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Geology, Geologic Time and Nebraska

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by Marvin P. Carlson

Educational Circular No. 10

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Conservation and Survey Division
Institute of Agriculture and Natural Resources
University of Nebraska-Lincoln

University of Nebraska

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Introduction and Acknowledgments

This publication provides an overview of the geologic framework of Nebraska and some explanation as to how this framework was created. To do this, we must understand a little about the science of geology. We must also have a sense of the immense magnitude of geologic time. Brief glimpses are given of the vast panorama of the geologic history of our state. With this information as background, we can begin to realize how geologic history has created patterns in nature that affect our daily lives.

The environment has come to be one of our major concerns, but the concept "environment" can mean many things to many different people. Basic to environmental quality is an understanding of the planet's natural systems--what they are, how they got there, and most importantly, how are they going to react as we put stress on them. The pattern of our geologic history is the common link within the natural systems.

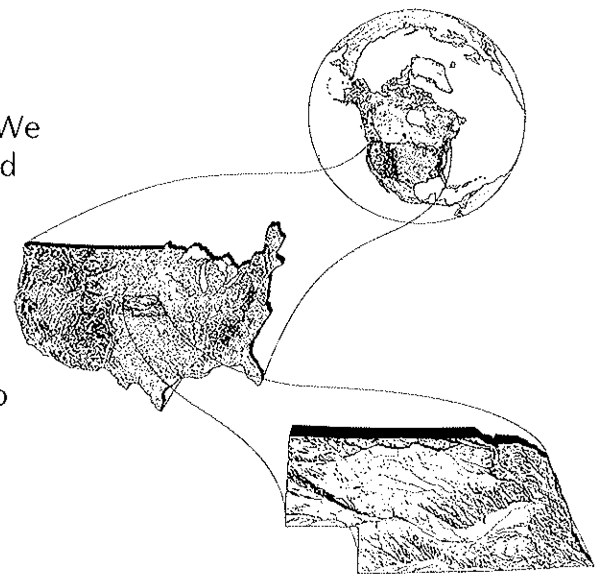
Many reports, maps and publications deal with these topics in Nebraska and across the region. Several are mentioned in the text. Many scientists have devoted years of study toward understanding Nebraska's geologic framework. This broad picture is drawn from their work. Numerous citizens of our state have provided information, support and access that allowed the research to be successful. These contributions are gratefully acknowledged.

The reviews of Duane Eversoll, Duane Mohlman, Jim Swinehart and Brian Witzke are gratefully acknowledged. Alan Cook and Dee Ebbeka drafted the illustrations.

The focus of the publication is on geology. The specific information provided should be of interest to a wide range of readers. More importantly, it is hoped that the reader will gain a sense of the immensity of geologic history in time and space. This perspective is the key to understanding the relationships we have with the natural world around us.

What Is Geology?

Geology is the study of the history of the earth. This study includes much more than the few hundred years of the history of the United States or the nearly 5,000 years of what we usually call "world history." Geologists are concerned with events and materials that extend into the history of the earth nearly *5 billion years.*



Each of us is interested in the world around us. We are curious about why there are continents and oceans, mountains and deserts and, even closer to home, the hills and valleys around us in Nebraska. And whether we realize it or not, we are dependent on the earth and its natural resources for our daily life. To discover and wisely use these natural resources, we need to know how and why they are formed.

For example, are we always going to have clean water every time we turn on the faucet? And where does this water come from? How did it get to a place where we could pump it? Where was it before that?

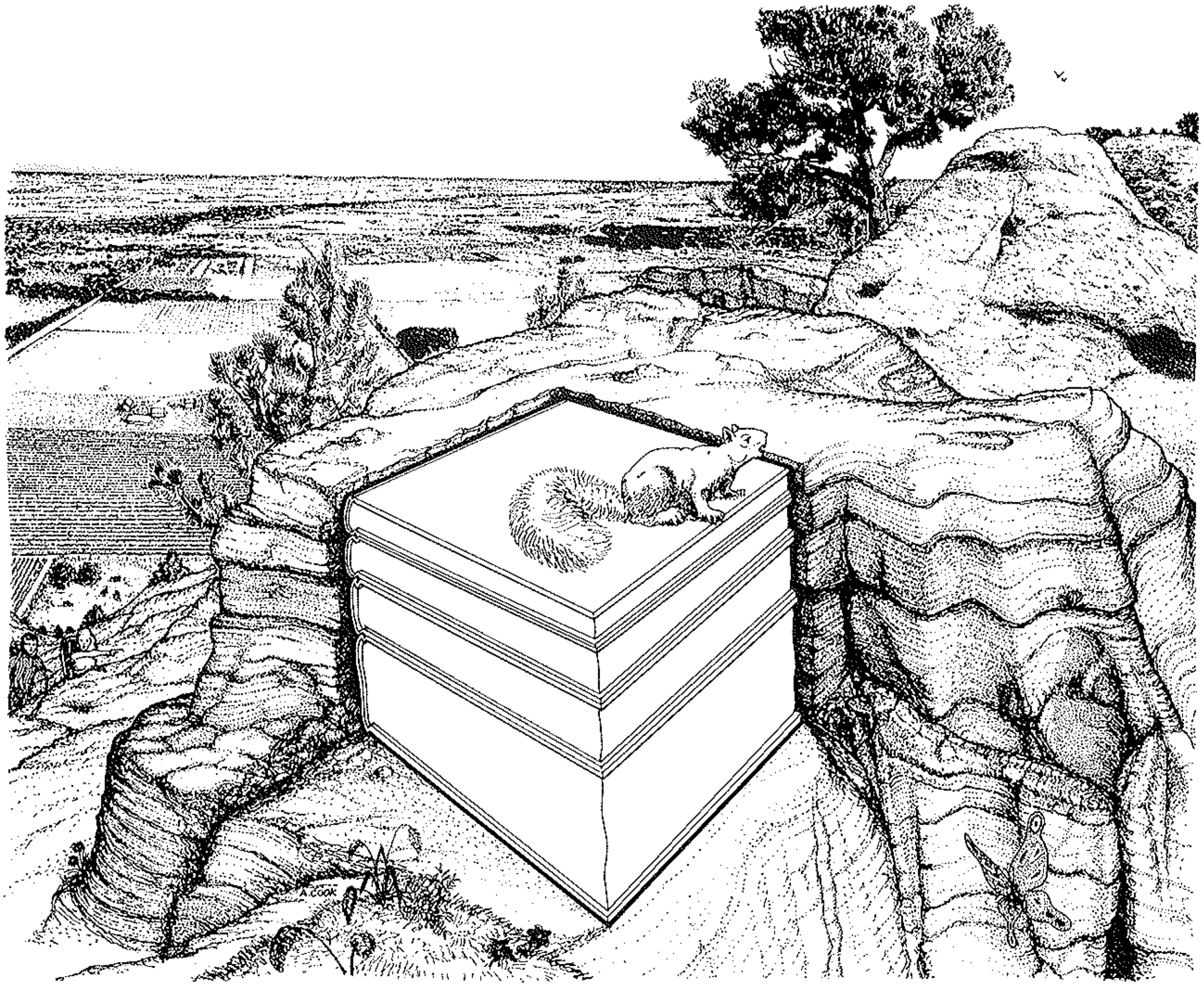
In addition, Nebraska is well known for its rich soil and agriculture. Where did this soil come from and why don't other areas have it?

Why are our cities and towns built where they are?

Might there be a gold mine or an oil well in our backyard?

These are some of the questions geology can answer by providing us with an understanding of the history of the earth.

Where do we go to discover this history? We certainly can't go to the library to find out how to train and feed a pet dinosaur, for example. Why not? Because no one was alive to write down facts about dinosaurs when dinosaurs were alive. There is no encyclopedia to tell us how deep the oceans were in Nebraska 400 million years ago. We don't have history books about geology like those that tell us about the adventures of Columbus or the life of Abraham Lincoln.

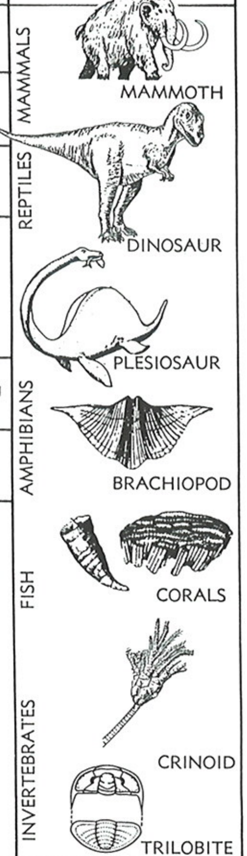


Alan Cook

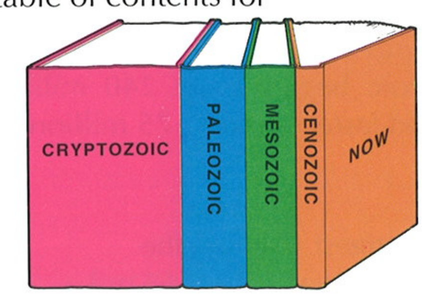
However, there is a "book" that tells us about geologic history. It's the earth under our feet. The big difference is that the story is not told in words and sentences but by layers of rocks. Each layer of rock is like a page telling us what was happening at a particular time in the earth's history.

One layer might tell us that if we had been in eastern Nebraska 800,000 years ago, we would have been covered by ice hundreds of feet thick. Another layer would show us that if we had been there 100 million years ago, we would have been sitting at the bottom of an ocean with giant reptiles swimming around us. Or, 300 million years ago, we would have been on the top of a mountain. But one rock layer is like a single page. We have to know where each layer fits in our rock book of geologic time.

AGE (MILLIONS OF YEARS AGO)	GEOLOGIC TIME UNITS		ROCK TYPES	MINERAL RESOURCES AND PRODUCTS	TYPICAL FOSSILS
1.6	CENOZOIC (RECENT LIFE)	QUATERNARY (Recent and Pleistocene)	Glacial till, silt, clay, sand, gravel, volcanic ash.	Agricultural soil, water, sand & gravel, volcanic ash.	
66		TERTIARY	Sandstone, siltstone, clay, gravel, marl, volcanic ash.	Agricultural soil, water, sand & gravel, volcanic ash, riprap & uranium.	
138	MESOZOIC (MIDDLE LIFE)	CRETACEOUS	Chalk, chalky shale, dark shale, varicolored clay, sandstone, conglomerate	Water, oil & gas, cement, brick, agricultural lime, & other construction materials.	
205		JURASSIC	Subsurface only. Sandstones and shales		
240		TRIASSIC			
290	PALEOZOIC (ANCIENT LIFE)	PERMIAN	Shale, limestone, dolomite, gypsum, anhydrite, sandstone, siltstone, chert.	Water, agricultural lime, oil, road rock, riprap.	
330		PENNSYLVANIAN	Limestone, shale, sandstone, coal.	Oil, cement, brick, concrete aggregate, lightweight aggregate, road rock, agricultural lime, rip rap, water.	
360		MISSISSIPPIAN	Subsurface only. Limestone, dolomite.	Oil, water.	
410		DEVONIAN	Subsurface only. Dolomite, gray shale.		
435		SILURIAN	Subsurface only. Dolomite.		
500		ORDOVICIAN	Subsurface only. Dolomite, sandstone, shale.		
570		CAMBRIAN	Subsurface only. Dolomite, sandstone.		
5,000 ?	CRYPTOZOIC (HIDDEN LIFE)	PRECAMBRIAN	Subsurface only. Granite, other igneous rocks, and metamorphic rocks.		?



The illustration above shows how our rock book is organized. Look first at the column of geologic time units. This is really like a table of contents for our geologic history.

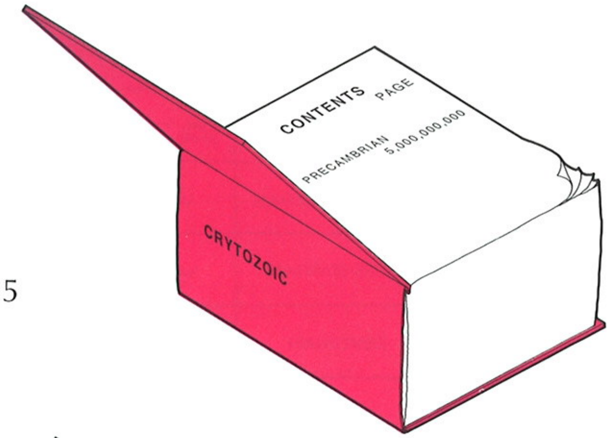


The story is told in four big volumes:
the Cryptozoic, which means *hidden life*;
the Paleozoic, meaning *ancient life*;
the Mesozoic, meaning *middle life*;
and the Cenozoic, which means *recent life*.

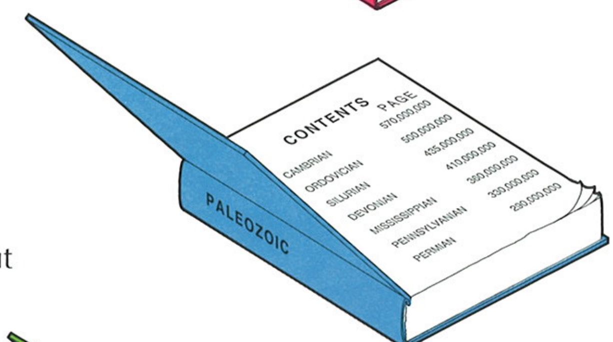
These big volumes of rock layers have been divided into "chapters." Along the left side of the chart are numbers telling us how long ago, in millions of years, each chapter began. By comparing these numbers, we can get some idea how many rock layers and how much history each geologic volume contains.

Most geologic units have a geographic name. That is, whenever a new series of rock layers is described, they are given a name related to their location. For example, the rock units of Devonian age were first described in the County of Devon in southwestern England. If other geologists want to better understand or relate other areas to the reference rock unit, they can examine the "type locality." These names make up the chapter headings in our rock book.

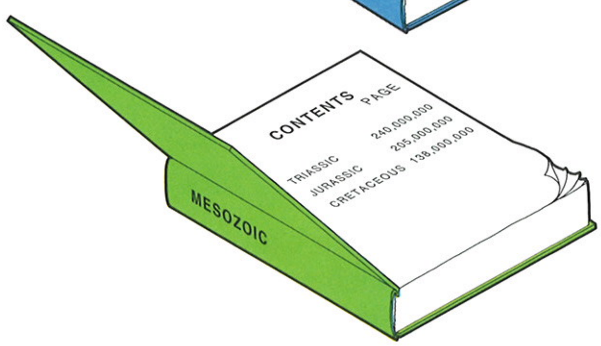
The Cryptozoic is the oldest and biggest volume and contains one chapter, *the Precambrian.* This unit of geologic history began about 5 billion years ago and lasted for nearly 4.5 billion years.



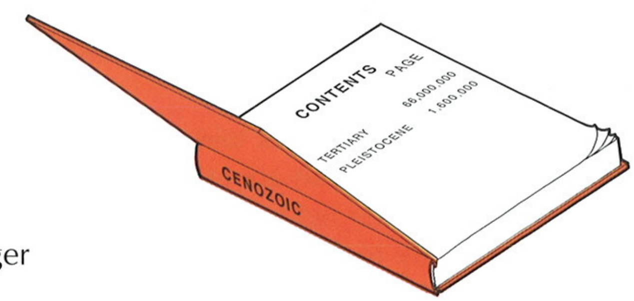
The Paleozoic volume began about 570 million years ago with the *Cambrian* chapter. This geologic time unit was followed by the younger chapters: *Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian,* and *Permian.* The Paleozic lasted about 330 million years.



The bundles of Mesozoic rock layers are called the *Triassic, Jurassic,* and *Cretaceous*. The Mesozoic began about 240 million years ago and lasted almost 175 million years.

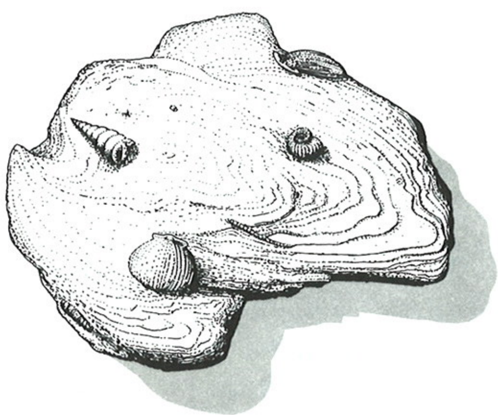


The youngest volume, the Cenozoic, began about 66 million years ago and contains the *Tertiary* and the *Pleistocene* and, our current time unit, the *Holocene*, or *Recent*. As with the older chapters, the age column on the chart tells us how much history these younger chapters contain.



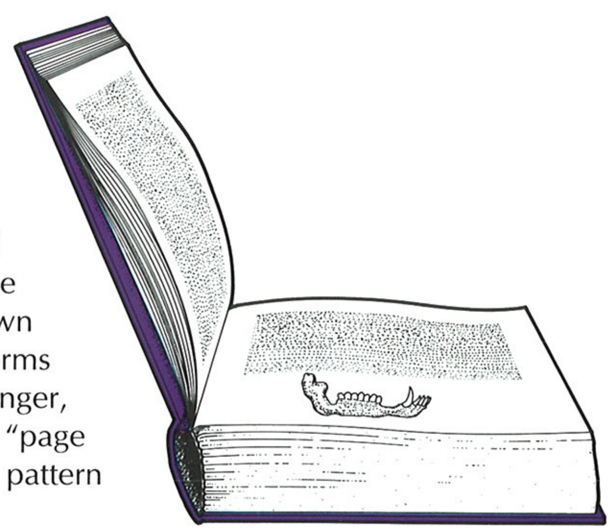
Just as the chapters in ordinary books contain many pages, each of our geologic time units contains many, many layers of rocks. The Pleistocene, for example, started only about 1.6 million years ago, so it's really a thin chapter. The Silurian, a much larger unit, started about 435 million years ago and ended about 410 million years ago. It covers 25 million years and contains many layers of rocks. So, you can see, we do have a book about geologic history, only it's recorded in layers of rock by nature, rather than written in words by people.

Now we know that in places like Nebraska, we can't just walk outside and see a tremendous pile of rocks with many layers telling us the history of the earth. More often we find a few layers along a roadcut or in a riverbank. So how can we tell where in this big book of geologic history these few layers of rock belong?



If we look closely, we can often see more than just rock. There may be shells, bones, teeth, or even footprints contained in the rock, all of which are rock-bound evidence of former life we call fossils.

These fossils are like page numbers that tell us where in our geologic history book these layers belong. This is true because at any particular time in the history of the earth, there were certain kinds of plants and/or animals living, and they were a little different from those that had lived earlier or later. And, of course, all these forms of life are related by the broad pattern of evolution. This pattern is known by the change in the fossil record from simple forms of life contained in the older rocks to the younger, more complex organisms. So we look at these "page numbers" and link them up with the overall pattern provided by all of evolution.



Alan Cook

Early in geologic history we find invertebrate fossils (animals without backbones). Later, more complex fossils appear such as fish. Then came the amphibians (animals that can live on either land or water) and finally the air-breathing creatures such as the dinosaurs. Most recently, mammals (warm-blooded animals) have become important and include complicated forms of life like humans. Of course, some of the simplest forms of life, such as algae (one-celled plant-like lifeforms), which first appeared in the Precambrian, are still living today. Some fossils are easier to recognize than others and are more useful to us as page numbers identifying the rock layers. A few of these are shown in the illustration above.

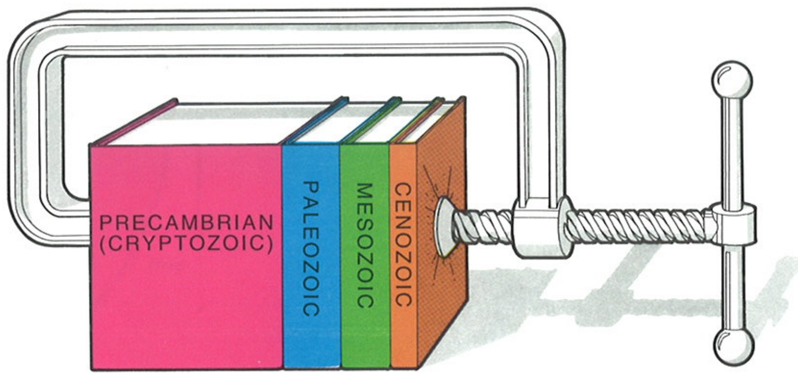
Fossils are important in other ways than just as page numbers. If we look closely at the kind of fossil and the kind of rock, we can get a good idea of what the environment was like when the fossil was alive. For instance, if we find a rock layer such as limestone with brachiopods *(see geologic time chart)* and other fossil seashells in it, we know that there was an ocean there when they were alive. If we find dinosaur bones and plant fossils in a mudstone or sandstone, we can imagine a land area or a swamp. By closely examining the rock layers and the fossils at the surface and in rock samples obtained by test drilling or drilling deep wells in search of oil and gas, we can discover the geologic history of any particular place.

We can see that geologic history is not too different from the history of the United States or world history. We do, however, have to learn to "read" and understand layers of rocks rather than words and sentences.

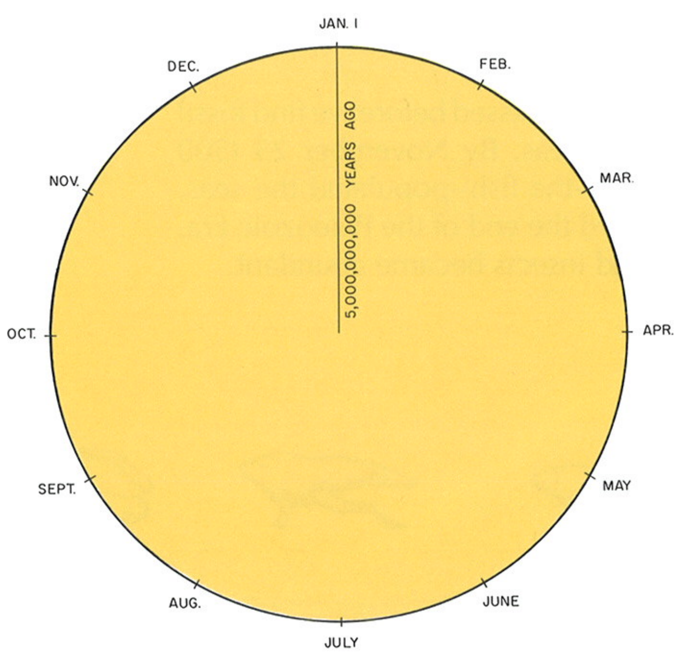
It is important to realize that many, many more years are included in our book of geologic history than in any history book. Even the soil under our feet may have taken thousands of years to form. And humans can easily destroy features of the landscape that have taken millions of years to develop. But by using our rock record--our collection of information on the rocks and our imaginations--we can better understand the vast number of years included in geologic history.

