The PALEONTOLOGY *of* KENTUCKY

I

The GEOLOGICAL SUCCESSION of LIFE In KENTUCKY

By

ROY LEE MOODIE

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INTRODUCTION

ORIGIN OF THE EARTH

The origin of the earth, from the viewpoint of geology and astronomy, is best accounted for by the Planetesimal Hypothesis, which is to the effect that, the earth, instead of originally being a molten mass, grew to its present form by the accretion of cold bodies from outer space. When the earth had attained about two-thirds its present size it is held that there was enough attractive force to retain a warm blanket of atmosphere. The presence of living things then became possible; simple plants and animals may then have begun to live.

AGE OF THE EARTH

The age of the earth is usually expressed in terms of millions of years, but such statements are largely meaningless since none of us can comprehend the vast stretches of time indicated by even a million years. It will help somewhat to understand the meanings of geological time if we say that the Mammoth Cave, in Edmonson County, had been in existence for many thousands of years when the most ancient Egyptians were first entering the Nile Valley, long before any of the pyramids had been thought of, thousands of years before the city of Babylon was built. Huge mountain chains had arisen and were worn down long before the waters of the earth

had dissolved the first tiny crevice of the colossal cavern. When we realize that solid rock blocks creep down a slope at the rate of about one inch a century, or that a thousand years may bring about almost imperceptible changes in earth's feature, then we gain some concept of the meaning of geological time.

DIVISIONS OF GEOLOGICAL TIME

The grand divisions of geological time have been made on the basis of the life supposed to have existed at the time. The names are handles for use in discussing past events of geological interest. The most ancient of these times is known as the Archeozoic. This witnessed the accretion of planetesimal bodies to the point where life was possible.

Lowly organized plants have been found in these ancient rocks. The next division of rocks is called the Proterozoic which we think witnessed the development of plants and animals to a very complex state. Bacteria and algae are known (Figure 1) in the limestones from this period and traces of animal life are abundant. Rocks of neither Archeozoic nor Proterozoic age occur within the borders of Kentucky. Following and therefore superimposed upon the Proterozoic is found a great system of rocks, rich in fossils, called the Paleozoic. The first stage of this great period, the Cambrian, with more than one thousand kinds of plants and animals, does not occur at the surface in Kentucky. Succeeding the Paleozoic comes an extensive system of sedimentary rocks with thousands of fossils, known as the Mesozoic. This time witnessed the development of many great and small reptiles, the first birds, many small mammals, and great changes in plant life and the smaller denizens of the seas. The Age of Mammals, called the Cenozoic, witnessed the origin and development of thousands of different kinds of warm-blooded animals. The Quaternary or Holozoic witnessed the last great Ice Age, and includes the Recent, the period in which we are now living.

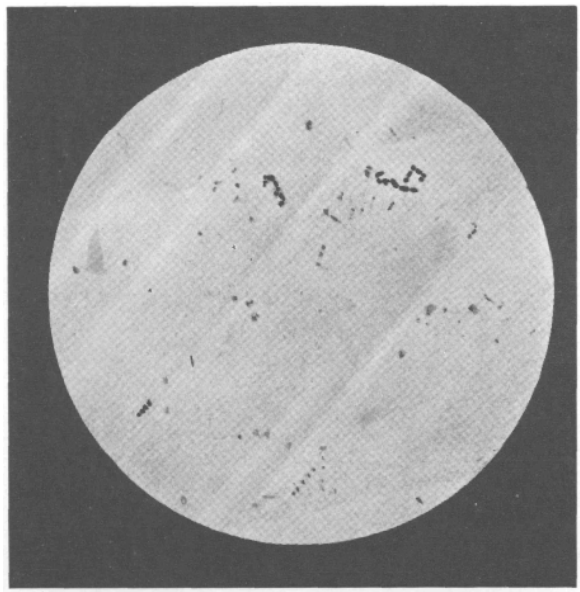

Fig. 1. The oldest known bacteria from the pre-Cambrian rocks. The chains of *Micrococcus* are associated with marine algae and both are believed to have been influential in the formation of limestone. After *Walcott.*

FIRST EVIDENCES OF PLANT AND ANIMAL LIFE

The earliest evidences of plant and animal life are found in iron-bearing rocks of the Archeozoic, and in limestones of the Proterozoic. The earliest living things were algae and bacteria which were instrumental in the formation of iron ore and the deposition of limestones. It is difficult to distinguish plant and animal life in these early rocks, for at first there was little to distinguish plants from animals. None of the earliest traces of life are found in Kentucky.

PROTEROZOIC LIFE

Life in the Proterozoic must have been abundant since the following age, the Paleozoic, started out with a vast array of living things. It is thought that all the geological time pre ceding the opening of the Paleozoic was much longer than all subsequent time.

DIAGRAMMATIC SECTION OF EARTH'S CRUST

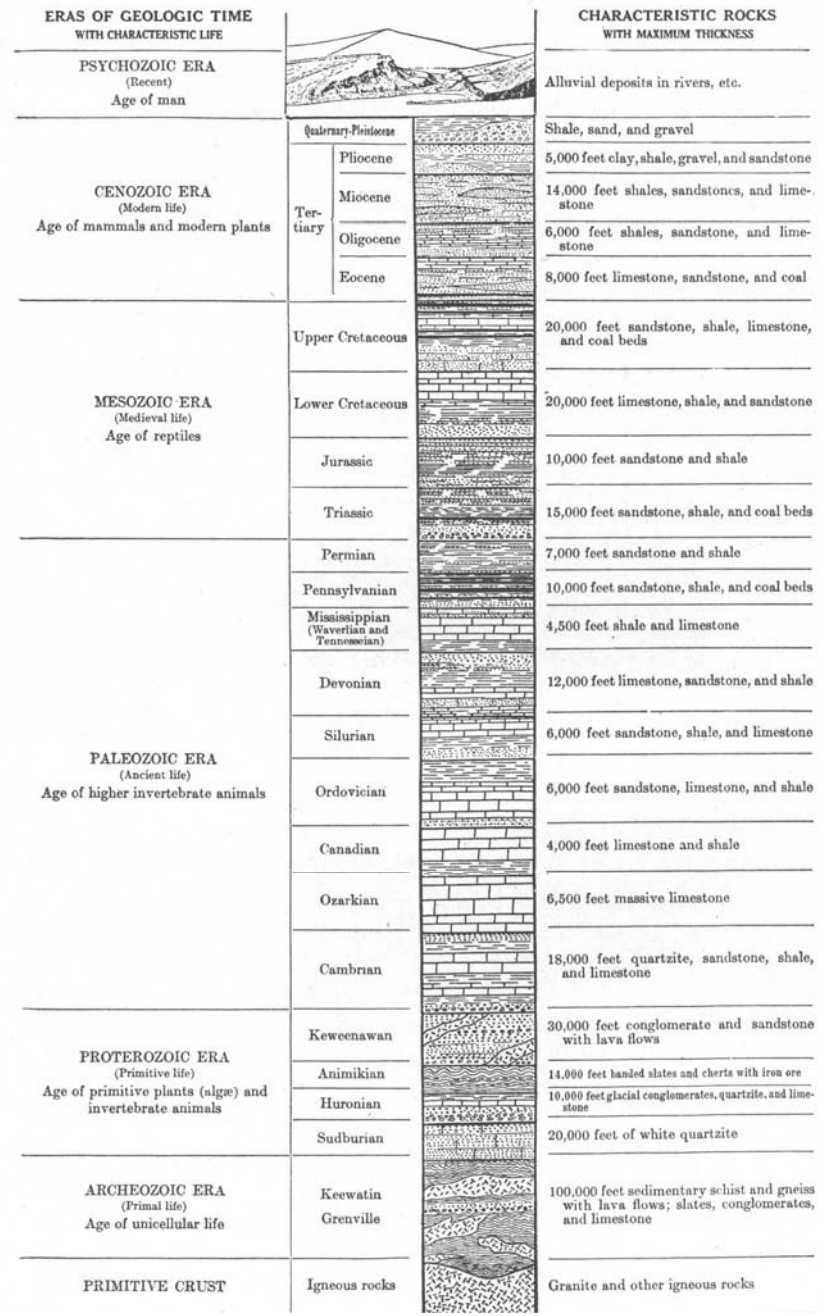

Fig. 2. Kentucky geological history occupies only the middle part of the geological column shown here. .

CAMBRIAN PERIOD

The Cambrian period with its thousand and more kinds of animals and plants is almost unknown in Kentucky, but the nature of the creatures of that time must be briefly discussed before we can understand the life which followed. If we should be able to restore to their living form the animals which are found fossil in Cambrian rocks, we should be greatly surprised to see jellyfishes, quite like those of today; crustaceans like those seen in recent seas; shell fish almost identical to those found on our beaches; and others would resemble somewhat familar creatures, while surprisingly few of them are strange. The unfamilar creatures are the trilobites, a group of animals which lived in abundance during the entire Paleozoic and disappeared at its close.

