# MICHIGAN ACADEMY OF SCIENCE, ARTS AND LETTERS

## VOLUME XXXVIII

PART I: BOTANY AND FORESTRY

PART II: ZOOLOGY

PART III: GEOGRAPHY AND GEOLOGY

PART IV: GENERAL SECTION

ANTHROPOLOGY, ECONOMICS
LANGUAGE AND LITERATURE
POLITICAL SCIENCE
PSYCHOLOGY

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# PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE ARTS AND LETTERS

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# CONTENTS

Part I: Botany and Forestry

BOTANY



Part III: Geography and Geology

GEOGRAPHY



GEOLOGY



# SILICIFIED PLANT REMAINS FROM THE MESOZOIC AND TERTIARY OF WESTERN NORTH AMERICA
# II. SOME FOSSIL WOODS FROM NORTHERN ALASKA*

CHESTER A. ARNOLD

THE woods described in this account were collected along the Colville River in northern Alaska during the summer of 1951, while I was exploring for fossil plants in Naval Petroleum Reserve No. 4 in connection with a project sponsored by the Office of Naval Research and the Arctic Research Laboratory at Point Barrow.

The material identified as *Xenoxylon latiporosum* (Cramer) Gothan was found at the “Big Bend” of the Colville River, about three air-line miles south of the mouth of the Awuna River. It came from the Chandler formation of the Nanushuk group (Gryc *et al*., 6), which, on the basis of plants as well as of invertebrate fossils, belongs to the Lower Cretaceous. The specimen described as *Cedrus alaskensis*, sp. nov., was found about thirty-seven miles east of this spot, where the Oolamnagavik River joins the Colville. Although the rocks in this general region belong to the Nanushuk group, the strata at the place where the wood was found are much folded and faulted, so the exact position in the stratigraphic column cannot be given. However, the presence there of a three-foot seam of coal and of a few associated plant fragments indicates the Nanushuk group. Both specimens are therefore regarded as Lower Cretaceous.

Both woods are silicified. *Cedrus alaskensis* is a member of the Pinaceae, and *Xenoxylon latiporosum* belongs to that complex of Mesozoic gymnosperms commonly referred to as the “transition conifers.” This term is derived from the fact that the members show characters in common with more than one family or genus of Recent Coniferales. *X. latiporosum* has been regarded by various authors (Holden, 8) as being araucarian, but it has some features of modern members of the Pinaceae and is at the same time quite distinctive in itself in a number of respects. Some species of *Xenoxylon* are said to be indistinguishable from *Sciadopitys* and *Podocarpus*.

There are numerous instances on record of fossil woods in the Mesozoic and Tertiary of the Arctic regions, but very few have hitherto been found in Alaska, and none, so far as is known, on the Arctic Slope.

### *Xenoxylon latiporosum* (Cramer) Gothan

(Pl. I, Fig. 2; Pl. II)

The specimen is a small piece of what was evidently a trunk of considerable size. Although silicification had been thorough, much of the original organic matter remains in partly altered form. The shape and distribution of the pits on the tracheid walls are well preserved, but some of the chemical constituents of the walls seem to have been removed, with the result that conspicuous diagonal striations have been formed. The pattern is strongly suggestive of fungous erosion (Pl. II, Fig. 1). In transverse section the tracheid walls have a somewhat frayed appearance. The thin walls of the ray cells have also suffered considerably, and tangential sections show little of the ray structure. The rays can be studied quite satisfactorily, however, in radial section.

The name *Xenoxylon* was proposed by Gothan (4, p. 38) for *Pinites latiporosus* described by Cramer (3, p. 176) from the Upper Jurassic of Green Harbor, Spitzbergen. The distinguishing characteristics of the genus are: (1) large, contiguous, vertically flattened bordered pits on the radial walls of the tracheids, (2) very large pits in the cross fields, and (3) absence of pits on the horizontal and end walls of the ray cells. It was on the basis of the last of these characters that *Xenoxylon* was regarded as a member of the araucarian alliance. Opposed to this interpretation, however, are the large pits in the side walls, which are quite unknown among araucarians. The genus is thus a typical "transition conifer." It was a common and widely spread tree in northern latitudes during late middle Mesozoic times, and has been found in Spitzbergen, King Charles Land, Yorkshire, Poland, France, Germany, Korea, Manchuria, and western Canada. Its occurrence in northern Alaska is therefore not unexpected.

A transverse section of the wood shows a series of narrow growth rings that range in width from 0.2 to 1.25 mm., averaging 0.5 mm. (Pl. I, Fig. 2). The late-wood zone is narrow, consisting usually of only one, but occasionally of two or three, cell layers. Average-sized tracheids in the broad early-wood zone are 30-45 X 40-60 microns in tangential and radial dimensions; those in the late wood have radial diameters of 12-16 microns. In shape, they show a decided tendency to rectangularity throughout the section. No resin cells are present, nor can xylem parenchyma of any kind (except ray parenchyma) be recognized. Dark material in some of the late-wood tracheids is evidently the residue from partial disintegration of the secondary walls. The rays are strictly uniseriate and narrow, scarcely exceeding 12 microns in width, and the thin horizontal and end walls are unpitted.

In the radial section the pits in the early wood are uniseriate, vertically flattened, and transversely elongate (Pl. II, Figs. 1, 3). The transverse dimensions of the pits vary from 21 to 35 microns, but the vertical measurement is rather constantly 12 microns, or close to it. The apertures are sometimes round and sometimes slightly elliptical, but rarely oblique. They are about 5 microns in diameter. An obvious feature in pit distribution is the fact that although the pits are always close together and mutually flattened, the entire radial wall of a tracheid is not pitted. The pits are in groups of from 2 to 30 or more, and the groups are separated by unsculptured wall portions from 0.02 mm. to 1 mm. high. In the larger groups the pits tend to be more compressed by each other than in the smaller ones. The cross and vertical diameters of the terminal pits in a group tend to be more nearly equal than those of the pits in the interior. No special arrangement of the pit groups (group patterns) can be made out. At some places, where the oblique striations coincide with the pit openings, the aperture looks deceptively oblique (Pl. II, Fig. 1).

An important feature that has apparently been overlooked in *Xenoxylon latiporosum* is the presence of narrow but distinct crassulae (bars of Sanio) between the bordered pits in the tracheid walls (Pl. II, Fig. 1). Because of the crowded condition of the pits, the crassulae are narrow, but in the best-preserved tracheids they show distinctly as fine black lines about 1.5 microns wide. These structures have some bearing upon the relationships of *Xenoxylon*, because they are generally regarded as abietinean rather than araucarian characters.

The thin transverse septations in the tracheids that have been figured by Gothan (5), Ogura (12), and others, are numerous in our material (Pl. II, Fig. 3). They are present in all the tracheids, and are spaced with relative regularity at intervals of from 35 to 100 microns throughout the tracheid length. They are nearly always transverse. Ogura presents evidence of the tylosoid nature of these septations and by means of drawings shows them connected to ray cells. Although this may be the most plausible explanation of their nature, in our specimen they are present in such great numbers that connection of all of them with ray cells does not seem quite possible. Preservation of cell detail is not adequate, however, to show their exact relation to the tracheids and the ray cells.

The pits on the radial walls of the late-wood tracheids are round or squarish, with oblique openings that extend diagonally across the whole width of the radial facet (Pl. II, Fig. 2). Because of the oblique position of the slit, its length is slightly greater than the diameter of the tracheid, and, owing to their proximity, the oblique bars of wall material present a specter of tertiary spirals. That they are not tertiary spirals is shown by the fact that they do not lie directly over the pit openings, but between them.

The rays, which are 2-12 cells high, consist of thin-walled cells with pits only on the lateral walls. The ray cells are approximately 25 microns high, and seem to be of two kinds, resinous and non-resinous. The resinous cells are in continuous rows that are interspersed among rows of nonresinous cells, there being several of the latter to each one of the former. Commonly, but by no means always, there are two rows of nonresinous cells at the top and bottom of a ray, and next to them a third row composed of resinous cells. Except for their contents, there are no visible differences between the two kinds of ray cells.

The very large pits in the lateral walls of the ray cells occupy practically the entire area of the cross field (Pl. II, Fig. 3). Generally there is only one, but there may be two where an end wall lies over a cross field.

Tangential sections reveal considerable pitting in the tangential walls of the late-wood tracheids. These pits are oblique, and closely resemble those in the radial walls except for being smaller.

There are some differences between the Alaskan material of *Xenoxylon latiporosum* and the material described by Cramer (3) and by Gothan (5), but they are hardly sufficient to justify separation as species. In our specimen the pits are not quite so large: the maximum width seems to be about 25 microns, as opposed to 40 microns in the type. In addition, Cramer gives the average diameter of the tracheids in his material as 62.4 microns, whereas in ours it is slightly less. However, all previously published figures of *X. latiporosum* show striking similarities with ours in form and arrangement of both the ordinary pits and those of the ray cells.

The combination of anatomical features shown by *Xenoxylon* makes it impossible to place the genus in any existing group of modern conifers, even though araucarian affinities have been favored by Holden and other authors who have worked with it. The araucarian features cited by them are: (1) lack of resin parenchyma or resin ducts, (2) lack of pits on the horizontal and end walls of the ray cells, (3) the crowded and mutually flattened condition of the pits on the tracheid walls, and (4) the absence of crassulae.

Holden maintained that the presence or absence of crassulae is more important in distinguishing between araucarian and abietinean conifers than is the type of tracheary pitting or the occurrence or nonoccurrence of pitting on the ray cells. Although the tracheary pitting in modern araucarians is quite different from that in the Pinaceae, the same distinction does not always prevail in fossil woods. In *Brachyoxylon*, for example, both types occur, and, moreover, *Brachyoxylon* pitting is said to occur in araucarian seedlings. These examples do not disqualify pit characters as a means of distinguishing mature secondary wood of the two families of conifers, but they do show that the difference is not quite so fundamental as was once supposed. Furthermore, the criterion of whether or not the ray cells are pitted, a feature stressed by Gothan (4), is not wholly satisfactory in distinguishing fossil woods, because *Araucariopitys*, a Lower Cretaceous genus, shows tracheids with typical abietinean pits along with unpitted rays of the araucarian type.

Because pit characters are not infallible criteria for distinguishing araucarian and abietinean fossil woods, Holden used the crassulae, maintaining that these thickenings in the middle lamella between pits are consistently absent from all araucarians and their relatives, both ancient and modern. Bailey (1), however, in an ably presented appraisal of anatomical features in common use for identification of Mesozoic coniferous woods, says that the absence of crassulae is by no means an absolute criterion of araucarian affinities. He points out the uncertainties of preservation, and notes that in some living woods careful differential staining is necessary to reveal these structures. Thus if too much trust is placed upon the fact that crassulae are not visible in a given instance, an abietinean would be proclaimed araucarian simply because the crassulae were not preserved or not stained.

If woods that show crassulae are positively not araucarian, as Holden maintained, we are forced to uproot *Xenoxylon* from among the araucarians and transplant it among the Pinaceae. However, the combination of characters present shows that this cannot be done with complete abandon because discovery of the crassulae does no more than subtract one of the several araucarian traits and substitute an abietinean trait in its place. There are other characters whose status remains unchanged. Considerable confusion and misunderstanding about the affinities of fossil conifers has resulted from an “either-or” attitude on the part of investigators who have endeavored to force *misfits* into modern families where they do not belong. Xenoxylon is an example of a fossil conifer that cannot be placed with positiveness in any modern family, and an arbitrary disposition of such woods only causes confusion.

Although there is no direct evidence of a connection between the wood and the other organs in the material under consideration, it may be noted that foliage of both *Podozamites* and *Baiera* is abundant at the place where it was found. Foliage of members of the Taxaceae is also present, but affinity with this family is not probable.

*Horizon*.—Chandler formation of the Nanushuk group, Lower Cretaceous.

*Locality*.—”Big Bend” of the Colville River, three miles south of the mouth of the Awuna River, Naval Petroleum Reserve No. 4, Alaska.

**Cedrus alaskensis**, sp. nov.

(Pl. I, Figs. 1 and 3; Pls. Ill and IV)

The specimen described here is a piece of secondary wood from the outer part of a silicified trunk embedded in sandstone above a three-foot seam of coal.

A transverse section shows a series of well-marked growth rings that range from 2 to 4 mm. in width. The early-wood zone is much wider than that of the late wood, and is made up principally of rectangular and hexagonal tracheids that measure 40-50 X 55-90 microns. In many of the tracheids the tangential walls are conspicuously thicker than the radial walls (Pl. IV, Fig. 2). During the process of partial degradation of the walls previous to silicification, the middle lamella and the primary layers disintegrated to a greater extent than did the apparently more strongly lignified secondary walls. The result is that in the thin sections narrow open spaces appear within the tangential wall complexes.

A few vertical resin ducts show in the transverse section. Some resemble the so-called normal type, but others are evidently the result of injury to the cambium.

The normal ducts are rare, only five being present in a section that measures 3 X 4 cm. They can consequently be easily overlooked, and in small wood fragments might not be present at all. Regardless of their scarcity, however, they are important from the standpoint of identification. The normal vertical ducts are considerably larger than the horizontal ducts (Pl. III, Figs. 1-2). The resin cavity is surrounded by a layer, one or two cells deep, of epithelial cells with slightly thickened walls and numerous pits.

The traumatic ducts occur both singly and in short arcs in the late wood (Pl. III, Fig. 3). Their cavities are similar in size to those of the normal ducts, and are surrounded by cells with similarly thickened walls. These ducts, too, are rare, only one short arc about 2 mm. long and a few isolated ducts occurring in the section 3 X 4 cm. large mentioned above.

All the rays except those containing horizontal ducts are narrow and have minute but distinct pits on the horizontal walls of the cells.

The horizontal resin ducts are long: in one instance a duct can be followed across seven growth layers. They are flanked by one or two layers of parenchyma cells that resemble ordinary ray parenchyma in wall characteristics and in pitting (Pl. IV, Fig. 4). Sometimes these ducts terminate abruptly at the outer limit of the late wood of a growth ring, with ordinary tracheids replacing them in the second ring. Connections between the horizontal and the vertical ducts can be observed in a few places, but it is uncertain whether all of the horizontal ducts arise from vertical ducts.

In radial section the pits on the walls of the late-wood tracheids are round, uniseriate, and distantly spaced. In the early wood they are mostly biseriate and opposite (Pl. I, Fig. 3; Pl. IV, Fig. 1), although the uniseriate and triseriate conditions may occasionally be observed. The pits vary from well separated to crowded. There is a tendency at places for the pits to be clustered into small groups of from 2 to 4 (Pl. IV, Fig. 3). Where separated, the pits are round, but the more crowded ones show slight flattening or angularity. The diameter of the pit cavity is about 21.5 microns, and the conspicuous torus is about 7-8 microns. The aperture is circular in all pits. Crassulae about 2 microns wide are present wherever the pits are close together (Pl. I, Fig. 3).

The ray cells are all parenchymatous, measure about 17 microns high, and have oblique ends. They are pitted on all walls— abundantly on the horizontal and end walls, but sparsely on the lateral ones. Each cross field has 2-4 small circular pits about 6 microns in diameter (Pl. I, Fig. 3).

In tangential section the simple uniseriate rays are narrow and very small—only about 12 microns wide and 2-30 cells high, the average being about 12 cells (Pl. III, Fig. 2; Pl. IV, Fig. 5). The triangular intercellular spaces show between the corners of the ray cells and the adjacent tracheids (Pl. IV, Fig. 5). Occasionally blind pits directed toward the intercellular spaces are visible.

The horizontal resin ducts are smaller and more numerous than the vertical ones. In one tangential section measuring 1.3 X 4 cm., eighty-seven ducts were counted. Although the ducts occur throughout the section, they tend to be somewhat patchy in distribution. There are places where as many as six can be seen within the bounds of a microscopic field 4 mm. in diameter; at other places none occur within an area of that size. It is impossible to see how these could all be connected with vertical ducts, because the latter are so scarce.

Pitting of the tangential walls of the tracheids appears to be limited to the outermost row of late-wood tracheids and then mostly to the outermost wall. On this wail a few small scattered pits can be seen. Tangential pitting is not a conspicuous feature in this wood.

In the wood under consideration the most important anatomical characteristics may be summarized as follows:

1. Conspicuous growth rings, with thin late-wood layers
2. Scattered normal and traumatic vertical resin ducts
3. Numerous horizontal resin ducts
4. Walls of cells surrounding resin ducts pitted
5. Tangential walls of tracheids thicker than radial walls
6. Predominately opposite, occasionally semiclustered, arrangement of pits on radial walls of tracheids
7. Large torus
8. Distinct crassulae between pits
9. Absence of ray tracheids
10. Ray cells pitted on all walls
11. From 2 to 4 small circular pits in each cross field
12. Sparse tangential pitting

The combination of anatomical characters listed above is more indicative of *Cedrus* than of any other genus of conifers, either living or extinct. The presence of apparently normal vertical and horizontal resin ducts immediately suggests affinity with *Pinus*, *Picea*, *Larix*, and *Pseudotsuga*, but these are all eliminated for one reason or another. *Pseudotsuga* is out of consideration because of the absence in the fossil of tertiary spirals in the tracheids. The pitted walls of the epithelial cells and the predominately biseriate pitting are contrary to what one finds in *Pinus*. There is no point in making detailed comparisons with *Picea* or *Larix* because of the lack of ray tracheids, the character of the pitting, and other features.

Although *Cedrus* is said to lack normal vertical resin ducts (Jeffrey, 9; Penhallow, 13), isolated ducts showing no visible differences from so-called normal ducts do occur. Living species have ray tracheids, which are lacking in the fossil material; but they are also lacking in *C. penhallowii*, a fossil species from the Miocene (Barghoorn and Bailey, 2). Except for the absence of ray tracheids in *C. alaskensis*, the structure of the rays is almost identical with that in modern species, the similarity extending to the occurrence of blind pits directed toward the intercellular spaces. The most evident features, however, pointing to *Cedrus* are the distribution of the pits on the radial walls of the tracheids, the large conspicuous tori, the presence of prominent crassulae between adjacent pits in vertical series, and the pitted epithelial cells. Biseriate opposite pitting is the rule throughout the broad early-wood zone, but multiseriation occurs occasionally. In the transition from early to late wood, where the tracheids begin to narrow, biseriation gives way to uniseriation, and it is in this zone that the slight tendency toward grouping and sometimes toward partial alternation is observed. In this transition zone the pits in some tracheids are widely separated and the crassulae disappear (Pl. IV, Fig. 3). The tendency toward alternation is never pronounced, and no special importance can be attached to it. Similar situations, however, have been noted in living species.

The problem of choosing suitable generic names confronts every investigator working with Mesozoic woods, and often the dilemma can be met only by describing new genera. The result has been that practically every author who has described Mesozoic woods has one or more generic names to his credit, and the tendency to set up new genera increases as time goes on. In the old days names like *Pinites* and *Pitus* were applied without much discrimination, but paleobotanists become more discerning as they learn more about living coniferous woods. Because of the necessity of drawing fine distinctions between fossil genera, the number is large. Kräusel (10) listed more than seventy in 1919, and additional ones have subsequently been named. Only a small share of these, however, have been described in sufficient detail to render them usable.

Bailey (1) has endeavored to simplify the situation with respect to abietinean-wood nomenclature by reducing the number of generic names to three, each one embracing those fossil woods that fall within the structural range of a particular genus or group of genera. Thus *Pinuxylon* includes those woods that come within the structural range of *Pinus*. *Piceoxylon* embraces those within the structural range of *Picea*, *Larix*, and *Pseudotsuga*, and *Cedroxylon* is the fossil counterpart of the woods of the *Keteeleria*, *Pseudolarix*, *Cedrus*, *Tsuga*, and *Abies* types. Several fossil genera would also be included under *Cedroxylon*.

In regard to the fossil wood under consideration here, the peculiar situation exists that the fossil genus *Cedroxylon* is not so appropriate for it as is *Cedrus*. *Cedroxylon*, as commonly defined, lacks vertical ducts (except for traumatic ones) and has ray tracheids, a situation largely reversed in our fossil. Furthermore, the resemblances to *Cedrus* are more exact in other respects. If a fossil epithet were to be used, the most suitable one would probably be *Pityoxylon*, which would merely denote affinity with the *Pinaceae*. *Cedrus alaskensis* differs from the modern species of the genus in lacking ray tracheids, thereby resembling *Cedrus penhallowii* from the Miocene (Barghoorn and Bailey, 2).

Wood identified as *Cedroxylon* has been reported several times from the Arctic in rocks ranging from Jurassic to Tertiary (Gothan, 5; Høeg, 7; Seward, 14; Walton, 15; Mathiesen, 11). The wood from the Colville River in northern Alaska, however, is not only the first instance of the occurrence of the genus *Cedrus* in Alaska, but apparently constitutes the oldest record of wood more appropriately referable to that genus than to *Cedroxylon*. Lack of ray tracheids appears to be the main difference between it and modern species. Three species of *Cedroxylon*, *C. greenlandicum* (Walton, 15), *C. orvini* (Høeg, 7), and *C. nordenskjoldi* (Mathiesen, 11), have been described from Greenland, but from formations believed to be of Tertiary age. None of them are identical with *Cedrus alaskensis*. *Cedroxylon greenlandicum* has vertical wood parenchyma interspersed in the late wood, and horizontal resin ducts are not mentioned in the description. *Cedroxylon orvini* also has vertical parenchyma; it differs further from our species in having a few marginal-ray tracheids. The regular tracheid pits are uniseriate, and horizontal resin ducts are apparently lacking. *Cedroxylon nordenskjoldi* appears to be based on root wood. It resembles *Cedrus alaskensis* rather closely in pit characteristics and in having horizontal ducts. It differs, however, in its rather numerous ray tracheids. *Cedrus alaskensis* is probably closer to *Cedrus penhallowii* than to any of the Arctic species of *Cedroxylon*, the main difference between the two being the crystal-bearing cells along the margins of the rays in *Cedrus penhallowii*.

*Horizon*.—Presumably the Nanushuk group, Lower Cretaceous.

*Locality*.—Right bank of the Oolamnagavik River at its junction with the Colville River, Naval Petroleum Reserve No. 4, Alaska.

I wish to express my appreciation to Dr. E. S. Barghoorn, who examined sections of *Cedrus alaskensis* and gave me his opinions concerning its relationships.

