Early Geological History of Chicago

BY
HENRY W. NICHOLS
ASSOCIATE CURATOR OF GEOLOGY

FIELD MUSEUM OF NATURAL HISTORY
CHICAGO
1925
## LIST OF GEOLOGICAL LEAFLETS ISSUED TO DATE

<table>
<thead>
<tr>
<th>No.</th>
<th>Title</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Model of an Arizona Gold Mine</td>
<td>$ .10</td>
</tr>
<tr>
<td>2.</td>
<td>Models of Blast Furnaces for Smelting Iron</td>
<td>.10</td>
</tr>
<tr>
<td>3.</td>
<td>Amber—Its Physical Properties and Geological Occurrence</td>
<td>.10</td>
</tr>
<tr>
<td>4.</td>
<td>Meteorites</td>
<td>.10</td>
</tr>
<tr>
<td>5.</td>
<td>Soils</td>
<td>.10</td>
</tr>
<tr>
<td>6.</td>
<td>The Moon</td>
<td>.10</td>
</tr>
<tr>
<td>7.</td>
<td>Early Geological History of Chicago</td>
<td>.25</td>
</tr>
</tbody>
</table>

D. C. DAVIES, DIRECTOR

FIELD MUSEUM OF NATURAL HISTORY
CHICAGO, U.S.A.
Early Geological History of Chicago

This geological history of Chicago may properly begin with that period, the Cambrian, when for the first time evidences of life were abundantly recorded in the rocks. This time is so inconceivably remote that Prof. Barrell has estimated that six hundred million years have since elapsed. We know something of world conditions in even more ancient times, but the rocks of that more ancient era are, in the vicinity of Chicago, deeply buried and at best the records they hold are obscure and difficult to interpret.

The geological history of Chicago has been peaceful and uneventful to a degree only occasionally encountered. There have been here no volcanic eruptions, no formation and destruction of mountains and, in short, no geological forces have here acted with that vigor, common elsewhere, which has left traces in broken, folded and contorted rocks. It is true that the site of the city has many times been submerged by the sea and emerged again, but these submergences have been slow and orderly processes due either to bodily changes in the level of the region as a whole or to variations in the level of the sea. Certainly the rocks under the city still lie nearly as horizontal as they were when they were deposited and they have undergone few changes save the hardening and recrystallization due to the pressure of overlying rock and the lapse of time. The changes of level which
have admitted and driven back the sea have not been great. But once has the region stood at any great elevation, and at no time have the submerging seas attained any great depths. Even at the present day a depression of the land levels of only six hundred feet would again submerge Chicago beneath the sea.

The rocks underlying the city are those formed wholly during Paleozoic time. The word Paleozoic means ancient life and the Paleozoic time or era was the time of ancient and primitive life. It began when evidences of life were first abundantly preserved in the rocks and continued with the gradual appearance of higher types of life until the time when the reptiles represented the highest forms of animal existence. Paleozoic time is divided into periods which correspond to stages in this gradual development of lower to higher forms of life. The opening period of the Paleozoic is the Cambrian, often called the Age of Trilobites, and it is with conditions during this period that this history begins. All the rocks under Chicago were formed during the earlier periods of Paleozoic time before even the most primitive types of vertebrate animals were numerous, so that the only fossils to be found here are, save for a few fish teeth, those of invertebrates and some obscure forms of primitive plants. These Paleozoic rocks must necessarily rest upon still older rocks but these are so deeply buried here that even the deepest artesian wells of the city have not penetrated them.

During the whole of Paleozoic time, the great mass of the North American Continent was in existence. It seems to have had much the same form that it now has. Highlands to the east and west were separated then as now by a broad, low, central valley. But as the land stood at a lower elevation than at present, this great central valley was submerged in a shallow interior sea of vast extent. This sea divided the land of
MAP OF NORTH AMERICA IN EARLY CAMBRIAN TIME.
AFTER SCHUCHERT.
the continent into a number of great islands which have been mapped and named. The interior sea was constantly encroaching upon the lands and retreating from them. The site of Chicago was therefore alternately sea bottom and dry land. When not submerged by the sea it was usually a part of the great northern land called the Canadian Shield.

