THE ANCIENT FISH TRAPS of MECCA

PART II

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OUR PLANET Earth has a history spanning about four and a half billion years. The earliest evidence of organisms living on its surface dates back more than 600 million years.[1]

All during these enormous intervals of geologic time, an infinite number of major and minor processes ran their courses. Chemical compounds were formed and destroyed, volcanic ash was transported by winds, gases were vented from marsh bottoms, the remains of plants and animals were buried in sediment—to mention just a very few. Many of these processes required no more than seconds, days, or weeks to be accomplished. Yet all these events, no matter how minute or seemingly insignificant, had some effect upon the environment in which they took place and hence left behind some mark of their occurrence.

The ancient fish traps of Mecca, described in the January BULLETIN, existed during Pennsylvanian time, a period that ended 280 million years ago. Dr. Eugene S. Richardson, Jr., and I have made a detailed study of the fossil fish graveyard found in the Mecca and Logan Quarry shales of Parke County, Indiana. Perhaps the most startling result of this study is that we were able, some 285 million years after the events, to examine and to reconstruct the history of a specific four-year period.

HOW WAS IT possible to date this sequence of events in which vast numbers of animals were destroyed on the fringes of a transgressing (flooding) Pennsylvanian inland sea?

The record is "written" in the rocks, our only source of information concerning ancient geologic events. Potentially, rocks contain a wealth of evidence regarding the conditions that prevailed prior to, during, and since their formation. Experience has taught us, however, that most rocks have undergone such severe changes since the time when they were formed that much of this evidence has been destroyed or so severely altered that we can no longer recognize it.

The present dense, tough, finely laminated shales of the Mecca and Logan quarries look as if their substance had been severely compressed from the time when they were presumably a smelly, semi-liquid mud. Clearly, these are not the kind of rock that one would expect to contain much evidence of the myriad physical, chemical, and biochemical processes that must have occurred on the site where thousands of animal carcasses were buried.

As it turned out, however, just the opposite is the case. These shales are full of fascinating phenomena that are, we believe, related to processes that took place in Pennsylvanian time when the ancient shales were accumulating mud on the coastal plains of the Mecca area.

Most of these phenomena seem to be the result of the disintegration of plant and animal tissues, a process that is always accompanied by the formation of gases (for example, methane and hydrogen sulfide). Under water such gases form bubbles that, being lighter than water, are vented to the surface. If a large bubble forms beneath mud, or within the carcass of an animal, or within a fecal pellet, the escaping bubble disarranges the structures in its path, and such disarrangement, if preserved, may leave a fossil record of that event.

If, on the other hand, the gas bubbles are tiny, they may remain trapped beneath a layer of mud and the gas may chemically react with other compounds in the environment. The result may be the formation of relatively stable substances (for example, pyrite) that become a part of the rock.

Evidence of this sort is very abundant in the Mecca and Logan Quarry shales; it gives testimony to commonplace events of little consequence—or so they would seem, except for the fact that these processes have a small time dimension, measurable in seconds, which provides us with a potential clock built right into the shale.

Suppose it could be demonstrated that the decay process left recognizable marks both in the fossil specimens and the mud in such a way as to indicate the thickness of the mud blanket that had accumulated on a decomposed carcass. This would mean that we could now measure directly the equivalent thickness on the present shale into which the mud has turned.

A SPECIMEN precisely fitting the described situation is shown on page 4. Fig. 1 represents a section cut through a stomach residue pellet of a shark from the Logan Quarry. The pellet contains mostly scales, the leftovers of a meal that consisted of parts of palaeoniscoid and acanthodian fishes. The palaeoniscoid scales appear on the section as elongated black bars, those of the acanthodian as squarish black spots. The scales are embedded in a ground-mass of light brown color.

It may be noted that the palaeoniscoid scales show a peculiar arrangement, and one of them, on the upper side of the mass, extends vertically into the shale; to the left of its tip there is a little "flag"

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[1] An article by Dr. Edward Olsen, Curator of Mineralogy, explaining the principles involved in absolute dating of the geologic past, will appear in a future issue of the BULLETIN.

