FIELDIANA
Geology

Published by Field Museum of Natural History

Volume 33, No. 14 November 28, 1975

This volume is dedicated to Dr. Rainer Zangerl

Taphonomy of Eocene Fish from Fossil Basin, Wyoming

PAUL O. MCGREW
PROFESSOR OF GEOLOGY
UNIVERSITY OF WYOMING
LARAMIE, WYOMING

INTRODUCTION

There have been many attempts to interpret the taphonomy of concentrations of fossil fish. Most of these have concerned marine occurrences and have been reviewed by Brongersma-Sanders (1957) and David (1957). One of the greatest concentrations of fossil fish is that in the Green River shales of the Fossil Syncline Basin of Wyoming. Bradley (1948, p. 646) attempted to interpret these concentrations as follows:

> "In this basin (Fossil, Wyo.) hundreds of thousands of beautifully preserved fish are entombed in the varved sediments. Even the delicate fin and tail rays and other bones originally held in place only by tissue are virtually undisturbed, and even the scales are in place almost completely undisturbed. It seems to me that the picture of this lake as a thermally stratified water body provides nearly all the necessary information to account for the excellent preservation of these fish. Only in the stagnant hypolimnion could they have escaped being torn to pieces by scavengers or distorted by bottom feeders. It is significant that all the well preserved fish are in varved sediments. Those in nonvarved sediments are a disordered mass of broken and chewed up bones.
>
> The only part of the story lacking now is how the fish died and got into the hypolimnion. Limnology offers two possible explanations. Sometimes when the surface of a lake gets excessively warm, fish will plunge into deep water and might thus penetrate the hypolimnion, be overcome by hydrogen sulphide, and also have the gas in their swim bladders chilled so that they sank at once to the bottom. Once there, only anaerobic bacteria would attack them. The other hypothesis is that the thermally stratified lake was suddenly chilled so that it overturned more rapidly than the hydrogen sulphide could be oxydized and so killed off large numbers of fish. This seems a little more probable as the fossil fish are of all ages and sizes."

Library of Congress Catalog Card Number: 75-25183

FIG. 1. Quarries in which studies were made-usually known as the Ulrich quarry. Control block is in the foreground.

The fish in these quarries have been collected since the 1870's but mainly by commercial collectors. Most museum collections were purchased from these commerical collectors, hence consist almost entirely of perfectly preserved fish, as poorly preserved specimens would be discarded by the collector as of no monetary value. The result has been that most people, including Bradley, were misled into believing all of the fish in the varved sediments of the quarry were perfectly preserved. In 1963 and 1964 I attempted to systematically collect and interpret this concentration of fish.

PROCEDURES

A bulldozer was employed to remove overburden from an area roughly 15 by 20 ft. Because of fractures in the shale it was convenient to select a rectangular area 8 by 16 ft. as a control block (fig. 1). The "fish layer" studied is approximately 14 in. thick, a zone in which the fossil fish are most abundant and most perfectly preserved. In this block all data such as distribution, orientation, genus, size, and degree of disarticulation, were recorded for each fish in the top 2 in. of the "fish layer." It was originally intended to