**CHICAGO IN EARLY CAMBRIAN TIME**

At the beginning of Paleozoic time and of the Cambrian period the site of Chicago had long been a land with a warm and equable climate. This land was part of a great continent (Plate I), larger than the North America of today. At times it was wider and at times somewhat narrower than the present continent. To the southwest it extended through Mexico into the Pacific and to the northeast it extended through Greenland and Iceland into Europe. Chicago' occupied a geographical position in this land much the same as it occupies in North America to-day. It was centrally located, nearer the Atlantic than the Pacific and probably in a great central valley corresponding to the Mississippi valley of to-day. Probably there were no great lakes in the vicinity and we know nothing of the water courses of that time. Nothing can be said with assurance of the rainfall or the amount of sunshine. The climate was warm and equable and it has been surmised that the prevailing winds were from the east. There were no mountains or high hills near. The air contained oxygen, but how much we do not know. The whole region was probably covered with loose, drifting sands. It was a place

---

1 By Chicago is meant the geographical position now occupied by the city. The same is to be understood of other place references except those referring to the Oceans which although varying greatly in size and shape have always retained their identities.
of moving dunes devoid of vegetation. Whether it was completely devoid of vegetation and terrestrial forms of life is not known but no traces of such have ever been found. The presence of oxygen in the air proves that vegetation existed somewhere and the presence of sea weeds in the sea is known. It is also probable that the rivers and ponds held algae and other primitive forms of vegetation. No woody plants yet existed. The streams apparently were inhabited by unknown forms of soft-bodied animals which have left no traces of their existence. At least, the fishes when they made their first appearance at a much later date seem to have originated in fresh water. The Eurypterid, a scorpion-like animal from which the scorpion and spiders have descended, may have inhabited the streams.

**CHICAGO IN LATE CAMBRIAN TIME**

During Early Cambrian time the sea began to encroach upon the land until after the middle of the period, Chicago was first upon the sea-shore and later was submerged by a shallow interior sea which finally reached nearly or quite to the northern boundary of Lake Michigan. (Plate II.)

The sands of this sea-shore and sea bottom are now found as a sandstone which has been penetrated by artesian wells at depths around fifteen hundred feet. Not much can be learned from the chips of sandstone brought up by the drilling operations, but this bed of sandstone appears at the surface near the La-croix river in Wisconsin and it has been studied there. The nearest land was the great mass of the Canadian Shield to the north and there were other lands to the east, southeast and northwest. The sea was shallow and the water was salt. Probably the saltness differed in quality and degree from that of the modern ocean. It was warm, for the climate remained mild.
MAP OF NORTH AMERICA IN LATE CAMBRIAN TIME.
AFTER SCHUCHERT.
The shores were bordered with sand dunes, the wastes from which added to the thickness of the sand on the sea bottom. There were no fish, for fish had not yet appeared on earth, nor were there any other vertebrate animals. There may have been jelly-fish, for traces of them have been found in other parts of the world in rocks of the period. If there were other swimming creatures they must have possessed soft bodies which did not become fossilized. In other respects the aspect was not in general different from that of the sandy beaches and shallow waters of the present day, although the details were altogether strange. The abundant forms of life were worms, lampshells or brachiopods and the crab-like trilobites.

The worms were very abundant, for their burrows and trails over the sand are numerous. As they were soft-bodied creatures, they have not fossilized, so that we know little of them except that they were numerous. A few impressions from their bodies left in the mud of other seas of the time show that some of them (Fig. 1) were equipped, centipede-fashion, with numerous legs and a few other features are obscurely indicated. The absence of fish or others of the larger, predatory animals seems to have permitted the worms to increase until they were a far more important element in the life of the Cambrian beaches than they are on modern shores. The lampshells were bivalved shells evolved from the worms of an earlier period. There were many of them and they often grew in
colonies. They were smaller than the common clam shell of the present and lived half buried in sand. They were more or less fixed in position by long muscular stems or peduncles which, buried in sand, acted as anchors. The peduncle also served to pull the animal completely under the sand in time of danger. It is very remarkable that one of these forms, the Lingula, has survived to the present time with only insignificant changes in form or structure. (Fig. 2.)

![Fig. 2.

a. A recent brachiopod.
b. Shell of a Cambrian brachiopod.

Fig. 3

A Cambrian trilobite.

Most of the other orders of shelled animals were represented by an occasional individual. The trilobites (Fig. 3), curious crab-like creatures which crawled over the sand, were the dominant animals of the period. They had lobed and jointed shells. While they resembled crabs they are not related to them nor are they closely related to any modern animal. It is thought by many that, at a later time, insects descended from them. They were at this time small, few meas-
uring more than an inch and a half in length. There were other shelled animals which were not common near Chicago and of course the life of the deeper seas, such as corals, was entirely absent here. Besides these there were numerous unknown animals with bodies which had no hard parts to fossilize. These have left no traces of their existence except an occasional track on the sand. Vegetation was confined to the sea-weeds. Beyond the fact that many of them, like the present sea-weeds were algae, little is known of them. They must have been numerous to provide food and oxygen for the abundant animal life.

