Geologic Framework of the Middle Raccoon River Valley in Whiterock Conservancy

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Landscapes and their associated soils and geologic materials can be thought of as a book of Earth's history. Each stream bank, road cut or well drilling reveals to earth scientists a few paragraphs or pages of the history. The book, however, is far from complete; pages have been torn out, words and sentences erased, and parts are written in languages that we haven't yet completely translated. By piecing together parts of the story from around the globe we are able to see how the few pages of Earth's history recorded at the place that is now Whiterock Conservancy (WRC) fit into the larger story of our planet.

Pennsylvanian Period

The part of Earth's story that we can see at WRC begins in the middle Pennsylvanian Period, about 310 million years ago (Figure 1, lowest red rectangle). Iowa sat near the equator on a low-relief coastal plain that was flooded by a shallow sea several times during the Pennsylvanian (Figures 2 and 3). Vegetation flourished in the warm moist climate and large primitive coniferous trees such as *Cordiates*, which could reach heights of 90 feet (30 meters), *Lepidodendron,* a giant bare-trunked club moss and *Calamites*, enormous horsetails and scouring rush grew in extensive swamps along river floodplains, lake margins, and estuaries (Figure 4). A wide variety of amphibians, reptiles and insects lived in these environments. The first reptiles evolved during the Pennsylvanian Period. These were small (about a foot long) and outnumbered by the amphibians, which were prosperous, diverse, and achieved lengths of up to 15 ft (4.6 m). Insects also were abundant, some with impressive dimensions -- dragonflies with 2.5-ft (0.76 m) wingspans were common. Over 1,000 species of cockroach have been identified from the Pennsylvanian, giving this period the alternative, informal title of the "age of cockroaches."

World geography was very different in the Pennsylvanian. Today's continents were in different places on the globe, were different shapes, and had different positions relative to each other thanks to the on-going process of continental drift. North America and most other continents presently in the Northern Hemisphere were joined together into the supercontinent Laurasia, while most continents presently in the Southern Hemisphere were joined in the supercontinent Gondwana. Most of Laurasia sat at relatively low northern hemisphere latitudes, while large parts of Gondwana were in polar latitudes of the Southern Hemisphere. This configuration of continents allowed large glaciers to build up in the polar region of Gondwana, sending the planet into an extended ice age often referred to by geologists as an "ice house" period. That ancient ice age, like the most recent ice age during which modern humans arose, witnessed several periods of continental glacier expansion and retreat. As glacial ice built up on southern Gondwana the vast volume of water tied up in glaciers caused sea levels to drop around the globe. During warmer intervals between glaciations water returned to the ocean from melting of the glaciers caused sea level to rise and flood low-lying areas such as estuaries and coastal plains. This raising and lowering of sea level alternately flooded and exposed vast tracts in the tropics and resulted in the accumulation of thick sequences of alternating organic-rich swamp deposits, mud and shallow marine limestone across central and eastern North America. These deposits became today's extensive coal measures in the Appalachians, Illinois, Iowa and Missouri. As the Pennsylvanian Period progressed Laurasia drifted northward and the part of the continent that is now Iowa began to get drier. Swamps became reduced in extent and sediments such as oolitic limestone, red bed sandstone and shale, and evaporites such as gypsum and halite (salt) that form in dry conditions with lots of evaporation began to accumulate.

Rocks dating from the Middle Pennsylvanian period are intermittently exposed along the Middle Raccoon River in WRC (Figure 5). These rocks consist primarily of gray mudstones split by occasional thin coal seams. These were deposited in swamps and poorly drained floodplains of rivers traversing a broad coastal plain when Iowa was near the equator and very moist (Figures 2 and 3). A thin seam of Pennsylvanian coal sandwiched between mudstones crops out at locality 22 along the right bank (facing downstream) just above water level at normal flow (Figure 5). The coal formed as woody peat in extensive swamps in the coastal plain and was compressed into coal after it was deeply buried during later parts of the Pennsylvanian and younger geological periods. Coal seams like this supported a small-scale seasonal mining industry from 1894 through 1941 along the Middle Raccoon River valley south of Springbrook State Park (Howes, 1998). During this time these thin seams of coal were mined by digging shafts back from the exposure, then widening the mine either using room-and-pillar or longwall mining techniques. At the "Whiterock" locality, along the right bank just below the bridge on Fig Avenue, the lower 15 meters of the bluff consist of gray-colored, thin bedded mudstone with scattered plant debris and siderite ($FeCO_3$) nodules (Figures 5 and 6). The age of this mudstone, though indicated as Pennsylvanian on Figure 6, is uncertain. This mudstone was either deposited in extensive swamps formed in low-lying parts of the Pennsylvanian coastal plain or it may be much younger -- Cretaceous in age -- and related to other mudstones that outcrop farther upstream in Long Creek hollow and the Middle Raccoon valley.

Cretaceous Period

Pages recording the next 205 million years are missing from Earth's history book at WRC. Periods of erosion that occurred before about 100 million years ago removed any record of what took place in the WRC area during the upper Pennsylvanian, Permian, Triassic and Jurassic periods (Figure 1). The next few pages of WRC's geologic story tell us about the lower part of the Cretaceous Period, around 100 million years ago (Figure 1). During this time Iowa sat in mid-latitudes north of the Equator on a broad, low relief coastal plain east of a shallow sea (known to geologists as the Kiowa-Skull Creek seaway) that bisected the North American landmass (Figure 7). By this time Laurasia and Gondwana had drifted apart and were separated by the ancestral Atlantic Ocean. The Appalachian Mountains were an imposing range along the eastern side of Laurasia and large river systems drained the continent and flowed westward to the midcontinent sea. The Earth was a "greenhouse" world during the Cretaceous, relatively free of glaciers and warmer and moister in the mid-latitudes than today's world.

The midcontinent of Laurasia was in the mid-latitudes during the Lower and Middle Cretaceous and witnessed changes in plant and animal life that set the stage for the development of many modern life forms. The first flowering plants (angiosperms) spread through the coastal lowlands and river environments during this period, most likely at first as "weedy" plants taking advantage of their ability to disperse rapidly and occupy disturbed areas (Retallack and Dilcher, 1986). Other angiosperms such as the ancestors of beech, fig, magnolia and sassafras also appeared and spread during this time while conifers and ferns continued to dominate upland environments (Figure 8). Closely associated with the angiosperms, and contributing to their rapid spread, were insects, including the first ants, butterflies and bees. Dinosaurs are the animals that the Cretaceous Period is most recognized for today, but a large variety of pterosaurs (flying, close relatives of dinosaurs), lizards, marine lizards (pleiosaurs and ichthyosaurs), amphibians, and the earliest mammals plied the Cretaceous landscape.

