained sandstone with many *Cordaites* leaves.	2.5 feet

The beds exposed here, like those to the north, displayed a marked inclination to the north. In the limited exposures a dip of five feet in fifteen was observed.

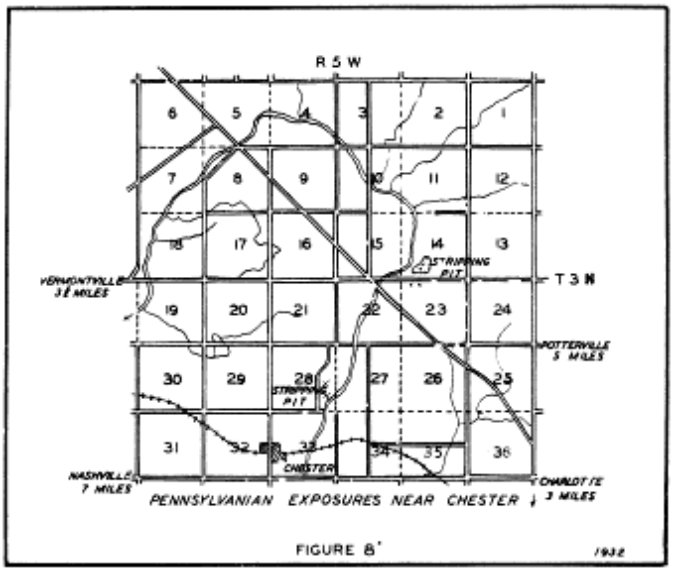

Figure 8. Map showing Pennsylvanian exposures near Chester, Eaton County.

Although but a small part of the stratigraphic section can be observed at either locality, it is very likely that the beds are the same. They are, therefore, tentatively correlated. It is probable that extension of mining activities to the northeast may show that these beds are present in the Grand Ledge area.

Outcrops in the vicinity of Eaton Rapids, Dimondale, and Potterville have been reported by Winchell (1861, p. 121), Rominger (1876, p. 130), and Lane (1902, p. 121). None of these was observed, however, although a search was made for them. It is probable that the dams along the Grand River near some of the towns mentioned above, have raised the water level sufficiently to conceal the outcrops mentioned by Rominger and Lane. Slumping, followed by growth of vegetation, may account for the absence of exposures near Potterville. That bed rock is close to the surface is indicated by blocks of sandstone thrown out on the banks of a drainage ditch in section 26, T. 3 N., R. 4 W.

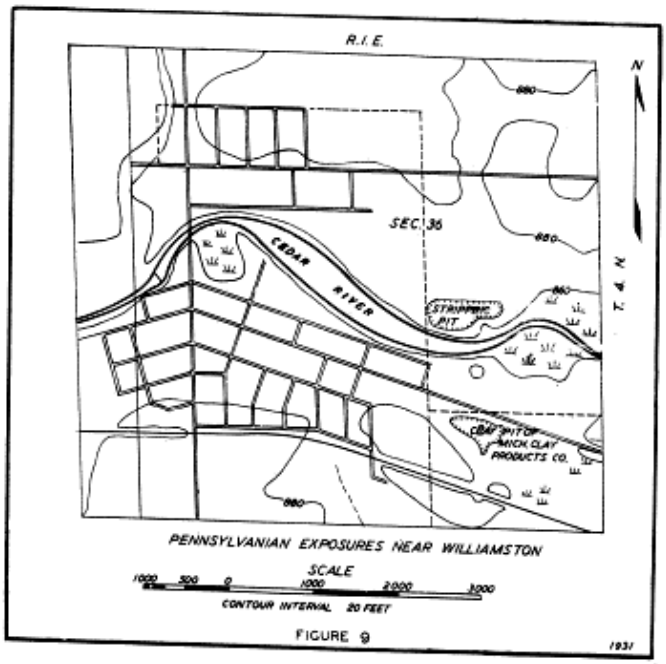

Figure 9. Map showing Pennsylvania exposures near Williamston, Ingham County.

Ingham County—Several outcrop localities within Ingham County are mentioned by Lane (1902, pp. 121, 205-218). Many of these are along the Grand River and are concealed since the erection of recent bridges and dams. One outcrop mentioned by Winchell in Locke township could not be located, (Winchell, 1861, p. 121), although a search was made for it.

In the excavation made to find a suitable foundation for the Capital Bank Tower in Lansing, sandstone was struck at a depth of 55 feet immediately below the glacial drift. Samples taken from below the drift were light gray, medium grained micaceous sandstones, characteristic of the Saginaw group.

The most extensive exposures of Pennsylvanian strata in Ingham County are near Williamston (Fig. 9), where quarrying operations have been carried on within recent years by the Michigan Clay Products Company. At the time of my visit the beds were exposed in an east-west direction for a distance of about 600 feet. A small anticline with a north-south strike exposes some of the older beds near the center of the quarry; thus giving a total exposure of about 60 feet of shales and sandstones.