UNIVERSITY OF MICHIGAN

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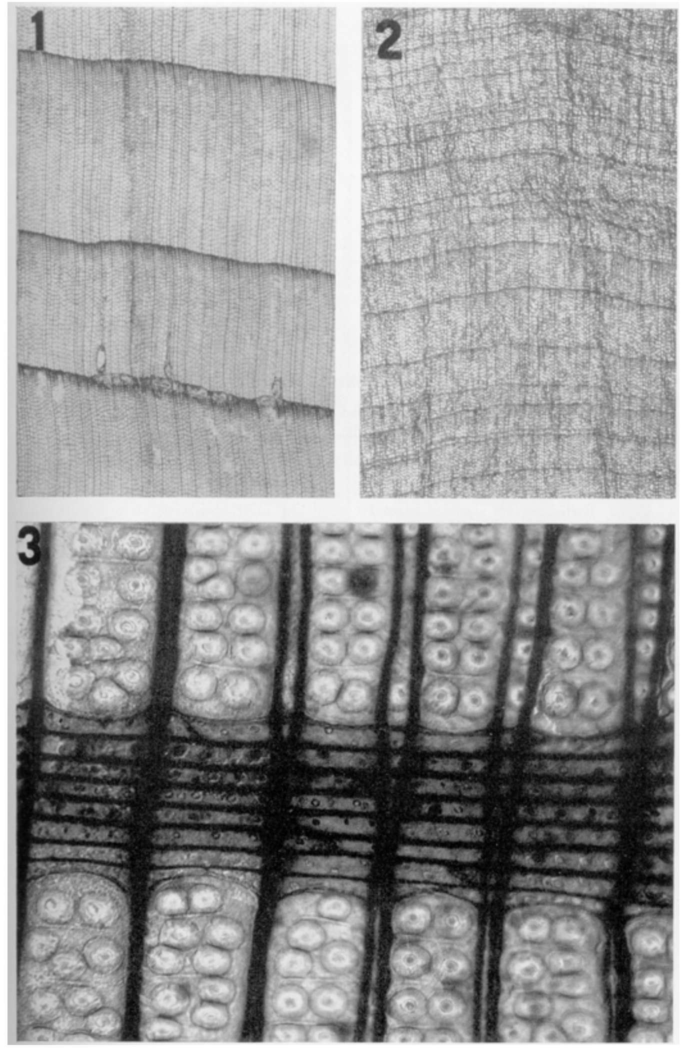
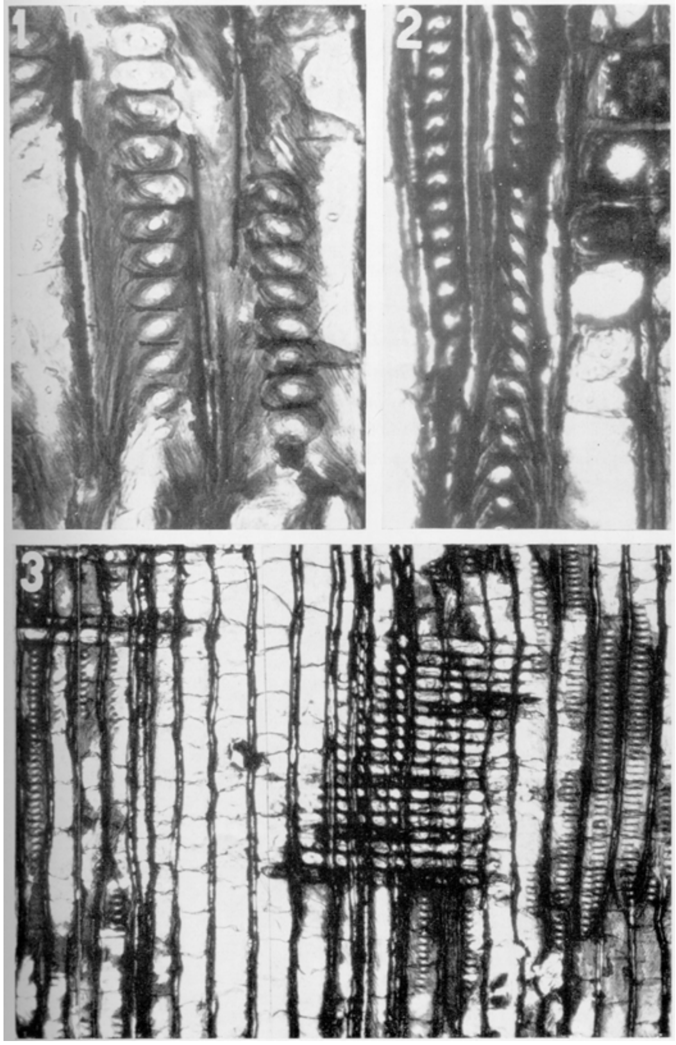



EXPLANATION OF PLATE I

FIG. 1. *Cedrus alaskensis* Arnold, sp. nov.: transverse section showing growth rings and arc of traumatic resin ducts. X 10

FIG. 2. *Xenoxylon latiporosum* (Cramer) Gothan: transverse section showing narrow growth rings. X 10

FIG. 3. *Cedrus alaskensis* Arnold, sp. nov.: radial section showing small circular pits in the cross fields and biseriate opposite pitting and crassulae in the tracheid walls. X 220



EXPLANATION OF PLATE II

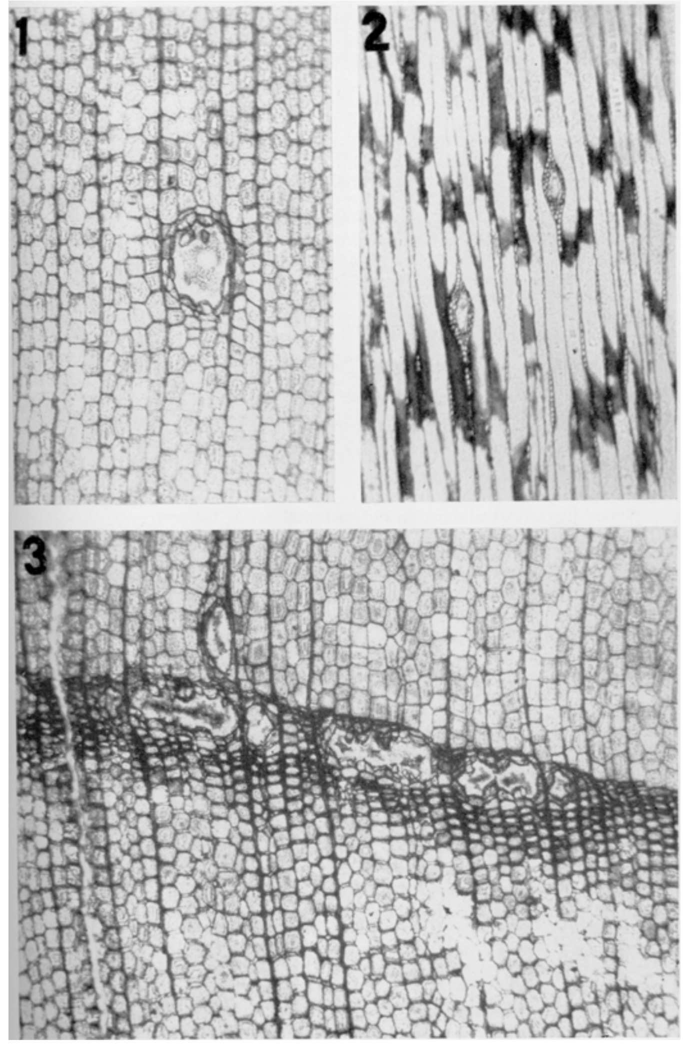
*Xenoxylon latiporosum* (Cramer) Gothan

FIG. 1. Radial section showing the crowded and flattened pits separated by crassulae, and unpitted portions of tracheid walls. X 490

FIG. 2. Radial section showing oblique pit apertures in narrow late-wood tracheids. X 490

FIG. 3. Radial section showing character of pitting in tracheids, septa in tracheids, and large cross-field pits and resin cells in rays. X 100





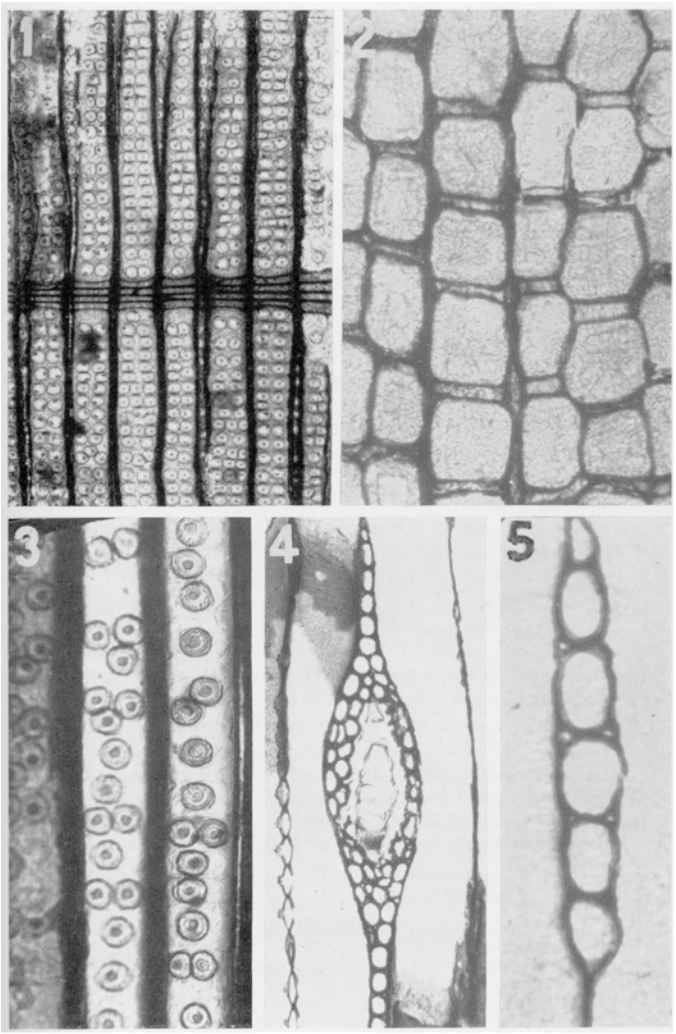
EXPLANATION OF PLATE III

*Cedrus alaskensis* Arnold, sp. nov.

FIG. 1. Transverse section showing normal resin duet. X 70

FIG. 2. Tangential section showing two horizontal resin ducts. X 70

FIG. 3. Transverse section showing portion of arc of traumatic ducts in late wood. X 70




EXPLANATION OF PLATE IV

*Cedrus alaskensis* Arnold, sp. nov.

FIG. 1. Radial section showing distribution of pits. X 100

FIG. 2. Transverse section showing difference in thickness of radial and tangential walls. In the tangential walls the middle lamella and primary wall layers have mostly disappeared. X 250

FIG. 3. Radial section in transition region from early to late wood showing tendency toward alternation and clumping into small clusters. X 185

FIG. 4. Fusiform ray containing horizontal resin ducts in tangential section. X 250

FIG. 5. Tangential section of an ordinary ray showing secondary wall thickening and intercellular spaces. X 700

# CLASSIFICATION OF MICHIGAN LANDS ACCORDING TO USE CAPABILITY

LINDO J. BARTELLI AND CLARENCE A. ENGBERG

THE science of land classification covers a multitude of activities, and during its growth it has become increasingly varied in technique and application. Throughout this development, the broad objective has frequently been, and still is, the promoting of the wise use of land resources. As the scope and the character of land problems have widened, the demands on classification have multiplied. The United States Soil Conservation Service, working with the soil-conservation districts, has evolved a system of classifying land and interpreting its qualities which is helpful in explaining land conditions to the layman. The success of this system has been well demonstrated by thousands of Michigan farmers who have effectively employed land-capability maps of their farms as a basis for the efficient use of each kind of land found there. The land-capability classification is one in which all the conditions of the land that affect its use in agricultural production are considered. Land characteristics and climatic factors as well as present and future production potentials are taken into account.

According to this system, each farm, or mapping unit, is classified according to the *degree* of its limitations in use, or the risks of damage, into one of eight broad land-capability classes. Subclasses are recognized within each class according to the dominant kind of limitation (risk of erosion, excess water, unfavorable soil characteristics, or climatic limitations). This paper is concerned with the criteria used in Michigan and in the other states of the Upper Mississippi Valley in placing a given kind of land in one of the eight land-capability classes.

Class I land needs little special conservation treatment. Classes II, III, and IV require increasing degrees of care and protection. The remaining four classes are not suited to cultivation; they need the protection afforded by a permanent cover of vegetation. Classes V, VI, and VII require progressively more care, even when used for grazing or forestry. Class VIII can be used safely only for wildlife recreation, or watershed purposes.

In other words, the land-capability classes are an index to the hazards in the use of a particular piece of land. If the hazard is relatively simple to overcome, the land is placed in class II; but if it is a little more difficult to overcome, in class III. Land-capability classes are thus distinguished from each other according to the degree of the inherent permanent limitations or risks involved in land use. Figure 1 shows the safe uses of land of each class (3, p. 10).

## Basic Considerations in Determining Capabilities

In order to make maximum use of the land-capability concept scientists of the Soil Conservation Service have developed criteria for judging the capabilities of various parcels of land. The system is founded on two sets of characteristics: first, the internal soil characteristics, which yield a tentative (basic) capability-class rating; second the associated features of the land. The final capability-class rating reflects the limitations or risks imposed by these two sets of characteristics.

### SOIL CHARACTERISTICS

The internal soil characteristics which are employed in determining the tentative capability class fall into three groups: (1) the physical group of depth, texture, and permeability; (2) the moisture-holding capacity, and (3) the nutritive group of organic-matter content and inherent fertility.

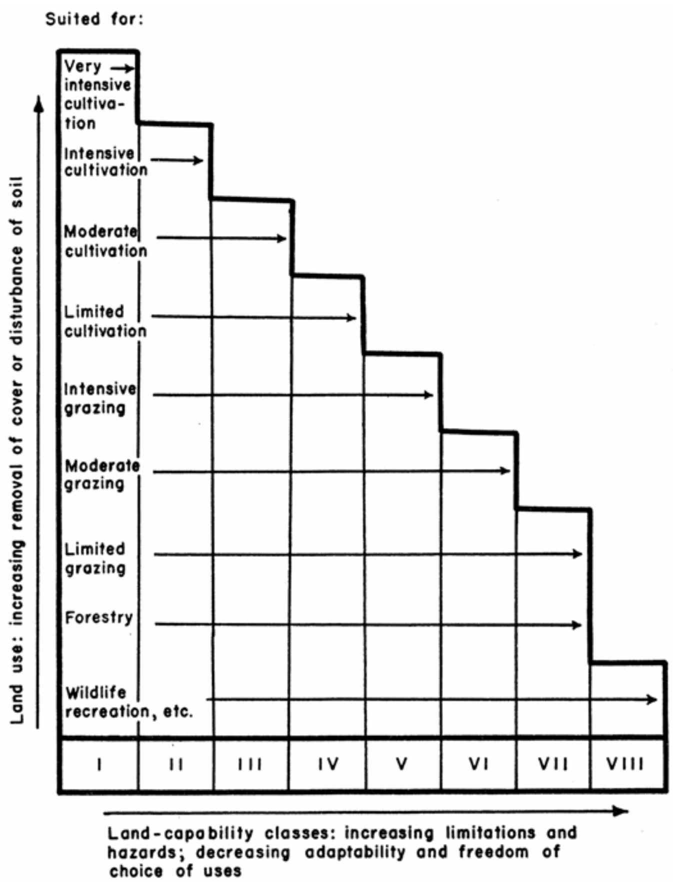



FIG. 1. Relation of land limitations and land-capability classes to safe land use

In the physical group, *depth* is defined as thickness of soil over any layer that greatly restricts or retards plant growth, such as bedrock, clay pan, or gravel. Depth is an important factor in the ability of the soil to furnish growing space for the root system of the plant and to provide sufficient water and nutrients. Most of the common crops do well in a root zone that is from three to four feet thick. Thus a soil depth of less than thirty-six inches imposes a degree of risk to cropping.

Texture of surface soil is closely associated with tilth and workability. It also influences erodibility, infiltration, permeability, and other soil characteristics significant in plant growth. Coarse and very coarse soils (sand and loamy sands) permit slippage and other difficulties in the operation of tillage implements, and they permit rapid decomposition of organic matter. On the other hand, very fine-textured soils (sandy clays, silty clays, and other clays) are extremely susceptible to clodding if worked when wet. Therefore, very coarse and very fine-textured soils are unfavorable for cultivation. Medium-textured soils (loams and silty loams), moderately fine-textured soils (silty clay loams, clay loams, and sandy clay loams), and moderately coarse soils (sandy loams), which do not give any particular trouble in tilth or working, are favorable. Fine-textured (silty clays and sandy clays) and coarse (loamy sands) soils represent intermediate conditions, with some hazards and problems in use. In organic soils, mucks are somewhat unfavorable and peats are unfavorable.

*Permeability* (of subsoil and substratum) may be defined as the capacity to transmit water or air. The seven degrees of subsoil permeability which express the most significant variations of this factor in agricultural soils (2, p. 9) are given in Table I.

TABLE I

PERMEABILITY CLASSES AND THEIR DEFINITIONS IN TERMS OF PERCOLATION RATES

| *Permeability class* | *Percolation in inches per hour through saturated undisturbed cores under one-half-inch head of water* |
|---|---|
| Very slow | Less than .05 |
| Slow | 0.05 to 0.20 |
| Moderately slow | 0.20 to 0.80 |
| Moderate | 0.80 to 3.00 |
| Moderately rapid | 3.00 to 5.00 |
| Rapid | 5.00 to 10.00 |
| Very rapid | More than 10.00 |

Soil permeability is an important factor in the design of an artificial drainage system. For example, drainage systems are often designed to remove one-half inch of excess water to plow depth in a twenty-four-hour period. That being so, soils with very slow permeability are not drainable as a rule, for it would take six days for one-half inch of water to move by gravity to a depth of seven inches. (An exception to this rule would be soils in which expansion and shrinkage occur and so facilitate the percolation of water.) In a soil characterized by slow permeability, it would require twenty-four hours to remove one-half inch of surplus water. Presence of excess water retards the rate of soil warm-up in the spring or after a rain. Thus, soils of very slow and slow permeability should be listed as unfavorable to cultivation. Very rapid permeability, on the other hand, permits a high rate of air movement and an excessive warming of the soil; these, in turn, stimulate oxidation of the organic matter. Consequently, very rapid permeability is considered unfavorable in agricultural soils. Field observations indicate that the most productive soils have moderate to moderately rapid permeability. Therefore, these permeabilities are listed as favorable. Moderately slow and rapid permeabilities are intermediate conditions and are listed as moderately favorable.

*Substratum permeability* is rated by the same system that is used for subsoil permeability. Although the character of the substratum is an important factor only for shallow soils, it does have some effect on soils of imperfect, poor, and very poor natural drainage.

The second internal soil characteristic, the *moisture-holding capacity* of a soil, is defined as its capacity to store water that is available for plant growth. Stated briefly, available water is that amount between the point at which plants wilt and field capacity. Under climatic conditions in Michigan a soil with optimum productivity must be able to store a thirty-day supply of water for most plant growth; consequently, a soil must have a moisture-holding capacity of six inches or more of water in sixty inches of soil depth to be classed as favorable to cultivation.

In the nutritive group of soil characteristics, *inherent fertility* is here defined as the ability of the soil to supply nutrients to the plant and the amount of nutrients available in the soil. It is also the ability of the soil to hold or retain the nutrients added to it until they are needed by plants. It affects plant growth, the kinds of crops which can be raised, and the yields. A soil of high or moderate fertility can be regarded as favorable, and one of very low fertility as unfavorable.

The *organic-matter content* of a soil is commonly a fair index of its durability and productive capacity. The amount of organic matter affects the tilth, structure, moisture capacity, and erodibility of a soil. A high or medium content can be regarded as favorable and a very low content as unfavorable.

Table II shows maximum capability-class ratings for each of the significant levels in these soil characteristics in Michigan. The lowest capability rating assigned to any characteristic of a particular soil unit determines the tentative capability rating of that soil unit. Thus a soil with a depth of forty-eight inches, fine texture, slow permeability, an eleven-inch moisture-holding capacity, very low organic content, and high fertility would have a tentative (basic) capability rating of III. An exception to this rule occurs where a minimum rating is given in each of the three groups of soil characteristics—the physical group of depth, texture, and permeability, the water-holding capacity, and the nutritive group of organic-matter content and inherent fertility. The basic capability rating of such a soil is class VII.

TABLE II

CAPABILITY-CLASS RATING OF SOIL CHARACTERISTICS IN MICHIGAN

| Soil characteristics | Class I | Class II | Class III | Class IV |
|---|---|---|---|---|
| Depth | Very deep, deep (36 in.) | Moderately deep (20-36 in.) | Shallow (10-20 in.) | Very shallow (less than 10 in.) |
| Texture | Moderately fine, medium, moderately coarse | Fine, coarse, muck | Very fine, very coarse, peat | .... |
| Permeability | Moderately slow, moderate, moderately rapid | Slow, rapid | Very slow, very rapid | .... |
| Moisture-holding capacity | 9 in. or more | 6 to 9 in. | 3 to 6 in. | Less than 3 in. |
| Organic-matter content | Medium to high | Low | Very low | .... |
| Inherent fertility | Moderate to high | Low | Very low | .... |

## ASSOCIATED FEATURES OF THE LAND

The final capability class is obtained by evaluating the effects of the associated features of the land and superimposing these on the tentative, or basic, capability-class rating. These associated features are: slope of the land, existing erosion, wetness, overflow or flooding, stoniness, soil reaction, and climate.

Slope of the land affects the velocity of runoff water and the rate of soil erosion. Since soil erodibility by water is closely related to degree of slope, capability class is related to slope. Research stations in several places have determined the rates of soil loss that may be expected for various degrees of slope. In relating these expected losses to the capability-class rating, a rate of loss in excess of 3 tons an acre a year is established as shifting a soil with a basic capability rating of class I to class II; a rate of over 12 tons shifts it to class III; of over 30 tons, to class IV; of over 55 tons, to class VI; and of over 85 tons, to class VII.[1] The expected soil loss is calculated from a soil-loss formula of the Soil Conservation Service, based on a corn-oats-meadow rotation and a slope length of 200 feet (1).

The amount of erosion that has already occurred also has an effect upon the hazards in the use of land. The degree of hazard varies with the nature of the subsoil and the depth of the soil. To facilitate the evaluation of erosion, soils are grouped into three broad classes: Group A includes soils in which the characteristics of the subsoil differ little from those of the surface soil except for organic-matter content. Group B includes soils with a subsoil that is finer textured and more compact than that of the surface soil. Group C includes soils in which the characteristics of the subsoil are markedly different from those of the surface soil and in which the subsoil is a much more unfavorable medium for tillage and plant growth. Degree of erosion influences the capability-class rating most in the soils of Group C.

When too much free water within the effective depth of soil during the growing season interferes with the growth of crops, this condition changes the capability class based on a consideration of the soil, slope, and erosion conditions. The degree of change is dependent on the extent to which crop usage of the land is limited. Wetness may be the result of a high permanent water table, of a suspended or temporary water table, of seepage from higher areas, of slow water movement (as on level areas), or of slow underdrainage due to fine texture or unsatisfactory soil structure. These conditions can usually be inferred from soil-profile characteristics or from the kind of vegetation present.

In some situations overflow or flooding also influences the use and management of land. When this condition exists, final capability-class ratings are made on the basis of the frequency of flooding or the amount of soil deposition to be expected.

Other land or site features such as stoniness, soil reaction, and climate may affect the use of the land. When occasion requires, they are considered in arriving at the final land-capability class rating.

This paper has dealt with the soil and the associated features of the land which are significant in determining the wise use of land resources. These factors are translated into land-capability maps, which are used by farm-planning technicians as guides in developing, in cooperation with the farmer, a scientific plan for the proper use and protection of all land on the farm.

UNITED STATES SOIL CONSERVATION SERVICE
EAST LANSING, MICHIGAN

[1] Class V land is level, wet land having no erosion problem; thus no soil-loss rate is assigned to it.

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# THE TREND OF RURAL AND URBAN POPULATION IN MICHIGAN FROM 1940 TO 1950

DONALD EUGENE BRUYERE

INCREASING urbanization has been a characteristic of population growth in much of the United States during recent decades, and has been apparent even in areas where there is a well-developed agricultural pattern. This trend is exemplified in population changes in Michigan during the period from 1940 to 1950. Because of the wide diversity of agricultural pattern and production as well as the great variation in urban settlement and industrial output in this state, a comparative analysis of the population trends there indicates many significant aspects of the widespread urbanization throughout the country.

More than half of the population of Michigan was living in cities by 1920.[1] Greater farm mechanization in conjunction with increasing industrialization promoted urban growth immeasurably, for mechanization of farms released rural workers to fill the new jobs created in the manufacturing centers. Migration to the highly urbanized southern part of Michigan from the northern rural areas became common.

Within the last two decades a trend toward dispersal of population has occurred in Michigan cities which somewhat alters the pattern of this farm-to-city movement. The coming of the automobile as an economical and general mode of transportation has influenced people to shift from the inner zone of the city toward its suburbs.[2] The rate of growth of the suburbs has tended to outdistance that of the inner zone, just as the growth of peripheral trade areas has outdistanced that of trade areas in the center.

