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The Address of the President - Our Underground Geology

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THE ADDRESS OF THE PRESIDENT

OUR UNDERGROUND GEOLOGY[1]

JAMES H. LEES

Title Misleading. — Before I begin the serious discussion of this topic may I make a few explanatory statements? In the first place I realize that the title I have chosen is misleading in that it may convey the impression that we geologists are, or think we are, thoroughly familiar with the strata beneath our feet. As a matter of fact we know little more than the bare outlines of the facts regarding these strata and many years and much labor will be needed for completing their study as thoroughly as must ultimately be done. But I am devoted to brief titles, and I prefer to explain my thesis in the body of my address rather than in its title.

Address Elementary. — In the second place I hasten to explain that this address is itself only a sketch of the available information, and an elementary sketch at that. A sketch because time does not permit me to present the minutiae of this information, and I shall find it sufficiently difficult to outline the history of the past 2,000 million years in the 2,000 seconds or so that are usually allotted to the president of this Academy for publicizing his knowledge regarding the world in which he lives. Elementary because I realize that most of the members of this group, even though it does comprise scientists of statewide and national reputation, are neither familiar with nor interested in the details of this particular branch of knowledge. Therefore I shall attempt to discuss with you only the major features of the broad subject that I am bringing to your attention.

Tribute to Pioneers. — Again I wish to pay a sincere tribute to the work and memory of those geological pioneers who made the first studies of Iowa geology and who laid the foundations for our present acquaintance with our state. David Owen, James Hall, Charles White, Samuel Calvin and a large group of their associates sketched firmly and clearly the broad background of the picture whose details their successors have striven and are still striving to perfect. However, it is without the slightest sense of deprecation of the efforts of these men that I today call especial attention to the

[1] Published with the consent of the Director of the Iowa Geological Survey.

work of Dr. William Harmon Norton. His good fortune and his task it has been both to assist in sketching the outlines of the picture of Iowa's underground geology and then to carry on most of the painstaking work of adding the details necessary for the completion of that picture. For forty years Doctor Norton has been studying the records of wells drilled in all parts of the state, and from these records he has derived the data that make our knowledge of Iowa's deep-lying geology probably as complete as that of any state in the Union. Doctor Norton already has prepared two volumes on the underground waters and geology of Iowa that have been published by the Survey and he has in preparation a third report.

Help of Drillers. — I also welcome the opportunity of expressing the appreciation of the Geological Survey for the coöperation of the well drillers of Iowa, without whose help in supplying records and sample drillings of their wells our information about our geological strata would be much less thorough than is today the case.

Glacial Geology Not Discussed. — Let me further explain that I do not propose to discuss the glacial geology of our state. This has been well treated by Doctor Kay, both in his presidential address before this Academy and in various papers that he has read to the geology section, as well as elsewhere. I shall confine myself today to the bedrock beneath the glacial deposits.

Negative Elements of the Picture

I have several times likened our underground geology to a picture, and it is perhaps well that in describing this picture I should first call attention to certain negative elements, features that are absent from our own state. And yet these elements are as important in their absence and in their failure to influence our geology as they are in those areas where they have been among the dominating factors in shaping geological conditions.

Absence of Mountains or Great Deformations. — Perhaps the chief among these negative elements is the absence of mountains from our topography. Furthermore, so far as available evidence can tell us there have been no mountains in the state throughout its history. By way of answer to the very natural question: "How do you know?" I may say that Iowa strata show no important deformations, such as those crumplings of the earth's crust that would be a part of the making of mountain ranges, or the great breaks in the strata that usually accompany such crumplings. There are some exceptions to this general statement, some small breaks in the crust, but they are too unimportant to be a part of such enormous activities as are involved in mountain making or in the movement of large parts of the continental mass. The most important known break in the Iowa strata is the Thurman-Wilson fault, a fracture that extends from Missouri river in Fremont county northeastwardly toward Des Moines, and along which has occurred a movement that brings the strata about three hundred feet higher on the north side than are the same beds on the south side. Some of the great faults in mountainous regions are said to show movements as large as 75 to 100 miles.