Overlying bed	Drift	Maximum observed thickness
15	Steeply dipping, white to light gray, medium grained micaceous sandstones and shales exposed in channel cut into underlying strata.	10.0 feet
14	Black fissile shale.	1.5 feet
13	Very dark gray, clay ironstone stratum with rectangular fracture partly filled with sphalerite. Uppermost layer with scattered specimens of *Anthracomya* sp. as at Grand Ledge.	0.5 feet
12	Black irregularly stratified compact shale.	3.0 feet
11	Coal and carbonaceous shale.	0.2 feet
10	Sandy underclay grading into light gray shale below.	1.5 feet
9	Coal and highly carbonaceous shale.	0.1 feet
8	Sandy underclay about four inches thick with fragments of *Stigmaria* overlying white, soft, underclay with oolitic texture succeeding to light gray, soft underclay. Lower boundary indefinite because of gradation into the underlying shale.	2.5 feet
7	Black moderately fissile shales containing numerous elliptical clay ironstone nodules.	4.0 feet
6	Light gray to white underclay with irregular nodular masses indurated by ferruginous cement. The nodular masses have an oolitic texture. This bed has a variable thickness.	3.0 feet
5	Coal with cubical fracture and tendency also to break into slabby layers. This bed is cutoff in a short distance by an unconformity.	1.7 feet
4	White soft underclay with rusty streaks.	4.0 feet
3	Gray, flaky shale with numerous nodules having septarian structure, the septaria formed in part by sphalerite.	11.0 feet
2	White, soft underclay.	3.5 feet
1	Black, compact plastic shale with a visible thickness of.	5.0 feet

The Williamston section can be subdivided into six cyclical formations. The first, or *A*, cyclical formation is represented only by bed 1; formation *B* includes beds 2 and 3 with a thickness of about 10 feet; formation *C* consists of beds 4 and 5 with an observed thickness of somewhat less than 10 feet, and is separated from formation *D* by a fairly well marked unconformity. Formation *D*, made of beds 6 and 7, is only six feet thick. Formation *E* consists of beds 8 and 9, less than three feet thick, and beds 10, 11, 12, 13, and 14, which together have a total thickness of about seven feet, make up formation *F*. The beds of the higher formations are sometimes cut off entirely by the unconformity at the base of the channel shales and sandstones which represent formation *G*.

The anticlinal structure observed in the section is in part at least dependent upon an unconformity. This is illustrated by a series of columnar sections (Fig. 10) made on the north side of the shale pit, which show that beds of the lower and upper cyclical formations, such as *B* and *D*, have less inclination on the eastern limb than do the beds of the intervening formation *C*.

Some of the beds are exposed on the north side of the river by the recent (1933) coal stripping operations. The upper beds here are sandstone (Fig. 10, column E), and they replace unconformably the beds of cycles *D*, *E*, and *F*, (Figure 10, column D), the sandstone at times resting directly upon the coal of cycle *C*. The beveling of older strata produced during the erosional interval preceding the deposition of sandstone is plainly observable in the western part of the pit.

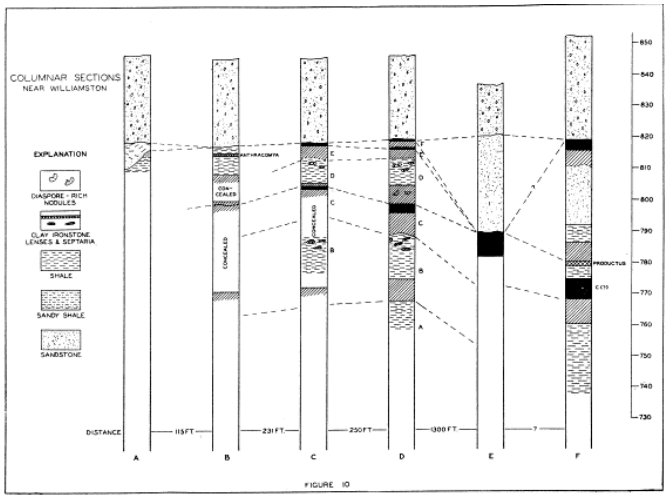

Figure 10. Columnar sections near Williamston, Ingham County.

A. South side of highway, west end of shale pit, Michigan Clay Products Company.
B. North side of pit, 115 feet east of section A.
C. North side of pit, 230 feet east of section B.
D. North side of pit, 250 feet east of section C.

E. North side of river. Coal stripping pit.
F. Rominger's Section (Rominger, 1876, p. 135)

No trace of the Verne fauna was noted in the sections described above. It is interesting to note, however, that Rominger (1876, p. 135) reports a *Lingula*, a *Discina*, and *Productus* and compressed lamellibranchs from a shaft near Williamston. I have seen shale specimens in the Museum of Paleontology of the University of Michigan, labeled Williamston. The shales have numerous specimens of *Orbiculoidea* missouriensis (S.) and crushed specimens of a relatively large *Anthracomya*. Although these two fossils have little stratigraphic significance, Rominger's mention of *Productus*, perhaps a *Marginifera missouriensis*, does suggest the Verne fauna.[1] Rominger's section (Fig. 10, Col. F.) is given below, and compared graphically with my sections in Figure 10:

Rominger's section (Rominger, 1876, p. 135)

Overlying bed—Drift	—15 feet
—Coal seam	—20 inches
—Fire clay with seams of sand rock	—12 feet
—Black shale	— 3 feet
—White, soft fire-clay	— 3 feet
—Kidney ore	— 6 inches
—Black, slate-like shale containing *Lingula*, etc.	— 2 feet
—Coal from	— 3 to 3½ feet
—fire clay	— 4 feet
—Gray shales	—12 feet

I suggest a correlation of Rominger's lower coal seam with the coal of formation *C*, since inquiries in the neighorhood of Williamston indicate that the coal of formation *C* was the one mined most extensively in the past. The absence of a fauna above that coal in the shale pits is readily explained by the unconformity at the base of formation *D*. If this correlation be correct it makes formation *C* of Williamston equivalent to formation *F* of Grand Ledge. The strata of formations *D*, *E*, *F*, and *G* would include, therefore, some of the youngest beds of the Saginaw exposed in Michigan.

