Depositional Setting of Late Ordovician Deposits (Upper Richmondian) on the Mid-Continent

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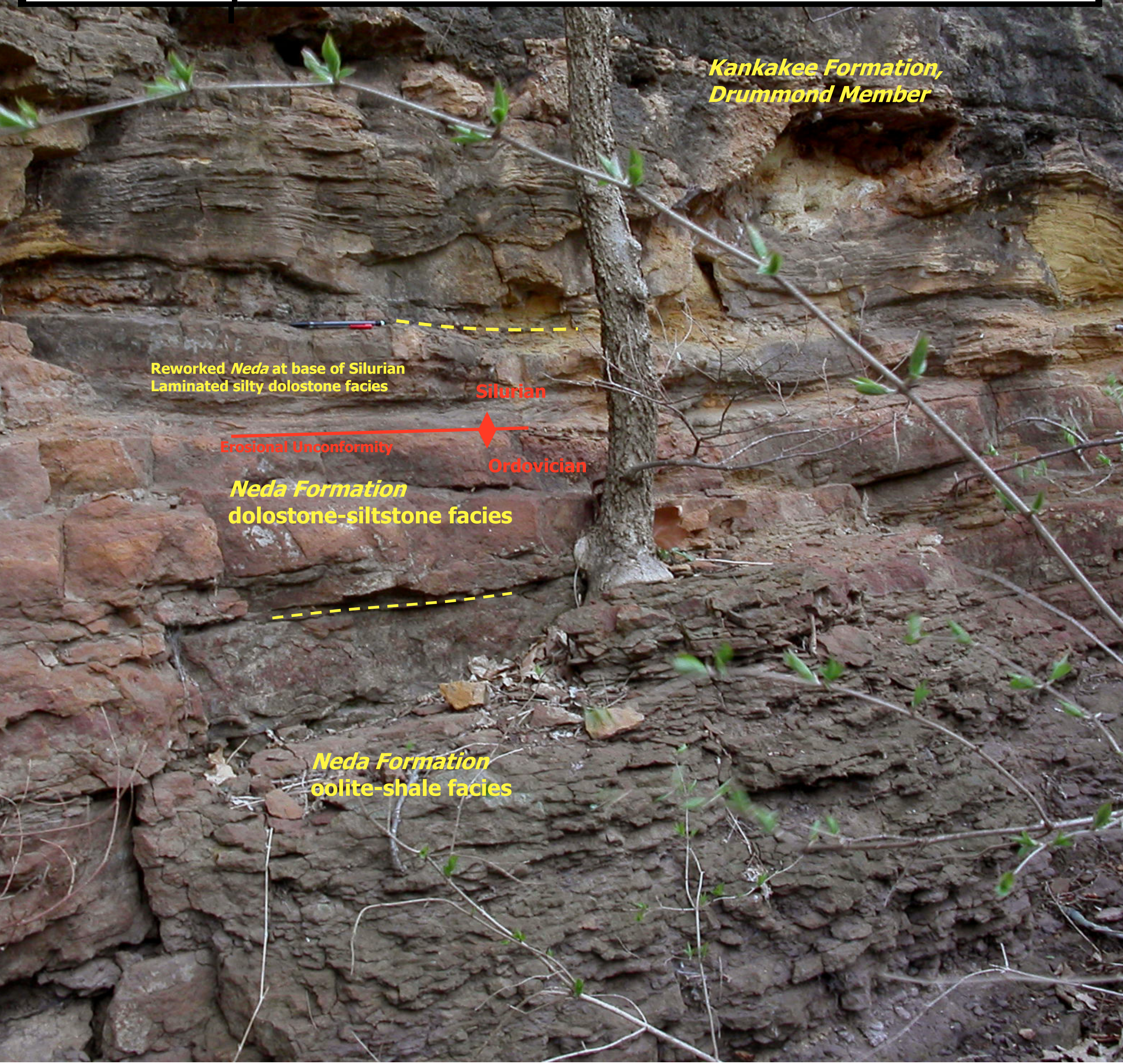
Written By: *Steven D.J. Baumann*



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Written By: ***Steven D.J. Baumann***
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Cover photograph taken by Steven Baumann on 04/04/2006 at the Chippewa Campground Section in Kankakee River State Park. Pencil for scale, on first ledge above the Ordovician-Silurian Contact.

Table of Contents

Abstract

The depositional origins of the Upper Richmondian Stage (Late Ordovician) has long been an issue of debate. Once it was established that the *Noix* and *Neda Oolites* were actually Ordovician and not Silurian, an explanation for their existence was needed. The Neda does seem to have its source from the east along the Taconic Source Area and appears to be entirely an extension of the Queenston Delta Complex. The *Noix Oolite* was deposited in a different environment altogether and does not have the same origins as the Neda. Due to lack of fossils in the *Neda* and other late Ordovician oolites, an exact age is difficult to pinpoint. Some authors have proposed that the Transcontinental Arch is the source for the *Noix Oolite*. Several lines of evidence show that the *Noix* actually formed around the Ozark Uplift once sand deposition (forming the middle to Upper *Brainard Formation* in Central Illinois) ceased in the area.