Another type of deformation that is represented, though on only a small scale, in the Iowa strata is a bowing down of the beds into troughs known as synclines, because the beds are inclined toward the central axis, or a bowing up into domes or into ridges known as anticlines, because the beds are inclined away from the central axis. The largest of these arches is called the Ames anticline because Ames is located on it. Its effect is to raise the strata over its area about three hundred feet higher than in surrounding territory. A number of small foldings affect the strata here and there over the state, none of them, however, to any important extent. Such foldings as these form the natural reservoirs for petroleum and natural gas, but so far none has proved to be productive in this state.

No Igneous Rocks. — Another negative element in this picture of Iowa geology is the absence of any igneous rock. We distinguish the igneous rocks as being those whose composition and structure indicate that they came to the upper crust of the earth in a hot molten condition and there hardened, most of them in crystalline form. The stratified sediments of the earth's crust everywhere lie on such igneous rocks, and this is as true in Iowa as elsewhere. But above this foundation rock of granite and allied types, at only one point has any igneous rock been encountered, namely in a deep well at Hull, in northwestern Iowa. This is one of the reasons, perhaps the chief one, for the absence of the precious metals in our strata.

Positive Elements of the Picture

Now let us consider the positive elements in the picture we are outlining — those elements that determine just what the character of our geology shall be, as the negative elements determine what it shall not be.

Rocks all stratified. — In the first place, then, the Iowa rocks all belong to the stratified, sedimentary types. That is to say, almost without exception they were formed as layers or strata from the sediments that had been dropped out of the streams that transported them from the old-time lands to the ancient seas. They include conglomerates, sandstones, shales and limestones, with all degrees of gradation and with repeated alternation from one type to another. The igneous rocks are, of course, the primary types, for they are the lineal descendants of those materials that made up the original mass of the earth. From their decay and alteration have been derived, perhaps directly, perhaps after many cycles of destruction and reconstruction, the sediments that make up the Iowa strata.

Strata Fairly Level. — In the second place these strata still lie nearly horizontal, approximately in the attitudes they occupied at the time of their formation. This is not to say that they have not moved from their original positions, relative to sea-level, for instance, but that despite these movements they are still nearly as level as when they formed the ocean floor. The minor deformations of strata that I have mentioned are, of course, exceptions to these general statements, but rather insignificant exceptions, and the general rule holds good, that such crustal movements as the Iowa strata have suffered have not greatly disturbed their horizontality.

Rocks in Natural Order. — It follows from these facts that the Iowa strata still lie superposed in regular original order. This may seem a very simple statement and an unnecessary one, it is so obvious. But it is possible for the strata to be so upheaved and deformed that the older overlie the younger instead of the reverse, as should normally be expected, and this is actually the case in regions that have suffered much deformation. In our state, however, we may confidently predict that wherever and whenever beds are found lying one above another the upper are the younger. This fact is one of great practical importance, for it gives an assurance, in searching the strata for any purpose whatever, that would be impossible were one not certain of the relative ages of the beds. This correspondence between the succession of the strata and their age is attested both by their level, undisturbed position and by the progressive development of their fossil life forms.

The Great Basin. — The feature of Iowa geology that I am disposed to regard as its dominating structural element is a broad shallow trough or basin that embraces the entire state in its extent and includes as well the neighboring parts of all the surrounding states. In Missouri and Kansas this depression is known as the Forest City Basin, and this name might well be applied to the Iowa part. The basin is limited on the north by the Minnesota Highlands, in Wisconsin by the Lake Superior Highland and the Wisconsin

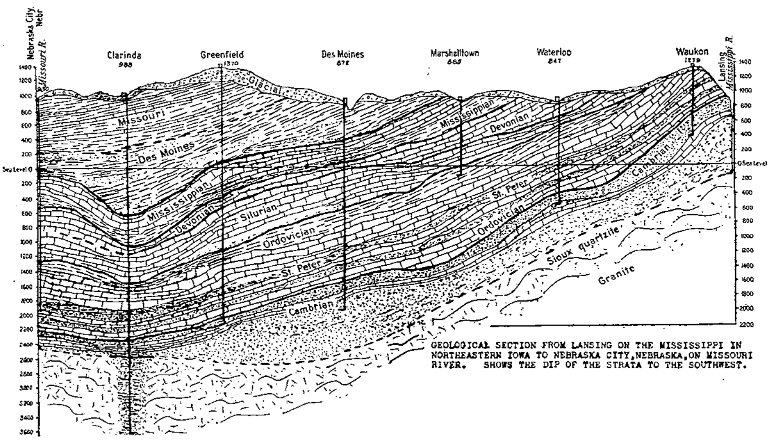


Fig. 1. Section showing strata across Iowa. The dip of the beds is greatly exaggerated.