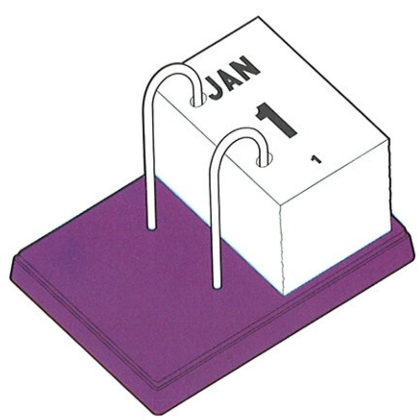
Geologic Time

Suppose we could take all of the rock layers that record the 5-billion-year history of the earth and squeeze them down to just *one imaginary year.*

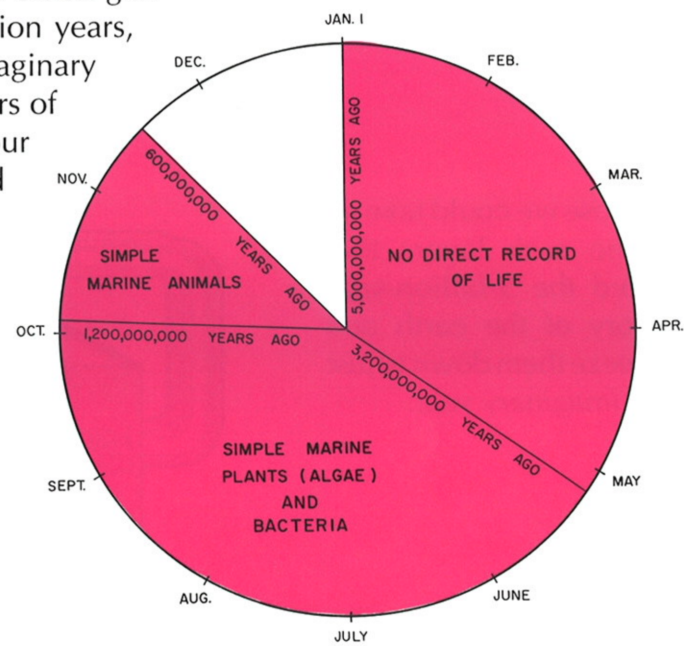


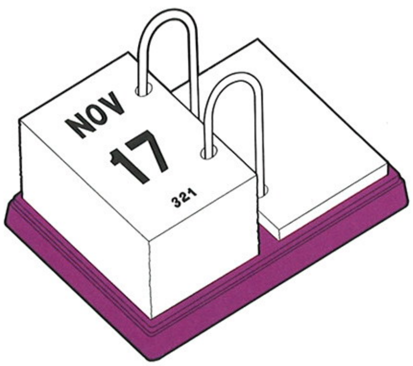
The earth's history would begin on January 1 and bring us to the present at midnight on December 31. Each day of our year would equal about *13.7 million years* of earth's history, and each imaginary second would equal *158 years* of geologic time.



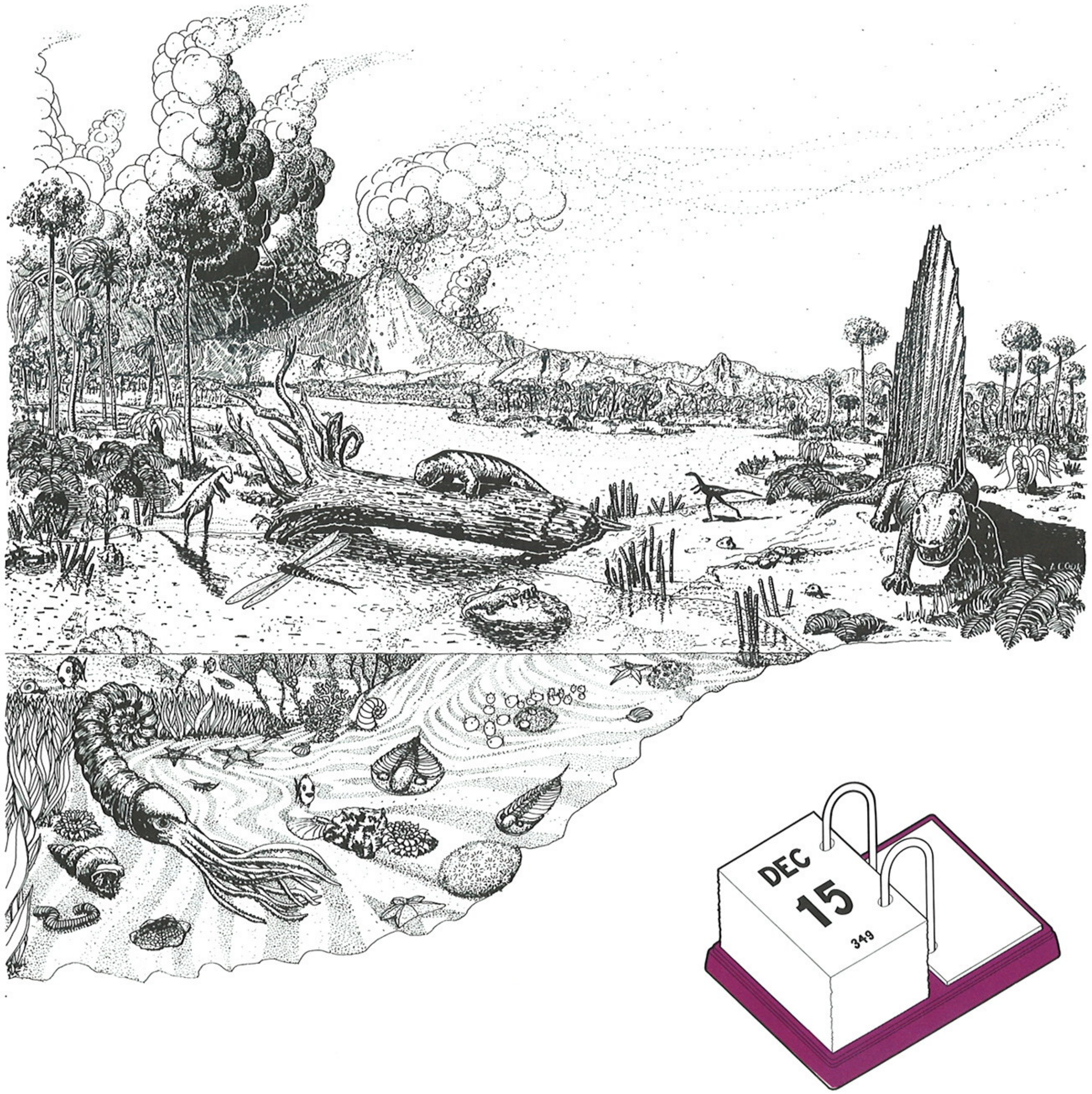


The Precambrian (or Cryptozoic) Era, the oldest geologic time unit that lasted about 4.5 billion years, would take until November 17 of our imaginary year. And for about the first 2 billion years of geologic history or until May 11 of our imaginary year, we have no direct record of life on earth. During most of the Precambrian Era, only simple forms of life were present. As mentioned earlier, some of these, such as algae, are still living today.

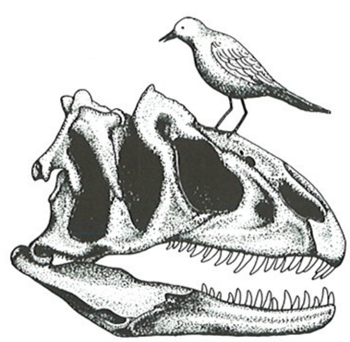


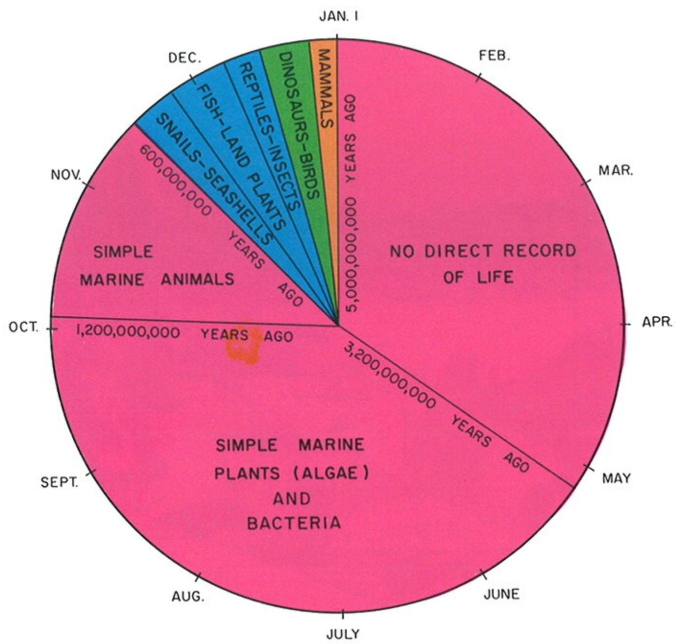


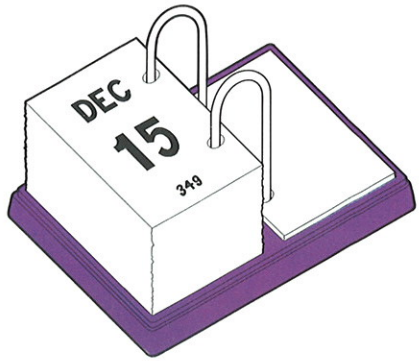
More than 11 months of our imaginary year have passed before we find fossil evidence of abundant life in the Paleozoic seas. By November 25 (500 million years ago), animals with backbones--the fish--populated the seas, and plants were growing on the land. Toward the end of the Paleozoic Era, in mid-December, air-breathing reptiles and insects became abundant.

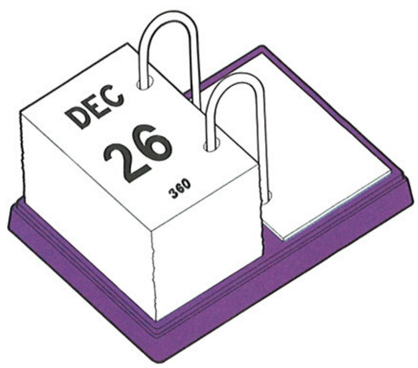


The Mesozoic Era began about 240 million years ago, or about mid-December, and lasted until about December 26. This part of geologic history is better known as the age of the dinosaurs. These animals were of all sizes, from a few inches to many tens of feet, and lived on land, in the sea, and in the air. They became extinct about 70 million years ago, long before early humans appeared on the earth.

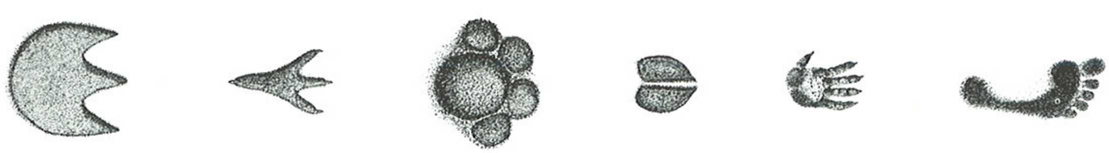




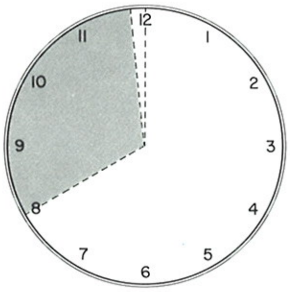




On December 26--or 66 million years ago--the last volume of our geologic history began. This era, the Cenozoic, includes only the last five days of our imaginary year. Mammals, such as camels, horses, and elephants, became important, and finally humans appeared. Nearly all of the features of our modern landscape were shaped during this relatively short segment of geologic time.



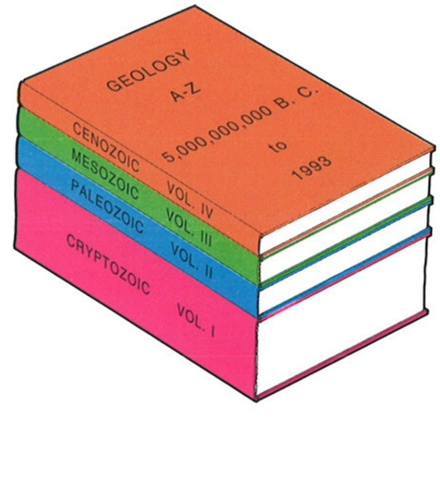
Let us look more closely at the last 12 hours of the last day of our imaginary year.



The "ice age" (most of the Pleistocene) began about 8 o'clock in the evening of December 31 and lasted until about one minute before midnight. During this time, primitive humans made their appearance.

At about 12 seconds before midnight, Jesus was born. Columbus sailed westward across the ocean at about 3 seconds before midnight. All of the history of the United States occurred within the last two seconds before midnight.

All of the events that humans have recorded as "history" took place during the very last minute of the last day of our imaginary year.



As we study our "book" of geologic history, it is important to remember the vast number of years included. Each thin rock layer and its fossils have a story to tell us about the events that occurred during their formation. These events and their ancient environments provide valuable clues to understanding our natural resources. We will examine some of these resources in later chapters.

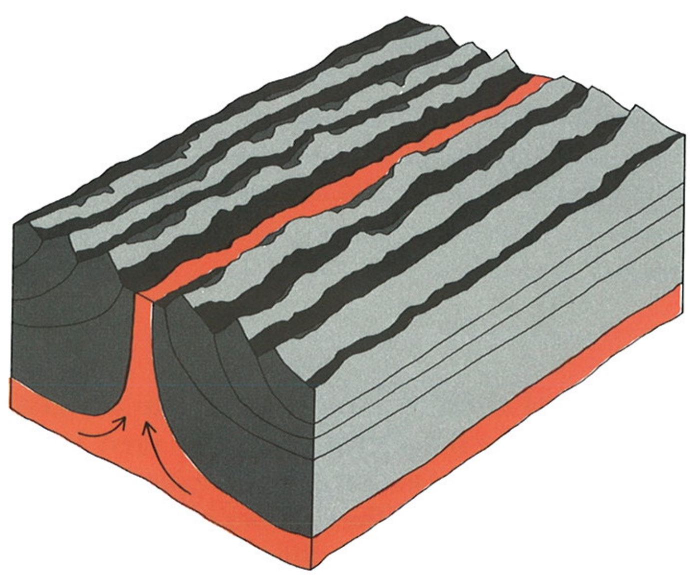
Plates and Processes

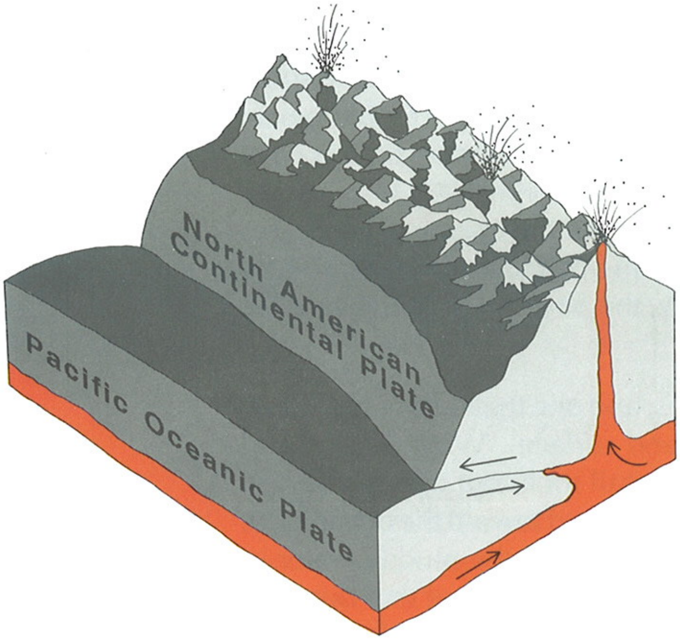
As we review the geologic history of Nebraska, we need to keep in mind the vast amounts of time involved in the story. We also need to understand some of the processes that occur as a record in rock is created. The biological processes are summarized in the fossils that we find in the rocks--both as page numbers for history and as clues to the past environments. In a similar fashion, the composition of the rocks tells us about the chemical processes that both created the rocks and then changed them. However, for the scale at which we will be telling the geologic story, the physical processes are the most significant.

One of the most important physical processes, and one that is obvious today, is the erosion that constantly attacks our land surface. Wind, water, and temperature change are continually making small rocks out of big ones and constantly moving material down the slope of the land toward the ocean. The dust we see in the air, the gullies formed on hillsides, the muddy water in streams, and even the potholes in our streets are all evidence that our land is being attacked by the elements and eroded away. The physical processes combine with gravity to level out the surface of the globe by eroding the land and filling up the ocean basins. And in the brief glimpse of geologic time that we can observe, they seem to be succeeding.

On the geologic time scale, however, there is another major physical process at work: *plate tectonics*, so named because the surface of the earth is broken up into several dozen major plates. *Tectonics* means anything related to change and deformation of the earth's surface structure. In general, each ocean basin and each continent act as a massive individual plate. These plates are constantly in motion, but very slowly--remember our geologic time scale. This movement is at about the same rate as the growth of your fingernails.

New rocks are formed by the upwelling of molten material from the earth's interior along extensive fractures in the ocean basins. The upward movement of this new material pushes the older oceanic rocks away from the fractures. The continental plates, being somewhat lighter--less dense--tend to float along ahead of the expanding oceanic plates. But if we have new rocks being formed at the earth's surface and oceanic plates becoming larger, something has to give way to make room.



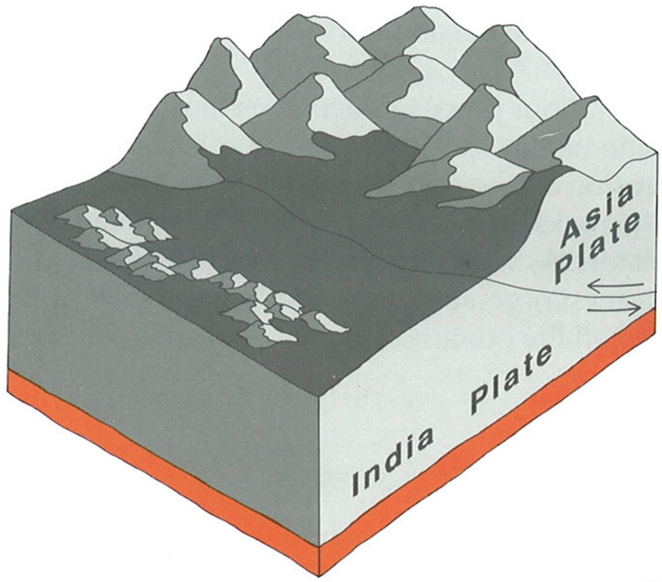


Some of the plate boundaries are expanding; others are colliding. A good example of this collision is on the west coast of North America. There the North American continental plate is colliding with and over-riding the Pacific oceanic plate. As the Pacific plate dives down, friction and increased pressure with depth raise the temperature of the rocks. Parts of both the Pacific plate and the overlying North American plate melt, and volcanoes are formed as the molten rock, under great heat and pressure, flows toward the surface as lava. This collision has created a series of volcanic mountains along the west coast of North America. Remember the eruption of Mount St. Helen's in Washington state in 1980?

Earthquakes are another result of the interaction of plates. The colliding plates don't always glide smoothly by one another. They tend to stick and, after significant stress has built up, release suddenly and jump ahead. The San Andreas Fault--a lengthy fracture system running through California--is a sign on the surface of the collision between the Pacific plate and the North American plate. The San Francisco Earthquake and the more recent "World Series" Earthquake (so called because it took place in the fall of 1989 as San Francisco and Oakland faced off in the World Series) are both the result of the North American Plate adjusting along the Californian fault systems.

This type of collision--continental plate to oceanic plate--is occurring all around the Pacific Ocean plate, as seen in the ring of volcanoes and earthquake activity in that part of the world. The eruption of Mt. Pinatubo in the Philippines during the summer of 1991 is another prominent example of the results of this kind of collision.

Sometimes there are continent-to-continent plate collisions. One of the most impressive is the result of the India plate converging with the Asian plate. The highest mountains in the world--the Himalayas--were created by this collision. Even though the most obvious evidence of plate tectonics is present at the plate boundaries, the stresses created are transmitted into the interior of the continental plates and reshape the land surface far from the collision zones. (We will see later how the formation of the Ouachita Mountains in Arkansas affected Nebraska.) Most of the major mountain belts and basins were created either directly or indirectly by plate tectonics. This elevation of old continental (and oceanic) rocks has furnished new material to restart the cycle of erosion.