WRC is well known among geologists for its Cretaceous Period rocks. All the rocks exposed in picturesque bluffs along the Middle Raccoon River and in the deep ravines and tributary streams cutting from the river into the uplands are included in the Nishnabotna Member of the Dakota Formation that dates to the late Albian Stage of the Early Cretaceous (about 100 million years ago; Witzke and Ludvigson, 1996; Ludvigson et al., 2010). Nishnabotna Member rocks in WRC record sediment accumulation in a large estuary along the late Albian coastal lowland on the eastern side of the Kiowa-Skull Creek seaway (Witzke and Ludvigson, 1996; 1998; Figure 8). The precise dimensions of this estuary are unknown but available evidence suggests it was of a scale similar to today's Chesapeake Bay and fed by a large, low-gradient river at least as long as today's Ohio River. Because the mid-latitudes were much moister in the Cretaceous than they are today the river likely had a much larger discharge than the present Ohio River does. Variations in the properties of rocks exposed in series of outcrops along the lower reaches of Long Creek and to the north along the Middle Raccoon River have been interpreted to represent changing positions in the estuary (Phillips and White, 1998).

Outcrops located on the north bank of Long Creek near its junction with the Middle Raccoon reveal three stratum deposited as estuary conditions changed at this location (Figure 5). The lowermost strata, from creek level to about 3 meters, consist of sandstone and siltstone with very thin beds of mudstone. These deposits are disturbed by 1cm wide and 3cm long subvertical burrows. Plant debris is present in some beds. These rocks were deposited near the mouth of the estuary in water that had enough oxygen to support organisms that burrowed on the estuary floor. The lower stratum is capped by iron-cemented medium-to-coarse-grained sandstone that stands out as a narrow ledge on the outcrop and that marks the base of the middle stratum. The middle strata consist of light gray to dark gray mudstone with common lenses of sandstone and siltstone. Plant debris and small subhorizontal burrows are common. The darker color, smaller grain size and more uniform bedding of the middle strata indicates that these deposits accumulated in the deeper, central part of the estuary where less oxygen was available to support bottom fauna and to help decompose organic matter. The uppermost strata consist of iron-stained crossbedded medium-grained sandstone. Small pebbles composed of quartz, chert, and mudstone are common in the conglomerate at the base of the stratum and at the base of small troughs that mark ephemeral channels throughout the unit. These upper strata were deposited by a river, and the absence of rooting or burrowing indicates that the deposits accumulated below water level, probably in the head of the estuary where river processes dominate. Similar strata deposited in a nearby part of the same estuary are exposed at the "Whiterock" section just across the river from the campground in WRC (Figure 6).

Higher parts of the Cretaceous landscape are also preserved in WRC. Downstream of the "Whiterock" locality at outcrop 25 near the southern extent of the WRC a reddish mottled paleosol developed in Pennsylvanian claystone is exposed in the right bank of the Middle Raccoon River (Figure 5). This paleosol developed during the Cretaceous in Pennsylvanian mudstone forming the upland bordering the Early Cretaceous estuary. The red and whitish mottling and clay content indicate that this soil is highly weathered, similar to many soils on today's coastal plain in the southeastern U.S.

Differences in the erosional resistance of mudstones and sandstones exposed along the valley walls of the Middle Raccoon River in WRC are reflected in the landscape. Benches elevated 10 to 20 feet above the floodplain are common and very well expressed along the western side of the valley from the mouth of Long Creek downstream to the bridge across Fig Avenue. The bench is formed by relatively resistant Cretaceous sandstone sandwiched between two less resistant mudstone layers. Seeps that feed wetlands emerge from the base of these benches where water infiltrating through the permeable sandstone encounters the underlying very slowly permeable mudstone, which causes it to flow laterally and emerge at the base of the slope. Similar seeps occur intermittently along the channel of the Middle Raccoon in WRC and contribute a significant amount of steady cold water input to the stream.

Seventy-four million years ago, near the end of the Cretaceous Period (about 25 million years after the Cretaceous rocks exposed in WRC were deposited) a stony meteorite, over one mile in diameter, weighing about 10 billion tons and traveling about 45,000 miles per hour, blasted through the atmosphere and crashed to earth in what is now central Iowa (Anderson, 1999). The impact formed a 24 mile wide crater that now lies buried by glacial deposits 100 to 300 feet below the town of Manson in Calhoun County. In a fraction of a second the meteorite penetrated about one mile into the ground and released the energy equivalent of about 10 trillion tons of TNT. An electromagnetic pulse moved away from the point of impact at nearly the speed of light, and instantly ignited anything that would burn within approximately 130 miles of the impact (most of Iowa). The shock wave toppled trees up to 300 miles away (Chicago, Minneapolis, and St. Louis), and probably killed most animals within about 650 miles (Detroit and Denver). This was not the meteorite that may have caused the great extinction event at the end of the Cretaceous (that occurred about 65.5 million years ago), but nevertheless the impact had incredible effects on the landscape and life of the Late Cretaceous.

Quaternary Period

The final chapter in the geologic story of WRC begins after a 98 million year gap. A lot happened during that unrecorded period at WRC. Midcontinental seas retreated from North America, the Rocky Mountains rose, the Mediterranean Sea came into existence, the Indian continent crashed into Asia forming the Himalayas, and the present configuration of oceans and continents came into being. Mammals evolved and diversified, most dinosaurs became extinct, except for those that evolved into birds. In essence, the world as we know it came into existence. The Quaternary Period, which began about 2.6 million years ago, marks the culmination of a 55 million year cooling period in earth history, a return to an "ice-house" world like the Pennsylvanian Period at the start of this geologic story of WRC. The hallmark of the Quaternary is the word-wide expansion of glaciers, especially in the Northern Hemisphere where large ice sheets expanded and shrank during several glacial periods with planet-wide effects. The Antarctic Ice Sheet and the Greenland Ice Sheet are the only two ice sheets that exist today but during several Quaternary glaciations two additional ice sheets joined and covered the northern half of North America and a fifth ice sheet covered most of northern Europe and part of the British Isles.

During each glacial period a very large amount of water evaporated from the ocean was stored in ice sheets on the continents rather than falling as rain or snow that subsequently melted and ran back to the sea as it does today. As a result, sea level fell worldwide – as much as 360 feet during the last glacial period. The lowered sea level exposed shallow parts of the continent margins and in some cases joined areas now separated by ocean water. These so-called "land bridges" made it possible for animals (including people) and plants to move into new areas during glacial periods. On the other hand, as ice sheets expanded animals, people and plants in the Northern Hemisphere were forced south.

The effects of the giant Quaternary ice sheets extended far beyond their margins. Rivers draining the glaciers carried large amounts of sand and gravel and had broad braided channels much like that of the Platte River in Nebraska today. Spring and early summer melt season floods filled the valleys and when the floods waned silt and fine sand left behind was swept by strong winds onto high terraces and uplands where it accumulated as sand dunes and wind-blown silt (loess – pronounced “lŭs”).

The WRC area was covered by ice sheets that advanced from the north at least six times between 2.4 million and 500,000 years ago (Figure 9). As these mountains of ice advanced they eroded upland areas and buried river and stream valleys and deposited mixtures of sand, silt, clay and rounded stones called “glacial till”. As the glaciers advanced deciduous forest gave way to boreal forest and eventually tundra along the ice margin. As the ice melted at the end of each glaciation it left behind a relatively flat “till plain” with abundant lakes and marshes that was rapidly colonized by boreal plant and animal communities much like those found at and north of the treeline in Canada and Russia today. Each glacial period quickly gave way to a shorter and warmer interglacial period with climatic conditions similar to those that have occurred for the past 10,000 years. During these interglacial periods the lakes and marshes gradually drained as river and stream networks eroded into the new till plain and formed hilly topography much like that found southwest of the Middle Raccoon River today.