**CHICAGO IN EARLY ORDOVICIAN TIME**

The second period of Paleozoic time was the Ordovician, formerly called the Lower Silurian. It was the time when cephalopods, a group of animals of which the nautilus, squid and octopus are the best known modern forms, first became prominent features in the life of the sea. Around Chicago there was a gradual transition from the Cambrian to Early Ordovician time. There was no abrupt change of any kind, but Cambrian forms of life were gradually superseded by the higher forms which characterize the Ordovician. The rocks of the transition period have not preserved their fossils well, so that not much can be said of the life of the time, beyond that it was intermediate in character between that of the Cambrian and that of the later Ordovician. The region was still the bottom of a shallow sea of fluctuating depth. The bottom was predominantly sandy. The water was clear, for at no time was the bottom muddy. The sandy bottom of the Cambrian sea had, as Ordovician time opened, become limey from an accumulation of the shells of small animals which inhabited the sea. This change was due, in part at least, to the distance from shore which increased with the continued advance of the sea. This
condition, which persisted well into the Early Ordovician, has left a record in the form of a limestone called in older descriptions the Lower Magnesian Limestone. In later descriptions it is sometimes called the Prairie du Chien limestone. This limestone was formed from the shells and other limey parts of the marine animals of the time. Under the city it has been penetrated by drills at depths slightly in excess of one thousand feet. A thickness of from 160 to 450 feet may give some hint of the long duration of this sea.

This great advance of the sea, which began in Middle Cambrian time, continued until in the first part of the Early Ordovician, it covered most of the interior of the North American continent. (Plate III.) It was followed by an equally great recession, which long before the end of the Lower Ordovician left Chicago once again in the interior of a great continent. (Plate VI.) Conditions were much like those of the earlier emergence both physically and geographically. The climate was arid. The surface was covered with moving sand dunes. The life in the streams and rivers must have been of a more advanced type than before, although no traces of such life remain. The streams may have held a primitive type of fish. Some fish remains have been discovered in deposits of this age in the Rocky Mountains. Artesian wells in Chicago and Cook County penetrate at depths of around 800 to 1000 feet, a coarse, white sandstone which is in places one hundred and fifty feet thick. This, the St. Peter's sandstone, is the sand of the dunes of this old land solidified into rock. It does not appear at the surface in the City of Chicago but may be seen along the Illinois River near Ottawa and in Deer Park. The site of Chicago remained land until the beginning of Mid-Ordovician time when it was submerged by a new transgression of the sea.
MAP OF NORTH AMERICA IN EARLY ORDOVICIAN TIME.
AFTER GRABAU.
CHICAGO IN MID-ORDOVICIAN TIME

Mid-Ordovician time was of long duration, with much oscillation between land and sea. It was inaugurated in this vicinity by a great advance of the sea. A shallow interior sea extending north from the Gulf of Mexico soon submerged the sand dunes of the earlier land. This was followed by a great inundation from the Arctic Ocean, which attained such vast proportions that little beyond a few large islands remained of the North American continent (Plate VII). Finally, before the end of the Mid-Ordovician, nearly all the marine water was withdrawn and Chicago was again on land. This sea was a shallow, clear-water sea much like the preceding ones, but probably deeper. The waters, even those of the extension of the Arctic Ocean, were warm. These waters swarmed with invertebrate life which resembled that of the preceding epoch as well as that of the Niagara to be later described. The rocks deposited in this sea, called the Galena-Trenton formation, reach the surface nowhere in Chicago or Cook County. They lie from 500 to 600 feet beneath the surface and are from 270 to 390 feet in thickness. They are cream-colored or yellowish magnesian limestones.

CHICAGO IN LATE ORDOVICIAN TIME

The withdrawal of the sea at the close of the Mid-Ordovician left Chicago upon the western shore of a great interior sea connected with the Gulf of Mexico and upon land which was part of a continent greater than the North America of the present day. Of conditions in the territory near the city we know little beyond the facts that there were no mountains and that the climate remained mild. This land did not persist long, for soon a new cycle of water movement began and the seas advancing northward from the
Gulf of Mexico soon resubmerged the site of the city in muddy waters. These waters were muddy because elevations of the land to the east and south had attained sufficient magnitude to increase the current of the rivers, which now carried large quantities of mud to the interior sea. This state of affairs continued until the site of Chicago was covered so deeply with mud that now when it is compressed to rock it covers the older rocks under the city to a depth of from 100 to 250 feet. This rock, formed from the consolidated muds of the Late Ordovician seas, is a shale mixed with limestone. It was formerly called by some the Cincinnati shale and by others the Hudson River shale. It is now generally referred to as the Maquoketa shale. It underlies the present rock surface at depths of from 250 to 400 feet. Before the close of the Ordovician the sea again withdrew for a considerable period leaving the site of the city again land. Nothing is known of the climate, geography or life of this land.