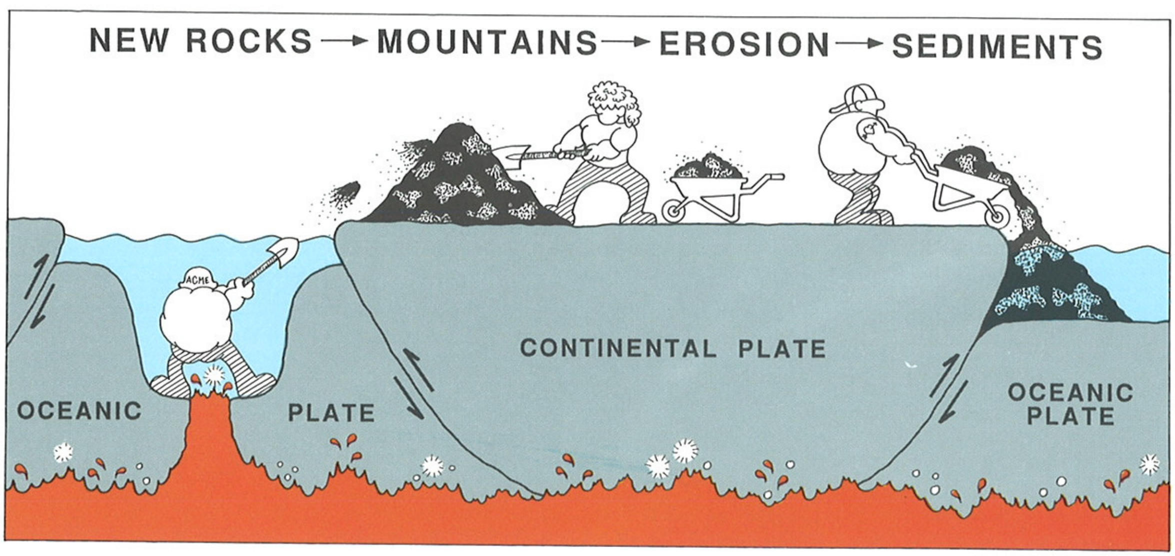


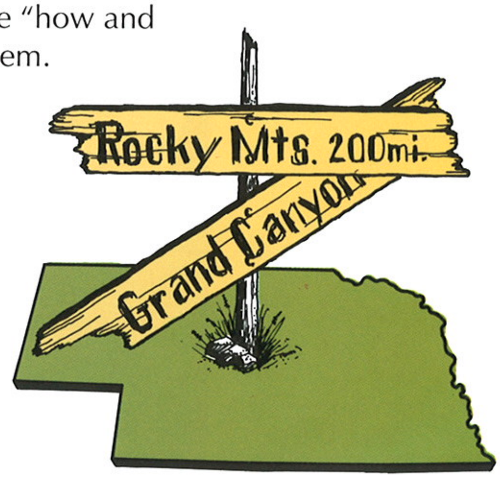
Plate tectonics and erosion are the two most significant physical processes that influence both the creation and destruction of the rock record of our geologic history. Because these physical processes have been active during geologic history, the continents and ocean basins as we know them are relatively modern features. Continents have fused together and then were torn apart. Mountains have risen, only to be eroded and the material deposited elsewhere. The oceans have spread across the land and then retreated, leaving behind thick marine deposits, the sediments that accumulated on the ocean floor.

The various processes acting on the earth make it difficult to reconstruct the patterns that existed at any one instant of geologic time. In most areas, erosion and/or non-deposition have made the rock record very incomplete. The rocks themselves may have been moved long distances by the drifting plates. As we examine the geologic history of Nebraska, keep in mind the vastness of geologic time, the constant shifting of plates on the earth's surface, and all the processes that have fragmented our rock record.

Undercover Nebraska

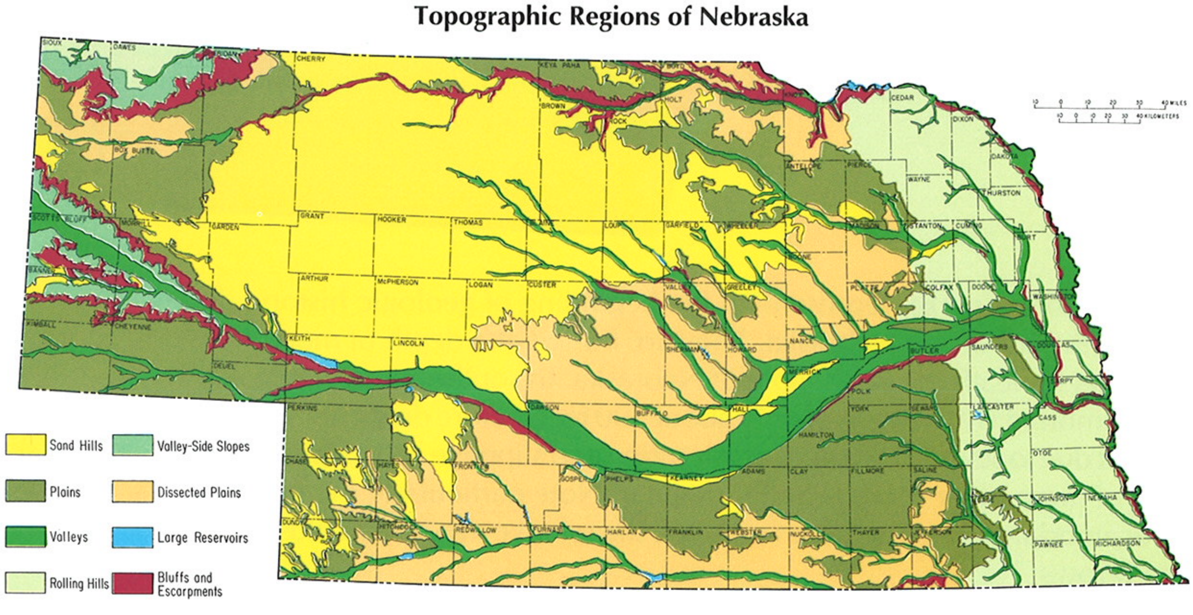
On the last page is a geologic map of the bedrock surface of Nebraska. This map was constructed by imagining that the surface material--the younger uncemented sand, silt, and clay--has been removed. We can then see the distribution of the older, more consolidated rocks--the bedrock. Geologists call it bedrock because they imagine what the surface would be like after removing the younger unconsolidated (looser) material.

By using the information on this map and the geologic history it illustrates, we will gain a better understanding of the natural characteristics of our state. The natural resources in any area are a major influence on the lifestyle of that area. Changes that take place in our environment are the direct result of the relationships between our actions and the earth on which we live. Learning the geologic history of an area will allow us to learn the "how and why" of its natural systems and how best to manage them.



Do we have a record of geologic history in Nebraska? If you travel around the state, you certainly do not see any large mountains or deep canyons with exposed layers of rocks.

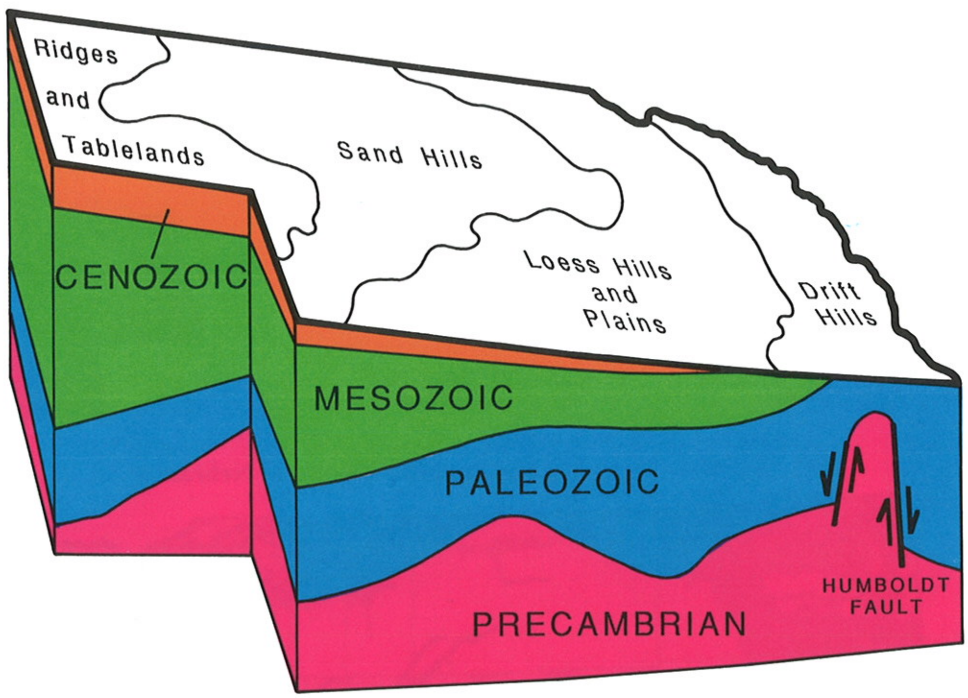
Topographic Regions of Nebraska



What we do see are different regions with different features and activities: the large wheat fields and high bluffs in western Nebraska, the ranches and grasslands in the Sand Hills, the rich soil and irrigated farms in southern Nebraska, and the rolling hills and bluffs of eastern Nebraska. But where is our record of geologic history?

Nearly 20,000 deep wells have been drilled in Nebraska in search of oil and gas. More than 70,000 irrigation wells have been installed. Many more shallow wells are used to supply drinking water. State agencies and businesses keep files that record information on each hole and, for many wells, actual samples are available of the rock material recovered during drilling. By studying the layers of rock penetrated in these holes, we have been able to learn about the different periods of geologic time that are represented beneath Nebraska.

If we could cut away the sides of our state and remove Wyoming, Colorado, and Kansas, we would see a part of this buried record of Nebraska's geologic history.



The Precambrian rocks, representing the beginning of geologic history, do not reach the surface in Nebraska. They are buried at a depth of more than 10,000 feet beneath the Panhandle of Nebraska. In southeastern Nebraska, the Precambrian is at a depth of only about 500 feet, before dropping sharply to the east due to several instances of fracturing and slippage called faults. The surface of these older rocks is quite irregular. Note particularly the offset of the Precambrian surface at these faults and the relative movement illustrated by the arrows.

The Precambrian consists mostly of dense crystalline rocks (igneous, meaning formed from molten rock, and metamorphic, meaning formed under intense heat and pressure). They underlie all of our state and serve as the foundation or basement upon which the younger sediments were laid down.

Notice how the sedimentary rocks (deposited by wind or water--in this case, limestone, mudstone, and sandstone) that represent the Paleozoic, Mesozoic, and Cenozoic units are thicker in the west and thin toward the east. The Paleozoic volume of geologic history consists of hundreds of feet of limestone, dolomite, shale, and sandstone, most of which represent mud and sand laid down at the bottom of an ocean. These rocks contain a wide variety of fossils representing life that existed in the sea or on the ocean bottom.

During most of Mesozoic time, a large ocean extended eastward across Nebraska. Great thicknesses of marine mud and sand were laid down, representing both ocean and near-shore deposits. These Mesozoic rocks have been removed from parts of southeastern Nebraska.

Near the end of the Mesozoic time, major uplift occurred in the Rocky Mountains, and the seas retreated for the last time. During the Cenozoic, large rivers flowed eastward across Nebraska, laying down sand, gravel, silts and clays. Wind-blown volcanic ash and silts covered old floodplains and lakes. The early Cenozoic (Tertiary) rocks are not present in eastern Nebraska.

The last chapter of our geologic history is not shown on the illustration above. The late Cenozoic (Pleistocene and Recent) and the older rock history will be described later in more detail.

Even though we don't have large parts of our rock book exposed at the surface in Nebraska, the records from about 100,000 wells drilled across the state provide small, individual bits of information about the buried history. Many years of study have put together these puzzle pieces and provide at least a general picture of Nebraska through geologic time.

This gives us an overview of the record in rocks preserved under our state. We will now look in more detail at each of the major volumes of the rock book of geologic history.

Rock History

Background

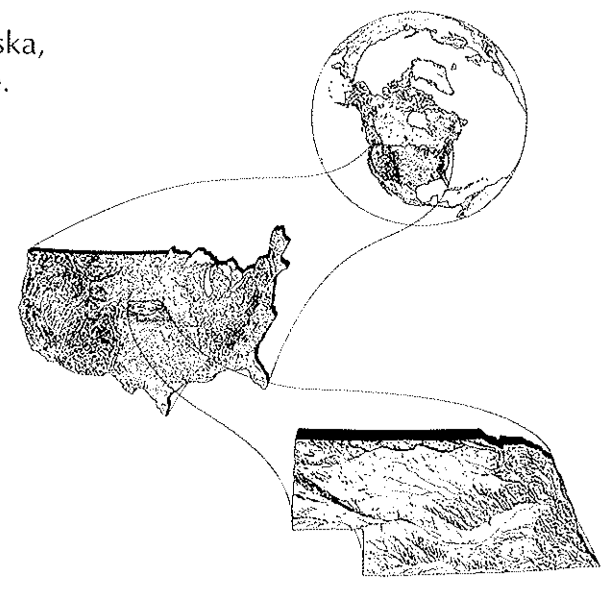
Many books explain the various aspects of geology and earth science, both the processes involved and the application of geologic studies. We will focus on the rocks present in Nebraska and how we relate--and correlate--the various rock layers to one another so as to understand the environment present at any particular point in geologic time.

To *correlate*, as geologists use the term, means to determine the age of rock layers wherever they are available for study and to interpret how these layers fit together to reconstruct geologic history. One approach is to use fossils as page numbers in our rock book. At any point in geologic time, certain kinds of organisms were living. If we find identical fossils, even many miles apart, we can be confident that the rocks that contain these fossils were deposited during the same time interval.

Another method is absolute age dating. Certain chemical elements decay into "daughter elements" at a fixed rate. If we are fortunate enough to find these combinations in our rock layer, the relative amounts of these elements will tell us about how long ago the rocks were formed.

A third approach, the most obvious, is to trace rock layers from one area to another. This may be as simple as actually walking along the outcrop or very carefully noting the sequence of occurrence of rock layers in a series of deep wells. By using any or all of these correlation techniques, we can reconstruct the patterns of rocks that record the geologic history of Nebraska.

As we review the geologic history of Nebraska, remember that we are looking at the big picture. There are many different sciences (and scientists) involved in reconstructing and interpreting the rock record. Also, over the vast amounts of geologic time involved, plate tectonics have busily moved the continents around the surface of the globe. Plate collisions and the development of new rift basins have also had an effect.



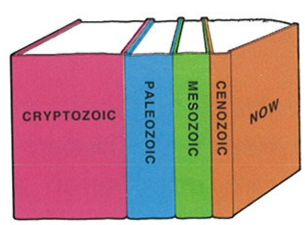
There are many textbooks available (the newer the better) that provide more information about geologic history, and any good encyclopedia will provide a brief technical background for geology and related sciences. In addition, The Geological Society of America (headquartered in Boulder, Colorado) has recently published a series of volumes for the Decade of North American Geology (DNAG), designated as the 1980s. "The Geology of North America--An Overview," Volume A in this series, does get technical but will explain the larger perspective in a small package.

In addition, the National Research Council published *Solid-Earth Sciences and Society* in 1993. The volume reports "on the state of solid-earth science and outlines a research agenda, with priorities keyed to the real-world challenges facing human society," according to the council. This publication has a good summary of geologic processes and the role of geologists in society.

A variety of publications, for both technical and general audiences (such as this educational circular), are available from the Conservation and Survey Division (which includes the Nebraska Geological Survey) and the U.S. Geological Survey. During our review, we will look first at the big picture, the overview of a major interval of geologic time, and then see what the rock record is for that time in Nebraska.

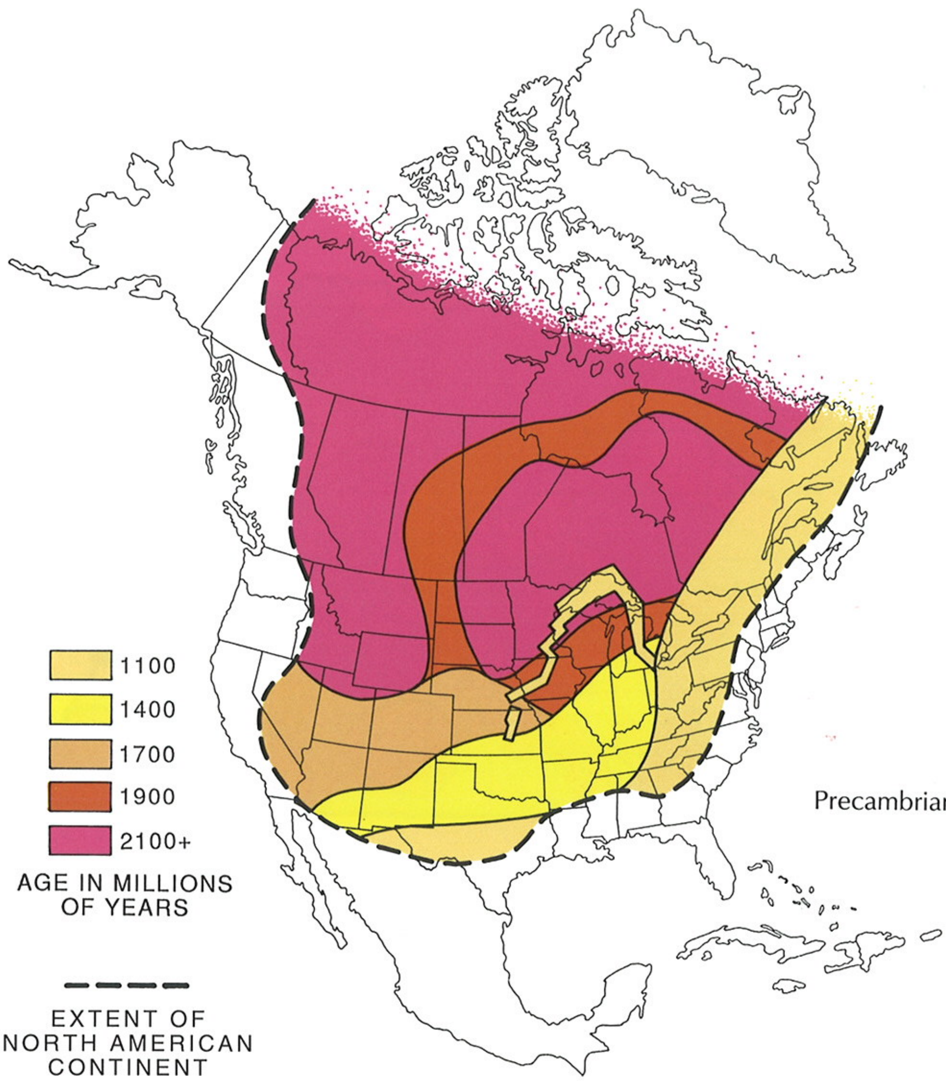
For most of geologic history, Nebraska was located near the center of the North American plate and protected from much of the ripping and tearing and volcanic activity that occurs near the plate margin. This lack of major structural movement has allowed for the preservation of generally flat-lying layers of rocks in our area. There were, however, several instances of folding and faulting that disturbed our "layer-cake geology" and allowed erosion to take some serious bites from our rock record.

Even though we are located on a continental plate, the combination of a lowering of the land surface and a raising of sea level allowed the oceans to cover our state during large parts of geologic history. These events are recorded by the rocks representing marine sediments and containing marine fossils. The incompleteness of the rock record also illustrates that for other major parts of geologic time, the surface of Nebraska was exposed and large amounts of rock material were eroded away. One of the challenges in geology is to reconstruct realistic pictures of geologic time while working with only a few of the puzzle parts available to us. Like most history books, we will start with the oldest chapter in the oldest volume of our rock book of geologic history, the Precambrian (Cryptozoic).



Cryptozoic Era: *Precambrian Period*

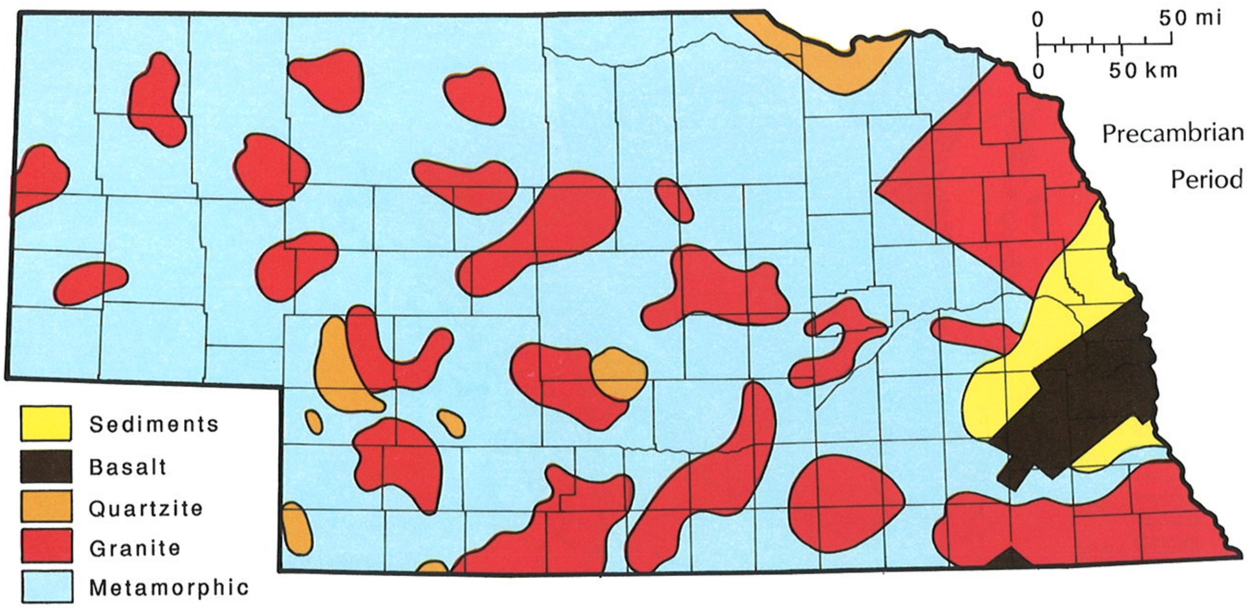
As noted earlier, the Precambrian includes nearly 90 percent of our geologic history. This period has been broadly subdivided, but the general lack of fossils and the destructive effects of plate tectonics and erosion make reconstruction of the Precambrian record difficult.



Precambrian Period

As we saw on the block diagram, the Precambrian underlies all of the state and it consists mostly of dense, crystalline rocks. The Precambrian history of North America is generally one of continental growth. The oldest rocks are near the center of the continent. They have been split apart by plate tectonics and later rejoined with new material added along the seams. Other continental plates have collided with the original North America and have become a part of the growing continent.

Much of Nebraska became a part of North America during the addition of the Central Plains Province, a plate fragment which attached about 1,700 million years ago (yes, *1.7 billion years* ago!). Other fragments joined up at about 1,400 and 1,100 million years ago and continued the growth of North America. About 1,100 million years ago, a large rift began to split apart the North American continental plate. The western limb of this rift extended from Minnesota across Iowa, Nebraska, and Kansas. The Midcontinent Rift System grew to be about 30 miles wide and was filled with more than 35,000 feet of basalt (lava) and sediments. This was a feature similar to the modern rifts along the Mid-Atlantic Ridge or the East African Rift Valley. The Midcontinent Rift, however, stopped spreading before North America had been split into two new continental plates so that no new intervening ocean plate was created. But the rift system did create some significant weak zones in the Precambrian basement rocks that have affected later geologic history.