In some areas, like along the Middle Raccoon River Valley today, Quaternary rivers eroded all the way through the glacial deposits into the underlying bedrock and formed a “bedrock valley”. When the glacial deposits are “removed” by mapping the elevation where outcrops and well drillings encounter bedrock a surface marked by a network of the bedrock valleys is revealed (Figure 10). WRC sits astride a major divide between bedrock valleys forming a western network and those of an eastern network. Interestingly, the Middle Raccoon River valley cuts down the center of this divide on its way to the eastern bedrock valley network. Studies by Iowa Geological and Water Survey geologists have concluded that most of this drainage network on the bedrock surface formed during the Quaternary period and that before about 2 million years ago the western network did not exist and rivers flowed from northwest to southeast across the entire area (Witzke and Ludvigson, 1990). Aside from their interest to the region’s geologic history the bedrock valleys are important sources of well water for many rural residents as well as the municipalities of Coon Rapids and Bagley.

A small protrusion along the southern margin of the last great ice sheet, advanced through north-central Iowa from about 40,000 to 22,000 years ago and again from 15,000 to 12,900 years ago. The last advance formed the Des Moines Lobe (DML) landform region and covered a tongue-shaped area extending from Mason City on the east, to Des Moines on the south and Carroll on the west (Figure 11). The greatest extent of the lobe is marked by the Bemis Moraine which passes through the northeast corner of WRC.   The DML has distinctive low-relief topography, poor natural surface drainage and more poorly drained soils compared to the landscape in the Southern Iowa Drift Plain landform region beyond the lobe's outer margin.

As these glacier lobes advanced rivers and streams flowing toward the southeast were blocked and several major drainage derangements occurred. The most well known of these occurred in the Spencer area when a Des Moines River tributary flowing to the southeast was blocked by the DML and Glacial lake Spencer formed behind the ice dam (Hoyer, 1980). Eventually the lake rose to a level high enough to spill over a low divide into the ancestral Little Sioux Valley near Petersen and the Little Sioux captured the former headwaters of the Des Moines River tributary and in the process formed the spectacular series of stepped terraces and gorges in the Little Sioux Valley between Gillette Grove in Clay County and Correctionville in Woodbury County.   The Middle Raccoon River also appears to owe its origin to drainage blockage and derangement during advance of the DML and its precursors. It appears that southeast-draining valleys in the vicinity of Carroll were blocked as the DML advanced to the position of the Bemis Moraine (Figure 12). A series of shallow lakes formed in the lower ends of the blocked drainages and eventually spilled across low divides just east of Willey and southwest of Carrollton in Carroll County.   Throughout its early development the Middle Raccoon was a proglacial stream – usually bordered on its eastern and northern side by glacial ice of the DML or earlier lobes, or receiving meltwater and outwash from channels draining the not-too-distant glacial margin. The DML and its precursors buried and blocked tributaries draining to the southeast and the Middle Raccoon formed as water collected and drained along the ice margin. This explains why the Middle Raccoon is flowing across a bedrock interfluve at WRC and at Springbrook State Park farther downstream.

Most of WRC lies beyond the Des Moines Lobe margin in the hilly loess-mantled landscape of the Southern Iowa Drift Plain landform region (Prior, 1991). This rolling landscape is formed primarily in eroded Pre-Illinoian glacial and interglacial deposits that are mantled with up to 15 feet of wind-blown silt (loess) deposited during the last glacial period between about 21,000 and 13,000 years ago Bettis et al, 2003). The modern soil is formed in the upper few feet of the loess. A reddish or grayish paleosol, known as the Sangamon Soil, formed in the upper part of the Pre-Illinoian glacial deposits during the last interglacial period between about 125,000 and 25,000 years ago before it was buried by last glacial loess. Today this old soil sometimes is evident as reddish brown patches on slopes where it forms seeps ("gumbo till") in the spring.

Outcroppings of Quaternary glacial tills and interglacial deposits are rare in WRC. Those that do occasionally occur are quickly covered by slumping and vegetation overgrowth. Despite the paucity of outcrops other evidence that WRC has been covered with glaciers is present in the form of glacial erratics. Erratics are fragments of rocks that occur far from the place where that type of rock is exposed. In the case of glacial erratics, the rocks were plucked from bedrock outcrops by advancing glaciers and transported by ice to the place where they now occur. Erratics litter the surface of the Des Moines Lobe because deposits of the last glacial advance have not been covered in this landform region. In the Southern Iowa Drift Plain, however, erratics only occur on steep slopes where the loess mantle has been eroded away and older Pre-Illinoian glacial till is exposed, or in drainage ways where stream incision has exposed them. Erratics are easy to find on the long, narrow slope just north of Long Creek in WRC. A large erratic can be seen on the west side of the fence line just west of archaeological site 13GT169. This boulder of granite was likely eroded from outcrops in northern Minnesota or southern Canada. Another large isolated erratic can be seen along the base of the slope on the right bank of the Middle Raccoon River just as the river enters the gorge through WRC (Figure 5).

The final few pages in WRC's geologic story are the best preserved part of Earth's history book.   These pages record the Holocene, the part of the Quaternary Period since the last glacier left the state about 11,000 years ago. These pages also record the time when people have lived in the area, at first adapting to the environment then transforming it with emerging technologies to meet the needs of growing populations and changing cultures. Because geologic deposits and paleoenvironmental records from this period are so well preserved, and since people have played an increasingly important part in the geologic story the Holocene history of WRC will be discussed in a separate report.

Summary

The geologic deposits in WRC record three brief periods in the long geologic history of the region. Unlike most of Iowa's rocks, those exposed at WRC do not record the ancient shallow seas that covered Iowa during large parts of its geologic history. Instead they record ancient coastal swamps along the equator inhabited by incredible insects and primitive plants during an icehouse period when massive glaciers covered the southern polar region. They provide us with glimpses of large rivers and estuaries in a younger greenhouse world where the earliest mammals and dinosaurs roamed among some of our planet's first flowering plants. The uppermost and youngest series of deposits bring us glimpses of the icehouse world of the Quaternary Period when WRC was covered by glaciers several times and when the processes of erosion, deposition and soil formation formed the landscape we see before us today. Like a good book, the geologic story of WRC takes us to places we have never been, lets us experience what we have not experienced and leaves us with an interesting and engaging tale that continues to provoke thoughts long after we've put it down.