(*Continued from preceding page*)
of the brown ground-mass of the pellet, separated from the pellet by a band of shale 2 millimeters thick. Our interpretation of this interesting picture is as follows: the shark regurgitated the stomach residue mass, which settled to the bottom. There it decayed in the presence of air dissolved in the water. Gas bubbles formed and escaped, and the process of decay reduced the volume of the pellet in its upper half, hence the flattened upper side. Then one final bubble formed in the middle of the pellet. As it grew bigger, the palaeoniscoid scales in its vicinity became tangentially aligned to its surface. Then the bubble escaped; as it left the residue mass, it drew a palaeoniscoid scale up into the escape channel, along with a bit of ground-mass. The scale was held in vertical position by the mud that had meantime accumulated on the pellet. The bit of ground-mass settled on the mud surface. Hence, the distance between the little "flag" of ground-mass and the surface of the pellet is the thickness of shale that had accumulated on the pellet during its phase of decay. This distance was 2 millimeters. Similar measurements on other specimens from the Logan Quarry were the same; in specimens from the Mecca Quarry, the comparable measurement was consistently 1 millimeter.[2]

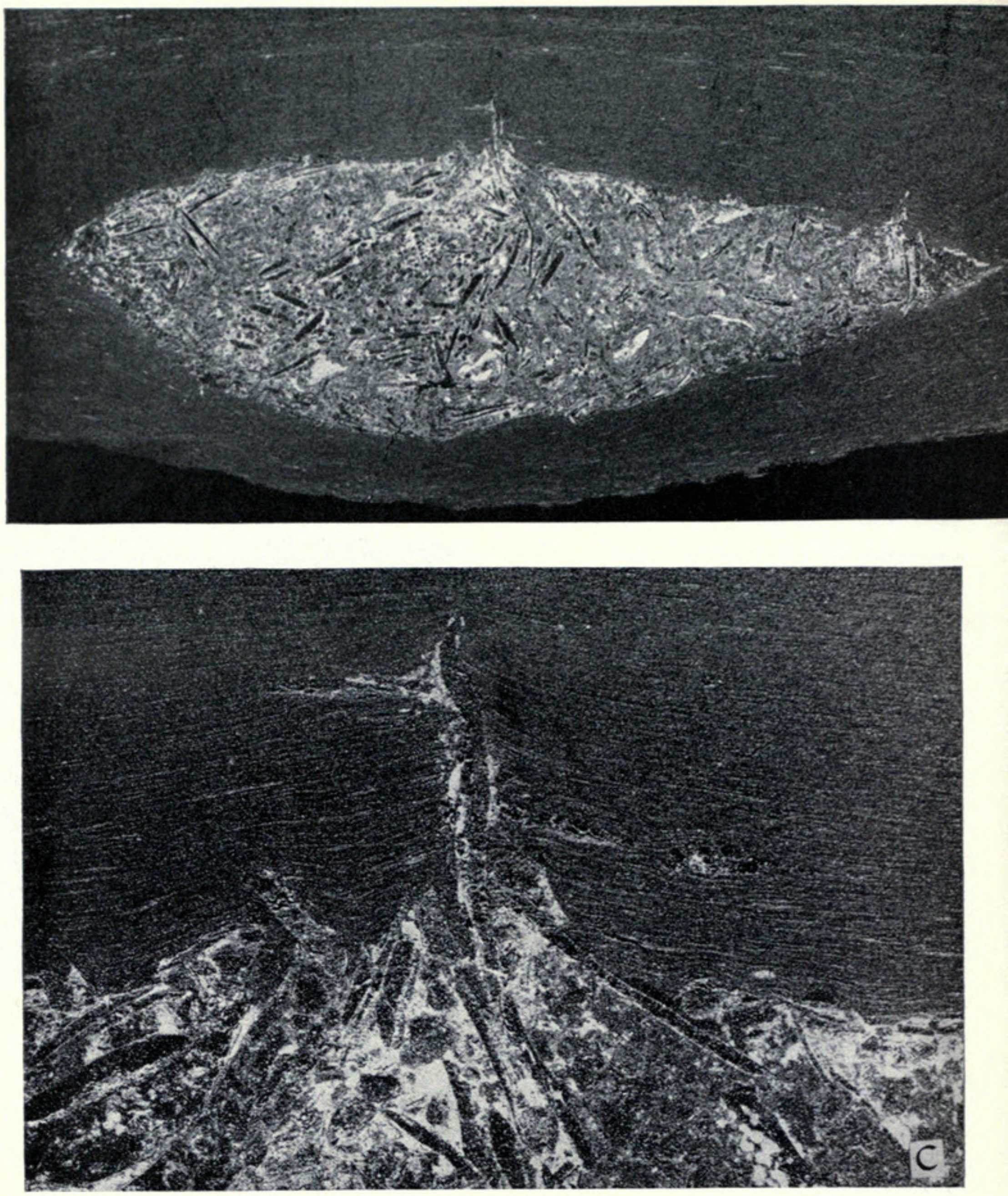

Fig. 1. Two photographs of a section cut through a stomach residue pellet of a shark from the Logan Quarry.

In order to learn how long it actually took to deposit this measured thickness of shale—and so "tell the time" by our clock—we now need a reasonable estimate of how long it took a fish to decay to bare bones at the site of the ancient fish traps of Mecca.

We are probably safe in assuming that bacterial decomposition of animal tissues in the presence of air was much the same process in Pennsylvanian time as it is today. The rate of decay today varies greatly with the temperature and there is good reason to believe that this was also true in the geologic past.

The question as to the climate of Pennsylvanian time has been much discussed, especially in connection with the origin of the coal beds that characterize rock sequences of this period all over the world. The evidence is primarily of a paleobotanical nature and is by no means wholly conclusive. But most paleobotanists agree that the Pennsylvanian climate must have been rather warm and devoid of sharp, seasonal temperature differences.