CHICAGO IN SILURIAN TIME

The Silurian division of Paleozoic time followed the Ordovician.¹ The Silurian is separated from the Ordovician more by changes in the relation of land and sea areas than by any radical change in the character of life. For, while nearly all the genera and species of animal life in the Silurian were new, they were members of classes and families of animals that were already common in Ordovician time. The beginning of Silurian time found Chicago on a land area, where it had been left by the retreating seas of the Ordovician. The records of early Silurian time are, in this vicinity, somewhat difficult of interpretation, but ap-

¹ The older geologists grouped the Ordovician and Silurian into one period which they called the Silurian. The Ordovician was then the Lower Silurian and the period now known as the Silurian was called the Upper Silurian.

[82]
COMMON FOSSILS FROM THE NIAGARA LIMESTONE OF CHICAGO.
1, CORAL, CLADOPORA. 2, COILED CEPHALOPOD, NAUTILUS. 3, CORAL, DIPHYLLUM. 4, CUP CORAL, OMPHYMA. 5, COMPOUND CORAL, FAVOSITES. 6, STRAIGHT CEPHALOPOD, ORTHOCERAS.
Early Geological History of Chicago

parently the site of the city remained land during the first part of the Silurian. This was a time of advancing seas and diminishing lands so that by Mid-Silurian time Chicago was again submerged by an interior sea. This Mid-Silurian time is called the Niagara epoch. This name is given the epoch because rocks formed in the seas of the time are exposed near Niagara Falls and were studied there. It has nothing to do with the falls and river, which did not come into existence until ages later.

For some time past there had been important changes in the elevation of many parts of the continent. Far to the east in New England, a range of mountains (the Taconic Mountains) appeared and these shut off access of the sea from the east. To the southeast was the Cincinnati uplift, where great areas had been raised above the general surface, and to the south and southwest there was another elevated region, the Ozark uplift. These highlands blocked access of the sea from the East, South and West and therefore Silurian transgression of the sea which submerged Chicago came from the Arctic.

When this invasion of the waters of the Arctic was at its height, Chicago was on the floor of a great interior sea which covered the northern part of the Mississippi valley. (Plate VII.) To the north it was open to the Arctic Ocean and to the south it at one time joined another sea which in turn opened on an eastward extension of the Pacific Ocean. The nearest land, Mississippia, a great land mass to the west, occupied what is now the west central part of the country and included parts of Canada and Mexico. Mississippia was separated by a narrow sea from Cascadia, which was a relatively long and narrow strip of land along the western border of the Continent. To the east and southeast another great land mass, Appala-
chia, included what is now the eastern border of the Continent. To the northeast and more distant were the shores of Atlantica, which extended as far south as the St. Lawrence valley and covered parts of eastern Canada, Greenland and some of Europe. Exact boundaries of these lands and seas are not yet definitely known and maps of them are constantly altered as the result of continued study. Although this sea was an arm of the Arctic Ocean, its waters were warm and semi-tropical conditions prevailed. The waters were clear and swarming with life.

As the shallow Arctic seas with their warm waters afforded a ready path of communication with the north of Europe, the Silurian fauna of the Chicago area had a decidedly European aspect. The great land of Appalachia to the east interposed a barrier to the migration of marine animals between the interior sea and the Atlantic coast and no intermingling of the life of these two regions was possible. Consequently the life of the Silurian seas of Chicago was more like that of Europe than like that of the nearer eastern part of the United States.

This was a coral sea. Primitive forms of corals had existed even in early Cambrian time but the early seas of Chicago were seldom favorable to their growth. By the middle of the Ordovician, corals had become numerous and had separated into many varieties. In the Niagaran seas of Silurian time, corals had become even more numerous and existed in even greater variety. The prominence of the corals was in fact one of the notable features of these Silurian seas. As the sea in the vicinity of Chicago was especially favorable to coral growth, these animals were an important feature of these waters. The coral is a simple form of animal. Its body is little more than a hollow cylinder of flesh. A mouth at the upper end is surrounded by
a crown of tentacles. The animal rests upon a skeleton or pedestal of carbonate of lime which is secreted by the animal itself. This pedestal is either cylindrical or conical. Conical forms are often curved so that they resemble blunt horns. There were simple individual corals (Fig. 4) each of which grew by itself on its own pedestal and there were compound forms in which the stony bases or pedestals were joined in one mass. (Fig. 5.) This mass commonly took either a
hemispherical or a dome-like form or grew as clusters of branching arms which roughly resembled branching trees. These colonies attained, under favorable conditions, considerable size. Some of the coral domes measured as much as fourteen feet across and a height of fifteen feet for branching forms has been recorded. Although the colonies attained considerable size the individual corals remained small. Usually they were less than a quarter of an inch in diameter, although there are some which measured more than an inch.