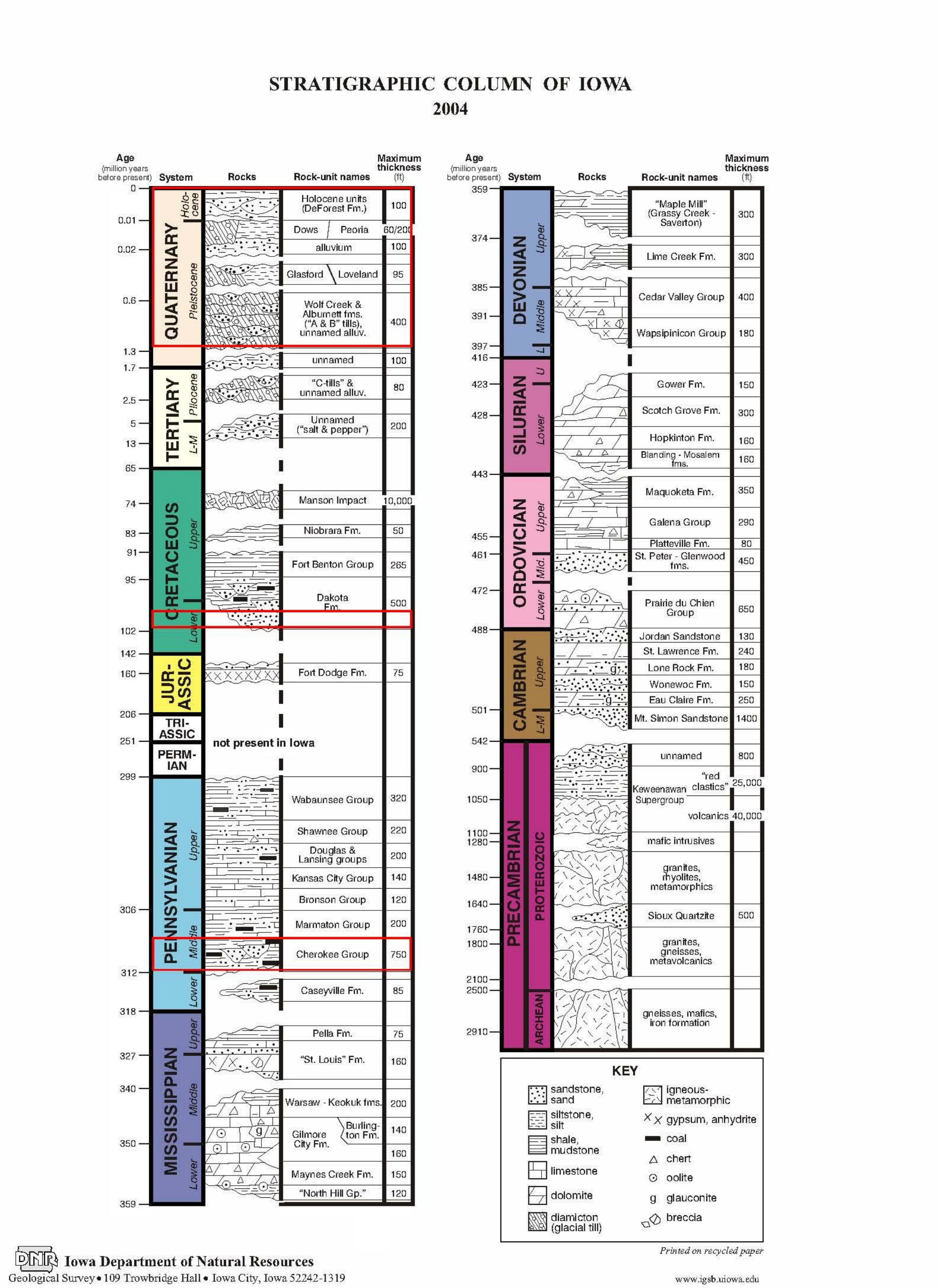

Figure 1. Stratigraphic column of Iowa with parts of the rock record exposed in Whiterock Conservancy highlighted in red rectangles.

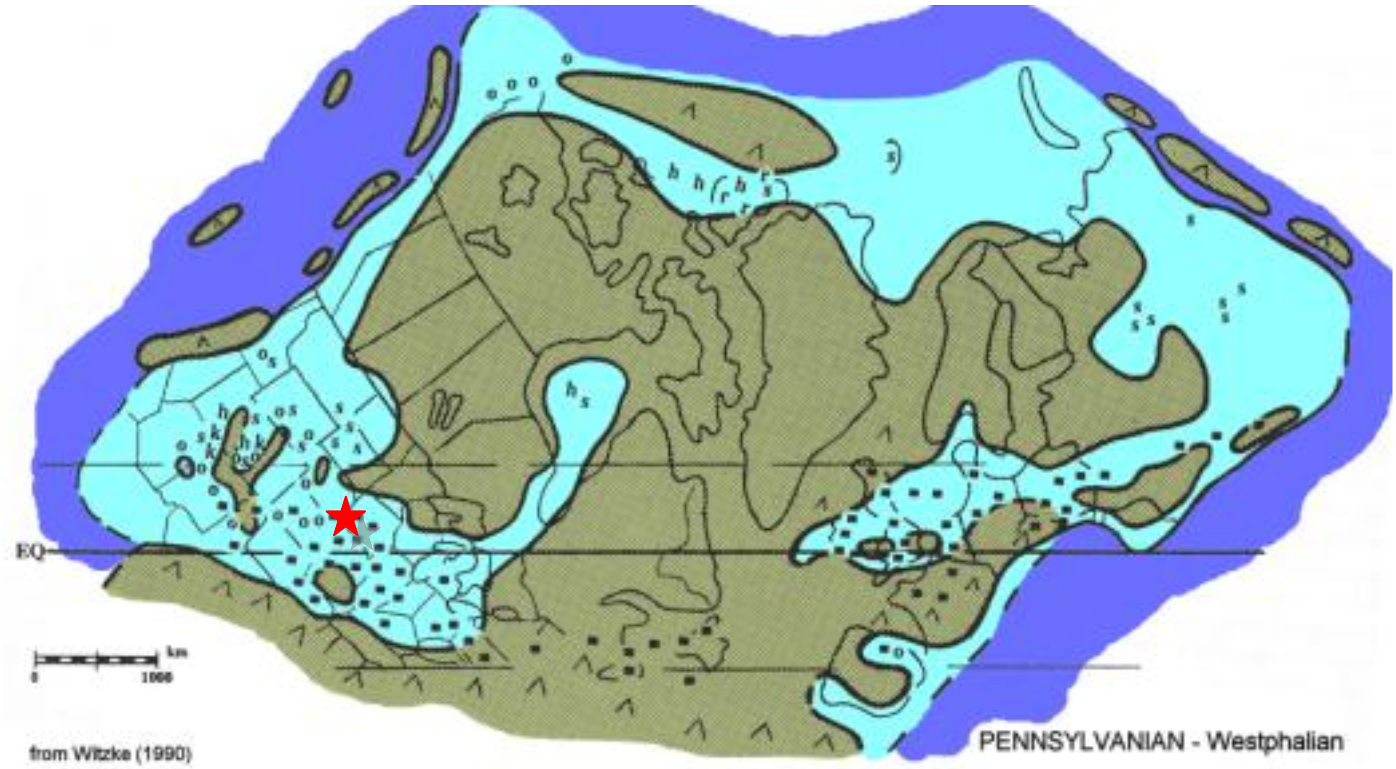

Figure 2. Paleogeography of North America during the Early Pennsylvanian Period, about 315 Million years ago (from Witzke, 1990; color version courtesy of Brian Witzke) Red star is the approximate position of WRC. EQ=Equator. Filled ovals are localities with coal, open ovals are localities with oolites.

