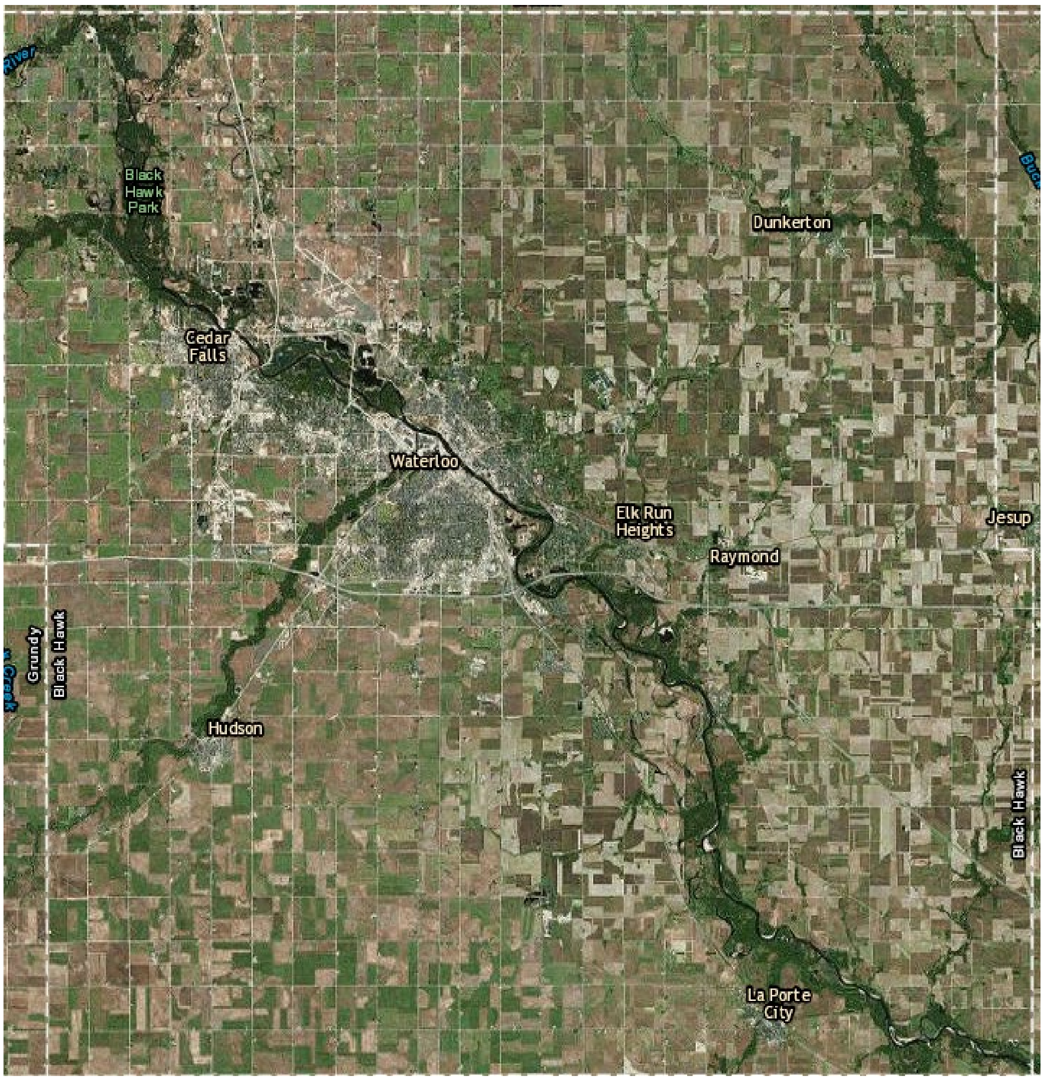
# The Geology of Black Hawk County




(Black Hawk County, Iowa State Geographic Information Systems, 2002, Iowa Geographic Map Server)

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EARTHSCI 6233-60 Workshop: Iowa's Geological Resources for Teachers

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# Abstract

Black Hawk County is not known for its exposures of ancient rock, but for its glacial topography, the limestone bedrock found in the Cedar Valley Formation, and the Silurian-Devonian aquifer. This topography from the Iowan Surface provides excellent conditions for the formation of karst and sinkholes. After briefly going over the geology of Iowa, students will conduct a lab examining what may happen if a landfill was built in a location containing karst, and how potential karst areas could react with agricultural and landfill waste. A short research paper will require them to contact their county's landfill and use the Iowa Geographic Map Server to determine why the location of the county landfill was chosen, and why certain types of waste are not accepted.