For these reasons we chose the bayou country of Louisiana to determine, by field experiment, the rate of bacterial decay of fishes under conditions that were probably quite similar to those of the ancient Mecca fish traps. At temperatures between 20° and 30° C., fishes weighing three-fourths of a pound decomposed to the bare skeleton in less than one week. It would thus seem reasonable to assume a similar rate of decay for the fishes now enclosed in the Mecca and Logan Quarry shales.

As described above, it was possible to measure the amount of shale (1 millimeter in the case of the Mecca Quarry shale) that had accumulated above a carcass during its process of decay. Since we may assume that the decay process at the ancient burial site near Mecca

(*Continued on page* 8)

[2] The curious aspect of this phenomenon is that the thickness of shale so measured appears also to have been the thickness of mud at the time of deposition. Ordinarily, as mud becomes compacted into shale, one would expect a severe reduction in volume. In this case, however, a great deal of additional evidence suggests that the Mecca and Logan Quarry shales did not undergo compaction in the generally accepted sense, but that compaction took place largely at the time of deposition.

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Founded by Marshall Field, 1893

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Members are requested to inform the Museum promptly of changes of address.

For the Children

CHILDREN taking the Museum's new Journey for spring will find themselves in an exhibit land of gay costumes, delightful toys and games, and elaborate puppet theatre. The Journey is to China, or more specifically, to the Museum's new exhibition hall portraying everyday life under the last Chinese emperors.

In traveling the prescribed Journey route, youngsters will discover: how boys and girls of Old China spent their out-of-school hours; the favorite arts and crafts of the Chinese, including some very special kinds of "cut-outs"; the materials with which Chinese students write; and the articles included in the wardrobe of the well-dressed family.

Instructions and questionnaires for the Journey are available at the information desk and at the north and south entrance doors of the Museum.