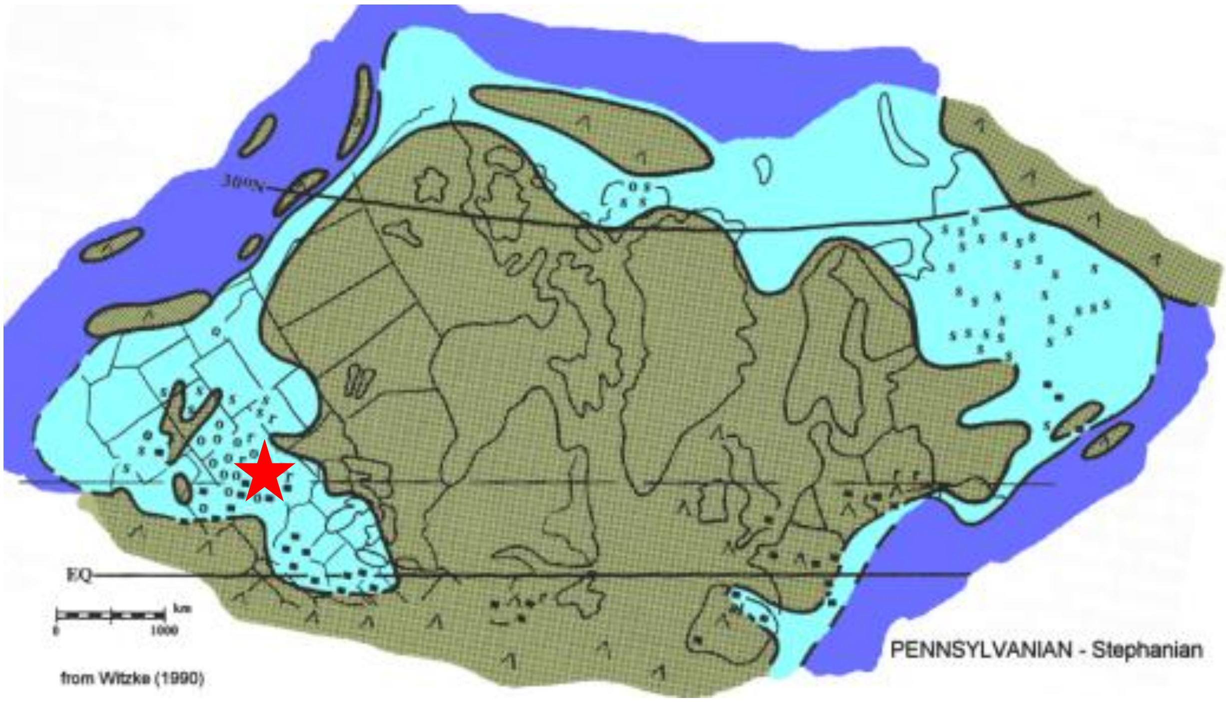

Figure 3. North American paleogeography during the Late Pennsylvanian Period, about 300 million years ago (from Witzke, 1990; color version courtesy of Brian Witzke). Red star is the approximate position of WRC. EQ=Equator. Filled ovals are localities with coal, open ovals are localities with oolites.

Figure 4. Artist's reconstruction of a Pennsylvanian coal swamp. "A millipede (Arthropleura) measuring two metres long, 25cm wide, crawls over a dead scaly bark of a Lepidodendron tree (Lepido=scaly, dendron=tree). Flying nearby is a dragonfly with wings measuring two feet across. Main trees at the back (forest) including growing trees in middle are Lepidodendron. Calamites: arcing structure on left and pair in distant. Relative of horsetails. Horsetails in water. From web site of Richard Bizley http://www.bizleyart.com/gallery/prehistoric/palaeozoic/carboniferous/carboniferous-scene-1.

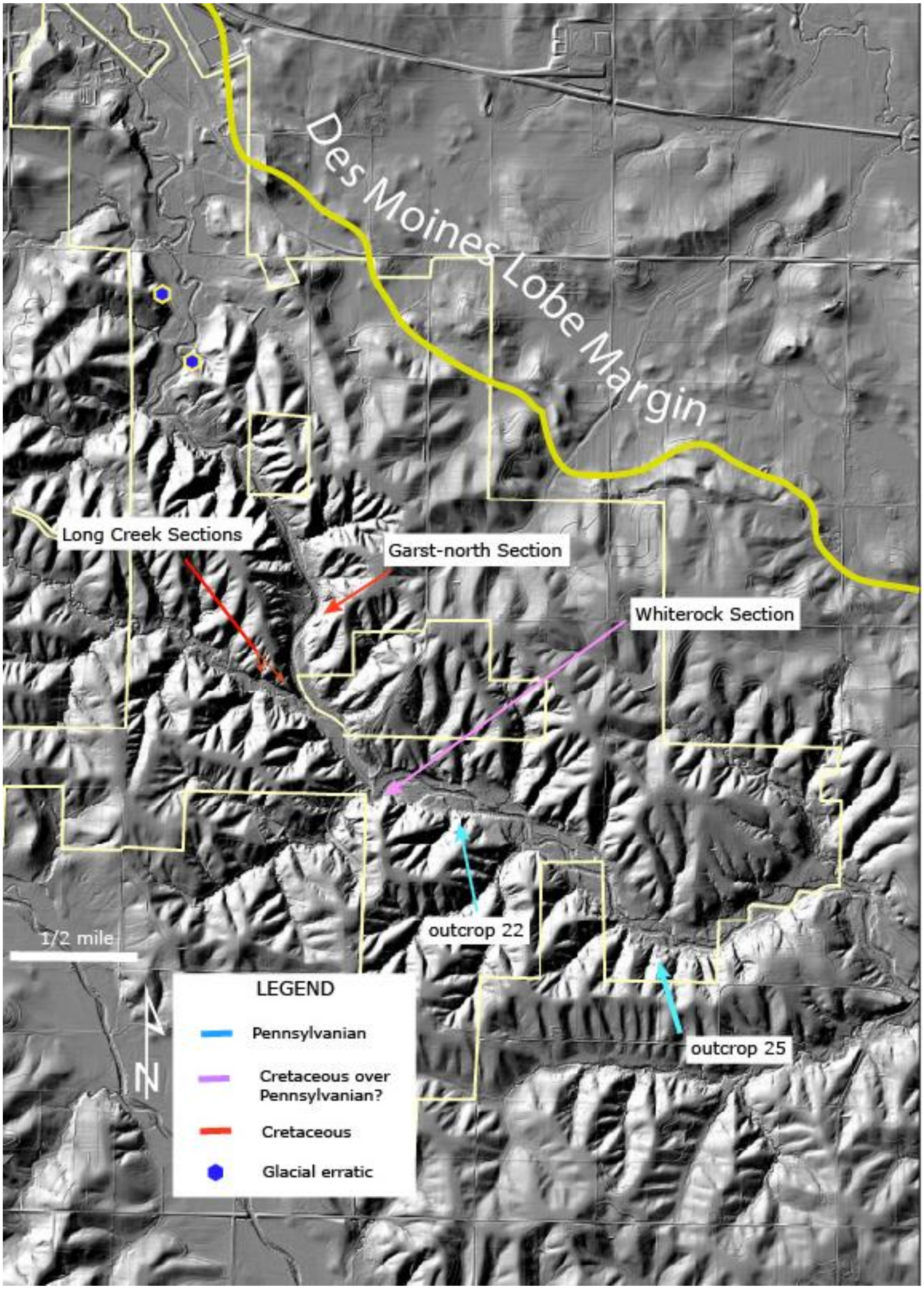

Figure 5. Bedrock outcrops, erratic locations and the Des Moines Lobe margin within WRC. Bedrock from the Pennsylvanian and Cretaceous periods crops out in the area.