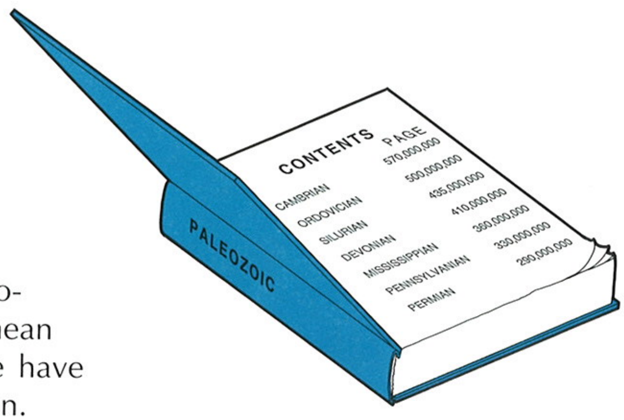
The map of Nebraska illustrates the type of rocks present at the upper surface of the Precambrian now buried under our state. The Central Plains Province, which underlies all of Nebraska except for the eastern part, consists largely of metamorphic rocks. These are sediments and volcanic rocks that were recrystallized by heat and pressure as they collided and became attached to the North American continent. Later, molten blobs of granitic rocks (hot igneous material) rose to the surface from deep within the interior of the earth, intruding into this province. (Granite is a crystalline igneous rock, often red, that is commonly used for building fronts and grave stones.)

Laid over this pattern in eastern Nebraska are the rocks of the Midcontinent Rift. The two rock types illustrated for the rift are the basalt that filled the original rift valley as lava flows from volcanoes and the sediments (clay, silt, and sand) that were deposited in the basins that bounded the central basalts after they had been uplifted. The result of this rifting activity about 1,100 million years ago was to furnish a foundation under the Lincoln and Omaha area of more than 35,000 feet of ancient lava flows (a similar foundation underlies Hawaii). These old rift-rocks are now deeply buried in Nebraska and covered by about 3,000 feet of younger rock layers.

There are currently no mineral resources provided in Nebraska from the Precambrian rocks, mainly because they are far below the land surface. There are, however, many fragments of Precambrian rocks at or near the surface that have been carried into our state by rivers and glaciers. Most of the copper and iron mines in the Lake Superior region are in the rift-related rocks. Several oil companies have drilled into the sediment associated with the Midcontinent Rift because this sandstone would make an excellent reservoir for oil and gas fields. So far they have had no success, but the wells did provide valuable information about the Precambrian rocks.

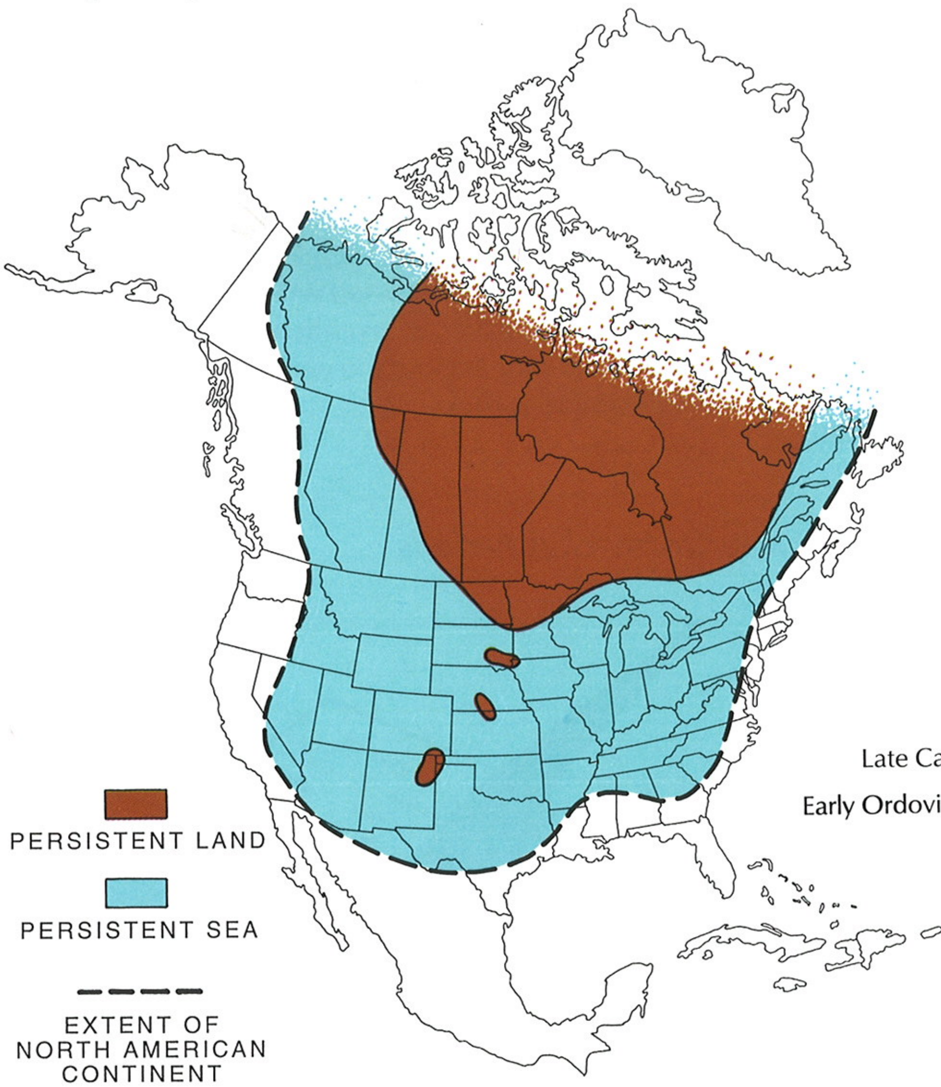
Paleozoic Era: *Cambrian and Early Ordovician Periods*

During the latter part of Precambrian time and into the early Paleozoic, the Precambrian surface was severely eroded and became relatively flat. Over most of North America, there was a gap of about 500 million years between the Precambrian and the Paleozoic chapters of our geologic history. When we say "gap," we mean that there are very few places where we have found rock layers that record this time span.



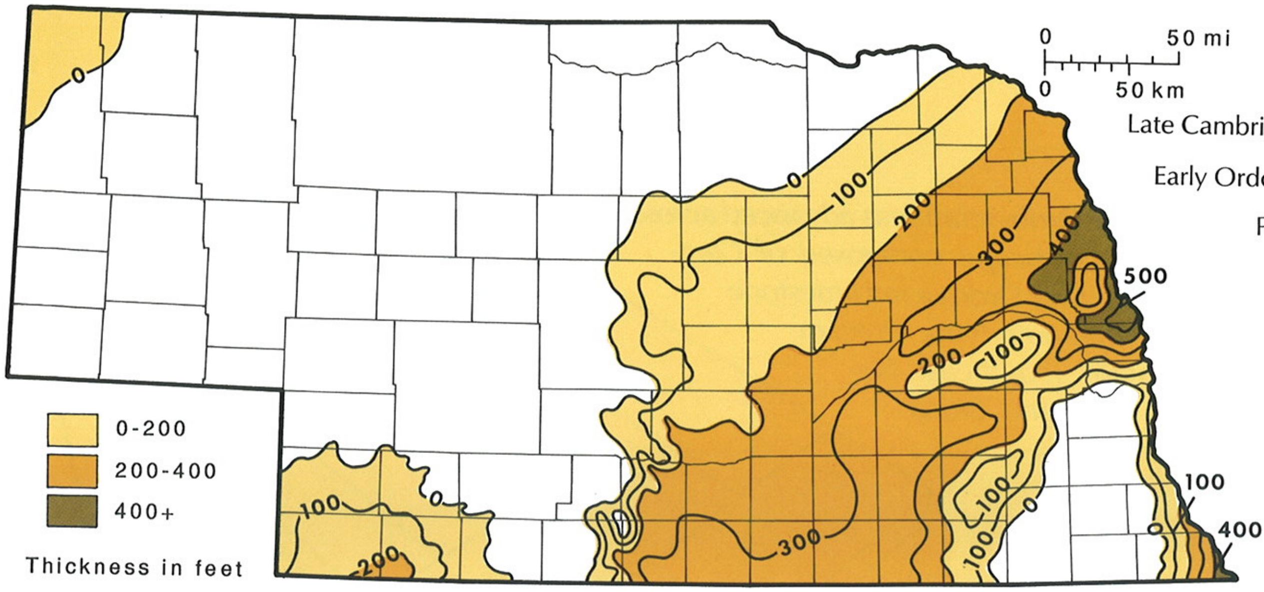
During most of Cambrian time, the seas were confined to the margins of North America, as illustrated by the small map showing the general land-sea relationships during the Cambrian. (The shape of the North American plate at the end of Precambrian time was the outline of the continent throughout most of the Paleozoic. Note the bold dashed line on the map of North America. Certain parts of North America were below sea level as the oceans advanced and retreated but the continental plate boundary remained about the same.)

It wasn't until the very latest Cambrian that the oceans reached Nebraska. Most of the Cambrian rocks have been identified in Nebraska by comparing our rock layers with rocks known to be of Cambrian age in adjoining states. We were fortunate to find one small pin-head-sized fossil in a rock core in extreme southeastern Nebraska that tells us of the ocean's presence. This sea shell was identified as *Linnarssonella,* a fossil known to occur in Late Cambrian rocks. So we have at least one "page number" for our Cambrian chapter of geologic history.



Late Cambrian and Early Ordovician Periods

Over most of North American there was no significant break in deposition between the Late Cambrian and Early Ordovician. In Nebraska, we lump the rock layers of both ages together for mapping purposes. The Cambrian and Early Ordovician rocks are thickest in eastern Nebraska and thin westward. They are absent in west-central Nebraska due to later erosion. (This pattern is common to most Early and Middle Paleozoic rocks because of uplift and erosion described later in the discussion of the Pennsylvanian.) The rock layers immediately overlying the Precambrian, whether Cambrian or Ordovician in age, are rounded grains of quartz sand. This material was eroded from the weathered Precambrian rocks by the advancing seas. The younger Cambrian and Early Ordovician sediments are dolomites, a rock formed from the limy mud deposited on the floor of the Cambrian seas.

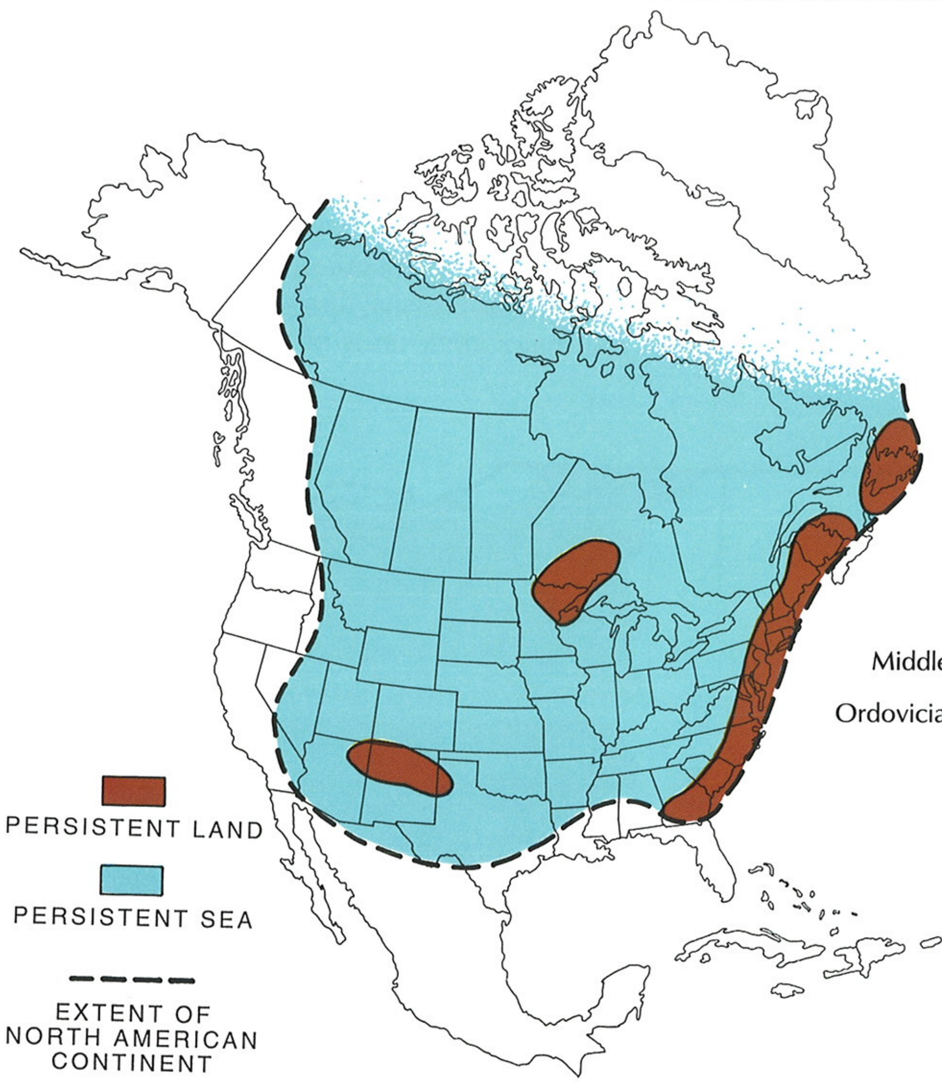


Late Cambrian and Early Ordovician Periods

The Cambrian rocks are important reservoirs for oil and gas in western Kansas, and several small oil fields are present in southwestern Nebraska. A few deep wells produce groundwater for industrial use in the Omaha area from the Cambrian and Early Ordovician rocks.

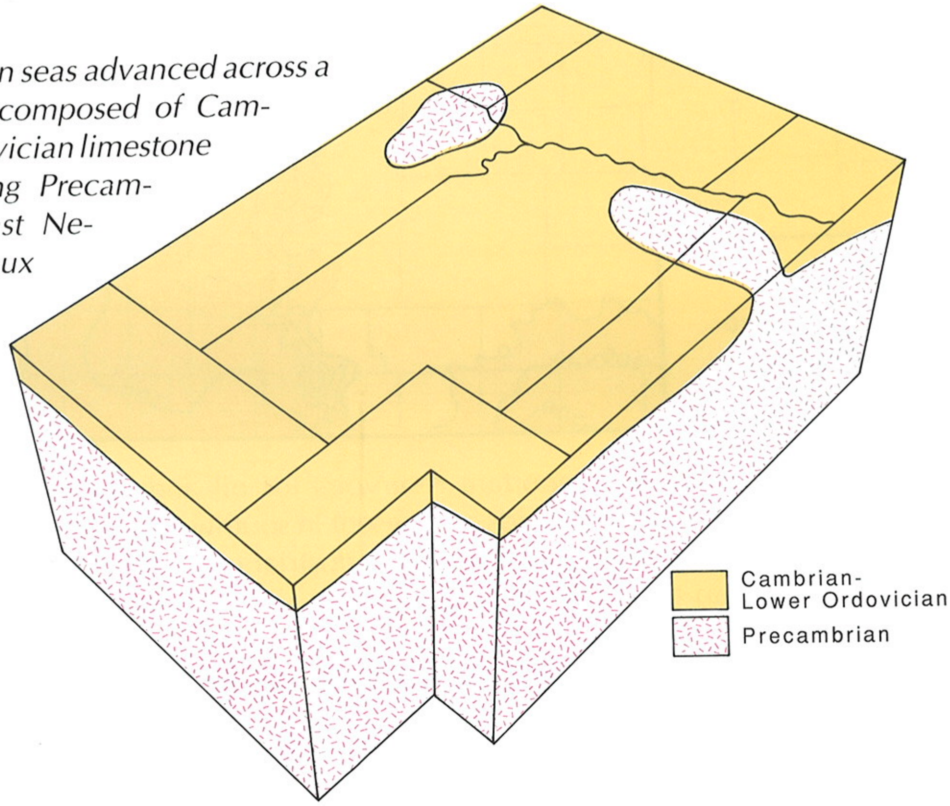
Paleozoic Era: *Middle and Late Ordovician Periods*

Near the end of Early Ordovician time, a part of southeastern Nebraska was uplifted and the Cambrian and early Ordovician rocks were eroded away. The seas of the Middle Ordovician advanced across Nebraska and eventually



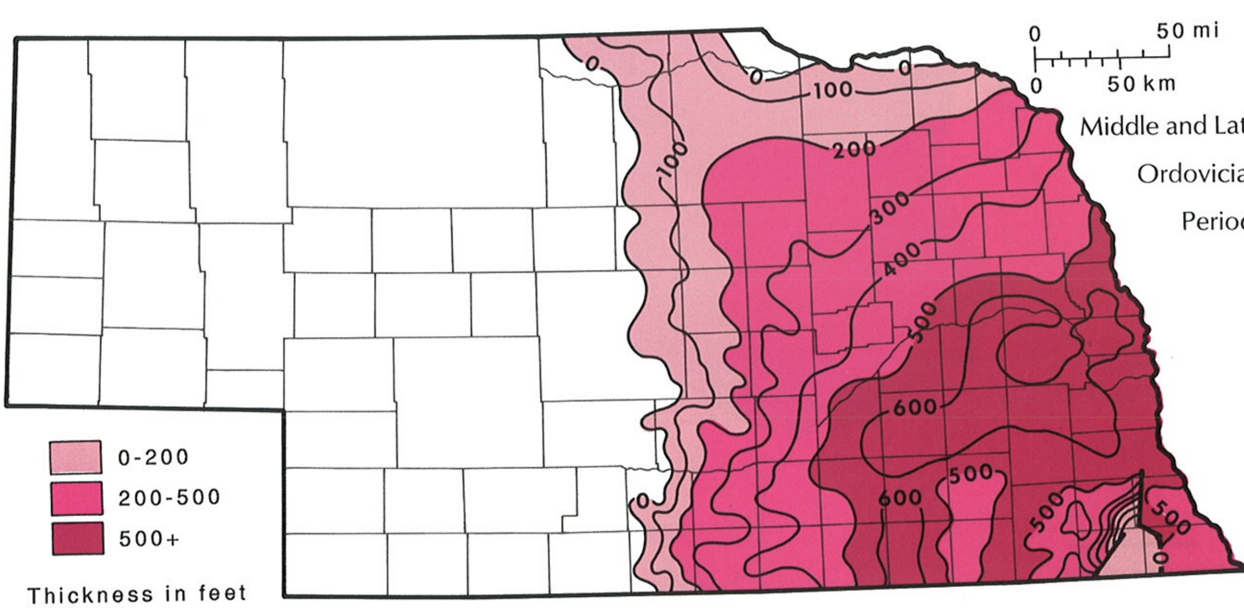
Middle and Late Ordovician Periods

The Middle Ordovician seas advanced across a low-relief landscape composed of Cambrian and Lower Ordovician limestone with several low-lying Precambrian highs (Southeast Nebraska Arch and Sioux Uplift).



covered most of North America. Again the earliest deposit was a rounded quartz sand formed mainly as a beach deposit as the seas advanced. As the water became deeper, the sands were buried by limy mud that became the limestone and dolomite rock layers.

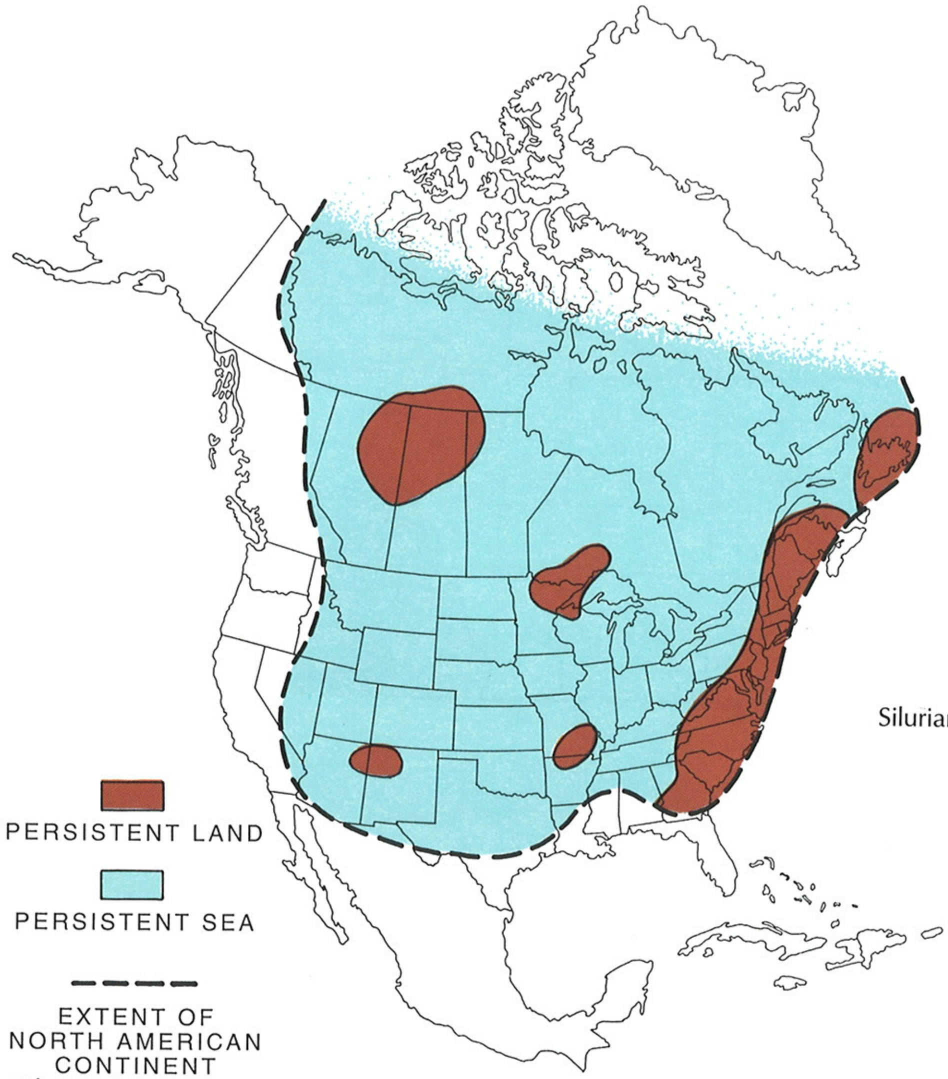
More than 600 feet of Ordovician rocks are present in parts of eastern Nebraska. Erosion has removed these rocks from the western half of our state. The distinctive sequence of rock layers and a few significant fossils allow us to be confident of the correlation and age of the major rock units of the Ordovician in Nebraska.