Detroit proper gained 226,116 people (a growth of 13.9 per cent) in the ten years preceding 1950.[3] In comparison, the combined suburbs of Detroit increased an impressive 64.8 per cent in total population.

The definition of “urban” used in previous censuses covered all incorporated places of 2,500 inhabitants or more and certain unincorporated areas (usually minor civil divisions) classified as urban under special rules relating to population and size. This definition includes the suburbs of Detroit and other cities, but fails to account for the “rurban”[4] population in the fringe areas. The gains recorded in rural population in Michigan are misleading, for they are predominantly based on concentrations around urban centers (see Figs. 1 and 2). It is not that people are moving to farms, but that they are moving to suburban homes on the periphery of the cities. Such settlement, classified as rural in the exact census, is essentially rurban in character. If these people were included in the urban statistics, the gain in population figures for Michigan cities would be impressively greater.

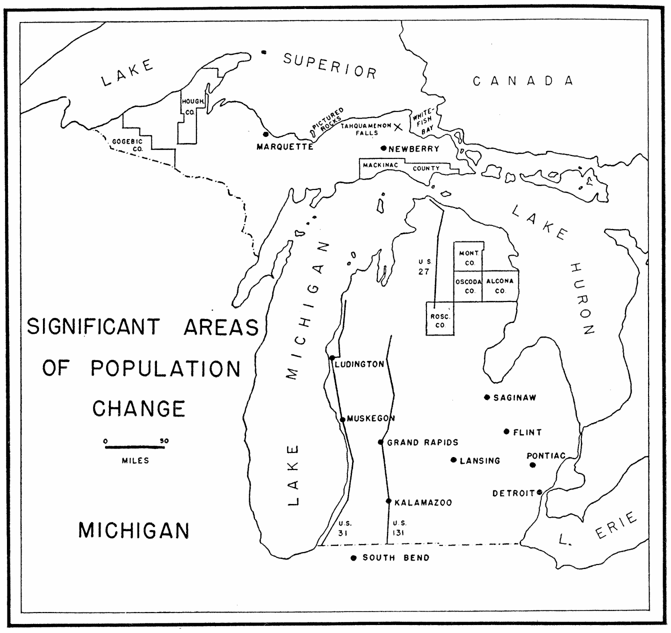


FIG. 1

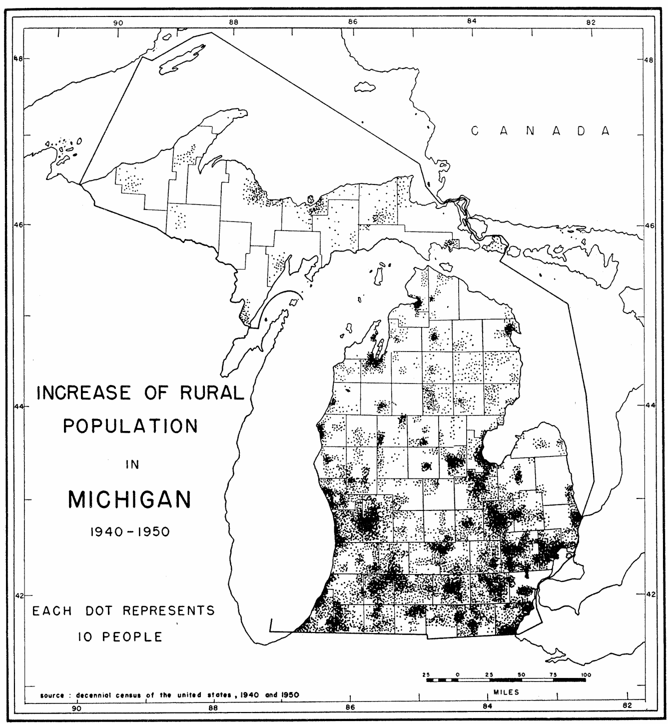


FIG. 2

Because 1950 was the first year that the new classification "rurban" went into effect, the earlier definitions employed in taking the census had to be used to map and analyze the trend in the rurban areas for the preceding decade. Under the old definition the urban population accounted for only 64.3 per cent of the state's total population, whereas under the new, 1950 definition which included the rurban fringe, urban inhabitants would constitute 70.7 per cent of the total.[5]

Under the new definition the 1950 urban population of Michigan included: (1) the 4,099,007 inhabitants of the 139 incorporated places with 2,500 residents or more; (2) the 58,890 inhabitants of the eleven specially mapped unincorporated places of 2,500 residents or more; and (3) 345,187 persons living in other areas in the urban fringes of nine cities.[6] The rurban population, 404,007 persons out of a total distributed rural increase of 671,520 persons, constitutes the gain in the urban centers of Michigan which resulted from the change in definition (Fig. 3).

Many areas throughout Michigan show increasing density of population while remaining essentially rural. These gains are not so much the result of new immigration as they are the expression of a marked tendency among residents to shift to better locations within the state. Only a few such areas have developed north of the Straits of Mackinac.

In the Upper Peninsula the region extending northeast from Newberry to Whitefish Bay exhibits a rural increase related to the fact that access has recently been provided to the Tahquamenon Falls, a major tourist attraction. A crescent-shaped area of population growth from Marquette to the Pictured Rocks (Fig. 2) is also attributable to tourism. People are settling in these places to serve the summer trade. The central part of Houghton County and the southeast corner of Mackinac County are likewise growing predominantly in response to increased recreational possibilities.

A high percentage of the rural gain in the Lower Peninsula, also, is traceable to new developments in the recreational use of land. The affected areas lie chiefly along the shores of the Great Lakes and on inland lakes. The thick clustering of people in the western half of Roscommon County reflects the presence of Houghton and Higgins lakes and their increasing importance as year-round recreational areas. Hubbard Lake in the north-central part of Alcona County is another regional attraction which has raised local standards of living and thereby helped cause a rearrangement of population in its immediate vicinity.

Improved transportation is likewise a factor in shifts in the rural population of Michigan. In Montmorency and Oscoda counties rural settlement has moved from one end of the county to the other with the development of tourism along a new or improved highway. Rural population gains are outstanding along certain lengths of U. S. Highways 131, 27, and 31.[7]

These increases in population resulting either from improved roads or from the development of recreation must be classified as rural gains. They are nonurban, and they should not be confused with the agricultural resident population.

Rural population gains among those engaged in farming are slight. Today in Michigan farmers seldom move from one farm to another. When, and if, they leave their farms, they tend to move either to a city or to its fringe, and their occupation changes to fit their urban environment.

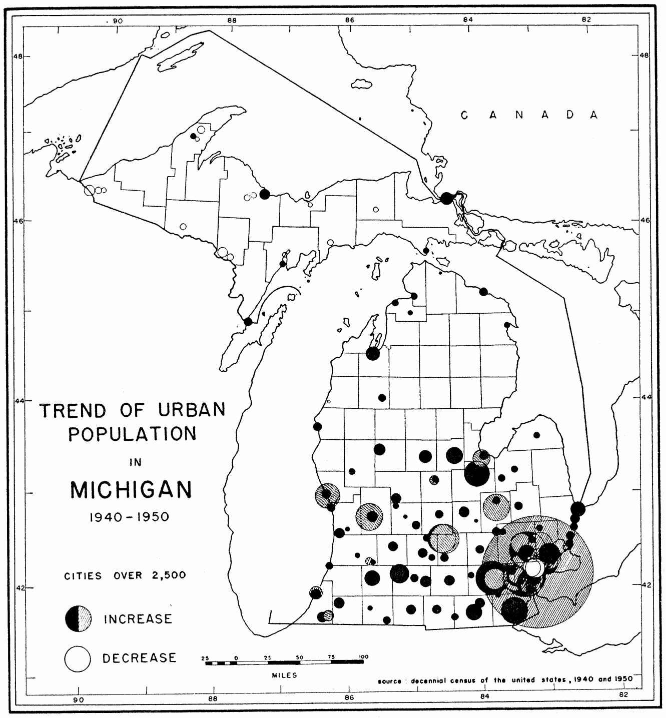


FIG. 3

Many areas throughout Michigan are losing their rural population. The rate of loss is greater in the Upper Peninsula than in the Lower Peninsula (Fig. 4). Pour out of every five Michigan cities which decreased in population were located north of the Straits of Mackinac. The majority of people in the Upper Peninsula, urban as well as rural, are supported by the exploitation of minerals there. The closing of copper and iron mines has spurred migration from the mineral ranges. Some people have moved to other areas within the Upper Peninsula, but large numbers have had to leave the region to find work elsewhere. Huge losses of population have occurred in the Keweenaw Peninsula and along the Michigan-Wisconsin border. In contrast to this general pattern, no rural losses have occurred in the Lake Superior coastal areas east of the Huron Mountains.

The Upper Peninsula, handicapped by a short growing season and poor soils, has never had a large farming population. The relatively few farms have been either subsistence enterprises or small plots bearing crops for the local urban markets. These markets have been reduced through emigration. Consequently, farmers who were dependent upon them have either had to find new markets or move to other farming areas in better economic balance. Farms have been abandoned, and some townships have lost more than half of their population.

In addition, severe losses of population in the Upper Peninsula have occurred in the areas around many smaller cities (Fig. 4), for people have moved from these areas to larger cities.

A general increase in population has characterized cities south of a line connecting Ludington with Saginaw Bay. This area is the most urbanized part of Michigan. Here, losses of rural population are scattered, rather than heavy in any one region (Fig. 4). North of that line the urban increase has been slight and confined to a few communities.

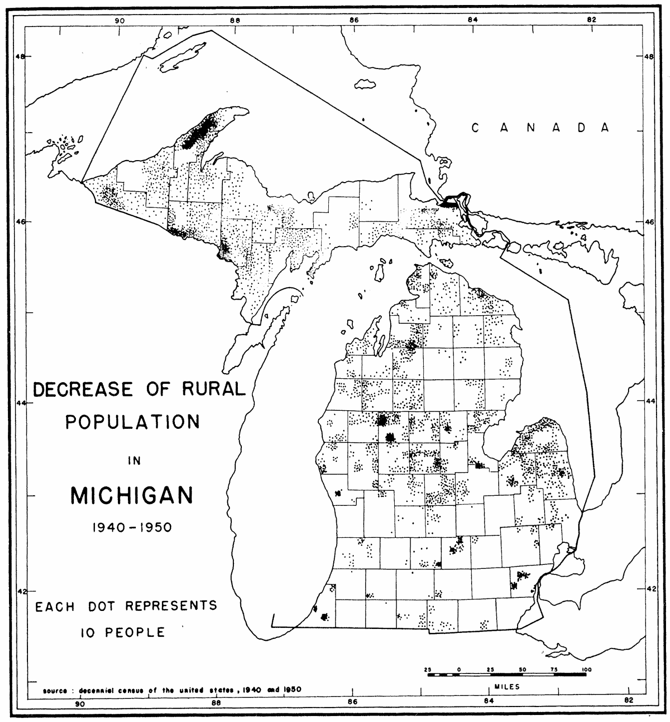


FIG. 4

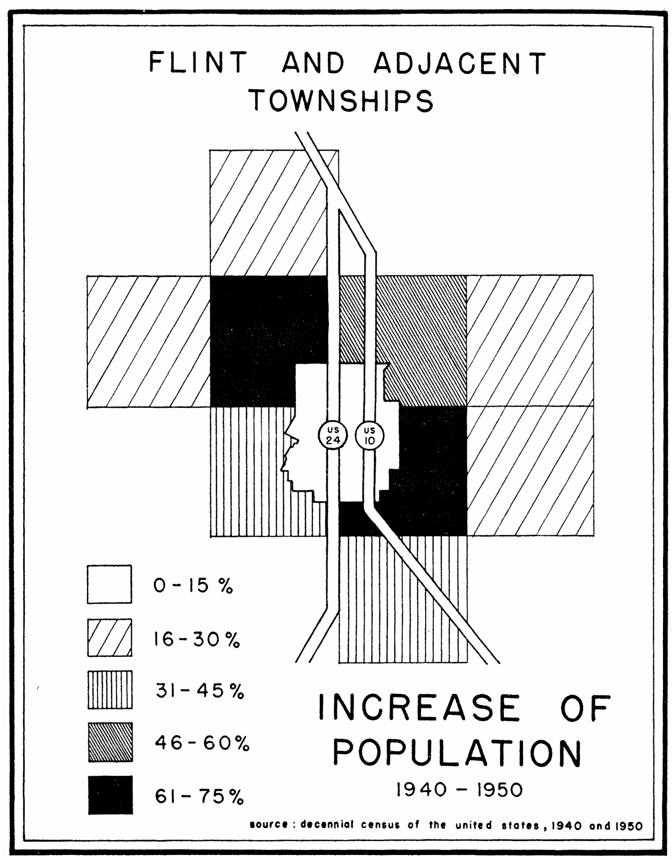


FIG. 5

The Detroit metropolitan area has dominated this urban growth in Michigan.[8] The concentration of skilled industrial workers brought government war contracts to Detroit, "the arsenal of Democracy," and opportunities for employment at high wages in turn lured people from other areas of Michigan and from all parts of the nation, especially from the southern states.

Detroit's position at midpoint on the Great Lakes system, North America's most used inland waterway, gives her enormous advantages. Iron and wheat come from the north and the west across lakes Superior, Michigan, and Huron. Coal and goods manufactured in the East move westward to Detroit across Lake Erie. All the Great Lakes serve as avenues of cheap and easy transportation to carry Detroit's automobiles and diverse other products to national and world markets. These are the locational factors which underlie the rapid growth of urban population in southeastern Michigan.

The highly urbanized areas in the state are arranged like spokes on a wheel, with Detroit as the hub,[9] and the rate of urban growth declines proportionally with distance from Detroit. Cities within approximately one hundred miles of the Motor City have grown most rapidly. The discernible lines of concentration are closely associated with highways and railways which radiate to all parts of Michigan, for growth has been along major lines of transportation. Flint is an excellent example of this (Fig. 5); its expansion has been on a northwest-southeast diagonal pointing toward Detroit. The arrangement of urban centers in a large part of the Lower Peninsula is a direct reflection of their roles as subsidiary commercial and industrial centers closely tied to metropolitan Detroit (Fig. 3).

In summary, it may be said that Michigan has greater industrial than agricultural potentialities. During 1940-50 a large part of her population was drawn to the great industrial and commercial centers or their satellites. Conditions of high productivity and employment have stimulated and accelerated the growth of Michigan's cities. Barring a curtailment in the economy of the state or the nation, or a catastrophic event such as an atomic war, this trend will continue.

WAYNE UNIVERSITY
DETROIT, MICHIGAN

[1] Urban population, 2,241,560; rural, 1,426,852 (data from the United States Bureau of the Census, *Fourteenth Census of the United States*, 1920 [Washington: Government Printing Office, 1921]).

[2] Chauncy D. Harris, "Suburbs," *Am. Journ. Sociol*, 49 (1943-44): 1-13.

[3] Data from the United States Bureau of the Census, *Seventeenth Census of the United States*, 1950 (Washington: Government Printing Office, 1951).

[4] "Rurban" is a coined word which has been accepted by the Bureau of the Census and by geographers generally to apply to persons who reside in rural areas but commute to work in urban centers.

[5] United States Bureau of the Census, 1950, as cited in footnote 3.

[6] Detroit, Flint, Grand Rapids, Kalamazoo, Lansing, Muskegon, Pontiac, Saginaw, and the Michigan part of South Bend, Indiana.

[7] Between Sturgis and Cadillac on U. S. Highway 131, between the Straits of Mackinac and Houghton Lake on U. S. Highway 27, and between Frankfort and the Indiana border on U. S. Highway 31.

[8] Bert Hudgins, "Evolution of Metropolitan Detroit," *Economic Geog.*, 21 (1945): 206-20.

[9] Arthur Field, "Road Patterns of the Southern Peninsula of Michigan," *Pap. Mich. Acad. Sci., Arts, and Letters*, 14 (1930): 305-28. 1931.

# LAND POLICY OF THE MICHIGAN DEPARTMENT OF CONSERVATION IN COÖPERATION WITH THE COUNTY LAND-USE PLANNING COMMITTEES

WILLIAM H. COLBURN AND CHARLES E. MILLAR

ONE of the foundations for the activities of the Michigan Department of Conservation is the extensive public ownership of land (now amounting to about 4,200,000 acres) in the forty-seven northern counties of the state. The evolution of this ownership, its administration, the best utilization of the land, the conservation of its associated resources, and its ultimate proper ownership are matters of perennial concern. The nature of this concern, however, has changed over the years. Decades ago the people were disturbed *about* public ownership primarily because it excluded private ownership. The change in viewpoint has been so complete that the concern is now *with* public ownership and the best possible public use of the land.

The great bulk of state ownership of land in Michigan resulted from a complex of factors related to the economic imbalance following the logging of the original forest, the lack of any subsequent economic use for the land in private ownership, and a taxing practice out of proportion to the economic resources of the land. The principle of valid and useful public ownership has become so well established, however, that the originally fortuitous nature of this ownership (arising largely from tax delinquency) has been profoundly altered through the purchase of 694,000 acres in northern Michigan and the sale of much of the tax-reverted land. Out of a total of 4,808,595 acres reverted since 1909 (the date of the establishment of the Public Domain Commission, predecessor of the present Lands Division of the Department of Conservation), 1,624,885 acres have been resold. Since 1939, 785,387 acres have been resold,[1] There has emerged from these purchases and sales a planned and balanced state-ownership pattern based on the character of the lands, conservation needs, administrative convenience, and public-use possibilities.

Two recently published papers provide the background for the material presented here. An article by L. R. A. Schoenmann, "Public Lands in Michigan,"[2] gives a historical picture of the development of the public domain in Michigan, with special emphasis on the activities of the Department of Conservation; the present paper is concerned with a particular land program of that department, having to do with the application of the recommendations for land utilization made by county land-use planning committees in the years following 1938. The initial stages of this program were described by Millar and Galloway in 1949, under the title "Cooperative Effort of the State Counties, and Municipalities in the Disposal of Tax-Reverted Lands in Northern Michigan";[3] our purpose is to complete the record in regard to that program.

The county land-use planning committees, organized under the United States Department of Agriculture and the land-grant colleges, were composed of local residents, largely farmers and township supervisors. The movement toward such organizations was nationwide, born of the land crisis of the depression. Michigan, with a large area of publicly owned land to which specific recommendations of the committees could be immediately applied by the Department of Conservation, has probably made more concrete use of these committees and derived more in the way of direct benefits than most states.

Under the broad powers conferred by statute, the Conservation Commission, which is the governing body of the state Department of Conservation, has jurisdiction over all lands for which title is vested in the state by reason of tax delinquency. The Commission can set aside, or reserve to state ownership, public lands which it deems suitable to forestry or to other conservation needs. Such reservation is spoken of as "dedication," and all state-owned land not so treated is open to application for purchase at public auction. Actually, in a "dedication" it is the practice to define an area within which all land owned by the state, or land which may in the future come to the state through tax delinquency, will be retained as part of the public domain. The state may also, under some circumstances, purchase additional lands within the "dedicated" areas. The privately owned land in such areas varies from twenty-five to fifty per cent of the total amount, and may be said to fall within the sphere of influence of the land activities of the state.

The major type of dedicated conservation project in northern Michigan, if judged by physical extent, is the multiple-use forest-and-game area. There are now twenty-one such projects, called "state forests," embracing a total of 6,050,000 acres, of which 3,668,600 acres are state-owned.[4] Each forest is composed of several discrete tracts spread over from two to five or more counties. Other important uses of state lands are to provide public fishing sites or to give public access to streams, the Great Lakes, and inland lakes. There are over 27,000 acres in these classifications, distributed in several hundred tracts ranging in size from about 10 acres to 200 acres or so. All of these are located outside the boundaries of other conservation projects. Several additional types of conservation projects, such as state parks, exist, but they involve a considerable amount of purchased land and are not of great concern here.

The history of the determination of conservation-project boundaries goes back to earlier years of the century, when such men as P. S. Lovejoy, Marcus Schaaf, K. C. McMurry, and L. R. A. Schoenmann laid the foundation for the public-land program of the Department of Conservation.[5] We are concerned here, however, with the period since 1938. In 1939 the problem of the disposition of un-dedicated lands became acute. Because of the depression a tax moratorium had set aside the process of reversion of land for nonpayment of taxes in the years following 1932. In 1939, when the moratorium was discontinued, 2,210,000 acres came under the jurisdiction of the department. While part of this land lay within the boundaries delimiting state forests and therefore automatically received "dedicated" status, much of it lay outside of these boundaries, and thus would remain open to purchase application unless specific action were taken to reserve it. Public feeling strongly favored such reservation, but the selection of lands for this action was a problem of considerable magnitude. By fortunate circumstance, the organization of the county land-use planning committees coincided with the emergence of this problem. These committees made a special study of state lands outside of forest units and submitted recommendations to the department for public and private use of these lands. Their proposals were reviewed by the department when the areas reserved for forest and game were extended. Boundary changes were approved by the Conservation Commission in 1941,[6] and the new boundaries included a gross area of 1,608,020 acres, with a net state ownership of 840,020 acres. At the same time, boundaries were withdrawn from gross area of 32,100 acres which included 5,960 acres under state ownership. This action cleared the way for the sale of many thou sands of acres of lands with, generally, the approval of the local land-use planning committees. The remarkable work of the committees on this project has been well reviewed by Titus[7] and Schoenmann.[8]

While the marketing of lands not dedicated took place at a good rate during the early forties, there were still nearly one million acres remaining by 1944. Public feeling seemed to indicate that the county land-use planning committees and the Department of Conservation had not gone far enough in their dedications of previous years, and that much of the remaining land should not be sold. Furthermore the fact that part of this land had reverted after the problem had been studied by the committees made it advisable to return to them in 1944 for further help. Their decisions were forthcoming in detail for each 40-acre parcel in turn. In 1946, when there was still some 800,000 acres outside of conservations projects, it was evident that it would be advisable to confer with the county committees in order to make the best practical use of their work of 1944. They had placed 51 per cent of the land in the "sell" category and 49 per cent in "dedicate," but since the opinion of the Department of Conservation differed somewhat on the actual division of land between these two categories, an effort had to be made to reach an understanding with the committees before action could be taken. A round of meetings was held for this purpose during the years 1946-49.

Before each county meeting (forty-three in forty-one counties[9]) a committee representing the Forestry, Fish, Game, Lands, and Parks divisions of the Department of Conservation drew up suggestions for every 40-acre tract in the particular county. Vegetation maps, soil maps, and all other available information were utilized. Existing departmental policies and the bearing on established projects were considered in relation to each description. A field examination was usually not made, because further detailed information could be gleaned from the committee members at the county meetings. The various proposals were explained by members of the department staff and by a land-use specialist from the Michigan State College Extension Service who attended all the meetings. Complete discussion and the presentation of alternative proposals and different viewpoints were encouraged. In contrast to the 1,700 people who took part in the work of the earlier period, 1938-40,[10] only about 530 attended this later series of meetings, and the discussions were more limited. The problem was smaller, both in scope and in amount of land. For the most part, a review and refinement of previous work was all that was required. Furthermore, the improved economic conditions of the times made land problems less acute, or at any rate less apparent, and of less interest. The character of the representation at the meetings is indicated by the following list: township supervisors, 70; farmers, 128; county and other local officials, 47; fieldmen of the department, 98; county agents, 41. The remaining 150 or more people who attended were mostly resort operators, sportsmen, timberland owners, small logging and pulpwood operators, teachers, and real-estate dealers.

The outcome of these meetings was satisfactory on the whole. Aside from the specific recommendations obtained, there was usually a discussion of other matters having to do with the land policy of the Department of Conservation, and a resulting improvement in public relations. Misunderstandings were cleared up in regard to the policies and procedures in land sales and land exchanges, the nature of deeds given by the state, and the conduct of conservation projects. Grievances were aired, suggestions were made, and, generally speaking, support was given to the work of the department, either by silent assent or declarative statement.