FOUR Saturday morning film programs for children will be presented this spring by the Museum's Raymond Foundation. They are:

March 7 **Nature's Children**
Camp Fire Girl Day

March 14 **Your Camping Through the Years**
Girl Scout Day

April 11 **The Kingdom of the Elephant**

April 18 **Secrets of Life**
(*A Disney color film*)

The free programs begin at 10:30 A.M. in the Museum's James Simpson Theatre.

Camp Fire Girls of the Chicago area will be honored at the March 7 program. On March 14 special recognition will be given to the Girl Scouts of Chicago. The April 11 film program will double as an honors program, with the presentation of Journey achievement awards to youngsters who have completed from four to 17 Museum Journeys.

LONGER Museum hours begin March 1 when the Museum doors will be open seven days a week from 9 A. M. until 5 P. M.

Saturday Programs for Adults

THE MUSEUM'S spring series of free programs for adults, on people and places around the world, gets under way on Saturday, March 7. The programs are presented every Saturday afternoon during March and April, each beginning at 2:30 P.M. in the Simpson Theatre. Reserved seats for Members are held until 2:25 P.M.

Following is the complete schedule:

March 7—American Indian Dances
A "live" performance by The Laubins

March 14—The New World Rediscovered
Laurel Reynolds

March 21—Bali, Java, and Sumatra
Phil Walker

March 28—The Last Cannibals: Expedition to New Guinea
Jens Bjerre

April 4—The Holy Lands
Charles Forbes Taylor

April 11—Valley of the Rhine
Clifford J. Kamen

April 18—Italy
Kenneth Richter

April 25—Here's Hawaii
Willis Butler

(A description of each program is given in the Museum's February BULLETIN.)

CLIMATES OF THE PAST and FUTURE

JOHN CLARK
ASSOCIATE CURATOR
SEDIMENTARY PETROLOGY

EVERYONE is aware that our climate is changing. Most people are aware that such temperate areas as Illinois are growing notably warmer. We see cardinals and mockingbirds in the Chicago area, whereas forty years ago they never came north of southern Illinois. Opossums have invaded as far north as central New York State.

From the more serious economic viewpoint, it has become clear that the maple-sugar industry of northern Ohio is dying out because the sugar-maple trees cannot endure the warmer climate. New Englanders who previously fished on the Grand Banks must now ply the less favorable waters off Greenland for their codfish. Siberia and Canada become more prosperous every decade, as the warming climate permits barley and wheat to grow farther and farther north.

How much warmer will our hemisphere become, and what will be the consequences? Even more important, how rapidly will these changes take place?

A glance at the history of climates may help us to predict the future.

The first of the four charts on page 7 shows that we are living in a very abnormal time, geologically speaking. We are either just emerging from a period of glaciation, or are in an interglacial phase of that period. Glaciations have occurred not more than four or five times in the last billion years (the earliest one is problematical both as to time and as to its actual existence), and have been spaced about 200 to 250 million years apart. Most of earth history has seen warm, equable climates, with the poles only a few degrees cooler than the equator.

Looking more closely at the last 100 million years, as shown in Chart 2, we see that there has been a cool time about every 20 million years, with warmer periods between. (Each chart is a blow-up of the right end of the preceding one, giving the added detail we are able to determine as we approach recent time.) A more important trend shows up on this second graph, however. About 35 million years ago, a cooling began that continued far longer than before. The warm time of 20 million years ago served merely to interrupt this general cooling trend. Progressively colder temperatures led finally to the Pleistocene Ice Age.

Even during the Ice Age, as shown in Chart 3, the climate did not remain continuously cold. Continental glaciers formed four times, with longer interglacial episodes of much warmer weather than we now enjoy.

The fourth graph shows climate during the last 10,000 years, since the waning of the last ice sheet. Warmer and cooler periods of a few hundred years' duration have alternated through this brief span of human history and prehistory. For almost a thousand years, from 4000 to 3000 B.C., the climate was much warmer than it is now. The present warming period began about 1850, following 300 years of cold.