Middle and Late Ordovician Periods

Several of the Ordovician units--the St. Peter Sandstone and Viola Dolomite—produce oil in Richardson County in extreme southeastern Nebraska. Ordovician rocks in nearby states contain valuable deposits of metallic minerals such as lead and zinc. Traces of these metals have been noted in Nebraska samples.

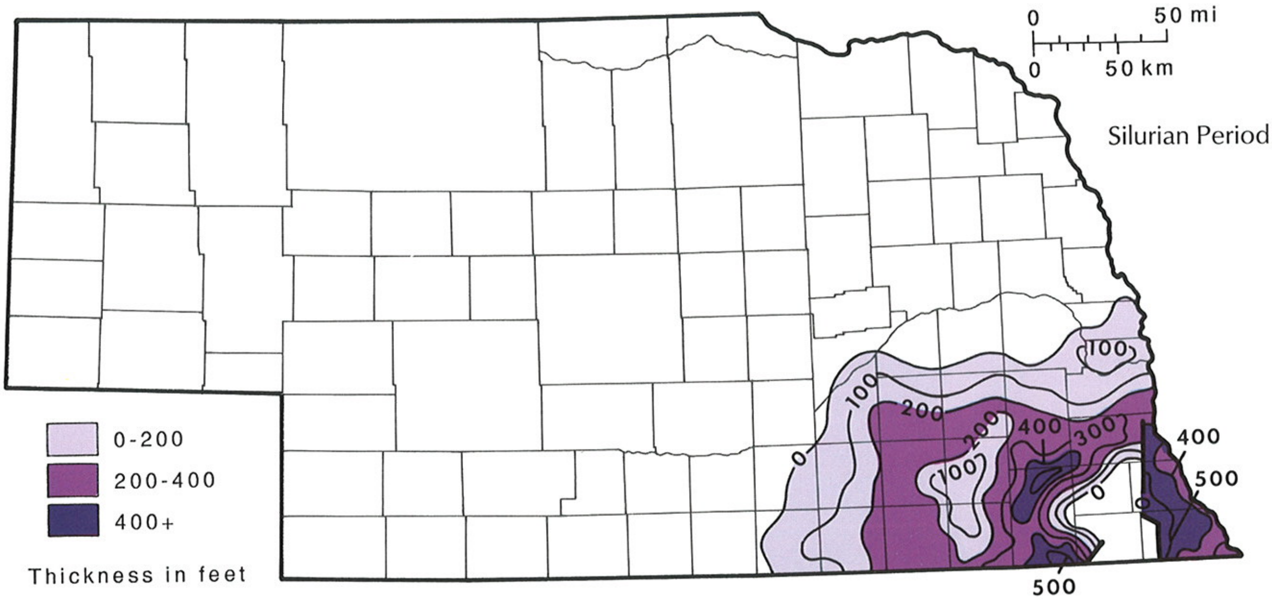
Paleozoic Era: *Silurian Period*



Silurian Period

Silurian rocks are not widely present across North America because of later erosion. The lack of rocks that represent shoreline deposits and the occurrence of isolated patches of Silurian rocks indicate that they were originally much more widely distributed. All the Silurian rocks remaining in Nebraska are marine deposits (dolomite), as is true for most of the other Lower Paleozoic rock layers. (It is much more difficult to preserve rock layers deposited on land areas--erosion commonly removes this part of our rock record.)

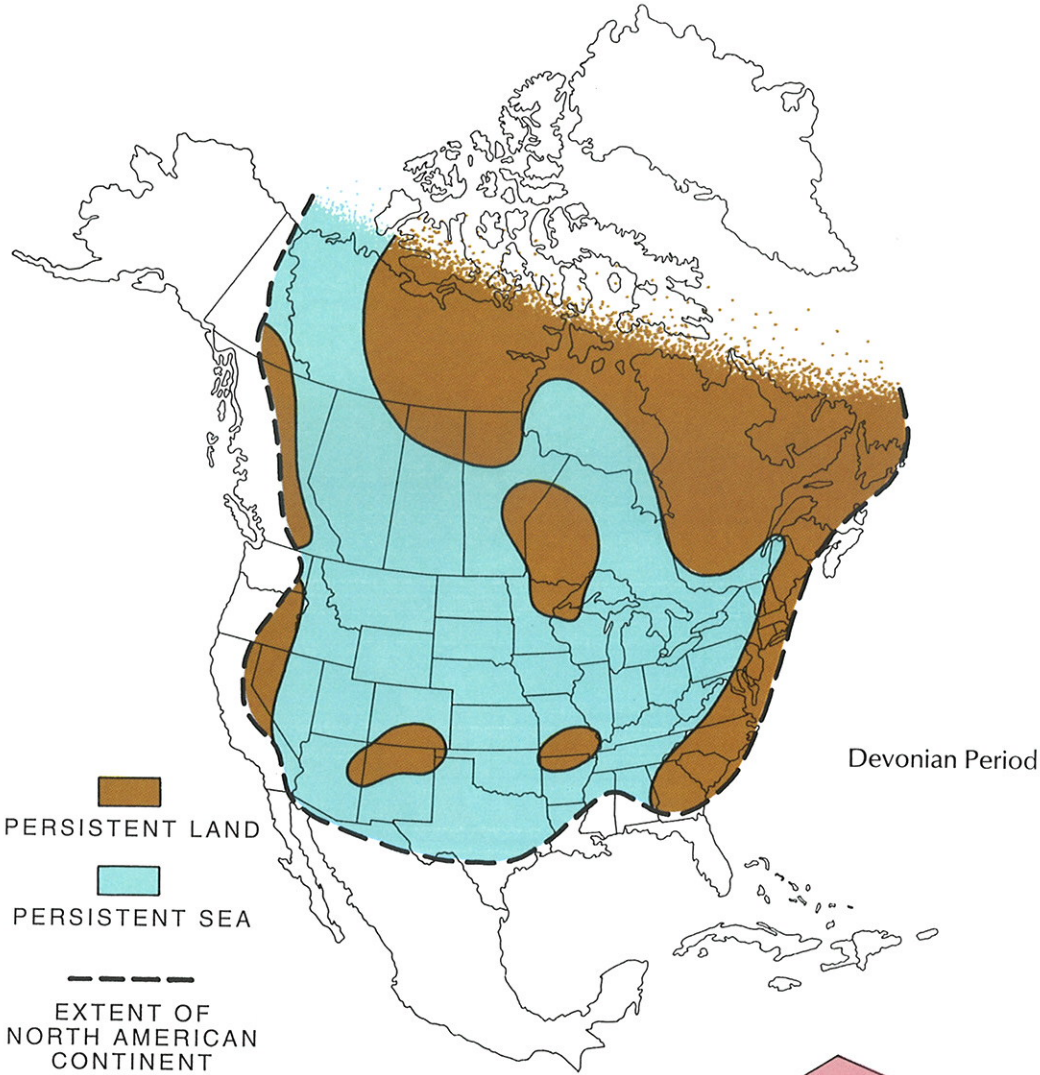
Although not widely distributed, Silurian rocks do exceed 500 feet in thickness in places. In rock cores from three different wells in southeastern Nebraska, we have found brachiopods that are common in the early Silurian. The combination of these fossil sea shells and the dolomite provides evidence of the presence of Silurian seas in our state.



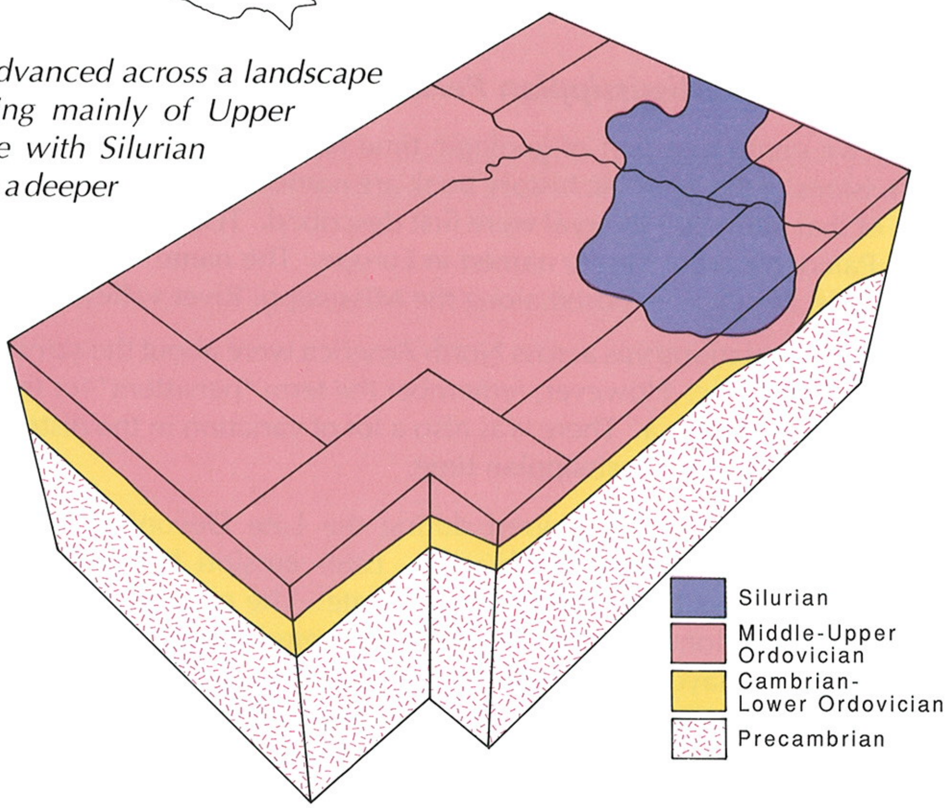
Paleozoic Era: *Devonian Period*

Broad uplift and erosion occurred before the advance of the Devonian seas. Land areas continued to be persistent in northern and eastern North America during the Devonian. We say "persistent" because the land-sea relationships varied greatly during Devonian time. As is true for other subdivisions of the Paleozoic, the seas advanced and retreated across the land surface, creating alternating intervals of deposition and erosion. Very few locations anywhere show a complete rock section representing Devonian time.

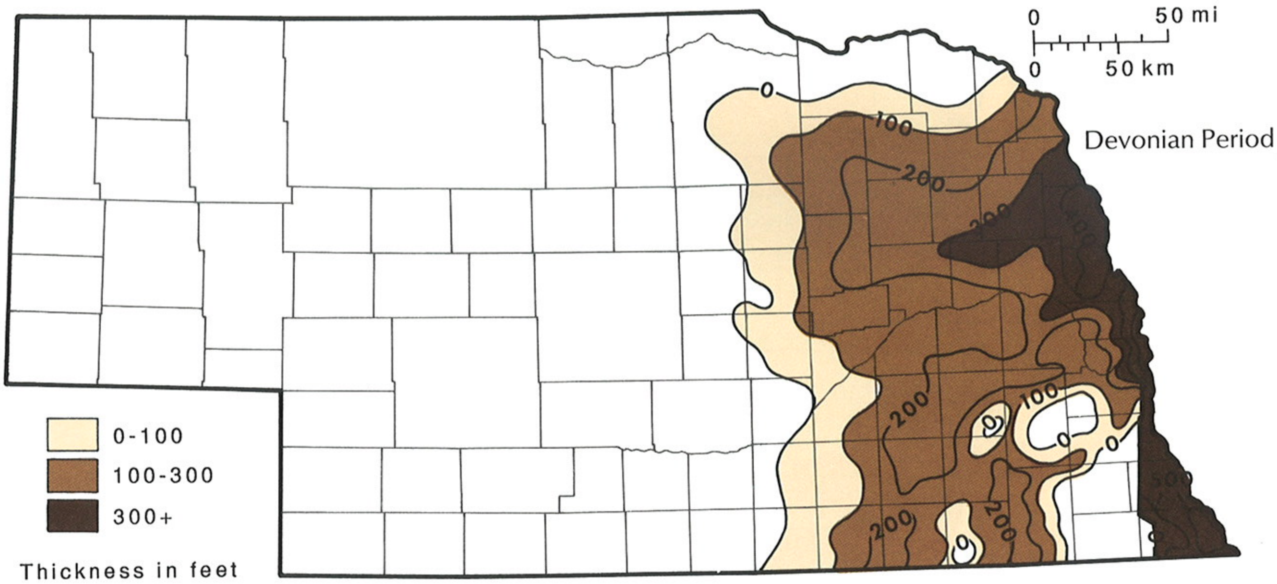
The oldest Devonian rocks present in eastern Nebraska consist of dolomites and limestone laid down during Middle Devonian time. During the Late Devonian, differing environments were present in the seas. Dolomite, the main rock type in southeastern Nebraska, changes to mudstone (shale) toward the northwest. Geologists call this change in rock type a "facies change," indicating the merging of two different types of environments of deposition during the same geologic time interval.



The Devonian seas advanced across a landscape of low-relief consisting mainly of Upper Ordovician limestone with Silurian limestone preserved in a deeper basin.



A variety of fossils have been found in Nebraska's Devonian rocks. Most important are the conodonts, tiny jaw-shaped fragments of a larger animal that are important as "page numbers" to identify rocks of differing ages within the Paleozoic.



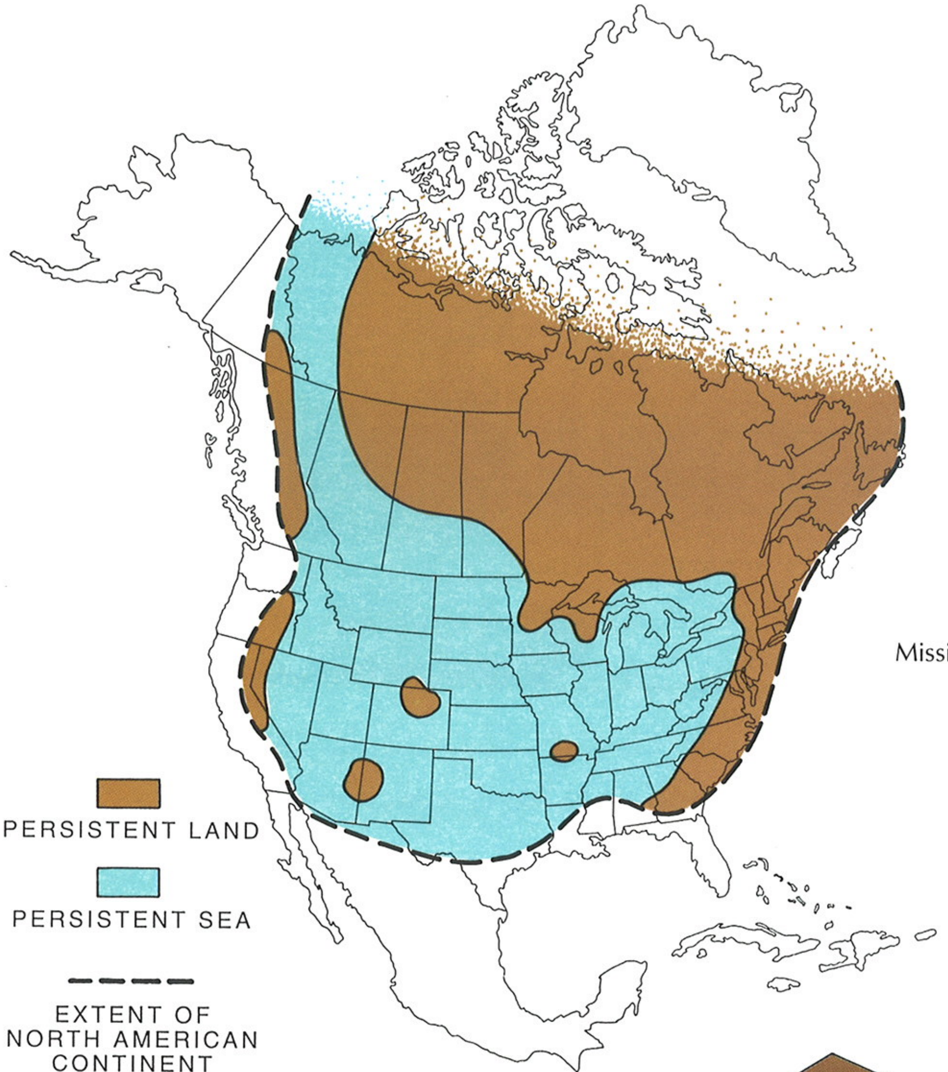
The Upper Devonian limestones are important reservoirs for oil in extreme southeastern Nebraska. Groundwater for industrial use is pumped from the Devonian near Omaha. The limestone and shale would make excellent construction material, but the depth of burial (500 to more than 2,500 feet) is too great for these rocks to be economically mined.

Paleozoic Era: *Mississippian Period*

Finally we come to a part of geologic time named in North America. All subdivisions of the geologic history book are named for locations where the rocks of that particular interval were first described. The older subdivisions of the Paleozoic were mostly named in Europe. The name "Mississippian" is based on the rocks exposed along the Mississippi River valley.

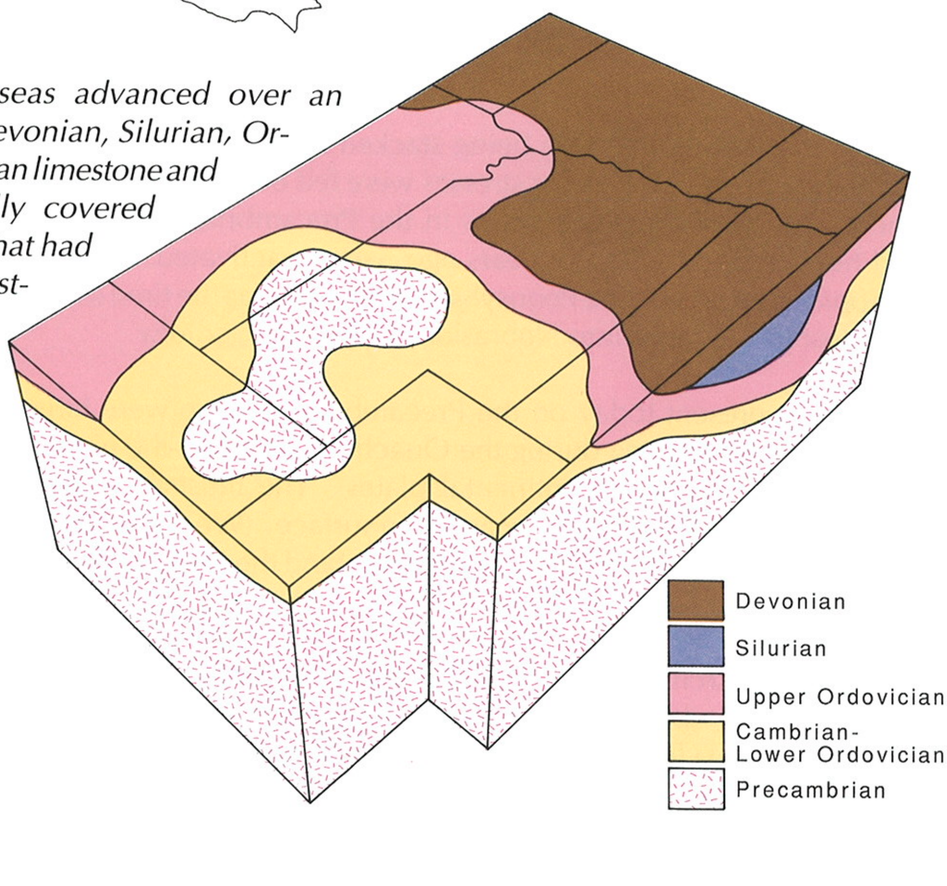
The land-sea relationships across North America were about the same as for the older Paleozoic. However, remember the term "persistent" for the land areas in North America. There was also a lot of variation in the distribution of the oceans during Mississippian time.

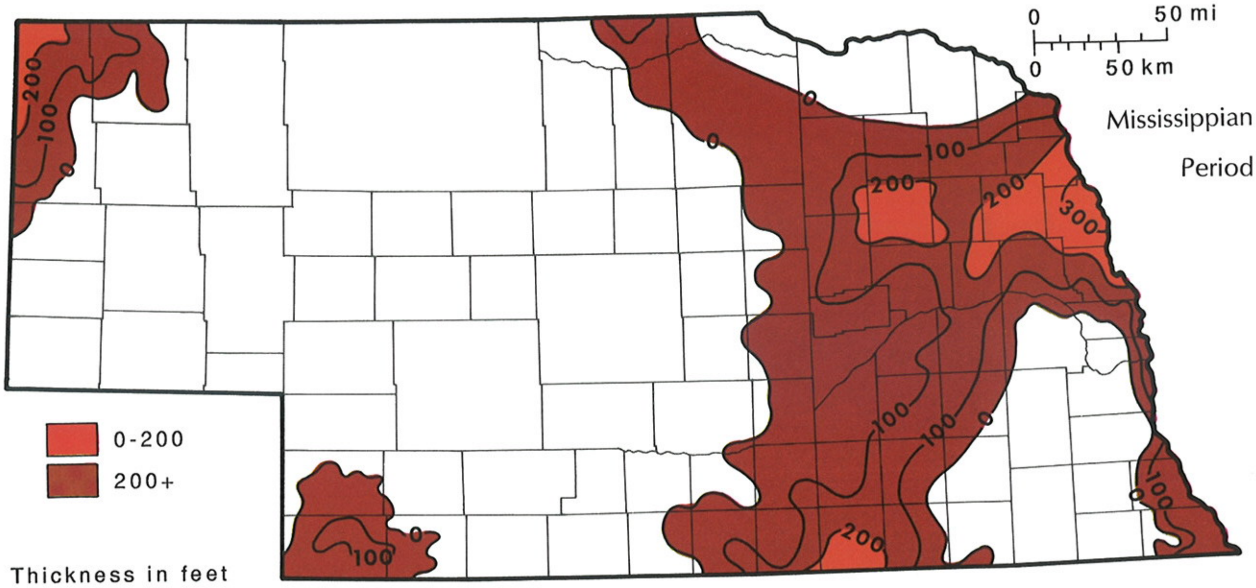
Uplift and erosion had occurred during the Late Devonian before the Mississippian seas covered Nebraska. Later erosion has restricted the Mississippian rocks to the corners of our state. The rock layers are mostly limestone and dolomite, again due to the limy mud deposited on the ocean floor. These rock layers also contain an unusual amount of nodules of chert—a dense rock composed of silica (good arrowhead material). Conodont fossils have also been valuable markers to identify and correlate the Mississippian rock units.