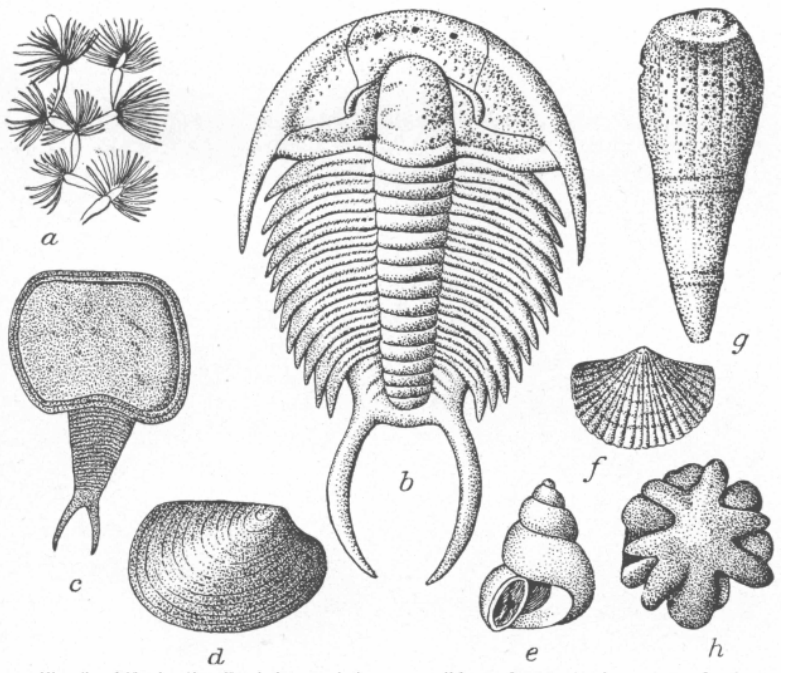

Fig. 3. Life in the Cambrian period, *a.* possibly a fragment of a sea-weed; *b.* a trilobite of the middle Cambrian. Such animals became extinct at the close of the Paleozoic; *c.* a small crustacean—a phyllopod, much like the small creatures seen today in fresh water pools; *d.* a very ancient mussel shell-fish; *e.* a Cambrian snail-like animal,; *f.* a hinged brachiopod, like those living in Puget Sound today, from the lower Cambrian rocks; *g.* an early sponge or coral-like growth; and *h.* a cast of a very ancient jelly-fish. From *Chamberlain* and *Salisbury.*

There were no fishes or other backboned creatures during the Cambrian, but in Vermont and in lower Cambrian rocks of Comley in Shropshire, England, are found scales which indicate lowly predecessors of the fishes. If we examine a Cambrian shrimp we see clearly that it is so like modern shrimps that we realize the amazing amount of pre-Cambrian time needed for the development of such an animal. We know little of the changes undergone during this extensive space of time but we can infer much. The Cambrian period is not the beginning of animal and plant life, but a period long past the noonday of the racial life of many creatures. In drilling a deep well for oil and gas in Jessamine County a few years ago the pygidium or tail of Cambrian trilobite was found in the drill cuttings, thus proving the existence of formations of this age beneath the Kentucky Bluegrass.

Records of Cambrian life were made elsewhere than in Kentucky. It will be important, however, to show what enormous advancement life had made at the opening stage of the Paleozoic. Geologists believe that pre-Cambrian time was considerably longer than all succeeding time. Little is known of the early growth of animals and plants in the pre-Paleozoic.

THE GEOLOGIC COLUMN IN KENTUCKY

The term geologic column is used to indicate the sequence and kind of rocks deposited. The sedimentary record in Kentucky is thus diagrammatically produced in a vertical column. Of course nowhere in the State does such a natural pile of rock actually exist, since as shown by the diagrams, all the Kentucky rocks are tilted showing that they have been disturbed. Moreover, in no one place in the State can the rocks be found exactly as represented in the generalized geologic column due to lack of deposition, erosion and other causes.

Nearly all of the rocks in Kentucky are sedimentary in origin; that is they were laid down under water. Soft mud is often converted, by pressure, into shale, the most satisfactory rock for the preservation of fossils, i. e., leaves, shells and the

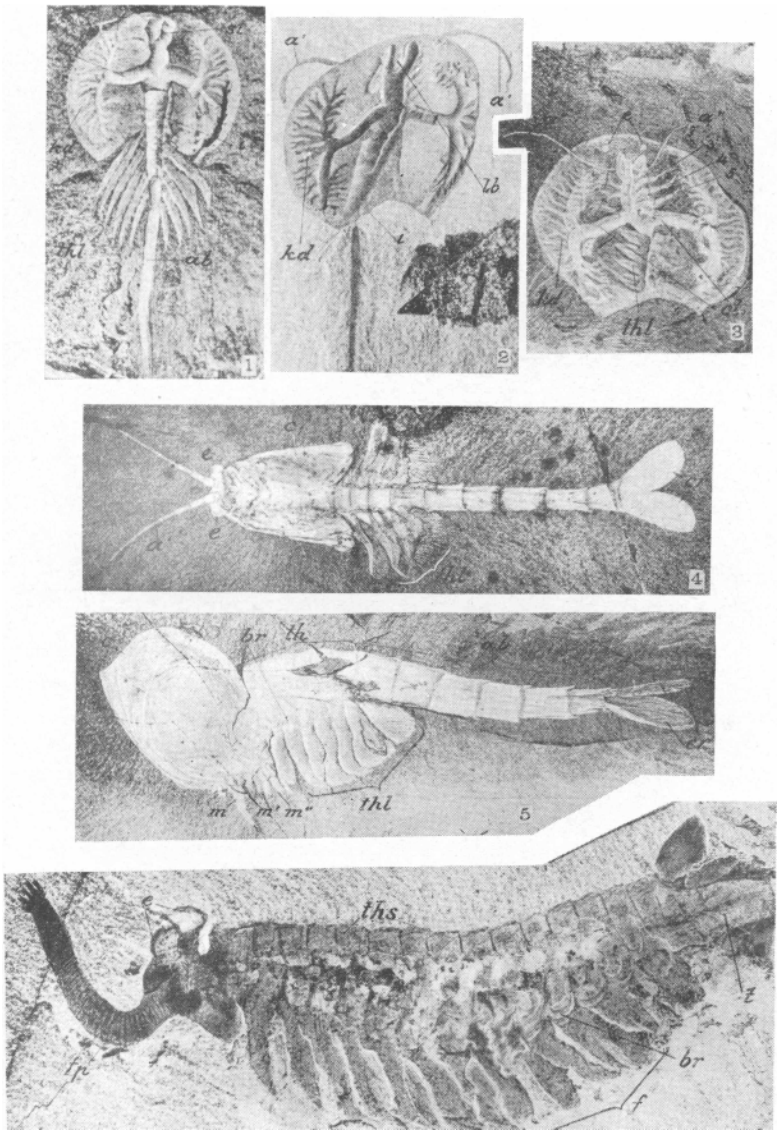

Fig. 4. A number of small crustacea found in rocks of middle Cambrian age. They look very much like modern shrimps. After *Walcott.*

like. Often soft-bodied animals like jelly-fishes, sea cucumbers, shrimps and so on are preserved in shale, greatly flattened of course, in the most exquisite detail. Loose sand and gravel become converted into sandstone and conglomerate which usually preserve fossils very poorly, or not at all.

The third great type of sedimentary rock is limestone, which is precipitated from the sea water by a variety of means; such as by the action of algae, lowly plants, by bacteria, and by animals such as the corals. Coral reefs have a very ancient geological history, and the fossil reef that forms the Falls of the Ohio in the river at Louisville is famous the world over. Limestone is also frequently formed from the shells of dead sea invertebrate animals. These three kinds of sedimentary rocks, shale, sandstone, and limestone, have many varieties each, and all may be changed by pressure, heat and chemical action into a variety of metamorphic rocks. The State exhibits a few igneous rock in place. These are called dikes.

All the hard rocks of Kentucky's geological column belong to the Paleozoic, but lack both a beginning and an ending. The Cambrian elsewhere records the opening of Paleozoic time, but it does not occur at the surface in Kentucky. Likewise rocks of Permian age, closing the Paleozoic are wanting in Kentucky. The periods called Ordovician, Silurian, Devonian, Mississippian and the Pennsylvanian form the principal part of the geological column for the State. The following tabulation shows the records from which the story of the geological succession of life in Kentucky has been read. We will record the oldest period at the bottom in the actual order of deposition.

System	Series	Stage
Silurian	Niagaran ------	East of Arch
		Alger (East)
		Osgood (West)
	Oswegan -------	Indian Fields
		Medina

The three remaining systems, the Devonian, the Mississippian and the Pennsylvanian are quite complex, for details of which the reader may consult the publications of the Kentucky Geological Survey in the attached bibliography. Each stage has several substages, all indicated by characteristic fossils.

LIFE IN THE ORDOVICIAN

Let us imagine ourselves transported backwards millions of years into the Ordovician times, and let us stand on or near the ocean, for we do not know much about the rivers of those far-off times. If we look around us on the land we see no traces of green vegetation, no grasses, trees, shrubs, flowers, ferns, but along the beaches we note a few marine plants. We hear no voice of bird, hum of insect, or call of mammals—there were no land animals at all. It clouds up quickly and the silence is broken by thunder, by the swish of the rain and by the splash of the waves. After the rain all is silence, no fishes leap in the sea. Approaching the shore again we glance into the water and see shell-fish such as brachiopods, clams, and snails. Under the loose rocks we find sponges and corals, while swimming along near the surface of the water, with occasional lunges, are the giants of the Ordovician—the cephalopods. Trilobites creep along the bottom, and out in deeper water are the sea-lillies, which we shall learn to call crinoids. It is indeed a strange world! Fish remains have been found in rocks of supposedly Ordovician age, but geologists now believe them to be Devonian.

The waters of the Ordovician sea—the Cincinnatian and the Champlainian—swarmed with a great variety of invertebrate animals. Hundreds of kinds of moss-like animals, the bryo-

zoans, were great limestone makers, accompanied by at least five hundred kinds of shelled animals—the brachiopods. There were also a host of snail-like creatures, and many corals for the first time showed a tendency to form reefs.

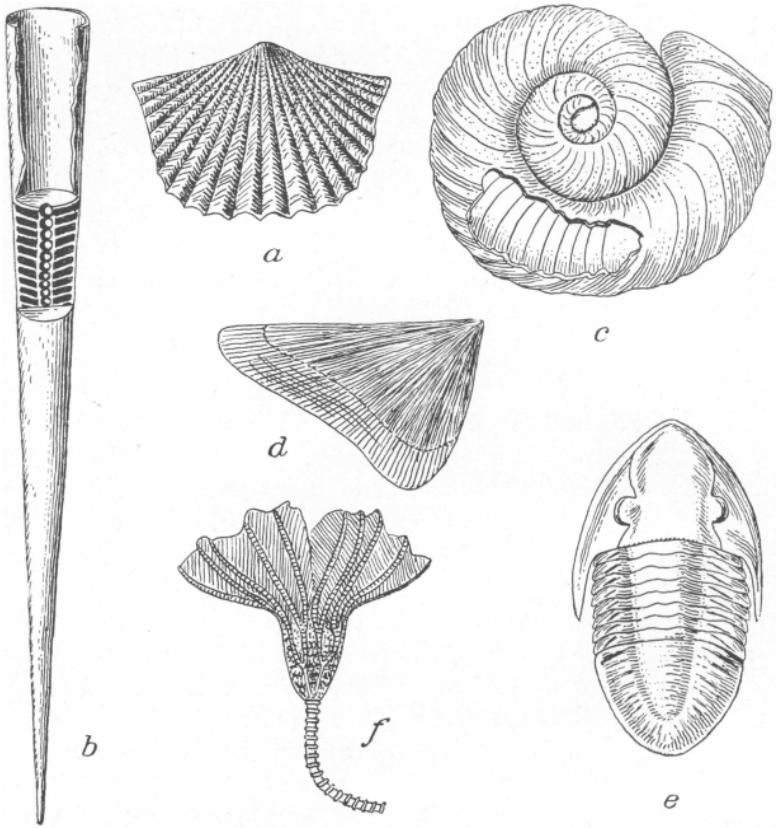

Fig. 5. Some of the sea animals we might have found near the shore had we visited the region of Kentucky during Ordovician times. These creatures were the highest forms of animal life of their time.