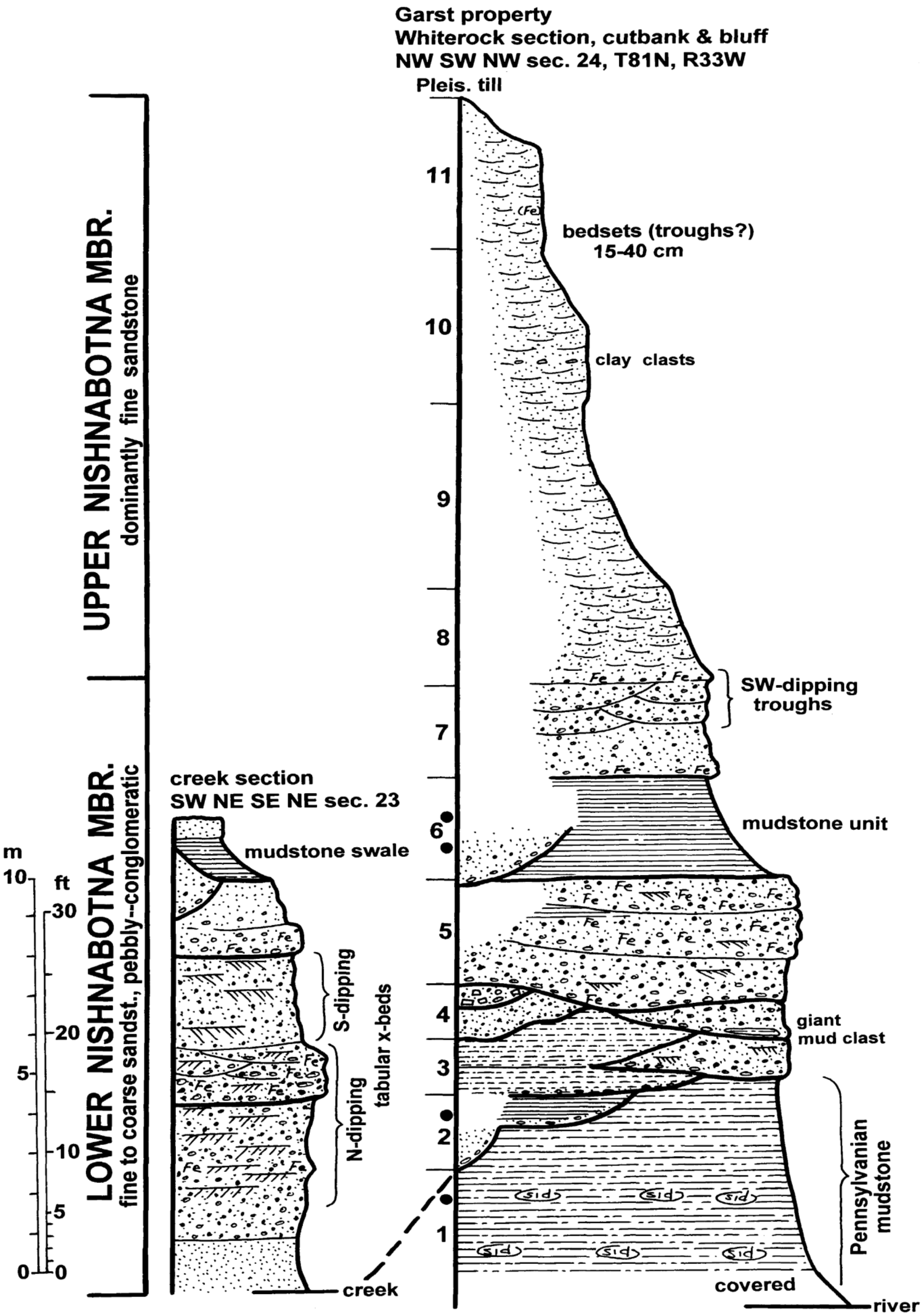

Figure 6. Stratigraphic section exposed in the river bank and bluff at the "Whiterock" exposure along the Middle Raccoon River and in the bank of the creek entering just upstream of the Whiterock section (from Witzke and Ludvigson, 1996).

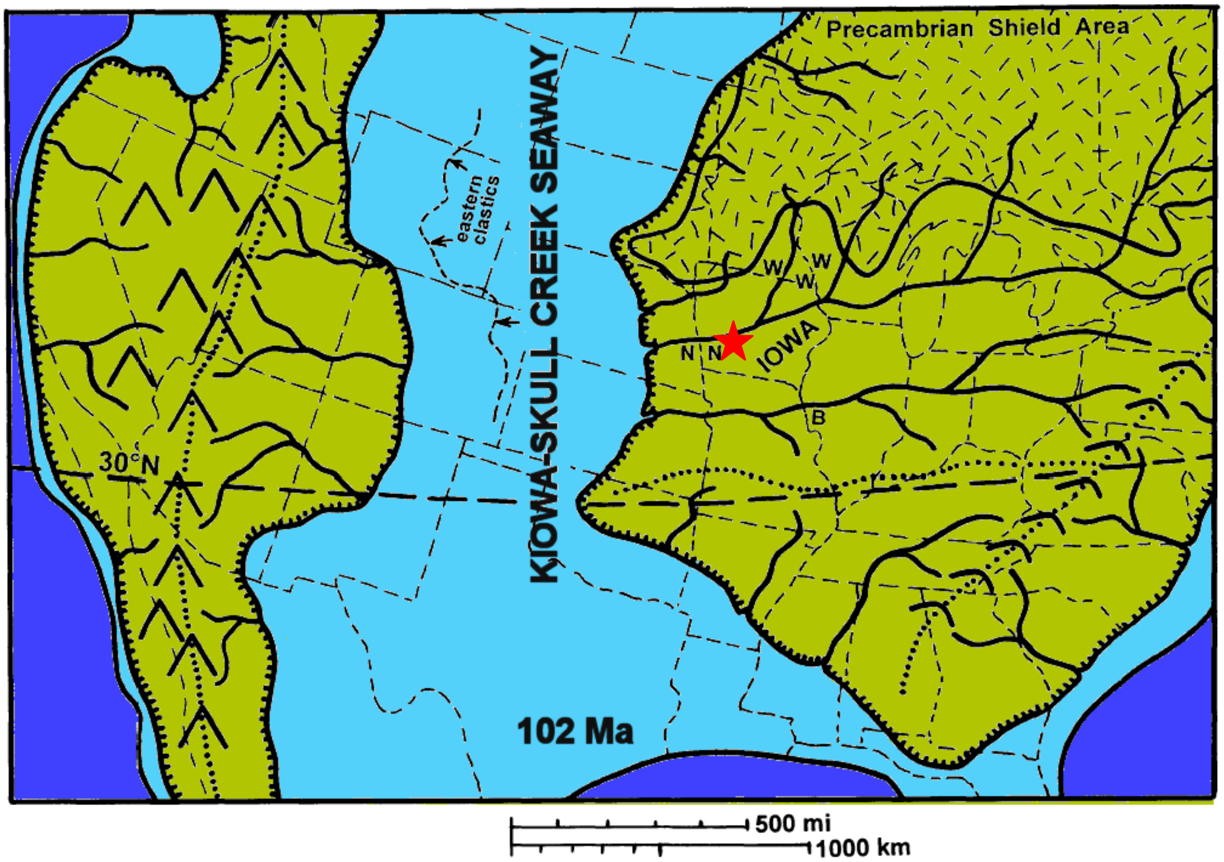

Figure 7. Paleogeography of North America during the Cretaceous Period, about 102 million years ago (map courtesy of Brian Witzke). Red star is the approximate position of WRC.