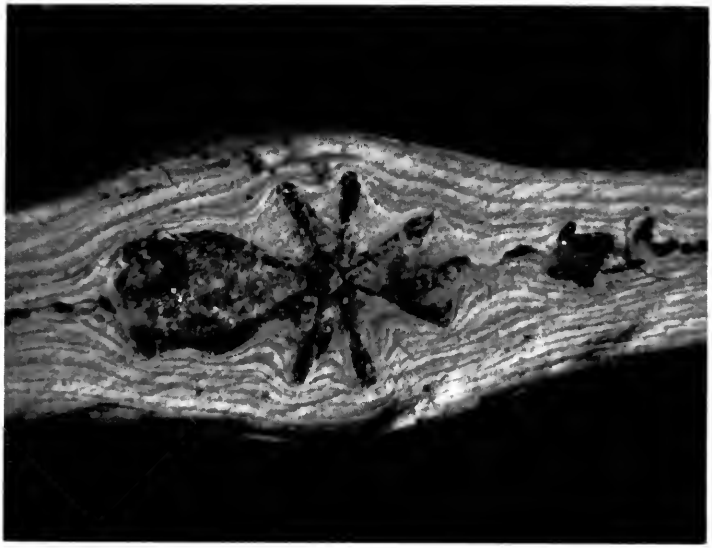

FIG. 2. Section of varved shale as it is compressed about a vertebra of a fish. × 12.

obtain all such data for the entire block in the field but for many reasons this proved impractical. Instead, the entire control block was removed in slabs 2 ½ in. thick measuring 2 by 2 ½ ft. These slabs were then transported to the laboratory at the University of Wyoming. There a portion of the main block 4 by 5 ft. was, in turn, split into slabs from one-half to 1 in. thick – thin enough for purposes of X-ray. From the X-rays it has been possible to obtain most of the data desired, but only for fish more than about 2 ½ in. long. The only important information not available was the relative vertical position of the fish within each slab.

Shales of the Green River Formation in general have been described by Bradley (1931) and he (1948, p. 645) specifically mentioned those of the fish layer in the Fossil Syncline Basin as follows: "Plate 1 shows a thin section of the varved marlstone in the small, unnamed Green River Lake west of Gosiute Lake, where the varves are better developed. Each varve or annual deposit, consists of a layer of microgranular carbonates and a thinner, dark layer of organic matter." Figure 2 of this paper shows these varves as they are compressed about a vertebra of a fish. X-ray diffraction analyses performed by John Ward Smith of the Laramie Energy Research Center showed that the shales of the "fish layer" consist predominantly of calcite (roughly 60 per cent), aragonite and dolomite (approximately 20 per cent), and quartz (up to 10 per cent).

DECOMPOSITION OF THE FISH

The X-ray photos show that a rather high percentage of the fish in the shales are not perfectly preserved but have undergone varying amounts of disarticulation. There appears to be an orderly sequence of stages of decomposition — from essentially perfect articulation to total disarticulation. Disarticulation first appears in the most anterior vertebrae. From there it it proceeds rapidly anteriorly into the head region and, apparently, slowly posteriorly. In many specimens the head and anterior half of the body are completely disarticulated while the posterior part of the body shows no disarticulation whatever.

Although fish are numerous throughout the thickness of this "fish layer," there are three laminae that contain so many fish that it is almost certain that they represent catastrophic mass mortalities. Two are made up primarily of *Priscacara* and one consists almost exclusively of *Knightia*. The fish are, for the most part, perfectly preserved.

It is assumed that after the dead fish settled to the bottom of the lake external anaerobic bacteria found access to the "innards" of the fish via the opercular opening. This would account for the first sign of decomposition and disarticulation being just back of the head.

In the blocks of shale covered by X-ray there were 385 fish. For convenience these were classified into six groups, Group I showing no discernable disarticulation and Group VI showing total disarticulation. The number and percentage of fish in each group are as follows (fig. 3):

Group	No. of fish	Percentage of fish
I	223	58 (figs. 4, 5, 6)
II	38	10 (figs. 7, 8)
III	14	4 (fig. 9)
IV	27	7 (figs. 10, 11)
V	24	6 (fig. 12)
VI	59	15

Because of the predominance of completely articulated fish throughout the quarry and the fact that the fish involved in the mass moralities show no disarticulation, it seems probable that