Introduction

The paleogeography of the Mid-continent during the last five million years of the Ordovician has posed a problem for geologists. There are multiple source areas for several **formations**. During the Upper Richmondian, the Mid-continent (or Midwest) was located 15^o to 20^o degrees south latitude and was rotated nearly 50^o clockwise from its present position.

At the end of the Ordovician there were two main bodies of land. The Appalachian Mountains were young and formed an area referred to as the Taconic Source Area. The Ozark Mountains were also above sea level in Missouri. These two areas served as the main source of **clastic** material for deposits throughout the Midwest (see Figure 1) at different times.

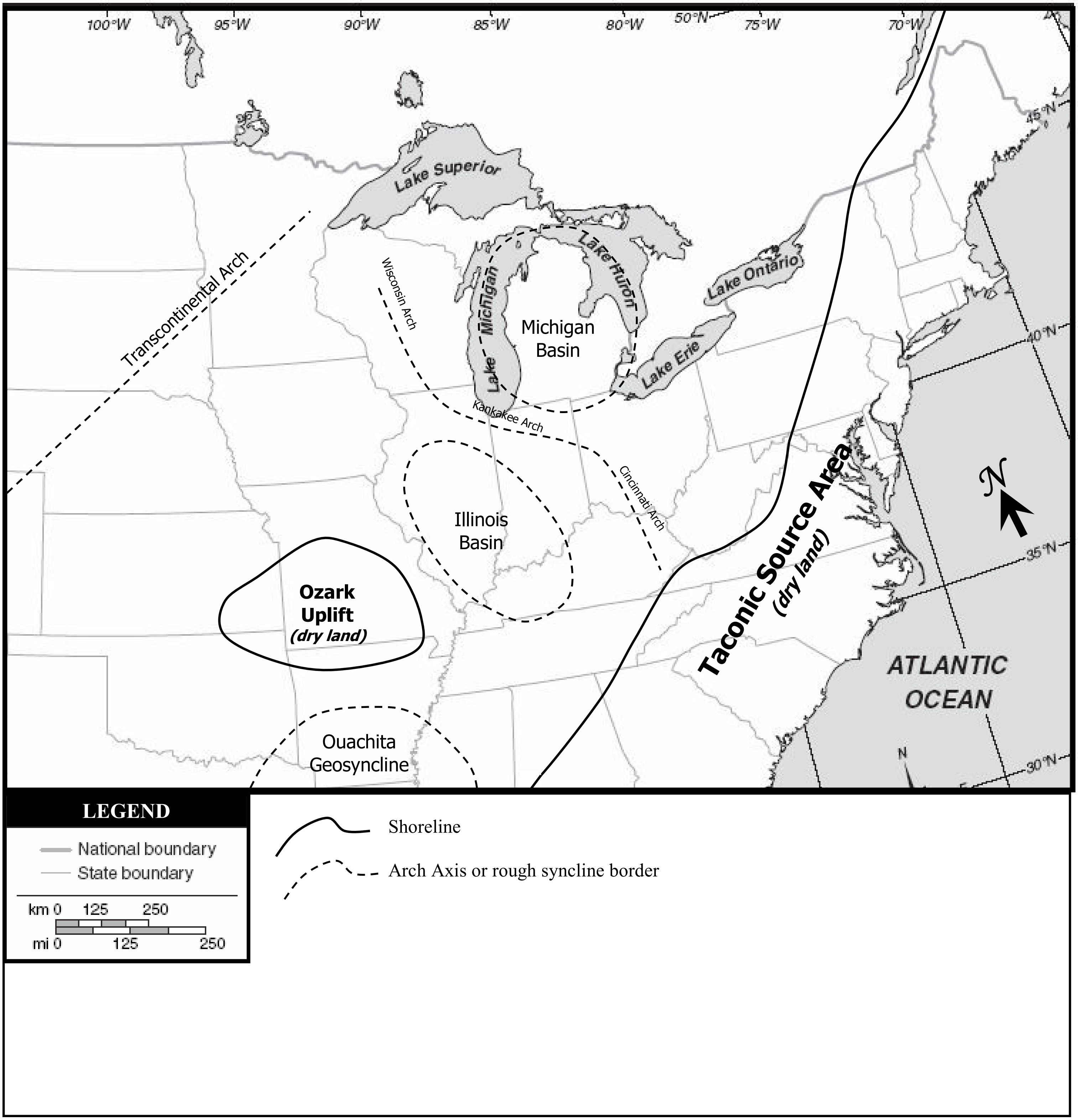
Sediment deposition was controlled by several factors. Geologic **structures** in the area were the most influential. The main structures that helped to shape deposition are the Transcontinental, Wisconsinan, Kankakee, Cincinnati **Arches**, the Michigan, Illinois Basins, and Ouachita **Geosyncline** (see Figure 1). All of these areas were below sea level until the very end of the Ordovician due to an ice age at the southern polar region. The Ordovician Ice Age exposed an area of land called the Midwest Coastal Plain, which left the area to an extended period of erosion for about three million years. Wind and ocean currents also influenced the deposition of sediments at the end of the Upper Richmondian. Warmer waters favored carbonate and oolite deposition. Cooler more southern currents favored clastic deposition.