# Introduction

## Thesis

Iowa is known for limestone and dolostone bedrock, resulting in hard water throughout the majority of the state. The Silurian-Devonian aquifer consists of 14 of the limestone and dolostone formations in Iowa, and underlies almost 90 percent of the state, including Black Hawk County. The water contained by this aquifer provides the state with the majority of its water needs for both agriculture and the general populace. Aquifers are recharged by precipitation, where water flows from the surface, through cracks and crevices, dissolving carbonate and other minerals as it travels. Due to the flow of water, one common occurrence in areas with large quantities of shallow carbonate rock is the sinkhole. Iowa is also known for its farmland, resulting in the use of large quantities of fertilizer, pesticides, and herbicides. Students will examine how both farm waste and landfill waste affects karst and could result in the production of sinkholes through a lab activity.

## Geography

### Black Hawk County

Black Hawk County is located in north-east Iowa in the fourth row of counties south of the Minnesota-Iowa border, and in the fourth column west of the Mississippi River (Figure 1). It includes the larger metropolitan area of Cedar Falls/Waterloo. The county seat is currently located in the city of Waterloo, which has the coordinates of 42.49°N, 92.35°W and an elevation of 883 feet above sea level (citylatitudelongitude.com). The county estimated population as of July 1, 2015 was 133 455. Demographics show Black Hawk County having a predominantly Caucasian population of around 86 percent, but with significant minority populations of African-American, Hispanic, and Asian compared to other areas in the state. However, these demographics are lower than the national average. Only about 26 percent of the population has completed college, and about 10 percent of the population has not completed high school. The median income is $47 000 per household, and about 15 percent of the county's population lives in poverty (U.S. Census Bureau, 2014).

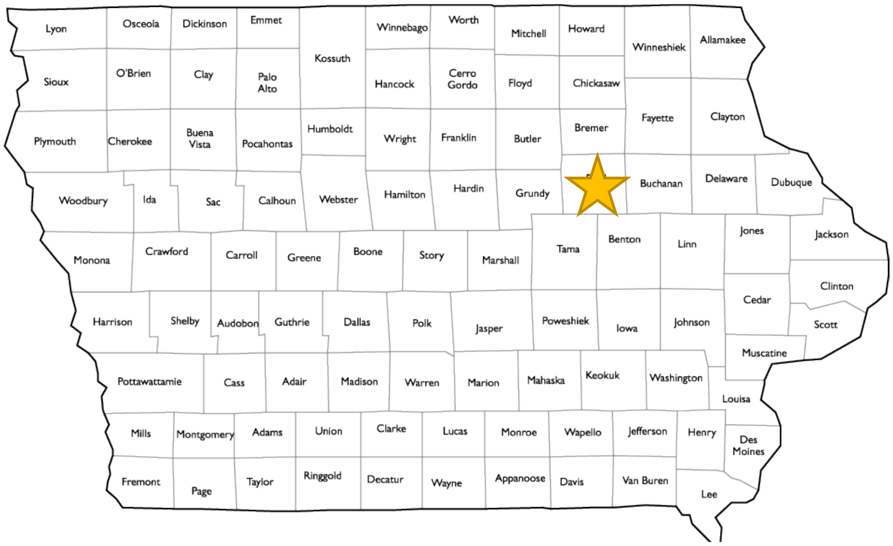


*Figure 1. Map of Iowa Counties (www.worldatlas.com, 2016)*

Black Hawk County occupies 573 square miles of Iowa, and contains 6.9 square miles of water in the form of several streams and rivers, the most notable being the Cedar River which runs diagonally through the center of the county from the northwest to the southeast. Other rivers and creeks in the county include the Wapsipinicon, Blackhawk, Elk Run, Crane, Virden, Beaver, Miller's, Mud, Prairie, Wolf, Poyner, Indian and Spring Creeks (Figure 2)