These charted records tell us that climates have fluctuated on rhythms of a few hundred years, several thousand years, 20 million years, and 200–250 million years. The briefer rhythms may have occurred throughout time, but our imperfect understanding of the geologic record prevents our recognizing them. Continental ice sheets were produced, apparently, only when cold episodes of the three larger rhythms coincided. Since we are now in a warming period, and ice sheets have all but disappeared, the question is, which one or more of the rhythms have passed into a warming phase? Unfortunately, we have no way of knowing.

The next question is of more immediate interest. How long will this warming continue, and how fast will it progress? Also, what will be its consequences? We do have some of the answers to these questions.

We know that essentially our atmosphere is a thin, fluid film surrounding the earth. The equator receives more heat than do the poles; this sets up a convection system, somewhat like what happens when a broad, shallow pan of water is set partly over a gas burner. This convection system of warm and cool winds, modified by local factors, determines rainfall, temperature, storms, in fact all aspects of weather and climate.

At present, the equatorial "burner" is much warmer than the polar cold spots, so we have an actively moving system like water boiling in a pan. If the poles were much warmer than at present, this "boiling" would partly break down to a series of weaker, local movements like water simmering in a pot. Some places now arid would receive more rain from local, wet winds, while other regions at present well-watered might become arid.

As shown in Chart 4, our climate is warming. At the latitude of Chicago, the increase is about 1° Fahrenheit every 35 years, but farther north it is almost twice as fast. At this rate, how long will it be until Chicago's climate becomes not only warmer, but actually different, due to the setting up of a new convection system? Will this changed climate be like the warm, wet, jungle-producing climate of Florida, or more like the hot, dry summers and dry, cool winters of west-central Texas? Will the change be permanent, or will we revert to our present climate?

In the Museum section on sedimentary petrology we are seeking the answers to some of these questions by looking at the past. We are trying to determine the actual weather pattern of the last warm time, 35 million years ago (see Chart 2) and the successive patterns as cooling progressed. If we know these, we can presume that the warming trend will again bring each stage to us successively in reverse.

The results of our studies are fascinating, but not yet conclusive. We can expect the present warming to continue for a minimum of 200 years, and probably much more. This should cause—but we are not yet sure—a change in the basic wind circulation of the northern hemisphere. If it does, Chicago *may* become as dry as west-central Texas—but of this we are even less sure. Certainly the present Illinois drought is a local, temporary misfortune unrelated to any long-term trend.

However, the long-term trend *is* causing our generally warmer, drier winters, and is thereby seriously altering our ground-water supply. Farther west, several dams and irrigation projects, built on the assumption that past conditions would continue, are already suffering perennial water shortages which can be expected to increase. There is no need for panic or for crash programs, but definite, practical reasons for pursuing these studies of long-range climatic trends are already with us.

One other important result of the present warming trend will affect the life of everyone on earth. As the polar ice melts, sea level will rise, slowly at first but with increasing speed. This has already started. Sea level is now rising two feet per century; in 1920 the rise was one inch in two centuries. The most conservative estimates anticipate a total rise of over one hundred feet. This would drown out Boston, New York, Philadelphia, Baltimore, and other crowded areas the world over. Altogether, about five hundred million people would be forced to move; where on this crowded earth they would go will be a major problem. How soon will this happen? Certainly not during our generation or our children's, but beyond that we cannot be sure. Probably it will not happen during the next century.

Climate, like everything else in our environment, is dynamic and changing. Our Museum is taking part, along with other research institutions, in studies that may enable us to predict the climates of the future, and to prepare for them. (END)