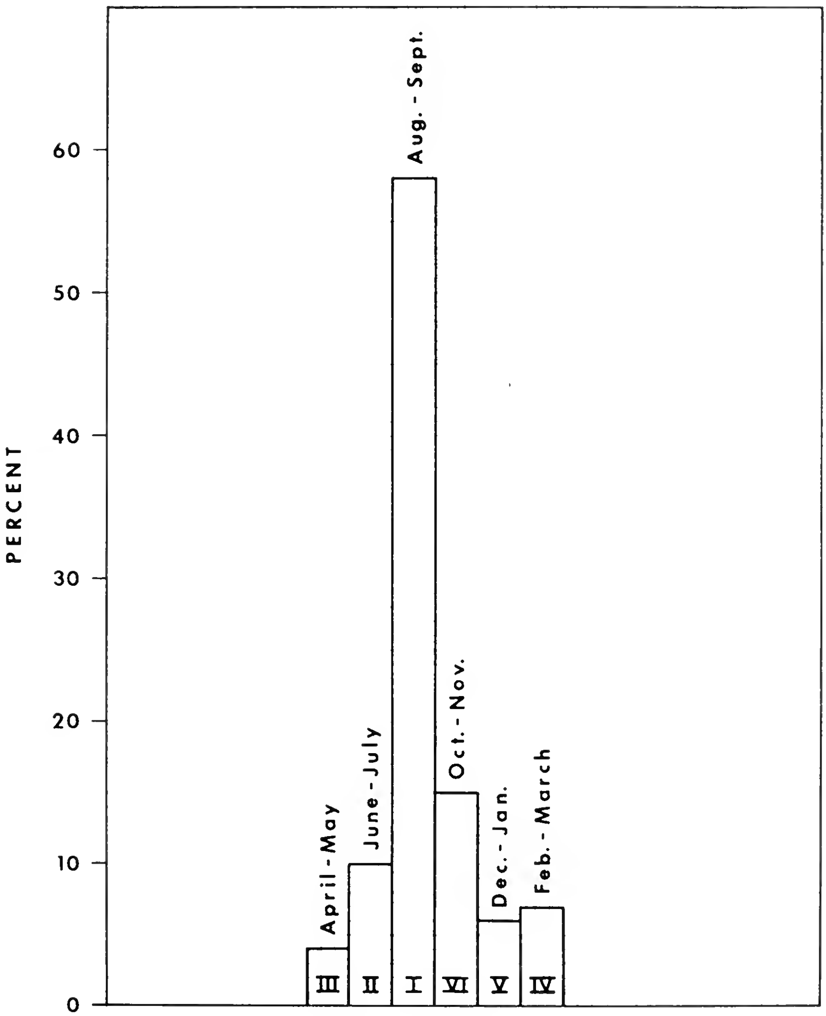

FIG. 3. Percentage of each stage of disarticulation among 385 fish and approximate time of death of each group, if interpretation in text is correct.

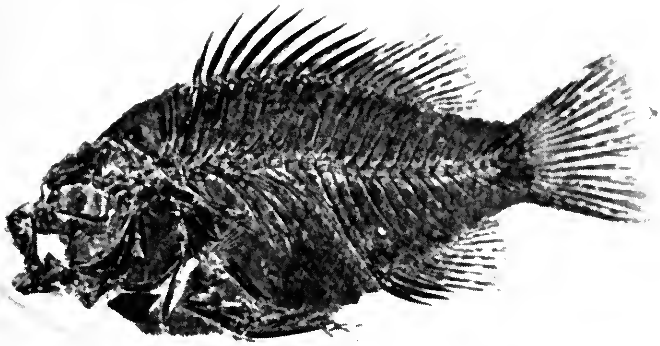

FIG. 4. A prepared specimen of *Priscacara* showing type of preservation in Group I (length: 12 cm.). This specimen was involved in a mass mortality.