a. an Ordovician brachiopod. The brachiopods have existed continuously in the oceans of the world since pre-Cambrian times; *b.* a straight and *c.* a coiled cephalopod, like the nautilus of today. Some of the early Paleozoic straight cephalopods grew to a length of fifteen feet and were giants of their time; *d.* a wing shell, like the butter clams now found in Puget Sound; *e.* an Ordovician trilobite; and *f.* a crinoid or sea-lily. After *Schuchert.*

LIFE IN THE SILURIAN PERIOD

Land plants are not definitely known until after the close of the Silurian. The first three periods of the Paleozoic—the Cambrian, the Ordovician and the Silurian—were the "Dark

Ages" so far as our knowledge of plant life is concerned. During these three periods a thickness of over twenty miles of rock were laid down in various parts of the world, all in salt water, where no land plants would be expected. Over one hundred kinds of sea-weed fossils and impressions have been described, but many of these are probably accidental markings on the rocks and are not plants at, all. The algae (sea-weeds) were active in the deposition of limestone. Many of the algae were floating. Some of these ancient sea-weeds were very large, attaining a diameter of two feet and a length of several hundred feet. These algae were later the progenitors of the land plants.

The first fishes and the first air-breathers have been found in rocks of Silurian age, but neither of them in Kentucky. Fishes are known from New York and from Pennsylvania (figure 6). These were fresh-water fishes and are abundant in Silurian rocks of that far-off, northern island of Spitzbergen. The earliest air-breathers were scorpions, between two and three inches long, in structure and appearance very similar to modern scorpions. Related to these early scorpions there lived during the Silurian numerous and often huge, scorpion-like creatures known as eurypterids (figure 6). They lived in brackish water, on the margins of the sea and some times entered the lower waters of the rivers. One kind of these creatures was about nine feet long. They were probably the enemies of the early fishes, all of which were small. Many of the eurypterids were regular demons in appearance.

Corals were abundant in Kentucky, during the Silurian. Coral reefs, especially well-developed at Louisville, were formed. Associated with the corals and coral reefs were many thick-shelled animals like snails, which had developed heavy shells to defend themselves from the heavy waves pounding on the reefs.

Many hundreds of different kinds of invertebrate animals left their remains in the marine deposits of the Silurian, upwards of 2,500 species being known from North America. None of the great groups we found in the Cambrian show much change in the Silurian.

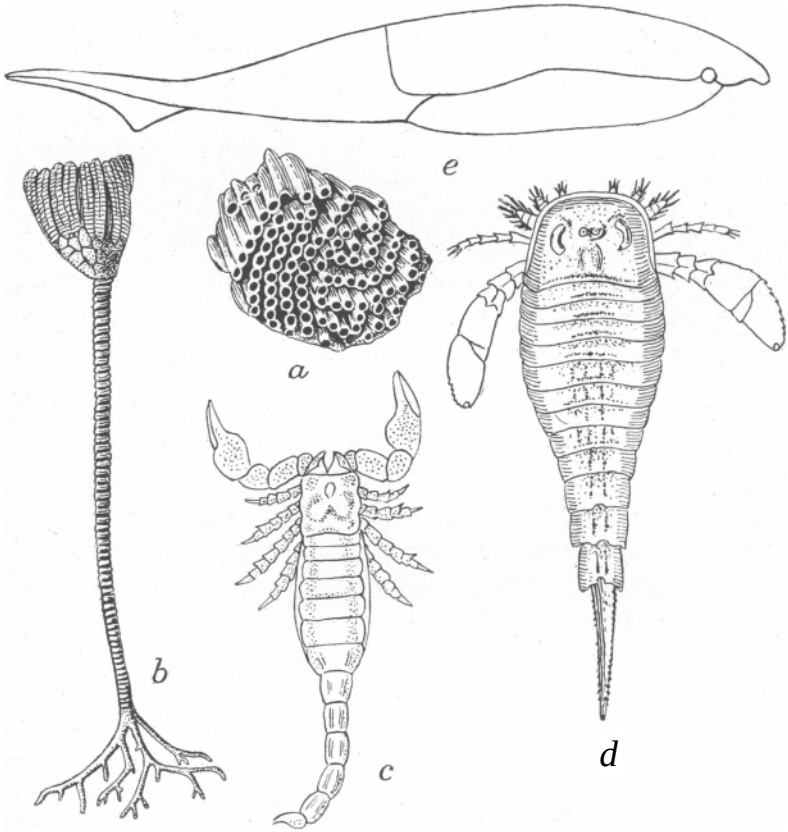

Fig. 6. The wonders of life in the old Silurian rocks, *a.* a fossil chain coral, found in Kentucky coral reefs; *b.* an animal of the star-fish group, a crinoid or stone lily, as it grew in the Silurian sea; *c.* the first air-breather found on land—a true scorpion; *d.* this odd-looking animal, hideous in appearance, had relatives in the Silurian which grew to nine feet in length. The eurypterids, as they are called, died out before the Coal period; *e.* a fish-like animal, *Palaeaspis*, found in Silurian rocks near Kentucky. After *Schuchert* and *Bryant.*

Great deserts are thought to have existed during part of the Silurian, on account of the occurrence of thick deposits of red rocks. Fossiliferous iron ore is abundant in regions near Kentucky, and thick salt deposits of this age are known to the north. Warm seas existed far northward into the Arctic circle, permitting the growth of extensive groups of animals at a place where life is now rare. This is one of the lessons of the rocks.

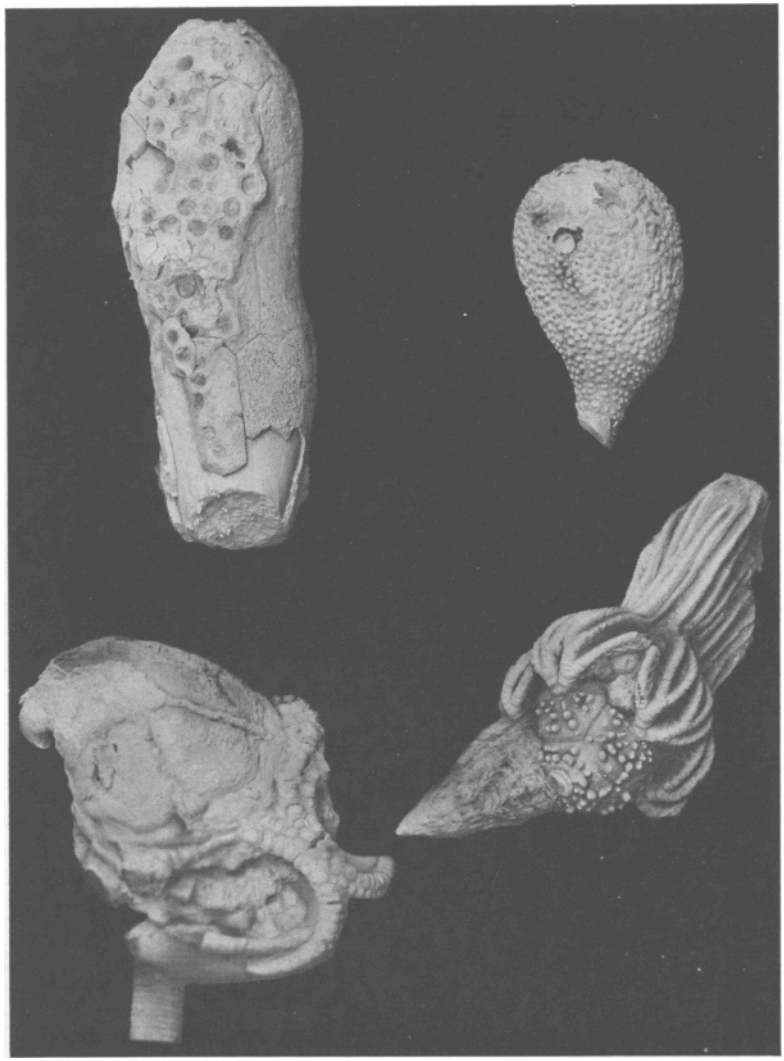

Fig. 7. Dependent life began early in the Paleozoic, as shown by the association of snails and sea lilies in the lower two figures. The upper two figures show evidences of disease.

LIFE OF THE DEVONIAN

There is no more significant or picturesque period in the history of the earth than the Devonian. Nowhere in the world

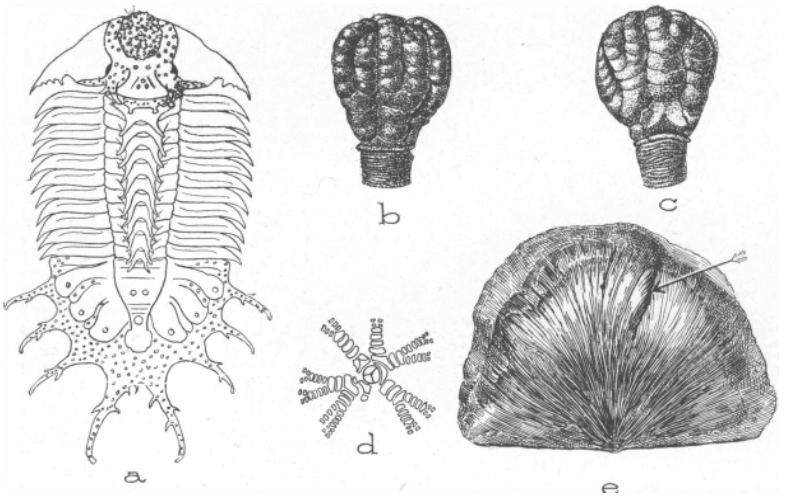

Fig. 8. Paleozoic animals showing evidences of disease, *a.* a large spiny trilobite; *b, c, d.* a crinoid head which has been injured; and *e.* a fractured brachiopod shell.

is found a more complete record of Devonian life than in eastern America. In this record Kentucky plays an important part.

