FISHES OF A PLEISTOCENE LAKE IN SOUTH DAKOTA

Thesis for the Degree of M. S. MICHIGAN STATE UNIVERSITY CLAIR RUSSELL OSSIAN 1970 THESIS





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ABSTRACT

FISHES OF A PLEISTOCENE LAKE IN SOUTH DAKOTA

By

Clair Russell Ossian

Pleistocene sediments (previously believed to be Oligocene) of the Cary-Mankato lake beds in Hand County, South Dakota were examined and sampled paleontologically. Fossil fishes and geologic data were collected by the author during the summers of 1966 and 1969. The fossils collected were mostly modern species that must be identified by comparison with recent fish skeletons. Thus a large reference osteological collection was prepared during the course of the study. The extent, thickness and stratigraphic relationships of the deposits were determined by geologic mapping and aerial observations.

Paleoecological analysis based on palynological evidence and fish faunal requirements indicate that the region resembled the modern high prairies in the area. Certain plant fossils disclose that the climate was more moist and slightly cooler than at present. Evidence was collected to support the premise that major portions of the modern upper Great Plains fish fauna was derived from the Mississippi River drainage, rather than the present Missouri River connections. The fossils recovered provide geographic range extensions for several species and the first fossil records for <u>Noturus cf. hildebrandi, Etheostoma exile, Percina sp</u>., Lepomis gibbosus and Lepomis macrochirus.

FISHES OF A PLEISTOCENE LAKE IN SOUTH DAKOTA

Ву

Clair Russell Ossian

A THESIS

Submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Geology

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ACKNOWLEDGMENTS

I wish to acknowledge the assistance of my graduate committee: Drs. J. Alan Holman (Advisor), Chilton E. Prouty (both of the Geology faculty, Michigan State University) and Dr. Jane E. Smith (Lyman Briggs College, Michigan State University) for supervising my program and for critically reading the thesis.

Drs. Reeve M. Bailey and Robert R. Miller (Museum of Zoology, University of Michigan) helped clarify taxonomic problems, verified certain species assignments and provided comparative materials from their recent collections. Professor Edward D. Cope's type specimens from Ree Heights were on loan to Dr. Miller and he allowed the writer to examine and photograph them.

Dr. C. Bertrand Schultz (Director, University of Nebraska State Museum) generously supported the author in the field, provided laboratory space, and authorized the loan of Ree Heights material deposited in his care.

Other assistance was offered by Dr. Aureal T. Cross (palynology) and his students Ralph E. Taggart and Leonard E. Eames of the Geology Department, Michigan

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State University. Mr. John Lundberg (Museum of Zoology, University of Michigan) aided the writer with the identification of the catfishes.

Thanks are also due to Mr. Leonard L. Fawcett, owner of the fossil site. Mr. Fawcett offered every assistance during the 1966 and 1969 seasons. The writer's field crews were guests in his home, used his ranch lands at will, and were taken in his private plane to make aerial surveys of the fossil site and its surroundings. The success of this study is due in large part to his interest and generosity.

Field work during the 1969 season was aided by grants from the Society of Sigma Xi and the American Society of Ichthyologists and Herpetologists. Some of the field supplies were provided by the Museum, Michigan State University. The entire cost of the 1966 field season and the expenses of my assistant for the 1969 season were borne by the University of Nebraska State Museum.

I owe special thanks to my wife, Eleanor, who has aided me in the field, assisted with mapping and the collection of recent fishes, served as typist for part of the thesis and offered suggestions and encouragement throughout the span of the investigation.

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INTRODUCTION

Fossils were first reported from the Ree Heights locality by Cope (1891) and these remains sparked a controversy over the age of the deposit that has persisted to the present. The original fossils were described as Oligocene in age, but they have not been thoroughly investigated although sporadic trips to the site have been made by various workers. New interest developed after several unreported fishes were collected in 1966. More specimens were excavated in 1969 and provided ecological data that aided in the analysis of the fossil site.

This thesis represents a revision of the fossil fish fauna of Ree Heights, South Dakota, as it relates to paleoecological and zoogeographical interpretations and to the age and stratigraphy of the site.

<u>Previous work</u>.--The site was first reported in a mining claim filed in 1882 by Edwin Putnam. This claim (called the Ree Heights Chalk Stone Lode) was intended to provide matrix for lime burning, but the business failed and the claim was re-filed in 1884 by two other parties. A third and final mining claim was filed in 1885 on the site specifying a placer mining operation. This also failed and the land has been utilized since that time to graze cattle.

In 1891 Edward D. Cope published an account of some fossil fishes sent to him from Ree Heights by two local clergymen. Cope was unable to visit the site, and was misled into describing its age as Oligocene. This mistake was probably responsible for the inaccuracies in the nomenclature of fossil species reported by him. His type materials are deposited in the American Museum of Natural History, New York.

Correspondence preserved at the University of Nebraska State Museum shows that the next collector at the site was A. G. Tagg of Highmore, South Dakota. He was hired in 1931 by E. H. Barbour (University of Nebraska State Museum) to collect samples. Barbour also sent a party directed by C. Bertrand Schultz to Ree Heights that summer that brought back about one hundred fossil fishes. The collection was sent to W. K. Gregory (American Museum of Natural History) for identification in 1933 and assigned to an assistant, Anthony Q. Keasby. No report was ever filed (Bobb Schaeffer, American Museum of Natural History, in litt.) and the collection was returned to Nebraska in 1939 after Gregory left the Museum.

David H. Dunkle visited the site in 1948 while in the field for the United States National Museum, and he made a small collection of fishes. He recognized that the site was not Oligocene, but was undecided about the correct assignment. At Dunkle's suggestion, Morris F. Skinner visited the site in 1954 (Skinner, <u>in litt</u>.). Uyeno and Miller (1963) reported Skinner's conclusion that the site was Pleistocene. J. C. Harksen (Associate Geologist of the South Dakota Geological Survey) also visited the area and concurred with Skinner's findings (Harksen, <u>in litt</u>.).

<u>Materials and methods</u>.--The fossil remains from Ree Heights are well preserved, numerous, and provide abundant information about the ecology of the site. It is difficult to estimate the total number of fishes in the collections as the early collectors made no attempt to keep part and counterpart of individual fishes together. There appear to be a maximum of 521 identifiable fishes (268 identifiable to species and 253 identifiable to genus only). Other vertebrates consist of eight frogs and a turtle that has been destroyed in a house fire at the Leonard Fawcett ranch, Ree Heights, South Dakota. Badly crushed gastropods were occasionally observed but not collected. Several plant mega-fossils were recovered, but most of the botanical evidence came from pollen and spores.

Special techniques were necessary to prepare the fishes for this study. The matrix is a fine-grained, evenly laminated diatomite. The fossil fishes are generally in life-like positions with many fine details preserved. The diatomite is very soft when freshly quarried and can be removed in blocks and split with a knife blade. Slabs with fossils were dried at the site and hardened with a mixture of white shellac and denatured ethyl alcohol (one part shellac to eight parts of alcohol). This mixture penetrates well and does not warp the laminae when dry.