CHART

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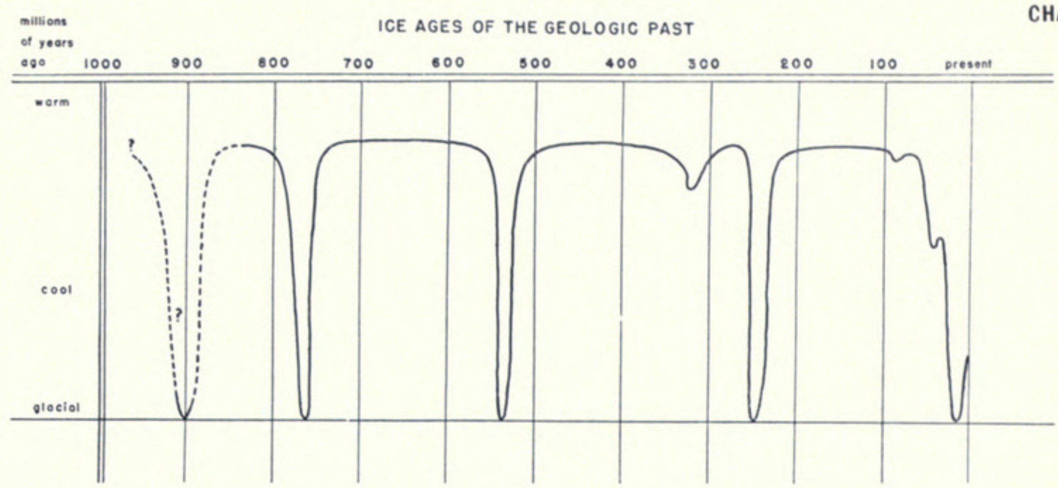

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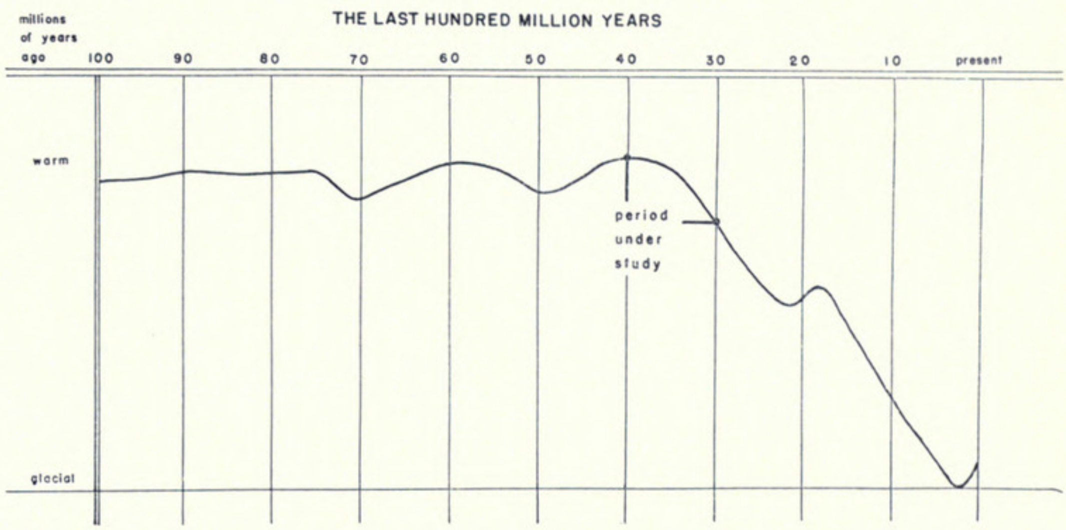