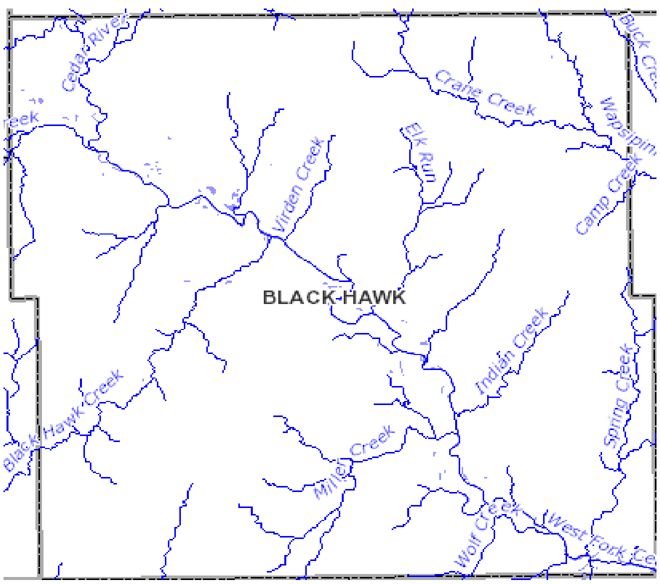


*Figure 2. Map of Black Hawk County waterways. (http://ortho.gis.iastate.edu/)*

## History

Iowa obtained its name from the Native American people who inhabited and owned the area until 1837 (USDA, et al., 2001). The first white man in the Black Hawk county area was a French hunter and trapper in 1837. Black Hawk County was created in 1843 when Iowa was still a territory as was initially attached to Delaware County and was named for the Sauk leader, Black Hawk. Iowa became the twenty-ninth state in the union at the end of 1946, and seven years later, in 1853, Cedar Falls was established as the county seat, and Black Hawk became recognized as a county in its own right with a population consisting of around 150 people. The first official Caucasian settlers of the county were William Sturgis and E.D.

Adams, who settled in Cedar Falls (Sturgis Falls) in 1845. Sturgis was drawn here by the river and the potential for water power at the rapids. Sturgis is considered to be the first person to break prairie land in the county when he broke five acres to farm. Waterloo (Prairie Rapids) was first settled in 1846 by Charles Mullan who became the first county surveyor. Waterloo is at the geographical center of the county and later became the county seat. (Historical Scraps, iagenweb.org). In the fifty years following the first settlement of the county, a distinct shift in rural to urban county occurred, with more than 50 percent of the population living in the Cedar Falls-Waterloo area. By 2000, this percent has jumped to almost 90 percent of the population occupying 22 percent of the county's land area (USDA, et al., 2001).

The major economic resource of the county is industry, employing about one-third of the population. Some of the major industries in the county include John Deere, Health Care services, Tyson Foods, Omega Cabinets Limited, Bertch Cabinets, and financial and retail service providers (Bronner, et al., 2013). John Deere is the largest employer in the county and has been operating in the county since 1918. 72 percent of the land area in Black Hawk County is farmed, despite declining numbers of farms. Corn and soybeans are farmed on all but 3.9 percent of the farmland in the county (USDA, et al., 2001).

The primary resources of the county are forests, wetlands, bodies of water, aquifers, and prairies. These can be found throughout the county, and can be observed in the single State Park and several county parks located in the county. Iowa's soil and waterways are considered to be some of the most important natural resources in the state, and the Iowa soil conservation program began in 1939 when the Iowa General Assembly passed legislation allowing the soil and water conservation districts to organize and administrate themselves. Iowa consists of 100 soil and water districts, the first of which was established in 1940, and the last which was established in 1952. The Black Hawk Soil and Water Conservation district was created in 1945 (Black Hawk Soil and Water Conservation District, 2016). These districts are managed by the Natural Resources Conservation Service, the Iowa Department of Agriculture and Land Stewardship and by elected commissioners. The importance for the need for conservation was brought about by a decade of drought and erosion, known in history books as the Dust Bowl, even though Iowa was not considered to be greatly affected.