The fossils were prepared for study with needles, an artist's brush and water. The washing technique was modified for specimens that had only broken bones exposed. These fossils were coated with a water-soluable casein glue, embedded fossil side down in a block of plaster of Paris and the matrix washed away from the back side. This exposed unbroken surfaces of previously undeterminable bones, allowing the identification of otherwise useless specimens. All diagnostic bones were coated with Alvar, a synthetic resin solution. Alvar tends to warp when dry and was not used on large areas.

A basic part of the problem was the preparation of a representative comparative osteological collection. Most of the Ree Heights fishes are referrable to modern species and must be identified by comparison with skeletons of existing species. Available collections

of reference osteological materials are scarce and generally only encompass a few of the species in any given family. During the course of the study, skeletons of more than 1200 fishes were prepared.

Various methods were used to make these recent skeletons. At first, all specimens were macerated by placing the fishes in water and allowing them to decompose, leaving a residue of disarticulated bones. This technique works well for fresh or alcohol preserved specimens, but animals preserved in formalin cannot be prepared this way. Also, the technique produces objectionable odors.

A greatly improved skeleton-making process was developed as a result of a search for more efficient procedures. Various enzymes have long been known to be useful in the preparation of cleared and stained zoological specimens (Taylor, 1967). The same enzymes will degrade tissues and cause specimens to fall apart if improperly used. When several companies began to market various brands of enzyme "pre-soakers" for laundry use, several of them were tried on preserved specimens and yielded excellent results. Once the technique was perfected (Ossian, 1970), it was used to prepare over half the skeletons in the comparative collection of recent materials.

Terminology for fish bones follows Harington (1955). The phylogenetic arrangement of families, genera and

species follows Moore (1957) whose treatment is a modification of L. S. Berg (1947). Plane table maps were prepared in the area of study to show the major features of the thesis site, determine the site's altitude in relation to the ancient drainages in the area, and to record the areal extent of the lakebeds by their outcrop patterns. A scale of 500 feet to the inch was used and all traverses were tied into a United States Geological Survey bench mark approximately a mile from the fossil site. Because exposures are limited, the cross-sections recorded (Table 1) were taken from the walls of the excavations at the fossil site and may not be typical of the lake beds in general.

In order to discuss the complete Ree Heights fauna, species are mentioned that were not collected by my parties. These are Cope's American Museum of Natural History holotypes and bear AMNH numbers. All other specimens discussed are deposited in the University of Nebraska State Museum and have UNSM numbers.

The illustrations were prepared by Eleanor L. Ossian and the author.

Location and general description of the region.--The fossil quarry (Figure 1) is located in the southwestern quadrant of Hand County, South Dakota, on the Leonard L. Fawcett ranch (northeast quarter of section 21, Township 111 North, Range 70 West).



The area of study lies in the center of a region of high, rolling hills known locally as the Ree Hills. They are dissected and drained largely by Elm and Crow Creeks which flow south to the Missouri River. The Ree Hills are terminated in the north by Wolf Creek and form a drainage divide between the Missouri River to the south and the James River to the northeast. The fossil site and adjacent sections are exposed in the highly dissected margins of the modern Elm Creek valley. The region displays topographic relief of about 450 feet, the Ree Hills being the highest area in the county (White, et al. 1956).

<u>Geology of the region</u>.--The Pleistocene strata of Hand County are complex and rest uncomformably on a bedrock of upper Cretaceous shales. The outcrop of these bedrock units is locally limited to members of the Pierre Shale. These units form the glacially scoured surface over most of the county and provide the major constituent of the tills in the area (Flint, 1955). The Pierre Shale forms the local water table's base, and its outcrop pattern can be determined by noting the location and elevation of springs in the sides of the hills. Recent exploratory drilling for agricultural water has disclosed the location of several east-west gravel-filled valleys in the Pierre Shale, transverse to the modern north-south trending valley.

These valleys were postulated by Flint (1955) and others, and help to substantiate several of the points below.

The Ree Hills, and the neighboring Orient Hills to the north, are prominent hilly regions representing erosional remnants of Tertiary and Pleistocene formations. Portions of the Ree Hills are said to be supported and capped by members of the Ogallala Pliocene (Flint, 1955). Flint stated that these Pliocene materials were sandstones, quartzites, marls and silts. Trips on foot and by airplane failed to turn up evidence of these materials in the vicinity of the fossil site.

The outcrop area is largely composed of Wisconinan tills with occasional patches of Illinoian strata (Flint, 1955). The Ree and Orient Hills became divided and dissected during the late Wisconsin by the eastward flowing Ancestral Bad River (White, et al. 1963). Flint stated that no evidence of Nebraskan or Kansan deposits were discovered in Hand County. Till boundaries beyond Hand County indicate that earlier glacial lobes overrode the county, but were removed by subsequent erosion or later glacial advances. Flint reported a site approximately twenty miles northeast of the thesis area which represents the only definite pre-Wisconsin deposits recognized in Hand County.

The Iowan and Tazewell substages of the Wisconsinan have yet to be located in the county with certainty. The most prominent Pleistocene strata at the thesis site are members of the Cary glacial substage. The Cary sediments are divided locally into two units, each represented by a till topped by an erosional surface bearing meandering stream courses. A thin veneer of Mankato drift caps the section. Mankato deposits cover the northern two-thirds of Hand County, but only the first of the two Mankato advances reached the thesis site (Flint, 1955).

In most places there is little to differentiate the first and second Cary units except the occasional channel fillings. The topographic expression at the time of the lower Cary erosional epoch was low and probably already formed part of the floodplain of one of the ancestral rivers. The upper Cary erosional surface is easily seen and was observed to be nearly flat (average relief less than ten feet). In addition to the lake beds and marshes of the fossil site, there are two major contemporary channel fillings within a mile of the excavated section. These channels are filled with cross-bedded particles of greatly disparate sizes (bedded particles include grains ranging from silt particles to boulders three or four feet in diameter). The gravels are quarried at the outcrops for road metal

and expose walls approximately thirty feet high (the quarry does not expose the base of the gravels). Where the upper Cary surface is not covered by later sediments, Flint (1955) noted that it was covered with gentle swells and swales occupied by undrained basins and ponds, much like the condition observed at the fossil site.

The Mankato surface shows even less relief than the Cary, giving the surface of the Ree Hills (away from the dissected margins) the appearance of an unbroken plain. Flint (1955) states that this surface also contains swells and swales, though gentler than those on the Cary surface.

The Cary rivers in Hand County appear to have been near a divide (Flint, 1955) and may have been drained to the south into the Ancestral White River or to the east into the Ancestral Bad River (which joined the Ancestral White River channel south-south-east of the thesis area). These channels are only exposed for short intervals in Hand County, but may be traced from border to border by scattered exposures. A channel to the south contains similar cross-bedded materials and is at nearly the same elevation as the lower Cary gravel. This southern stream parallels the modern Elm Creek drainage and was recognized by Flint (1955) as a tributary to the Ancestral White River. The Ancestral White River collected all the contemporary rivers in the

area and trended southeast to the vicinity of the modern Big Sioux River of Iowa. Although definite traces cannot be found east of this point, the Ancestral White is believed to have followed the Minnesota River basin or the Des Moines River basin to the upper Mississippi River (Flint, 1955).