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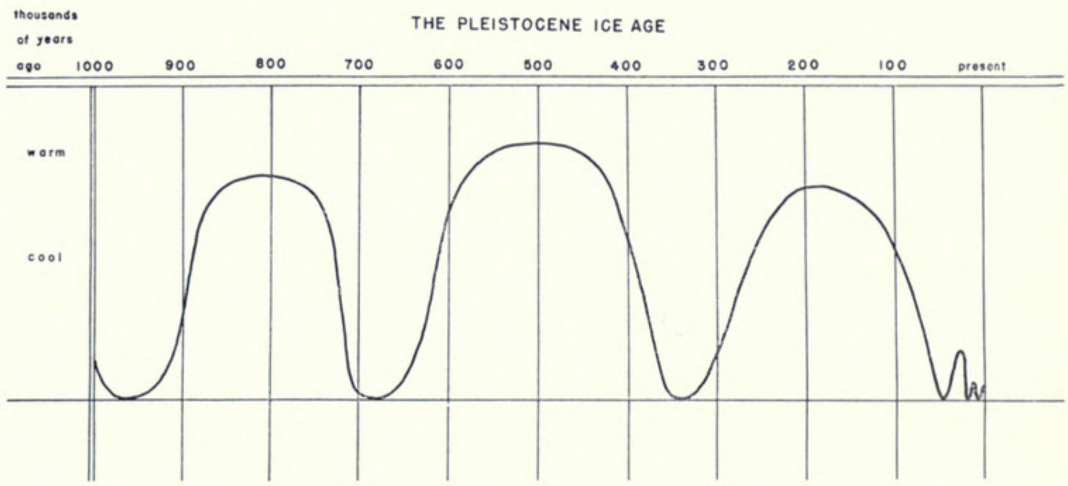

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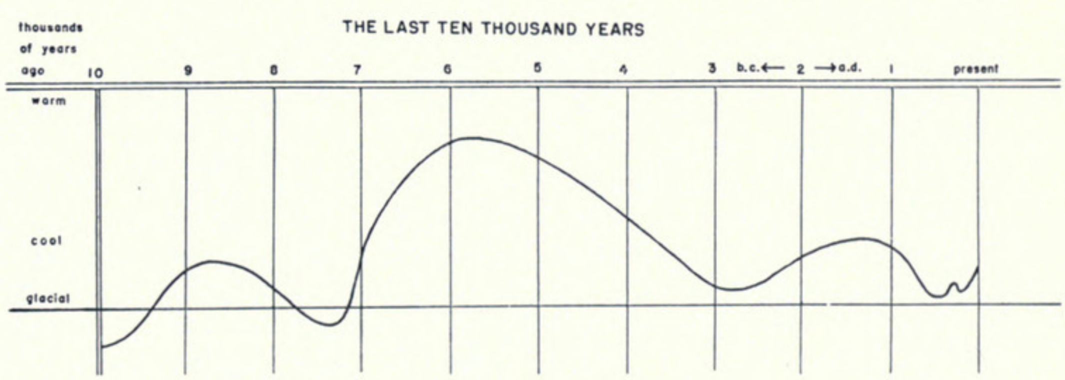

ARMORED FISHES—

(*Continued from page 2*)

be easily capable of biting other fishes in two. The body and tail of this fish are unknown, but his total length is estimated to be as much as 15 feet. If he was a strong swimmer, and we have no way of knowing surely, he must have been a formidable predator. If, on the other hand, he was a poor swimmer, he may have been a scavenger or a feeder on larger invertebrates. The original of the *Dunkleosteus* in our exhibit is one of many placoderms that have been found in the black shales that underlie the city of Cleveland.

One of the most peculiar placoderms, and, for that matter, of all fishes, is *Bothriolepis*, the best known genus of a group that was common in middle and late Devonian streams (see Fig. 1). Their distribution was world-wide, and, except for South America, they are known on all continents, including Antarctica and Greenland. Their armor is an exaggerated form of the usual placoderm jointed shield. Instead of proper fins, they had developed a pair of peculiar flippers, usually jointed, with which they propelled themselves around on stream bottoms. The form of the tail is known from impressions that have been preserved in one famous locality on the Gaspé peninsula of Quebec. Their mouth was a small opening bounded by strange jaws on the flat lower surface of the head.

Some years ago, when I was working at Dartmouth College, I had an opportunity to study material collected on the Gaspé by the late Professor William Patten. Serial sections sawed through his specimens of *Bothriolepis* showed a variety of sediments filling the shield. Most of the fill was the same coarse-grained sandstone in which the fossils were buried, yet in the trunk shield of many specimens was a mass of fine mudstone. I soon became convinced that this was a filling of the intestine, and almost certainly was a remnant of some mud that the *Bothriolepis* had eaten shortly before its death. This indicated that this fish fed on mud of the stream bottoms and extracted nourishing material from it in its digestive tract.