In these Silurian seas the first coral reefs appeared, for at this time the coral first acquired the reef building habit. Although the group to which modern corals belong had not yet developed, there is no reason to suppose that the appearance of a Silurian coral bed was in essential features different from that of a modern coral reef. (Fig. 6.) On a base composed of the stony skeletons of past generations, great dome-like masses of coral mingled with branching tree-like forms and all were crowded together. Resemblance to modern coral beds was heightened by the presence of many forms of the more delicate incrusting and branching bryozoa. These bryozoa were coral-like animals which grew in colonies of minute individuals, grouped like the compound corals on supports of carbonate of lime which the animals secreted. These supports resembled in a general way the branching corals, but they were commonly more slender and inclined to grow together into intricate network patterns. Many grew in fan or leaf form, others were netted or branching threads incrusting corals or other solid supports.

Swarming over the sea bottom in great abundance were the crinoids, strange, flower-like creatures utterly unlike in appearance any animal commonly encountered at the present day, although a few species still
exist in tropical seas. They were attached to the sea bottom by long stems and their small, round bodies were provided with many long, feathery arms. Their appearance was so flower-like that they are often called stone lilies. They were gregarious in habit and in parts of the Niagara sea at Chicago they were so numerous that these places have been described as "veritable flower beds of stone lilies where beautiful and varied forms grew in groves, as it were." Although they do not look at all like them, they are actually closely related to the starfish. They are somewhat like a starfish turned upside down and perched on the top of a long, jointed stem and provided with many, long, feathery arms in place of the five short rays of the starfish. The stem is intended to keep the animal out of the mud and to anchor it so that it cannot drift away into places where food supply and other living conditions might be unsuitable. This stem is built up from many short discs or joints. These joints are of a stony material, a mixture of the carbonates of lime and magnesia. The stem is terminated below by branching roots or by a kind of flat foot which anchors it to its support. On the top of the stem is the body, which is in many species, of the size and shape of a walnut. This body is inclosed in a jointed armor of limestone plates, which is called the cup. From the top of the body grow the jointed arms which wave in the water and direct food to the mouth. (Fig. 7.) There were many kinds of crinoids, some having long, feathery, branching arms, while others were simpler and less conspicuous. Blastids grew with the crinoids. These were much like the crinoids and grew on stems but had no arms.

Although crinoids and corals were the most numerous inhabitants of this sea, other animals were by no means rare. The brachiopods were animals cov-
Fig. 7. A crinoid of Niagara time. Drawn by Carl F. Gronemann.
ered by shells which at first sight appear somewhat like clam shells, although these animals are no relatives of the clam. Brachiopods were anchored to the bottom much as the common mussel shell of the present day seas is, by a long, slender thread.

Sponges were not uncommon, but they were not like the common sponge of the present day. The sponge was an animal with a jelly-like, hollow body, supported by a stiff, porous skeleton. In the valuable varieties of modern sponge, this skeleton is composed of horny matter, but these ancient sponges had skeletons composed of the mineral silica. These silica skeletons were sometimes in the form of a continuous, porous network like the horny skeleton of modern, commercial sponge and sometimes they were disconnected, minute rods and spicules. It is probable that sponges with horny skeletons also lived at this time, but as such varieties had no hard parts, no trace of them remains.

Not all the inhabitants of this sea were, like those already mentioned, anchored to the sea bottom. There were crawling and swimming forms as well. The trilobites, dominant animals of the Cambrian seas were still numerous, though not as important as they had been. They had the habits and much of the appearance of crabs. Like crabs they were scavengers, eating carrion. They did not have the long, spreading legs of the crab but moved on numerous short, jointed legs attached to the underpart of the body, either crawling around on the bottom or skimming along just above it. Like the crab they relied for protection on a horny shell, which however did not cover the under side of the body. When threatened by an enemy, most Silurian trilobites coiled themselves into a compact ball which presented on all sides an unbroken armor of horny shell. The commoner trilobites of the Chi-
Early Geological History of Chicago

Chicago seas were about an inch to two inches long. They were oval in outline and the shell consisted of three parts. A front end, the head, was connected by a many-jointed thorax to the rear end, the abdomen. (Fig. 8.) Although so crab-like in habits and appearance, the trilobite was no relative of the crab, but belonged to a group of animals which have long been extinct.

The dominant animals of the Chicago seas at that time were the cephalopods. They are called the dominant animals, not because they were the most numerous, for they were not, but because some of them were large and they were the most highly developed form of animal life then existing in any considerable numbers. In modern seas, the cephalopods are represented by only a few forms, of which the octopus, squid and nautilus are the best known. In Silurian seas there was a great variety of these animals and they were provided with large, strong shells. The common cephalopod of the Chicago Silurian seas was the Orthoceras. (Fig. 9.) This mollusk had a long, perfectly straight, spear-like shell. This shell gradually tapered from a cup in front inhabited by the animal to a point

![Fig. 8. Trilobites of Niagara time. Drawn by Carl F. Gronemann.](image)

at the rear. The shell was divided into segments. As the animal outgrew its shell, instead of moulting, as trilobites did, it grew a new and larger cup in front of the old one and moved into it and for the rest of its life it dragged its old, abandoned residence along be-