Arch, and in South Dakota and northwestern Iowa by the Sioux Uplift. All of these high areas are very old, even as geologic time goes, and for many ages they have strongly influenced the structure of the upper Mississippi valley and also have supplied much material for the Iowa rocks. This means, then, that this basin has been existent in some form nearly all of the time during which our strata have been in the making. In the quiet periods of the continent's history, when sediments were being brought into the shallow continental ocean, this basin was filled with such sediments — sands, clay mud and limy oozes — and probably sank as it filled. Then with the coming of a period of unrest the basin was elevated above the ocean, the sediments were hardened, and doubtless some of them were eroded and carried away to the distant seas. Another period of depression (structural, not financial) followed, the basin was again flooded and deposition of sediments was resumed. This cycle has been repeated time after time in the Mississippi valley, as elsewhere, and the changing types of deposits, as well as their relations to each other, bear witness to changing conditions and alternate mastery of contending forces.

Because of the presence of the various high areas on the north the slope of the basin's floor is toward the south, or, more accurately, toward the southwest. Naturally, therefore, the strata are thinner in northern Iowa than farther south; they are also older, older at least than the upper beds in southern Iowa. The sections across the state will show this character to the best advantage, and a few examples may be helpful. The axis of the trough extends across Iowa from the vicinity of Mason City southwest to Clarinda and so into Missouri. The strata that at Mason City are 400 feet above sea level at Clarinda are 2,000 feet below sea level — they have declined 2,400 feet in the 200 miles between the two cities, an average slope of 12 feet per mile. An east-west section across the southern counties shows that a given bed which at Fort Madison is 40 feet above sea level at Lamoni is 400 feet below sea level, at Clarinda has sunk to 1,050 feet below sea level and at Nebraska City has risen to 510 feet below sea level.

It should be clear that this basin does not terminate with the southern boundary line of Iowa. On the contrary it extends southward in Missouri until it reaches the Ozark Uplift. To the southwest it stretches, with local interruptions, into Oklahoma and Texas. In it were formed the coal beds that contribute so important a share to the mineral wealth of Iowa, Missouri, Kansas and Oklahoma. In it were distilled also the enormous quantities of petroleum and natural gas that make the southwestern interior one of the great oil fields of the world.

The Rocks and Their History

The General Succession of the Strata. — So far I have laid emphasis chiefly on the structural features of our geology, the lie of the land, so to speak. Now I should like to discuss briefly the character and succession of our strata and the history of the times in which these strata were being built up as well as the history of those other times when different forces were in control and different results were being achieved.

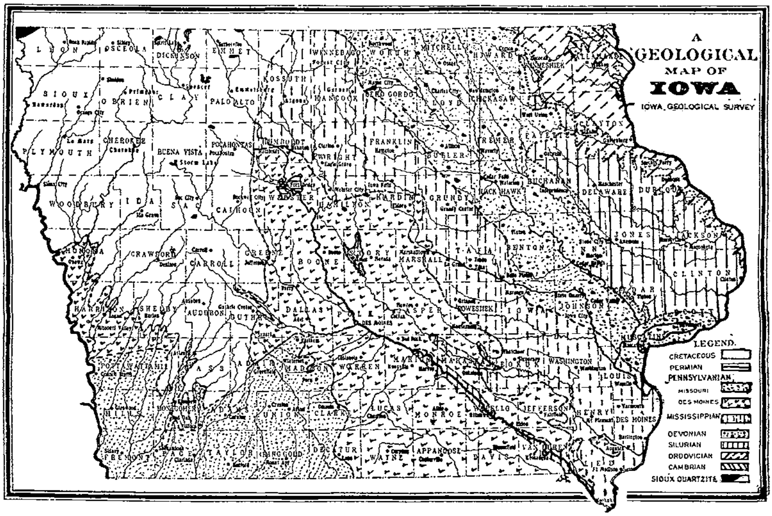
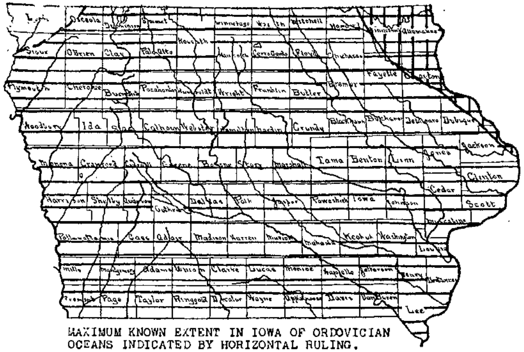