The Soil and Water Conservation Districts focus on maintaining Iowa's natural resources through practices designed or aimed to improve both water quality and soil health. For the soil, this includes cover crops, nutrient management practices, and conservation tillage methods among other things. Black Hawk County has two major ongoing watershed projects to prove that even without regulations, nutrient and soil runoff can be reduced, these are located at Dry Run Creek and Miller Creek.

## Iowa Geology

Iowa has a varied and incomplete geological history ranging from the Precambrian age to the present. Rocks from some ages are only visible at the surface in small portions of the state, and other periods found elsewhere in the Midwest are absent completely. To understand the geology of the area surrounding Hawkeye Community College and the populations served, a better understanding of the geologic history of the entire state is needed.

## Precambrian

Exposures of Precambrian rock can only be found in northwestern corner of Iowa, although Precambrian basement complex can be found throughout the state and Midwest when drilling wells. The Precambrian era dates back to between 541 million and 4.6 billion years (Heinzel, 2016) and consists of igneous and metamorphic rock. Radiometric dating has been elemental in the determination of the age of the rock record. Precambrian rocks can easily be found in the surrounding states such as South Dakota, Wisconsin, Minnesota, and the upper peninsula of Michigan. The Precambrian exposure in Iowa is known as Sioux Quartzite and is classified as Baraboo-Interval Quartzite. The Sioux Quartzite has been determined to be between 1.64-1.76 billion years old.

Prior to the formation of the Sioux Quartzite, evidence of the Penokian Volcanic Belt can be found in central and eastern Iowa, and the Central Plains Orogenic Belt can be found in southwestern Iowa. These two belts fall in the range of 1.70-1.88 billion years old, with the Volcanic Belt being the older of the two occurrences. The Penokean Volcanic Belt has an abundance of volcanic and plutonic rocks, but does include some sedimentary rock. The Central Plains Belt shows evidence of both igneous and metamorphic rock, and many of are comparable age to those found in the Volcanic Belt. The igneous rocks found in Iowa's basement layers may not have been related to magma sources at plate boundaries, but rather to hot-spots (Anderson, W.I., Iowa's Geological Past, pgs. 27-31).

An interesting feature that is younger than the Sioux Quartzite is the Midcontinent Rift System, which made a valiant attempt at splitting the continent in half, and did manage to cut through five older Precambrian terranes. This rift system has its northernmost point in Lake Superior, and its west branch extends southwest through Iowa down to Oklahoma. This rift can be identified by the magnetic and gravimetric anomalies observed as a result of the highly magnetic and dense igneous rocks. The high density and magnetic nature of igneous rocks is due to their mafic nature (high in iron), which has an effect on the gravity of the sample. In a study done by a team of researchers from Northwestern University, it was determined that the west branch of the rift contained significantly more magma, and as a result, large quantities of clastic rock can be found in drilled wells along the rift's path through Iowa. Basalt is another rock that is common along the rift throughout Iowa, and in Figure 3, is found in gray, simply labeled as igneous. This block of basalt is known as 'Iowa Horst' and measures from 20-40 miles in width, and is estimated to have faulted upwards over 30,000 feet. The Iowa Horst is bordered by basins full of more felsic rock like shale, siltstone and sandstone which indicated Precambrian lakes existed in the area. Together, the igneous and metamorphic rock from these orogenies and rift make up the "basement" of Iowa's bedrock. The best example and the thickest section of sedimentary rocks discovered along the Midcontinental Rift System were drilled in 1987 with many thanks going to Amoco.