The dedication proposals of the department staff were approved by the committees largely as presented to them, which indicates that the department had been able to concur in the fundamental thought behind the original recommendations of the committees. In most counties, however, there were scattered suggestions for the release of a few, particular tracts and the dedication of others. Local knowledge and understanding of the land was evident in the suggestions. In all but two or three counties there was no prevailing opinion that the state was withholding too much land. In at least five counties however, a strong feeling existed that none of the remaining land should be sold, and in fact the people in these counties regretted that so many of the state holdings there had been disposed of in the past. All of these counties were in the Lower Peninsula, where population pressure is greater than in the Upper Peninsula and where there is more development and occupance of the land for private recreation. A thorough understanding and firm support of the public-land program was often apparent. This was most frequently and decisively evident in the appreciation expressed of the vast acreage available for public hunting. Veterans who had seen the great private hunting preserves of Europe were especially aware of the advantages in the easily accessible hunting and recreation areas of the public domain in their own country.

In only one county was there a well-developed and consequential difference of opinion on the proper disposition of an area. This occurred in Marquette County, where an articulate group of sportsmen urged the dedication of 3,400 acres of state-owned land in Wells Township, T. 42 N., R. 26 W. The sportsmen averred that the land was needed for public hunting, as a reservoir for game reproduction and a center of dispersal, and for public management of winter deer-yard areas. The Department of Conservation, together with local timber operators both large and small, was in favor of sale, and held that there was no substantial amount of deeryard in the area, that the land was not being hunted because of its inaccessibility, and that private timber operations would lead to the building of roads, as well as increase the game-carrying capacity of the forest. After three local hearings the Conservation Commission ruled in favor of sale. A transcript of the final hearing is on file in the Lands Division.

Dedications made by the commission differed only in minor respects from the plans approved by the county committees, who had always been well aware of the final responsibility of the commission. All differences in opinion were not erased, but that would have been impossible.

The results of the dedications are presented in Table I. A total area of 465,793 acres, which included 193,047 acres under state ownership, was added to state forests. A total of 15,735 acres in a great many scattered parcels, most of them between 20 and 80 acres large, was set aside for public access to water. It will be noted that 48 per cent of the land owned by the state was dedicated and 52 per cent was released for sale, other disposition, or future dedication. This compares closely with the figures of the 1944 recommendations made by county committees, which advised dedicating 49 per cent of the land and releasing 51 per cent for sale or other disposition. The percentages do not indicate the true magnitude and nature of the change from the 1944 recommendations, however, since a considerable number of parcels of land were transferred from “sell” to “dedicate” or the reverse.

The water-frontage dedications included only those tracts not requiring the sort of intensive study carried on by the Department of Conservation under its program dealing specifically with this type of land. Many of the parcels of such land dedicated at this time lay in wilderness areas on streams known to offer good fishing, and could safely be set aside for public use without the expensive and time-consuming examinations needed on most of the lake frontage. Sufficient information was available, both through departmental sources and local residents, to permit sound judgment of the public-use or conservation values of these lands. The water-frontage lands not dedicated at this time were nonetheless withheld from sale until specific examination could be made under the water-frontage program. It was understood that dedication might take place later, after a full assessment had been made of conservation needs and the public-use possibilities of individual parcels.

By March 1952 rapid sales had reduced the land under the jurisdiction of the Department of Conservation and outside of conservation projects to 56,000 acres. The period of great concern with additional dedications is past. Some new stream- and lake-frontage lands continue to be set aside, however, and there are always a few pieces of other sorts of land to be disposed of. Such questions of dedication usually arise in making appraisals in preparation for the sale of a tract. At that time factors may be brought to light which suggest that a small block, usually not containing more than several 40-acre descriptions, should be added to an existing forest unit.

TABLE I

LANDS IN NORTHERN MICHIGAN DEDICATED UNDER COUNTY LAND-USE PLANS, 1946–49 (IN ACRES)

| County | State-owned lands dedicated as state forest | State-owned lands dedicated for public access to water | Total state lands dedicated | Gross area added to state forests | Gross area removed from state forests | State-owned lands remaining undedicated |
|---|---|---|---|---|---|---|
| Alcona | 0 | 120 | 120 | 0 | 0 | 80 |
| Alger | 7,692 | 1,120 | 8,812 | 13,440 | 0 | 8,944 |
| Alpena | 0 | 190 | 190 | 0 | 0 | 280 |
| Antrim | 665 | 320 | 985 | 1,720 | 0 | 2,975 |
| Arenac | 948 | 80 | 1,028 | 1,200 | 0 | 400 |
| Baraga | 46,560 | 740 | 47,300 | 128,720 | 12,920 | 14,200 |
| Benzie | 64 | 50 | 114 | 120 | 0 | 1,040 |
| Charlevoix | 12,475 | 400 | 12,875 | 31,573 | 0 | 1,332 |
| Cheboygan | 7,295 | 865 | 8,160 | 14,800 | 5,120 | 2,920 |
| Chippewa | 4,912 | 2,030 | 6,942 | 7,160 | 0 | 15,280 |
| Clare | 1,590 | 130 | 1,720 | 3,040 | 0 | 1,160 |
| Crawford | 800 | 0 | 800 | 3,040 | 1,600 | 520 |
| Delta | 4,620 | 740 | 5,360 | 7,840 | 0 | 16,720 |
| Dickinson | 4,910 | 410 | 5,320 | 9,640 | 0 | 21,760 |
| Emmet | 4,510 | 170 | 4,680 | 8,880 | 0 | 3,480 |
| Gladwin | 160 | 0 | 160 | 160 | 0 | 1,560 |
| Gogebic | 0 | 0 | 0 | 0 | 0 | 620 |
| Grand Traverse | 60 | 180 | 240 | 60 | 0 | 740 |
| Houghton | 13,590 | 280 | 13,870 | 28,800 | 0 | 10,760 |
| Iosco | 0 | 100 | 100 | 0 | 0 | 720 |
| Iron | 7,530 | 1,910 | 9,440 | 21,120 | 2,240 | 27,060 |
| Isabella | 480 | 0 | 480 | 1,920 | 0 | 280 |
| Kalkaska | 1,975 | 125 | 2,100 | 3,280 | 0 | 2,280 |
| Keweenaw | 3,240 | 0 | 3,240 | 3,880 | 3,120 | 1,880 |
| Lake | 1,060 | 0 | 1,060 | 4,200 | 0 | 640 |
| Leelanau | 3,823 | 0 | 5,543* | 8,140 | 0 | 320 |
| Luce | 3,120 | 0 | 3,120 | 5,120 | 0 | 6,820 |
| Mackinac | 9,062 | 300 | 9,362 | 14,400 | 0 | 9,608 |
| Manistee | 120 | 0 | 120 | 320 | 0 | 2,400 |
| Marquette | 24,023 | 3,545 | 27,568 | 79,080 | 0 | 22,112 |
| Mason | 0 | 0 | 0 | 0 | 0 | 280 |
| Mecosta | 3,010 | 40 | 3,050 | 14,240 | 0 | 520 |
| Menominee | 5,350 | 570 | 5,920 | 11,760 | 2,160 | 17,600 |
| Midland | 1,020 | 0 | 1,020 | 2,240 | 0 | 950 |
| Missaukee | 2,680 | 0 | 2,680 | 6,920 | 0 | 980 |
| Montmorency | 525 | 65 | 590 | 1,040 | 840 | 270 |
| Newaygo | 0 | 0 | 0 | 0 | 0 | 1,240 |
| Oceana | 1,880 | 0 | 2,220† | 1,700 | 0 | 740 |
| Ogemaw | 1,480 | 280 | 1,760 | 3,080 | 0 | 480 |
| Ontonagon | 0 | 0 | 0 | 0 | 7,520 | 7,760 |
| Osceola | 0 | 270 | 270 | 0 | 0 | 973 |
| Oscoda | 0 | 0 | 0 | 0 | 0 | 0 |
| Otsego | 5,960 | 0 | 5,960 | 10,080 | 9,520 | 5,840 |
| Presque Isle | 1,950 | 250 | 2,200 | 5,040 | 0 | 1,000 |
| Roscommon | 0 | 0 | 0 | 0 | 0 | 0 |
| Schoolcraft | 2,708 | 455 | 3,163 | 5,760 | 0 | 9,312 |
| Wexford | 1,200 | 0 | 1,200 | 2,280 | 0 | 780 |
| Total | 193,047 | 15,735 | 210,842‡ | 465,793 | 45,040 | 227,616§ |

* 1,720 acres dedicated as state park. † 340 acres dedicated as state park. ‡ 48 per cent. § 52 per cent.

For years an anticipated further reversion of land lay in the background of many deliberations and decisions in the land program. But the 15-mill tax limitation, the decrease in land taxes in relation to the total tax load, and increasing prosperity have rapidly reduced this possibility. Since 1947, reversion has amounted to only from three to four thousand acres a year, and it seems to be stabilized at this level. It is reasonable to suppose that the state will not again receive deeds to any significantly large acreage of land through tax delinquency, unless there is a land depression of unusual severity or unless the tax structure changes.

State forest boundaries are now firmly fixed, and are not expected to shift unless there is much greater emphasis placed on a purchase program or until an agricultural development unforeseen at the moment makes possible the agricultural use of the small acreage of good soil that lies in the forests at present. The procedure used since 1938 in the setting of these boundaries by the Conservation Commission has permitted the application of the disciplines and practices of forestry, soil classification, game management, fisheries management, and geography through the use of specialists on the department staff, and the integration of their work with that of organized groups of interested laymen, whose functions were purely advisory and consultative. In the view of the authors, admittedly not impartial observers, the results have been highly satisfactory, both in the fields of applied technology and public administration and in the utilization of a unique, extra-statutory means, the county land-use planning committees, of obtaining the impress of public opinion on the conduct of the affairs of a state agency.

LANDS DIVISION
DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

[1] All figures as of January 31, 1952.

[2] *Fifty-third Annual Report, The Michigan Academy of Science, Arts, and Letters* (Ann Arbor, Michigan, 1952), pp. 17-36.

[3] Charles E. Millar and Harry M. Galloway, in *Pap. Mich. Acad. Sci., Arts, and Letters*, 33 (1947): 195-213. 1949.

[4] Allegan State Forest, in southern Michigan, is excepted from these figures.

[5] Schoenmann, *op. cit*.

[6] *Proceedings, Department of Conservation* (Lansing, Michigan, n.d.), 21: 189-204

[7] Harold Titus, *The Land Nobody Wanted* (Michigan State College Agric. Exp. Sta. Spec. Bull. No. 332 [1945]).

[8] Schoenmann, *op. cit*.

[9] In six of the forty-seven northern Michigan counties, Alcona, Alpena, Gogebic, Mason, Oscoda, and Roscommon, the land involved was so small (620 acres or less) that meetings were not held. In one county, Marquette, there were three meetings.

[10] Titus, *op. cit*.

# GLACIAL GRAND RIVER, MICHIGAN

J HARLEN BRETZ

## INTRODUCTION

THE great channel of Glacial Grand River, Michigan, cut across eleven of the recessional moraines of the Saginaw lobe, carries a record of three episodes: (1) the erosion of a premoraine Pleistocene channel, now obscured and partly obliterated by the moraines, (2) meltwater discharge during the building of seven of this series of moraines, and (3) marked deepening during discharge from the succeeding lake stages in the Erie and Huron-Saginaw basins on the east, to Lake Chicago in the basin now occupied by Lake Michigan at the western end of the channel.

Long recognized as the channel of a great glacial river, the valley of Grand River has received most attention from Leverett and Taylor, in their monumental monograph on the Pleistocene of Indiana and Michigan.[1] Leverett is quoted as having said that enough work remained after publication of the monograph to occupy the attention of glacialists for a hundred years. So far as Grand River valley is concerned, a third of a century elapsed before any further study was undertaken.[2] Two recent papers by me (1951)[3] have dealt largely with reinterpretations of glacial lake histories in both the eastern and the western basins connected by Glacial Grand River. The present paper, a study of the connecting channel, includes an attempt to test and establish the correlations proposed in 1951.

In the latitude of Grand River, the Saginaw lobe of the Gary substage pushed southwestward from the Lake Huron basin to within thirty miles of the western edge of Michigan's southern peninsula, where it made contact with the Lake Michigan lobe at Grand Rapids. With a small portion of the Huron lobe on the east, it covered more than five sixths of the state's greatest width, inside from its earlier moraines farther south, the Saginaw lobe in retreat from Grand Rapids built eleven entirely land-laid moraines,[4] the series extending eastward from Grand Rapids to the middle of the state. Melt water discharge from each of these moraines was largely concentrated into Glacial Grand River, whose course almost bisected the convex loops described by the moraines and was continuously lengthened eastward during this second episode of the channel's history (see Fig. 1).

Retreat finally exposed the divide between the Huron-Saginaw and the Michigan lake basins, and the seven succeeding moraines of the Saginaw lobe were deposited wholly or in part in water ponded between this divide and the retreating ice front. Grand River channel then became the outlet for standing water in front of the Saginaw, Huron, and Erie lobes. This was the third episode. Before it closed, all meltwater from more than five hundred miles of continental ice front escaped down the Grand into Lake Chicago, contemporaneously ponded in front of the retreating Lake Michigan lobe.

Taylor[5] believed that the channel was made during retreat from the land-laid moraines and the later discharge of lake water. He thus had no place for what is here called the first episode: channel-making along approximately the present course at some undated earlier time. The evidence for this first episode follows.

## THE FIRST EPISODE IN THE HISTORY OF GLACIAL GRAND RIVER

### TOPOGRAPHIC RECORDS

Taylor[6] correctly stated that there is no suggestion in the ground plan of any of the land-laid moraines, except the last,[7] that a valley way existed before they were built. His concept that the full depth of the channel was made after the moraines had been deposited requires that all channel walls carry unquestionable evidence of post-moraine trenching. It does not allow of morainic topography descending these slopes.

In only two places, so far as is known, did the glacial river reach bedrock. Nowhere did it cut into it. The channel walls are all in drift. But they are not all the relatively steep, aligned stream-channel walls demanded by Taylor's concept. Instead, the fifty miles or so stretching across the land-laid moraines exhibit a dozen or more localities where a kettly morainic topography descends from the uplands almost to the channel floor. Trimming of the lower slopes in such places does not invalidate the evidence. In only a few spots are there stream-cut bluffs for the full depth of the channel.

Examples of moraine topography constituting the channel slopes may be found on the Grand Rapids, Cedar Springs, Lowell, Ionia, and Portland topographic maps of the United States Geological Survey. In the extreme northeastern part of the Grand Rapids quadrangle and on the west side of Grand River valley broad, low, irregular sags in the valley wall with floors forty feet or less above the lowest glacial channel floor extend back into the Charlotte moraine upland for as much as a mile and lie more than one hundred feet below the moraine summit, which, nearby, comes within half a mile of the channel floor.

On the Cedar Springs quadrangle similar sags and depressions lie on the same side of the channel, with similar altitude relations to channel floor and morainic upland. At Chauncey, on this quadrangle, Bear Creek's lower course is entirely in a morainic sag hardly forty feet above the channel floor for two miles back from Grand River and 175 feet below the closely adjacent morainic upland (see Fig. 2). An eighty-foot kame stands isolated on the bottom of the sag and less than a mile from Grand River.

Flat River enters Grand River from the north, at Lowell on the Lowell quadrangle, using a valley whose floor for two and a half miles above the junction is from one to nearly two miles wide, twice to more than three times as wide as Grand River valley itself just above the junction. The topographic map (see Fig. 3) seems to show this wide valley bottom as a stream-made flat, but field examination reveals muck-filled tamarack swamps in shallow but steep-walled kettles interrupting its gently rolling surface, with a sharply incised ravine leading out of the largest kettle to Flat River. Three kame piles stand in the northern part of this flat, their bases not more than fifty feet above present Grand River two miles distant. Adjacent moraine tops are more than one hundred feet above the flat. An arm of the flat, impossible to explain by any postmoraine stream erosion, extends back into the moraine behind one of the kames for half a mile, its undrained floor lying at the same altitude as that of the broader flat.

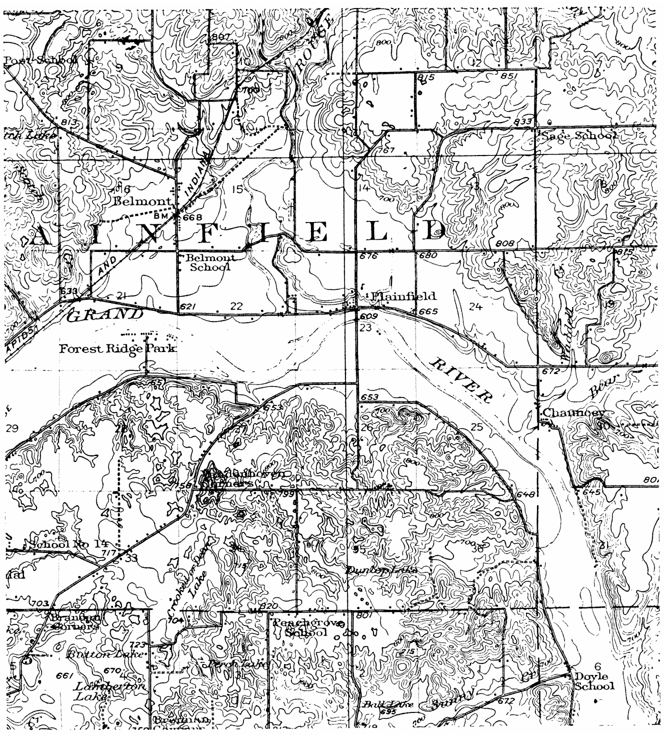


FIG. 2. Grand River valley in the vicinity of Plainfield (part of Cedar Springs quadrangle map, U. S. Geol. Survey)

Just upstream from this broad Lowell flat, Flat River uses a short stretch of valley less than half a mile wide, a definite transection of a ridged member of the Inner Charlotte moraine. Upstream from this narrows is the Fallassburg depression, elongated for two miles at right angles to the course of Flat River. Its floor, swampy in places and scarcely more than fifty feet above present Grand River, bears two small kame piles. Immediately upstream from this depression, Flat River crosses a second moraine ridge in another short gorge cut eighty feet deep in drift.

The Lowell flat's western margin, a mile north of Grand River, is broken down by a further branching projection into bordering moraine. It was used briefly by glacial water escaping westward out of the flat to reach the Glacial Grand two miles farther west. Some kamelike knolls and at least one kettle still survive on its floor.

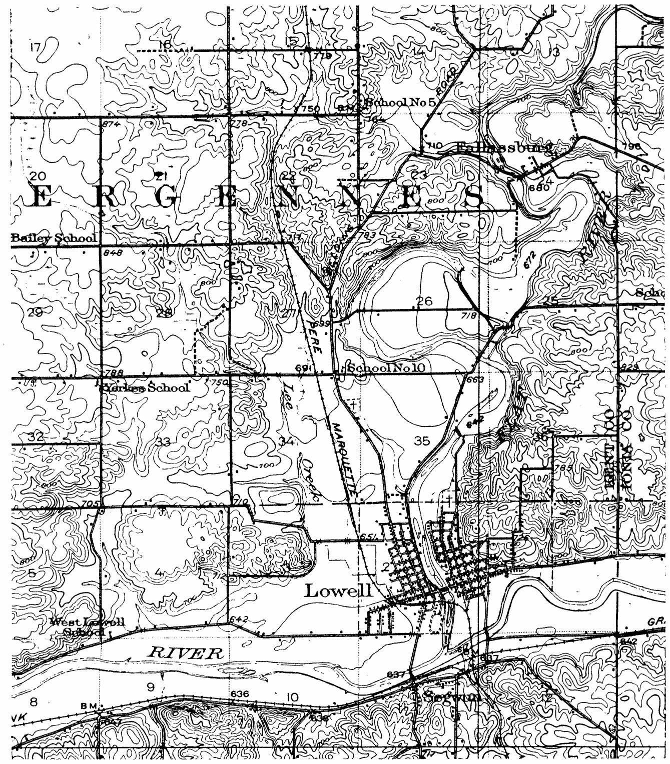


FIG. 3. Junction of Flat and Grand River valleys (part of Lowell quadrangle map, U. S. Geol. Survey)

An old gravel pit on the Flat River flat now shows only a number of reject boulders on the floor, ranging up to four feet in diameter. No other gravel pits are known. None of the features mentioned support the idea of valley-train origin and, as will appear later, the altitude of the flat is too low to fall into the profile made by entering valley trains along the channel of the Glacial Grand. The ensemble is explicable only if a major depression existed here before moraine building occurred, and if a large block of stagnant ice lingered in it while Glacial Flat River functioned.

Thornapple River valley, as shown on the Lowell quadrangle map, is less than half a mile wide between moraine hills about two miles upstream from its junction with Grand River. A mile from the junction, it is a full mile wide, and at the junction it is three fourths of a mile wide and one hundred feet below bounding moraine hills. It became filled from wall to wall with a valley train when the front of the Saginaw lobe stood on the Inner Charlotte moraine. The gravel is at least as thick as the modern stream trench is deep. The aberrant widening of Thornapple valley closely resembles that of lower Flat River valley.

Another place on the Lowell quadrangle is significant. From three to four miles east of the village, Grand River valley's north slope breaks down into morainic topography in which the bottoms of former kettles are almost as low as the glacial channel floor. Nothing here suggests that the glacial river excavated in the topography it crossed, and there is nothing that at all resembles the splendid river-cut bluff north of Saranac (Ionia quadrangle) three or four miles farther east. This moraine topography far down the valley slope lies at the eastern edge of the Inner Charlotte moraine, as mapped by Leverett and Taylor.

On the Ionia quadrangle the last mile of Bellamy Creek valley, where State Highway 21 margins Brock County Park, shows good moraine topography descending to within from twenty to thirty feet of the nearby glacial-river bottom, and surviving subsequent modification by the creek.

The broad lower valley of Prairie Creek (Ionia quadrangle) carries remnants of a gravel fill of fluvioglacial origin, bottomed so low that a sag in the moraine topography is indicated here, similar to the one at the mouth of Thornapple River.

Two of the largest depressions attributable to a premoraine Grand River valley lie on either side of the Fowler moraine, Stony Creek occupying the western depression, Hayworth Creek the eastern one (see Fig. 1). Both are disproportionately broad, reaching three times the width of Grand River valley near their junctions with it. Both are floored with fluvioglacial gravel thirty feet or so thick. They are shown on the Portland, Dewitt, and Perrinton topographic maps. The original depth of the Stony Creek depression was close to eighty feet below the Fowler moraine summit; that of the Hay worth may have been even more. The ground plan of each shows that the upper stretches of the glacial rivers they brought to the Grand left well-marked channels only from a fourth to a third as wide as these low tracts in which they deposited the gravel fills.

These places where moraine topography descends into broad depressions, nearly as low as Grand River valley bottom, range the full length of that valley. No sags comparable in depth occur elsewhere among the moraines. This line of depressions so nearly coincides with the course of the Grand River valley that the interpretation of them as surviving portions of a premoraine valley, largely blocked and filled during deposition of the land-laid moraines, seems fully justified. Buried ice blocks appear to have lingered in some of the deeper ones near the channel during the second episode. Otherwise, their low bottoms would have been aggraded to the level of that channel floor. The concept of a premoraine valley has other items of field evidence in its favor, one of which is discussed under the heading below.