Mississippian Period

The Mississippian seas advanced over an eroded surface of Devonian, Silurian, Ordovician and Cambrian limestone and shale and eventually covered Precambrian rocks that had been exposed in western Nebraska.





The Ouachita Orogeny: *An Interruption in Layer-cake Geology*

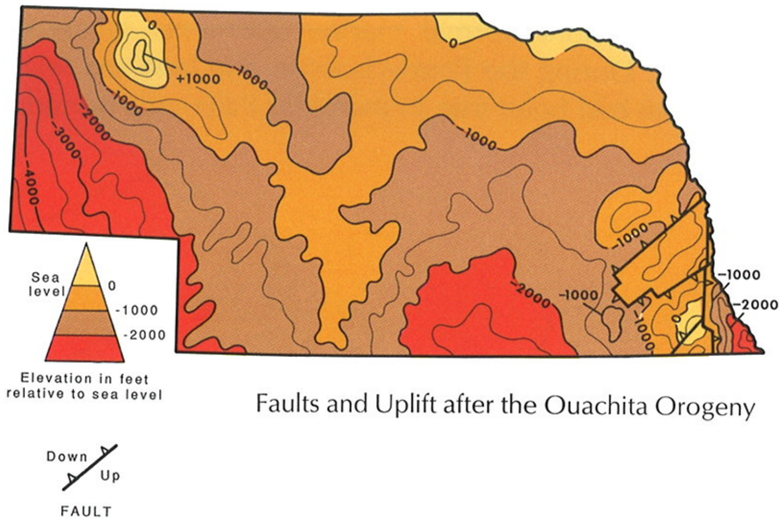
Near the end of Mississippian time, big things were happening along the southern edge of North America. The South American continental plate (then joined with the African plate) had been moving in our direction and, about 300 million years ago, collided with North America. This event is marked today by the presence of the Ouachita Mountains in Arkansas. The Appalachian Mountains in eastern United States mark the collision of Europe with North America.

And while the mountains were being stacked up along the edge of North America, the effects of the major stresses were felt even in the interior of the continent. Many of the weak zones in the Precambrian basement rocks, created hundreds of million of years ago, were reactivated. From the Late Mississippian and on into the Pennsylvanian Period was the time interval that did the most to put kinks into Nebraska's layer-cake geology.

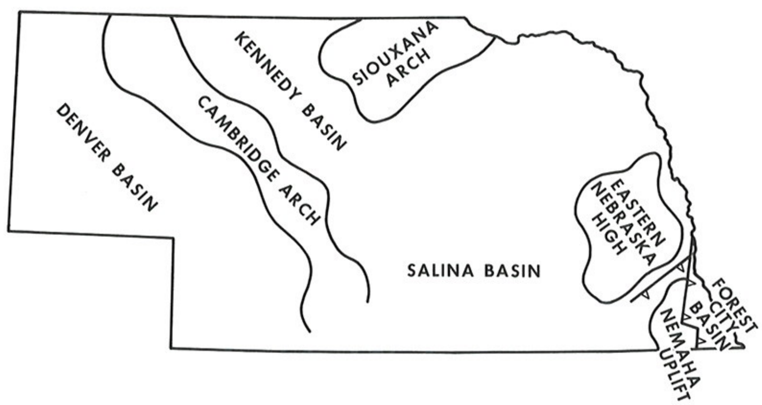
The structures present today on the Precambrian surface were largely the result of uplift and faulting during the Ouachita Orogeny--the name for the collision of the American continental plates. The illustration shows the "highs and lows" of the buried Precambrian surface. (We talked about these rocks earlier, but it is probably easier to understand the story of the structures now.)

The Cambridge Arch is the structural high that trends northwest across western Nebraska. It reaches a maximum height in Nebraska (more than 1,000 feet above sea level) at the Chadron Dome, near, as you might expect, Chadron, Nebraska. Remember, however, that although we describe the features in relationship to sea level, they are still deeply buried in Nebraska. Another structural high is located in north-central Nebraska, the Siouxana Arch.

Several features in southeastern Nebraska are also the result of the stress created by the Ouachita Orogeny acting on the old weak zones created 800 million years earlier by the Midcontinent Rift System. The Nemaha Uplift is a structural high that extends from near Omaha southward to Oklahoma City. This uplift is bounded on the east by the Humboldt Fault Zone. The Precambrian rocks near the Nebraska-Kansas line have been offset vertically nearly 3,000 feet along this fault, which is the boundary between the Nemaha Uplift and the Forest City Basin. Note again that we are discussing these features as related to the buried Precambrian surface. There are only slight traces of these features on the present land surface



Faults and Uplift after the Ouachita Orogeny

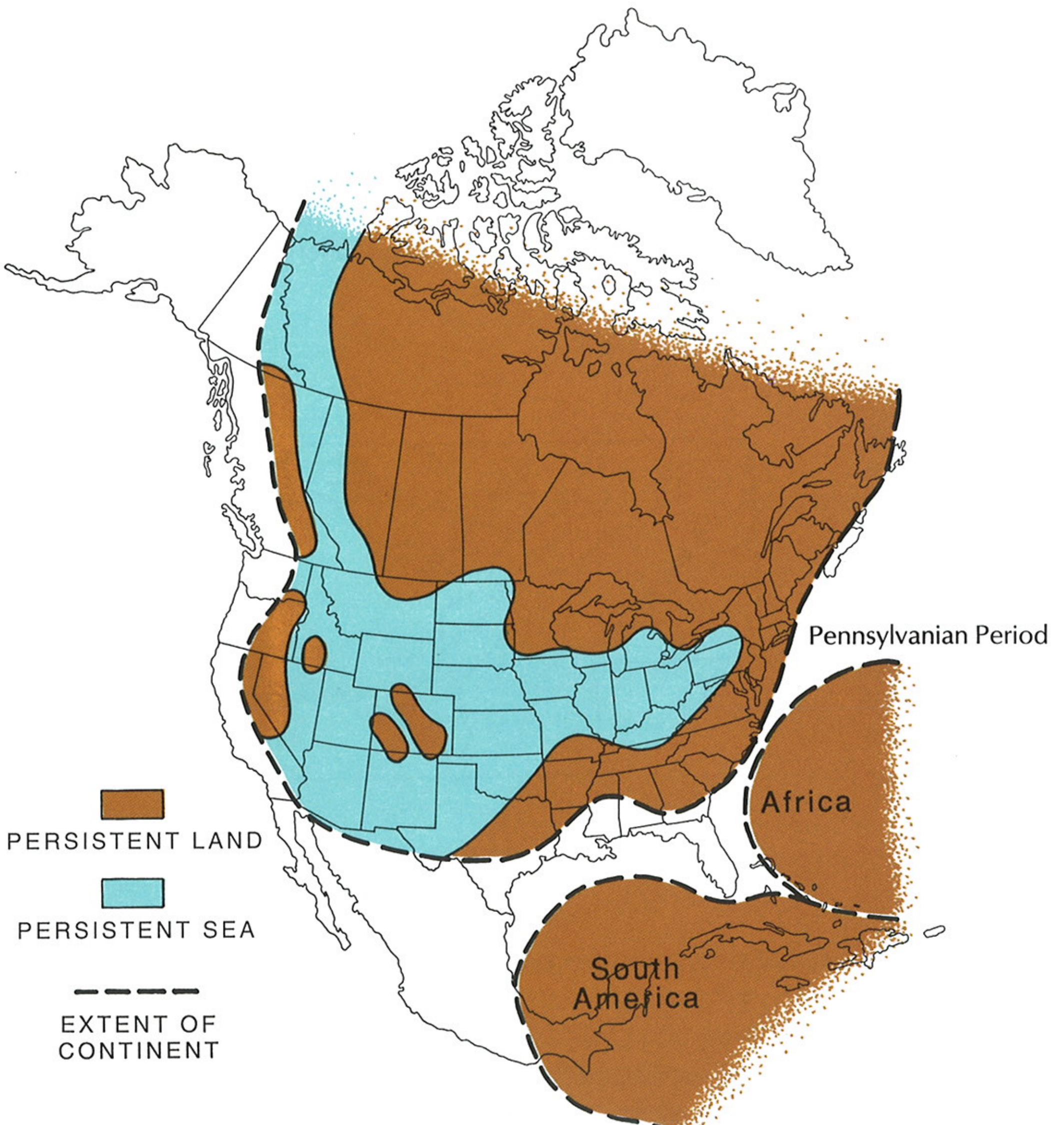


Structural Features after the Ouachita Orogeny

Nebraska lost a lot of rocks as a result of erosion from the uplifts created by the Ouachita Orogeny. All of the earlier Paleozoic units (Ordovician through Mississippian) were stripped off of the Nemaha Uplift. This explains the area of zero thickness in southeastern Nebraska on the earlier maps of the Paleozoic subdivisions. Erosion also removed these older rocks from the Cambridge Arch, which explains their absence on the maps in western Nebraska. Given the amount of time available in geologic history, nature is efficient at moving large volumes of rocks through the various processes of erosion. The surface of Nebraska was exposed to erosion for about 20 million years before the seas again advanced.

Paleozoic Era: *Pennsylvanian Period*

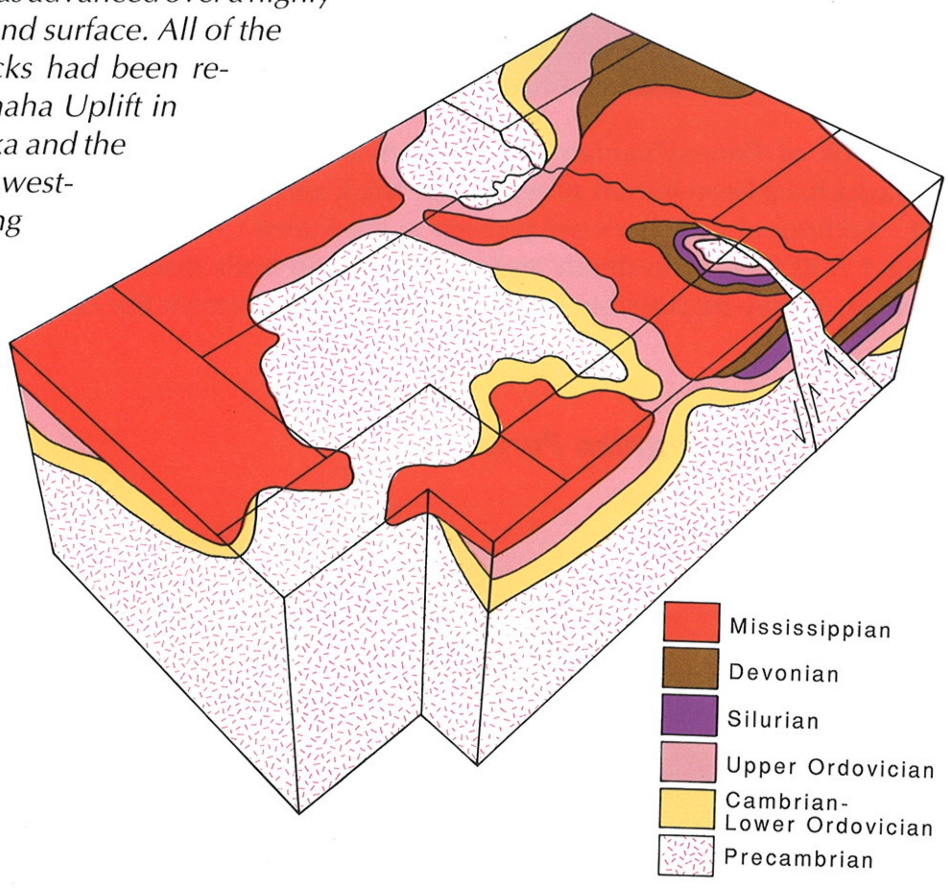
Eventually the Pennsylvanian seas, advancing across a highly eroded surface, covered most of Nebraska. (Yes, the Pennsylvanian Period is another geologic unit named in North America). Because of the availability of the debris eroded from the older rock units, the older Pennsylvanian rock units are mainly composed of sand and silt. As the land surface became submerged, more normal marine sediments--layers of limy mud--were deposited. During the Pennsylvanian, the land-sea relationships were less stable than had been true in the older Paleozoic periods



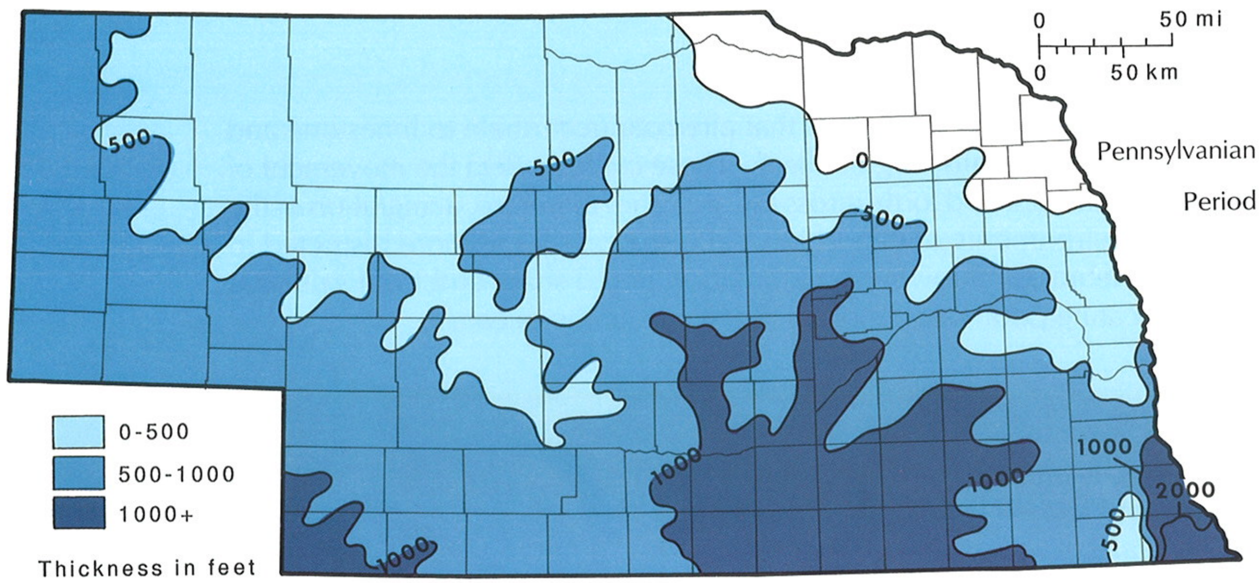
The rock record for the Cambrian through Mississippian periods is composed of limestone and dolomite with only minor amounts of sand and silt. These rocks represent a fairly continuous marine environment of limy mud accumulating on the sea floor. During the Pennsylvanian, however, the environments of deposition were more variable, particularly in eastern Nebraska.

The rock record consists of units that alternate from shale to limestone and back to shale on a fairly regular basis. These cycles reflect the movement of the shoreline back and forth across the area and, therefore, a migration of the various environments of deposition. The seaways were more restricted in western Nebraska, allowing accumulation of red shale and even salt beds and indicating poor circulation of the waters of the oceans.

The Pennsylvanian seas advanced over a highly eroded and faulted land surface. All of the earlier Paleozoic rocks had been removed over the Nemaha Uplift in southeastern Nebraska and the Cambridge Arch in western Nebraska, exposing Precambrian rocks.

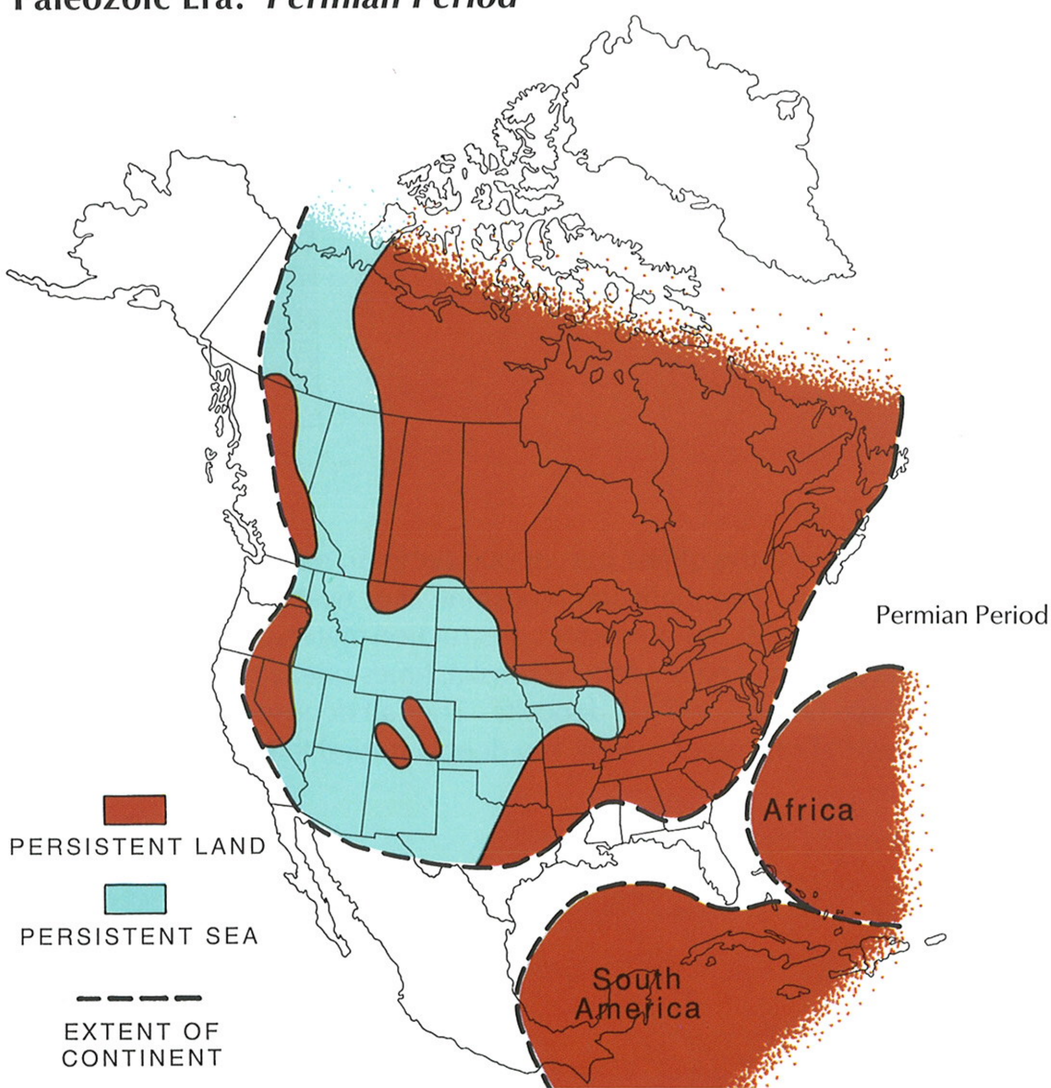


Rock units of Pennsylvanian age are the oldest part of our geologic record exposed at the surface in Nebraska. The shale and limestone at or near the surface in eastern Nebraska are valuable resources for construction materials and agricultural lime. In southwestern and western Nebraska, limestone and sandstone of Pennsylvanian age host oil and gas deposits. The salt deposits in western Nebraska are potential resources but are too deeply buried to be of current interest.



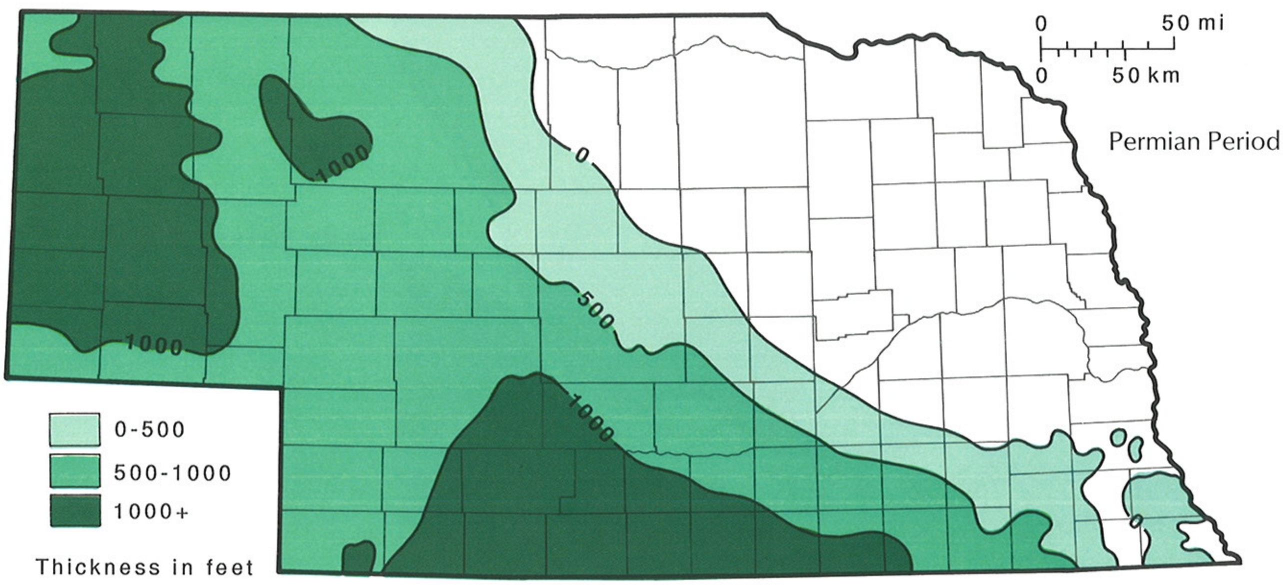
Coal beds of Pennsylvanian age at or near the surface in southeastern Nebraska have been mined as very small "pick and shovel" operations in the past. Additional coal beds are present in the Forest City Basin at depths of about 1,500 feet. The depth and relatively thin beds discourage mining; however, it may be possible to produce methane gas from the coal.