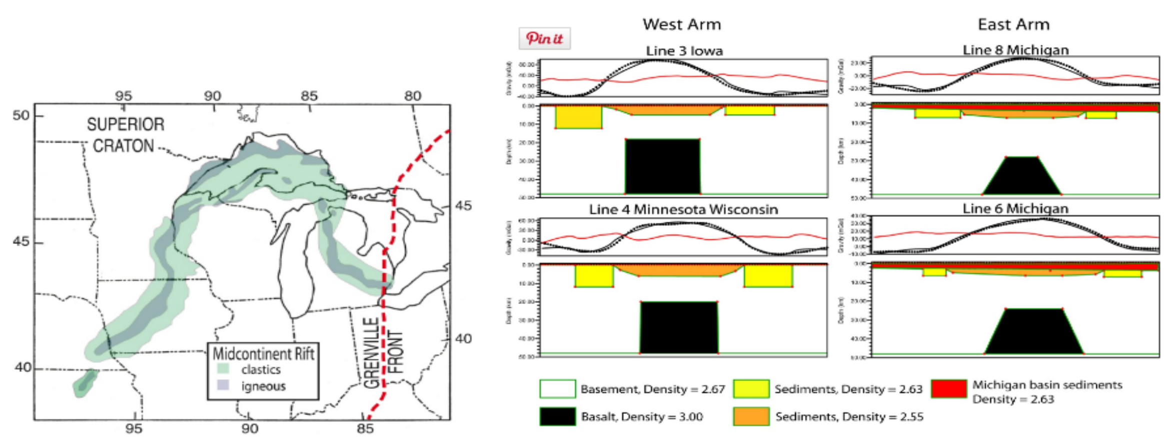


*Figure 3.Map of Midcontinent Rift. (Stein, S. http://www.earth.northwestern.edu/people/seth/research/mcr.html)*

The Eischeid well was 5442.4 m deep and has been the deepest well drilled in Iowa to date. Both the Upper and Lower Red Clastic sequences from the Precambrian were in evidence in this well, as well as some highly mafic igneous gabbro basement rock. Although Amoco did not find the petroleum they were searching for, they made a significant contribution to understanding Iowa's geologic past.

Another drill hole of significant scientific importance is the Quimby Drill Hole. In the 1980s, several positive magnetic anomalies were picked up by some aeromagnetic surveys and were used to determine a site to drill to study the Precambrian basement rocks in northwestern Iowa. The center of a positive anomaly in Cherokee County was selected as the drill site, and was able to confirm a hypothesis of magnetite-bearing granite in that part of the state. The granite was located 609.8 m below the surface and roughly 100 m of granite core were obtained and determined to be 1.43 billion years old. This granite appears to be a sample of the continent-wide rhyolite and granite formation and shows evidence of forming after the periods of orogeny earlier in the period (Anderson, W.I., Iowa's Geological Past, pgs. 32-35).

Other core drilling exercises have also provided geologists with further insight to Iowa's Precambrian period. The Matlock cores are responsible for the acquisition for pyroclastic rock, providing evidence of volcanic activity about 1.76 billion years ago, which is around the age of the Penokian Volcanic Belt. It also confirmed evidence of sodium-rich keratophyres do indeed underlie the Sioux Quartzite.

The Sioux Quartzite is an unconformity over older Precambrian and Archean Rocks, and unlike other quartzites of its age, does not contain significant quantities of uranium or gold. This has resulted in its main economic use being road aggregate, railroad ballast and building stone. The Sioux Quartzite can be visited at Gitchie Manitou State Preserve in Lyon County in the northwestern-most corner of the state.

## Cambrian

Following the Precambrian period, Iowa underwent a period of erosion and weathering, and was then under a shallow, well-oxygenated, inland sea for the end of the Cambrian era. These levels of high oxygen led to what is known as the 'Explosion of Life'. Much of the sediment found within this series is quartz sandstone which was produced by the erosion and weathering of Precambrian rocks that occurred during the Early to Middle portion of the Cambrian Period. Clay minerals can also be found in some sandstones, siltstones, and in carbonate rocks within the Cambrian series. During the Late Cambrian, a sequence of transgression-regression cycles took place, which allowed for fairly thick deposition of rocks known as the Sauk sequence. Due to these transgression-regression cycles, we find that the Cambrian rock in Iowa consists primarily of sandstones. The majority of these sandstone are what geologists consider to be mature, with well-rounded and well-sorted grains of stable minerals. Minerals containing iron and magnesium are not likely to be found in this portion of Iowa's rock record. Closest to the shoreline of the Late Cambrian sea, quartz-rich sandstone is primarily found, and can also be found where the seafloor was agitated by waves. As the rock samples move away from the shoreline towards greater depths, clay (argillaceous) sandstones and siltstones can be found. Carbonate rocks such as limestone and dolostone can be found in fairly thick accumulations along the edges of the sea's craton. Due to the number of fluctuations in sea-level, it can be noted that mature quartz sandstone deposits are seen to reoccur. The Mt. Simon, Wonewoc, and upper Jordan Formation all contain large quantities of quartz sandstones, whereas formations such as the Eau Claire, Lone Rock, and St. Lawrence are more argillaceous in composition. This suggests the latter three formations deposited in deeper waters further from the shoreline.