## BOULDERY GRAVEL UNDER THE GLACIAL GRAND RIVER CHANNEL FLOOR

The gradient of Glacial Grand River during the second episode, a theme elaborated elsewhere in this paper, is obtained from outwash terraces lying in the mouths of tributaries that carried valley trains to the trunk route. It was approximately one foot to the mile at the close of that episode. During the following episode, valley-train contributions ceased and the glacial river carried only lake water from the east and run-off additions made en route. The channel then suffered erosional deepening throughout, which totaled forty feet at the mouth because of the fall in Lake Chicago levels and about ninety feet at the head, where it crossed the youngest of the land-laid moraines. Its last attained and still essentially continuous floor has a gradient of three quarters of a foot per mile. Most terraces surviving along the main channel lie at or between these two recorded gradient profiles.

There are several low, midchannel hills along the course of the glacial river, all but one of which fail to reach the upper profile. Two have large gravel pits in them, and one reveals its characteristics on natural slopes. From their locations and character it appears probable that all are erosional remnants of bouldery gravel deposited in front of or beneath a moraine, or left as lag material from channeling across a moraine during the second episode. Bottoms of these deposits are so low that there must have been deep places for their accumulation, as deep as, or perhaps deeper than, the finally attained lowest channel floor of the third episode.

One well-opened midchannel hill lies partly on the Ionia quadrangle and partly on the Portland. Large numbers of reject boulders litter the floor at the eastern end of the pit but are rare elsewhere. Surviving bruises, soles, facets, grooves, and even striae indicate rather brief experience with the meltwater which otherwise sorted and stratified the gravel. Some boulders may be seen in the pit walls, where they are sporadically distributed in the gravel and do not suggest a boulder bed or a stratum with scattered boulders. This deposit lies at the intersection of the glacial river channel and the Ionia moraine.

The best illustration of the character of a midchannel hill along the courses of the Glacial Grand is found on the Ionia quadrangle, just south of Grand River and extending two miles or so west of Sessions Creek (see Fig. 4). The hill's flattish summit is more than fifty feet above the river, and the abandoned channel on the south side of the hill is a little less than thirty feet above. A smaller and shallower channel crosses the elongated hilltop.

Excavation in this hill has left a series of partly connected gravel pits about a mile long on the riverward and steeper slope. In only one pit does the gravel suggest morainic origin. Elsewhere there is fairly uniform stratification, good sorting in general, and but little sand. Boulders are almost entirely lacking in some pits and very abundant in others. Many boulders are six feet in diameter, a few range up to nine feet. Glacial bruising, grooving, and scratching can be found on some. It appears as though an older and bouldery gravel deposit with an irregular surface had been buried under a far less bouldery stream gravel.

The bottom of the deposit is nearly as low in places as the lowest glacial-river channel floor. It is clear that that river has deepened its course here some fifty feet since deposition of the gravel. Therefore a place in the topography approximately as low as the last channel floor must have existed before the washed but bouldery deposit was made. The hill lies a little back of the Grand Ledge moraine's transection by the river channel.

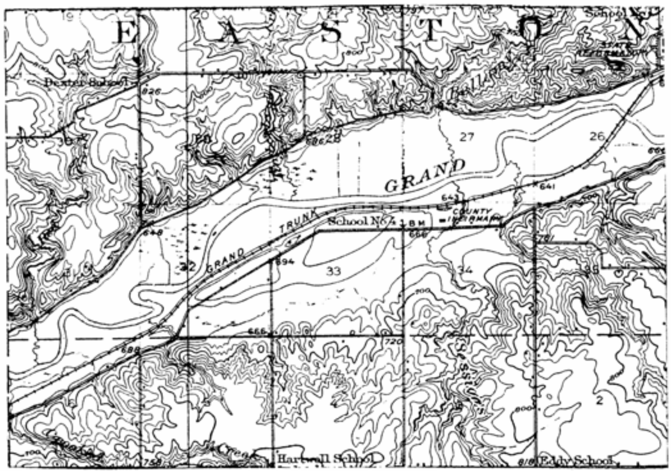


FIG. 4. Sessions Creek "wide" in Grand River valley (part of Ionia quadrangle map, U. S. Geol. Survey)

The valley at the site of the double channel is twice as wide as it is immediately upstream or downstream and is bounded by low but aligned bluffs. It appears probable that, at all these midchannel hills, a gravel deposit made in an already existing depression during the second episode proved to be more resistant to the clear-water river of the third episode than was the bordering sandy till of the region. When deepening began, the river found it easier to divide and erode a new channel on either side. Some of the deposit suffered removal, of course, for the shape of these hills is streamlined and a small channel crosses the Sessions hill.

There are two pits in boulder-containing gravel in terraces along the channel length, low on the erosional channel slopes. One is at Saranac (Ionia quadrangle), the other a mile east of Lowell, both on the south side of the river. Both show, or have shown, that glacially marked boulders occur fortuitously in otherwise stratified river gravel. They range up to five feet in diameter. The Saranac deposit is out in the middle of an unusually wide place in the channel and lies beneath the surface of next to the lowest of five terraces. The glacial river was in its third episode when the terraces were made at both places and only floating ice would seem a plausible method of boulder transportation at that time. It appears much more likely that these terrace surfaces were erosionally made during the third episode, on a gravel deposit dating from the second episode. The abundant boulders on the Lowell terrace are thus a lag accumulation. The gravel deposit at Saranac was bypassed on the north side only, so that no double channel and no midchannel hill resulted. This unilateral bypassing produced a marked undercutting on the north and left the fine river-made bluff. Although descending to the lowest channel floor, it overlooks one of the "wides" of the valley and is not a product of deepening from the top.

There is considerable evidence from moraine patterns, blocking of drainage ways and lake outlets, and overriding of outwash gravels that the Saginaw-Huron ice front retreated in an oscillatory fashion, with readvances retrieving part of the ground lost during a preceding retreat. At Lowell the terrace gravel lies at the intersection of the glacial-river channel and the Inner Charlotte moraine and, by this view, was deposited while the Saginaw lobe was readvancing to build that moraine. The terrace gravel at Saranac stands a mile in front of the mapped outer edge of the Lansing moraine and probably never was overridden. At the midchannel hill near Sessions Creek the very bouldery deposit is found a mile back of the inner edge of that same moraine. The bouldery part of the deposit there could well be a washed product from the readvancing ice, and the nearly boulderless gravel could be part of a valley train made later, when the ice was retreating and after the morainal till had been scoured away. Morainal gravel in one exposure here supports this idea. Even this boulderless and presumed-later gravel does not record any lengthy journey along the valley and certainly is not an extension of the valley train depending westward from the Owosso moraine,[8] last of the wholly land-laid moraines.

## THE SECOND EPISODE IN THE HISTORY OF GLACIAL GRAND RIVER

Glacial Grand River, trunk stream of the glacial drainage system of south-central Michigan, was supplied by branch streams from both north and south whose courses were determined by the successive land-laid moraines built during retreat of the Saginaw lobe. The drainage area and stream pattern of the modern Grand corresponds in general with that early system (Bergquist, *op. cit*.). However, not every moraine during its building had a marginal branch stream of sufficient magnitude to leave a record. Plate 7 in the Leverett and Taylor monograph correctly shows only five such rivers from the north and four from the south (see Fig. 1).

Because each of these streams ceased to carry meltwater as soon as the ice retreated from the moraine it paralleled,[9] and because each one received more waste than it could transport, all built valley trains leading to the Grand,[10] with gradients steeper than that of the master stream. Had the Grand ceased to flow at the end of this sequence (the second episode), its floor today would be a trunk valley train adjusted to the altitudes of the tributary valley-train termini and to the highest (Glenwood) level of Lake Chicago. But discharge from the eastern glacial lakes during the third episode, when Glacial Grand was greatly augmented in volume, promptly destroyed most of the traces of the second episode in its valley, and only from the altitudes of these tributary valley trains at their junction with the Grand can the lost record be reconstructed.

All of the tributary valley trains were more or less terraced by their glacially fed streams. Some of the terraces seem to record contemporaneous lowering of the gradient of the Grand itself. Some terraces along the

Grand may be the result simply of channel shifting, for all are channel floors, and channel depths must have varied in time and place. None should be thought of as a flood-plain record. Precise measurement of their altitudes does not guarantee precision in correlation.

The destruction of the presumed Grand River valley train began when the first marked increase in river volume occurred, i.e., when Lake Maumee in the western end of the Erie basin abandoned its Wabash River discharge way for a lower route northward to reach the Grand, at the time when the Saginaw lobe retreated from the Fowler moraine. Although no early lake shores have been positively identified on the Fowler's back slope, the level of that earliest ponding very probably was not much higher than 740 feet above sea level. A profile controlled by this figure at the east and 640 feet above sea level, the level of Glenwood Lake Chicago on the well-marked Allendale delta west of Grand Rapids (see Fig. 1), has a gradient of about one foot to the mile. This was the lowest gradient the great river developed during the second episode. To it, all except two tributary valley trains approximately conform at their junctions with the trunk route. Special factors determining the nonaccordance of these two are considered later. Western valley trains are a little high for good accord with this profile because, apparently, the Grand itself had a higher gradient in its western portions during the earlier part of the episode. The plotted profiles of the system suggest the feathering on one side of an arrow pointed downstream along the Grand, the pinnae bent slightly forward.

The earliest and westernmost of the tributary glacial streams to function was the Glacial Rouge River.[11] It drained from the interlobate area lying to the north and entered the Grand at Plainfield, a few miles upstream from Grand Rapids (see Fig. 1). At that time the Lake Michigan lobe still covered the site of the Allendale delta and the Saginaw lobe stood on the westernmost moraine of its land-laid series. This very earliest discharge of Glacial Grand River was, as Leverett[12] indicated, southward from Grand Rapids toward Kalamazoo Valley, first by a channel past Ross to Little Rabbit River, later and more briefly by one past Jamestown (see Fig. 1). Scarcely ten miles of the valley called the Glacial Grand then existed. Maps that show this river as discharging southward from Grand Rapids toward the Kalamazoo Valley for its full length across the Saginaw moraines do violence to Leverett's text and the field evidence. Almost all of Glacial Grand is younger than the southern discharge. Taylor[13] erred when he said that during the later stages of Lake Maumee the drainage of the Imlay outlet river was down Grand River past Grand Rapids and "thence south along the ice front to Lake Chicago." The error is also recorded on plate 14 of the monograph. The two authors obviously did not discover the discrepancy in their interpretations before publication.

A "wide" of Glacial Grand River's channel, not already noted, lies at the junction of Rouge and Grand rivers (near Plainfield on the Cedar Springs quadrangle) and is traversed longitudinally by Grand River for four miles (see Fig. 2). It is two miles in greatest width, five times as wide as Grand River valley only a mile upstream. Because no very bouldery gravel was found here, this wide place was not noted previously although it does contain a midchannel hill. The floor of the "wide" where untrenched by the two rivers is very obviously glacial-river channel bottom, an interpretation supported by the one-hundred-foot aligned bluffs descending to it. Most of the floor is from fifty to seventy feet above Grand River and constitutes the most extensive terrace along the entire channel above Grand Rapids. It is too high to be correlated with the Allendale delta's Glenwood level, almost high enough to pass as channel bottom leading to the Ross spillway along the east side of the Valparaiso moraine. The midchannel gravel hill is fully high enough for this correlation. A few square miles of equally high fluvioglacial gravel belonging also to the Ross discharge way lies southeast of the Grand at Plainfield, so high above the valley and so pitted with kettles that its terrace character is not readily recognizable.[14]

The main terrace flat at the Plainfield "wide" is to be correlated either with the Jamestown channel of Leverett, lying between the Valparaiso and the outermost Lake Border moraines, or with some unmapped lower discharge way southward between units of this system.

The composition and structure of this terrace clearly record a place as low as the present Grand River valley. A large gravel pit a mile east of Plainfield[15] shows about forty-five feet of poorly washed morainal gravel, with some scattered, strongly glaciated boulders and an abundance of till cobbles and pebbles. Structurally, the deposit consists entirely of long deltaic fore-sets dipping southward into the Grand. About five feet of good stream gravel topping the section is taken to be floor material of the channel terrace. The underlying dirty morainal gravel is considered a local filling in another remnant of the premoraine Grand, deposited early in the second episode, when glacial ice closely margined this interlobate angle on both sides. Rouge River flows on a valley train for many miles upstream from Rockford with a gradient of four feet a mile but crosses the moraine immediately north of the Plainfield terrace in a narrow valley from one hundred to two hundred feet deep, along which it drops forty feet in two and one half miles. The Plainfield terrace, therefore, does not belong to the Glacial Rouge. It records a Glacial Grand heading among the Charlotte moraine ridges farther east while the southern channels were still in use. Glacial Thornapple's early flow quite probably used this channel floor and possibly also water from the earliest Flat River discharge.

Another "wide," a little downstream from Grand Rapids, has morainic slopes descending into it from the northwest side. Near the western edge of the Grand Rapids quadrangle, it is more than three miles from side to side. In contrast, the valley width between the city and the Plainfield terrace is less than half a mile. The southeast side of this wide place is a scarp cut in the extensive gravel deposits of the Burton Heights district, remnants of a pitted plain at the head of the Ross channel. The scarp is about fifty feet high and mostly, if not all, in gravel. At its base is a broad flat at the Glenwood level of Lake Chicago, on which stand several isolated gravel-hill remnants of the former high-level fill. There is even an old subsidiary river channel, now a muck-filled swamp, paralleling the base of the scarp. Obviously the premoraine "wide" had even greater width before the Ross channel fill was made.

A gravel pit in one of the smaller hills on the later channel floor, half a mile north of Wyoming Park and at least eighty feet below the summit of the scarp, shows south-dipping fore-sets containing till pebbles and a few boulders up to four and five feet in diameter. Here the Grand Rapids "wide," when first exposed by ice retreat, was as deep as is the present valley, product of all subsequent erosion.

The valley train of Thornapple River (Lowell quadrangle) is readily traceable through wides and narrows as far upstream, at least, as Whitneyville. It is shown on plate 7 of the Leverett and Taylor monograph but was unaccountably omitted from the 1924 revision of this map.[16] At least two marked terraces exist, the lower one correlated with the Glenwood level on the Allendale delta. The glacial river was marginal to the middle member of the Charlotte moraine but may have received later meltwater from as far east as the Lansing moraine. Retreat of the Lake Michigan lobe to allow Glenwood Lake Chicago to reach the site of the Allendale delta appears to have coincided approximately with retreat of the Saginaw lobe from the Inner Charlotte moraine.

The broad lower valley of Flat River (Lowell quadrangle) (see Fig. 3) is exceptional in several ways: (1) No stream terraces, other than postglacial, appear to exist in it. (2) The flat bottom just above junction with the Grand lies lower than do two stream-made terraces of the Grand itself, a mile to the west. (3) Most of this extraordinary "wide" has very poor drainage. Three little creeks connecting some swamps flow parallel only a quarter of a mile apart for about two miles, and two of them are ditched to improve their performance.

The higher of the two Grand River valley terraces west of Lowell may date from the time of southward drainage past Grand Rapids; the lower one fits the Glenwood profile of Glacial Grand. Both appear to be erosional forms. If the Lowell "wide" along lower Flat River, here interpreted as ground moraine, were actually a valley-train surface, the tributary glacial river would be required to have flowed until after the last moraine of the land-laid series, forty miles farther east, had been deposited. This appears quite impossible, although Leverett's map shows that the Glacial Flat did receive meltwater from both the Lansing and the Grand Ledge moraines. If it be a ground moraine surface left in a premoraine sag, a residual ice mass must have lingered here until the second episode of Glacial Grand's history was closed, else backfilling from the Glacial Grand would have occurred. And some satisfactory explanation for the absence of a valley train along Glacial Flat must be found.

The explanation best fitting the field evidence is that outwash traversed the lower Flat River valley on the surface of a stagnant, partly buried ice block, found or made holes in three places to deposit the gravel of the three kame piles, and, for a time during the southward drainage from Grand Rapids, used the immature channel previously noted as leading out of the west side of the flat. The lower end of Flat River valley is too low to be a valley train and apparently is not underlaid with stream gravel.

The Lansing, Grand Ledge, and Ionia moraines have no marginal valley trains leading directly to Glacial Grand. Taylor noted thin sand and gravel mantles on intervening ground moraine, apparently the only record of outwash from them other than the discharge to the Glacial Flat noted above.

The abandoned channel south of the island hill near Sessions Creek (Ionia quadrangle) falls below the Glenwood profile, as do the lower terraces at Saranac. Thus the higher valley-bottom gravel at both places is considered part of an earlier, higher level of the presumed Grand River valley train, Glenwood in age but not latest Glenwood.

Prairie Creek valley (Ionia quadrangle) has a terraced gravel deposit at the mouth, the highest surface of which is ten feet too low to coincide with the Glenwood profile. Plate 7 of the Leverett and Taylor monograph shows a sand- and gravel-floored break in the combined Portland and Lyons moraines about fifteen miles north of Grand River. Conceivably water from the Fowler moraine might have crossed here and discharged down Prairie Creek valley. This channel-like break is omitted from Leverett's 1924 map, but one in almost the same latitude is added across the Fowler and connected with a local lake bed in front of the Flint moraine at Ithaca. Possibly drainage as late as Flint time used the Prairie Creek route. If so, this would account for the low altitude of its terrace at Ionia. Anyway, ten feet is not a great discrepancy in correlating channel bottoms of these glacial rivers.

The Portland moraine on the south side of Glacial Grand had a margining river, the Glacial Lookingglass,[17] mouthing a little west of Lyons (Portland quadrangle) at about 740 feet above sea level. Although its point of junction with the Glacial Grand shifted from the west to the east side of the moraine as the ice front retreated, apparently no change in altitude of the mouthing occurred. Three or four miles farther up the trunk valley way, on the back side of the Lyons moraine and marginal to the Fowler, is Glacial Stony Creek's wide, flat, gravel plain, nowhere, except at the very foot of the Fowler, over 730 feet above sea level. Most of it appears to lie closer to 720 feet. A narrow distributary channel, Cook Drain, leads southwest across the Lyons moraine from Stony Creek to the sag between this moraine and the Portland, its bottom a little below 720 feet.

The Stony Creek gravel deposit falls in the eastward-rising Glenwood gradient of Glacial Grand, and the Cook distributary shows the same thing—a Glacial Grand channel at Lyons at least as low as 720 feet. But the Glacial Lookingglass channel mouth is about thirty feet too high for the Glenwood profile, which is too great a discrepancy to be explained on the basis of varying depths of channels. No satisfactory explanation for this high junction has been found. The gravel deposit at the mouth west of the Lyons moraine is thin, and the bouldery channel floor a few miles farther south appears to be entirely erosional. It is conceivable that the Glacial Lookingglass was a small, shallow stream incapable, during its brief lifetime, of grading its lower course down to accordance with the Glenwood profile of the Glacial Grand.

The Stony Creek valley train appears to be composed almost entirely of Fowler contributions. Although Leverett's 1924 map shows two tributary routes crossing the Fowler from the later Imlay channel, field examination proves that they were inconsequential streams.

## The Third Episode in the History of Glacial Grand River

Retreat from the Fowler moraine marked (1) the first glacial lake discharge down Glacial Grand, (2) the earliest stage (not noted in the Leverett and Taylor monograph) of Early Glacial Lake Saginaw, and (3) the beginning of Glacial Lake Maumee's shift from the Wabash spillway to Glacial Grand. The marked increase in flow set up a new regimen, and is considered to have closed the second episode of the great channel's history and to have inaugurated the third, although two more land-laid moraines (Flint and Owosso) were yet to be built and one valley train (Owosso) was yet to be deposited.

Imlay River, outlet for the second and third stages of Lake Maumee in the Erie basin, is well recorded by a channel along the front of the Flint moraine (see Fig. 1). Its earliest functioning, during the second stage of Lake Maumee, must have occurred in the process of recession from the Fowler and before advance to the position of the Flint, a fact of which Taylor was aware, although he was in error regarding Glacial Grand's contemporaneous course beyond Grand Rapids.

Advance of the Saginaw lobe to the position of the Flint moraine then shoved the earliest Imlay River broadside toward the southeast and south onto the higher ground where it now lies, and consequently raised the surface of Lake Maumee to a level only a little lower than that of the Wabash spillway. This, the lake's third and longest stage, is recorded by its middle shoreline.

This glacial advance also obliterated all record of a pre-Flint earliest stage of Early Lake Saginaw. That stage is theorized from the known height of the Fowler moraine above the till plain east of it and from a conviction based on field observations that the Fowler was built continuously across what became the Glacial Grand channel. The altitude of this flat ground moraine on both sides of the channel is a little less than 740 feet above sea level, close to that of the Glenwood profile projected eastward across the Fowler. This earliest ponding was undoubtedly small and of importance only in notching the Fowler moraine.

But Lake Maumee in its second and third stages caught the wastage of the Erie and Huron lobes all the way from northwestern Pennsylvania to the base of the Thumb in Michigan, and its Imlay outlet river must have increased the volume of the Glacial Grand several fold. In spite of the debris contributed from the erosion of the Imlay channel along the front of the Flint moraine, Glacial Grand became an eroding stream immediately on receiving the Imlay influx. Thus was opened the third episode in the history of Glacial Grand.

All the Saginaw lobe moraines exhibit discontinuities of varying extent. The Flint had two such breakdowns critically located with reference to present problems, one at Maple Rapids and one at Duplain. No lake could have been formed back of such a moraine if the breaks were low enough. But the Imlay and Grand channels were deepened sufficiently during Flint maximum to hold the newly arrived river to its course during the ensuing retreat. An inviting detour across to the back side of the Flint at Duplain, with a return to the front side at Maple Rapids, apparently was never used.[18]

Imlay channel-making continued along the front of the Flint moraine during the Flint retreat and the following Owosso advance. By Owosso maximum, it was a capacious waterway. Considerable debris from its erosion probably was dropped in the Hayworth "wide"; the rest went on down the Grand.

At Owosso maximum one of the most marked valley trains from any Saginaw moraine was deposited in the Imlay channel, despite the volume of the Imlay discharge. Glacial Kersley Lake, a ponding along Glacial Imlay River south and east of Flint, probably owed its existence to the Owosso valley train, which is recognizable today from Owosso westward as far as Maple Rapids and which constitutes the upper gravel deposit and the 720-725-foot terraces of the Hayworth flat. How much farther the valley train reached down Glacial Grand is not known, for subsequent channel enlargement there has been great. Its thickness in places is at least thirty feet. Yet its surface is a little lower than the projected Glenwood profile of the Grand. This can only mean that the combined Imlay-Grand had already carved a channel more than thirty feet deeper than the one the Grand occupied at the close of the second episode.

If the level of Lake Chicago had remained unchanged, this pre-Owosso deepening, starting on a gradient of a foot a mile, would have lowered that gradient to eight inches to the mile in the time consumed by the Flint retreat and the Owosso advance. Even with the greatly increased volume from Imlay River, this seems impossible. Because Lake Chicago is known to have been lowered through erosional deepening in its own outlet channel, a correlation of the two deepenings appears unavoidable. The cause was the same: the increased volume that deepened the Grand was discharged through Lake Chicago and, as it deepened the outlet of that lake, it lowered its level correspondingly. The gradient of the Glacial Grand was not greatly decreased during this pre-Owosso erosion.

Thus, also, trenching of the Glenwood portion of the Allendale delta, which had been growing ever since the Saginaw lobe abandoned the Inner Charlotte moraine, is to be correlated with retreat from the Fowler moraine, the first incursion of Imlay outlet river, and the opening of Glacial Grand's third episode.

Advancing Owosso ice pushed a blunt tongue into the four-mile-wide break in the Flint moraine's continuity at Maple Rapids, closed the gap with its moraine, and established conditions for the Early Lake Saginaw of the Leverett and Taylor monograph. This lake's highest shoreline is 735-740 feet, and the line was held there during retreat from the Owosso moraine and during advance to and retreat from the next, the Henderson, moraine. The Imlay-Grand River, during this time, was engaged in removing much of the Owosso valley train and reëstablishing its marked channel. Only after Henderson retreat did Imlay River find a short cut to Lake Saginaw, abandon its course westward from Flint, Michigan, dump its debris in the Flushing delta of Lake Saginaw (see Fig. 1), and then, with clear water only, resume the downcutting of the channel of Glacial Grand, as Lake Chicago subsided toward its second, or Calumet, level.