Paleozoic Era: *Permian Period*



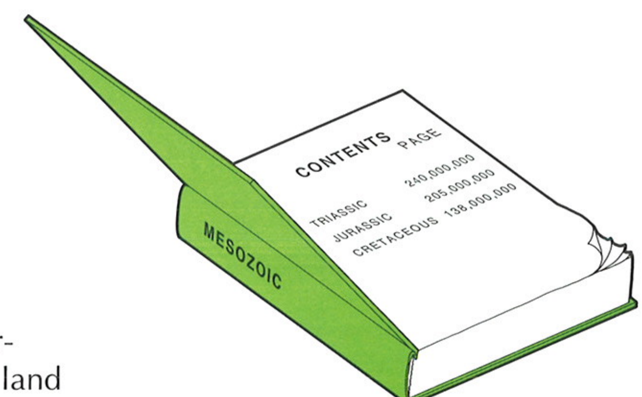
The same general land-sea relationships continued from the Pennsylvanian Period into the Permian Period, the last chapter of our Paleozoic volume of rock history. The depths of the seas were quite variable, so that the resulting rock units vary from the limestone and shale of "normal" marine environments of deposition to so-called "red beds," named for their iron-oxide coloring, and salt deposits, indicating restricted seas and more saline waters. In Nebraska, the older Permian limestone and shale record an open-sea environment. The younger Permian rock units consist of red beds, salt deposits and more abundant sandstone that also indicate restricted seas, as well as the erosion of nearby land areas.

Resources of the Permian rocks are similar to but less abundant than those of the Pennsylvanian units. Limestone and shale are mined at the surface in southeastern Nebraska, and some oil is produced in southwestern Nebraska. The Permian rocks of Kansas are extensively mined for their salt deposits.



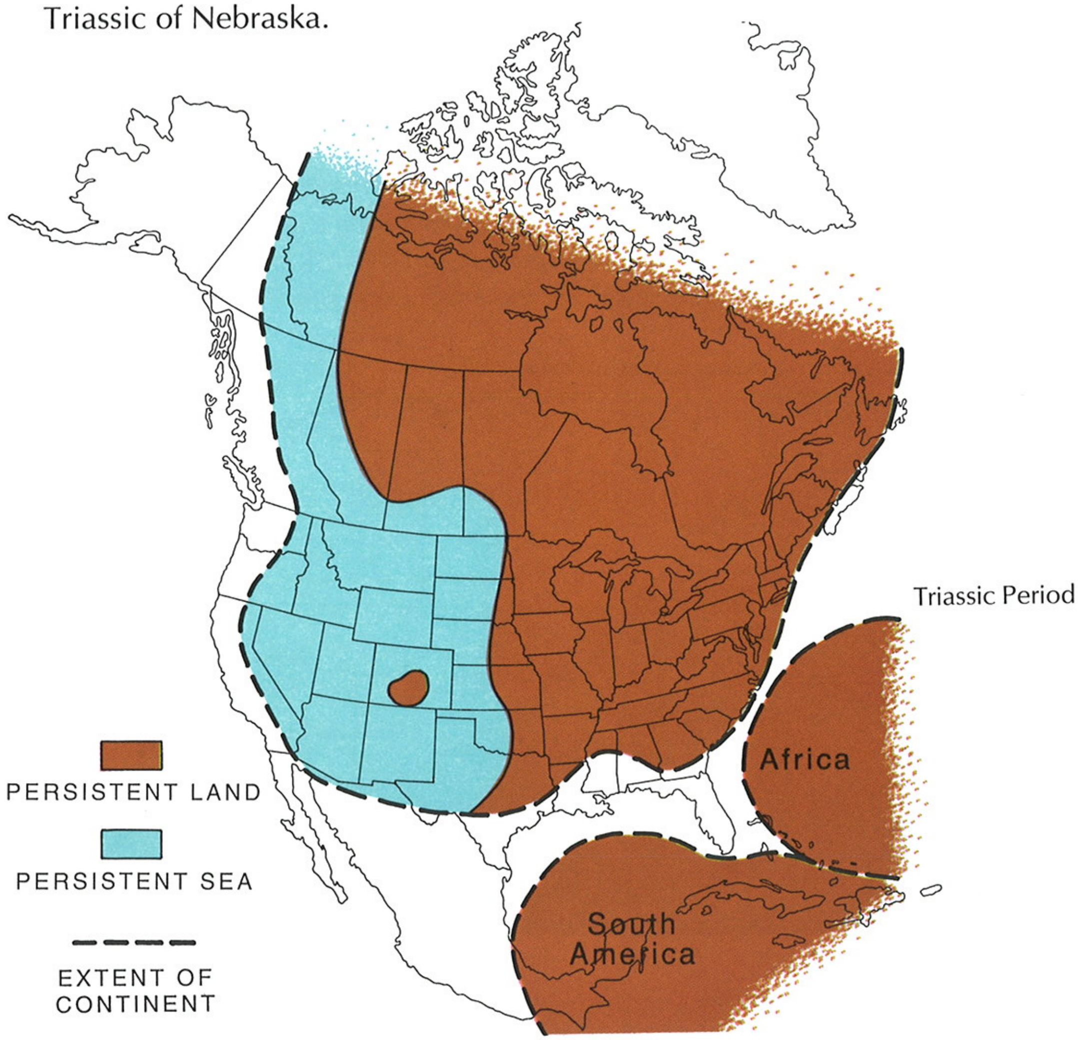
Mesozoic Era: *Triassic Period*

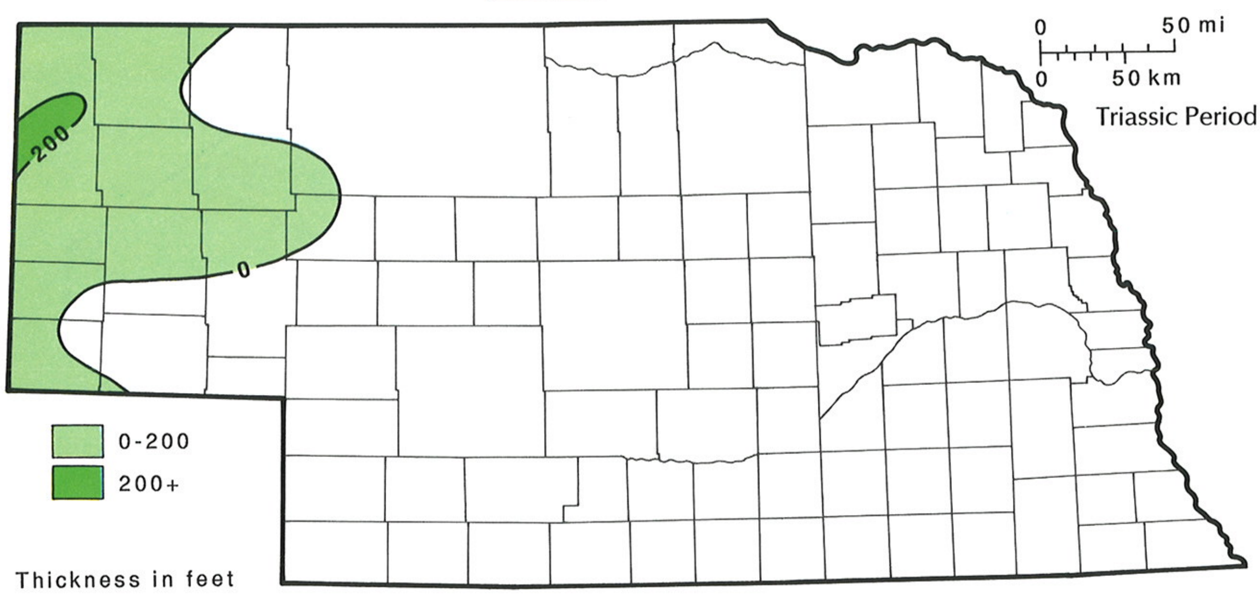
The beginning of Triassic time is the start of the Mesozoic volume of geologic history. The rock record, however, indicates that in our area there was no significant break in geologic history from the patterns of the Permian Period. The extent of the persistent land areas was greater, as indicated on the map of



North America. Only the Early Triassic rocks are present in Nebraska and consist of red mudstone and sandstone at depths of about 4,000 feet under the western portion of the Panhandle.

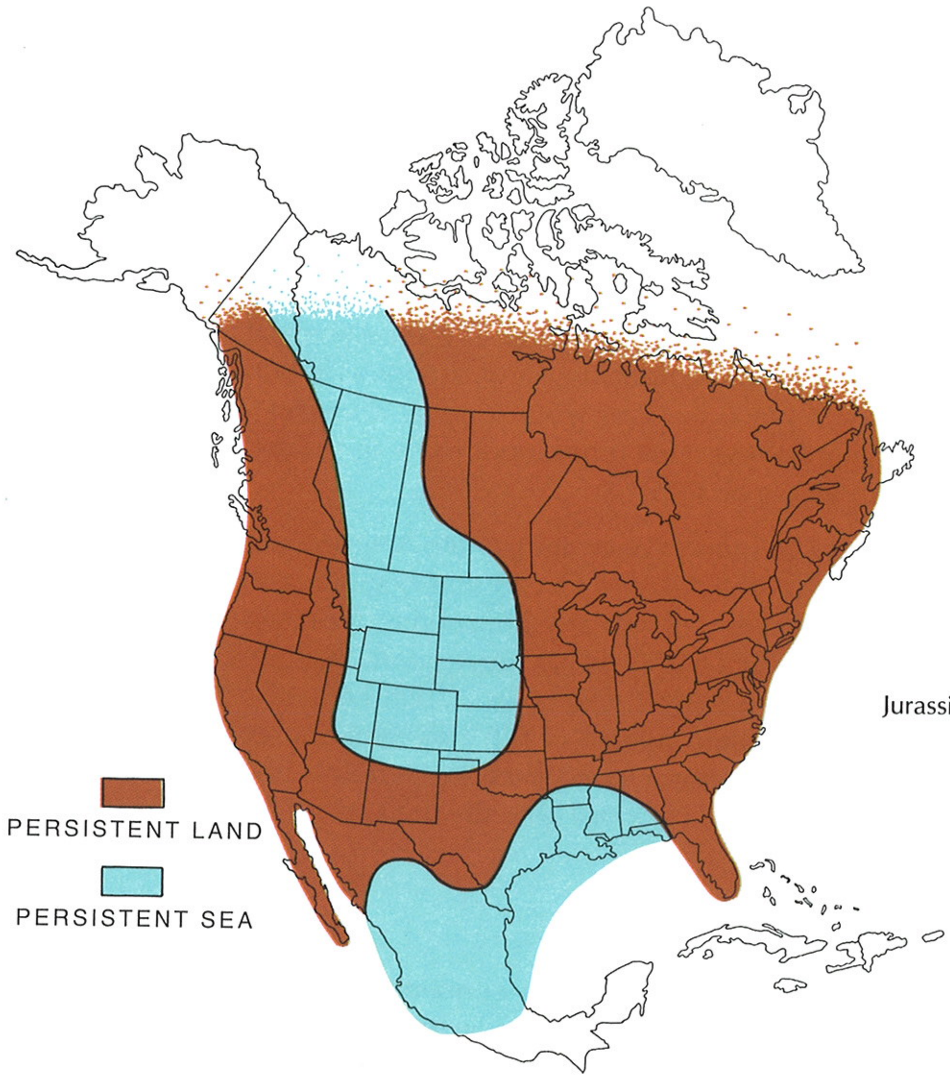
Because the environments of deposition were similar from the Permian into the Triassic, it is difficult to distinguish these rocks in the records of deep wells drilled in this part of our state. No resources have been identified in the Triassic of Nebraska.





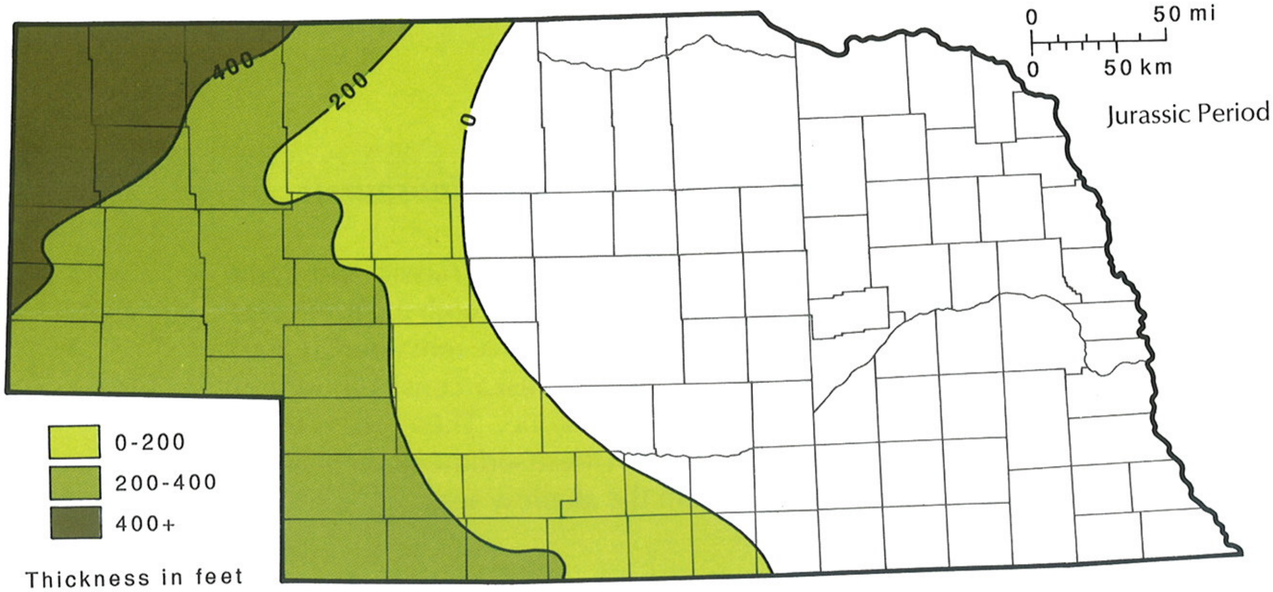
Mesozoic Era: *Jurassic Period (And Finally the Dinosaurs!)*

Most of North America was land area during the Late Triassic and Early Jurassic. During the Middle Jurassic, seas advanced from both the north and south. An area across Texas and Oklahoma seems to have remained as land separating these oceans. The Jurassic rocks of Nebraska consist mostly of green-gray to brown-gray mudstones and sandstone. These rock types indicate the presence of land nearby, from which these sediments were being eroded and deposited on floodplains and in the shallow seas.



Jurassic Period

The Jurassic underlies the western portion of our state but has yielded no mineral resources. And since we have only the fragments of Jurassic rocks provided us by the drill holes in western Nebraska, there are no records of dinosaur fossils found in Nebraska's Jurassic rock units.



The Jurassic rocks exposed at the surface of western North America contain most of the abundant fossils of the dinosaurs that are so popular. These animals ranged from roughly the size of a chicken to that of a locomotive. They roamed the earth for almost 140 million years during the Mesozoic Era.

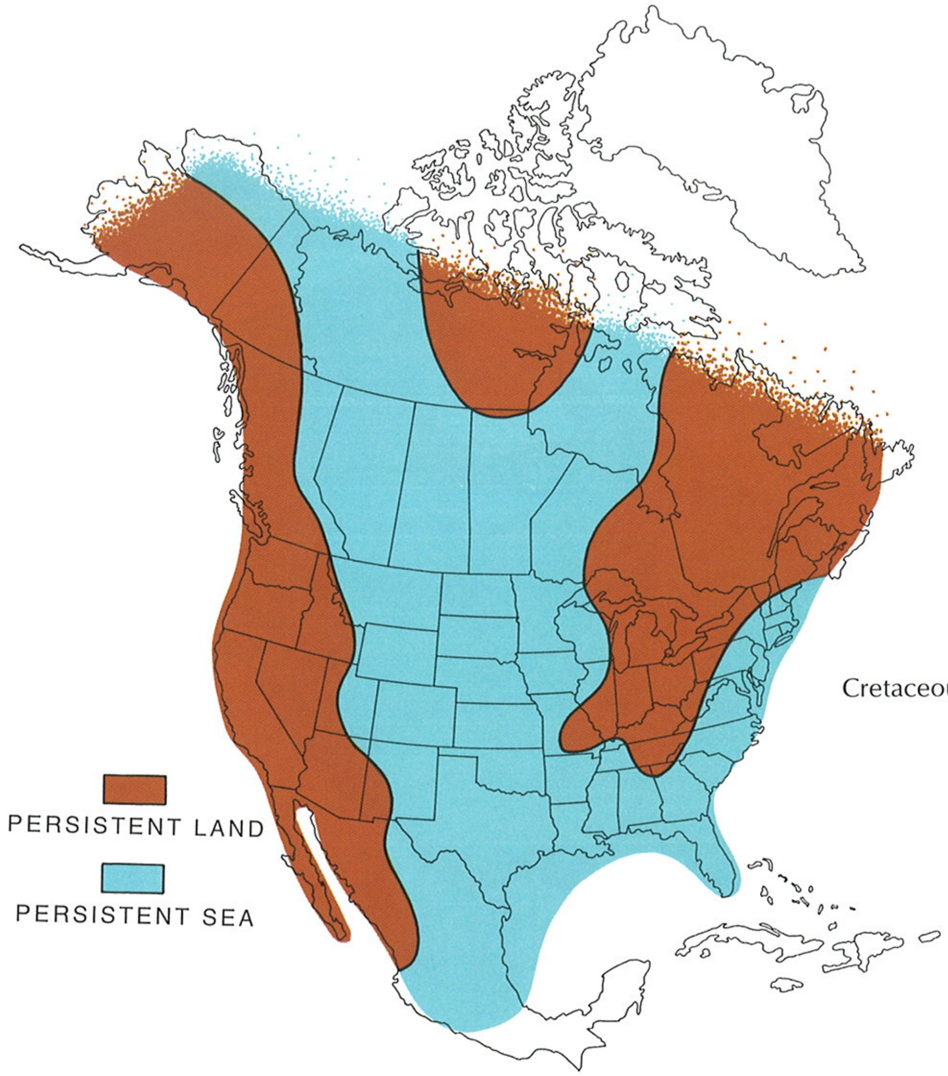
Despite what's been depicted in the movies, cartoons and stories, early humans did not appear until nearly 65 million years after the dinosaurs became extinct. The cave dwellers may have had troubles with large vicious animals, but those animals weren't dinosaurs. However, if you believe the movie, "Jurassic Park," perhaps in the future truth may be as strange as fiction and you may have to look for a place to "Park your Jurassic dinosaur." (Actually, no serious scientist yet believes that dinosaurs can be re-created from genetic material found in fossils or amber.)

Late in the Jurassic Period (about 150 million years ago), South America and Africa split off from North America--the Atlantic Ocean was beginning to develop. As the ocean basin enlarged during the early Cretaceous, the south Atlantic opened, causing South America and Africa to move apart. Western North America was also active in the early Cretaceous. Uplift created a mountain belt along much of the western margin of the continent. Large amounts of sediment (sand and mud) were eroded from these uplifts and transported into a basin sag to the east and onward onto the flatlands of the Midcontinent.

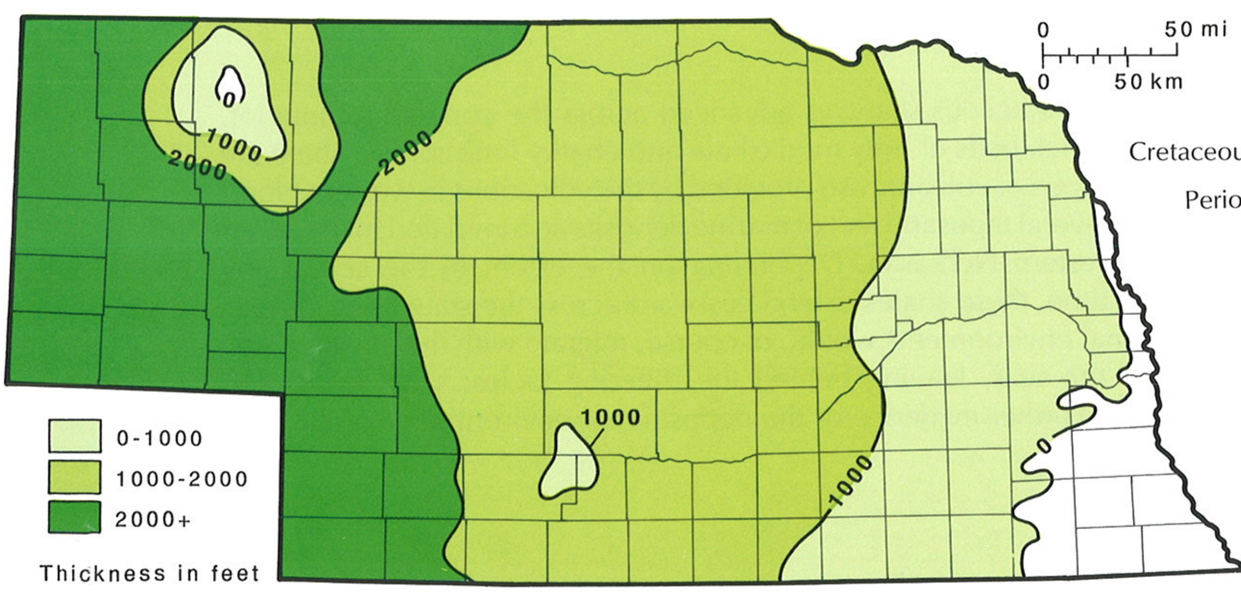
Mesozoic Era: *Cretaceous Period*

Throughout most of Cretaceous time, North America contained a central seaway accumulating thick deposits of marine sediments on the ocean floor. Coarser sands and silts were washed into the ocean margins from land areas to the east and west. These Cretaceous seas advanced eastward across Nebraska and blanketed the older Mesozoic and Paleozoic rocks. The Cretaceous rock units are excellent examples of facies deposits--rock types that intertongue and record different environments present across an area during the same instant of geologic time. As any particular segment of Cretaceous time is traced eastward across North America, a pattern emerges.

Sands from the western mountains merge into finer grained mud (shale). These in turn intertongue with the deeper water limestone (limy mud on the ocean floor). The pattern reverses back into shale and sand as the the ocean approaches the eastern land area.



