INTRODUCTION TO GEOLOGICAL PROCESS IN ILLINOIS

GEOLOGIC HISTORY

INTRODUCTION

The geologic history of Illinois is written in the rocks beneath your feet. Each rock unit tells the story of its formation. Geologists identify rock units and place them in order to create a geologic column. In the field, geologists record the locations of rock units to create a geologic map. The geologic column and the geologic map can be used to read the geologic history of Illinois. The rock units are arranged in order from the oldest on the bottom to the youngest on the top. Each rock unit is a chapter in the geologic history of Illinois; the story of each rock unit may be read using the characteristics of its rocks.

GEOLOGIC MAPS & COLUMNS

A geologic map shows the rocks or surficial deposits present in an area. Geologic maps are made by geologists who first study the stratigraphy of an area and create a geologic column listing all of the rock units present. The geologist then walks the area and makes a detailed record (on a map and in a notebook) of the geology.

Stratigraphy is the study of layered rocks (primarily sedimentary rocks). Stratigraphy includes placing rocks into distinct units, interpreting their origin, correlating them with rock units in other locations, and placing them in context with other rock units. Rock unit classification can be based on lithology or on the geologic time of deposition. The three types of units.

> **Time Units** (eon, era, period, epoch, age) are names given to sections of the geologic time scale. The time scale was originally developed by putting formations observed in Western Europe in order from oldest to youngest and by dividing them into groups based on similar characteristics such as sediment type and fossils. The geologists who developed the time scale wanted to be able to place rock units observed throughout Europe (and later, the world) into a comprehensive sequence based on age. Later, actual dates were added using modern absolute dating techniques.
>
> **The Geologic Time Scale**
> http://www.ucmp.berkeley.edu/help/timeform.html
>
> On the geologic timescale, an eon represents the greatest amount of time, followed by era, period, epoch and age. (Ages are too short to be shown on the scale.)
>
> **Time-Rock Units** (erathem, system, series, stage) are names assigned based on the geologic time when the rocks were deposited. The time is determined by correlation with other rock units and absolute dating techniques both of which are described later in this lesson. For example, the Pennsylvanian System includes all of the rocks that were deposited during the Pennsylvanian Period. The table below shows the correlation between time and time-rock units.

Time Units	Time-Rock Units
Rocks deposited during a/an...	are part of a/an...
era	erathem
period	system
epoch	series
age	stage

Lithologic Units (largest to smallest are: group, formation, member) are defined based on a detailed description of a rock layer including rock type (igneous, sedimentary, metamorphic), rock name (granite, limestone, sandstone, gneiss, etc.), specific mineral composition, color, mineral grain size, fossils, contact with adjacent layers, and any other characteristics useful in identifying the unit. The formation is the primary lithologic unit and usually represents a single environment of formation. A formation is defined at a type location where it is well exposed and displays most, if not all, of its distinctive characteristics. A formation is given a name based on a geographic feature near its type location. The second part of the formation name is a rock type if that type dominates the unit, or the word "Formation" if the unit is made of several rock types, none of which are dominant. For example, the St. Peter Sandstone is a sandstone with its type location near St. Peter, Minnesota; while the Carbondale Formation is made of a variety of sedimentary rocks and has its type location near Carbondale, Illinois. Larger units (called groups) are named when several similar formations are placed together, and smaller units (called members) are named when a single formation is subdivided.

Geologic columns are graphical representations of the lithologic units found in an area. The column depicts the rock's lithology with a symbol.

Key to strat. columns and symbols: http://imnh.isu.edu/digitalatlas/geo/basics/sedstrat.htm

Each lithologic unit within the column is given vertical space proportional to its average thickness. The lithologic unit names and a brief description of each lithologic unit are placed to the right of the column, and the time-rock unit names are listed to the left of the column. The column is developed by examining rocks at outcrops and in well logs, to ensure that all lithologic units are included and in their proper order.

Sample strat. columns:
http://imnh.isu.edu/digitalatlas/geog/rrt/part2/images/14map.gif

In a geologic column, the oldest rocks are on the bottom. When a geologist interprets the Earth's history, the story is read from bottom to top.

Geologic maps show the distribution of geologic units that are present at or near the surface. A geologic map is developed by a geologist who examines rock outcrops and well logs, records the rock units observed, and interprets the rock units present between the observed locations. The interpretation stage requires a great deal of knowledge and experience, and the resulting map is part science, part art. The interpretation can be checked by drilling wells to collect samples.