A third sediment, this one a fine-grained sandstone, filled certain parts of the *Bothriolepis* that communicated with the exterior. This filling may have happened when a flood killed a number of these fishes by burying them on a stream bottom. The fine sand preserved in part the shape of the mouth cavity and gills. In addition, I could recognize the filling of a pair of elongated, bladder-like organs that connected with the pharynx. These sacs could be identified only as lungs, though lungs are air-breathing organs that had previously been thought to occur only in two groups of fishes: lungfishes, and the crossopterygian ancestors of land vertebrates. These sedimentary fillings made it possible for me to reconstruct some of the soft anatomy of *Bothriolepis*, as is shown in the accompanying illustration (Fig. 2).

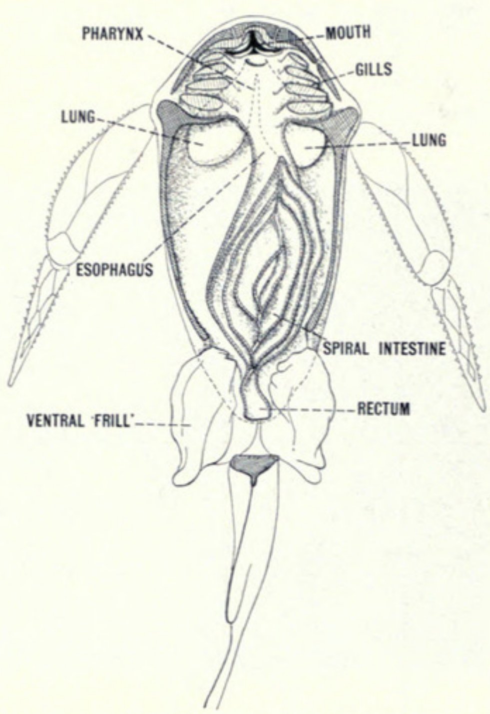

Fig. 2. Drawing by the author.

A third group of placoderms is represented in the featured exhibit by *Gemuendina*, which has a flat body, much enlarged pectoral fins, and a relatively narrow tail. Superficially it looks much like some modern skates and rays, and it must have had similar habits. But in the details of its structure, *Gemuendina* shows its relationship to placoderms, and its similarities to modern skates and rays have resulted from convergent evolution.

Placoderms are generally believed to have died out at the end of the Devonian period, which lasted for about 60 million years. It is possible, however, that some members of the group survived until late Paleozoic times and perhaps even until today. Among the fishes found by Dr. Zangerl in Pennsylvanian rocks at the Mecca Quarry (see his articles in this and last month's Bulletin), are a few that cannot be assigned to any familiar group of fishes; it is not impossible that they will be shown to have a relationship to placoderms. In today's oceans are a number of peculiar fishes with a skeleton of cartilage, known as chimaeroids or ratfishes. Ordinarily they are classified with the sharks and rays, which also have a cartilaginous skeleton. But a number of characteristics suggest that their real relationship may be to a group of placoderms of the Devonian period. Current research may well solve the problems of these questionable relationships and determine whether placoderms, like the lungfishes and crossopterygians, may have survived to modern times. (END)

MECCA—

(*Continued from page 4*)

spanned a similar period of time as it does under like conditions today, we may calculate the rate of deposition of the Mecca Quarry shale as 1 millimeter in about 5 days. For the entire foot of shale at this place (308 millimeters), the period of deposition would thus come to 1,540 days, a value that suggests the order of magnitude of 4 years.

It remains to be seen to what extent this simple and rather accurate method of determining the passage of time in the distant past is applicable to other rocks than the Mecca and Logan Quarry shales. Henceforth, students of sedimentary rocks are bound to look over their fossils with care for evidence of the kind displayed by the lowly gastric residue pellet from the Logan Quarry. (END)

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Zangerl, Rainer. 1964. "The Ancient Fish Traps of Mecca Part II." *Bulletin* 35(3), 3–8.

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