There is some evidence for an earlier diversion of the regional drainage into the Hudson Bay area (Metcalf, 1966), using the Cheyenne, Grand and Moreau River basins to move across southern Saskatchewan into Manitoba to join the pre-glacial Red River. Although evidence for this diversion is well documented (Lemke, et al. 1965), there is little reason to suggest that any of the modern South Dakota fish fauna was derived in this manner. If any species did arrive from this direction, they were probably deflected by later glaciation and re-entered the area via the Missouri or Mississippi River connections.

The Ancestral White River with its Mississippi River connections was interrupted and its tributaries captured by the Missouri River (Flint, 1955). The Missouri River was open throughout the Wisconsinan glaciation and provided a logical path for the recolonization of eastern South Dakota when the ice retreated.

The Mississippi River connections have been tested by an examination of the modern fish fauna. Bailey and Allum (1962) analyzed the recent fishes and found that

fifty-five of the ninety-three extant South Dakota species are native to the upper Mississippi River, while only twenty-eight are derived from the Missouri River route. There is little doubt among modern workers that these connections existed, and they have been tested by others with equally convincing results (Underhill, 1957 darters, minnows and madtoms; Leonard, 1959 - gastropods; Metcalf and Distler, 1961 - crayfish).

SYSTEMATIC PALEONTOLOGY

Proballostomus longulus Cope

(Figure 2-C)

Material .-- Partial skeleton (AMNH 8090), holotype.

<u>Geologic range</u>.--Wisconsinan. Restricted to Ree Heights.

<u>Remarks</u>.--Cope considered <u>Proballostomus longulus</u> to be a cyprinodontid fish, and Rosen and Gordon (1953) concurred on the basis of the presumed presence of a gonopodium. This structure was later shown to be a crack in the matrix (T. Uyeno, pers. comm.). After examination, Uyeno and Miller (1963) assigned this fossil to the family Cyprinidae and Rosen (loc. sit., p. 14) agreed. Most of the fishes from Ree Heights are representative of living species, and Uyeno and Miller (1963) point out that <u>P. longulus</u> probably also belongs to an extant species.

Cope's specimen was difficult to analyze due to its poor state of preservation. Uyeno and Miller (1963) re-examined the holotype in their review of the freshwater Pleistocene fishes of North America, and found a tripus and modified fourth vertebra of the Weberian

apparatus. These structures accompanied by intramuscular bones in the trunk and a hypural plate composed of more than two hypural bones prove that this specimen is a cyprinid. The specimen is too poor for more precise assignment.

The author did not collect this species, so there are no data concerning habitat choice. The other minnows were collected mainly from the shallow zone and further specimens of <u>P</u>. <u>longulus</u> will probably be found there, too.

? Sardinius blackburnii Cope

(Figure 2-A)

Material .-- Holotype (AMNH 8091), lacking the head.

<u>Geologic range</u>.--Wisconsinan. Restricted to Ree Heights.

<u>Remarks</u>.--Cope (1891) reservedly believed this fish to be a sardine, but the author has recently examined it, as have Uyeno and Miller (1963), with the conclusion that it is definitely not in this genus. It can be identified as a cyprinid, although at present it is impossible to assign this fish to a taxon lower than family.

This fossil is so poorly known that it would be of little value to repeat Cope's (1891) diagnostic characters.

No specimens of this fish were collected by the author. Because of this and the uncertain taxonomic



situation, no comments can be made about the stratigraphic position in the lake beds, distribution of the species or its ecological requirements.

<u>Fundulus diaphanus</u> (<u>LeSueur</u>) - Banded killifish (Figure 2-D)

<u>Material</u>.--Holotype (AMNH 8089), a well preserved complete fish. A second specimen was collected by the author's party in 1966 and tentatively identified as this species. This specimen could not be found after a recent move of the vertebrate paleontology laboratories of the University of Nebraska State Museum and is presumed lost.

<u>Geologic range</u>.--Wisconsinan to Recent. Restricted to Ree Heights.

Remarks.--Cope (1891) recognized that AMNH 8089 was a cyprinodont, but failed to recognize it as the genus <u>Fundulus</u> and erected the taxon <u>Gephyrura concentrica</u>. R. M. Bailey, R. R. Miller and T. Uyeno re-examined the specimen and noted characters that assigned it to the species Fundulus diaphanus (Uyeno and Miller, 1963).

The osteology and relationships of this fish have been exhaustively treated (Cope, 1891 and Uyeno and Miller, 1963).

The specimen collected in 1966 came from the shallow margin of the lake accompanied by fossils of reeds and other shallow water organisms (frogs, gastropods and fry). Recent members of this species prefer the same quiet, reedy environment throughout their range (Hubbs and Lagler, 1949).

Ictalurus melas Rafinesque - Black bullhead

(Figure 3-A)

<u>Material</u>.--Five complete or nearly complete skulls (UNSM 71132 - 71136), six fragmentary skulls (UNSM 71143 -71148), five dentaries (UNSM 71149 - 71150, 71152 -71153, and 71159), two angulars (UNSM 71151), a partial hyoid aparatus (UNSM 71154), six cleithra bearing spines (UNSM 71137 - 71142) and five slabs bearing sections of vertebrae and ribs (UNSM 71155 - 71158, and 71160).

<u>Geologic range</u>.--Illinoian (C. L. Smith, 1954, 1958; G. R. Smith, 1963) to Recent. This represents the first Ree Heights record of the species.

Remarks.--Identification of <u>I</u>. <u>melas</u> is based primarily on the morphology of the pectoral spines, cleithra and neurocrania. The terminology of Hubbs and Hibbard (1951) will be used to describe the spines, while that of C. L. Smith (1961) will be used for the neurocrania.

Pectoral spines have been widely used to define ictalurid species in the past, but Lundberg (pers. comm.) has stated that specific variation is frequently so great that pectoral spines must be used cautiously. The six spines at hand all fall within the range of variation of I. melas.

The shaft of a catfish spine may bear dentations on both the anterior and posterior edges. <u>I. melas</u> has dentations only on the posterior edge, and these are situated on the rim of the basal recess, but never in the recess. Modern ictalurids may bear notches on the anterior edge of the shaft near the tip. <u>I. melas</u> shows only one notch, or none. In all respects, the spines from Ree Heights agree with the characters of <u>I. melas</u> (Paloumpis, 1963).

The posterior tip of the ictalurid cleithrum terminates in three pointed projections, two forming a Y-shaped fork at the tip of the bone, while the third projects at a lower level. This last projection is termed the humeral process and its proportions are very species constant. In <u>I. melas</u>, the humeral process tends to be smaller and less strongly developed than in other ictalurids (except in some species of <u>Noturus</u>). Below the humeral process, the cleithrum bends sharply. The outer edge of this curve is sculptured to varying degrees in ictalurids, and the Ree Heights specimens agree with <u>I. melas</u>. This species has a less rugose sculpture than any other catfish examined.