The *Productus* horizon mentioned by Rominger is at an estimated elevation of about 830 feet above sea level. Its relation to the Verne limestone in Eaton, Shiawassee, Saginaw, and Bay counties is shown in Figure 4, Column 6.

Coal also is in section 33, T. 3 N., R. 1 W., where it was exposed in a drainage ditch. An excavation in this locality is said to have exposed two seams of coal, each about 45 inches thick and separated by a thin shale parting. The report could not be verified because the excavation had been filled. In the winter of 1934 some coal was mined from the northern part of the section.

[1]In the spring of 1934 Prof. S. G. Bergquist of Michigan State College, discovered two thin seams of spore coal in a recently opened pit near Williamston. Samples were examined by Dr. George Sprunk, formerly with the Pittsburgh Experiment Station of the Bureau of Mines, who reported a similarity between the spores of the Williamston coal and the Pottsville Elkhorn coal.

Jackson County—Beds assigned to the Saginaw group were formerly exposed within the city of Jackson (Rominger, 1876, p. 123), but those outcrops are now concealed by buildings. A quarry north of the city of Jackson in section 11, T. 2 S., R. 1 W., and near the confluence of Portage River with Grand River, (Figure 1) exposes a series of shares interbedded with a minor amount of sandstone. The shales were formerly worked by the American Vitrified Products Company. The oldest beds are in the northeastern part of the quarry, which was partly filled with water at the time the exposures were visited. The beds have a gentle inclination toward the south, and may be an example of secondary dip since limestones assigned to the Bayport formation of the Mississippian, outcrop and at a higher elevation one quarter mile north, and at a lower elevation about 3 miles south.

A section was measured by tracing beds from one part of the quarry to the other. The details of the section are given below:

Overlying bed		
	Drift	5.0 feet
12	Thin ledges of light gray, fine-grained micaceous sandstone containing about one percent zircon.	9.5 feet
11	Concealed. Talus shows light and dark gray shales.	10.0 feet
10	Clay ironstone layer.	0.5 feet
9	Light gray shale, grading into bed 8, the contact irregular.	1.5 feet
8	Black, compact shale with 6-inch clay ironstone parting.	5.5 feet
7	Black shale with clay ironstone layers.	1.5 feet
6	Coal.	0.3 feet
5	Light gray, soft underclay with carbonaceous residue.	2.5 feet
4	Black, somewhat fissile shale.	0.5 feet
3	Hard, fine-grained sandstone.	0.5 feet

2	Light gray, somewhat sandy, nodular under-day with fragments of *Stigmaria* near top.	8.0 feet
1	Dark gray, thinly-bedded compact shale with clay ironstone layer near base	6.0 feet

Materials thrown out from the deepest part of the quarry show that the lowermost strata are made up of black shale with many clusters of crystals of iron pyrite.

The exposed section indicates at least three and possibly four cycles of sedimentation. The upper part of the first, or *A* cyclical formation, is the underclay bed 2. Cyclical formation *B* includes 3 to 10, the last two of which appear to be the weathered product of bed 8. Shale of marine origin is probably represented by bed 8. Although no fossils were obtained from it, the lithologic characters of this shale are very similar to the "Lingula" layers of other localities. If this interpretation is correct, the concealed area, bed 11 of the section, together with beds showing evidences of being weathered products, namely beds 9 and 10, must represent cyclical formation *C*. The lower beds of cyclical formation *D*, are represented by bed 12.

Specimens of highly argillaceous limestone containing *Lingula carbonaria*, and now in the collections of the Museum of Paleontology at the University of Michigan, and labeled Blackman, Jackson County, may be from a locality near that mentioned above, since Blackman is the name given to T. 2 S., R. 1 W. The brachiopod *Lingula* indicates the presence of marine, or at least brackish water conditions in this area during Pennsylvanian time, but does not aid in correlating the sections in Jackson County with sections to the north.

Rominger (1876, p. 127) records the occurrence of *Lingula* and some compressed shells of lamellibranches from Jackson. Specimens of shale in the Museum of Paleontology of the University of Michigan, labeled Jackson, Jackson County, contain *Lingula carbonaria*, and Rominger's specimens probably belonged to the same species. The compressed lamellibranchs referred to by Rominger are either lost or else were never deposited in any collection available to me. They may have been specimens of *Anthracomya*, which is commonly found in a crushed condition, and not necessarily individuals of the Verne fauna (Lane, 1902, p. 43).

Several abandoned mines in Jackson County were visited, and collections of sandstone, shale and coal samples were made from the dumps. One of the abandoned mines, known as the Sam Graham mine, is also one of the Woodville mines, being located in the NE¼ section 25, T. 2 S., R. 2 W. The sandstone samples are assigned to the Woodville formation. The shales, although burned to brick-like consistency, are typical of the shales of the Saginaw formation, and contain plant remains, among which is a species of *Lepidodendron* and one of *Cordaites*.

Other Counties—Most of the counties which are partly or wholly underlain by beds belonging to the Saginaw group, do not possess any outcrops. These counties are not referred to in this report since there are no existing records. Descriptions of developments and borings within the coal basin are given in Lane's report (Lane, 1902, p. 157-220).

Chapter IV

GRAND RIVER GROUP

NAME

The Pennsylvanian formations in Michigan which are stratigraphically higher than beds of the Saginaw group, have been variously called Woodville, Ionia, and Red Beds. Of these three terms, Woodville has undoubted priority, and its history is briefly reviewed.