It seems probable that early in the Devonian green plants of a lowly type were to be found along the margins of rivers and fresh-water lakes. These plants spread with relative rapidity over the moist land surfaces, and sedge-like organisms, primitive ferns, and other similar plants became fairly abundant, foreshadowing the enormous expansion of plant life during the great Coal period. One of the most remarkable of these growths was a tree-like seed-fern, whose stumps and roots have been found in place in certain Devonian rocks, actually preserved in the soil in which they grew millions of years ago. The trees were slender and tall, attaining a possible height of forty feet when alive. The discovery of scores of these stumps has led to our knowledge of the oldest petrified forest, a reconstruction of which is shown in figure 11. These odd trees bore seeds in pairs at the ends of modified leaflets, the seed being about one-quarter inch in diameter and enclosed in an outer husk. The first wood is found within the stems of certain of these tall, fern-like trees, as well as in other plants of the

Devonian. No true flowering plants are yet known. Kentucky shares with other states the pride of having grown some of the earliest woody plants which existed on the earth.

Among the animals the great groups of fishes, both freshwater and marine, constitute the most significant advance in the upward progress of life toward the present. Kentucky seems not to have shared fully in the life of the Devonian, although subsequent discoveries may show unknown fossils. Many of the fishes lived in fresh-water bayous or in rivers into which paleontologists believe they had been chased by the active denizens of the sea, especially by the large and active cephalopods.

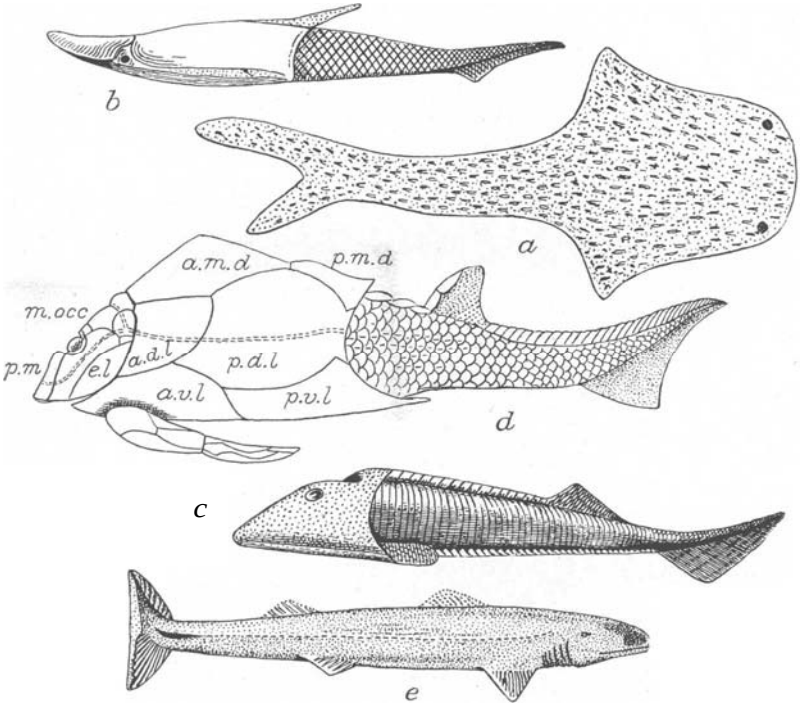

Fig. 9. A group of queer, fishlike animal which lived during the Devonian times, and recorded in the Devonian strata of North America (the eastern states) and Europe. *a.* a soft-bodied, small, fish-like animal, with forward placed eyes and hard scale-like spicules. This creature is flattened out, dorsoventrally, and when seen from the side is quite different in appearance; *b.* a fish-like animal, called *Pteraspis,* from the lower Old Red sandstone of Great Britain; *c.* a fish-like animal related to the lampreys found in Silurian and Devonian rocks of America, Norway, and Spitzbergen, The head shield is most frequently preserved and the form of the brain and nerves can be seen; *d.* an outline of one of the queerest of the early vertebrates. It had no true jaws, no true fins, and a heavy armor. It died out during the Devonian *e.* a primitive, slender shark, sometimes attaining a length of fixe feet, found in concretions within Devonian shales near Cleveland. Ohio. Figures from *Eastman.*

It will be necessary for us to go outside of the boundaries of Kentucky to find the kinds of animals which filled the place of fishes during this great geological period—the Devonian. The adjacent states of Ohio, Pennsylvania, Iowa, New York, and Canada furnish all the domestic evidences we need, but for comparisons we must cross the seas to Scotland where the stone mason, Hugh Miller, made known the nature of the Devonian vertebrates, and to Norway and Spitzbergen for other kinds of fish-like creatures.

The earliest fishes were so strange that nothing like them is now known. We have no clues as to where they came from, and when we find them they were well along in their racial history. Some seem to have been very soft-bodied creatures without definite fins; the body sparsely covered with minute spines. Others had a part of the body covered with a hard bony armor. Some had an armor-like head shield, and the rest of the body naked or scaled. Some looked curiously like scorpions. All of these diverse looking animals are called ostracoderms. They were the predecessors of the true fishes and lived in fresh and brackish water.

The primitive sharks constitute the earliest representatives of fishes as we know them today. Near the city of Cleveland, Ohio, not far to the north of Kentucky, in Devonian black shales the primitive sharks, called cladoselachians, are found in hard rounded concretions. These sharks are often so perfectly preserved that the minute structure of the muscles and kidney can be seen, under the microscope. None of these sharks exceeded five feet in length. The body was elongated and rounded, with a blunt snout and eyes placed far forward. *Cladoselache* is the best known of all ancient sharks. Marine sharks of the Devonian are known from scattered teeth and isolated fin-spines. These are usually found in limestones—once calcareous oozes—where they must have fallen at or following the death of the individual.

Other marine, shark-like animals occur abundantly in certain Devonian rocks. These are called Chimaeroids, the dental plates of which are at times found in thousands at certain quarries. This group of fishes has persisted almost unchanged

throughout all subsequent geological time, and are found today, in relatively deep water, along the continental shelves of the Pacific Ocean.

It is surprising to find in the Devonian the earliest representative of the lung-fishes, known today in the muddy rivers of Africa, Australia, and South America. These queer fishes, during the dry season when the waters of the river disappear, coil themselves into a ball of mud and live, quiescent, until the next rains soften their prison, and they swim out. Although they breathe air they have no true lungs and are not related to the land vertebrates.

A group of small to huge fishes of a new and unexpected type arose, lived and perished during the Devonian. These armored fish-like animals are known as Arthrodires, and are unlike any fish now living. We do not at the present time know either their predecessors or their descendants. The largest of them attained a length of nearly twenty feet and in their day were the rulers of the sea. They surpassed the giant cephalopods which in size had ruled the seas for many geological periods. It is thought by some that the arthrodires are related to the sharks; by others to the lung-fishes; and to other groups. The complete bodily form is unknown. The head region was covered with a very heavy bony armor and it is possible that the body back of the pectoral fins was naked, and thus hard to preserve.

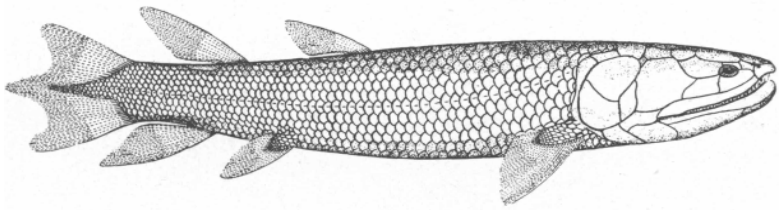

Fig. 10. A restoration of the Devonian crossopterygian fish which is thought to have been an ancestor to later air-breathing vertebrates. After *Bryant.*

A fifth group of fishes, which lived during the Devonian, has been called the Crossopterygii. These fishes looked a great deal like modern fishes (figure 10), but in their structure appear to have been organized like the primitive land vertebrates,

to which they may have been ancestral. The bones of the pectoral fin are arranged much the same as they are in the fore limb of a land vertebrate.

The presence of land vertebrates (amphibians) in the rocks of the Devonian is indicated by a single, imperfect footprint (figure 12) found many years ago in Pennsylvania. The specimen is preserved in the Yale University Museum.

The host of invertebrates which swarmed in the seas of earlier periods persist during the Devonian in slightly changed but undiminished force. These were of the types seen in the Silurian;—corals, brachiopods, bryozoans, starfishes, crinoids, trilobites, blastids, and groups of shell fishes.

Corals were especially wide spread and are found from Louisville to Alaska. Reef formation was common, and the great fossil coral reef in the bend of the Ohio River at Louisville is famous the world over. This Kentucky reef is formed of a number of species of corals; with cup corals over two feet in length and three inches wide, compound colonies eight feet across, associated with many kinds of bryozoans. In the upper Devonian colonies of 'glass' sponges existed, represented by upwards of ninety kinds. In a certain deposit in the Devonian of an eastern state occur more glass sponges than are known from all the rest of the world together. These sponges lived in deep cold water.

Decadence among the numerous trilobites is thought to be indicated by the spiny species existing in Devonian times. Dependent life and the inception of parasites began during this period. Previously all animals had been independent, and disease is thought to have been non-existent. Scars on shells and bones indicate accidents or attacks of the weak by the strong. With the increase of species and numbers of individuals within a species, tragic death of individuals and sudden extinction of species becomes more and more common—a fact truly indicative of the increasing struggle to persist among all organic forms.

Insects may have existed on dry land during the Devonian but they are unknown as fossils. Scorpions and millipeds must

have lived somewhere since they are known in the Silurian. Eurypterids, the huge scorpion-like animals of fresh and brackish water which occurred so abundantly in the continental deposits of the Silurian, persist in the lower Devonian beds; one species attaining a length of six feet. This was their last appearance, and during the somewhat later Pennsylvanian the group became extinct.