Each map is accompanied by a symbol key, which shows the colors or symbols used to represent each formation. The symbols are arranged in a vertical column, with the oldest units on the bottom. On many geologic maps, each formation name is abbreviated for use on the map as follows: a capital letter representing the system followed by the first letter of the formation name in lower case (for example, the Pennsylvanian Carbondale Formation is abbreviated Pc). These abbreviations, in combination with the symbol or color assigned to each formation, provide clarity on what can be a busy map.

There are two common types of geologic maps:

> A **surficial geology map** shows the materials present immediately underfoot and may display only the stratigraphic units of the Quaternary Period (the most recent period on the geologic time scale).
>
> A **bedrock geology map** shows the lithified stratigraphic units present at the surface or immediately beneath the unconsolidated surface materials.
>
> This map contains many rock units (groups and formations) and would probably be easier to read if the units were labeled with abbreviations as described above. Because the map shows such a large area and rock formations tend to be thin, only the Pennsylvanian System units are formations, the units from the remaining systems are groups. In Illinois, the youngest rocks are found at the southern tip of the state (they were deposited as the early Gulf of Mexico filled with sediment). The Paleozoic rocks (Pennsylvanian and below on the symbol key), make a bulls-eye pattern centered in southeastern Illinois, with the youngest (Pennsylvanian) rocks in the center, and the older rocks around the outside edges of the state.

In addition to the map and key to symbols, a geologic map may include a geologic column. The map may also include a brief written description of geologic features present, cross sections, inset maps to illustrate additional geologic features, and references.

One especially useful feature found on many geologic maps is the cross section. The cross section is a slice through the Earth that shows the rocks present below the surface, their horizontal and vertical relationships, and any folds or faults that might be present. The cross section is developed using the geologic map to show the rocks present at the surface, information about the trends of those rocks (the direction and angle at which they dip into the ground), and well logs.

Geologic Map & Cross Sections
http://www.nhnct.org/geology/csection.html

INTERPRETING EARTH'S HISTORY

Once the lithologic units have been described and mapped, the geologic history of an area can be interpreted. The underlying rule of interpreting geologic history is "the present is the key to the past," also called uniformitarianism or actualism. The idea behind this rule is that natural processes operating today were also operating in the past in the same way (although the scale and importance of various geologic processes may vary). This means that geologists can study processes that created ancient rocks by observing the processes that create those rocks today. In addition, physicists must assume that physical processes, such as radioactivity, operate today in the same manner as in the past.

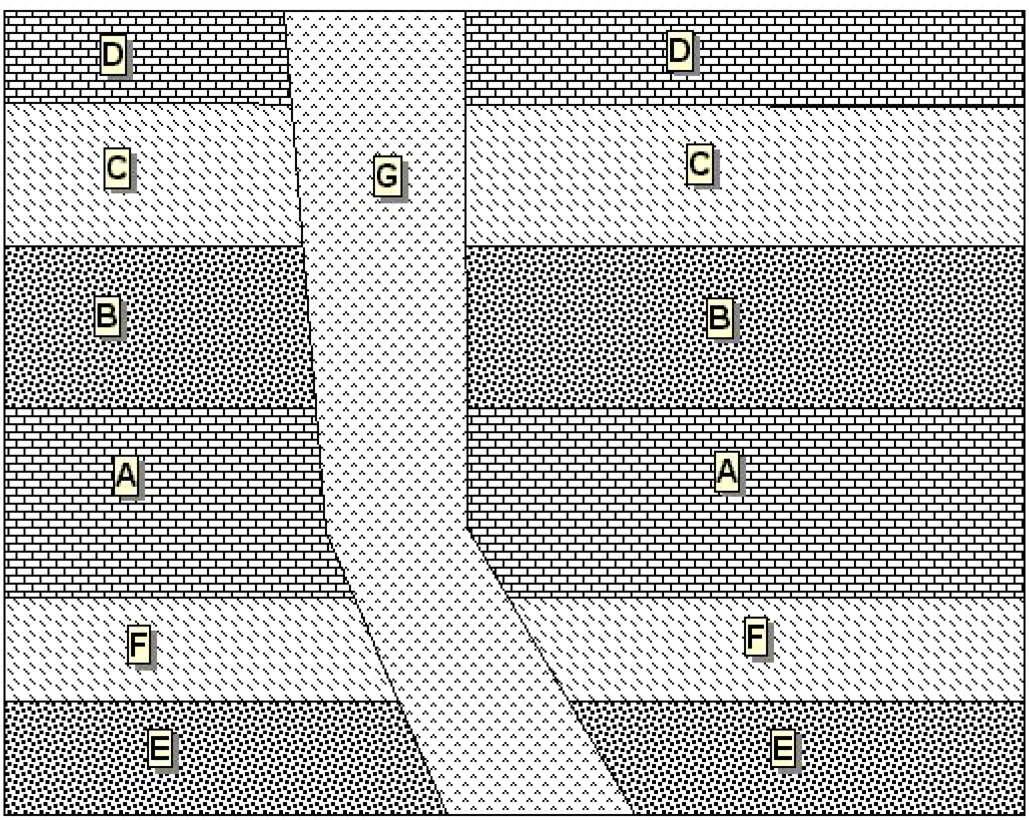
Scientists extend this idea of uniformitarianism by saying that "the past is the key to the future." The idea is to forecast what might happen in the future, based on the assumption that natural processes will continue to behave in a similar manner. This extends the importance of historical geology from interpreting the past to understanding what the Earth might be like in the future. For example, the rocks tell geologists that the Earth was warmer in the past. Understanding why the Earth was warmer and the impact that had on life allows geologists, climatologists, and biologists to describe the probable causes and effects of global warming.