During the Upper Richmondian the deposition of many different formations over many different areas were affected. This has led to the naming of many formations of the same approximate age. **Geologic nomenclatures** for Illinois, Wisconsin, Iowa, and Missouri will be used in the text. These nomenclatures will include equivalent sediments, which will be noted when relevant. The key formations involved (from youngest to oldest) are the *Noix*, the *Neda*, and the *Brainard Formations*.

Method

Multiple sources of literature were consulted when reconstructing the paleogeography and depositional environments during the Upper Richmondian (see references). Many authors have provided actual field work over the past fifty years. Some of the authors either directly or indirectly contributing to our understanding of depositional environments in the Midwest are; B.J. Witzke (Iowa), T.L. Thompson (Missouri), T.D. Fouch, H.B. Willman, T.C. Buschbach, D.R. Kolta, A.M. Graese, and S.D.J. Baumann (Illinois).

FIGURE 1: Geologic Structures Influencing Clastic Deposition During the Upper Richmondian 445.5 to 443 Million Years Ago



Description and Details

BACKGROUND:

The time span involved for the deposition of sediments in the Midwest during the Upper Richmondian (Late Ordovician) is around two and a half million years, from about 445.5 to 443 million years ago. At this time what we know today as the Midwest, changed more than it has in the most recent three million years. At the end of the **Ordovician** what we now know as the Appalachian Mountains were almost complete. The Ozark Mountains formed a tight network of Islands to solid ground. The entire Midwest was under water until the very end of the Richmondian. During this time it is important to remember that land plants had not yet evolved. If they had been around many of the deposits derived from the Taconic Source Area may have been ideal to form **coal**, instead of shaley oolites and siltstones.

In order to understand the depositional sequence each formation will be addressed in ascending order, from oldest to youngest. This includes the upper half of the *Brainard Formation* and its equivalents (upper *Orchard Creek*, *Girardeau*, upper *Whitewater*, and *Drake Formations*). The *Neda Oolite* and its equivalents (*Queenston*, *Junita*, *Sequatchie*, and *Becancour*), and the *Noix Oolite* and its equivalents (*Keel* and *Leemon Formations*).

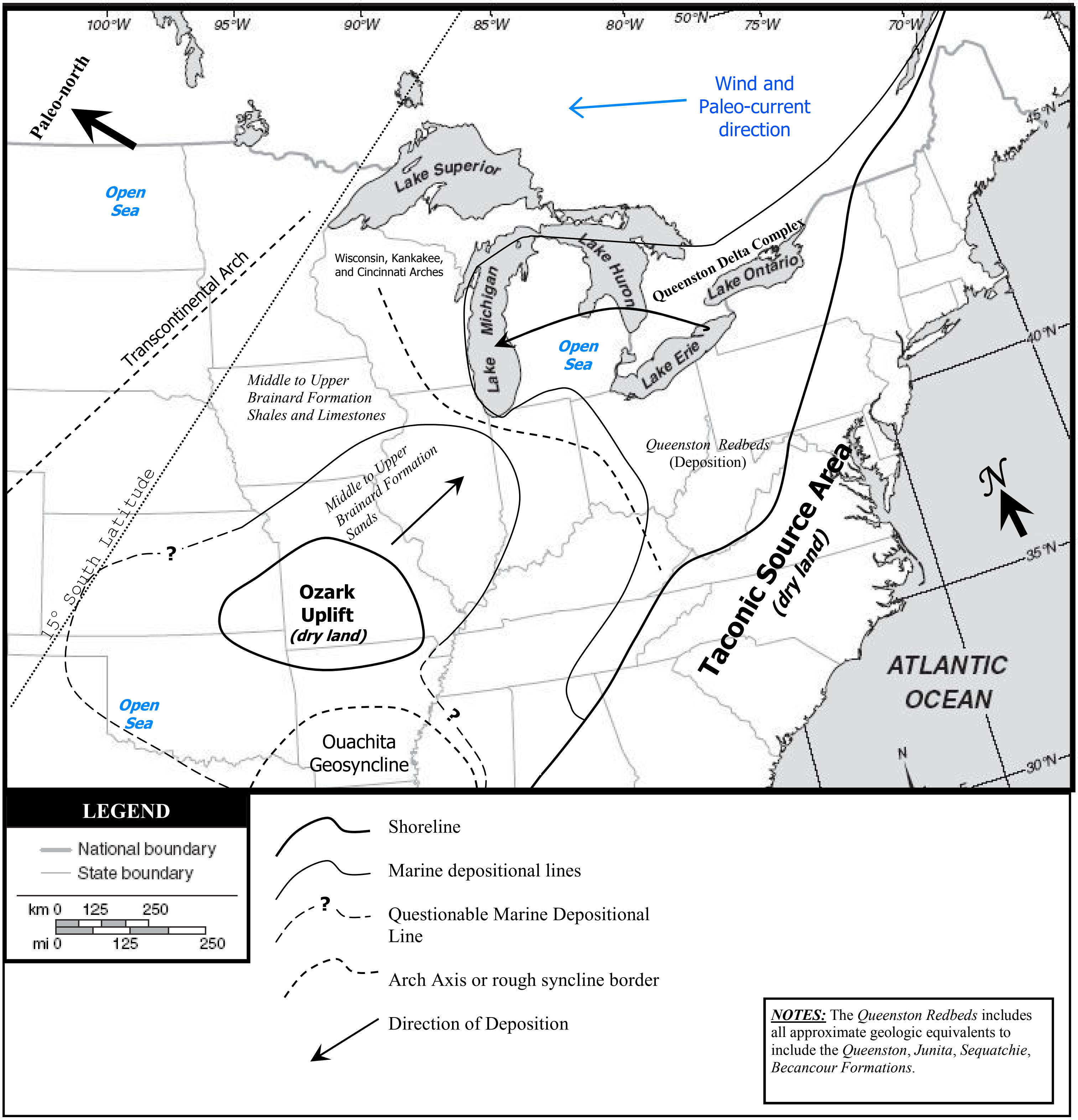
UPPER BRAINARD FORMATION:

The *Brainard Formation* is mostly green to gray shale with minor beds of **limestone** and **dolostone**. However, at several locations in Central Illinois and Eastern Missouri, it is a fine sandstone to siltstone that resembles the *Thebes Formation* (Missouri and Southwest Illinois). The *Thebes* is equivalent to the *Scales Formation* in Illinois, Iowa, Indiana, and Wisconsin. The *Thebes* is known to be derived from the Ozarks due to mineral content. Sandstone (*Thebes*) near a source area grading into a shale (*Scales*) makes sense in a normal clastic marine depositional environment. The presence of **sand** in the younger *Brainard Formation* is a bit odd. The sand extends at least fifty miles past the outer limits of the *Thebes*. This situation would occur if the ocean currents shifted due to the advance of the Queenston Delta. The more southern currents helped to extend the Queenston Delta and its sediments, perpendicular to the Taconic Source Area. This essentially increased the turbidity and velocity of ocean currents allowing for further transport of sands from the Ozark Uplift (see Figure 2). Around 444.5 million years ago this mechanism stopped as the environment changed again.

NEDA OOLITE:

Around 444.5 million years ago the Queenston Delta had extended approximately 800 miles from its source area (Taconic Source Area). The extension of the delta led to a cut off of currents from the southeast. This situation favored the deposition of **argillaceous** carbonate oolites at the front of the delta. It essentially stopped clastic deposition from the Ozark Uplift and favored **carbonate rock** deposition of the *Girardeau Limestone* of Missouri and Southwestern Illinois (see Figure 3).

FIGURE 2: Paleogeography of the Mid-continent During the Upper Richmondian 445.5 to 444.5 Million Years Ago



NOTES: The *Queenston Redbeds* includes all approximate geologic equivalents to include the *Queenston*, *Junita*, *Sequatchie*, *Becancour Formations*.

Witzke claims that the *Neda* of Iowa "does not directly relate to the Queenston Complex" (1980 p.13). His reasoning was that the *Neda* in Western Iowa parallels the Transcontinental Arch, which it does. However, if you look at the depositional remains of the Neda throughout the Midwest, they are perpendicular to the migration of the Queenston Delta deposits. This resembles a depositional environment depositing sediments in a similar manner as a glacier, which leaves an **end moraine** at its front. This pattern, along with a shift of deposition around the Ozarks from clastic to carbonate sediments indicates a single **source area** for the *Neda Formation*. The *Neda* throughout Iowa is lithologically similar to the *Neda* in Illinois. There is no need to derive two separate source areas. At the time the Transcontinental Arch was not exposed to the surface. Submarine structures do not usually serve as source areas of sediment. They are typically depositional areas. The Transcontinental Arch would have formed a barrier to the expansion of the Queenston Delta Complex (which includes both the *Neda* and the *Queenston Redbeds*). This would help explain why it never got past Iowa.

NOIX OOLITE:

Approximately 445.5 million years ago the depositional environment of the Midwest changed once again. Deposition of the *Neda* ceased and the continent subsided, deepening the **seas** in the area. At this time the Queenston Delta was still actively depositing sediments, but it was doing so much closer to its source area (see Figure 4). This retreat of the delta should have favored clastic deposition once again for the Ozark Uplift. However, due to deeper waters and a change in paleo-current from the east, the Ozark Uplift and the Taconic Source Area were not shedding as much clastic material. North America had moved several hundred miles south since the beginning of the Richmondian, bringing it out of the arid climate belt (~5 - 15^{o} latitude). This change in environment favored the deposition of the *Noix Oolite* and its carbonates, around the Ozark Uplift (see Figure 4).