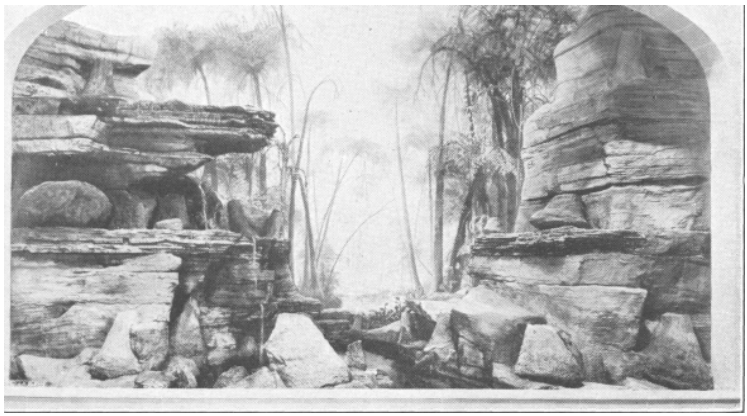

Fig. 11. A restoration of the earliest known petrified forest of tree-like seed ferns, as preserved in the State Museum at Albany, New York. In the foreground is seen an idealized reproduction of the rock section from which the tree stumps were secured at different levels. In the background is a painting of the forest of seed-ferns as it probably looked in the Devonian, with life-size restorations at either side. Trees like these were very abundant later in the Pennsylvanian and furnished a large share of the material for coal.

The climate of the period was warm, and animals and plants lived far north where now there is little life at all. The complete union of North America and Europe, during this time, across Greenland, Spitzbergen, Norway, and Great Britain allowed an unusual intermingling of floras and faunas. Abundant red rock indicates that a part of the period was semi-arid. Devonian coal-beds are thin and of little value, in Kentucky their greatest thickness being occasionally only as much as a fraction of an inch.

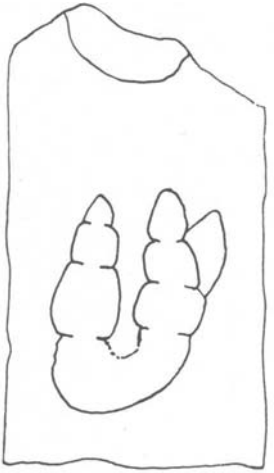

Fig. 12. A Devonian footprint of a land vertebrate, found in Pennsylvania. The original is about three inches long.

THE MISSISSIPPIAN PERIOD IN KENTUCKY

The records of the rocks of the Mississippian period all show that the life of the time bears closer relations with immediately subsequent developments, rather than with the preceding life. It marks a great change from early Paleozoic life to that of a later time. This significant relationship is clearly indicated by the inclusion of the Mississippian rocks (lower or sub-Carboniferous) in a common division, the Carboniferous of older geologists, with the Pennsylvanian and the Permian. Mississippian life is more nearly that of the Carboniferous (carbon or coal-bearing) rocks than it is Devonian.

People living in western Kentucky know the rocks of the Tennesseeian division of this period as the producers of numerous caves and sinks, causing the term "the land of ten thousand sink holes" to be applied to much of this area. Mammoth Cave occurs in the rocks of this period. Sink holes from all sizes, as small as a barrel to an area of 3,100 acres occur in western Kentucky up to the number of 60,000 of which 9,000 have been mapped, according to the observations of State Geologist Jillson.

The plants of the Mississippian show a decided advance over those of the Devonian and are much like those of the later Coal period, the Pennsylvanian, and a more exact account of the plant life of the Mississippian will be included under that period, where illustrations of Carboniferous plants will also be given. While coal in irregular lenses does occur in the Mississippian rocks yet the beds are never so productive as those of the Pennsylvanian. The fossil trees of this period in Kentucky show an increase in woody parts, some of them attaining a height of one hundred feet. Most of them did not branch until near the top. Some of the trees were primitive conifers. The several thousand species of fossil plants known from the Carboniferous rocks of the world formed one of the most luxuriant, though not the most varied, floras the world has ever known. It is quite probable that the fossil plants so far known constitute only a part of those which actually existed. Ferns of a wonderful variety abounded. More exact details will be given in the next section.

Curious fossils called conodonts occur abundantly in the Mississippian rocks of Kentucky. The conodonts are minute glistening, brownish or black, tooth or scale-like fossils, of an uncertain nature. They are supposed by some geologists to be teeth and scales of small fishes or fish-like animals. These minute objects occur in extraordinary abundance in some localities where the rocks bear literally thousands of them.

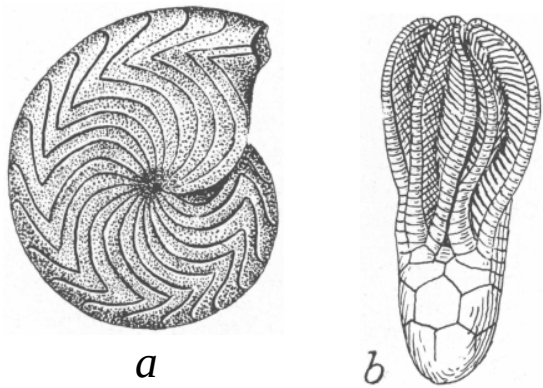

Fig. 13. Two animals from rocks of the Mississippian period. *a*. a beautifully preserved fossil cephalopod; *b.* a fossil stone lily. After *Schuchert.*

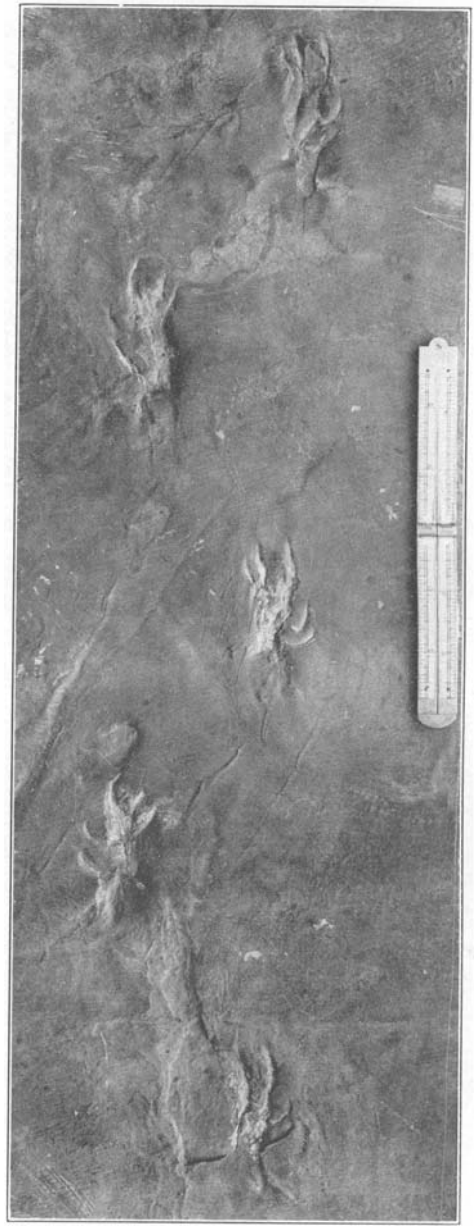

Fig. 14. Amphibian footprints found in Mississippian shales. One-third natural size. After *Branson*.

Land vertebrates must have existed somewhere in Kentucky during the Mississippian, but their fossils are yet unknown, not only within the State but throughout the entire Western Hemisphere the only indications of land vertebrates are some fossil footprints (figure 14). Even in Europe the record is scant. The later Coal period, however, bears records of many scores of different kinds of amphibians and reptiles, though principally from outside the State.

A group of large sharks, with pavement-like teeth, known as cochliodonts, adapted for crushing shell-fish, and possessing large fin spines, occur abundantly in rocks of the Mississippian period, in a great variety of species. A general progress in the development of fish-like forms toward the dominance of the bony fishes took place at this time. The huge arthrodires of the Devonian had disappeared, as had also the diversified ostracoderms.

The hosts of invertebrate animals which swarmed in the warm Mississippian seas show progress over their Devonian predecessors. The trilobites were becoming reduced in numbers, for they were approaching extinction. A most astonishing diversification occurred among the crinoids, or "sea-lillies," animals of the star-fish group usually growing on a stem attached to the sea bottom. Nearly four hundred species or kinds have been found in the limestone quarries of one locality. It is strange that the corals formed no reefs during the Mississippian, such as were seen during the Devonian. The cephalopods were being held in check by the shell-feeding sharks, and the nautaloids no longer ruled the seas.

The fossils found in the Mississippian of Kentucky indicate that the seas were warm and equable, a condition conducive to the expansion of many types of life. On the land the vegetation shows the effects of a mild climate, for the most part, although this was varied by semi-arid and cold conditions which had some notable effects on the expansion of life.

THE GREAT COAL PERIOD

The most conspicuous feature of the deposits formed in Kentucky and elsewhere is the many layers of coal. While coal

was formed in other places at later times yet by far the greatest amount of coal was formed during the Pennsylvanian period or the "Coal Measures" as the period is often called. About seven-tenths of the coal supply of the world is found in rocks of this age. It is an obvious and well known fact that ordinary coal is a compact, stratified mass of plants which have suffered some decay. The remains of animals, fishes, amphibians and invertebrates, mingled with the coal undoubtedly added to its volatile nature.

The significant advance in the life of the Pennsylvanian was the wide expanse of the land plants and their enormous development; the spread of the amphibians, now known for the first time from abundant fossilized skeletons; the beginnings of the true reptiles; the gradual development of bony fishes; the elimination of certain groups of invertebrates and the expansion of others. The insects were present in great numbers of cockroach-like forms. Spiders of an archaic type; millipeds, centipedes, scorpions, and other arachnid forms were present—their development being favored by the rapidly expanding forests of the warmer climates, and the abundance of food. Since the land plants, insects, amphibians, and reptiles constitute the new things in the geological succession of life in Kentucky accounts of these groups will be given in considerable detail. It is to be remembered however, that while all these changes were going on among the dwellers on the land, changes were also taking place among the inhabitants of the seas. The marine records are preserved in the thousands of feet of limestone which were deposited during the Pennsylvanian.

The climate of Pennsylvanian time was warm and genial the world over, and the lands bordering the seas were moist, with an abundant and well distributed rainfall. Conditions, such as these favored the rapid growth of plants and animals and brought about enormous developments, which under less favorable conditions, would have been of very slow accomplishment.

Since petroleum is of organic origin, being derived from the decomposition of animals and plants, the Coal Measures are rich in oil and gas. Pools of oil occur throughout the Mid-

Continental region in rocks of the sub-Carboniferous or Mississippian. In Kentucky the Devonian Sediments have been the largest producers of petroleum up to the present time.