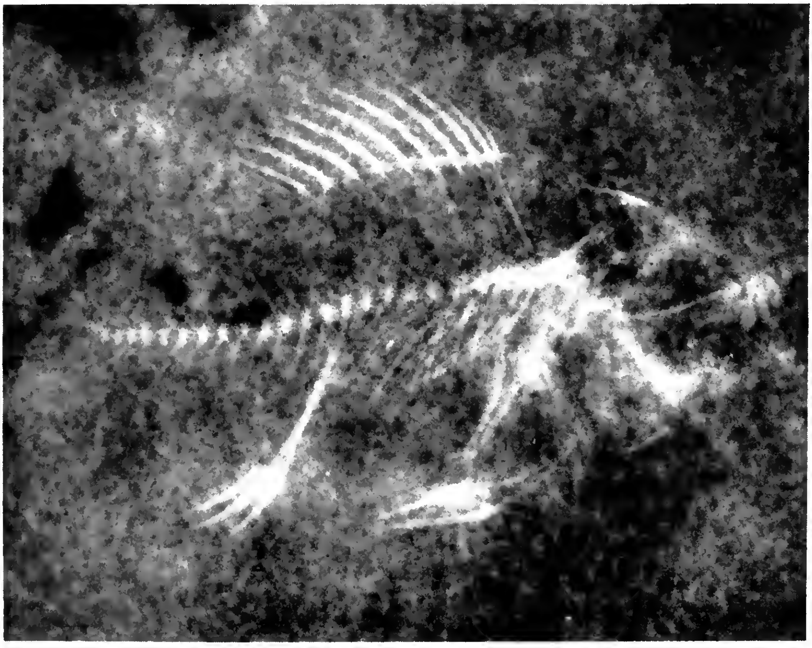

FIG. 5. Radiograph of a *Priscacara* in Group I (length: 12 cm.). This specimen was involved in mass morality.

some connection exists between the death of the fish and conditions on the lake bottom that would cause their perfect preservation. It would seem that rapid burial might be the most obvious reason for excellent preservation. Thus any factor or combination of factors that would cause rapid precipitation of carbonates and also would cause mortality of fish would satisfy our requirements. One obvious factor that could, at least theoretically, fulfill these requirements would be an annual bloom of blue-green algae that are known to be toxic to fish (Prescott, 1948). Such blooms usually occur during the warmest part of the summer when $CaCO_3$ is least soluble. By extracting CO_2 from the water these algae are known to cause precipitation of $CaCO_3$. Thus we have a possible cause for some annual fish kill and perhaps an occasional superbloom that would bring about a catastrophic mass mortality. The highest mortality of fish then might have occurred during late summer algal blooms and at this time also would occur the most rapid precipitation of $CaCO_3$.

It is not known how much deposition of $CaCO_3$ would be required to protect a fish from disarticulation. It may be that a very thin layer, especially if mixed with organic ooze, might provide an effective seal to slow decomposition and prevent disarticulation. If sufficient $CaCO_3$ was precipitated and deposited to cover the fish

FIG. 6. Radiograph of a small *Knightia* (length: 9 cm.). in Group I.

FIG. 7. Radiograph of a *Priscacara* in Group II (length: 18 cm.).

FIG. 8. Radiograph of a *Diplomystus* in Group II (length: 40 cm.).