There is one interesting observation about the Upper Richmond oolites. They don't seem to have been deposited in either the Illinois or Michigan Basins. There are a couple of reasons as to why they aren't in these areas. They may have been deposited and subsequently eroded. This isn't likely since the basins have thicker deposits of the Richmondian. The real cause was probably water depth. Oolites don't form when seas reach a depth of around 375 to 400 feet. They also prefer water no shallower than about 200 to 250 feet below sea level. The seas in the Illinois and Michigan Basins would have been deeper than 400 feet at the end of the Ordovician. However, the water around the Ozark Uplift and along the Wisconsin, Kankakee, and Cincinnati Arches would have provided an excellent bench for oolite deposition.

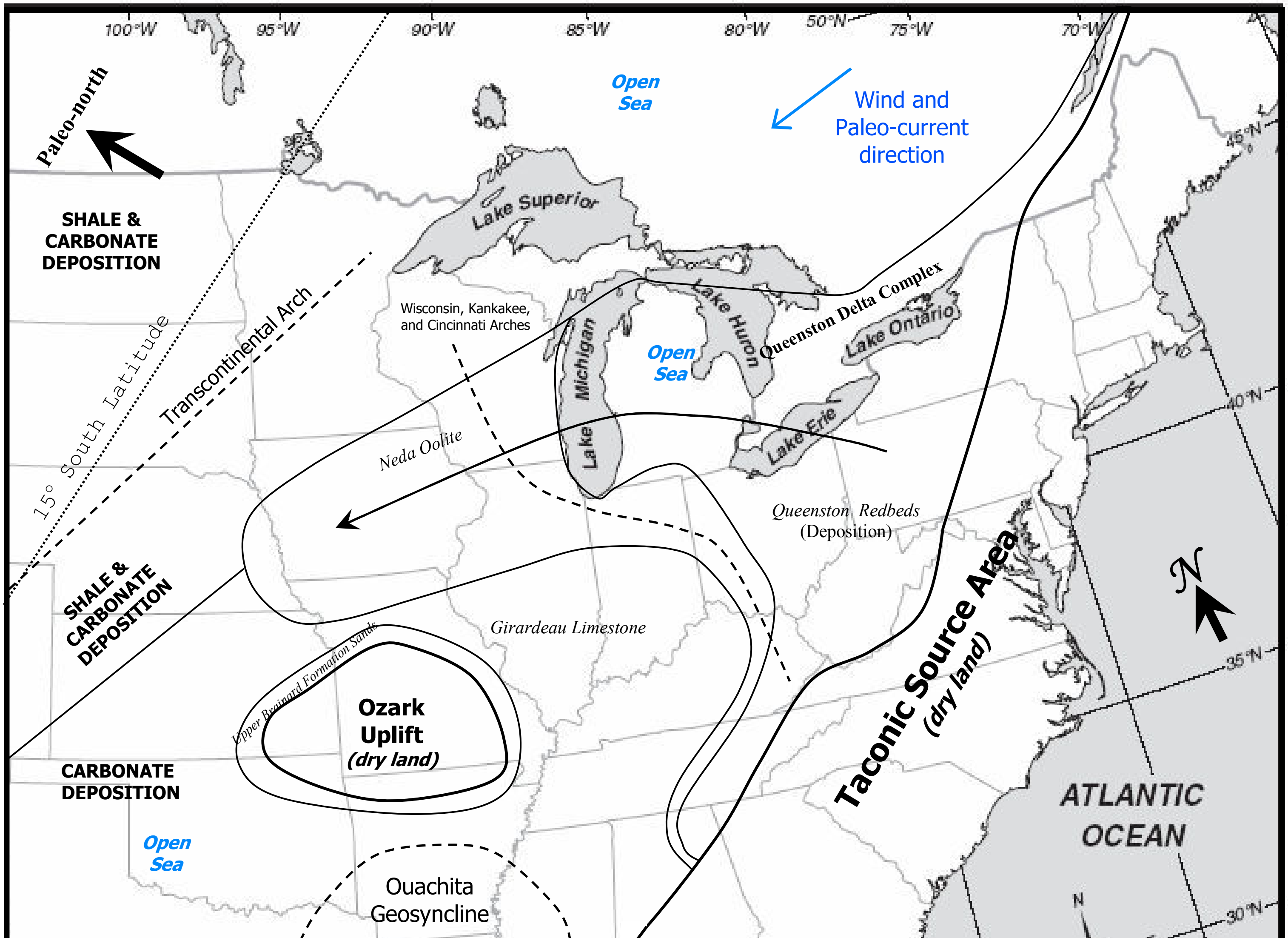
END OF AN ERA:

Around 445.5 million years ago, at the very end of the Richmondian, the most drastic environmental change in 150 million years occurred. Most of the continents had clustered around the Southern Hemisphere, leading to the creation of a vast ice sheet in the southern polar region. Although the Midwest was ice-free during this time, the southern ice cap still had a profound affect on the area.