Fig. 2. Geological map of Iowa

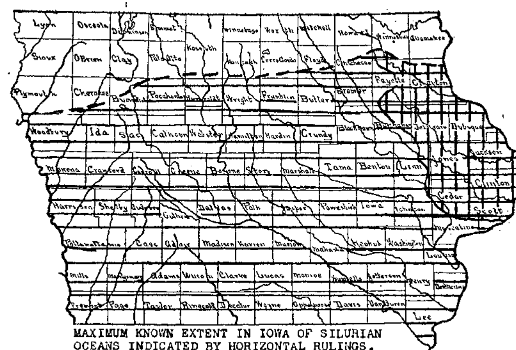
Geologic time is divided into eras, periods and lesser divisions; the rocks formed during these time divisions are classed as groups, systems and smaller units. Usually the same names are applied to the time divisions and the rocks formed during those divisions. The following table shows the succession of geologic chronology and rock formations. The common rocks are not listed, as they were formed in every period.

Era (Time) Group (Rocks)	Period System	Estimated Time	Rocks and Minerals	Chief Life Forms
Cenozoic (Recent life)	Pleistocene (Glacial)	1,000,000	Glacial clays and sands	Man
	Pliocene	9,000,000 (10,000,000)*		Mammals,
	Miocene	15,000,000 (25,000,000)	Oil, gas, coal	birds,
	Oligocene	15,000,000 (40,000,000)	No rocks in	modern
	Eocene	20,000,000 (60,000,000)	Iowa	plants
Mesozoic (Middle life)	Cretaceous	60,000,000 (120,000,000)	Coal, oil, gas, salt, gypsum	Reptiles, primitive birds and flowering plants
	Jurassic	25,000,000 (145,000,000)	No Jurassic or Triassic in Iowa	
	Triassic	25,000,000 (170,000,000)		
Paleozoic (Ancient life)	Permian	40,000,000 (210,000,000)	Red shales and sands, gypsum, salt	Amphibia, insects, primitive conifers
	Pennsylvanian	45,000,000 (255,000,000)	Coal, oil, gas, salt	Early reptiles, fernlike trees
	Mississippian	30,000,000 (285,000,000)	Oil, gas, coal, gypsum	Sharks, land floras
	Devonian	40,000,000 (315,000,000)	Oil, gas	Fishes, early land plants
	Silurian	25,000,000 (340,000,000)	Iron, salt, oil, gas	Lung fishes, insects
	Ordovician	60,000,000 (400,000,000)	Oil, gas, lead, zinc, marble	Early fishes and land plants, corals
	Cambrian	90,000,000 (500,000,000)	Marble, Quartzite	Trilobites, brachiopods, algae
Proterozoic (Very old life)	Several divisions	500,000,000 (1,000,000,000)	Iron, copper, igneous and metamorphic rocks	Primitive aquatic plants and animals
Archeozoic (Very primitive life)	Several divisions	500,000,000 (1,500,000,000)	Igneous and metamorphic rocks. None exposed in Iowa	Very primitive life in oceans
Pregeologic time, maximum igneous activity, beginnings of life.				

* Total duration to present time.



MAXIMUM KNOWN EXTENT IN IOWA OF ORDOVICIAN OCEANS INDICATED BY HORIZONTAL RULING. PRESENT SURFACE EXTENT OF ORDOVICIAN BEDS IS SHOWN BY VERTICAL RULES.