Figure 8. Artist's reconstruction of a Cretaceous swamp forest, similar to those that were present in the WRC area about 100 million years ago. Image from the Australian National Museum (http://www.karencarr.com/auto_image/auto_image_mid/Australian_Museum_Late_Cretaceous_plants.jpg).

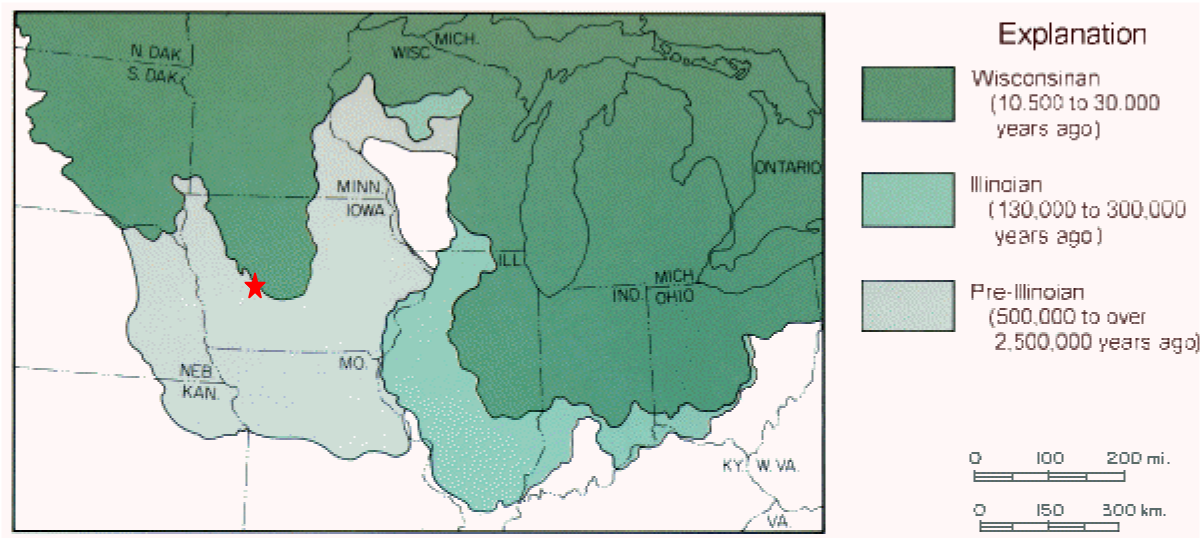

Figure 9. Extent of Quaternary Glaciations in the Midwest. Approximate location of WRC is indicated with a red star. Diagram courtesy of Iowa Geological and Water Survey.

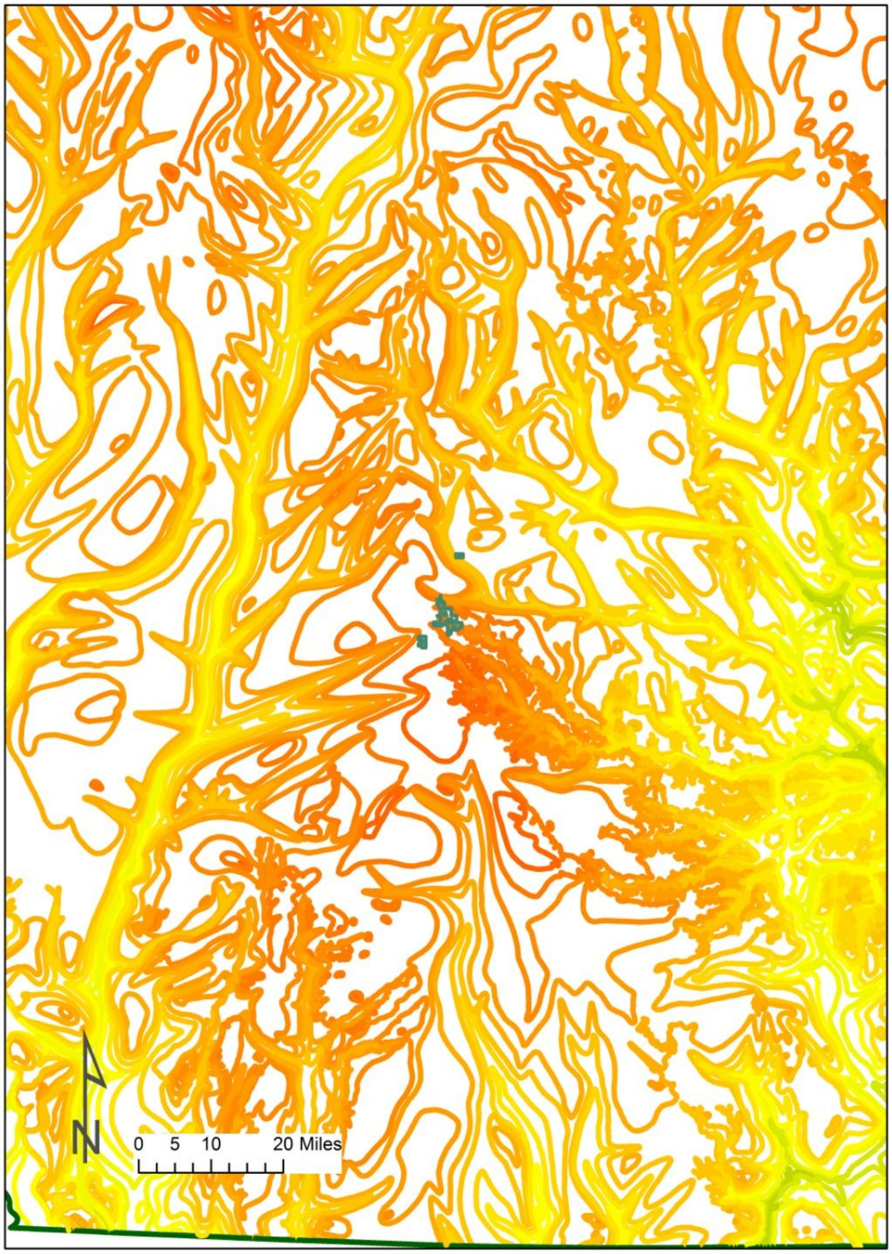

Figure 10. Elevation of the bedrock surface around the junction of Guthrie, Carroll and Audubon counties, Iowa. WRC boundaries are shown in dark green. Higher bedrock elevation contours are orange, lower elevation contours yellow - green. Data from NRGIS Library, Iowa Geological and Water Survey.