Woodville is the name by which Winchell (1861, pp. 115 and 125) provisionally designated the "friable, rather coarse, quartzose sandstone stained to a variable extent with oxide of iron" which he found to be "the capping stone of the coal measures." The type locality was the "good exposure in the cut of the side track from the (Woodville) mine to the Central Railroad." The name has no reference to the village of Woodville, in Newaygo County, but to the old Woodville mine in Jackson County.

Rominger (1876, pp. 122, 128, 129) did not retain Winchell's term and grouped all beds younger than the Bayport under the term Coal Measures. At a later date the name Woodville sandstone was revived by Lane (1895, p. 15), because he thought the coal series ended with a sandstone often enough to justify its separation. In his coal report Lane (1902, pp. 40, 41, 175, 195) uses the name Woodville sandstone, although indicating in most cases that a doubt existed in his mind concerning the intra-state correlations that he made. In an article on the geological column of Michigan, Lane (1909, p. 83) retained the name Woodville sandstone, although he states that Ionia would be a better name for the sandstone which caps the Saginaw group in the central part of the coal basin. Other authors since Lane's time have continued to use the term Woodville, although with such doubt as to partially justify Rominger's scepticism regarding its propriety. Lately the term has been abandoned by R. B, Newcombe (1931) in the classification of formations shown on his map of the Southern Peninsula of Michigan, but it is still recognized by the U. S. Geological Survey and is being used on the geologic map of the United States which is in course of publication (Miser, H. D., 1932).

The principal difficulty with the term Woodville sandstone is in connection with Winchell's definition that it is the

capping stone of the Coal Measures, or Saginaw group, as the series is called in this report. It is not known certainly whether the Woodville sandstone at the type locality represents a lentil of limited distribution which should be grouped with the sandstones of the Saginaw group—which Rominger must have thought might be the case—or whether the Woodville sandstone is a formation younger than any member of the Saginaw group, as the sandstones outcropping in the vicinity of Ionia seem to be. The use of the term Ionia would meet with less objection. However, to apply the name Ionia to sandstones, such as those outcropping near Grand Ledge, would either imply correlation, or else involve the use of the term in a group sense. Rather than introduce new difficulties of nomenclature, I, therefore, propose the term GRAND RIVER GROUP, and define it so as to include the massive, crossbedded, coarse grained sandstones which contain little or no mica, and which are frequently iron stained on fresh fracture.

The group includes the Woodville sandstone, the Eaton sandstone, and the Ionia sandstone.

EATON SANDSTONE

The name Eaton sandstone is proposed for the uppermost sandstones forming the bluffs or ledges along the valley of the Grand River and its tributaries in the vicinity of Grand Ledge in the northern part of Eaton County. The beds are post-Saginaw in age, but their true stratigraphic relations to the Woodville sandstone, the Ionia sandstone, or other strata of the Grand River group cannot be determined.

IONIA SANDSTONE

The name Ionia sandstone was originally suggested by Lane (1909, p. 83) for the sandstone which caps the Saginaw group in the central part of southern Michigan. The name is familiar to Michigan geologists and can well be applied to the cross-bedded, coarse grained, varicolored sandstones outcropping in the valley of the Grand River near Ionia. Ionia sandstone overlies the shales and micaceous sandstones of the Saginaw group.

The Grand River group overlies the shales and light-colored, typically micaceous sandstones of the Saginaw group, and underlies the shale and gypsum beds in the upper part of Newcombe's Red Beds (Newcombe, 1931.) Formations of Grand River group are exposed in mines and quarries, and natural outcrops in the valley and drainage basin of the Grand River, from the vicinity of Jackson to that of Ionia.

SOURCES OF STUDY

Information on the Grand River group has been gained from literature and from specimens collected from several localities within the State. The chief outcrop localities of the Grand River Group are shown on a map included in this report. (Figure 3).

Plate V. Conglomeratic zone at base of the Eaton sandstone. The pebbles consist of nodules derived from the Saginaw underclay. A long band and many lenticular streaks of coal may be seen.

STRATIGRAPHIC RELATIONS

The relations of the Grand River group to the Saginaw group has already been given. It is known, however, that the Saginaw group is not always capped by a sandstone, since mines in Saginaw county (Smith, 1917, p. 225) and wells drilled in Roscommon and Ogemaw counties have struck shale and gypsum beds just above shales and sandstones assigned to the Saginaw group. Where the gypsum beds have been reported in association with a Grand River sandstone, (Smith, 1917, p. 225) that sandstone underlies the shale and gypsum. The shale and gypsum series does not outcrop in Michigan. Newcombe (1932) refers to this series as the "Red Beds." I have had no opportunity to study this series and hesitate to include it in the Grand River group, because of the marked difference in lithology.

LITHOLOGIC AND OTHER CHARACTERS

The Grand River group consists predominantly of coarse sandstone, although conglomeratic beds are present near the base. The basal conglomerates have irregular fragments of coal, shale, and clay ironstone included in a sandstone matrix. (Plate V). The sandstones consist chiefly of quartz with a siliceous or ferruginous cement. Subordinate feldspar, and a small amount of heavy minerals are also present. Tourmaline and zircon are the most common of the heavy minerals. Many of the heavy mineral grains show well formed crystal outlines.