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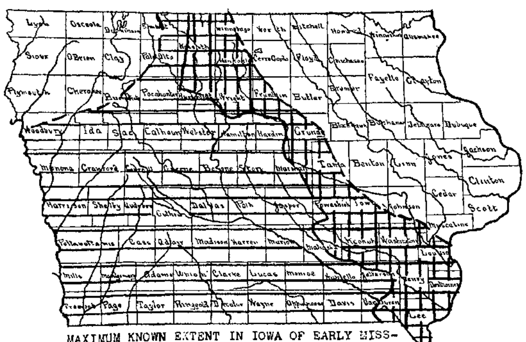

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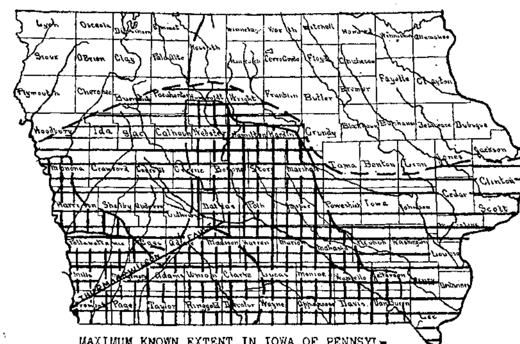

MAXIMUM KNOWN EXTENT IN IOWA OF PENNSYLVANIAN SEAS INDICATED BY HORIZONTAL RULING. PRESENT SURFACE DISTRIBUTION OF PENNSYLVANIAN STRATA SHOWN BY VERTICAL LINES.

Fig. 3. Extent of seas in Iowa during different periods

No rocks of the pregeologic ages are known at the present surface of the earth, at least not in their original condition. All are merged with or covered by rocks of later formation. Rocks of the Archeozoic era are chiefly igneous, with minor sedimentaries, all highly altered — metamorphosed — into schists — flaky rocks — and similar types that show evidence of great change in character. As I have suggested before these rocks form the universal foundations under our state in common with other parts of the earth's crust. However, they come to the surface nowhere in the state and have no direct effect on our underground geology. The Archeozoic granites and schists have been reached in wells at Decorah, Algona, Le Mars, Sioux City and Holstein, all of them in the northern counties. These rocks are exposed in the Minnesota and Lake Superior Highlands.

The real geology of Iowa, then, may be said to begin with the Proterozoic. It was an era of long duration and was marked by rocks of many varieties and of enormous amounts. The only Iowa formation assigned to this group is known as the Sioux quartzite and occupies only a very small share of the Proterozoic section. The Sioux quartzite is a sandstone that has been recemented to extreme hardness by silica. It owes its name to the fact that it is widely exposed over a region centering about Sioux Falls and along Bix Sioux river — the Sioux Uplift. In Iowa it comes to the surface only in the northwest section or two of Lyon county, in the extreme corner of the state. The best exposures are now safeguarded in Gitchie Manitou State park. However, it doubtless underlies the entire state, and it has a maximum thickness of well over a thousand feet. It has been reached in wells as widely separated as Inwood, Lansing, and Tipton.

The Paleozoic strata are by far the most important in Iowa's bed-rock geology. In fact only three other formations are present in our geologic column — the Sioux quartzite and two stages of the Cretaceous — all of them mere fragments of the rock groups they represent. A similar importance holds true for the continent as a whole, although the post-Paleozoic rocks are very abundant in some of the southern and western states.

The oldest system of Paleozoic rocks, the Cambrian, is exposed in Iowa only along Mississippi river and its tributaries, and north of McGregor these rocks form an increasingly large share of the magnificent bluffs that guard the great valley. Below the three hundred feet that rise above the river at New Albin, in the northeast corner of Iowa, these strata extend downward to a depth of about seven hundred feet, making them one of the thickest systems in the Iowa sequence. The sandstones are very porous, especially in the northeastern part of the state, and form one of the best and most widespread water-bearing beds of the continent.