The Wonewoc Formation is the old exposed Cambrian rock in along the Mississippi River near Lansing, Iowa. The uppermost portion of this formation is visible only, and consists of quartz sandstone exhibiting well-developed cross-bedding. Fossils such as trilobites and brachiopods, and the remains of marine invertebrates can be observed in this formation in Iowa. The formation thins out and disappears as it moves towards west-central Iowa.

The St. Lawrence Formation can be seen in Allamakee County, and two members can be distinguished. The Lodi Member contains dolomitic siltstone as well as well-sorted sandstone. The other member, the Black Earth Member consists of dolomitic siltstone and silty dolomite. This mix of silt with the dolomite indicates currents which carried and deposited sediments. Some of these currents were fairly strong since conglomerate can also be found in the St. Lawrence Formation. Fossils in this formation include trilobites, brachiopods, burrows, conodonts and quite a few other varieties although fossils are not abundant.

Along with the St. Lawrence Formation, the Lone Rock Formation is also exposed in Allamakee County. The Lone Rock Formation is unique among the other formations in that it contains greensand layers due to the mineral glauconite. Glauconite is high in potassium and only occurs in marine environments, providing concrete evidence of a marine setting over Iowa during the Late Cambrian period.

One of Iowa's best known records of Cambrian rock is the Jordan Formation in northeastern Iowa. This formation can be observed along the bluffs of the Mississippi River in the northeastern corner of the state. The Jordan Formation exhibits well-developed cross-bedding which allows the direction of current movement from the ancient sea to be determined. Numerous measurements have shown this Late Cambrian sea to be moving in a southerly direction. Due to the moderate permeability and the high porosity of the sandstone making up the Jordan, it is considered to be one of Iowa's best groundwater aquifers (Heinzel, 2016). The Jordan can be distinguished by the irregularity of dolomite-cemented layers and is more resistant to weathering than other Cambrian period rock in Iowa. Very few fossils are found in the Jordan formation in northeast Iowa. Through drilling, Jordan sandstone can be found across most of the state, with the exceptions of the northwest corner and the Manson area. Due to excessive water usage and periods of drought, water levels in the Jordan have declined significantly.

## Ordovician

Following the Late Cambrian, Iowa was covered by warm shallow seas and remained so for the majority of the Ordovician period although significant transgression-regression phase occurred. A major regression occurred towards the end of the Early Ordovician, resulting in significant weathering of Upper Cambrian and Lower Ordovician rocks which created an erosion surface. Later Ordovician rocks were deposited on this erosion surface after the seas transgressed back over Iowa.

The transgression of the sea over Iowa led to the deposition of sand and mud which formed sandstone and mudstone. The sandstone in this period consists of extremely mature Precambrian quartz sand from the Transcontinental Arch, and a blanket deposit of sand can be observed and is known as the St. Peter Formation. The St. Peter formation covers a large portion of the Midwest, including Iowa. One interesting feature that can be observed in Ordovician rocks are the presence of ooids, which can only form in warm, shallow seas that are near the saturation point of calcium carbonate ($Ksp=3.8*10^{-9}$ at 298

Kelvin). Ooids form when grains of sand are coated with layers of calcium carbonate, similarly to how pearls form by coating parasites with layers of nacre. Many ooids look like grains in chia seed or tapioca pudding and are typically less than two mm diameter and spherical in shape.