Historical geology may be divided into three parts:

> *Relative dating* puts the rocks in their proper order from oldest to youngest.
> *Absolute dating* determines the actual age of the rocks.
> *Geologic interpretation* develops an explanation of the environment in which the rocks formed.

Together, these three techniques allow geologists to present a story of the Earth's history.

In the diagram below, the horizontal layers represent layers of sedimentary rock and the vertical unit represents an igneous intrusion.



Relative dating is accomplished using a set of logical rules that allow events to be placed in their proper order based on the relationships of the rock units. As illustrated on the previous page, the rules are easy to apply and require very little special knowledge. The primary rules are:

> **The Law of Superposition**: When examining a sequence of undeformed sedimentary rock units, the oldest unit is on the bottom. This can become complicated when the rock layers have been overturned, so a geologist must be aware of this possibility. *Layer E is the oldest rock unit on the above diagram.*
> **The Principle of Original Horizontality**: Layers of sediments are deposited in a horizontal position. The implication of this principle is that if sedimentary layers are found tilted or folded, something must have happened to them to cause the deformation
> **The Principle of Cross-Cutting Relationships**: When a rock unit such as an igneous intrusion or a geologic feature such as a fault cuts across another, the one that cuts across is younger. *Intrusion "G" is the youngest rock unit on the above diagram.*
> **Inclusions**: When one rock unit contains a piece of another, the rock unit that includes the piece is younger.
> **Unconformities**: When deposition of sediment stops, an unconformity is created. Alternatively, an unconformity may indicate that erosion has occurred. Unconformities can be easy or difficult to recognize depending on the type and orientation of the rock units above and below the break. Unconformities are missing pages in the geologic story and can represent days, years, or eons. Only by correlating the units above and below with other rock units elsewhere, can the size of the missing section be determined.

Absolute dating determines the age of a rock. Radiometric dating is the primary technique used for absolute dating.

Radioactive isotopes are forms of chemical elements whose nuclei spontaneously decay. This decay can occur through the loss or gain of particles. The key aspect of the decay process of interest to historical geologists is that it occurs at a constant rate called a half-life. A half-life is the time it takes for half of the original "parent" material to decay into "daughter" material. The table below shows a simple example, where the parent isotope decays directly into a daughter isotope.

Half-Lives	Parent Proportion	Daughter Proportion
start	1	0
1	1/2	1/2
2	1/4	3/4
3	1/8	7/8
4	1/16	15/16
5	1/32	31/32

As you can see, the amount of parent material steadily decreases, while the amount of daughter material increases. In a rock, the "clock" starts when a mineral crystal containing a radioactive isotope forms, the parent and daughter are both trapped inside the crystal. The half-lives that have passed is determined by opening the crystal, counting the amount of parent and daughter material, and comparing the counts to a graph showing how the decay process proceeds. The number of half-lives is then multiplied by the length of a half-life for the isotope examined.