The ictalurid neurocranium has structures that are useful in the identification of species. The most



obvious feature of the skull roof is the pair of dorsal foramena which run the length of the skull roof. The posterior dorsal foramen remains open nearly to the transverse crest at the rear of the skull, and continues back farther as two raised ridges which join to form a paper-thin crest extending far beyond the main body of the neurocranium (this is the supraoccipital spine of C. L. Smith, 1961). In all other northern ictalurids this foramen either closes before reaching the transverse crest, the ridges on the edges of the closed foremen become depressed, or these ridges are produced backward as a heavy, massive crest. The wellpreserved Ree Heights specimens all show the condition found in <u>I. melas</u>.

The lower jaw aparatus was found intact in several specimens and the angular bone proved useful. The fossils were compared with all northern ictalurids and found to match the <u>I</u>. <u>melas</u> condition in which the rear projection (point beyond the articulation with the quadrate) was found to be shorter and less well developed than in any species except I. natalis.

None of the Ree Heights catfishes were recovered from strata lower than eight feet from the top of the lake beds. It is at this point where the fauna changes downward from shallow-water to deep-water fishes (fry and minnows are no longer evident). The specimens were

restricted to the diatomite layers that would have provided muddy bottomed environments preferred by catfishes, while none were found in the sandy zones. The presence of fossil cattails near two of the skeletons, indicate that the depth of water at those points was not more than three feet (Benton and Werner, 1958).

<u>I. melas</u> is a common modern fish in South Dakota and may be found living in habitats very similar to that found in the Ree Heights fossil site (Bailey and Allum, 1962).

Noturus cf. Noturus hildebrandi

Bailey and Taylor - Least madtom (Figure 4-A, B and C)

<u>Material</u>.--One nearly complete fish (UNSM 71130), preserved as part and counterpart. A second specimen (UNSM 71131) is represented by a cleithrum and pectoral spine.

<u>Geologic range</u>.--Wisconsinan to Recent. Restricted to Ree Heights.

<u>Remarks</u>.--North American freshwater catfishes are divided into two groups: <u>Ictalurus</u>-like catfishes and bullheads, and madtoms and stonecats of the genus <u>Noturus</u> (Taylor, 1969). Madtoms have a rear extension of the underside of the premaxilla, an elongate snout, and a modified caudal fin to distinguish them from the other ictalurids. Standard ictalurid caudal fins have a ray count of ten, while madtoms always have a higher number, ranging to more than fifty (Taylor, 1969). UNSM 71130 has been damaged in this area, but shows at least twenty-five countable caudal fin rays.

Madtoms have recently been divided into three subgenera by Taylor (1969) on the basis of a number of characters, several of them osteological. The Ree Heights madtoms can be keyed into the subgenus Rabida primarily because the pectoral spines have dentations on both the anterior and posterior edges. Of the thirteen species in the Rabida group, the fossils may be assigned to Noturus hildebrandi on the basis of the following characters: a short and blunt humeral process on the cleithrum (shorter than the diameter of the pectoral spine, not including the dentations); the tooth patch on the premaxilla is rectangular and has rounded posterior corners; and a pectoral spine with the anterior dentations reduced in number and size, and whose posterior dentations (with the exception of the first) are retrorse.

Taylor (1969) lists vertebral counts for all of the species of <u>Noturus</u>. The count for the fossil madtom lies within the <u>N</u>. <u>hildebrandi</u> range, but this is not sufficient to distinguish it from several other species.

Work in progress on recent catfishes by John Lundberg (Museum of Zoology, University of Michigan,

pers. comm.), indicates that the species of the <u>N</u>. <u>hildebrandi</u> group (Taylor, 1969) cannot be separated on the basis of pectoral spines alone. The osteology of the family Ictaluridae is being examined by Lundberg and positive assignment should await the conclusion of this study. Therefore, the name <u>Noturus hildebrandi</u> should be considered tentative.

The madtoms were recovered from the shallow-water area accompanied by minnows and fry, but there are too few specimens to support conclusions about habitat choice.

<u>Micropterus</u> <u>salmoides</u> (Lacépède - Largemouth bass (Figure 3-B)

Material.--Partial skeleton (UNSM 71037).

<u>Geologic range</u>.--Illinoian (G. R. Smith, 1963) to Recent. This specimen represents the second occurrence in the fossil record.

<u>Remarks</u>.--The generic assignment is made mainly on the shape of the angular and urohyal bones. The angular bone of <u>Micropterus</u> is more elongate than in other centrarchids. In addition to being generally more robust than in related species, the lower portion of this bone is terminated anteriorly by a sharply lunate edge.

Urohyal bones are among the more variable bones in this family. Species of Lepomis always are either unforked and blunt anteriorly, or else are forked with a ninety degree or greater angle between the two branches of the fork. In <u>Micropterus</u>, the tip is always forked in juveniles and young adults (there is some tendency toward bluntness in very large adults) and has an angle of less than ninety degrees between the branches (typically less than sixty degrees). The Ree Heights specimen is approximately forty-five millimeters in standard length and is, therefore, a sub-adult fish.

Dorsal and anal fin ray counts are in the proper range for this species (Bryan, 1969). The only other member of the genus occurring in the area today is <u>M</u>. <u>dolomieui</u>. Comparison of recent <u>M</u>. <u>salmoides</u> and <u>M</u>. <u>dolomieui</u> skeletons with the fossil shows only points in common with M. salmoides.

The Ree Heights specimen was collected from the shallow region near the top of the exposure. This area preserves a habitat that is similar to that chosen by young <u>Micropterus</u> in recent faunas (Hubbs and Lagler, 1949). <u>M. salmoides</u> is a common fish in South Dakota today, but the recent populations may represent human introductions during this century (Bailey and Allum, 1962).
Lepomis humilis (Girard) - Orange-spotted sunfish

(Figure 6-A and B)

Material.--Thirty-three nearly complete fishes (UNSM 70676 - 70709), fifty-seven skulls (UNSM 70710 -70767), the holotype of <u>Oligoplarchus squamipinnis</u> Cope (AMNH 8078) and three paratypes (AMNH 8080, 8081 and 8083).

<u>Geologic range</u>.--Possibly Late Illinoian (G. R. Smith, 1963, <u>L. humilis</u>?) to Recent. Ree Heights is the only fossil site with definite <u>L. humilis</u> materials. NUMBER OF STREET, STRE

<u>Remarks</u>.--This species was reported by Cope (1891) as <u>Oligoplarchus squamipinnis</u>, though he was aware of its similarities with the genus <u>Lepomis</u>. R. M. Bailey examined the type materials during a review of the family Centrarchidae (Unpub. Doctoral Diss., Univ. Mich., 1938) and determined that the fossil was close to or identical with <u>L. humilis</u> (Uyeno and Miller, 1963). After examining the large series of fossils listed above, the author can find no difference between the fossils and skeletons of recent L. humilis.