The major depositions of the Middle Ordovician period are the Decorah and the Dunleith formations in northeastern Iowa and consist primarily of carbonate rock such as limestone and dolomite. Thin layers of bentonite, which formed from volcanic ash can be observed in both of these formations. Bentonite appears as gray or orange clay, depending on the mineral composition. Large quantities of marine invertebrate fossils can be found in this period in areas where dolomitization has not damaged them.

The Upper Ordovician also displays large areas of dolomite, limestone, and shale, including a vast array of fossils, including graptolites. These graptolite fossils provide evidence of a deeper seafloor or of oxygen-deficient conditions as they were not suited for high concentrations of dissolved oxygen. Ordovician rock can be observed at the Fort Atkinson Historical site and in Johnson, Dubuque, and Polk counties.

## Silurian

The Silurian period was another period of major marine phases. Five major transgression-regression phases occurred, resulting in highly dolomitized and resistant bedrock. During the Silurian period, Iowa was located south of the equator in warm, carbonate-rich, inland sea. Due to the high levels of dolomite in this era, many fossils are not nearly as well preserved as those in previous periods, yet, a wide variety can still be found. An interesting discovery for the TR phases of this period, is that the changes in sea level appeared to be global changes, not localized ones. Similar TR patterns have been observed in the Silurian record in other locations in North America, the Baltic region, and in China. This global change in sea level indicates the presence of extensive continental glaciers.

The Silurian rock record in Iowa contains six formations: the Mosalem, Tete des Mortes, Blanding, Hopkinton, Scotch Grove, and Gower. Out of these, the latter three are most commonly observed in Eastern Iowa. The first four formations are placed in the Lower Silurian period, and the Upper Scotch Grove and Gower formation are said to be in the Upper Silurian. These six formations are dolomite formations, and two limestone formations, the Waucoma and the La Porte City formations can also be observed in the Silurian period. Silurian rock is best observed in Eastern Iowa where glacial deposits are thin or nonexistent, but has been eroded away in northwestern and southeastern Iowa.

The Hopkinton formation can be found in eastern to southwestern Iowa. It is visible in Eastern Iowa, but become bedrock as it moves to the southwest. An interesting characteristic of the Hopkinton formation is the presence of sinkhole and other solution features. Many of these features can be observed at various state parks, and a variety of fossils can be found in the formation. In Maquoketa Caves State Park, the Hopkinton formation is overlain by the Scotch Grove formation which forms a natural bridge.

Silurian rock can been seen at Maquoketa Caves, Backbone, Palisades-Kepler, and several other state parks in Eastern Iowa.

## Devonian

The Devonian period is known for a variety of marine deposits, the first insects, terapods, and the first seed-bearing plants. Devonian period rock is full of economically valuable resources and is an aquifer for the vast majority of the state. Devonian rock sits unconformably on Silurian and Ordovician rock, and can be seen on Precambrian Rock near Sioux Ridge in northwestern Iowa (Anderson W.I., Iowa's Geological Past, pg 136, 1998). The majority of Iowa's Devonian rock is in what has been named Iowa Basin, and was an area with warm, carbonate-rich shallow seas, tidal flats, and evaporite deposition during the Middle to Late Devonian (also known as the Upper Devonian). Middle Devonian rock consists largely of limestones and dolomites but evaporates and shales can be found. The Wapsipinicon Group is one where all of these can be found since the deposits are suspected to have formed in a constrained sea that later became tidal mudflats. Fossils are rare in the Wapsipinicon, indicating the seas at this time were hostile to marine life. Evaporites are a common occurrence in the group and the gypsum deposits left behind are currently mined in southeastern Iowa. Due to the high solubility of gypsum and its anhydrite, it easily dissolves into groundwater, leading to the formation of caverns and sinkholes, and brecciation of carbonated beds (Anderson, W.I. Iowa's Geological Past. pg 147, 1998).

Breccias are also common in the Cedar Valley group which spans the Middle and Upper Devonian. The Little Cedar and Coralville formations of the both contain quantities of fossilferous carbonates, and an abundance of fossils can be seen in these formations. The fossils in these formations indicate deposition occurred during the Middle Devonian and during a single transgression-regression phase. The Lithograph City and Shell Rock formations of the Cedar Valley group vary considerably in composition from the preceding formations. Lithograph City is known for extremely pure and fine grained limestone, which was used to create lithograph engravings early in the twentieth century. However, the town itself and its quarries only lasted 30 years as metal engraving soon took over the printing industry.