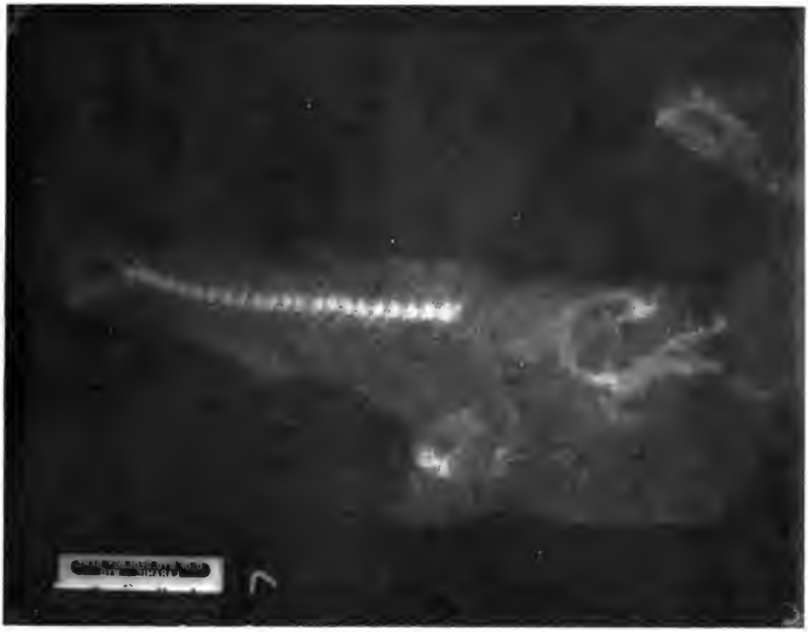

FIG. 9. Radiograph of a *Mioplosus* in Group III (length: 36 cm.).

that died during this period one might expect perfect preservation. Such fish would fit into our Group I. Those fish that died just after this period might lie exposed on the lake bottom for most of a year and be subject to disarticulation. If little or no deposition took place during the rest of the year fish that died just after the period of deposition should be the most completely disarticulated and fit into our Group VI. During the fall, winter, and spring, fish that died of attritional mortality would be disarticulated according to the length of time they lay on the bottom prior to the next period of deposition.

If the foregoing is true, one should be able to determine the approximate time of year each fish died by the degree of disarticulation. One might assume that blooms of blue-green algae and hence precipitation of $CaCO_3$ would take place sometime during August and/or September. Thus we should expect the most fish and those most perfectly preserved to have died during this time period (Group I). Those fish that died in October and/or November should be the most completely disarticulated (Group VI), and those that died in June or July should show only a slight degree of disarticulation (Group II). The distribution of the stages of

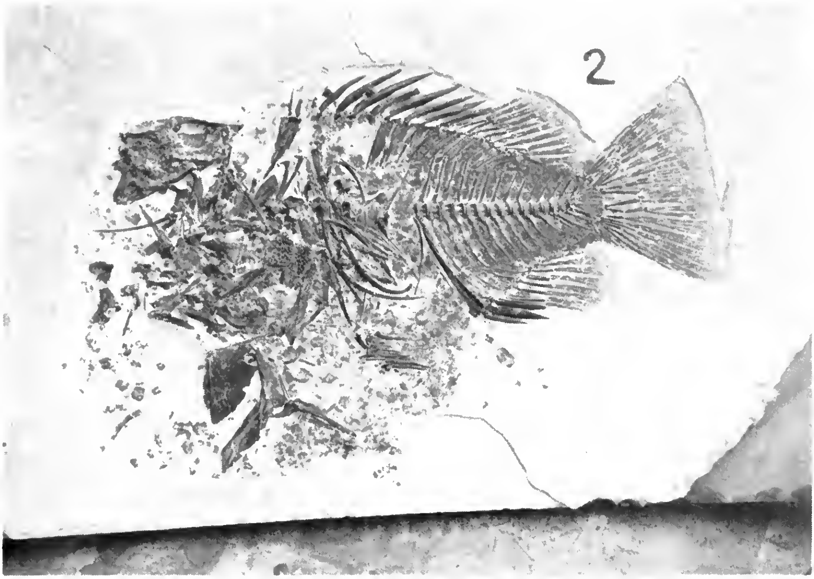

FIG. 10. Prepared specimen of a *Priscacara* in Group IV (length: approx. 28 cm.).

FIG. 11. Radiograph of a *Priscacara* in Group IV (length: approx. 26 cm.).