Almost the entire Midwest had become low lying dry land, less than 300 feet above mean sea level called the Midwest Costal Plain. Erosion began to take hold throughout the Midwest. As a result most of the *Noix*, *Neda*, and a good portion of the *Brainard* were eroded. Springfield Bay was the only water outlet connected to the sea (see Figure 5).

It is possible that the Transcontinental Arch was exposed, forming a series of low lying islands that were susceptible to erosion.

FIGURE 3: Paleogeography of the Mid-continent During the Upper Richmondian 444.5 to 444 Million Years Ago



LEGEND

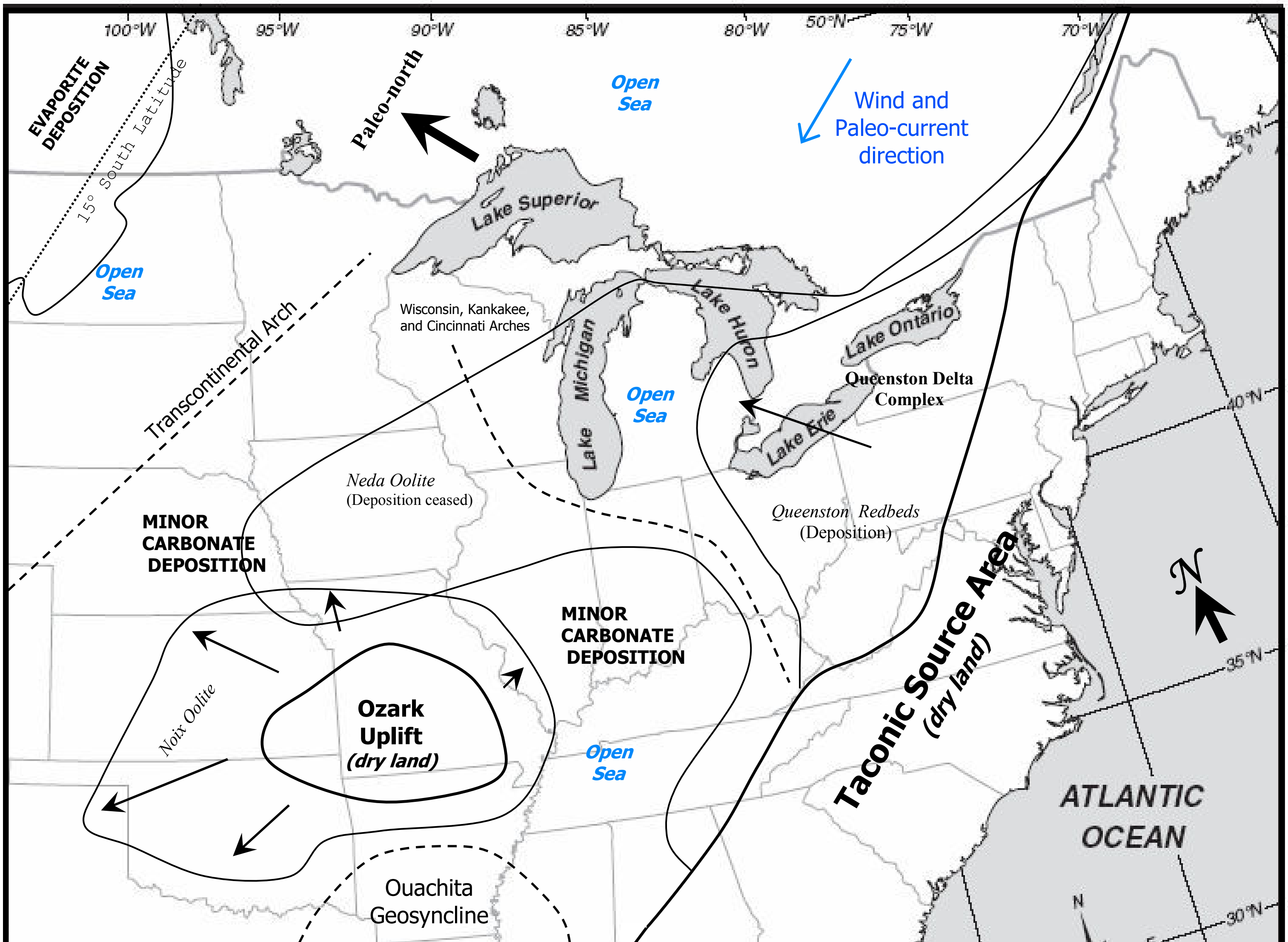
- National boundary
- State boundary

km 0 125 250
mi 0 125 250

- Shoreline
- Marine depositional lines
- Arch Axis or rough syncline border
- Direction of Deposition

NOTES: The *Queenston Redbeds* includes all approximate geologic equivalents to include the *Queenston*, *Junita*, *Sequatchie*, *Becancour Formations*.