Flowering plants are unknown in the Pennsylvanian, nor had the forage plants and grasses developed. They came on much later. It is estimated that more than three thousand kinds of plants lived in the swamps of the Pennsylvanian. Many of the kinds of plants which clothed the lands in late Devonian undoubtedly continued without much change into the Carboniferous, and the expansion of plant life to form the great coal beds doubtless consumed over a million years. It is reasonably certain that many plants existed during this time which are at present, unknown. New forms are being described constantly.

This great Coal period has often been called the Age of Ferns, because plants of fern-like characteristics far outnumber all of their associates. They are the commonest fossils seen in the Kentucky coals, and some of the fern-like plants were of large size. The Paleozoic tree ferns (figure 11) are fairly well known. Some of them had trunks two feet in diameter and a height of 60 to 70 feet, with a splendid crown of large, spreading compound fronds at the summit. Some of these tree ferns of the Paleozoic are related to the elephant ferns now found growing in the tropics, much smaller than their ancient progenitors.

Seed-ferns we found existing in the Devonian, and we find them in great numbers in the Coal Period. One of these treelike seed-ferns had a slender stem which growing in close association with thousands of other plants depended on its neighbors for support, and was probably unable to stand alone. It had adventitious roots exactly like the root-like growth Kentuckians see on their corn stalks. These were for support. The leaves were arranged spirally on the stem and formed a large graceful crown near the top. Some of the leaves were more than three feet in length. The seeds were barrel-shaped, about a quarter of an inch long, and enclosed in a cupule.

Tree-like plants of great importance during the Coal Measures were those known as the *Lepidodendrons.* These are

represented today by the little ground pine. Some of the Carboniferous scale trees (*Lepidodendrons*) were four feet in diameter, with a large trunk one hundred feet high. One trunk was found measuring 114 feet up to its first branches, and the crown above this must have attained a height of 135 feet. The trees had no true roots, but heavy underground parts, root-like in appearance, supported the enormous trunk. The trunk of the Lepidodendron was distinctly woody, though not like the solid wooded trees we know today.

Other tree-like plants are known as *Sigillaria,* looking oddly like the giant cactus travellers see in Arizona. One trunk six feet in diameter at the base and a foot at the top, was only eighteen feet high. Still other *Sigillaria* were tall and slender, attaining a height of a hundred feet, and without branches. The leaves were held for a long time and when finally dropped left six-sided scars. Both *Lepidodendron* and the *Sigillaria* bore cones, sometimes a foot in length, borne in a close whorl around the stems, from which spores, not seeds, were produced.

The *Cordaites* looked much like the Joshua trees or giant yuccas seen in the Mojave Desert of California. They were tall slender trees, often attaining great heights. The center of the trunk is pithy, and not very strong.

The scouring rushes, before the introduction of scouring powders, were used by housekeepers to scour their pots and pans, for which the rough, harsh coat of the horse-tail rushes fitted them. These plants were represented in the Coal Measures by large plants called *Calamites* and they are among the commonest fossils of the Carboniferous. The plants grew in wet, swampy places, had underground parts and upright stems, which bore branches at the nodes in whorls. Spores were borne by cones often a foot long.

It is thought that the evergreen trees, the conifers, began their development during the Pennsylvanian, but none of the fossils so far found permit a satisfactory study of the species.

Living in the pools and swamps, where the coal-forming plants grew so luxuriantly, there were a number of different kinds of amphibians, whose skeletons and rarely the soft parts,

are found in Pennsylvanian deposits in many places throughout the world—although none have yet been found in Kentucky. Some of their skeletons were found fossilized in *Calamite* trunks, along the coast of Nova Scotia. A single reptile has been found in cannel coal in Ohio.

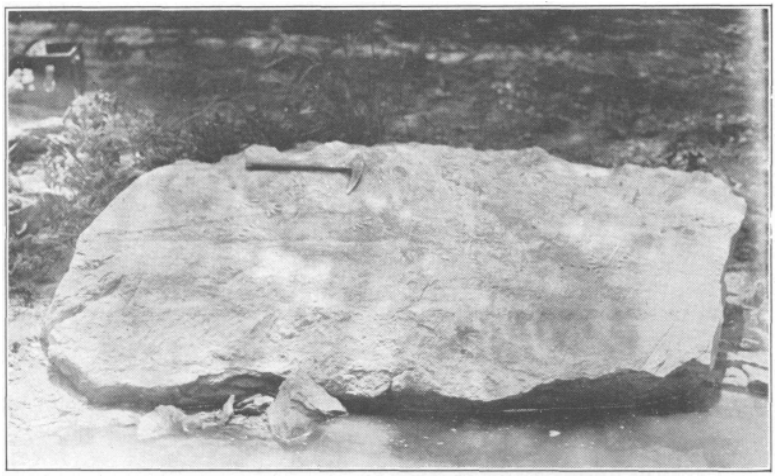

Fig. 15. A large slab of rock of Pennsylvanian age showing footprints of land vertebrates. Photo by *W. R. Jillson.*

The amphibians of the Pennsylvanian period are for the most part, small semi-aquatic vertebrates, comprising both naked and armored forms. In the cannel coal of eastern Ohio there occur a number of kinds of amphibians represented by hundreds of specimens. They are all crushed flat by the pressure of the rocks above the coal. Examples of these early land vertebrates may also be found in the extensive coal beds of Kentucky—a possible discovery of great, interest. In rounding nodules in shales above the coal in Illinois occur other amphibians, and a large number are known from the Coal Measures of Canada.

Some of the amphibians appear to have been ancestral frogs, while others, known as *Branchiosauria,* gave rise to the salamanders known in Kentucky today as mud-puppies or water newts and efts living in the shaded streams and in many caves. The salamander-like creatures of the Carboniferous are very

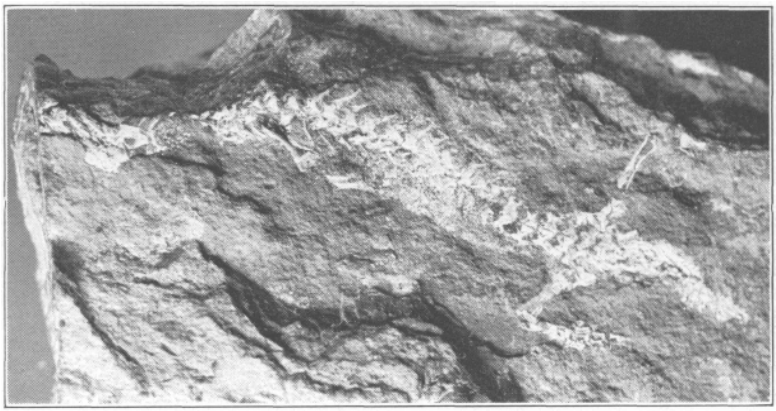

Fig. 16. Part of the skeleton of an amphibian, enlarged, as preserved in the rock. Part of the head is missing. The left fore limb is drawn close to the body. Part of the right hind limb is lost. Specimen in Walker Museum, Universty of Chicago.

small, ranging from two inches in length up to five inches. Their bodies are so well preserved that the muscles, skin, scales, eye pigment, lateral line canals and organs, the liver, the intestines and stomach are known. They seem to have been air-breathers without lungs, oxygenating the blood through the walls of the extensive buco-pharyngeal pouch.

Snake-like amphibians with skeletons consisting simply of a vertebral column and head are known to have lived with those species which were reptile-like. The animals are mostly known from fragments which were picked out of the dump at the mouth of the coal mines, while some were found in systematic splitting of hundreds of tons of coal.

The fresh-water and marine fishes of the Pennsylvanian are more nearly like the Mesozoic fishes than like the earlier Paleozoic fishes. The fishes of today were foreshadowed in the Coal Measures by forms showing a tendency toward the bony type. No new groups were developed and no great group was lost. The general tendency among piscine forms was upward toward the later types.

The insects of the Pennsylvanian were, many of them, the largest ever known, giants of their kind. The maximum size

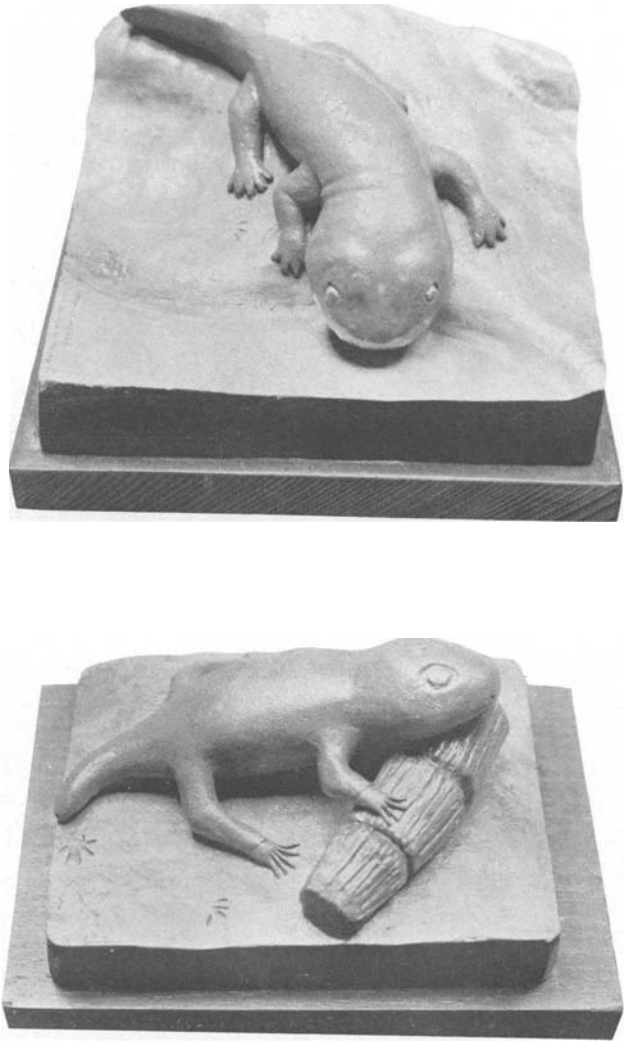

Fig. 17. Restorations of two Coal Measures (Pennsylvania) amphibians. Above is the salamander type, the originals of which measured less than two inches, and looked like small, modern, mud-puppies. Below is a reconstruction of a reptilian type, about three inches long, with short body, long legs and sharp claws. Both animals possessed small scales buried in the skin of the back.