The lower beds of the Grand River group are believed to be exposed in the vicinity of Grand Ledge, where the contact is markedly irregular. The formation seems to have a localized occurrence. This may be illustrated in the vicinity of Grand Ledge and also near Ionia, where a well just south of the city (Smith, 1917, p. 225) starting at 660 feet above sea level, struck gypsum at 93 feet and reel sandstone at 97 feet below the surface, although about four miles east red sandstone outcrops in the flats of the Grand River at an elevation of a little over 660 feet above sea level. The sandstone beds near Ionia are about 80 feet thick (Rominger, 1876, p. 134). Erosion on

a large scale is indicated here if we assume the gypsum to be younger than the Grand River group. Red colors appear to be characteristic. In the sandstones capping strata of the Saginaw group at Grand Ledge individual beds show rusty layers alternating with layers of white sandstone, seeming to indicate that the color originated contemporaneous with the formation of the sediment, and was not due to post-Pleistocene weathering. This feature is in strong contrast to the gray and light buff sandstones of the Saginaw group.

Inner and outer molds and thin carbonized residues of such plants as Calamites and Lepidodendron are scattered through the lower beds. I have never found any plant remains in the upper beds near Ionia, although they have been reported. (Rominger, 1876, p. 134). From the fragmentary character of the fossils found in the Eaton sandstone it is possible that most of them were transported to the sites of burial.

The various characters of the Grand River sandstones indicate a fresh water origin. I am inclined to believe that much of the formation is due to river deposition, and that some of the beds are channel sandstones. The sediments were deposited under climatic conditions which differed considerably from conditions which obtained during the deposition of the Saginaw group, and the changed climates are reflected in the brown and red colors of the younger formation. Distribution of the Grand River sandstones is probably largely dependent upon the trends of post Saginaw valleys.

THICKNESS

The thickness of the Grand River group (Woodville sandstone) has been variously estimated by different authors. Winchell (1861, p. 115) gives 30 feet for a mine close to the type locality and Rominger (1876, p. 134) cites 80 to 110 feet for the sandstones near Ionia. Rominger's assistant (Lane, 1902, p. 195), reported from memory a thickness of 143 feet in a well a few miles east of Ionia. In a report on deep borings, Lane (1895, plate 73) gives an estimate of 304 feet but in his report on the geological column of Michigan the thickness given for the Woodville is 80 feet. The columnar section on the 1916 edition of the geological map of Michigan gives 100 to 110 feet (Allen, 1916). Most of the later publications, including Newcombe (1928, p. 157) give 80 to 95 feet. The last estimate will be used in this report, with the implication that it applies to any single section.

CORRELATION

The Grand River (Woodville) has for some time been correlated with the Conemaugh (Lane, 1909, p. 83). This correlation was based largely on the prevalence of sandstone in the Conemaugh. At present there seems some likelihood that an inter-basin correlation based upon more than lithological evidence is possible. The few plant remains found in the basal sandstone at Grand Ledge and other localities have not been described. From their occurrence as inner and outer molds it is probable that they are not derived from the Saginaw group, but that they represent plants which grew contemporaneously with the deposition of Grand River sediments. I have never found plant fossils in the sandstones near Ionia, but if such are found they would have added significance.

Correlation of the sandstones within the State is also a difficult matter. The original statement by Winchell (1861, p. 126) that the Woodville occurs in the Woodville mine in Jackson, in Ionia County, at Corunna, and Owosso, as well as the type locality, never seems to have been carefully checked. I have attempted to trace some continuity between the sandstones at the southern end of the basin with sandstones near Ionia by an examination of well samples. The problem is a difficult one, since most drillers do not save samples until they reach the Mississippian formations. In general the statement of Winchell's referred to above is substantiated. To the occurrences mentioned I would add those of Grand Ledge, evidence being put forward for this correlation under the discussion of local details.

WOODVILLE SANDSTONE

Jackson County—The exposure of sandstone which Winchell chose as the type locality of the Woodville formation can no longer be observed. Winchell gives a section measured in a mine shaft close to the type locality (Winchell, 1861, p. 115) and this is reproduced here for the sake of reference.

E	Superficial materials	12 feet
D	Woodville sandstone	30 feet
C	Shales, dark, bituminous, with 6 feet of fine light colored clay	43 feet
B	Bituminous coal	4 feet
A	Underclays	3 feet

The elevation of the contact between beds *C* and *D*, judging from the general elevation of that area, is about 925 feet.

I collected samples from the dump of an abandoned mine, which, from its situation in the northeast quarter of section 25, T. 2 S., R. 1 W., must be close to the original Woodville mine. The samples studied are moderately coarse grained and consist principally of quartz intermixed with minor amounts of carbonaceous and argillaceous particles. Little or no mica is present. Some specimens display reddish and purplish red colorations, and resemble some of the beds in the quarries near Ionia.

EATON SANDSTONE

Eaton County—The coarse grained porous sandstones outcropping in the vicinity of Grand Ledge have a maximum thickness of 50 feet. The sandstones are separable into two divisions, a lower massive and an

upper bedded. Between the two a shale parting is sometimes present. In the quarry of the American Vitrified Products Company the lower beds are distinctly cut off by an unconformity and replaced by shale which seems to have filled a small channel. The upper beds overlie the lower sandstone in one locality, and where these are cut off overlie the channel shale. It is not always feasible to map the two divisions separately and they appear under one symbol on the map (Fig. 3). The lower sandstones, however, have a limited distribution. The lower contact is highly undulating and appears to correspond to the slopes of the valleys (Kelly, 1932), the elevation of the contact varying between 795 and 830 feet above sea level.

Plate VI. Shale boulder at the base of the Eaton sandstone. It overlies undisturbed shale of the Saginaw Group.