FIGURE 4: Paleogeography of the Mid-continent During the Upper Richmondian 444 to 443.5 Million Years Ago



LEGEND

- National boundary
- State boundary

km 0 125 250
mi 0 125 250

- Shoreline
- Marine depositional lines
- Arch Axis or rough syncline border
- Direction of Deposition

NOTES: *Noix Oolite* includes all approximate geologic equivalents to include the *Noix*, *Keel* and *Leemon Formations*.

The *Queenston Redbeds* includes all approximate geologic equivalents to include the *Queenston*, *Junita*, *Sequatchie*, *Becancour Formations*.

At this time the paleo-current had shifted from east to northeast. This helped to bring warmer air from the equator. The warmer environment, in conjunction with the newly exposed land all but halted carbonate and clastic deposition.

All these conditions would lead to **weathering** of the Midwest Coastal Plain. Not only was **erosio**n taking place but so were other weathering processes. **Soil** began to form on exposed land. The soil is not like modern soil. Since there were no land plants this usually led to the rocks being altered by groundwater, which often turned them red or yellow and chemically altered them. This created a soil which is more of an intensely weathered zone, rather than the organically altered soil.

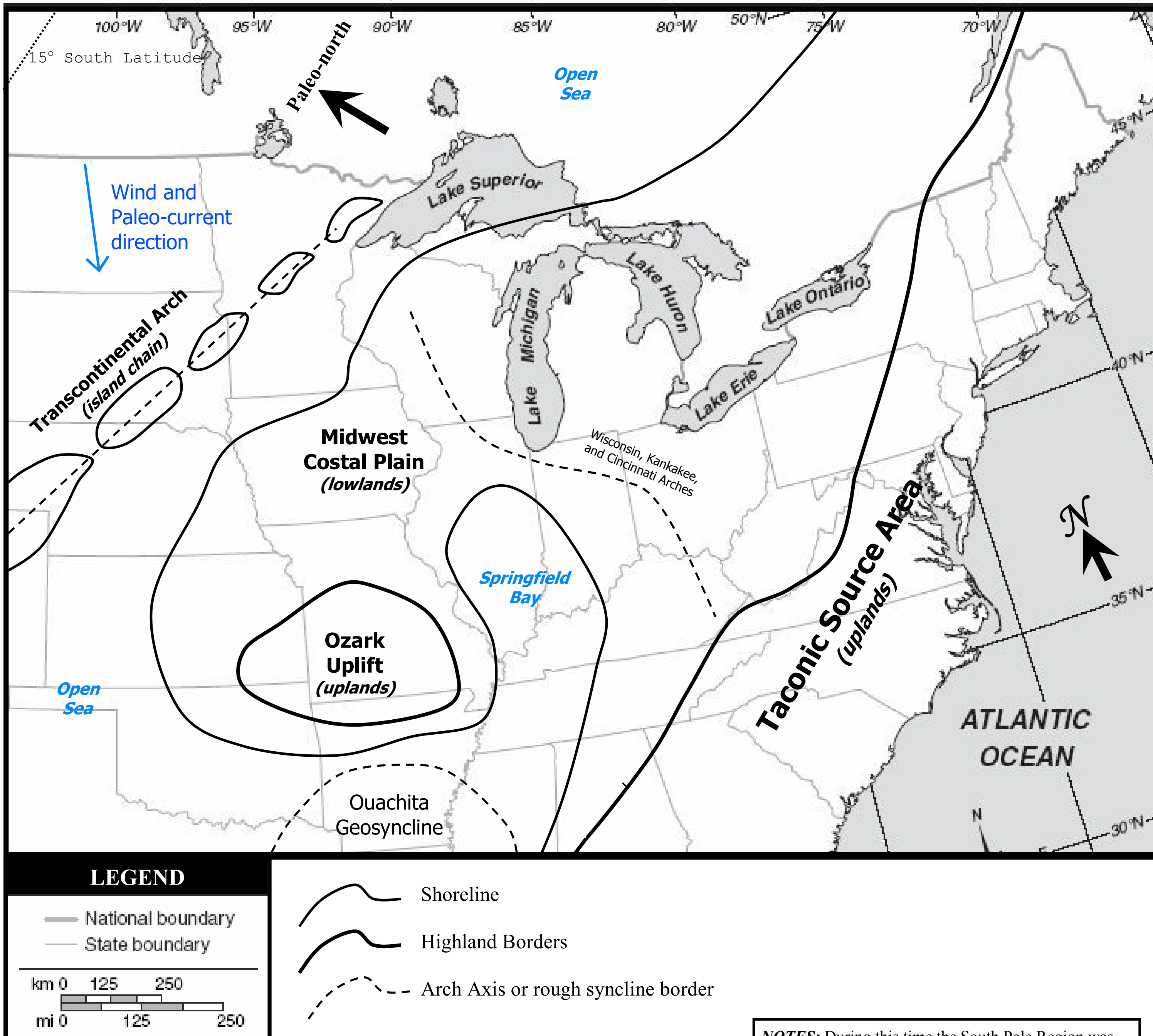
Once the glaciers retreated during the beginning of the **Silurian** the land would once again be covered by the sea and massive carbonates would form.