More: http://pubs.usgs.gov/gip/geotime/radiometric.html

The table below shows several isotopes used by geologists for radiometric dating. The number after the element name is the atomic mass number of the isotope being examined. A thorough explanation of mass numbers and isotopes may be found in an introductory-level college or high school chemistry textbook.

Radioactive Parent	**Daughter Product**	**Approximate Half-life (years)**
Rubidium-87	Strontium-87	48.6 billion
Thorium-232	Lead-208	14.0 billion
Uranium-238	Lead-206	4.5 billion
Potassium-40	Argon-40	1.3 billion
Uranium-235	Lead-207	700 million
Carbon-14	Nitrogen-14	5730

There are two primary limitations to radiometric dating:

1. The length of the half-life sets a maximum and a minimum to the age of the material that can be analyzed accurately. If not enough time has passed, there won't be enough daughter material to detect (to date a rock using rubidium-strontium, it must be at least 100 million years old). If too much time has passed, there won't be enough parent material to detect (to date a rock using carbon-nitrogen, it must be less than 70,000 years old). Newer, more sensitive equipment is helping remedy this problem.
2. Only certain materials can be dated. The rock or other material to be dated must contain the radioactive isotope. For example, carbon 14 is found in dead organisms and only certain rocks and minerals contain the other isotopes. In addition, the date gives the time the mineral crystallized, so many sedimentary rocks, which contain crystals were originally in other rocks cannot be dated. Most dating gives the time an igneous rock crystallized from molten material or the time when a metamorphic rock was recrystallized from a preexisting rock.

When combined with relative dating techniques, the approximate ages of most rocks can be determined.

Interpreting the rocks is the final step. The lesson on rocks described how a variety of rocks form. After the rocks have been put in order and their ages determined, the history can be completed by using a rock's composition to reveal its story. A brief description of some of the key characteristics and what they indicate is given below.

Igneous Rocks The composition and texture of an igneous rock indicates where it formed. The composition of an igneous rock indicates the source and history of the molten rock from which it formed. Mafic igneous rocks form where two pieces of the Earth's surface (tectonic plates) are pulling apart, while felsic and intermediate igneous rocks form where two tectonic plates are colliding. The ocean floor is made primarily of mafic rock and the continents are made primarily of felsic and intermediate rock. The texture of an igneous rock indicates where it cooled. Fine-grained igneous rocks form when molten rock cools on the Earth's surface; small crystals form when the molten rock, in contact with water or the atmosphere, cools quickly. Coarse-grained igneous rocks form when molten rock cools slowly below the Earth's surface; large crystals form when molten rock, insulated by surrounding rock, cools slowly.

Sedimentary rocks have characteristics such as rock type, color, sedimentary structures, and fossils that indicate the environment in which the sediment was deposited. The table below provides the environments of deposition for some common sedimentary rocks.

Sedimentary Rock Type	Environment of Deposition
conglomerate	river bed, glacier
breccia	alluvial fan
quartz sandstone	beach, desert
arkose sandstone	river bed, alluvial fan
greywacke sandstone	river bed or delta
siltstone	river flood plain or delta, marine continental shelf
claystone or shale	river flood plain, marine continental shelf
limestone (micrite, crystalline)	marine (continental shelf)
limestone (oolitic)	marine (shallow tropical lagoon)
limestone (chalk)	marine (continental shelf or abyssal plain)
limestone (coquina, fossiliferous)	marine (shallow continental shelf or organic reef)
dolostone	marine (same as limestone type they resemble)
gypsum or halite	enclosed lake or bay
coal	swamp

The color of the rock can indicate whether or not the sediment was exposed to free oxygen in the atmosphere; most sediments contain a small amount of iron, which will be orange or red when exposed to free oxygen and gray, green or black when under water. Sedimentary structures such as ripple marks and cross-bedding can indicate water flow or wind direction, and mud cracks can indicate that the sediment was periodically dried out. Fossils in a sedimentary rock indicate the life forms that were present when the sediment was deposited and can give a picture of an ecosystem.