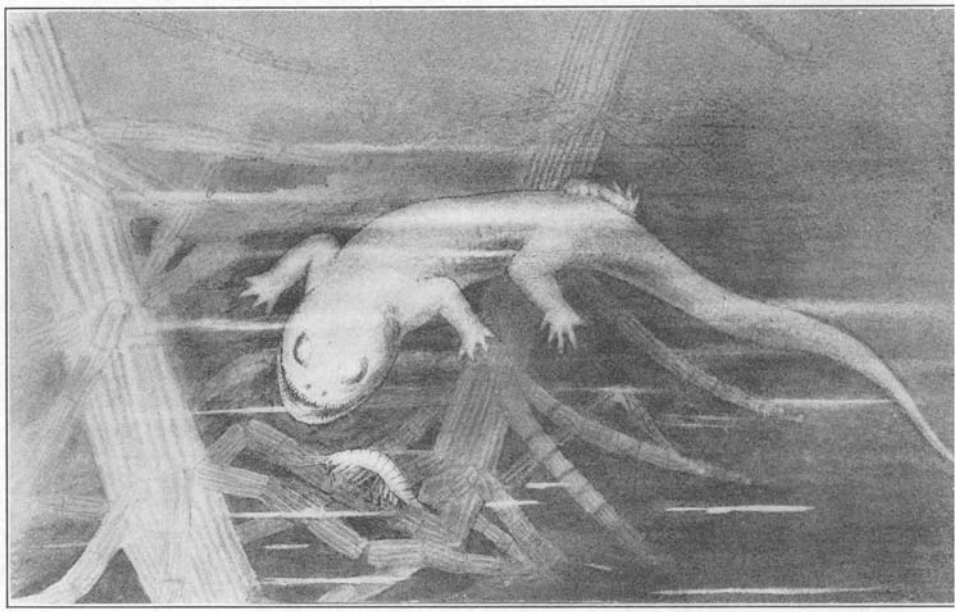

Fig. 18. One of the slender elongate legged salamander-like stegocephalians, whose remains are known from the Mazon Creek Shales of Illinois. The animal, about five inches in length, is shown in the act of grasping a small crayfish-like animal. The picture is based on specimens in Yale University. On account of the fact that the crustacean is a salt water or brackish water creature the early Amphibia have been thought to inhabit the margins of the seas, a habitat now entirely unfamiliar to the group.

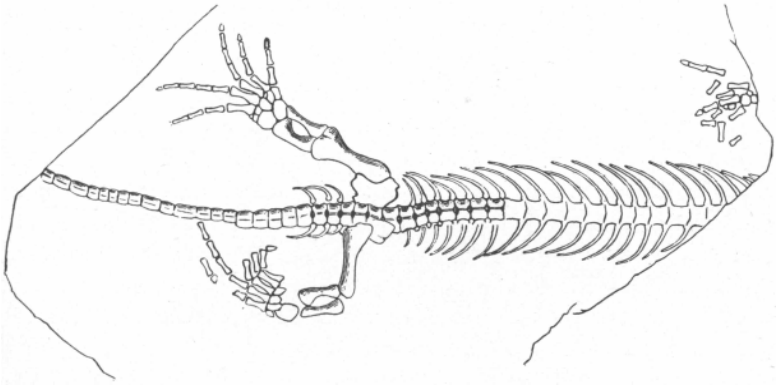

Fig. 19. The only known reptile found in the American Coal Measures. This specimen, preserved in the U. S. National Museum at Washington, was found in cannel coal in a nearby state.

was reached by those of the dragon-fly type, one of which, found in the Coal Measures of Belgium, measured 29 inches across the wings. They were the only flying creatures of their time. There are over 400 kinds of insects known from the Coal Period. At no subsequent time have insects grown so large. In addition to the large number just mentioned occurring in the lower and middle Pennsylvanian, there were some 800 different kinds of cockroaches, carnivorous and often measuring four inches in length.

The spiders of the Pennsylvanian in general resemble modern spiders. Closer examination, however, shows the body to have been segmented, unlike modern arachnids.

Scorpions of modern appearance, thousand legs or millipeds, land snails and fresh-water clams are some of the interesting developments of the great coal age. The small land snails were found in the hollow stumps of fossil trees (Sigillaria).

The invertebrate marine life of Pennsylvanian time was not only prolific but also varied, faunas everywhere being similar. Many of the Pennsylvanian limestones are composed exclusively of fossil shells of one-celled animals, the Protozoa.

PALEOZOIC CORAL REEFS

It is rather surprising to learn that coral reefs exist in Kentucky. The oceans where corals live are now far away from the State but the fossil coral reefs assure us that the ocean has, in the past, covered the area now called Kentucky and has left coral reefs in the rocks formed at various times in the Paleozoic. The present climate of Kentucky, too, is not favorable for the growth of corals, even if marine waters were present. Present day corals live in tropical or warm waters, and we believe that the finding of fossil corals in what is now the Arctic indicates a change in climate.

Present day coral reefs are the combined product of the activity of many organisms, both plants and animals. The coral animals themselves are of primary importance because of their lime-secreting nature but in reef formation they are accompanied by the lime-forming bryozoans, with many at-

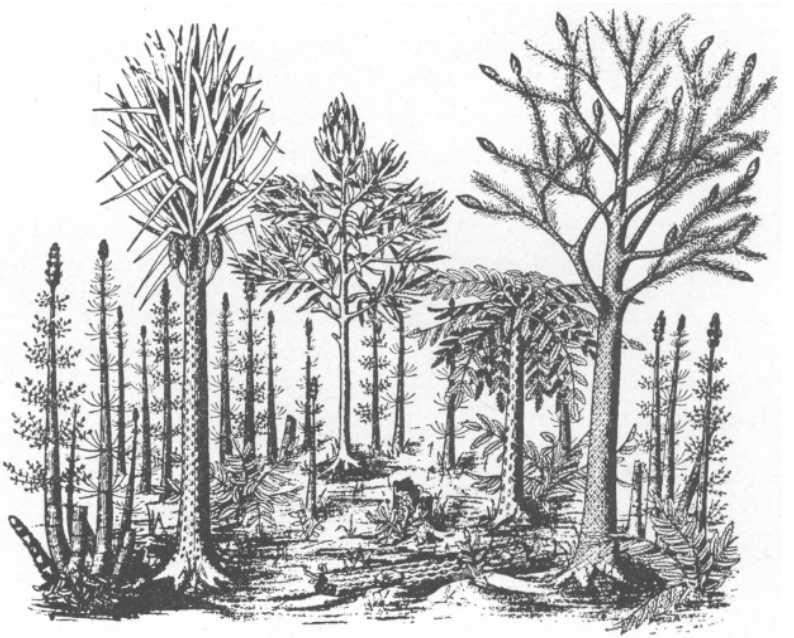

Fig. 20. Composite restorations of Coal Measures trees, as they may have appeared in the Kentucky swamps, millions of years ago. The *Lepidodendron* (the scale tree) is in the right foreground. *Sigillaria*, and huge scouring rushes, in the left foreground; *Cordaites* and a forty foot fern in the background; *Calamites* in outer circle. These tree-like plants had some woody parts. By permission of Henry Holt & Co.

tached shell fish. A great quantity of lime was also deposited by the action of bacteria and by lime-depositing sea-weeds. Reefs hundreds of feet thick, and many hundred miles long, both fossil and recent, are thus composite structures.

Geologically the history of fossil coral reefs begins in the pre-Cambrian and Cambrian, but of these we have no records in Kentucky. Reef masses of the bedded type occur in the State in rocks of Ordovician times, constituting the earliest Kentuckian representatives of this interesting rocky material. Coral reefs, of a complex nature are well developed in the Silurian and in the Devonian reach a very massive form, such as those near Louisville. The corals which occur in the Louisville reef extend northward into Alaska, so we are assured that Devonian climate was quite different from what it is at present.

Coral reefs during the Mississippian, whose rocks are so important in Western Kentucky, are not so well developed and wide-spread as in the Devonian, and none are known from the rocks of the State. Little is known of the nature of coral reefs during the Pennsylvanian. Life activities during the Coal period were more interesting on land than in the seas.

Coral reefs furnish protection for numerous animals but the nature of the sediment prohibits the preservation of many of these creatures. The action of the surf, in the past as now rends the coralline growths and by repeated poundings of the coral boulders produce a form of coral sand, and of course silicious sand was often washed into the growing reef. The irregular nature of reef formation, as well as the absence of regular bedding planes, renders fossil coral reefs unimportant for commercial quarrying.

GAPS IN THE GEOLOGICAL HISTORY OF KENTUCKY

Between the closing of the Pennsylvanian—the great Coal Period—and the Pleistocene, millions of years later, the geological record in Kentucky is a blank, except for a short time during the Cretaceous and the Eocene. Great as this gap in the record is, and important as it has been in shaping the surface features and drainage pattern in Kentucky, we know that it was not the first but rather the last of a long series of sedimentary

breaks which are easily seen far back in our lower Paleozoic section particularly the Devonian and Silurian. During all of this time, however, in other parts of the world, significant events in the upward progress of life were taking place. In order to keep in mind some of the events which were transpiring elsewhere, it will be well to state briefly what these happenings were, naming the periods of the times.

Among the plants true woody plants came in; flowering plants and grasses became common and furnished food for many herbivorous animals. Great periods of dryness and intense cold left their impress upon animal and plant life.

The Permian period witnessed the closing of the great Paleozoic, and during this time all of North America was dry land. The period was one of great aridity, and desert conditions prevailed throughout much of the land areas of the world. The cold, glacial climate with numerous large sheets of ice made the period one of extreme hardship for plants and animals. Yet, here and there groups survived and made progress. Insects developed into many .groups, and land animals became common. This period witnessed the last of many of the Paleozoic invertebrates.

The Mesozoic era, lasting for millions of years after the end of the Permian, includes the Triassic, the Jurassic, the Comanchian and the Cretaceous periods, all properly constituting the Age of Reptiles. While the smaller denizens of the seas continued and expanded yet the new things on earth were the reptiles of land, sea and air. Accompanying these strange vertebrates and doubtless feeding on their eggs, were small mammals which were the ancestors of the creatures of the next era—the Cenozoic.