In the sequence of water-laid moraines and lowering lake levels in the Saginaw-Huron and Erie basins which Leverett and Taylor so convincingly portrayed but never satisfactorily explained, there were seven pauses when shorelines converging to the head of the Glacial Grand were formed, and one significant stage (Lake Wayne) when leakage occurred eastward past the edge of the Erie lobe and found an outlet into the Mohawk, lower than the Glacial Grand channel was ever eroded. Imlay had already been abandoned, and new outlet channels for Erie and Huron meltwater had been discovered farther north in the Thumb, near Ubly. But all these channels, including the Glacial Grand itself, ceased to function as glacial river-ways during the drop to Lake Wayne levels. A low-water stage that occurred in Lake Chicago (the Bowmanville or Two Creeks) before the Calumet beach was built, during which stage the Lake Chicago outlet also went dry, is logically correlated with the Wayne low water in the Saginaw-Huron and Erie basins.[19] This was during retreat from the Port Huron moraine, the greatest retreatal oscillation in the record of the Saginaw lobe.[20]

Deepening of entrenched distributaries on the Glenwood portion of the Allendale delta came, perforce, to an end, their floors being left at the same altitude as the dry Lake Chicago outlet. I have termed this the first-attained Calumet level of the lake. Its surviving land-form record is found only in the delta's abandoned distributaries.

After this, readvance of the Great Lakes lobes closed the Lake Wayne outlet and the Michigan-Huron connection at the north, the glacial lakes returned to their former levels, Grand River channel and the Lake Chicago outlet again functioned, and the Calumet and highest Warren shores were made at the outlet levels which had been abandoned when the drop to Lake Wayne occurred.

Lake Warren was larger than any earlier lake stage and had a longer ice front. With more water than ever before using the Glacial Grand, the erosion of the third episode was inevitably resumed, and the outlet of Lake Chicago was also deepened. The drop to the lowest Warren level was a direct result of Lake Chicago's drop to its lowest or Toleston level. The little-altered broad valley bottom of today is the Warren-Toleston channel floor, descending about nine inches to the mile. The lowest channel floor at the head of the Glacial Grand is about fifteen feet below the lowest Warren shoreline, indicating a river fifteen feet deep. Because (1) all channel terraces are channel-bottom fragments, (2) the vertical intervals between successively made lake shores do not exceed fifteen feet, and (3) any one channel's depths must have ranged from perhaps fifteen feet in central positions to only a few feet along the margins, it follows that a convincing correlation of surviving terraces along the Glacial Grand with the successive lake stages at the head cannot be made. What can be said with confidence is that in the entire length of the channel of Glacial Grand River there is no consistently reappearing terrace to be correlated with the Calumet stage of Lake Chicago. Only the Glenwood and the Toleston are recorded.

The very brief Calumet stage marks only (1) the abandonment of the outlet of Lake Chicago because of the Bowmanville-Two Creeks-Wayne low water, and (2) the later refilling of the affected lakes when the eastern low outlet was closed off. Had no Lake Wayne discharge way ever been opened, Lake Chicago would have left only two shorelines, the Glenwood and the Toleston.

## THE ALLENDALE DELTA

Leverett recognized only the two higher levels of Lake Chicago in the Allendale delta. I have reported two considerable Toleston portions. A later field examination has made it clear that all gravel pits on the delta are in Glenwood or Toleston portions. There seems to have been no recognizable increment to the delta at the Calumet level. Instead, the Calumet record appears to consist entirely of distributary channels cut into

Glenwood surfaces. Two such channels continued in use during the drop to the Toleston level; the others were abandoned. Indeed, some of the Allendale delta's distributary channels are bottomed between the Glenwood and the Calumet levels, and some between the Calumet and the Toleston. Were there no Calumet beach elsewhere around the margin of Lake Chicago, our interpretation of the Allendale delta might not include this intermediate level.

Later observations also lead me to increase the estimate of the area of the delta to five times what Leverett showed.

In addition, it is to be noted regarding the Toleston channels that the fore-set gravel in them goes down at least twenty feet, to present river level. It appears that there must have been another low-water stage in the Lake Michigan basin, occurring between Calumet and Toleston time, a stage not yet recognized in the eastern basins. It would appear to be correlatable with Stanley's Mackinac Straits River[21] and with the existence of post-Valders submerged valleys at Milwaukee and near Manitowoc, Wisconsin.[22] For eroding a pre-Toleston deep channel in the delta, however, only a river like the modern Grand could be effective. If the episode occurred as suggested, Glacial Grand ceased to exist a second time.

A further observation concerning the Allendale delta is that glacial rivers other than the Grand contributed to its Glenwood portion. It will be recalled that Glacial Rouge River, north of Grand Rapids, occupied the compressed interlobate area between the Valparaiso moraine of the Lake Michigan lobe and the Outer Charlotte moraine of the Saginaw lobe, and that its water escaped southward along the Ross channel. During retreat of the Lake Michigan lobe from the Valparaiso moraine three successive Lake Border moraines were built, here named the Casnovia, Ravenna, and Eastmanville. Between them two southward-draining glacial rivers developed, duplicating on a smaller scale the character of the Saginaw lobe's retreat. But by this time the site of the Allendale delta was ice-free and the head of the Ross channel had been left hanging fifty feet or so above the Glenwood channel floor. Channels of these two glacial streams have sandy and gravelly floors descending about five feet a mile and joining the Grand at the Glenwood level, just to the east and the north of the area Leverett indicated as delta surface. Both are shown on his map as glacial drainage ways. He suggested that, "in case no lower passage toward the west was available," the Sand Creek channel, between the Casnovia and Ravenna moraines (Ravenna quadrangle), drained to the Ross channel.

For the western channel, lying between the Ravenna and Eastmanville moraines and now followed by Deep Creek, Leverett thought that discharge was probably "directly into Lake Michigan [meaning Lake Chicago] near Holland." The Muskegon, Ravenna, and Holland quadrangles were not surveyed until from fifteen to thirty years after publication of the Leverett and Taylor monograph. The topographic maps of these quadrangles clear up much of the uncertainty and, with field study, show that the head of the Glenwood portion of the Allendale delta is almost as far upstream as Grandville. The earliest entrance of the Glacial Grand into Lake Chicago doubtless was at Holland and Zeeland, at the time when the Sand Creek glacial river also existed. But the later Deep Creek river made its contribution to the Glenwood delta at Lamont, directly across the modern Grand from the area where Leverett placed the delta top.

Bluffs along lower Crockery Creek show the deltaic sand of this part of the Allendale delta to be underlaid by laminated clay and silt to the bottom of the sections. The ground moraine surface is below valley bottoms, and the clay and silt are interpreted as bottom-set beds, deposited early in the delta's growth. Similar sections exist along lower Bass River, west of Allendale.

By the time the Lake Michigan lobe had retreated from the Eastmanville moraine, the apex of the interlobate area had been shifted perhaps three tiers of counties farther north and its drainage was following intermorainic sags southward to a crossing of the strong Lake Border moraine at Newago, where the modern Muskegon now crosses. The Glacial Muskegon was turned southward, however, a little west of this transection, because the Lake Michigan lobe still covered much of the plain on which the modern river flows westward. A thin, sandy, deltaic flat, now considerably dissected by Crockery Creek, was deposited on the ground moraine west of the low Eastmanville ridge at 630-640 feet above sea level. The contributions of the Glacial Muskegon to the Glenwood Lake Chicago appear to have been spread out subaqueously in shallow water.

The Glacial Muskegon ceased to flow before the Glacial Grand was finally abandoned. The lack of any channels in it to record the Calumet stage, in contrast to their presence in the delta at Allendale, indicates that cessation occurred before that lake stage had begun, i.e., before retreat from the Fowler moraine. Only the modern Muskegon trench can be pointed to as a possible earlier Calumet channel across the Muskegon plain.

UNIVERSITY OF CHICAGO
CHICAGO, ILLINOIS

[1] Frank Leverett and F. B. Taylor, *The Pleistocene of Indiana and Michigan and the History of the Great Lakes*, U. S. Geol. Survey, Mon. 53 (Washington, D.C.: U. S. Government Printing Office, 1915).

[2] S. G. Bergquist, "Glacial Evolution of the Grand River in Michigan," *Geol. Soc. Am. Bull.*, 59 (1948): 1311 (abstract).

[3] J H. Bretz, "Causes of the Glacial Lake Stages in Saginaw Basin, Michigan," *Journ. Geol*., 59 (1951): 244-58; "The Stages of Lake Chicago: Their Causes and Correlations," *Am. Journ. Sci*., 249 (1951): 401-29.

[4] Outer, Middle, and Inner Charlotte, Lansing, Grand Ledge, Ionia, Portland, Lyons, Fowler, Flint, Owosso.

[5] Leverett and Taylor, *op. cit*., p. 256.

[6] *Ibid*., p. 257.

[7] The one exception, the Owosso moraine, exhibits a definite overriding in several different places of the next earlier (Flint) moraine and cannot be used as evidence for my contention that an earlier channel existed.

[8] Bretz, "Causes of the Glacial Lake Stages in Saginaw Basin, Michigan," *Journ. Geol.*, 59 (1951): 252.

[9] There are three exceptions where drainage from a moraine crossed the next earlier one and continued to use an earlier drainage way.

[10] Lack of topographic maps covering the main courses of Prairie, Fish, and Pine creeks forbade detailed field examination in the time available. A few crossings of lower Pine Creek showed no valley-train forms or materials; depiction of its valley train is entirely on the authority of Leverett and Taylor.

[11] Locally spelled and pronounced "Rogue." Misprints in the Leverett and Taylor monograph (pp. 220, 221, and 225) read "Rapid."

[12] Leverett and Taylor, *op. cit*, pp. 225, 226.

[13] *Ibid*., p. 323.

[14] The extensive eight-hundred-foot, more or less, flat summits of the moraine country both northeast and south of Plainfield appear to record meltwater escaping southward between the two lobes even earlier than the development of the Ross and Jamestown channels.

[15] As shown on the 1916 Cedar Springs map. Plainfield today is on the south side of the river.

[16] Frank Leverett, "Map of the Surface Formations of the Southern Peninsula of Michigan" (Dept. of Conservation of Michigan, Geol. Survey Div., 1924).

[17] Bergquist's upper segment of the Glacial Grand. His abstract (*op. cit*.) might give a casual reader the impression that this Lookingglass-Grand tributary functioned before retreat had reached the position of the Portland or Lyons moraine, an impossibility of course. A misprint of "westwardly" for "eastwardly" in his fourth paragraph should not lead an intelligent reader astray.

[18] Bretz, "Causes of the Glacial Lake Stages in Saginaw Basin, Michigan," *Journ. Geol*., 59 (1951): 253.

[19] Bretz, "The Stages of Lake Chicago: Their Causes and Correlations," *Am. Journ. Sci*., 249 (1951): 414.

[20] If a break between Cary and Mankato substages of the Wisconsin glaciation, now identified in Wisconsin, Illinois, Iowa, and Minnesota, exists in the Saginaw basin, Lake Wayne constitutes the marker. The moraine on Michigan's west coast which Leverett identified as Port Huron is a composite of two, a younger one of red drift overriding an older and more massive one not of that color. The younger one is Valders (Mankato); only the older one is Port Huron.

[21] G. M. Stanley, "The Submerged Valley through Mackinac Straits," *Journ. Geol*., 46 (1938): 966-74.

[22] F. T. Thwaites, personal communication.

# A NEW SPECIES OF THE TETRACORAL GENUS *PALASTRAEA* FROM THE MISSISSIPPIAN OF KENTUCKY

GEORGE M. EHLERS AND ERWIN C. STUMM

## Introduction

THE species of the tetracoral genus *Palastraea* described in this paper is based on four specimens collected by Professor A. C. McFarlan, of the University of Kentucky, from the Vienna limestone of the Upper Mississippian Chesterian series of Kentucky. According to Professor McFarlan, the specimens were found in debris of loose white chert at the top of the Glen Dean limestone about one mile south of Sugar Grove, Little Muddy Quadrangle, Butler County, Kentucky. In a letter Professor McFarlan states that the chert horizon from which the debris certainly was derived is in the Vienna limestone.

We wish to thank Professor McFarlan for the opportunity to study these specimens and for permission to deposit some of the type material in the Museum of Paleontology of the University of Michigan.

### SYSTEMATIC DESCRIPTION

Phylum Coelenterata
Class Anthozoa
Subclass Tetracoralla
Family Palaeosmiliidae
Genus *Palastraea* McCoy

*Palastraea* McCoy, 1851, p. 111.

*Genotype*.—By monotypy, *Astraea carbonaria* McCoy, 1849, p. 125; 1851, p. Ill, pl. 3A, figs. 7-7a, pl. 3B, figs. 1-1a. Carboniferous limestone, near Bakewell, Derbyshire, and Corwen, North Wales, = *Cyathophyllum regium* Phillips, 1836, p. 201, pl. 2, figs. 25-26, Carboniferous limestone, Derbyshire, England.

**Palastraea mcfarlani** Ehlers and Stumm, sp. nov.

(Pl. I, Figs. 1-3)

*Description*.—Coralla aphroid, low subhemispherical, with low convex distal surfaces, composed of corallites averaging 13 mm. in diameter. Calyxes polygonal with shallow axial pits and broad, inwardly sloping peripheral platforms. Centers of pits with small, low axial bosses, each with a medial depression representing enlarged axial part of a fossula.

In transverse section, septa thin, smooth, radially arranged, averaging 50 in mature corallites; major septa reaching almost to axis; minor septa extending to borders of tabularium; cardinal septum shorter than other major septa but longer than minor septa. Shortened cardinal septum and major septa on sides of this septum indicating presence of obscure fossula, narrow in the dissepimentarium and oval in the tabularium; axial ends of major septa in cardinal quadrants deflected toward axial end of cardinal septum. Peripheral ends of a few septa of adjacent corallites confluent; peripheral ends of most septa separated by narrow zones of elongate dissepiments.

In longitudinal section, tabularia averaging about 5.5 mm. in diameter; axial part of tabularia composed of closely set, incomplete, distally arched tabulae, bent sharply proximally at their peripheries; periaxial part of tabularia composed of small, irregularly placed tabellae. Dissepimentaria wide, composed of elongate dissepiments, axially directed adjacent to tabularia and distally convex toward peripheries of corallites.

*Remarks*.—The genus *Palastraea* has been regarded by most investigators of Paleozoic tetracorals as a synonym of *Palaeosmilia*. The genotype of *Palaeosmilia*, *P. murchisoni* Milne-Edwards and Haime, has a simple corallum with an epitheca; the genotype of *Palastraea*, *Astraea carbonaria* McCoy, has a compound corallum in which the corallites are separated by dissepiments. Most workers have not considered these differences sufficient for generic distinction. In spite of the fact that the coralla of the two genera have similar internal structures, we believe that the aphroid corallum of *Palastraea* is so distinct from the simple corallum of *Palaeosmilia* that these two genera should not be combined.

The only previously described species of *Palastraea* from North American strata is *P. compressa* (Easton). This species from the Mississippian Golconda(?) formation at Sherwood, Tennessee, differs from *Palastraea mcfarlani* in having larger corallites, a larger number of septa, and more complete and horizontally disposed tabulae. See Plate I, Figures 4 and 5.

The species is named after Professor A. C. McFarlan who has contributed much to the knowledge of the stratigraphy and paleontology of Kentucky.

*Occurrence*. — Upper Mississippian (Chesterian series — Vienna limestone; one mile south of Sugar Grove, Little Muddy Quadrangle, Butler County, Kentucky.

*Types*.—Holotype No. 28892; paratype No. 28893, Museum of Paleontology, University of Michigan. Parts of the holotype and of the paratype and a topotype are in the collection of the Department of Geology of the University of Kentucky. Another topotype, No. 28894, is in the Museum of Paleontology, University of Michigan.

UNIVERSITY OF MICHIGAN

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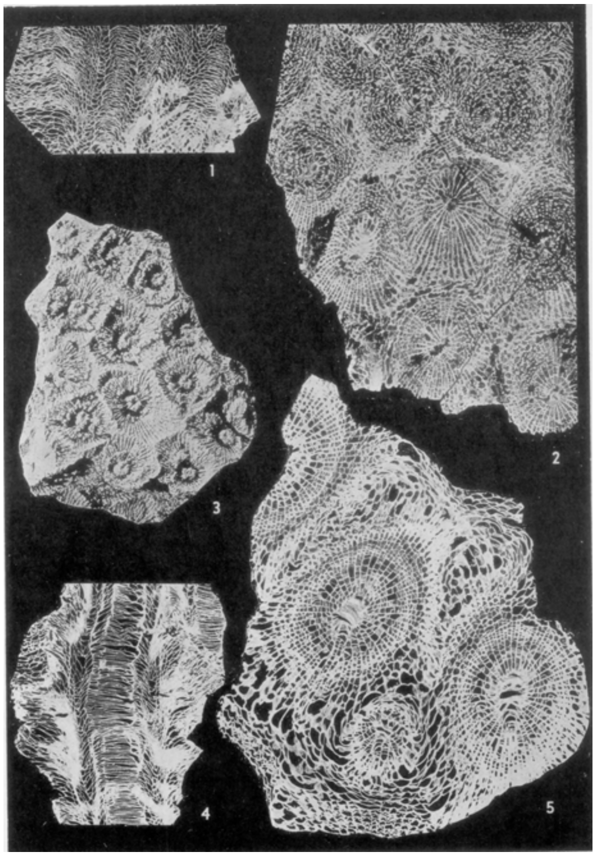

EXPLANATION OF PLATE I

*Palastraea mcfarlani* Ehlers and Stumm, sp. nov.

FIG. 1. Longitudinal section of a corallum showing tabulae and elongate dissepiments. Holotype No. 28892, Museum of Paleontology, University of Michigan. Upper Mississippian (Chesterian series—Vienna limestone); one mile south of Sugar Grove, Little Muddy Quadrangle, Butler County, Kentucky. X 2

FIG. 2. Transverse section of the same corallum as in Figure 1 showing thin septa, peripheral ends of septa of adjoining corallites separated by elongate dissepiments, and arrangement of axial parts of septa about oval, axial parts of fossulae. X 2

FIG. 3. Distal view of a part of the weathered surface of another corallum showing polygonal corallites with axial bosses in small axial pits and a medial depression in each axial boss representing the enlarged, oval, axial part of a fossula. Paratype No. 28893, Museum of Paleontology, University of Michigan. Same stratigraphic position and locality as holotype. X 1

*Palastraea compressa* (Easton)

FIG. 4. Longitudinal section of a corallum showing tabulae and elongate dissepiments Hypotype No. 24372, Museum of Paleontology, University of Michigan (thin section of a specimen collected by Dr. Charles Butts and preserved in the United States National Museum). Upper Mississippian (Chesterian series—Golconda[?] formation); quarry at Sherwood, Tennessee. X 2

FIG. 5. Transverse section of same corallum as in Figure 4 showing larger corallites, more numerous septa, and larger fossulae than exhibited by *Palastraea mcfarlani*. X 2

# THE SAW ROCK CANYON FAUNA AND ITS STRATIGRAPHIC SIGNIFICANCE

CLAUDE W. HIBBARD

## INTRODUCTION

ONE of the best Pliocene and Pleistocene continental deposits in North America occurs in a small area in southwestern Kansas (Clark, Meade, and Seward counties) and northwestern Oklahoma (Beaver and Texas counties) (Fig. 1). This area is in the High Plains region east of the Rocky Mountain slope and south of the glaciated region. In it there exists between 700 and 1,000 feet of sediments, which have yielded the largest number of invertebrate and vertebrate continental faunas of Pliocene and Pleistocene age that are known from any given geographical locality (Fig. 2).

These faunas are of great importance in the interpretation of paleoclimatology, paleoecology, vertical and horizontal distributions, speciation through time, extinction, the time of appearance of migrant forms, and the shifting of the faunas during the Pleistocene age.

The Middle Pliocene Optima fauna in the Ogallala formation (Stirton, 1936a, p. 186) of Texas County, Oklahoma, was the first to be worked, followed shortly by the study of the Lower Pliocene Beaver fauna (Stirton, 1935, and Hibbard, 1951) of Beaver County, Oklahoma. The intensive study of the Pliocene and Pleistocene faunas of Clark, Meade, and Seward counties, Kansas, which was started in the summer of 1936, has also been reported (Hibbard, 1949 and 1950), but the description of the large Middle Pliocene fauna taken from the Swayze Quarry, Clark County, Kansas, by George F. Sternberg for Childs Frick has not been completely published.

Dr. Thad McLaughlin, of the United States Geological Survey, and I discovered the Pliocene deposit containing the Saw Rock Canyon fauna in Seward County, Kansas, in June, 1943. The war, and a lack of financial support, prohibited a detailed study of the fauna at that time, although I (1944) reported upon *Osteoborus progressus* taken from the site, and assigned a Middle Pliocene age to the deposit on the basis of numerous, isolated *Dipoides* teeth recovered from it. Additional fossils from this deposit were reported by me later (1949a) and assigned to the lower Upper Pliocene because of the advanced stage of the development of the mammals and the presence of the genus *Cosomys*. The fauna in part bridges the gap between Hemphillian (Middle Pliocene) and Blancan (Upper Pliocene) time. (These provincial time terms are discussed in detail by Wood and others, 1941.)

Field parties from the University of Michigan Museum of Paleontology made collections of this fauna in the summers of 1950 and 1951; the specimens recovered then form the basis of the present report. Unless otherwise indicated, all specimens mentioned are in this museum.

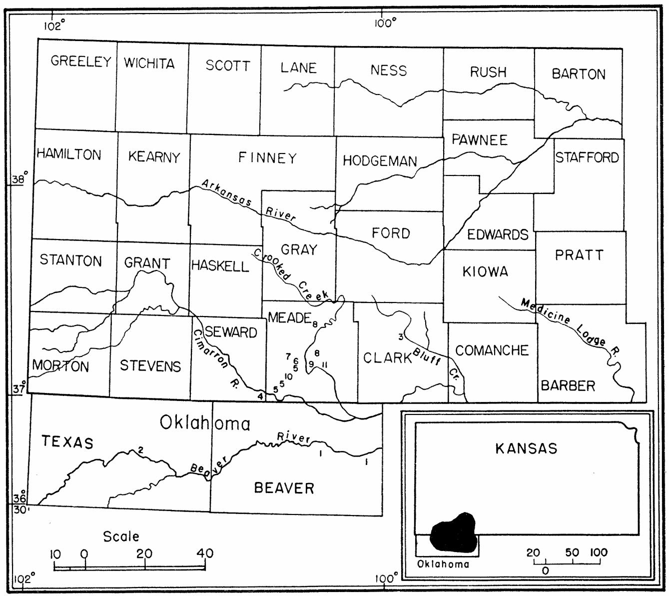


FIG. 1. Location map of local faunas. Locality in which studies were made is shown in black on small Kansas outline map. Local faunas: 1, Beaver; 2, Optima; 3, Swayze Quarry; 4, Saw Rock Canyon; 5, Rexroad; 6, Deer Park; 7, Seger gravel pit; 8, Cudahy; 9, Borchers; 10, Jinglebob; 11, Jones Ranch.