Metamorphic rocks tell the geologist that preexisting rocks were subjected to high pressures and/or temperatures. The metamorphic rock environments are: contact with molten rock, pressure along a fault zone, regional compression (most often due to the collision of tectonic plates), and meteor impact. Each metamorphic environment produces a unique set of characteristics, the most important of which are index minerals, which indicate how much change the rock has undergone, and foliation, which is the alignment of minerals under high pressure. In addition the geologist may be able to determine what type of rock was metamorphosed, allowing interpretation of the origin of the rock that was metamorphosed.

A BRIEF GEOLOGIC HISTORY OF ILLINOIS

This section will describe the rocks found in Illinois and briefly explain what they indicate about the geologic history of Illinois. This generalized geologic column for Illinois shows the rocks present below the surface of Illinois.

Precambrian Era (4.5 billion-450 million years ago)
The Precambrian rocks of Illinois are found buried deep beneath the surface (2,000 to 14,000 feet down!). The rocks are granite and rhyolite (intrusive and extrusive, felsic, igneous rock) that are approximately 1.5 to 1.0 billion years old. The surface above the rocks is a hilly erosional unconformity. Illinois was probably formed when several small tectonic plates collided with a larger plate to the north to form the core of North America (geologists call this early version of our continent Laurentia). The area would have had very large mountains (like the Rockies or Alps) which were eroded over the years into a hilly terrain.

Paleozoic Era (540-248 million years ago)

Cambrian Period (540-490 million years ago): The rocks of the Cambrian System are (from bottom to top) sandstones, sandy dolostones, and dolostones; beneath the Cambrian rocks is an erosional unconformity. The dolostones are much thicker in the southern part of the state and were deposited at the same time as some of the sandstones in the northern part of the state. The erosional unconformity at the base indicates that the Cambrian began with Illinois above sea level. Rising sea level flooded the state and the shoreline advanced from the south as sand washed in from the exposed land to the north.

Ordovician Period (490-443 million years ago): The rocks of the Ordovician System are primarily limestones with a thick sandstone located near the bottom; beneath the Ordovician rocks is an erosional unconformity, and several additional unconformities are located within the System. The limestones indicate that Illinois was a shallow marine environment for most of the Ordovician, although the sea level fell occasionally to allow the erosion of the unconformities and to allow the widespread deposition of the St. Peter Sandstone which indicates a beach environment. Cross-beds in the St. Peter Sandstone indicate that the prevailing winds blew from the east, telling geologists that Illinois was much closer to the equator in the zone of the trade winds (at our present latitude, the prevailing winds blow from the west). The Ordovician rocks also contain a few thin (1 to 2 cm thick) layers of bentonite, a clay that develops from ash fall deposits; the bentonite is an indication of volcanic activity (there is no evidence that the volcanic activity was in Illinois).

Silurian Period (443-417 million years ago): The rocks of the Silurian System are primarily limestones and dolostones with a few thin layers of shale and siltstone; beneath the Silurian rocks is an erosional unconformity. Illinois was below sea level for almost all of the Silurian. The Silurian rocks contain large organic reefs (made by corals and sponges), indicating a warmer climate, so Illinois was still close to the equator.

Devonian Period (417-354 million years ago): The rocks of the Devonian System are limestones and dolostones and cherts at the base, more limestones in the middle, and shales at the top; below the middle limestones is an erosional unconformity. In the early Devonian, the rocks in the west central part of Illinois were folded into an arch, exposing that part of the state to erosion. The rest of Illinois was under shallow water and gradually filling with more sediment. In the late Devonian, sea level dropped and the water retreated to the south, allowing the deposition of shales with a terrestrial source to the north.

Mississippian Period (354-323 million years ago): The rocks of the Mississippian System are shales at the base, mostly limestones in the middle, and alternating shales, limestones and sandstones at the top, the uppermost Mississippian is represented by a large unconformity. The Mississippian rocks are only present in the southern 2/3's of Illinois. Folding during and before the Mississippian lifted the northern part of the state above sea level. During the Mississippian, sea level rose, covering most of the state and allowing the deposition of thick layers of limestone. Periodic fluctuations of sea level resulted in alternating types of rock. The Mississippian rocks are very rich in fossils and provide a peek at the life present at that time. At the end of the Mississippian, sea level fell, exposing most of Illinois to erosion. Deep valleys were incised into the Mississippian sediments and later filled during the Pennsylvanian Period.