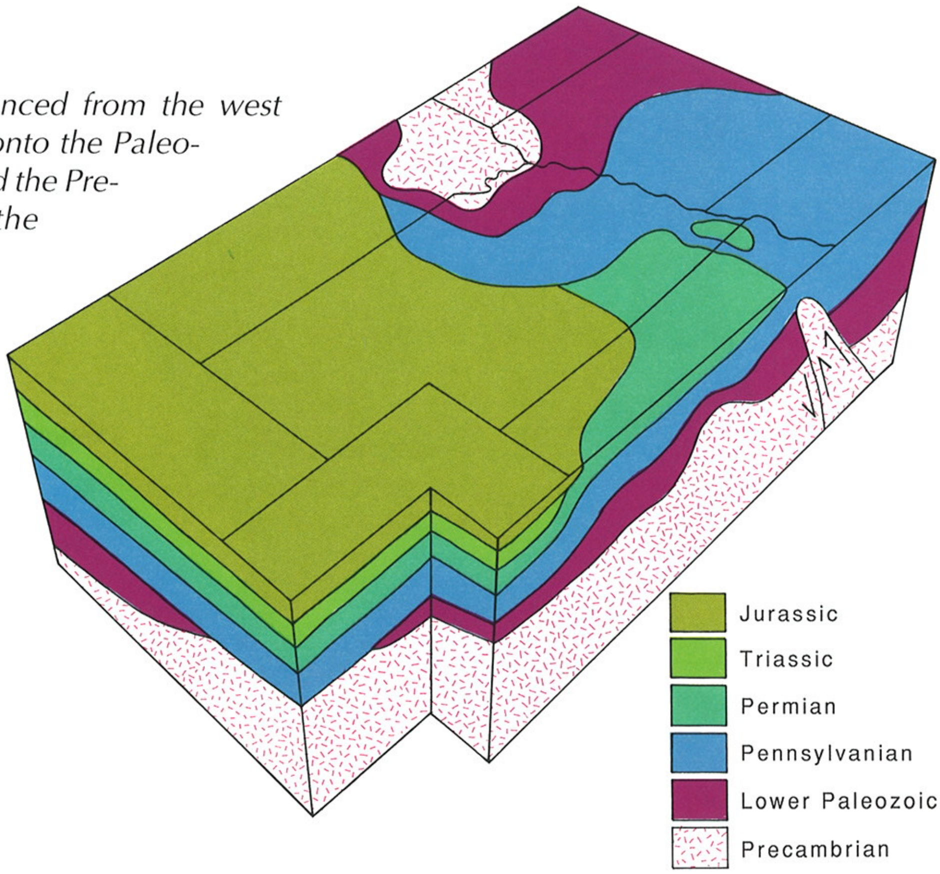
Cretaceous Period



Cretaceous Period

The Lower Cretaceous sandstones and siltstones are more than 500 feet thick in the Denver Basin area of western Nebraska. Many of these rock units, however, are sandbar, beach and river (fluvial) deposits, indicating shallow-water, near-shore, and continental environments of deposition. In order to maintain these environments yet accumulate the thicknesses, the basin must have been gradually subsiding as the sediments were deposited. Most of these Lower Cretaceous units provide a record across Nebraska of beach sands and delta-type environments. We'll learn more about these rock units, particularly the Dakota Group, in later discussion.

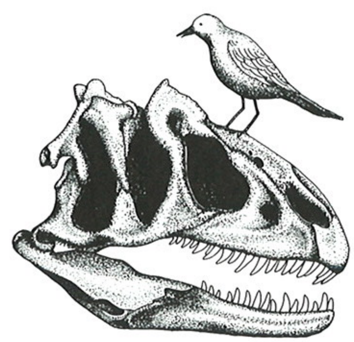
Cretaceous seas advanced from the west across Jurassic rocks onto the Paleozoic rocks and covered the Precambrian rocks of the Sioux Uplift.



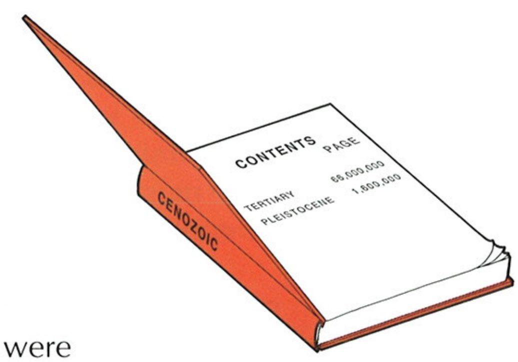
The Upper Cretaceous seaways advanced across the continental interior, depositing thick beds of limy mud (shale and chalky limestone). There are a few thin layers of volcanic ash provided by the volcanoes in western North America. Several thousand feet of marine deposits accumulated in the major basin in western Nebraska. Depending on the extent of the sea at any particular time, these shales extend eastward across the state. The various depositional environments would, of course, migrate with the advance and retreat of the seas, leaving behind the differing facies: sand, mud, and limestone. Further evidence of the depositional environments of the rock units are the fossils they contain. Large clams and even marine reptiles are found in the limy mud. Plant fossils (leaves and stems) have been discovered in the sandy units.

The Dakota Group is the name applied to the sandstone and mudstone in a part of the Lower Cretaceous. These deposits are at the surface in eastern Nebraska and supply a surprising variety of resources. The Indian statue in Pioneers Park near Lincoln was built on outcrops of the Dakota Group. The reddish-yellow color of these rock units here and in roadcuts along the interstate between Lincoln and Omaha was caused by the high iron content that formed the cement for these sandstones. The Dakota Group is also used for construction materials and for making bricks and tile. In east-central Nebraska, the Dakota Sandstone is an important aquifer, supplying groundwater for domestic use and irrigation. In the Panhandle, most of the numerous oil and gas fields produce from reservoirs in the Dakota sand units at depths of 4,000 to 6,000 feet. And actually, one small fragment of a dinosaur was found in the Dakota rocks of eastern Nebraska—but not much to show for the millions of years these animals dominated the earth. The Cretaceous rocks provide both an interesting cross-section of geologic history and valuable resources for our economy.

The end of the Mesozoic Era (which comes at the end of the Cretaceous Period) marks the final retreat of the oceans from Nebraska. The uppermost Cretaceous rocks in western Nebraska are again sandstone, indicating a continental environment--the seas had departed. Late in Cretaceous time--about 70 million years ago--a major mountain-building event began--the Laramide Orogeny. This was the onset of the formation of the Rocky Mountains, a series of uplifts extending from Mexico into Canada. An entirely new pattern of geologic environments was created for central North America.



Cenozoic Era: *Tertiary Period*



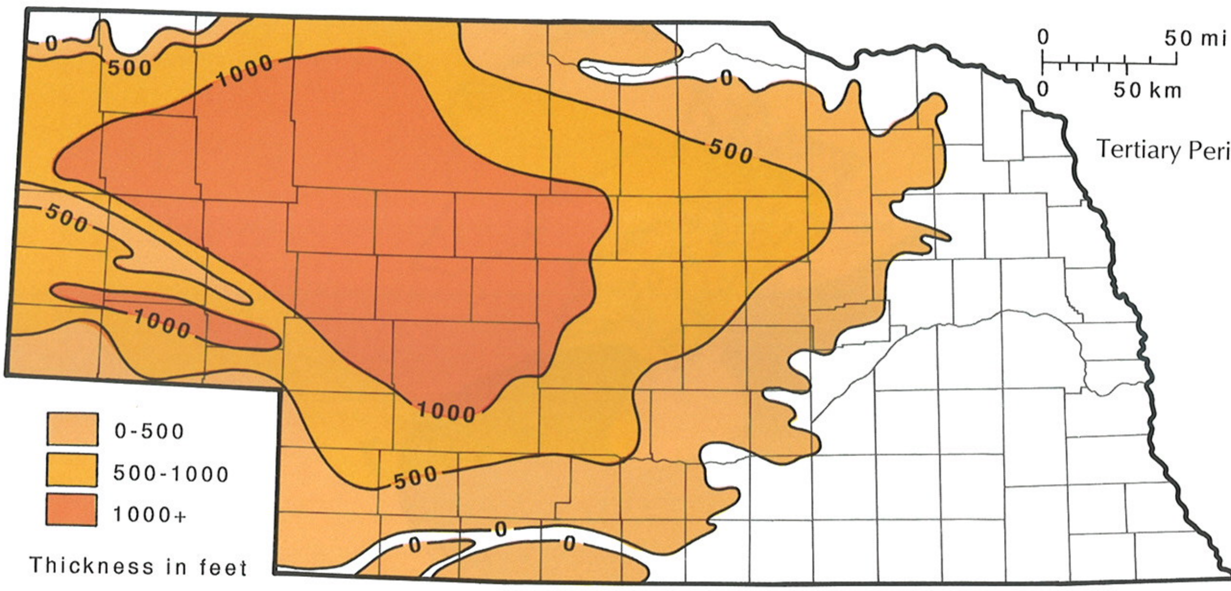
The early part of the Cenozoic has no rock record in Nebraska. From about 68 to 37 million years ago, Nebraska must have been undergoing erosion. The Cambridge Arch was reactivated, and large amounts of the Cretaceous rocks were eroded from western Nebraska. In a part of northwestern Nebraska, all of the Cretaceous rock units were eroded and rocks of Jurassic age were exposed.

Tertiary Period

The oldest Tertiary deposits are river sand and floodplain mud that filled up the low-lying areas on the eroded Cretaceous surface. All of the Tertiary rock units are of continental origin. The two major kinds of deposits are fluvial (from streams and nearby floodplains) and eolian (wind-blown).

Eolian deposits make an important part of the Tertiary rock record. These wind-blown clays and silts were derived in part from the older rocks exposed in the rising Rocky Mountains. However, the majority of the material was provided by the numerous volcanoes active over western North America. Hundreds of feet of volcanic ash, mixed with other sediments, were deposited in Nebraska. For the most part, this deposition was slow enough that both plants and animals could survive and flourish.

Stream erosion really accelerated about 17 million years ago in the later Tertiary. Large rivers flowing eastward from the Rocky Mountains carried not only silt and sand but larger gravels and cobbles out across Nebraska. It is



Tertiary Period

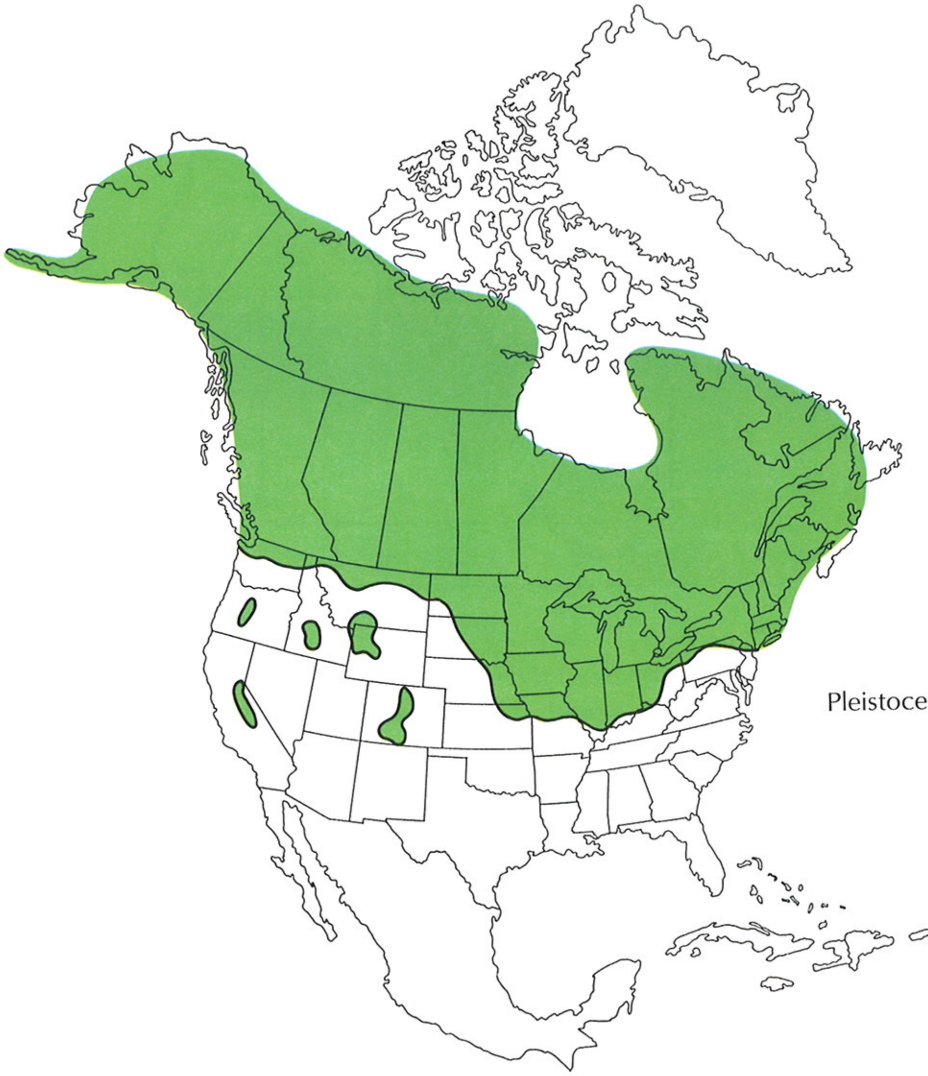
these deposits that make up the major part of the High Plains (Ogallala) Aquifer. The river systems of the Tertiary wandered across the Nebraska landscape for more than 35 million years. The rock units record both deposition and erosion in numerous repetitions, gradually building thicknesses of over 1,000 feet in west-central Nebraska.

Parts of Nebraska during Tertiary time must have looked much like modern Africa--the open grassland and the stream valleys. Many of the fossils on display in the University of Nebraska State Museum (Morrill Hall) document the large herds of grazing animals that roamed across the state. A good summary of the Tertiary deposits, including the development of the Sand Hills region and a description of the High Plains (Ogallala) Aquifer, is provided in *An Atlas of the Sand Hills,* published by the UNL Conservation and Survey Division.

Cenozoic Era: *Pleistocene Period*

The end of Tertiary time marks the end of the rock record in many parts of the world. The remaining years of geologic history consisted mainly of erosion attacking the older rocks, carrying silts and sands on toward the sea and shaping the landscape as we see it today.

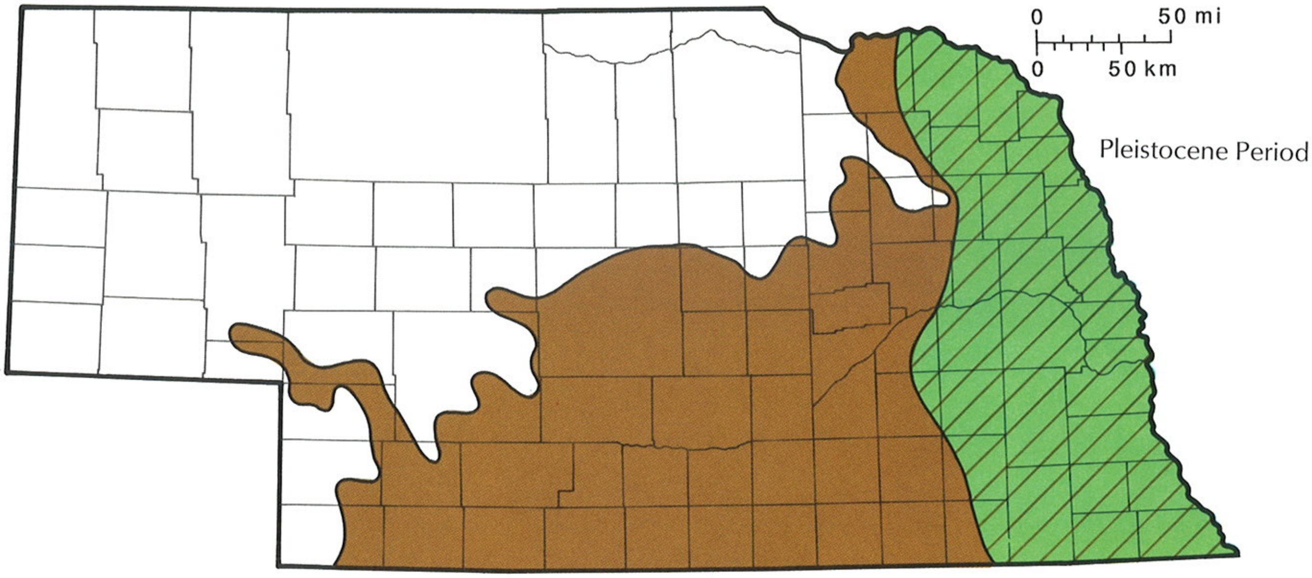
In Nebraska and adjoining areas, however, the Late Cenozoic is an important part of our rock record. Beginning about 2 million years ago, continental glaciers advanced southward across North America, creating the "ice age." For about a million years, glaciers advanced and retreated across the Midcontinent.



Pleistocene Glaciers

Ice hundreds of feet thick moved across eastern Nebraska, bringing with it large volumes of rock fragments ground to dust (sometimes called "rock flour") by the action of the ice. The ice melted, leaving behind glacial till, a mixture of clay, silt and sand. Even large boulders were brought in, particularly if they were composed of resistant rock. The pink Sioux Quartzite, a favorite in rock gardens in eastern Nebraska, is a Precambrian-age rock brought in by the glaciers from South Dakota and Minnesota. Glaciers also gouged out the older Cenozoic and Mesozoic deposits, grinding up these rocks and mixing them with the transported rocks.

The presence of the glaciers in the eastern part of our state also had a profound effect on the rivers that had been flowing generally eastward across Nebraska for millions of years. New drainageways were cut around the glaciated areas. Large volumes of sand and gravel were deposited in east-central Nebraska, adding to the groundwater-storage capacity of the major aquifer systems.



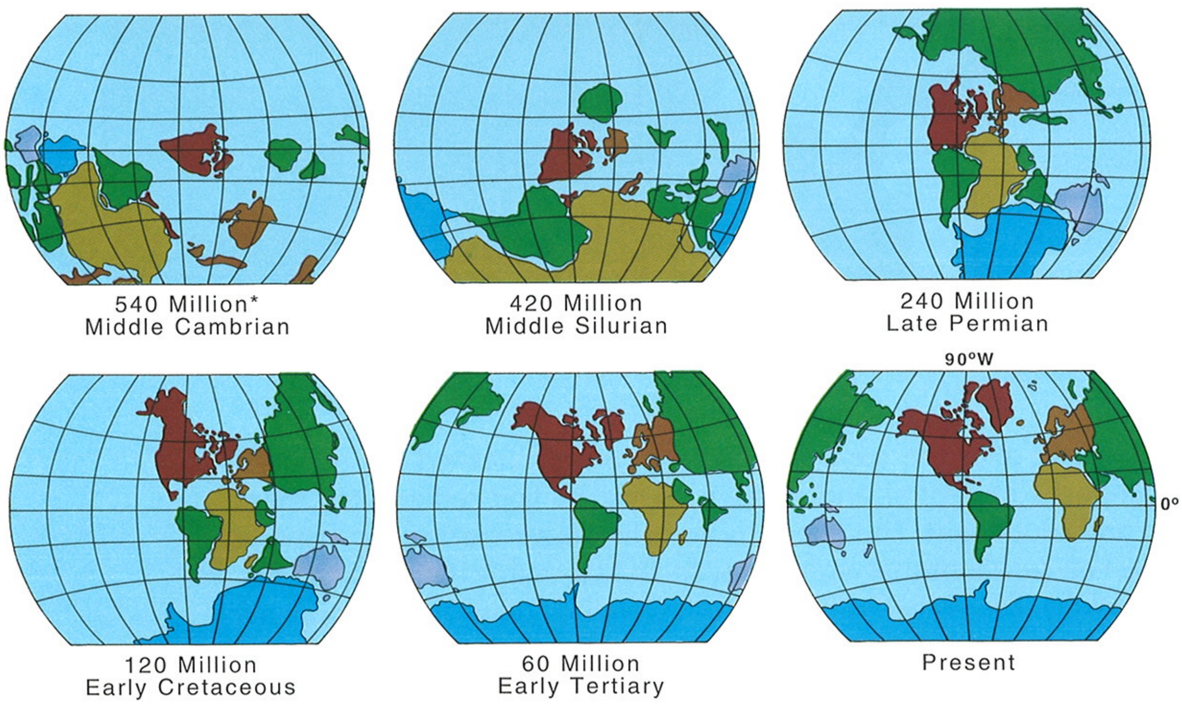
(glaciated part in green; loess in brown and stripes)

Both during and after the ice age, wind and water attacked the exposed Tertiary deposits in central and western Nebraska and redeposited them eastward and southward. The finer silts and clays were carried out, leaving behind the coarser sands that would later serve as a source for the Sand Hills region. Blankets of loess (wind-blown dust) were laid down across southern and eastern Nebraska. The thicker deposits formed bluffs along the major drainages because the floodplains of these rivers served as a source for the loess.

Other than the modern drainage systems, the Nebraska Sand Hills were the last major alteration recorded in our geologic history. This region--the largest area of dune sand in the Western Hemisphere--was formed during several episodes of blowing sand over the last 10,000 years.

The thick deposits of sand and gravel that form the groundwater reservoir for the High Plains Aquifer are a major resource contributed by the Cenozoic. A major uranium discovery in northwestern Nebraska is hosted by sands filling old channels at the base of the Tertiary rocks. Potash was mined during World War I from the western Sand Hills lakes. Silt, sand, and gravel from the Tertiary, Pleistocene, and recent river deposits are used for aggregate and road material. Peat and volcanic ash are potential resources that occur in the Tertiary rocks. And, over most of Nebraska, the Cenozoic provides the parent material for most of the soils, particularly the mantle of loess covering the southern and eastern portion of Nebraska.

In our earlier discussion on plate tectonics, we pointed out how the plates on the earth's surface separated and collided to reshape the continents and ocean basins. As we traced the history of Nebraska, the general evolution of the North American continent was included. The illustrations below are like snapshots taken at various times during the long span of geologic history. Each picture shows the relationships of the continents and ocean basins as they were "drifting" across the surface of our earth.



* *Time shown in millions of years before present.*

(After Christopher Scotese, Department of Geology, University of Texas at Arlington)

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