Because of the troughlike structure of the Iowa beds the strata of eastern Iowa come to the surface or underlie the glacial drift in irregular belts that extend in a general northwest-southeast direction. From these belts of outcrop they extend beneath the younger strata far beyond the limits of the state. The relative horizontality of the beds permits a wide areal distribution of each system, in spite of the basin structure and in spite also of the fact that these beds are thinner here than in some states. Therefore the diversified strata of Ordovician age cover several counties in northeastern Iowa and completely conceal the underlying Cambrian beds except where these have been revealed by the streams. The beautiful scenery of the Switzerland of Iowa is carved chiefly in these Ordovician rocks and to some extent in those of the underlying and overlying systems, and the enduring character of many of these strata makes possible the rugged charm of this most delightful corner of Iowa. The strata of the Silurian system, of the Devonian, the Mississip-

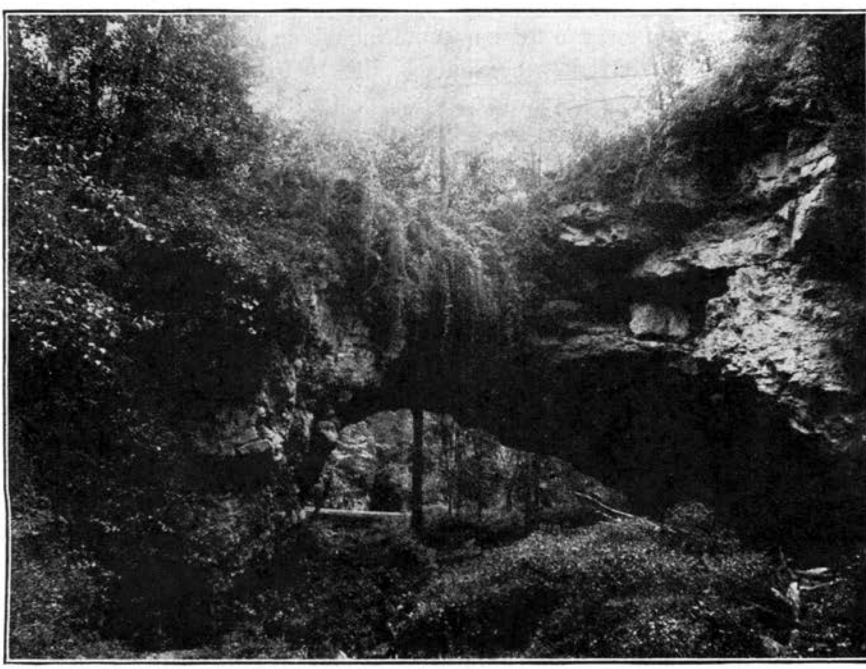

Fig. 4. The natural bridge at Maquoketa Caves, State Park, Jackson county, Iowa. The bridge is formed in strata of Silurian age.

pian and the Pennsylvanian systems have similar superficial distribution, and the Pennsylvanian rocks seem to have so nearly filled the great basin that it has had slight influence if any on later sedimentation. The lead ore that made Dubuque a famous frontier post a hundred years ago and that gave its name to the town of Galena was mined from the Ordovician limestones; the shales that for years made Mason City the drain tile center of the world, and the millions of barrels of portland cement that flow from the Davenport and Mason City factories yearly are taken from strata of Devonian age. The coal that is hoisted from so many Iowa mines to heat our homes and drive our engines belongs in the Pennsylvanian strata, and the plaster that covers our walls is made from gypsum quarried in the patch of Permian beds in Webster county or from deep-lying layers of Mississippian strata in Appanoose county.

One of the remarkable features of the underground extensions of the surface strata is the fact that for scores and even hundreds of miles many of them retain their identity and characteristics to such a degree that wherever found they may be recognized. For instance a bed of brown bituminous Ordovician shale that outcrops in the bluffs above Dubuque was found in the Clarinda oil prospect 2,950 feet below the surface. It retained similar characters and served as a reliable horizon marker for locating other deep-lying strata. Certain beds of gypsum that are present in the Silurian of some eastern states but that are absent from the exposed Silurian of eastern Iowa have been penetrated in deep wells in central and western Iowa, as at Grinnell and Greenfield. On the other hand the Pennsylvanian strata change from the richly coal-bearing beds of the area of outcrop in central and southern Iowa to more barren beds in the western counties.