Pennsylvanian Period (323-290 million years ago): The rocks of the Pennsylvanian System are alternating layers of limestone, shale, sandstone, and coal. Within and between these layers are many erosional unconformities. During the Pennsylvanian, Illinois varied from slightly above to slightly below sea level. The rock layers are found in repeating sequences called "cyclothems." Each cyclothem is thought to represent a complete cycle of sea level rise and fall. The shales and limestones represent times when sea level was up and the sandstones and coals when sea level was down. Some of the sandstones are in the form of river channels which cut through the underlying layers. The sandstone layers indicate when sea level was at its lowest and are used to mark the bottom, or start, of a cyclothem. The coal layers vary in thickness from an inch to over six feet and represent tropical swamps (Illinois was still near the equator) that probably covered most of the state.

Permian Period (290-248 million years ago): There are no Permian rocks in Illinois. Permian rocks in nearby states indicate that Illinois was probably below sea level in the Permian and that sediments were probably deposited and later eroded. Sea level fell in the late Permian and, except for the southern and westernmost parts of the state, Illinois has been dry land ever since.

Mesozoic Era (248-65 million years ago)

Triassic & Jurassic Periods (248-144 million years ago): Illinois does not have any rocks from the Triassic or Jurassic Period. Rocks in nearby states indicate that Illinois was probably above sea level throughout this time. Since dinosaurs fossils have been found in adjacent states, we can assume that they lived in Illinois; however, since no sediments were deposited, no fossils were preserved. During these periods, Illinois began to move north toward our present latitude.

Cretaceous Period (144-65 million years ago): The rocks of the Cretaceous System are unconsolidated (not cemented) sand, silt and clay, and are found only at the southern tip of the state and in far western Illinois. During the most of the Cretaceous, Illinois was well above sea level; however, at the end of the period, a rising sea flooded the southern and western portions of the state and left some thin layers of sediment. It was during the Cretaceous that Illinois finally reached its present latitude (about 40 degrees north of the equator).

Cenozoic Era (65 million years ago to present)

Tertiary Period (65-1.8 million years ago): The rocks of the Tertiary System are unconsolidated (not cemented) sand and gravel, and are found only at the southern tip of the state. The sea level rise at the end of the Cretaceous still covered the southern tip of the state. As the area filled with sediment, the shoreline slowly retreated to the south.

Quaternary Period (1.8 million years ago to present): The Quaternary System of Illinois is not represented by rock, but by sediment deposits. The deposits are mostly an unsorted mixture of sand, gravel, clay, and silt called diamicton, with occasional layers of gravel and sand and of fine silt called loess. Large boulders of rock not native to Illinois (glacial erratics) are evidence of the glaciers. The diamicton was left by large continental-size glaciers; the gravel and sand was deposited by meltwater from the glaciers; and the loess was deposited by the wind. Today, all of Illinois is exposed to the rain and wind and the surface of our state is an unconformity in the making.

ILLINOIS STATE PARKS AND NATURAL AREAS OF NOTE FOR THEIR GEOLOGIC HISTORY (ages of exposed rocks)

Apple River Canyon (Ord & Sil)
Beall Woods (Penn)
Buffalo Rock (Penn & Ord, unconformity)
Castle Rock (Ord)
Chain O'Lakes (Quat)
Dixon Springs (Penn, Miss)
Ferne Clyffe (Penn)
Franklin Creek (Ord)
Fults Hill Prairie (Miss)
Giant City (Penn)
Golcanda Marine (Miss)
Jubilee College (Penn)
Kankakee River (Sil)
Kinkaid Lake (Penn)
Lowden (Ord)
Lowden Miller (Ord)
Mattheissen (Ord)
Mazonia-Braidwood (Penn, collection of Mazon Creek fossils encouraged)
Mississippi Palisades (Ord, Sil)
Mississippi River Area (Miss)
Pere Marquette (Miss)
Piney Creek Ravine (Penn)
Randolph County (Miss)
Ray Norbut (Miss)
Rock Cut (Ord)
Siloam Springs (Miss)
Starved Rock (Ord)
Stephen A. Forbes (Penn, ancient river channel exposed near spillway)
Trail of Tears (Dev)
Tunnel Hill Trail (Penn-Miss, a walk south along the trail will take you from the Pennsylvanian through the Mississippian)
Union County (Miss, Dev)

White Pines Forest (Ord)