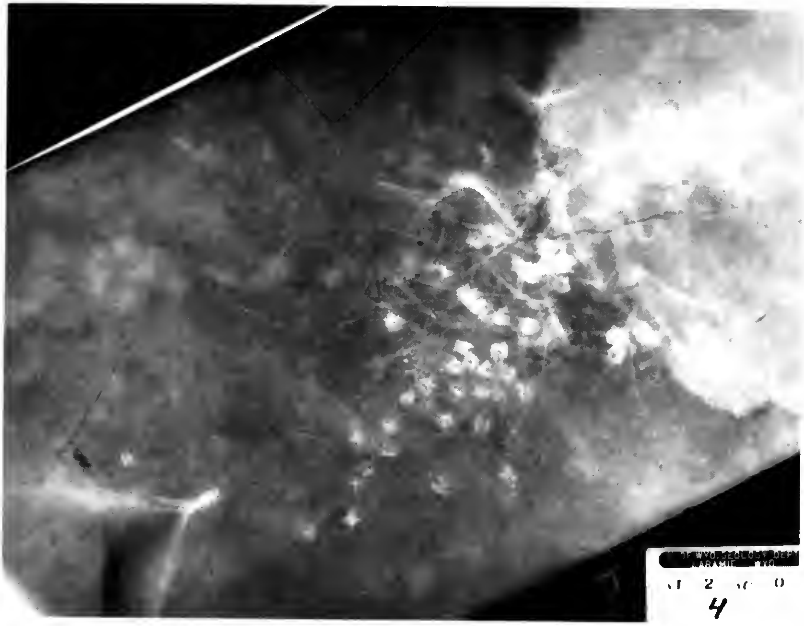

FIG. 12. Radiograph of a *Diplomystus* in Group V (length: approx. 40 cm.).

disarticulation seems to fit almost exactly the pattern that one would expect if our interpretation is correct (fig. 3).

Gunter (1947) has shown that annual periods of excess salinity in Texas lagoons cause an annual increase in the death of fish and occasionally a catastropic mass mortality. Because Lake Gosiute is known to have been saline it might be assumed that somewhat similar chemical conditions prevailed in the Fossil Syncline Lake. It is not known definitely that the two lakes were ever connected, but if they were it was most probably a narrow connection near the southern end of Fossil Syncline Lake and probably a rather temporary connection.

That a rather long period of aridity occurred in the general region is demonstrated by various depositional features, primary structures, and salt deposition in Gosiute Lake in the Wilkins Peak Member of the Green River Formation. Most of the Wilkins Peak appears to have been deposited during Lost Cabinian (Late Early Eocene) time (Eugster and Surdam, 1973). Because the Wasatch Formation immediately underlying the Fossil Butte Member of the Green River Formation in the Fossil Syncline Basin is Lysitean

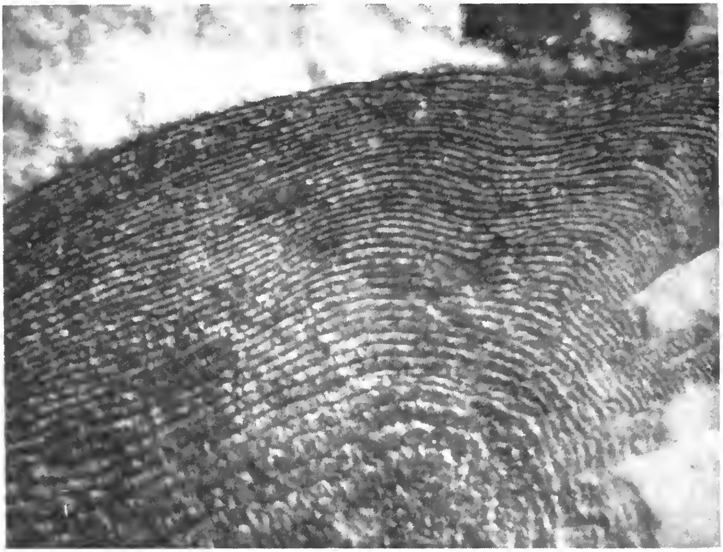

FIG. 13. Scale of a *Priscacara* in Group III. × 50

(Middle Early Eocene), it is probable that the fish deposits are of Lost Cabin age. Thus it may well be that the long period of aridity occurred during the deposition of the fish beds. While the Fossil Syncline Lake probably never reached the high degree of salinity present during Wilkin's Peak time in Lake Gosiute, it was probably sufficiently saline that periods of excessive evaporation could increase the salinity enough to contribute to the mortality of fish and occasionally cause a catastrophic mass mortality such as those described by Gunter. The presence of aragonite and dolomite in the shales suggests that at least some of the carbonate deposition might well have been because of excessive evaporation and high concentrations of carbonates (Smith, 1974, pers. comm.).