STRATIGRAPHIC SUCCESSION of PLIOCENE and PLEISTOCENE FAUNAS in SOUTHWESTERN KANSAS and NORTHWESTERN OKLAHOMA

| EPOCHS | Time Units (Tentative Pleistocene correlation based on four major glaciations) | ROCK UNITS | Local Fauna Name | Reference and Remarks |
|---|---|---|---|---|
| PLEISTOCENE | WISCONSIN 4th glacial | VANHEM fm. | JONES RANCH (cool) | (Hibbard, 1949b) Late Wisconsin. Last of camels and peccary. Invertebrates and some northern species of mammals, etc. |
| | SANGAMON 3rd interglacial | KINGSDOWN fm. | JINGLEBOB (warm moist) | (Hibbard, 1953) Invertebrates, *Gopherus*, *Blarina*, *Oryzomys*, etc. |
| | ILLINOIAN 3rd glacial | | UNNAMED (cool) | (Rinker and Hibbard, 1952) Invertebrates, *Perca*, *Emys*, *Paradipoides*, *Castoroides*, etc. |
| | YARMOUTH 2nd interglacial | CROOKED CREEK fm. | BORCHERS (warm semiarid) | (Hibbard, 1949) *Testudo*, *Perognathus*, *Sigmodon*, *Synaptomys*, *Equus (Equus)*, etc. |
| | | Pearlette ash mem. | | |
| | KANSAN 2nd glacial | | CUDAHY (cool) | (Hibbard, 1949) Invertebrates, *Sorex*, *Neosorex*, *Microsorex*, *Synaptomys (Mictomys)*, *Microtus*, *Pitymys*, etc. |
| | | | SEGER GRAVEL PIT Probably pre-Kansan | (Hibbard, 1951) *Nannippus*, *Equus (Plesippus)*, *Stegomastodon*, etc. |
| | AFTONIAN 1st interglacial | MEADE fm. | UNKNOWN | |
| | NEBRASKAN 1st glacial | | DEER PARK (cool) | (Hibbard, 1949) *Nannippus*, *Equus (Plesippus)*, *Pliolemmus*, *Procastoroides*, etc. |
| PLIOCENE | BLANCAN | REXROAD fm. | REXROAD (warm) | (Hibbard, 1950) Invertebrates, *Equus (Plesippus)*, *Nannippus*, *Dipoides*, *Procastoroides*, *Sigmodon*, etc. |
| | | | SAW ROCK (warm) | (This Report) Invertebrates, *Dipoides*, *Cosomys*, *Baiomys*, *Osteoborus*, etc. |
| | HEMPHILLIAN | OGALLALA fm. | SWAYZE QUARRY | (Hibbard, 1942) |
| | | | OPTIMA (warm temperate) | (Hesse, 1936) *Osteoborus*, *Pliohippus*, *Calippus*, *Teleoceras*, etc. |
| | CLARENDONIAN | LAVERNE fm. | BEAVER (warm temperate) | (Hesse, 1936a; Hibbard, 1951) Plants, Invertebrates, Alligator, *Eucastor*, *Calippus*, *Nannippus*, etc. |

FIG. 2

## ACKNOWLEDGMENTS

I am greatly indebted to the members of our field parties for their careful handling of the matrix removed from the Saw Rock Quarry and for their enthusiastic and painstaking search of the washed matrix for fossils. The fieldworkers in 1950 were Thomas M. Oelrich, James P. Rogers, Frederick T. Sparrow, Dwight W. Taylor (students at the University of Michigan), and myself. In the summer of 1951 they were Thomas M. Oelrich, graduate student, University of Michigan; Clyde O. Priddy, graduate student, Kansas State College; Alex F. Ricciardelli, graduate student, University of Pennsylvania; John C. Wagner, undergraduate student, University of Michigan; and Faye Ganfield Hibbard and I.

The field parties are grateful to Dave Leahy, Director of the Kansas Forestry, Fish and Game Commission, and to Harry Smith, Superintendent of Meade County State Park, for permission to live at the park and to wash the fossil-bearing matrix there. I am also indebted to J. D. Center, of Plains, Kansas (who has leased the ranch on which the deposit is located), for allowing us to continue our field work at the Saw Rock Quarry.

In addition, I wish to express my appreciation for permission to study specimens under the care of Dr. Robert W. Wilson, of the Kansas University Museum of Natural History; Dr. C. Lewis Gazin, of the United States National Museum; Dr. Alfred S. Romer, of the Museum of Comparative Zoology at Harvard; and Dr. W. H. Burt, of the University of Michigan Museum of Zoology. Financial support for the help of Thomas M. Oelrich, research assistant, in preparing and cataloguing the microvertebrates of the Saw Rock Canyon fauna was provided by the Board of Governors of the Horace H. Rackham School of Graduate Studies of the University of Michigan. The illustrations were made possible by grants from the Faculty Research Fund of the University of Michigan. All drawings were made by Jane S. Mengel (J. S. M.) or W. C. Sherman (W. C. S.).

## SAW ROCK CANYON FAUNA

This local fauna occurs in the XI member[1] of the Rexroad formation near the head of Saw Rock Canyon and near the center of the west section line of Sec. 36, T. 34 S., R. 31 W., XI Ranch, Seward County, Kansas. (For a discussion of the Saw Rock Canyon geological section see Hibbard, 1949a, pp. 93-97.) The vertebrates reported were recovered from an area 8 feet by 10 feet and from 12 to 14 inches thick. They were taken from a stream deposit consisting of fine sand, sandy silt, and silty clay. The matrix was removed, dried, and washed. The method used for the recovery of the fossils was that reported by Hibbard (1949c).

## Class PISCES

### Family Ameiuridae

Numerous pectoral spines, cleithra, and skull elements of small catfish were collected in association with the other vertebrates.

## Class AMPHIBIA

A few frog and toad vertebrae and girdle elements were found.

## Class REPTILIA

Parts of pond and river turtles are the most abundant remains of vertebrates in the deposit.

Lizard and snake vertebrae are common. A few jaws were recovered. Two of these jaws, No. 27674, were identified by John W. Twente, Jr., a graduate student at the University of Michigan, as *Eumeces striatulatus* Taylor. They are slightly smaller than the jaws of this species from the Rexroad fauna.

## Class AVES

Only a few bird bones were found, most of them fragmentary. They are being studied by William A. Lunk, a graduate student at the University of Michigan.

## Class MAMMALIA

### Order INSECTIVORA

### Family Soricidae

The first left upper incisor of a shrew, No. 29202, was collected; it is nearly as large as that of *Paracryptotis rex* Hibbard. The incisor is broader than, though not so high as, that of *Blarina brevicauda* (Say). It is grooved posteriorly for the reception of the first unicuspid.

### Order Rodentia

### Family Sciuridae

*Marmota? sp*.

Only fragments of the teeth of a large woodchuck-like sciurid were taken. The incisor, No. 29227, is smaller than that of *Marmota mexicana* Wilson, of Hemphillian age, from Chihuahua, Mexico, and *Paenemarmota barbouri* Hibbard and Schultz, of Blancan age, from Texas, Kansas, and Nebraska. It has an anteroposterior length of 6.65 mm. and a transverse width of 4.3 mm., and is rugose and striated along the enamel surface. There is also a fragment of a large upper molar or premolar.

### Family Geomyidae

Two upper incisors of a gopher were taken from the deposit. They have two grooves, as in *Geomys*. Associated with them were $P^4$ and $M_3$, No. 28286, of a gopher the size of *Nerterogeomys*? *minor* (Gidley). The base of $P^4$ had begun to constrict and would eventually close. $M_3$ is constricted at the base and would close in old age.

### Family Heteromyidae

*Perognathus mclaughlini* Hibbard

(Fig. 3C)

*Perognathus mclaughlini* Hibbard, 1949. Contrib. Mus. Paleontol., Univ. Mich., 7 (5): 98, fig. 1.

Besides the holotype and the paratypes there have been taken parts of two right rami with $P_4$; a left ramus, No. 28171, with $P_4$-$M_1$, which has an anteroposterior length of 2.1 mm.; a left ramus, No. 28169, which has the incisor present and $P_4$-$M_3$. The anteroposterior length of $P_4$-$M_3$ is 3.7 mm. Specimen No. 28168 is a nearly complete right ramus with incisor and $P_4$-$M_3$ (Fig. 3C). The anteroposterior length of $P_4$-$M_3$ is 3.9 mm.

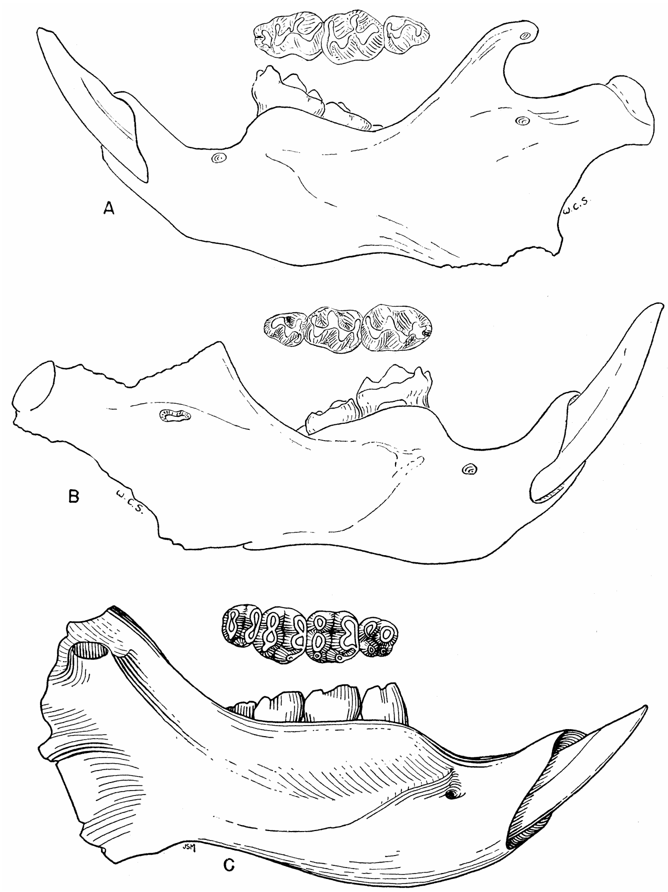


FIG. 3. A-B, *Baiomys sawrockensis*, sp. nov.: A, No. 27506, holotype, left ramus, lateral and occlusal views, X -10; B, No. 27503, paratype, right ramus, lateral and occlusal views, X -10. C, *Perognathus mclaughlini* Hibbard, No. 28168, topo-type, right ramus, lateral and occlusal views, X -8

Two fragmentary right rami of a kangaroo rat, Prodipodomys, were recovered from the deposit. One, No. 24342, is of an adult with $M_1$-$M_2$. The teeth are completely surrounded by enamel (Fig. 4D). Both teeth have a greater anteroposterior crown length than those of *Dipodomys ordii richardsoni* (Allen), although the transverse width of the crowns is less. The bases of the teeth are closed, and each tooth has two short roots. $M_1$ is larger than $M_2$ and is nearly circular in outline. The anteroposterior length of $M_1$-$M_2$ is 2.2 mm. The transverse width of the crown of Mi is 1.35 mm.

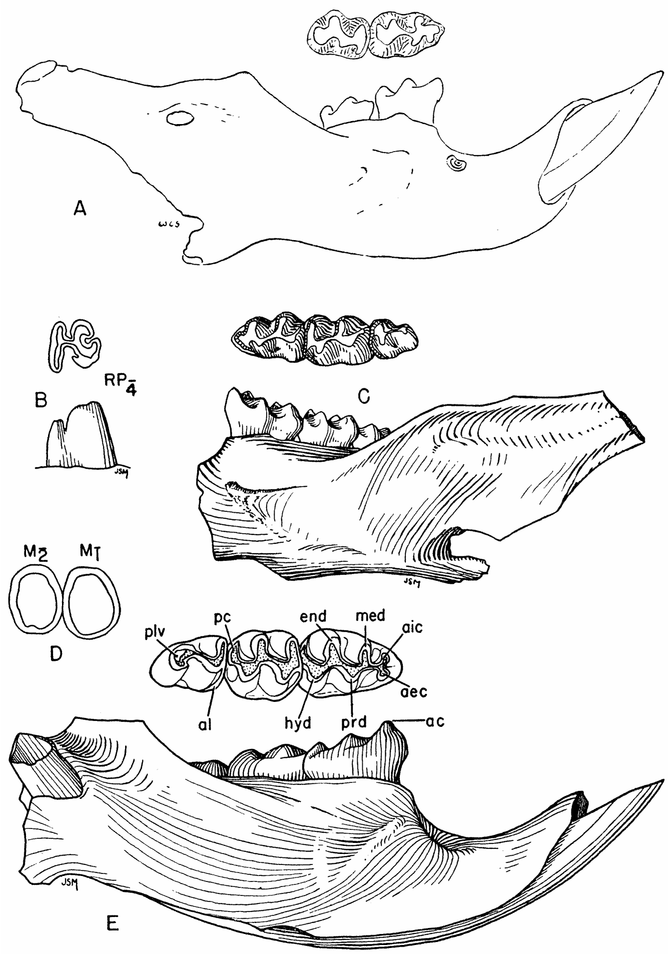


FIG. 4. A, *Onychomys martinii* (Hibbard), No. 6201 M.C.Z., plesiotype, right ramus, lateral and occlusal views, X 6. B, *Prodipodomys sp*., No. 28172, right $P_4$, labial and occlusal views, X 8. C, *Onychomys larrabeei*, sp. nov., No. 27486, holotype, left ramus, $M_1$-$M_3$, lateral and occlusal views, X 6. D, *Prodipodomys sp*., No. 24342, right $M_1$ and $M_2$, occlusal view, X 8. E, *Cimarronomys stirtoni*, sp. nov., No. 28173, holotype, right ramus, lateral and occlusal views, X 8

*Key to Abbreviations in Figure 4*

*ac*, anteroconid
*aec*, anterolabial (anteroexternal) conulid
*aic*, anterolingual (anterointernal) conulid
*al*, anterolophid (anterior cingulum)
*end*, entoconid
*hyd*, hypoconid
*med*, metaconid
*pc*, posterior cingulum
*plv*, posterolingual reëntrant valley
*prd*, protoconid

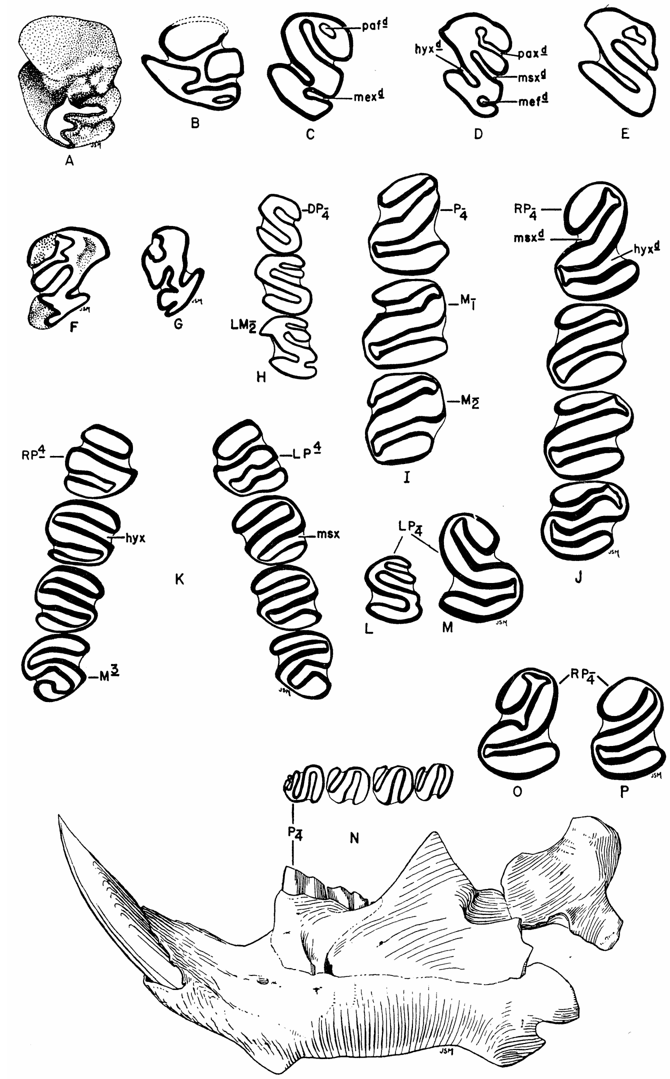


FIG. 5. *Dipoides wilsoni* Hibbard

EXPLANATION OF FIGURE 5

A-H, teeth of immature beavers, occlusal views: A, No. 29232a, $RP_4$?; B, No. 29232b, $LP_4$; C, No. 29232c, $LM_1$; D, No. 29232d, $LM_2$; E, No. 29232e, $LM_2$?; F, No. 29232f, $RM_2$; G, No. 29232g, $RDP_4$ or $LDP^4$; all X -5. H, No. 24338, left $DP_4$-$M_2$; I, No. 27287, $RP_4$-$M_2$; J, No. 29225, $RP_4$-$M_3$; K, No. 28158, right and left $P^4$-$M^3$; L, No. 29233, young adult $LP_4$; M, No. 29234, adult $LP_4$; occlusal views, all X -3. N, No. 27288, lateral and occlusal views of left ramus with $P_4$-$M_3$; X -1.5. O, No. 29235, adult $RP_4$; P, No. 29236, adult $RP_4$; occlusal views, both X -3

*Key to Abbreviations*

*hyx*, hypoflexus
*hyx^d*, hypoflexid
*mef^d*, metafossettid
*mex^d*, metaflexid
*msx*, mesoflexus
*msx^d*, mesoflexid
*paf^d*, parafossettid
*pax^d*, paraflexid

### *Prodipodomys sp.*

(Fig. 4 B and D)

No. 28172, the other fragment, is the anterior end of the ramus of a young individual with $P_4$. The ramus and $P_4$ are larger than that of *Prodipodomys kansensis* Hibbard (1939) from Edson Quarry (Middle Pliocene), of Sherman County, Kansas. The tooth is completely surrounded by enamel. It is high-crowned, slightly worn, and has two well-developed roots. The anterolophid shows that there were three cusps. The largest and most distinct one is on the lingual side. It is separated from the anterolabial cusps by a shallow groove in the anterior enamel face of the tooth (Fig. 4B) which extends downward about one third of the length of the crown and would disappear with wear. Well-developed labial and lingual enamel reëntrant grooves nearly separate the posterolophid from the anterolophid. The labial reëntrant groove extends farther across the crown of the tooth but it is shallower and not so broad as the lingual groove. It goes about one third of the distance down the side of the tooth, while the lingual groove goes one half of the distance. Both would disappear in old, adult wear of the tooth. The anteroposterior length of the occlusal surface of $P_4$ is 1.0 mm. The greatest anteroposterior length of $P_4$ is 1.4 mm. The greatest transverse width, across the posterolophid, is 1.2 mm. The masseteric ridge is well formed and has the same relationship to $P_4$ as it does in *Dipodomys*. It ends in a knoblike process. The $P_4$ of the Saw Rock specimen is higher crowned than that of *Prodipodomys kansensis* and does not appear as advanced as that of *P. minor* (Gidley). It seems that these forms were ancestral to the Pleistocene *Dipodomys*.

## Family Castoroidae

### *Dipoides wilsoni* Hibbard

(Fig. 5 A-P)

*Dipoides wilsoni* Hibbard, 1949. Contrib. Mus. Paleontol., Univ. Mich., 7 (5); 100-103, fig. 2 A, B, and F.

Considerable material of this species was recovered during the summers of 1950 and 1951; it shows variation among individuals as well as variations due to age.

A left ramus, No. 28153, of an immature specimen has the alveolus for $DP_4$, which had two well-developed roots. $M_1$ and $M_2$ are present and wear is more advanced than in No. 24338 (Fig. 5H). Both molars have an S-pattern. An enamel islet on Mi shows the occurrence of the paraflexid (dental nomenclature after Stirton, 1935, p. 392) in the early pattern of $M_1$. The anteroposterior length of the occlusal surface of $M_1$ is 3.1 mm., and of $M_2$ is 3.35 mm.

A left ramus, No. 27288, with $P_4$-$M_3$ (Fig. 5N), is that of a young adult animal. $P_4$ has a paraflexid reaching almost as far across the crown as the mesoflexid. There is a shallow striid anterior to the parastriid that opens into the paraflexid and produces a small enamel column. This anterior striid is 0.5 mm. in length, in contrast to the parastriid, which extends 1.5 mm. down the lingual side of $P_4$. Both of these would soon disappear with wear and the tooth would have a normal S-pattern. The anteroposterior occlusal length of $P_4$-$M_3$ is 18.15 mm., and the alveolar length is 19.9 mm. $P_4$ has an anteroposterior occlusal length of 4.4 mm. Among the isolated teeth collected is $LP_4$, No. 29233 (Fig. 5L), that has an anteroposterior occlusal length of 3.8 mm. It has a well-developed parastriid that extends 4.5 mm. down the lingual side of the tooth. The tooth has a height of 13.0 mm.

A right ramus, No. 27287, with $P_4$-$M_2$ and alveolus of $M_3$, is from an older beaver. The anteroposterior occlusal length of $P_4$-$M_2$ is 15.9 mm. The teeth all have an S-pattern (Fig. 51).

The right ramus, No. 29225, with $P_4$-$M_3$ (Fig. 5J), though badly broken, is the best ramus recovered. It is also the largest. The posterolingual part is missing, so that the alveolar length of the teeth cannot be measured. The anteroposterior occlusal length of $P_4$-$M_3$ is 20.7 mm. The transverse width of $M_2$ at the alveolar border is 5.05 mm. The width of the incisor is 5.1 mm., in contrast to the width of the incisor in the immature specimen, No. 24338, where it is 2.2 mm. There is a slight pit between $M_3$ and the ascending ramus, for muscle attachment. The coronoid fossa is deep and is located between the capsular process for the base of the incisor and the coronoid process. The tip of the coronoid process is missing on all specimens. Its base is narrow. The incisor passes from the lingual side of the jaw to the labial side beneath $M_3$ and ends in a prominent capsular process 12.5 mm. below the dorsal surface of the condyle. The angle projects posteriorly as a broad, thin shelf.

The maxillaries, No. 28158, are those of a young adult. From their size and the stage of wear they could belong with the left ramus, No. 27288. The anteroposterior occlusal length of $P^4$-$M^3$ (Fig. 5K) is 17.2 mm. $P^4$ is in an early stage of wear, and the paraflexus and hypoflexus are united. The anterior part of the tooth has enamel surrounding the dentine tract. The fourth premolars have a length of 12.6 mm. The tooth structure is the same at the base as at the occlusal surface. Whether or not the crown pattern would have changed in this individual to a typical S-pattern is not known, but in the other upper premolars the parastria and paraflexus disappear with growth and wear. This type of occlusal surface was observed by Wilson (1934, pl. 1, fig. 4) in *Dipoides stirtoni* Wilson. The teeth of *D. wilsoni* grow from persistent pulps. The bases of all the teeth in old adults are open. In the adult upper fourth premolars at hand there is only one labial inflection (mesoflexus) and one lingual inflection (hypoflexus). The largest tooth recovered is $RP^4$, with a length of 10.7 mm. The base is entirely open. The greatest transverse width of the occlusal surface is 6.3 mm. The anteroposterior occlusal length of the crown is 5.0 mm.

Many fragmentary remains of skeletons were recovered. No elements were found associated and very few are complete. Little can be added to the discussion of the skeleton of *Dipoides* given by Wilson (1934). The individual bones vary greatly in size because of differences in age in the animals represented.

A humerus, No. 28156, from a young adult, lacks the tip of the deltoid ridge. Its greatest length is 44.6 mm., and the width of the distal end is 17.9 mm.

Two nearly complete femurs were taken. No. 29237, a left femur, is of a young adult. The epiphyses are not closed. No. 28154, a right femur, is of a fully adult animal. Its greatest length is 64.5 mm. The characters of the femur are those given by Wilson (1934, p. 25).

A few fragments of skulls were found which may belong to *Dipoides*. One specimen is the back of the skull of an adult animal with the interparietal present and with prominent occipital and sagittal crests. Another is a frontal region which is broad anteriorly and has a decided interorbital constriction as compared with *Castor*.