The lower beds of the sandstone are conglomeratic and characterized by fragments of shale, coal, and nodules. (Plate VI). The upper bedded sandstones are more uniformly distributed, and where absent give evidence that absence was due to comparatively recent erosion. They appear to have been deposited after the initial topographical irregularities were filled. The texture and composition of both the lower and upper sandstones is very similar. Quartz, the principal constituent, is mixed with a little decomposed feldspar and from 5 to 10 percent of decomposed silicates occur as mud and silt between the sand grains. Iron oxide as a cement forms up to 5 percent of the rock. On weathered surfaces the rock appears a rusty brown, but on fresh fracture the glassy quartz alternates with white silicates and rusty red grains of quartz, giving the rock a fine mottled appearance. Some beds show distinct grouping of colorless or white grains, and of rust colored grains. Tourmaline and zircon are both found in small amounts.

The outcrops of this sandstone extend along the valley slopes into Clinton County. A small outcrop occurs in the bed of a creek discharging into Looking Glass River, in section 14, T. 5 N., R. 4 W. The lithology is similar to the Eaton sandstone at Grand Ledge.

IONIA SANDSTONE

Ionia County—Sandstone is quarried on the flats of the Grand River east of the city of Ionia in the west half of section 23, T. 7 N., R. 6 W. The quarries extend over a distance of about 2000 feet in a north-south direction, but the outcrops are only partly accessible since the pits are partially filled with water. The upper beds of the quarry are massive, but the beds at water level show marked cross-bedding, a structure brought out distinctly by the purplish-red coloration. Evidence of contemporaneous erosion is mentioned by Rominger (1876, p. 134). The sandstones are coarse and friable, although Rominger states that after quarrying they are more strongly indurated. The most peculiar character is the mottled and variegated coloring of some of the beds. The ground-mass is white, but purplish and red laminae are quite common. Quartz is the predominant mineral constituent. Under the microscope most of the grains appear clear and glassy, but some are coated with a film of ferruginous cement. Angular grains of zircon are relatively abundant.

This sandstone differs radically from the other sandstones referred to the Grand River group. Well records give a thickness of 80 feet for the formation, but no samples from the base of this sandstone are available for comparison with samples near the surface. The base, judging from Rominger's figures (1876, p. 134), is computed to be at an elevation of about 580 feet, and therefore considerably lower than the massive sandstones near Grand Ledge. Unless regional dips account for their depth, this seems to imply very deep post-Saginaw erosion in this locality. The lower beds may be the stratigraphic equivalent of the Eaton sandstone. If such a correlation is proved the name Ionia should take precedence over Eaton, because it is better known and was suggested at an earlier date.

No other sandstone outcrops within the county are known. The wells south of Ionia, however, report a few feet of red sandstone overlying the Saginaw and underlying gypsum and shale. The red sandstone may represent the Ionia, and if so, appears to imply that it too was subject to erosion before the deposition of the gypsum series.

Shiawassee County—The upper sandstone beds exposed in the quarry of the New Corunna Brick Company near Corunna are about two feet thick. The basal layer is conglomeratic. The upper layer is a coarse-grained sandstone consisting of quartz grains held together by a cement of iron oxide and argillaceous material. A little mica is present and tourmaline is comparatively common. The rock has a resemblance to the Eaton sandstone at Grand Ledge and is tentatively included in the Grand River group.

The elevation of the lower contact of the sandstone is about 765 feet above sea level, but within a distance of a quarter of a mile the same contact was observed 25 feet lower (Fig. 5, column C).

Other Counties—A large area in central Michigan is underlain by sandstones, shales, and gypsum assigned to the "Red Beds" (Newcombe, 1931). So far as I am

aware, however, there are no exposures of the Grand River group in counties other than those described.

STRUCTURE

Several authors, (Lane, 1902, p. 30; Smith, 1912, p. 263; Newcombe, 1928, p. 156) have stated that the beds of the Saginaw group do not share in the basin ward dip of the pre-Pennsylvanian formations. I do not agree with this statement entirely but believe that the beds of the Pennsylvanian do reflect a structure that cannot be adequately explained by primary dips alone.

There is reason to believe, as was shown under the discussion of stratigraphy, that the limestone member of the Saginaw formation, to which the name Verne is applied, and the unconformable boundary between the Saginaw and Grand River groups can be recognized wherever encountered. I have noted the available evidence concerning the elevation of the Verne limestone and the Saginaw-Grand River contact in several counties.

The data are scanty, but what there are indicate that a low area, roughly parallel to the axis of Saginaw Bay was in existence during Pennsylvanian time. It is interesting to note that this statement supports Winchell's conclusions (1861, p. 125) that the center of the coal basin lay along the axis of Saginaw Bay. The indication supports in a general way the conclusions drawn by R. B. Newcombe (1932) that post-Devonian folding in Michigan differs in trend from that of pre-Devonian time. The folding initiated perhaps in Mississippian time was probably continued in post-Verne time. This seems to be indicated in the great difference in elevation between the Verne limestone at Grand Ledge and the same limestone in the Saginaw valley. This is partly borne out by observations made on the joint system in the Grand Ledge area. The master joints have average trends of about N. 50 E. and N. 50 W. respectively. The dips of the joint surfaces approach the vertical. The joint system suggests shear planes due to a deformation involving torsion which took place subsequent to the deposition of the Eaton sandstone.

Recent work on the structure of the coal seam of cycle B of the Grand Ledge section by Messrs. Gordon Pringle, Gaylord Walker, and Rex Grant indicate an alignment of small pitching folds in a northeasterly direction. The absence of a haphazard arrangement of the folds may be due to unequal settling along some pre-Pennsylvanian ridge. The structures of the Pennsylvanian beds may reflect indirectly structures of the older systems. These minor folds are superimposed upon a regional structure, in which the beds have a northwest dip of about one-half degree.