At the University of Wyoming an attempt is being made to interpret scales of fish from the quarries. In a number of specimens annuli can be observed and circuli counted. Although removal of scales for study is extremely difficult, a number have been removed and photographed with a scanning electron microscope (fig. 13). In Lake George, Florida black crappie develop annuli during January, February, March, and April (Huish, 1953). Climatic conditions in north central Florida may be similar to those that existed in western Wyoming during the early Eocene. Thus annuli may have developed at the same time. By counting the number of circuli between the last annulus and the edge of the scale, it should be possible to determine the approximate time of death of a fossil fish. If this should correlate with the degree of disarticulation, a check on our interpretation should be possible. Sufficient data are not yet available, however, for the results to be conclusive.

It is not intended to suggest that the conditions outlined above could account for all of the fish concentrations in the Green River Shales. In the Laney Shale, for example, are concentrations of *Knightia* in non-varved shales that appear to have been deposited in quite shallow water. These fish are extremely well preserved, but were obviously laid down under conditions quite different from those at Fossil Butte. Much study of the Laney occurrence will be necessary before interpretations are possible.

ACKNOWLEDGEMENTS

I am indebted to many people for helpful discussions of various aspects of this study. Particularly I wish to thank Ward Smith, geochemist, U.S. Bureau of Mines; James I. Drever, geochemist, University of Wyoming; Ronald C. Surdam, geochemist, University of Wyoming; John Adams, microbiologist, University of Wyoming; Michael Parker, limnologist, University of Wyoming; W. H. Bradley, geologist, United States Geological Survey; and George T. Baxter, zoologist, University of Wyoming. Michael Voorhies, presently at the University of Nebraska; Michael Hager, presently at Augustana University, and Bruce Smith, United States Geological Survey, all helped as assistants in the preparation. Mr. Carl Ulrich of Diamondville, Wyoming, aided us in many ways during the quarrying operations. This project was supported by National Science Foundation grant GB-943.

REFERENCES

BRADLEY, W. H.

1931. Origin and microfossils of the oil shale of the Green River Formation of Coloradao and Utah. U.S. Geol. Surv. Prof. Paper 168, pp. 1-58, figs. 1-3, pls. 1-28.

1948. Limnology and the Eocene Lakes of the Rocky Mountain region. Bull. Geol. Soc. Amer., **59**, pp. 635-648, figs. 1-6, pls. 1-2.

BRONGERSMA-SANDERS, MARGARETHA,

1957. Mass mortality in the sea. Geol. Soc. Amer., Mem. 67, **1**, pp. 941-1010, figs. 1-6.

David, Lore Rose
1957. Fishes (other than Agnatha). Geol. Soc. Amer., Mem. 67, **2,** pp. 999-1010.

Eugster, Hans P. and Ronald C. Surdam
1973. Depositional environment of the Green River Formation of Wyoming: A preliminary report. Bull. Geol. Soc. Amer., 84, pp. 1115-1120, figs. 1-3.

Gunter, Gordon
1947. Catastrophism in the sea and its paleontological significance, with special reference to the Gulf of Mexico. Amer. Jour. Sci., **245,** no. 11, pp. 669-676.

Huish, Melvin T.
1953. Life history of the Black Crappie of Lake George, Florida. Trans. Amer. Fisheries Soc., **83,** pp. 176-193, figs. 1-5, tables 1-10.

Prescott, G. W.
1948, Objectionable algae with reference to the killing of the fish and other animals. Hydrobiologia, **1,** no. 1, pp. 1-13.