Fig. 9.
An orthoceras of Niagara time. Drawn by Carl F. Gronemann.

hind it. The animal itself was much like its relative, the octopus. It had a mouth in front, surrounded by a ring of long, fleshy tentacles which served both as grasping arms and as feet. Like the octopus of the
present day, it crawled on these tentacles and probably it could swim as well. It was carnivorous and fed on smaller animals. It was variable in size. Many of the fossils of this animal found in Chicago are from one to three inches in diameter and represent shells that when complete were several feet long. One specimen in the Museum, of local origin, is six inches in diameter and over two feet long and yet it is only part of a shell. Specimens have been found elsewhere eight to ten inches in diameter and fifteen feet long. These long, straight shells must have been cumbersome to carry around. Snails and most other animals both ancient and modern that inhabit long shells have the shell coiled so that it occupies less space. Cephalopods of later ages inhabited coiled shells and in these Silurian seas there were, besides the straight shelled orthoceras, other animals of the kind, some with partially coiled shells and a few with shells completely coiled.

There were other animals present in decidedly lesser numbers in this part of the Silurian sea. There were many varieties of gasteropods, small, coiled shells closely related to the snail and an occasional member of other classes of the lower animals.

As animal life was so plentiful it follows that vegetation must have been equally abundant or these animals could not have found food. But the vegetation, which was confined to members of the lower orders of plants, had no hard parts, so that no trace remains of the thick growths of seaweeds which must have been there.

**THE NIAGARA LIMESTONE.** Thousands of successive generations of the animals just described lived and died in the Silurian sea. Their hard parts, which usually had the composition of limestone, were practically indestructible and slowly accumulated on the sea floor. In the course of time they built up a bed
of limestone hundreds of feet thick. This is the Niagara limestone which underlies the whole city. All quarries, rock cuts, canals and tunnels and other rock exposures in or near the city are in this Niagara limestone. Nowhere in Cook County have any openings larger than drill holes penetrated through this limestone to the older rocks below.

Although the hard parts of these Silurian animals were practically indestructible they have proven to be by no means unchangeable. Most of the original fossil forms have been obliterated by the recrystallization of the rock to a compact, crystalline limestone. This recrystallization has not been complete, for numerous fossils, relics of this ancient life, can be found practically anywhere in this limestone. Around Chicago these fossils are not ordinarily the actual petrified remains of the animals but are merely casts or impressions from which the actual animal substance has long since disappeared. They represent only the stony or hard parts of the animals, as the softer parts did not last long enough for these casts to form. (Plates IV and V.)

Frequently in this limestone little nut-like objects, anywhere from a cherry to a walnut in size, may be found. Some are rough and plain of surface, others are beautifully ornamented with intricate designs of raised and incised lines. These are the bodies or cups of crinoids. In those found near Chicago the arms have not been preserved, but in deposits in the same sea in other parts of the country, and in particular near Louisville, Kentucky, beautiful specimens showing arms have been secured. With the fossil crinoid bodies there are often found numerous flat discs, commonly a quarter of an inch or less in diameter. These are sections of the jointed stems by which the crinoids were anchored. Most of these sections are circular,
COMMON FOSSILS FROM THE NIAGARA LIMESTONE OF CHICAGO.
1, CRINOID HEADS, EUCALYPTOCRINUS. 2, CYSTIDS, HOLOCYSTITES. 3, TRILOBITE, CALYMENE. 4, CRINOID STEMS. 5, BRACHIOPODS, SPIRIFER. 6, GASTROPOD, PLEUROTOMARIA.
but five-sided or even star-shaped outlines are not uncommon, and other shapes are occasionally found.

Corals are, after the crinoids, the most common of the local fossils. Owing to the great diversity of Silurian coral life, these fossils are present in great variety. The honeycomb coral resembles a mass of honeycomb imbedded in rock. Cup corals are often found. A common local form, the Zaphrentis, is a small, curved cone resembling a blunt horn. Its larger end is hollowed into a cup, which is lined with numerous thin plates running from the outside towards the center. These fossils can seldom be broken from the rock. What is most frequently seen is a section which appears on a limestone surface as a circle showing the edges of numerous thin plates running from the rim toward the center. Sometimes the section runs lengthwise of the coral so that the outline of the curved, horn-shaped cone is visible. Fragments of branching, tree-like corals are not uncommon and remnants of other varieties are found at times. The branching forms of bryozoa are also frequent. These resemble branching corals but can be distinguished from them by a study of their more minute details. Often a network of fine, branching lines will be found incrusting a large fossil. These also are bryozoa.

Another common fossil is the trilobite. When well preserved, as it frequently is, it is a most curious object. The common variety, an inch or so long, looks something like a bug with a rounded head and large eyes. This head is joined by a central portion composed of many jointed rings to an abdomen of about the same size. The trilobite is sometimes found lying flat and sometimes coiled into a ball.