Distinguishing osteological characters for the species of Lepomis are taken from the following authors: Branson and Moore, 1962; Moore, 1957; Trautman, 1957 and Cross, 1967. The genus <u>Lepomis</u> may be distinguished from the percids by the spinous and soft-rayed portions of the dorsal fins. In centrarchids, these portions are continuous, not separate. Percids have two or fewer anal spines, while centrarchids always have three or more (three in <u>Lepomis</u>). Features that separate <u>Lepomis</u> from the other centrarchids are: a preopercle whose limbs form an angle of less than one hundred degrees (about ninety degrees), no teeth on the pterygoid bones, and twelve precaudal vertebrae.

<u>L. humilis</u> is osteologically distinct from the other species in its group. The most useful characters in the genus are the lateral-line-canal systems buried in the skull bones. These have frequent openings to the surface whose arrangement and size are diagnostic of species. In <u>L. humilis</u> the pore opening on the frontals and dentaries are very large in proportion to the bones, the diameter of the openings being greater than the width of the bone between adjacent pores. In other members of the genus, the pores are always narrower than the bony space between.

The preopercles of sunfishes bear serrations on the posterior and ventral edges of the bone. In <u>L. humilis</u>, these serrations are restricted to an area extending from the upper edge of the lateral-line pore at the

angle of the bone to the posterior margin of the anterior-most aperture of the preopercle.

The urohyal bones of sunfishes also proved diagnostic. These are spoon-shaped bones with the "handle" end branched. In <u>L. humilis</u> this branch leaves the main axis of the bone at a right angle, and is long and slender. The pharyngeal tooth plates are not massive, as in <u>L. gibbosus</u>, but are long and narrow like those of the majority of the sunfishes. <u>L. humilis</u> has a long dentary (shared only with <u>L</u>. <u>cyanellus</u> and <u>Chaenobryttus</u> among the sunfishes), other sunfishes have relatively short and stout dentaries.

This species is probably the commonest fish at the site, and was collected everywhere in the shallow region at the top of the lake beds but not from the deeper zone. <u>L. humilis</u> is a common recent fish in eastern South Dakota (Bailey and Allum, 1962), and is probably part of the native pre-glacial fish fauna of the Great Plains region.

Lepomis gibbosus (Linnaeus) - Pumpkinseed sunfish (Figure 2-B)

<u>Material</u>.--Six nearly complete fishes (UNSM 70767 - 70772), and fourteen skulls and partial skeletons (UNSM 70773 - 70787).

<u>Geologic range</u>.--Wisconsinan to Recent. Restricted to Ree Heights.

<u>Remarks</u>.--The characters that separate the genus <u>Lepomis</u> from related fishes were listed under the discussion of <u>L</u>. <u>humilis</u>. Distinguishing osteological features of L. gibbosus are as follows.

The preopercle of <u>L</u>. <u>gibbosus</u> is also distinctively serrated. The serrae are restricted to an area only slightly above to slightly below the angle made by the limbs of the preopercle. The edge of the preopercle is produced as a smooth arc, not extended backward into an "ear-flap", as in several closely related species.

The lateral line openings of the dentary and frontal bones in this species are much smaller in proportions than those of <u>L</u>. <u>humilis</u> (the diameter of the pores is always less than the width of the bones between adjacent pores). The dentary in <u>L</u>. <u>gibbosus</u> is of the short-jawed variety (see L. humilis, "Remarks").

Sunfishes have pharyngeal mills bearing crushing teeth. These are usually composed of elongate bones with surfaces covered with small, sharp teeth. In <u>L</u>. <u>gibbosus</u>, these bones are broad and massive, bearing blunt pavement teeth. Bean and Weed (1911) demonstrated that the characters of the pharyngeal mill are constant regardless of age of an individual and can be used to differentiate the youngest of sunfishes with confidence.

The urohyal bone was described while under "Remarks" for <u>L. humilis</u>. It is also distinctively shaped in

L. gibbosus, with the branch at right angles to the axis being longer and more massive than the axial branch. The general shape of the bone is more "scoop-like" than in L. humilis.

Otoliths, or ear bones, have been used by several authors to identify genera and species from many ages and localities. Fifteen specimens from Ree Heights have well preserved otoliths identical with those of modern northern L. gibbosus.

The <u>L</u>. <u>gibbosus</u> fossils were located in the lower portions of the shallow zone, where the water is presumed to have been three to five feet deep. <u>L</u>. <u>gibbosus</u> was accompanied by a few fossils of <u>L</u>. <u>humilis</u>, some large minnows and medium-sized <u>Perca flavescens</u> (100 to 150 millimeters in standard length). While living <u>L</u>. <u>gibbosus</u> are found in the area today, Bailey and Allum (1962) state that they believe their presence is due to human introductions.

Lepomis macrochirus (Rafinesque) - Bluegill sunfish (Figure 3-C)

Material.--Three skulls and partial skeletons (UNSM 71034 - 71036).

<u>Geologic range</u>.--Wisconsinan to Recent. Restricted to Ree Heights.

<u>Remarks</u>.--The characters that distinguish the genus Lepomis are discussed in the description of L. humilis.

L. <u>macrochirus</u> is distinguished by the criteria listed below.

The preopercle of <u>L</u>. <u>macrochirus</u> displays a distinct kind of serration along the posterior and ventral borders. These edges of the bone bear alternate patches of large and small serrae, and the body of the preopercle behind the serrae is striated.

The urohyal has a unique manner of branching, with a side branch extending from the axis of the bone at an angle of about seventy degrees. This side branch is longer and more massive than the axial branch, and originates near the tip of the bone. In all other lepomids, this branch originates well below the tip of the axial branch with both elements separate.

L. <u>macrochirus</u> is one of the short-jawed sunfishes (see <u>L</u>. <u>humilis</u>, "Remarks"). The dentary and frontal in this species have small lateral-line-pores (diameter of the pore openings is less than the width of the bone between pores). The pharyngeal mill and its teeth are of the slender, sharp-toothed variety (like those of L. humilis, not massive and blunt like L. gibbosus).

All three fossil <u>L</u>. <u>macrochirus</u> came from the deeper portions of the deposit (believed to represent water deeper than five feet), but there were too few fossils recovered to support definite comments about habitat. The only fossils recovered with L. macrochirus

were large <u>Perca flavescens</u>. <u>L. macrochirus</u> is a common fish in the area today, but appears to have been introduced by modern man (Bailey and Allum, 1962).

Perca flavescens (Mitchill) - Yellow perch

(Figure 6-C)

<u>Material</u>.--Six complete fishes (UNSM 70652 - 70654, 70674 - 70675), eight partial skeletons (UNSM 70656, 70664, 70666, 70668 - 70669, 70671 - 70673), fifteen skulls (UNSM 70655 - 70661, 71172 - 71180), one preopercle (UNSM 70665) and one cleithrum (UNSM 70663). The holotype of <u>Mioplosus multidentatus</u> Cope (AMNH 8075) was also examined.

Geologic range.--Illinoian (C. L. Smith, 1954, 1958 and G. R. Smith, 1963) to Recent.