In addition to the general northeast-southwest regional structure mentioned, the Pennsylvanian strata show numerous minor structures which are undoubtedly due to deposition upon an irregular surface and later settling and compaction of sediments. Examples of such structures are cited at Grand Ledge and Williamston.

REGISTER OF LOCALITIES GIVEN IN FIGURE 2 AND TABLE 2

A. Michigan Geological Survey No. 18978. Wolverine No. 3 Mine, Room 23, entry 4 W. of south part, S.E. corner, N.E. quarter, section 12, township 14 N., range 3 E.

B. Michigan Geological Survey No. 18999. United City Coal Mine, section 17, township 14 N., range 5 E. This locality is the same as No. 3 of the faunal list (Table 3) and No. 3 of the map (Fig. 2).

C. Michigan Geological Survey No. 18998. Bay Coal Shaft No. 2, S.E. quarter, section 4, township 13 N., range 4 E. Locality the same as No. 9 of figure 2 and Table 3.

D. Michigan Geological Survey No. 18997. Pittsburgh Shaft, quarter line section 15, township 13 N., range 4 E. Locality the same as No. 11 of figure 2 and Table 3.

E. Michigan Geological Survey No. 18989. Standard Mine, section 6, township 11 N., range 5 E. Locality the same as No. 14 of figure 2 and Table 3.

F. Michigan Mine, Black Pearl Shaft, near St. Charles. Locality near that of No. 15 of figure 3 and Table 3.

G. St. Charles Coal Company, near St. Charles. Locality near that of No. 15 of figure 2 and Table 3.

H. J. H. Somers No. 2 Shaft, near St. Charles. Locality near that of No. 15 of figure 2 and Table 3.

I. Big Chief Mine, St. Charles. Collector, C. A. Arnold. Locality near that of figure 2 and Table 3.

J. Owosso Coal Company, Owosso, Michigan.

K. New Corunna Brick Company, S.E. quarter, section 22, township 7 N., range 3 E. Locality the same as that of No. 22 of figure 2 and Table 3.

L. Grand Ledge district, sections 4, 5, 8, 9, township 4 N., range 4 W. Locality same as No. 24 of figure 2 and Table 3.

M. S.E. quarter, section 28, township 3 N., range 5 W., Eaton County. Collector, W. A. Kelly. Locality the same as that of No. 25 of figure 2 and Table 3.

N. Dump of Sam Graham Mine, N.E. quarter, section 36, township 2 S., range 2 W. Collector, W. A. Kelly.

O. Vicinity of Jackson, Jackson County. Locality probably the same as No. 28 of figure 2 and Table 3.

P. Unknown locality.

REGISTER OF LOCALITIES GIVEN IN FIGURE 2 AND TABLE 3

1. Section 3, township 19 N., range 4 E., Arenac County.
2. Wenona Beach Mine, section 33 or 34, township 15 N., range 5 E.
3. Michigan Geological Survey No. 18999. United City Coal Mine, Section 17, township 14 N., range 5 E.
4. Michigan Geological Survey No. 18993. Monitor Shaft, S.W. corner, SE. quarter, section 28, township 14 N., range 4 E.
5. Michigan Standard Coal and Mining Company, section 25, township 14 N., range 4 E.
6. Central Coal and Mining Company, section 30, township 14 N., range 5 E.
7. Michigan Geological Survey No. 18994. Central Mine Shaft. S.E. corner section 25, township 14 N., range 4 E.
8. Michigan Geological Survey No. 18995-6. Michigan Coal and Mining Company. S.E. quarter, section 25, township 14 N., range 4 E.
9. Michigan Geological Survey No. 18998. Bay Coal Shaft No. 2, S.E. quarter, section 4, township 13 N., range 4 E.
10. Michigan Geological Survey No. 18992. Valley Coal and Mining Company, S.E. corner, N.E. quarter, section 1, township 13 N., range 4 E.
11. Michigan Geological Survey No. 18997. Pittsburgh Shaft, quarterline, section 15, township 13 N., range 4 E.
12. Michigan Mine, Bay County. Specific location lacking. It may be the same as Number 8.
13. Uncle Henry Mine No. 2, Mine Dump, section 6, township 12 N., range 6 E. Collector, W. A. Kelly.
14. Michigan Geological Survey No. 18989. Standard Mine, section 6, township 11 N., range 5 E.
15. Somers Mine No. 1, near St. Charles.
16. Michigan Geological Survey No. 18983. Verne Mine, section 23, township 10 N., range 4 E.
17. Left bank of Cass River, one-half mile below bridge at Tuscola, section 29, township 11 N., range 7 E. Collector, W. A. Kelly.
18. Right bank of Flint River, near center of section 22, township 8 N., range 5 E. Collector, W. A. Kelly.
19. N.W. quarter, section 26, township 8 N., range 5 E. Collector, Alexander Winchell.
20. Mine dump near mouth of Six Mile Creek, section 18, township 8 N., range 3 E.
21. Strip mines in Section 22, township 7 N., range 3 E.
22. New Corunna Brick Company, S.E. quarter, section 22, township 7 N., range 3 E.
23. Grand River roof of mine and also outcrop near section line between sections 32 and 33, township 5 N., range 4 W.
24. Grand Ledge district, sections 4, 5, 8, 9, township 4 N., range 4 W. Collector, W. A. Kelly. The specimens indicated by a star were never observed by the author, but are reported by J. A. Cushman and J. A. Waters.
25. S.E. quarter, section 28, township 3 N., range 5 W., Eaton County. Collector, W. A. Kelly.
26. Williamston, Michigan. Collector, probably Rominger. Also, Shale pit of Michigan Clay Products Company. N.E. quarter, section 1, township 3 N., range 1 E., east side of Williamston, Michigan. Collector, W. A. Kelly.
27. Blackmail, Jackson County. Collector unknown.
28. Vicinity of Jackson, Jackson County. Specimens cited in report by Rominger (1876).
29. Looking Glass River, section 14, T. 5 N., R. 4 W.
30. East one-half, section 33, T. 3 N., R. 1 W.
31. S. W. ¼, section 24, T. 1 N., R. 5 W.
32. Section 15, T. 1 S, R. 1 W.