Another fossil often encountered in this limestone takes the form of a cylindrical, jointed rod. It is commonly from one to three inches in diameter, although
smaller and larger specimens are not infrequent. A complete individual may be several feet long and taper to a point. Specimens of these have, on account of their size and jointing, been mistaken for fossil backbone. These fossils are the shells of the orthoceras, the straight-shelled cephalopod. Curved cephalopod shells are also found but are not common.

Occasionally nodules of flint, usually flat and irregular of form, are encountered. These are the remains of Silurian sponges. Other fossils are present in the Niagara limestone of Chicago, but they are in lesser numbers and so they are less likely to be noticed.

In the Chicago District the Niagara limestone varies from two hundred and fifty to four hundred feet in thickness. Even this is not the original thickness, for during the ages that it has been exposed to the weather, much of it must have eroded away. Numerous quarries and outcrops afford ample opportunity for its study. Perhaps the best exposure is in the cut of the Drainage Canal near Lockport. (Frontispiece.) The limestone lies in undisturbed, horizontal beds as it was deposited. There are some local gentle undulations and at Stony Island there is a dome with steeply sloping sides. The origin of this dome is somewhat of a mystery. It has been suggested that it may be merely a mounding of limestone beds over an ancient coral reef, but this is only one of a number of suggested reasons for its existence.

There are two kinds of limestone. One, typical limestone, is essentially a pure carbonate of lime. The other, called dolomite, is a mixture of the carbonates of lime and magnesia in nearly equal parts. Many limestones are intermediate in composition between these two. The Niagara limestone of the Chicago District is a dolomite. Many theories have been proposed
MAP OF NORTH AMERICA AT THE END OF EARLY ORDOVICIAN TIME.
AFTER GRABAU.
to account for the presence of magnesia in such limestone as this, but no one of them has been universally accepted as applying in this instance. Few shell-bearing animals secrete, as was formerly supposed, a pure carbonate of lime. Most of them grow shells or skeletons which contain notable quantities of carbonate of magnesia. It happens that the crinoids, the most abundant animals of local Silurian seas, secrete for their skeletons a mixture unusually rich in carbonate of magnesia. It is quite possible that the skeletons of the Silurian crinoids, living as they did under conditions unlike those of the present, may have contained magnesia in even greater quantity. It may well be that the magnesia originally present in the skeletons of the Silurian fauna is sufficient to account for that now present in the limestone. This, however, is to be taken as a possibility, not as a certainty. Asphalt impregnates the limestone in places. It is especially apparent in the limestone outcrops at Windsor Park and in the quarries at Thornton. This asphalt is a product of the decay of perishable tissue of Silurian animals. Years ago, some of the wells of the city were contaminated by petroleum apparently derived from the upper layers of the limestone. This seems to have been present only in small quantities, for it soon disappeared. It probably had the same origin as did the asphalt.

The Niagara epoch of Silurian time was terminated by a withdrawal of the seas which had submerged the continent. It is possible that this withdrawal did not at once bare the site of the city, but it is certain that at some period of late Silurian time the city was again on land. Local records of this time are missing, as any rocks which may have formed in the seas of the time have long since been destroyed by weathering and erosion. We may infer something of local conditions by a study of better preserved records found in other
parts of the country, but such inferences are of real value only as they refer to general conditions. All that we may say with assurance is that this land was of great size, probably as large or larger than the North America of the present day. Desert conditions existed over much of New York, Ohio and Michigan. This great desert may have included Chicago within its boundaries.

CHICAGO IN DEVONIAN TIME

The Devonian division of Paleozoic time followed the Silurian. This was the Age of Fishes, so-called because then for the first time fishes were an important element of the life of the waters. When Devonian time began, almost all of North America had emerged from the sea and Chicago was on land. During the progress of Devonian time there were several oscillations of sea level. Several of these may have submerged the city, but if so, any local traces have, except in one instance, long since disappeared. Until 1899 it was believed that there was no trace of a Devonian sea in the Chicago region, nor were any Devonian rocks known nearer than those in the vicinity of Milwaukee. In 1899, however, a few Devonian fossils were discovered in a quarry near Elmhurst. This quarry is in the Niagara limestone. During much of Devonian time this was a land area. The limestone formed in the seas of the earlier Silurian time was then surface rock. The upper part had eroded away and the numerous cracks which are such a noticeable feature in this as in all other limestones had already formed. The waters which collected on the land surface percolated through these cracks in the limestone and enlarged them. An opening six inches wide at the base and sixteen inches high was excavated in one place. At a later period, near the close of the Devonian, when the sea again covered this region, sand sifted from the sea bottom
into this opening and with it were carried shells and and teeth of fishes which inhabited the sea thereabout (Plate VII.) From this one, small deposit we learn, first, that Chicago had been for much of Devonian time on land and, second, that near the close of Devonian time it was again a sea floor. This Devonian sea was not unlike the preceding one and its invertebrate life was much the same. Corals still abounded but there were fewer crinoids and trilobites. The principal difference, however, lay in the presence of fish.