<u>Remarks.--P. flavescens</u> was collected by Cope's correspondents, but he incorrectly assigned it as the taxon <u>Mioplosus multidentatus</u> Cope (1891). He had erected that genus for the perch-like fishes of the Eocene Green River fishes of Wyoming (Cope, 1884). Both fishes are similar in some respects, but the correct relationships were overlooked. Curiously enough, the species name referred to the serrate lower edge of the preopercle, the most easily recognizable bone in the perch skull (well preserved and visible in the holotype).

The Ree Heights fossils display the typical percid dorsal fin, consisting of separate spinous and soft-rayed



portions. In those specimens with entire dorsal fins, spinous and soft ray counts match those of the living <u>P. flavescens</u>. This species can be separated from other percids by the spiny margins on several of the skull bones. These are the preopercle, subopercle, posttemporal, cleithrum and supracleithrum. Spines on the lower edge of the preopercle are especially robust and are directed forward.

All darters and percids known to inhabit South Dakota and adjacent areas were examined. <u>P. flavescens</u> has an opercle, dentary, angular, quadrate, maxilla and premaxilla that differs from related fishes in its proportions, spination and lateral-line pore arrangement.

P. flavescens was recovered from nearly all levels of the deposit. The only segregation noted was that the larger fishes were recovered from the deeper layers, while smaller fishes were restricted to the shallow areas. This was expected, as modern perch fry tend to remain in the shallow areas until they are large enough to cope with the majority of the predators found in open waters. Yellow perches were the largest fishes recovered from the site, ranging in standard length to more than 300 millimeters.

The species is common in the area today and probably forms part of the ancestral fish fauna of the

Great Plains and was possibly present in pre-glacial times.

Percina sp. Haldeman - "Log perch"

(Figure 5-A)

<u>Material</u>.--A single headless specimen (UNSM 71170) preserved as part and counterpart.

<u>Geologic range</u>.--Wisconsinan to Recent. This and <u>Etheostoma</u> <u>exile</u> (this paper) are the only known fossil darters.

Remarks.--Although this specimen is incomplete, characters are present that justify giving it a tentative generic name. The fish is covered with fine, ctenoid scales that are much smaller, in proportion to the size of the fish, than those on the fossils of Etheostoma exile. The pectoral fins are close together and have a ray count of one spine and ten soft rays. The pectoral fins appear to be complete and are larger than those of most darters in the Etheostoma group. The dorsal fin shows the typically divided spinous and soft-rayed portions and the segments are well separated. The dorsal fin-ray count consists of ten spines and ten or eleven soft rays. The anal fin has a count of one spine and eight soft rays, and is smaller than the soft-rayed portion of the dorsal fin.

The fossil fish is more elongate than the darters in the collection that were assigned to Etheostoma <u>exile</u>. Its body depth to estimated length ratio is five and a half to six, more than most darters of the genus <u>Etheostoma</u>, but less than those in the genus <u>Ammocrypta</u>. The above data suggest that the fossil should be assigned to the genus <u>Percina</u>, but are not diagnostic enough to allow a species name at this time.

The unique specimen was collected in 1966 from float materials at the foot of the outcrop. At the time, the only matrix exposed at the surface was from the uppermost few feet of the lake beds. Therefore, the fish must have come from the very last, shallow portions of the lake and occupied a habitat similar to that in which <u>E. exile</u> was collected at Ree Heights. Various members of the genus <u>Percina</u> live in South Dakota today, but are normally found over gravel bottoms, not silty ones like those at the fossil site. As noted in the cross-section of the lake beds, these latter stages were marked by periodic influxes of sand and show evidences of disturbance by running water. This fish may have entered the lake during one of these fluviatile periods.

Etheostoma exile (Girard) - Iowa darter

(Figure 5-B and C)

<u>Material</u>.--Seven complete fishes (UNSM 71162 - 71169), and two partial skeletons with skulls (UNSM 71161 - 71168).

<u>Geologic range</u>.--Wisconsinan to Recent. <u>Etheostoma</u> <u>exile</u> and <u>Percina</u> <u>sp</u>. from Ree Heights are the only recorded fossil darters.

<u>Remarks</u>.--These fossils were assigned to the genus <u>Etheostoma</u> on the basis of a divided dorsal fin composed of separate spinous and soft-rayed portions, large ctenoid scales and an unserrated preopercle. The fossils are not as elongate as fishes of the genus <u>Percina</u> or <u>Ammocrypta</u>, but more so than those of the genera <u>Perca</u> of Stizostedion.

The genus Etheostoma is a large and diverse group whose relationships are still little known. It is not always possible to differentiate the numerous species of modern darters without careful study. Because of these difficulties, the fossils were only compared with those darters most likely to have inhabited South Dakota at some time in the past. All of the darters known to live currently in South Dakota, North Dakota, Nebraska, Iowa, Minnesota and most of the darters of Kansas were These were: Ammocrypta asprella, A. clara, examined. Etheostoma asprigene, E. blenniodes, E. caeruleum, E. chlorosomum, E. exile, E. flabellare, E. microperca, E. nigrum, E. punctulatum, E. spectabile, E. zonale, Percina caprodes, P. evides, P. maculata, P. nigrofasciata, P. phoxocephala and P. shumardi.



The characteristics of the fossils include: scaled cheeks, pelvic fins placed closely together, two anal fin spines and seven to eight anal soft rays. The pelvic fins have one spine and five soft rays.

Four bones in the head regions of recent darters were chosen as good species indicators for two reasons; they were both highly species specific and were preserved on most of the specimens. These bones were the opercle, premaxilla, angular and dentary. When the series of recent skeletons was examined, it was apparent that Etheostoma was the correct genus assignment. In the fossil form, the opercle has a normally curved posterior border with the entire opercle ossified. The dorsal border of the opercle rises gently posteriad to a maximum height three-quarters of the way along the horizontal ridge, and then falls away sharply in a lunate curve that merges with the spine. In Ammocrypta the upper border is either absent (no expansion above the spine) or the border parallels the spine. The condition in Percina varied from a smoothly arched border to one that formed a hook at the maximum expansion, but never approached the fossil condition. Various species of Etheostoma resembled the fossil, but differed in ways mentioned below.

The premaxilla of the fossil is an elongate bone with the upper margin rising to a high point two-thirds

of the way from the front. The vertical process at the anterior end is rather short, rising only slightly above the bulbular expansion adjacent to its base. In <u>Ammocrypta</u> the premaxilla is short, stout and massive and does not resemble the fossil darter. Several species of <u>Percina</u> and <u>Etheostoma</u> were like the fossil in a few points, but differed in others.

The shape of the fossil angular is markedly different from the condition in <u>Ammocrypta</u>, <u>Percina</u> and nearly all of the <u>Etheostoma</u> species examined. Only <u>E</u>. <u>exile</u>, <u>E</u>. <u>flabellare</u>, <u>E</u>. <u>caeruleum</u> and <u>E</u>. <u>blenniodes</u> were near the fossil angular in shape.