BIBLIOGRAPHY

Allen, R. C. 1917—Geological map of Michigan in colors, 32 x 42 inches, scale, 1:750,000. Michigan Geological and Biological Survey, Publication 23, Geological Series 19.

Arnold, C. A. 1933—Personal communication.

1934—A preliminary Study of the Fossil Flora of the Michigan Coal Basin. Contributions from the Museum of Palaeontology, University of Michigan. Vol. IV, No. 11, pp. 177-204 (7 p. 1., 1 map)

Bartlet, H. H. 1928—Fossils of the Carboniferous Coal Pebbles of the Glacial Drift at Ann Arbor. Mich. Acad. Sci. Arts and Letters, Vol. 9, pp. 11-28.

Brown, G. G. 1926—Clays and Shales of Michigan and Their Uses. Mich. Geol. and Biol. Surv., Publ. 36, Geol. Series 30.

Cooper, W. F. 1906—Geological Report on Bay County. Geol. Surv. Mich. Ann. Rep. for 1905, pp. 135-426.

1909—"Paleozoic Geology," in Davis, C. A., Report on the Geology of Tuscola County, Michigan, Geol. Surv. Mich., Annual Report for 1908, pp. 175-183; 187-196.

Cushman, J. A. and Waters, J. A. 1927—Pennsylvanian Foraminifera from Michigan. Contrib. Cushman Lab. Foram. Res., Vol. 3, Pt. 2, pp. 107-110.

Gregory, W. M. 1902—Preliminary Report on Arenac County. Geol. Surv. Mich., Annual Report for 1901, pp. 9-29.

1912—Geological Report on Arenac County. Mich. Geol. and Biol. Surv., Publ. 11, Geol. Series 8.

Houghton, Douglass 1838—Report of the State Geologist. Documents of the House of Representatives of the State of Michigan, Document 24, pp. 276-316.

Kelly, W. A. 1930—Lower Pennsylvanian Faunas from Michigan. Jour. Paleon., Vol. 4, No. 2, pp. 129-151.

1931—A Review of the Stratigraphy of the Saginaw Formation. Mich. Acad. Sci. Arts and Letters, Vol. 14, pp. 453-461.

1933—Pennsylvanian Stratigraphy near Grand Ledge, Michigan. Jour. Geol. Vol. 41, pp. 77-89.

Lane, A. C. 1895—Geology of Lower Michigan with Reference to Deep Borings. Geol. Surv. of Michigan, Vol. 5, Pt. 2.

1901a—"Suggestion from the State Geologist" Michigan Miner 3 (No. 10) 9.

1901b—The Northern Interior Coal Field. U. S. Geol. Surv., 22nd Annual Report, Pt. Ill, pp. 315-31.

1902—Coal of Michigan. Its Mode of Occurrence and Quality. Geol. Surv. of Michigan, Vol. 8, Pt. 2.

1908—Annual Report of the State Geologist. Geol. Surv. of Michigan, Annual Report for 1907, pp. 7-31.

1909—Notes on the Geological Section of Michigan. Pt. 2, Geol. Surv. Mich., Annual Report for 1908.

Miser, Hugh D. 1932—Personal letter.

Newcombe, R. B. 1928—Oil and Gas Development in Michigan. Mich. Geol. and Biol. Surv. Publ. 37, Geol. Ser. 31, Pt. III.

1931—Map of Areal Geology of Michigan, Southern Peninsula. Issued by Dept. of Conservation, Geol. Surv. Division.

1932—Unpublished manuscript.

Ries, H. 1900—Clays and Shales of Michigan, Their Properties and Uses, Geol. Surv. Mich., Vol. 8, Pt. 1, pp. 1-62.

Rominger, Carl 1876—Geology of the Lower Peninsula, Coal Measures, Geol. Surv. Mich., Vol. 3, Pt. 1, pp. 122-50.

Smith, R. A. 1912—Michigan Coal, Mineral Resources of Michigan. Mich. Geol. and Biol. Surv. Publ. 8, Geol. Ser. 6, pp. 257-303.

1917—Deep Well Borings, Mineral Resources of Michigan. Mich. Geol. and Biol. Surv. Publ. 24, Geol. Ser. 20, pp.209-256.

Walcott C. D. 1903—Twenty-fourth Annual Report of the Director of the United States Geological Survey.

Weller, J. M. 1930—Cyclical Sedimentation of the Pennsylvanian Period and its Significance. Jour. Geology. Vol. 38, pp. 97-135.

Winchell A. 1861—First Biennial Report of the Progress of the Geological Survey of Michigan, embracing observations on the Geology, Zoology, and Botany of the Lower Peninsula, pp. 112-127.

STATE OF MICHIGAN

DEPARTMENT OF CONSERVATION
P. J. Hoffmaster, Director

GEOLOGICAL SURVEY DIVISION
R. A. Smith, State Geologist