Although the Devonian is called the Age of Fishes, it must not be supposed that Devonian seas were, like modern oceans, swarming with fish. Most Devonian fish were dwellers in fresh water. At that time only a few kinds had migrated into salt water. No species, genera or even families of Devonian fish have survived. The great class of bony fish to which more than nine-tenths of all modern species belong had not then come into existence. There were sharks in the Devonian seas and the ganoid fishes, now represented only by the sturgeon, gar and a few others, were in Devonian times much more important than they are at present. Nearly half of all known species of Devonian fish belonged to classes which are now wholly extinct. Many of these extinct forms were so unlike modern fishes that it is questionable whether they should be called fishes at all. Many of them were covered with jointed armor and some, unable to swim, crawled along the bottom. As already stated, most of them lived in fresh water and, as no record of the land life of Devonian time in the Chicago District remains, we do not know whether any of these strange creatures ever inhabited this region. The only fish that we positively know to have inhabited the seas of Devonian time here are two species of small sharks or primitive fish related to sharks. We do not know what these shark-like ani-
mals looked like, for the only parts that have been preserved are teeth and scales. They were probably quite unlike the modern shark in appearance. It is known that the Dinichthys or "terrible fish" inhabited the eastern part of this Devonian sea and it may have been present in the waters around Chicago as well. The Dinichthys were large, heavily armored, swimming fish. Some of them were over twenty feet long. More than forty species of smaller relatives of this gigantic fish inhabited the North American seas of Devonian time.

All records of the geological history of Chicago from the close of Devonian time to the opening of the glacial period in, geologically speaking, almost recent time, have been destroyed. We know from a consideration of the known history of other parts of the country, that submergences under the sea and subsequent emergences of land continued, but gradually the submergences became fewer and shorter and the emergent periods longer, so that this later unknown part of the history would be, if known, more and more a record of events upon land. The rocks in which the records of these ancient times are preserved are, with few exceptions, formed on the sea floor. When the marine waters are withdrawn, these rocks become a part of the land. The surface layers are then constantly exposed to such destructive agencies as weather, running water and frost and are slowly worn away. The region around Chicago has been a land area so much of the time since the Devonian period that any rocks deposited during times of submergence have completely disappeared.

Since the last records now existing of the early geological history of Chicago were deposited on the floor of the Devonian sea at Elmhurst, so much time has passed that, if it were computed in years, the fig-
MAP OF NORTH AMERICA IN MID-ORDOVICIAN TIME.
AFTER GRABAU.
ures would be too stupendous for human beings to realize their meaning. It has been said that as the astronomer finds the mile too short a measure for his distance and uses a larger unit, the light-year, so the geologist finds the year too small for his computation of time and uses the larger unit, a million years, as a basis of his calculations. The time since the Devonian period is a matter of hundreds of millions of years. During that time much of the world's life history has arisen and passed on. The coal forests have grown and the coal beds have formed. Reptiles have increased from insignificant beginnings until they dominated the life of the planet and then decreased in importance to their present minor position. Mammal and bird life have had their beginning and have developed to their present important position in the life of the world and there have been other happenings of major importance. The region around Chicago saw its share of all these events but the records are gone and we can have no knowledge of them derived from local sources. We do know, however, that the progress of events remained peaceful and uneventful, for any violent action of geological agencies would surely have left unmistakable evidences of its presence.

Henry W. Nichols
For those who desire further information on the geology of this region, and yet do not intend an exhaustive study of the subject, the following list of references is provided:

Pirrson and Schuchert.—Text Book of Geology, Vol. II.
Grabau, Amadeus.—Text Book of Geology, Vol. II.
Chamberlain and Salisbury.—Geology, Vol. II.
Geologic Atlas of the United States.—Chicago Folio No. 81, Published by the U. S. Geological Survey. This contains a bibliography.

Weller, Stuart.—The Paleontology of the Niagara Limestone in the Chicago area. Bull. No. 4 of the Natural History Survey, Chicago Academy of Sciences, Part 1, the Crinoidea and Part 2, the Trilobita.

MAP OF NORTH AMERICA IN MID-SILURIAN (NIAGARA) TIME.
AFTER GRABAU.
POCKET OF GLACIAL CLAY IN NIAGARA LIMESTONE, CHICAGO DRAINAGE CANAL.

IT WAS IN A SIMILAR POCKET FORMED IN DEVONIAN TIME THAT THE DEVONIAN FOSSILS FOUND IN ELMHURST WERE PRESERVED.

Photograph by O. C. Farrington.