The age of mammals—the Cenozoic, is recorded by fossils in the rocks of the Eocene, Oligocene, Miocene, and Pliocene periods covering millions of years. The era witnesses the diversification, expansion, and advance of many groups of mammals. Some of them were strange and ill-adapted for a continuance of life under strange conditions, and so lost out. Many of them survived as present day warm-blooded animals. During this long period all of Kentucky, broadly speaking, was a

land area with the exception of some districts west of the Cumberland and the Tennessee Rivers. A wide and constantly changing variety of land animals traversed Kentucky during this time without doubt, but conditions in so humid and rapidly eroding an area were not good for the preservation of their remains in fossil form. Consequently this part of the geological record in Kentucky is essentially a blank.

THE QUATERNARY IN KENTUCKY

A large number of terms are used by writers on geological subjects to designate that extent of time and events toward the close of the Cenozoic. The Great Ice Age, the Glacial Period or Epoch, the Quaternary, the Holozoic, the Psychozoic, the Pleistocene, and the Age of Man all designate, more or less closely the periods of time with which we are now concerned. The greatest events were the development of modern trees and plants, the occurrence of many groups of mammals, some of which became extinct during this time, and the appearance of man. The greatest physical event was the Great Ice Age, with its oft recurring advance and retreat of the great sheets of ice over the northeastern part of the continent, which extended southward to the Ohio River. The climatic changes were great and the intense cold affected life all over Kentucky but, only the northern edge along the Ohio River suffered any physical changes.

The Pleistocene period may have endured for a hundred thousand years or more. It is regarded by some geologists as having closed 20,000 years ago. The action of the ice, at one time in places 6,000 feet thick, and the enormous amount of water liberated at its melting brought about vast changes in the northern lakes and rivers. The distribution of animals and plants advanced and retreated with the fluctuations of the ice sheets.

About 250 species of Pleistocene plants are known in all of North America, less than twenty of which are extinct. Leaves of trees in Pleistocene deposits near Toronto, Canada, show that the trees now living in Kentucky lived at that time far north. This indicates one of the striking changes in climate.

Another change is shown by the discovery of musk-ox bones, now an Arctic animal, in regions south of Kentucky. Blue Grass caves near Lexington have given up their significant treasures of Arctic bear and fox as well as other probably glacial animals.

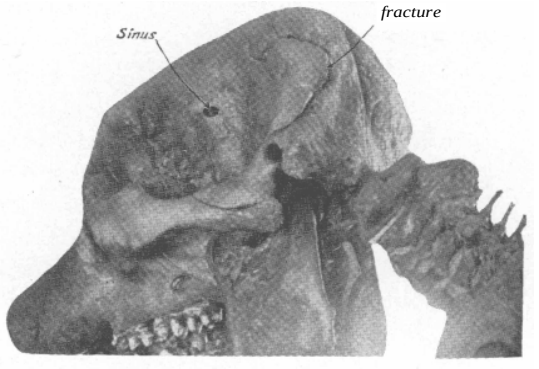

Fig. 21. An injured skull of a Pleistocene mastodon. Pus had discharged from the opening marked "sinus" for a long time before the "fracture" was made.

Many strange mammals, long since extinct, lived in Kentucky during the Pleistocene. At Big Bone Lick in Boone County, animals have come for their salt for thousands and thousands of years. Scores of hundreds of them left their bones at many of these "licks." Among the most curious animals of these mammalian assemblages are the great ground sloths belonging to the same group as the modern anteaters and sloths. These huge Pleistocene edentates are thought to have been exclusively plant feeders, like the modern, upside-down-tree sloth of South America which feeds exclusively on the large leaves of the Cecropia tree. These large sloths are found in Pleistocene deposits all over the eastern states, and far away on the Pacific Coast, within ten miles of the ocean, they left their bones in the asphalt pits of the Rancho la Brea.

Remains of the Pleistocene mastodon have been found at eight localities along the northern boundary of Kentucky (figure 22). These have usually been uncovered by steam shovels in railroad or canal building or in excavations for wells. No complete skeletal materials of these proboscidians have been found within the State, but elsewhere complete skeletons are mounted, as in many of the great eastern museums. Enormous quantities of teeth have been found at Bigbone Lick. The famous Blue Licks area has also made its contribution, and in one instance, at least, described by Professor Jillson before the Kentucky Academy of Science, a well preserved tooth has been found well within the Eastern Kentucky coal field. The mammoths, of two species, are represented in Kentucky by fragmentary remains.

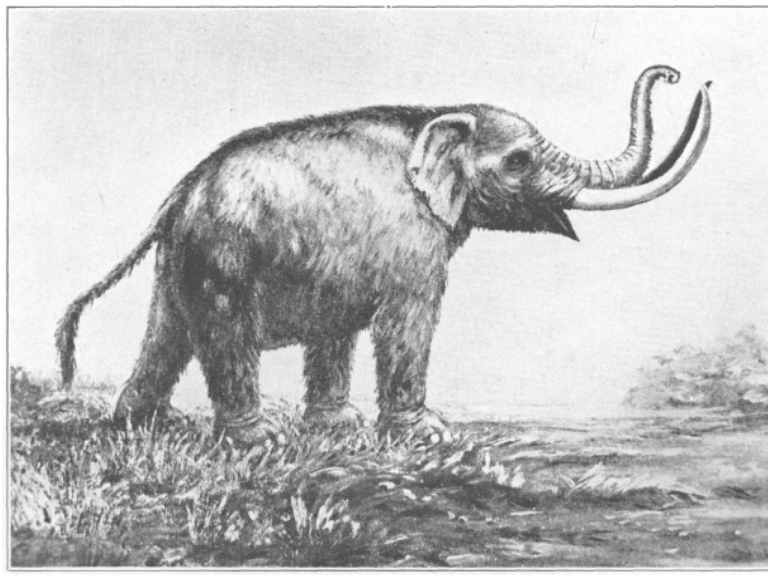

Fig. 22. The American Mastodon, whose teeth were so abundant at the Bigbone Lick that in 1804 Dr. Gofcrth took away a four-horse wagon load.

Fossil horses in America represent almost the entire history of that useful and intelligent mammal, beginning far back in the Cenozoic, from which time to near the close of the Pleistocene the group persisted, to become extinct shortly after the

Fig. 23. The teeth of the mastodon and mammoth.

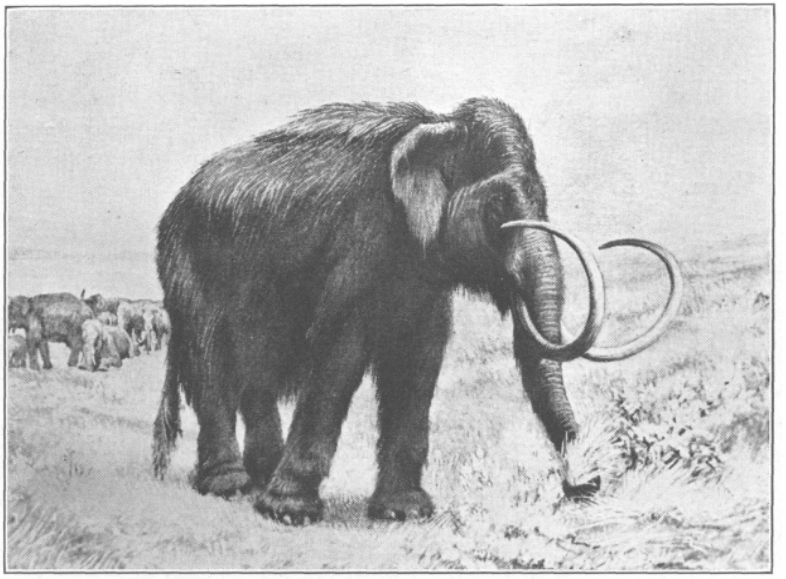

Fig. 24. The mammoth of the Kentucky Pleistocene.

Ice Age and when brought over by the Spanish explorers, thousands of years later, the horse family again found life kind in the continent, of its ancestors. At Big Bone Lick fragmentary horse remains show that the equines lived in Kentucky at the time of the mastodon and mammoth.

The tapir, a long-snouted animal now living in Brazil; the peccary; the Virginia deer; the elk; the reindeer; the musk-ox; the buffalo of two species are all represented in the Pleistocene of Kentucky by unsatisfactory and incomplete remains. Their geological position is often doubtful and even the place of origin is sometimes obscure. Further study of the exact paleontological history of these mammals in Kentucky is greatly needed to establish their status in the Pleistocene life of the State.

Of the nature of the fishes and the invertebrates living in Kentucky during the Pleistocene little is known. We have no reason to suppose they differed much from the animals now living within the State.

THE RECENT PERIOD IN KENTUCKY

The Recent is the geological period in which we are now living. It is usually regarded by geologists as having begun about 20,000 years ago. The most important event in the geological succession of life in Kentucky was the introduction of man.

We do not know when ancient man first reached Kentucky but it seems probable that the early human migrants, entering North America by way of Alaska, lived along the North American Pacific Coast, in the region of New Mexico, Yucatan, and Peru thousands of years before a group of forest dwellers found the Blue Grass State. Great civilizations undoubtedly grew and waned before Kentucky was inhabited by the human race. They reached this State, however, long before the coming of Columbus into Western waters.

One of the most interesting ways to study the manner of life of the ancient—the original Kentuckians, is by examinations of their mounds and forts. Excavations into the "trash-piles," garbage heaps, or Kitchen-middens as they are called, have also revealed much. These mounds of refuse were many generations in the making and at times burials were made in parts of the heaps. The bones of the animals which they have eaten, their pottery and stone implements, the hearths by which they cooked their food and warmed their bodies, the shells of mussels, the skeletons of fishes, not only give us an insight into the daily life of the early Kentucky Indian, but show us the kinds of animals and plants which lived at this time. We learn that the elk, deer, bear, and wild turkey furnished the largest amount of meat for the early inhabitants; while nuts, acorns, corn, and wild grains and fruits varied their diet. Fish, fresh water bivalves, and crawfish were not an inconsiderable item.

It is possible, by careful work, to study the chronological sequence of events by a study of these mounds, for the materials tend to be arranged in a stratigraphic order, much like the more ancient rocks whose evidences of life we have been considering. Many Indian graves have recently been opened, and from this single source a wealth of information and artifacts has been gleaned.

A most interesting, exact, and well-illustrated account of "*Ancient Life in Kentucky*" written by two Kentuckians, Professors Funkhouser and Webb, issued by the Kentucky Geological Survey, gives a very interesting account of early man in the State. Every Kentuckian should see and read this book. It is one of which they may feel proud.

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