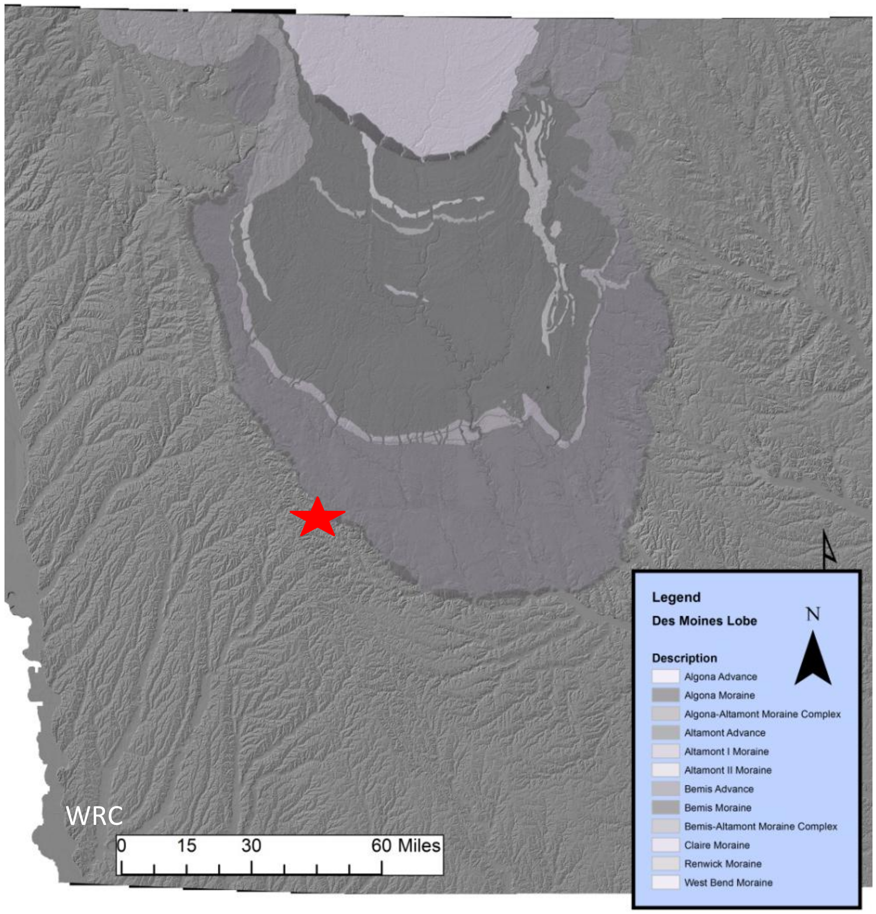

Figure 11. End moraines and ground moraines of the Des Moines Lobe, the last glacial advance into Iowa. Red star shows location of WRC.

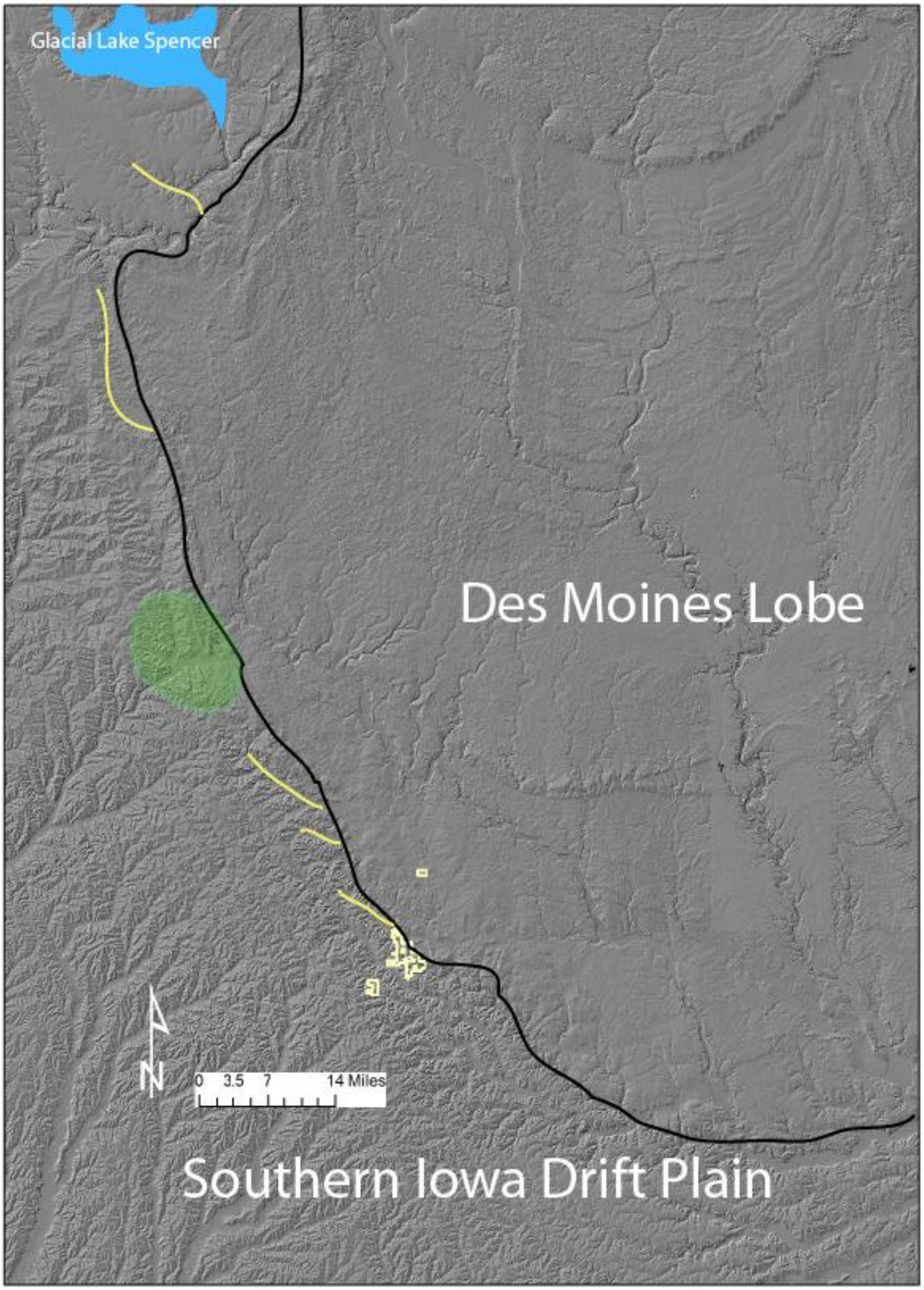

Figure 12. Glacial Lake Spencer and other drainage blockage features along the western margin of the Des Moines Lobe. Yellow lines show southeast-flowing drainages blocked during advance of the DML. Green area shows the headwaters of a southwest–flowing drainage that was buried by the advancing DML. WRC boundaries are indicated by cream color.

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