A diagnostic feature observed on the dentary was the vertical expansion of the upper, tooth-bearing limb of the bone. In the fossil form there is a paddlelike development seen only in the genus <u>Etheostoma</u> and only in the species <u>E. exile</u> and <u>E. flabellare</u>. But <u>E</u>. <u>flabellare</u> was shown to have an opercle differing from the fossil, while <u>E. exile</u> is identical to the fossil form. The vertebral number is within the range of modern E. exile (Bailey and Gosline, 1955).

All specimens came from the top three feet of the section in shallow, reedy areas sheltering the smaller fishes. <u>E. exile</u> is present in South Dakota today and is found in a similar habitat.

DISCUSSION

Based on the ecological requirements of the fishes and upon palynological evidence, the fossil site was situated in a high prairie region similar to that of the area today. Grasses and composites covered most of the uplands, with trees confined to the lowlands and stream courses. The area about the lake beds was lightly wooded and formed part of the floodplain of the adjacent river. The fossil site was a series of marshy ponds connected by channels of slow-moving water. Occasional floods invaded these marshes, depositing layers of sand derived from the load of the nearby river bed.

Paleoecology of the fishes.--Most of the Ree Heights fishes prefer lentic (standing water) situations (see Table 2). <u>Etheostoma exile</u> is said by Harlan and Speaker (1956) to be especially common in ponds and lakes that are adjacent to major rivers, a situation resembling the Ree Heights condition.

Noturus cf. <u>hildebrandi</u> is the only Ree Heights fish restricted to rivers (Taylor, 1969), presently occupying two southern river systems. In one of these, the bottom

consists of gravel to pebble-sized grains in a swift current. In the other system, the current is slower and the bottom is composed of shifting sand, mud and silt (Taylor, 1969). Neither of these environments seem to be represented in the fossil lake beds, but similar sediments can be found in the contemporary channel deposits nearby. The lakebeds represent the floodplain of these channels and <u>N</u>. cf. <u>hildebrandi</u> was probably swept into the lakebeds during periods of high water.

Floods probably introduced the darters and madtoms, forms usually found in fast-moving, gravel-bottomed streams.

Fossils were only found in the finely laminated diatomite layers of the lakebeds, never the clastic zones (see Table 1). These fine-grained sediments accumulated evenly and with little or no disturbance for appreciable periods of time. Fishes as small as eleven millimeters in total length were preserved intact and the damage seen in most specimens is only a slight disarticulation caused by compaction of the matrix after deposition.

In most aquatic ecosystems, scavengers consume dead fishes and scatter their bones, especially the smaller types. The perfection seen in some of the specimens suggests that they might have been victims of

a winter-kill or a drought. In either case, the cadavers might have escaped scavengers for a while, perhaps long enough to be covered and protected.

Paleoecology of other fossils.--Vertebrate fossils other than fishes are rare in the area and do not prevent one from envisioning a landscape very much like that at Ree Heights today. The only mammals reported by Flint (1955) were <u>Rangifer sp</u>. (caribou), <u>Equus sp</u>. (small form like those of the late Pleistocene of Alaska according to C. B. Schultz, in Flint, 1955) and <u>Archidiskodon sp</u>. (a mammoth). These were interpreted by Flint as indicating subartic types living near the edge of a retreating ice sheet. However, references in Hall and Kelson (1959) suggest that caribou do not necessarily indicate this at all, citing records of specimens and populations recently living as far south as Minden City, Michigan (taken as late as 1942).

Paleobotanical evidence supports the idea that the site represented a lake and provides climatic indications that suggest that the area was cooler and more moist than at present. A. T. Cross of the Michigan State University Geology Department and R. E. Taggart and L. E. Eames (graduate students), examined the matrix for pollen and spores and noted that the sediment was an impure diatomite. Some diatoms are known to be specific in habitat and may be used to determine environmental

conditions at their resting sites, provided there has been no significant transport. Table 3 points out that six of the recorded diatom genera tend to inhabit still or slow-moving water. The others are non-specific types (ubiquitous in the habitat), but none indicate rapidly moving water.

Spruce (<u>Picea</u>) and pine (<u>Pinus</u>) were detected by their pollen. Conifers are uncommon in the Great Plains today and were probably equally rare in Cary times. Cross (pers. comm.) states that conifer pollen can travel great distances and the Ree Heights materials could have been derived from sources as remote as the Black Hills or the Rocky Mountains. This pollen is common in the sample and might represent a local source, as Flint (1955) cites a fossil spruce forest of about the same age from a site north of the Ree Heights fossil locality.

Hickory (<u>Carya</u>) pollen was recognized, but this tree is not common in the Great Plains. In this region, the genus is presently limited to the Missouri River valley as far north as the central eastern border of Nebraska (Pool, 1961). Oak (<u>Quercus</u>) leaves and pollen were found, but these are not precise indicators of habitat. The oak appears to be the bur oak, <u>Quercus</u> <u>macrocarpa</u> Michaeux, a common tree in the area today. Bur oaks prefer moist lowlands, but do well in the drier uplands as well (Pool, 1961).

Birch (<u>Betula</u>) pollen was also detected and indicates a cool moist growing site. Birches are rare in the region today, the nearest living groves are found in canyons tributary to the Niobrara River at Valentine, Nebraska. This stand has been interpreted as a relict forest left behind by a retreating glacier (Pool, 1961).

Several undetermined genera of grasses are present, accompanied by a number of composite plants (represented by pollen). These fossils are so difficult to differentiate and so wide ranging in the present plains region that they provide little precise environmental data. Pollen was noted from the submerged aquatic plant, <u>Myriophyllum</u>. This common "water-weed" tends to inhabit slow-moving or still water, and is unlikely to flourish over a gravel bottom (Taggart, pers. comm.). <u>Myriophyllum</u> is a fragile plant that cannot stand much transport and probably grew in place.

Source of the fish fauna.--The majority of the Ree Heights fishes used an eastern connection with the Mississippi River valley (see Table 4), probably across Iowa or Minnesota (Flint, 1955; Underhill, 1957).

Only two of the species at Ree Heights are clearly derived from the Missouri River route. <u>Lepomis humilis</u> is known from deposits of Illinoian age in Kansas (G. R. Smith, 1963) and probably forms part of the

ancestral Great Plains fish fauna. This species occupies slow-moving streams at times and might well have ascended the Missouri River. <u>Ictalurus melas</u> is also known from the Great Plains Pleistocene (C. L. Smith, 1954, 1958; G. R. Smith, 1963), and probably also used the Missouri River to reach South Dakota.

Several of the fishes could have been derived from either river system. <u>Perca flavescens</u> is found in the Great Plains Pleistocene and together with <u>Micropterus salmoides</u> (believed native to Nebraska by R. E. Johnson, in Bailey and Allum, 1962) might have ascended either the Missouri or Mississippi Rivers. <u>Etheostoma exile</u> has been reported from the lower Great Plains recent fauna, but apparently in error (Cross, 1967).

Noturus cf. hildebrandi presents problems of another sort. Presently restricted to two tributaries of the Mississippi River in western Mississippi and Tennessee, this species may have used either branch of the Mississippi River system. The disjunct distribution represented by the discovery of <u>N</u>. cf. <u>hildebrandi</u> was greater than the author expected, but may only reflect the lack of information about the ancient distribution of the genus Noturus.