*Dipoides wilsoni* is distinguished from *D. williamsi* Stirton by the less clearly triangular outline of the molars and by a narrower hypoflexid, which appears to extend more lingually across the crown of the molar.

*Discussion*.—*Dipoides wilsoni* is closely related to *D. williamsi*. From the material at hand it is fairly evident that it was derived from either *D. stirtoni* or a closely related species. Wilson (1934, p. 23) states in regard to *D. stirtoni*: "The fourth lower premolar (pl. 1, fig. 10a) is a large, rather straight tooth characterized by one large external inflection of the enamel [hypoflexid] and two internal inflections [paraflexid and mesoflexid], the posterior one being the deeper. This pattern is very persistent, for in only one of twenty-six specimens examined was there any indication of a change with wear. . . . In eighty-nine cheek-teeth examined, two (incidentally from the same individual) were found in which the bases of the teeth were closing." As shown by Wilson, the teeth of *D. stirtoni* do not grow throughout life from persistent pulps. *D. wilsoni* is a more advanced form, in which the teeth grow from persistent pulps and the bases of the teeth do not close. Furthermore, the tooth pattern of *D. stirtoni* is present in unworn and slightly worn teeth of *D. wilsoni*. This pattern is lost with wear and an S-pattern is found in adult animals.

Stirton (1936, p. 280) in his description of *Dipoides williamsi* states: "The absence of a parafossettid on $P_4$ makes it difficult to derive *D. williamsi* from any of the known species of the Lower Pliocene Eucastor, although some species, apparently, are near the line of descent." The parafossettid of $P_4$ is an isolated paraflexid where the parastriid fails to extend to the base of the tooth, leaving an open reëntrant enamel fold which wears to an islet. The specimen of *D. williamsi* described by Stirton is an adult animal and could have had a minor paraflexid present in youth. From the study of the teeth of *D. wilsoni* it appears that the passage of time was the principal factor needed for *D. williamsi* and *D. wilsoni* to be derived from *D. stirtoni*. In my opinion this is a more logical conclusion than trying to derive them directly from *Eucastor*.

*Dipoides stirtoni* is considerably older than *D. wilsoni*. Wilson (1937) reported upon the fauna associated with *D. stirtoni*, which was found near Rome, Malheur County, Oregon. He considered the Rome fauna equivalent in age to the Rattlesnake-Thousand Creek faunas of Middle Pliocene age. On the basis of *Mylagaulus*? cf. *monodon* Cope, *Teleoceras fossiger* (Cope), and other mammals listed by Wilson, the Rome fauna seems comparable in age to the High Plains Hemphill-Edson Quarry faunas. It is evident that a considerable period elapsed between the Hemphill-Edson Quarry faunas of Texas, and Kansas, and the Saw Rock fauna.

It is obvious that *Dipoides*, which has been considered an "index fossil" of Hemphillian age (Middle Pliocene) failed to die out when it was thought to, and continued on as a group in this geologic period much longer than has been previously realized. *D. rexroadensis* Hibbard and Riggs (1949) is Upper Pliocene in age, and *Paradipoides stovalli* Rinker and Hibbard (1952) is Upper Pleistocene (probably Illinoian).

**Onychomys larrabeei**, sp. nov.

(Fig. 4C)

*Holotype*.—No. 27486, University of Michigan Museum of Paleontology, a left ramus with $M_1$-$M_3$. The anterior part of the ramus is missing. Collected in the summer of 1950, by the University of Michigan field party.

*Horizon and type locality*.—Lower Upper Pliocene, XI member of the Rexroad formation, Saw Rock Canyon, Sec. 36, T. 34 S., R. 31 W., Seward County, Kansas.

*Diagnosis*.—A grasshopper mouse larger than *Onychomys martinii* (Hibbard) (Fig. 4A), from the Ogallala formation, Middle Pliocene, of Sherman County, Kansas. It is distinguished from *O. gidleyi* Hibbard from the Rexroad fauna, of Meade County, Kansas, by the narrower transverse width of the molar series.

*Description of holotype*.—The ramus is that of a young adult mouse. The anterior part is missing, and the ramus is broken at the posterior border of the mental foramen. The masseteric ridge ends on a line with the anterior root of $M_1$. The capsular process for the reception of the base of the incisor is but slightly expanded. A deep groove situated between the capsular process and the upper border of the ramus extends on the labial side to the articular condyle, a condition not observed in recent specimens of *Onychomys*. The external reëntrant angles of $M_1$ and $M_2$ in *O. larrabeei* are broader than in *O. gidleyi*. $M_3$ is smaller than in *O. gidleyi*. The greatest anteroposterior length of $M_1$-$M_3$ is 4.35 mm. In eleven specimens of *O. gidleyi* from the Fox Canyon faunule the greatest anteroposterior length of $M_1$-$M_3$ ranges from 4.2 to 4.5 mm., the average being 4.34 mm.

This species is named for Lee Larrabee, of Liberal, Kansas, who has contributed greatly to the success of our work in southwestern Kansas for the past fifteen years.

*Discussion*.—*Onychomys larrabeei* is larger than *O. bensoni* Gidley, and has broader labial reëntrant valleys in the molars. *O. pedroensis* Gidley is larger than *O. larrabeei*, with much narrower reëntrant valleys in the molars. In *O. martinii* (Hibbard, 1939, p. 459), No. 6201, in the Museum of Comparative Zoology at Harvard, the posterior external reëntrant valleys are much narrower than in *O. larrabeei*, and the depth of the ramus is less.

*Onychomys larrabeei* is more closely related to *O. gidleyi* than to *O. martinii*.

**Baiomys sawrockensis**, sp. nov.

(Fig. 3 A and B)

*Baiomys rexroadi* Hibbard, 1949. Contrib. Mus. Paleontol., Univ. Mich., 7 (5): 103, fig. 2G.

*Holotype*.—No. 27506, University of Michigan Museum of Paleontology, a nearly complete left ramus with $M_1$-$M_3$. Paratypes: Nos. 27503, 27504, 27505, 28160, 28161, 28162, and 28165, right rami with $M_1$-$M_3$; and No. 28164, a left ramus with $M_1$-$M_3$. The holotype was collected in the summer of 1950 by the University of Michigan field party. The paratypes were taken in the summers of 1950 and 1951.

*Horizon and type locality*.—Lower Upper Pliocene, XI member of the Rexroad formation, Saw Rock Canyon, Sec. 36, T. 34 S., R. 31 W., Seward County, Kansas (University of Kansas, Locality 6).

*Diagnosis*.—A small *Baiomys* the size of *B. rexroadi*, with a broader lower incisor, a broader diastemal region, and a deeper anteromedian groove on the front (anteroconid) of $M_1$. The anterolabial cingulum ("anterolophid," Hooper, 1952, p. 21) of $M_2$ is narrow, with a pit between it and the protoconid. A cingular ridge is present at the mouth of the posteroexternal reëntrant valley between the protoconid and the hypoconid.

*Description of holotype*.—Specimen No. 27506 is a nearly perfect left ramus of an adult animal (Fig. 3A). Only the tip of the angle is missing. The incisor is as broad as the incisor in *Baiomys musculus* (Merriam) but it is not so thick anteroposteriorly. The incisor is not so large or so rounded as in the genus *Reithrodontomys*. The diastemal region is broader than in *B. taylori* (Thomas) and *B. rexroadi*. The masseteric ridge is well developed but does not extend so far forward as it does in *B. taylori*. The mental foramen is high on the labial side of the ramus and near the anterior root of $M_1$. The mandibular foramen is situated as in *B. rexroadi*. The condylar process of the ramus is broad and short. The coronoid process is broader and better developed than in *B. rexroadi*. The posterior part of the jaw is shaped like that of *B. musculus*, though it is smaller. The valley between the capsular process of the incisor and the coronoid process is not so deep as in the specimens of *B. rexroadi* that were examined. The crowns of the molars are narrower than those of *B. kolbi* Hibbard. The anteromedian groove on $M_1$ is the same as in young individuals of *B. rexroadi*. The anterolabial cingulum of $M_2$ is narrow and pronounced. $M_3$ is smaller than $M_3$ in *Reithrodontomys rexroadensis* Hibbard. The external reëntrant valley of $M_3$ is open and well developed. The anteroposterior length of $M_1$-$M_3$ is 2.6 mm.

*Description of paratypes*.—Specimen No. 27503 (Fig. 3B), a right ramus of an adult mouse with $M_1$-$M_3$, shows the greatest variation from the holotype. The anteromedian groove is deep and extends well down on the anterior face of the crown of $M_1$. Accessory cusplets occur in the major internal and external valleys of $M_2$. $M_3$ has a greater transverse width than $M_3$ in the holotype. The other paratypes agree with the holotype in the size of $M_3$. They range from slightly worn teeth of young animals to the well-worn teeth of adults. The cingulum is more pronounced in young specimens than in older ones. The anteromedian groove on the anterior edge of $M_1$ is deep in all specimens, in contrast to the shallower groove in *Baiomys rexroadi*. The maximum length of $M_1$-$M_3$ in the holotype and paratypes ranges from 2.5 to 2.72 mm., the average being 2.65 mm.

In the collection from this locality there are a number of rami with one or two molars. No maxillaries of this mouse have been found in the deposit.

*Discussion*.—The five specimens which were assigned to *Baiomys rexroadi* and for which measurements of $M_1$-$M_3$ were given earlier (Hibbard, 1950, p. 145) were not specimens of *B. rexroadi*. The measurements were those of specimens later described as *B. kolbi* and *Reithrodontomys rexroadensis* which were collected in association with *B. rexroadi* and at that time considered to be variants of *B. rexroadi*.

The anteroposterior length of $M_1$-$M_3$ in six specimens of *Baiomys rexroadi* from the Rexroad fauna ranges from 2.61 to 2.8 mm., the average being 2.7 mm.

**CIMARRONOMYS,** gen. nov.

*Genotype*.—*Cimarronomys stirtoni*, sp. nov.

*Diagnosis*.—*Cimarronomys* is a cricetine rodent with a large mental foramen located near the dorsal surface of the diastemal region anterior to $M_1$. The teeth are short-crowned. The anteroconid of $M_1$ has a deep anteromedian groove, and the anterolingual valley is broad, widely separating the anterolingual conulid (Hooper, 1952) of the anteroconid from the metaconid. $M_3$ is not reduced. It has two internal reëntrant valleys. The posterointernal valley of $M_3$ is shallow; with wear it forms an isolated enamel pit which later disappears. The external cingulum is well developed on all molars, closing off the reëntrant valleys between the cusps and forming basins. The name *Cimarronomys* is formed from *Cimarron*, for the Cimarron River, combined with -*omys*.

**Cimarronomys stirtoni**, sp. nov.

(Fig. 4E)

*Holotype*.—No. 28173, part of a right ramus bearing incisor and $M_1$-$M_3$. The posterior part of the ramus is missing. Paratype: No. 28174, part of left ramus bearing $M_1$-$M_3$. Both specimens were collected in the summer of 1951 by the University of Michigan field party.

*Horizon and type locality* .—Lower Upper Pliocene, XI member of the Rexroad formation, Saw Rock Canyon, Sec. 36, T. 34 S., R. 31 W., Seward County, Kansas (University of Kansas, Locality 6).

*Description of holotype*.—The coronoid process, articular condyle, and angular process of the jaw are missing. The stage of wear in the molars is that of a young adult. The masseteric ridge is well formed and ends in a pronounced knob in front of the anterior root of $M_1$. Its anterior end is just posterior to the border of the mental foramen. The transverse width of the diastemal region is as great as in *Peromyscus difficilis* (Allen) from Acultzingo, Vera Cruz, Mexico, but the diastemal region has a shorter anteroposterior length. The capsular process for the base of the incisor protruded enough so that a valley existed between it and the coronoid process. The molars are low-crowned.

$M_1$ has a deep anteromedian groove on the face of the anteroconid. The first lingual (internal) reëntrant valley between the anteroconid and the metaconid is broad and deep. The first labial (external) reëntrant valley is slightly wider. The deep anterior groove and the first reëntrant valleys produce distinct anterolingual and anterolabial conulids on the anteroconid. The second lingual and labial reentrant valleys are broad. The valley between the entoconid and the posterior cingulum is narrow. The cingulum along the labial side of the tooth is well developed between the labial edge of the anteroconid and the protoconid, also between the protoconid and the hypoconid. The cingulum projects upward, closing off the basal entrance to the external valleys and forming shallow basins which in later stages of wear would produce small depressed enamel islets or pits on the occlusal surface.

$M_2$, in comparison with $M_2$ of *Peromyscus*, has a greater transverse width in relation to its anteroposterior length. The anterior cingulum (anterolophid) joins the base of the protoconid, producing a distinct pit between the cingulum and the protoconid. The external cingulum closes the valley between the protoconid and the hypoconid. The posterior cingulum joins the entoconid, forming a pit between the cingulum and the entoconid; therefore the posterior internal reëntrant valley of $M_2$ is not open, as is that of $M_1$.

$M_3$ is not reduced. The crown of the tooth is broad anteriorly and narrows posteriorly. The anterior cingulum (anterolophid) joins the base of the protoconid, forming a deep, narrow pit. The external reëntrant valley extends halfway across the tooth and has a small cingular ridge at its mouth. A posterior internal reëntrant valley was formerly present, as is indicated by a small, isolated enamel pit. The cingulum closes the base of the anterointernal reëntrant valley. The valley in a later stage of wear would form a small enamel islet with a depression on its surface. The cusps of the molars are alternate. The anteroposterior length of $M_1$-$M_3$ is 4.55 mm.

The tooth pattern of the paratype, No. 28174, agrees with that of the holotype. The stage of wear of the teeth is that in an adult animal. The anteroposterior length of $M_1$-$M_3$ is 4.5 mm.

This species is named in honor of R. A. Stirton, who has contributed greatly to our knowledge of Cenozoic stratigraphy and faunas.

*Discussion*.—The genus *Cimarronomys* appears to be more closely related to the genus *Peromyscus* than to the other genera of cricetine rodents. It is distinguished from *Peromyscus* by the short crown of the molar teeth, the broad, deep, anterointernal reëntrant valley between the anteroconid and the metaconid of $M_1$, and the greater transverse width of $M_2$ in relation to its anteroposterior length. *Cimarronomys* is distinguished from *Bensonomys* Gazin by the broad, deep, anterointernal valley between the anteroconid and the metaconid, the deep pit between the entoconid and posterior cingulum on $M_2$, the closed anterointernal valley of $M_3$, which wears away to form an enamel pit, and the presence of a posterointernal valley on $M_3$.

If *Cimarronomys* is closely related to *Peromyscus*, this relationship is probably with the *P. boylii* group or the *P. truei* group.

*Cosomys primus* Wilson

*Cosomys primus* Wilson, 1932. Journ. Mammalogy, 13 (3): 150, 5 figs.
*Cosomys primus* Wilson, Hibbard, 1949. Contrib. Mus. Paleontol., Univ. Mich., 7 (5): 103, fig. 2 C-E.

Only isolated teeth and jaw fragments of this vole have been recovered. In the summer of 1951 two palatal regions were taken. Specimen No. 28166 is broken just anterior to the posterior border of the incisive foramina (the anterior palatine foramina) and just posterior to the posterolateral pits, which are approximately opposite the middle of the alveolus of $M^2$. Only $RM^1$ is present. It consists of an anterior loop and four alternating triangles. The first triangle is nearly closed off from the anterior loop. It is confluent with the second triangle, which is closed off from the third. The third and fourth triangles are confluent. The palatal region is distinct from that of *Ogmodontomys poaphagus* Hibbard from the Upper Pliocene. The lateral palatal grooves are deeper in *Cosomys*, especially in the anterior region of the palate, where they enter the incisive foramina, and the maxillary forming the outer wall of each groove is vertical, not sloping upward and outward to the alveolar plane as in *Ogmodontomys*. The shape of the outer walls of the lateral grooves is more like the condition observed in *Pliophenacomys primaevus* Hibbard, but the grooves are deeper in *Cosomys*. They diverge slightly outward as they approach the palatine bone, though not so much as in *Ogmodontomys*. There is a narrow posterior horizontal median process (ridge) separating the posterolateral pits. The pits are larger than those in *Ogmodontomys*, but the horizontal median process is developed as in that genus. In *Pliophenacomys* this ridge is lower and broader.

*Discussion*.—The genus *Cosomys* is preferred for our specimens to the generic name *Mimomys*, which has been used, to a degree, as a catchall for early forms of European voles with rooted teeth. Furthermore, even though *Mimomys* is restricted to include only those early European voles with rooted teeth which have an $M_1$ with a posterior loop, three alternating triangles, and an anterior loop, it is still not certain that these voles are generically the same as the Saw Rock specimens.

Stirton (1951, p. 81) states: "The microtine *Mimomys* which is restricted to the Blancan in North America ranges from the Villafranchian into the early Pleistocene in Europe." Stirton's use of "Blancan" was (*sensu stricto*) as the term was defined by Wood and others (1941, pp. 12-13). The Saw Rock Canyon fauna contains the Hemphillian (Middle Pliocene) "index fossil" *Dipoides* and the Blancan (Upper Pliocene) "index fossil" *Mimomys* = *Cosomys* Wilson. It has been suggested (Hibbard, 1950, p. 182) that a logical disposition of the Saw Rock Canyon fauna and other Pliocene faunas of approximately the same age would be to place them in the Blancan time unit.

### Order CARNIVORA

The only remains of a carnivore taken from these deposits, except the lower jaws of a bone-eating dog (*Osteoborus progressus* Hibbard, 1944), was a left $M^1$, No. 29203, of a small mustelid. The tooth has a transverse width of 6.0 mm.

### Order ARTIODACTYLA

### Family Camelidae

#### *Gigantocamelus* cf. *spatulus* (Cope)

*Pliauchenia spatula* Cope, 1893. Texas Geol. Survey, 4th Ann. Rep., 1892, p. 70, pl. 21, figs. 1 and 2., *Gigantocamelus fricki* Barbour and Schultz, 1939. Univ. Neb. St. Mus. Bull, 2 (2): 20, figs. 5-10.

*Gigantocamelus spatula* (Cope), Meade, 1945. Univ. Texas Pub. 4401: 531, pls. 53 and 54.

In the summer of 1951, a toe bone (phalange), No. 29047, of a large camel was collected which was indistinguishable from the toe bones of *Gigantocamelus spatulus* reported by Hibbard and Riggs (1949) from the Rexroad fauna, Keefe Canyon, Meade County, Kansas. This phalange was taken from near the top of the XI member, between the quarry where the specimens of *Dipoides* and of associated vertebrates were recovered and the locality where the specimen of *Osteoborus progressus* was collected. The length of the phalange is 116.4 mm. The width of the proximal end is 48.2 mm., and the distal width is 42.8 mm.

## STRATIGRAPHIC SIGNIFICANCE OF THE FAUNA

It has long been believed, in North America, that a hiatus existed between the vertebrates from the Middle Pliocene (Hemphillian) and those from the Upper Pliocene (Blancan). Stirton (1951, p. 81), for example, made the following statement: "One of the most significant gaps in our knowledge of the Cenozoic record of North America is that between the Hemphillian and the Blancan."

This gap is now bridged, in part, by the Saw Rock Canyon fauna (Fig. 2), which is considered to be lower Upper Pliocene in age and to be more closely related to the younger Rexroad fauna (Blancan) of Kansas than to the Edson Quarry fauna (Hemphillian) of Kansas for the following reasons: (1) The specimen of *Osteoborus progressus* Hibbard is larger than *O. cynoides* (Martin) from Edson Quarry. It has a much heavier jaw, with a large $P_4$ approaching the size and shape of that tooth in *Borophagus* from the Blanco and Rexroad faunas. It is a matter of individual preference which genus it is assigned to, since the skull is unknown. On the basis of the characters of the jaw it can be considered a very advanced *Osteoborus* or an early *Borophagus*. (2) *Dipoides wilsoni* is a descendant of *D. stirtoni* or a closely related species. It is more advanced in having teeth growing from persistent pulps throughout life, and in the loss of the paraflexus and paraflexid in adult individuals. (3) Mylagaulid rodents are unknown from the Saw Rock Canyon Quarry. A horned mylagaulid rodent, No. 5908, in the University of Kansas Museum, from the Swayze Quarry, Clark County, Kansas, of Middle Pliocene age, is from deposits that are older than the Saw Rock Canyon beds and younger than the deposits at Edson Quarry. It has only the upper and the lower fourth premolars and one upper and one lower molar. The specimen is that of a young adult. It is more advanced than the Edson Quarry specimens in that it has lost a molar tooth in the lower and upper tooth series. (4) The species of *Perognathus* and *Onychomys* from the Saw Rock Canyon Quarry are more closely related to those of the Rexroad fauna than to those of the Edson Quarry fauna. (5) *Cosomys* (*Mimomys* of some authors) is present in the Saw Rock Canyon fauna. Stirton (1951, p. 81) considers *Mimomys* to be restricted to the Blancan (*sensu stricto*) in North America. In the Saw Rock Canyon fauna there are associated the Hemphillian "index fossil" *Dipoides* (Wood and others, 1941) and the Blancan "index fossil" *Mimomys*. (6) The species of *Baiomys* from the Saw Rock Canyon fauna shows a close relationship to *Baiomys* from the Rexroad fauna. (7) The Saw Rock Canyon fauna lived in that area at a time when conditions were comparable to the conditions at the time that the Rexroad fauna lived. (8) The Saw Rock Canyon fauna occurs in deposits of the Rexroad formation that are younger than the Ogallala formation, Middle Pliocene, in southwestern Kansas and northwestern Oklahoma.

The larger vertebrates of the fauna are unknown. Their recovery would contribute greatly to a better understanding of the fauna and its relationship to other local faunas of North America, because the majority of specimens collected from the other faunas are larger vertebrates,

Much more time elapsed during the Middle and Upper Pliocene than has been estimated by students of Cenozoic geology. Considerable speciation took place in both subepochs. When the faunas from these ages are known, it will be found that many of them were not contemporary, but lived a little earlier or a little later than others; they will thus bridge more than a few of the so-called gaps between faunas.

Unfortunately for the convenience of the vertebrate paleontologist, a genus or a species did not die off, or live as long, as the paleontologist might want, or think it should. Past life has no respect for a line drawn by man on the geological time scale to represent its beginning or its end in nature. If one makes correlations of deposits on the basis of one or two "index fossils," he is inevitably prejudiced in his views and fails to take into account the entire faunal picture. The rate of evolution in different genera and species is not the same, nor is it the same in a given genus or species throughout its history. Teaching students "index fossils" and their application in the correlation of deposits has sent young people into the field with preconceived ideas regarding the age of fossils and the use of such indexes. This has caused many errors. For example, I myself made an error in age determination of late Cenozoic deposits and in the correlation of one deposit with another by the use of "index fossils" when, on the basis of *Equus* (*Plesippus*) and *Nannippus* recovered from early Pleistocene deposits, I correlated Lower Pleistocene deposits with Upper Pliocene deposits. In the past it had been thought that when these two horses were found together in a deposit, that deposit was Upper Pliocene in age (Wood and others, 1941). Vertebrate paleontologists in North America have been confused because all of the individuals of *Nannippus* failed to die off at the close of the Upper Pliocene. In addition, all of the members of *Equus* (*Plesippus*) failed to migrate to Asia before the beginning of the Pleistocene, or failed to evolve into *Equus, s.s*.

To attempt any correlation of the Saw Rock Canyon fauna with faunas in Eurasia would only add to the confusion. Correlations of faunas and deposits can be made in the future, when faunas are better known, and then they will be made on the basis of faunas and not on the basis of "index fossils." The fallacy of correlations between Eurasia and North America has been recently discussed, in part (Hibbard, 1950, pp. 183-84). I might add that it will only be a miracle if a matching sequence of late Cenozoic deposits and faunas is ever found on the two continents. At best, such correlations will be approximations.

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[1] This member of the Rexroad formation takes its name from the XI Ranch.

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