Another noteworthy feature of the strata is their general uniformity of thickness throughout the state, as is shown by the shale just mentioned, which is about 10 feet thick at Dubuque and at Clarinda. Of course there are local differences, such as a thinning of the Devonian beds from 125 feet at Greenfield to 85 feet at Clarinda, but in general the thicknesses of the rock systems under various parts of the state stand at fairly even figures. This is not entirely true, however, for the southern states. In an oil prospect near Clarinda, in the trough of the syncline, the entire Paleozoic group of strata is over 5,200 feet thick. In Arkansas, on the other hand, the Mississippian and Pennsylvanian alone are 18,000 feet thick, and in the Ardmore Basin of Oklahoma the Paleozoic beds

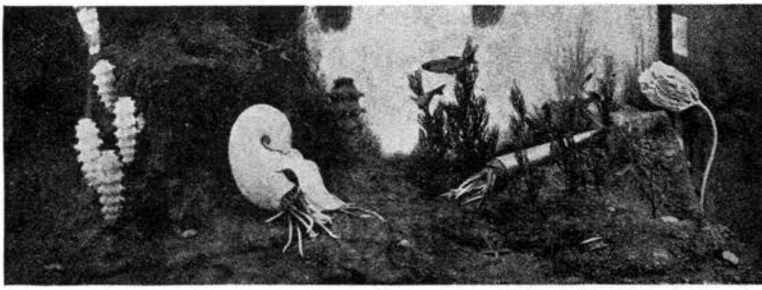

Fig. 5. Restoration of Devonian marine life in New York. New York State Museum, Albany.

are estimated to reach a depth of 40,000 feet. Most of the thickening to the south of Iowa seems to be in the Mississippian and Pennsylvanian. The lower systems in general retain approximately the thicknesses they have farther north.

Still another feature that must be kept in mind is the absence of some of the strata from northwestern Iowa owing to their wedging out on the flanks of the Sioux Uplift. This fact is of importance in seeking for water or for other materials that are to be expected in certain strata, and ignorance or ignoring of it has cost a number of cities and citizens dearly.

The Historical Record. — From a study of the strata we may gain a knowledge of their origin, deposition and later history. We know that much of the material of which they were built came from the higher lands to the north. We know also that most of them were deposited in rather shallow oceans that advanced progressively over the lands, usually from the south, but in a few instances from the north or west. Nearly all of the Iowa strata are salt water, oceanic deposits. In course of time these materials have hardened into sandstones, shales and limestones, and with their fossil contents have given us a partial record of those far-off days.

But the relations of many of the strata show that they were not deposited in immediate succession. Indeed we know that in many cases long periods of time intervened between the formation of what are now successive beds. We have here a gap in the record that may involve thousands and possibly millions of years. What was occurring in the interval between the formation of the beds? I have already suggested the probable history of the sediments in discussing the basin structure — elevation, induration, erosion, transportation, deposition — the endless cycle that never ceases. If this interval occurred during one of the early geologic periods the land was probably barren and desolate, though the seas would be teeming with life — primitive in the earliest periods, more advanced as time progressed. The oldest Iowa strata, the Sioux quartzite, contain no fossils, so far as is known, although life was abundant in other seas. The next younger, the Cambrian, contain some highly developed types of invertebrate animals along with some much more lowly types. The earliest of the backboned animals, the fishes, seem to have originated, or at least taken definite character, during the Ordovician, and the same is true of land plants. It was not until the Devonian, however, that these forms came to be important members of their respective life groups. Devonian rocks yield specimens of the oldest known forests and also multitudes of wierd, bizarre armored fishes — the masters of the Devonian seas.

Fig. 6. Restoration of forest of Devonian seed ferns in New York. New York State Museum, Albany.

Later came sharks and amphibia, and following these were reptiles and birds, which became the dominant forms in the waters, on the land and in the air during Cretaceous time. During Pennsylvanian time plant life was remarkably abundant, and some of it has been preserved to our day in the coal beds we find so useful. Marine sedimentation had practically ceased in Iowa, however, before the mammals became very important.