With the exception of \underline{N} . cf. <u>hildebrandi</u>, none of the fishes is out of place ecologically, although several

are beyond their present geographic ranges. Identifications in this study represent range extensions for <u>Micropterus salmoides</u>, <u>Lepomis gibbosus</u>, <u>Lepomis</u> <u>macrochirus</u> and <u>Noturus cf. hildebrandi</u>. <u>Fundulus</u> <u>diaphanus</u> presently occurs only in the northeast corner of South Dakota (Bailey and Allum, 1962). The discovery at Ree Heights constitutes a minor range extension for this species, too.

The present South Dakota fish fauna began its dispersal into the region at some time prior to the Wisconsinan glaciation. The fishes were probably temporarily deflected southwards during one or more of the Wisconsinan advances. Those species found at Ree Heights not native to South Dakota are mostly still living nearby and are presumably in the process of re-colonization. Table 1. Vertical section in the fossil quarry.

Measurements in centimeters.

0-700 (max)	Mankato boulder-tills capping the lake beds and forming the tops of the hills.
31	Coarse gravel and sharp sand. Shows slight cross-bedding, but without fossils.
8	Clay layer with patches of fine sand, no fossils.
46	Poorly bedded diatomite, no fossils.
25	Coarse, cross-bedded sand with occasional pebbles. Contains lenses of sand and clay with fragments of diatomite buried at random angles in the matrix (up to 38 cm. long), no fossils.
18	Poorly bedded, powdery diatomite without fossils.
22	Weathered, limonitic materials without fossils.
15	Well laminated diatomite with good fossils, limonite band at the base.
28	Laminated diatomite with many fossil fishes.
14	Sandy diatomite, poorly laminated and without fossils.
28	Well laminated diatomite with fossil fishes.
22	Sandy, cross-bedded diatomite, limonitic and unfossiliferous. This zone marks the end of the upper, shallow-water region. At the base of this layer is a series of gravel, sand, limonite and clay lenses.

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Table 1 (cont'd.)

46	Well laminated diatomite with scattered fossil fishes.
47	Muddy, poorly laminated sand. Divided by limonite bands into three equal layers, fossils only found in the lowest layer.
15	Coarse, limonitic sand without fossils.
15	Clean, sharp, white sand without fossils.
22	Well bedded diatomite with scattered fossils.
13	Limonitic sand without fossils. Marks the lower limit of the intermediate depth zone.
68	Well laminated diatomite with scattered fossils.
16	Limonitic sand layer without fossils.
85	Well laminated diatomite with few, large fossil fishes. Marks the limit of excavation. The base of the author's pit did not penetrate this layer.

Morris Skinner (in litt.) states that he bored to the base of the lake bed series with an auger and found gravels beneath the lake deposits at a depth of thirtytwo feet.

Habitat preferences of the modern counterparts of the Ree Heights fishes (Y = immature Table 2. populations; A = adult populations; ? depending on species present, may occupy either habitat).

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	Lentic environments only	Lotic environments only	Both habitats, with preference for lotic bodies	Shallow depth 0 to 5 feet	Jeeper water 5 feet or more
Proballostomus longulus					
Sardinius blackburnii					
Fundulus diaphanus		х		х	
Ictalurus melas			х	х	
Noturus hildebrandi	х			х	
Etheostoma exile			х	х	
Perca flavescens		х		Y	А
Percina sp.	?	?		х	
Micropterus salmoides			х	Y	А

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Micropte

Lepomis humilis

Lepomis gibbosus

Lepomis macrochirus



Table 3. Palynological data.

	Lotic bodies	Lotic and Lentic bodies	Non-specific forms	Moist lowlands	Dry uplands	Cool, wet indicators	May not be local, easily transported	
Diatoms								
Cocconeis			х					
Cymbella			х					
Denticula			х					
Fragilaria		х						
Gomphonema			х					
Navicula			х					
Pinnularia	х							
Stephanodiscus	х							
Surirella		х						
Tabellaria	х							
Other Algae								

والمتعاقبة والمترجين المترجع فتحرج المحادية

Other Algae

Pediastrum



May not be local, easily transported Lotic bodies bodies Lotic and Lentic Non-specific forms Moist lowlands Dry uplands Cool, wet indicators Higher plants Pteridophyte Х Х (Fern) Equisetum Х х Picea Х Pinus х Х х Carya Tilia Х Quercus Х Х Betula Х Х Grasses, various Х Composites х Myriophyllum Х

(Determined by A. T. Cross, R. E. Taggart, and L. E. Eames, Department of Geology, Michigan State University.)

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Table 3 (cont'd.)

Dakota.	P10 ,10	ting (Uu
	Missouri River drainage	Mississippi River drainage	Minnesota River drainage	Des Moines River drainage	
Proballostomus longulus					
<u>Sardinius</u> <u>blackburnii</u>					
Fundulus diaphanus		Х	х		
<u>Ictalurus</u> <u>melas</u>	х	х	х	х	
Noturus hildebrandi		Х			
Etheostoma exile	Х	Х	х	х	
Perca flavescens		х	х	х	
Percina sp.		х	х	х	
Micropterus salmoides		х	х	х	
Lepomis humilis	Х	Х	х	х	
Lepomis gibbosus		х	х	х	
Lepomis macrochirus		х	х	х	

Table 4. Drainage connections providing access to South



Figure 2. Ree Heights fishes. (A) <u>Sardinius blackburnii</u> Cope AMNH 8091; (B) <u>Lepomis gibbosus</u> (Linnaeus) UNSM 70781; (C) <u>Proballostomus longulus</u> Cope AMNH 8090; (D) <u>Fundulus</u> <u>diaphanus</u> (Le Sueur) AMNH 8089. Each line equals ten millimeters.



Figure 3. Ree Heights fishes. (A) <u>Ictalurus melas</u> Rafinesque UNSM 71139 (detail of pectoral spine); <u>Micropterus salmoides</u> (Lacépéde) UNSM 71037; (C) <u>Lepomis</u> <u>macrochirus</u> (Rafinesque) UNSM 71034. Each line equals ten millimeters.



Figure 4. Ree Heights fishes. (A) and (B) <u>Noturus</u> cf. <u>hildebrandi</u> Bailey and Taylor, part and counterpart of <u>UNSM 71130;</u> (C) detail of pectoral region of (B) showing spine dentations and humeral process of the cleithrum. Each line equals five millimeters.





Figure 5. Ree Heights fishes. (A) <u>Percina sp</u>. Haldeman UNSM 71170; (B) <u>Etheostoma exile</u> (Girard) UNSM 71164; (C) <u>Etheostoma exile</u> (Girard) UNSM 71167. Each line equals ten millimeters.



Figure 6. Ree Heighte fishes. (A) Lepomis humilis (Girard) UNSM 70682; (B) Lepomis humilis (Girard) AMNH 8078 (holotype of <u>Oligoplarchus</u> squamipinnis Cope); (C) <u>Perca</u> <u>flavescens</u> (Mitchill) UNSM 71177. Each line equals ten millimeters.
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