Conclusions

Reconstruction of the environment and geography at the end of the Richmondian has provided a great challenge. Due to the vast amount of erosion at the end of the Ordovician, much of the geologic record has been erased. The Upper Richmondian also tends to be **fossil**-poor throughout the Midwest, making environmental reconstruction even more difficult.

Due to the uniqueness of the environment and its unstable nature, a plethora of different and rare rocks were deposited throughout the Mid-continent. Such a variety of deposits would not occur again until modern times with the onset of our most recent ice age.

FIGURE 5: Paleogeography of the Mid-continent During the Late Richmondian 443.5 to 443 Million Years Ago



NOTES: During this time the South Pole Region was glaciated. This lowered the sea level as much as 300 feet. As a result new lowlands formed, the Midwest Costal Plain formed and became an active area of erosion. The only outlet to the sea was Springfield Bay. The Ozark Uplift and the Taconic Source Area continued to erode. During this time almost all deposition on the Mid-continent ceased.

Glossary

anticline: A geologic structure where the individual beds of rock are bowed up with the high point along the center axis.

arch: (see "anticline")

argillaceous: A term used to describe clay-sized particles scattered throughout a rock.

carbonate rocks: Rocks primarily composed of the minerals calcite (which forms limestones) or dolomite (which forms dolostones).

clastic: Sediments that are composed of non-carbonate sedimentary rocks, such as shale, siltstone, and sandstone.

coal: Black rock composed of living material derived from peat. Used as a fossil fuel.

dolostone: A sedimentary rock formed when magnesium replaces some of the calcium in limestone. Usually forms where salt and fresh water mix.

end moraine: A topographic ridge of sediment or till, formed at the front of a stagnant glacier.

erosion: The breakdown of rocks through either mechanical, chemical, or organic processes.

formation: The basic formal unit of rock. It has specific characteristics that make it traceable horizontally and/or vertically based on composition and lithology.

fossil: Any direct evidence of past life. Includes: bones, shells, roots, burrows, buried top soil, and plant debris.

geologic nomenclature: The process of dividing rocks into formal units such as groups, formations, members, tongues, lenses, or beds.

geologic units: (see "rock unit")

geosyncline: (see "syncline")

groundwater: Water that exists below the surface, usually filling the pore spaces of rocks, moving through the rock depending on the rock's permeability.

limestone: Is formed from the mineral calcite ($CaCO_3$). In many sedimentary rocks it was formed by living organisms in reef and inter-reef environments.

lithology: The classification of rocks based on the physical characteristics of the rocks, i.e. color, texture, composition, grain size, structure, etc.

lithostratigraphy: The study of formations and how they relate to one another.

oolites: Groupings of ooids which are round balls of calcite, dolomite, aragonite, hematite, or chert, less than 2mm in diameter.

Ordovician Period: A system of rock units that were deposited during a period of time from 505 to 438 million years ago.

Ordovician-Silurian Contact: An erosional unconformity at the top of the Ordovician caused by a rapid drop in global sea levels due to glaciation in the southern hemisphere.

rock unit: A generic term for an assemblage of related rocks based on lithology. A rock unit can be a facies, tongue, lens, bed, member, formation, or group of rocks.

sand: A grain of rock with a size between 0.0625mm and 2mm.

sea: Any body of salt water that has encroached on the continent, regardless of depth.

sediments: Accumulations of unconsolidated land deposited by glaciers, rivers, lakes, and seas.

shale: The rock version of clay. It has a grain size of less than 0.004mm.

Silurian Period: A system of rock units that were deposited during a period of time from 438 to 408 million years ago. During this time most of the stone presently quarried in the Chicago area was deposited as carbonate reefs.

soil: A type of surface exposed to the air that undergoes chemical or organic alteration. During the first half of the Paleozoic all soils were caused by the chemical alteration of rock, since there were no land plants at the time. This often forms phosphatic nodules in the soil.

source area: An area of rocks that serve as the raw materials for sediments.

stratigraphy: The study of rock units and their physical relationships to other rock units.

structural geologic feature: An assemblage of rock units that form a non-flat orientation such as an anticline, syncline, fold, or fault. It also refers to unique features within a rock unit such as crossbeds, porosity, grain orientation.

subsurface: Below the exposed ground surface.

syncline: A geologic structure where the individual beds of rock are bowed down with the low point along the center axis.

unconformity: A period of time where the rock record is incomplete due to either erosion, tectonics, or a period of non-deposition.

weathering: The process of erosion that breaks down rock and soil.

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Credits

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ATTACHMENT: Mid-continent Correlation of the Late Ordovician and Richmondian Stages

NOTES: This chart graphically depicts the accepted geologic units and their rough, equivalent, neighboring units within the Mid-continent region. The literature in the text only deals with the upper half of the Richmondian, above the *Fort Atkinson Formation*. Areas where there are no correlative units represent unconformities.