It used to be said that Iowa had spent more time as ocean floor than as dry land. A few years ago Doctor Thomas made a study of this question, dividing geologic time into the following percentages: Archeozoic, 30; Proterozoic, 25; Paleozoic, 30; Mesozoic, 11; Cenozoic, 4. Only Paleozoic and later time was considered. My estimate of the problem was that during the period considered Iowa

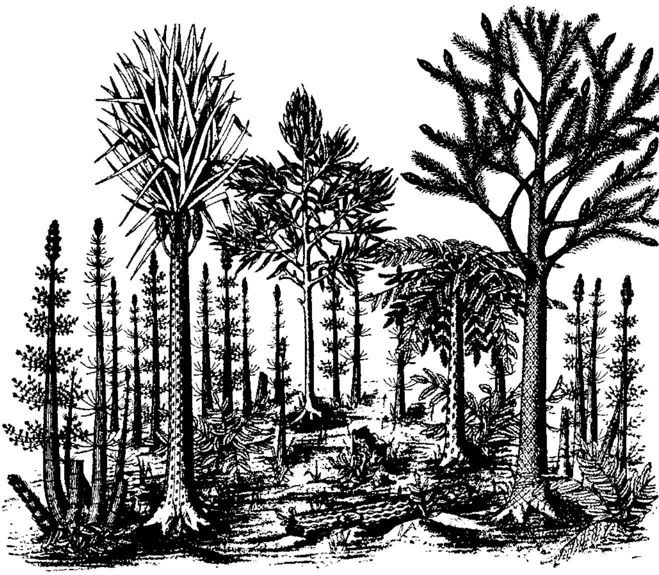

Fig. 7. A forest of ferns, club mosses, horsetails and other coal making plants of Pennsylvanian time.

had been under water about one-third of the time. This at least gives a basis for considering the changes that have taken place — construction and destruction of successive topographies, elevation and depression of the lands, weathering and erosion of the rocks and redeposition of minerals — but in our state at least all progressing slowly, quietly, with comparative peace and uniformity.

It may seem unorthodox to state that during known geologic time Iowa's climates have been for the most part mild and equable. Please banish from your minds the picture of boiling oceans, of dense, impenetrable atmospheres, of hot unhealthful climates — all proceeding, however, toward ultimate refrigeration, final destruction. The evidence is all to the contrary. To be sure there have been times of colder climates, even of glaciation in various parts of the world. In fact there is scarcely a system of rocks later than mid-Proterozoic that does not somewhere give evidence of the presence of more or less extensive glaciers. Probably the greatest glaciation of all time occurred during the Permian, while that second in degree is the one from which the northern hemisphere has recently emerged — that of the Pleistocene. There have likewise been periods of severe aridity, as is attested by the gypsum beds of the Permian, such as that at Fort Dodge, by similar beds in the Silurian, as already mentioned, by the salt beds of New York, Michigan, Kansas, and especially those of Europe, some of which are over a thousand feet thick. Nevertheless the statement holds good that the normal climatic conditions during known geologic time have been moderate and favorable to life development. It must be significant, however, that man has evolved among the more or less severe conditions of glacial and interglacial climates.

Summary

To sum up our underground geology very briefly, then, while our state is cradled on a bed of igneous and metamorphic rock the overlying strata are almost universally of sedimentary character, laid down on the floors of oceans that have repeatedly flooded these parts of the continent. There are no mountains or major deformations and the strata still lie in nearly their original positions. The most important structural feature is a wide trough that embraces the entire state and that affects the attitude of nearly all the beds, giving them gentle dips southward and toward the axis of the trough. There are numerous gaps in the succession of the beds, suggesting that our area has been under water and subject to sedimentation only about one-third of the time since the beginning of the Cambrian, apparently much less during pre-Cambrian time. The ancient climates were in great part mild and uniform, although some were cold, some were dry. It is, however, a biologic necessity that since early geologic time, that is early Archeozoic, the atmosphere has varied but little from its modern character and climates have ranged only slightly from the normal. Life has been protected from its beginnings to the present.

Our underground geology unfolds as a fascinating panorama, and its study reveals a story of continuous progress, from primeval creation toward present day — not perfection, but definite trends in that direction.

Iowa Geological Survey,
Iowa City, Iowa.