Dolomitization significantly altered the limestone in the Cedar Valley group, which makes interpretations of the depositional environments difficult. The end of the Devonian period was one of extensive muddy environments, which resulted in excellent preservation of fossils. Devonian rock is widely quarried throughout the state for aggregate and for Portland Cement. Significant surface exposures of Devonian period fossils can be found near Rockford and Coralville.

### Mississippian

The Mississippian period was the last time Iowa experienced coverage by carbonate-rich seas. These seas deposited plenty of limestone, but other rocks such as dolomite and chert can be found, as well as evaporates such as gypsum. The Mississippian period experienced ten transgression-regression cycles of the seas, and is known for remarkably preserved fossils and a variety of carbonate facies. The seas of this time were of similar environment to today's Bahama Banks, and the deposits occurred in a southeast to northwest direction, and make up an important groundwater reservoir for two-thirds of the state. The Mississippian period consists of four series, which have exposures in Iowa and vary considerably from one part of the state to another.

The Kinderhookian series is part of the Lower Mississippian, and contains several recognizable formations in southeast Iowa, including the McCraney, Prospect Hill, Starrs Cave, and Wassonville. In the north-central portion of the state, these formations are the Prospect Hill, Chapin, Maynes Creek and Lower Gilmore City. The Kinderhookian rests unconformably on Upper Devonian rock. These formations primarily consist of dolomite and limestone, and were deposited during the first three transgression-regression cycles. The McCraney formation can be observed in Des Moines County, and is easily recognizable by a unique banded appearance from the course-grained brown dolomite and a fine-grained light-colored limestone. The Prospect Hill formation consists of dolomitic quartz siltstone containing shales and is recognized by concentrations of fish teeth and bones, as well as a variety of other marine fauna. For the most part, the Prospect Hill formation is rather thin, but is known to thicken to 90 feet in some locations. The Prospect Hill formation ranges from the southeast to north central part of the state. The Chapin and Maynes Creek formations contain fossilferous crinioidal and oolitic limestone as well as dolomite. The Maynes Creek formation has been known to contain excellently preserved starfish fossils. The Gilmore City formation is known for a variety of high purity limestone, and the city itself has been called Iowa's limestone capital. The Gilmore City formation is quarried extensively for its calcium carbonate (Anderson, W. I. Iowa's Geological Past, page 206, 1998.).

The Starrs Cave formation is known for exposures along the Flint Creek area near Burlington, Iowa, and is identified by its oolitic grainstone. This is a fairly thin formation, but plentiful in variety of fossils. Many of these fossils are similar to those occurring in the Wassonville formation, which overlies the Starrs Cave. The Wassonville consist primarily of cherty dolomite, but limestones can also be found. The Wassonville formation is believed to have formed during a period of frequent storms due to areas of flat laminae and hummocky cross-stratification that can be located throughout the majority of the formation. The Wassonville contains many fossils including crinoids, fish, corals, and conodonts to name a few. A discontinuity separates the Wassonville from the Burlington formation.

The Middle Mississippian contains both the Osagean and Meramecian series which occurred in the fourth through ninth transgression-regression cycles. The Osagean series contains the Burlington, Keokuk, and Warsaw formations, and are located near the cities after which they are named (Warsaw is across the river, in Illinois). The Burlington formation is one of the best-known formations in the state, and is known for crinoidal limestone and was known by the natives for its flint. The Burlington formation is known outside of Iowa, and occupies a decent portion of the Midwest. The crinoidal limestones in the formation are characterized by their grainstone and packstone textures and consist of three members. The Burlington formation is believed to have formed during the fourth and fifth transgression-regression cycles of the period, and some of the limestone was converted into dolomite after deposition. The Burlington is overlain by the Keokuk formation which consisted of cherty carbonate rock. Keokuk limestones are brown in color, making them easy to distinguish from the lighter Burlington limestones. The Keokuk contains more dolomite and shale than the Burlington and is overlain by the Warsaw formation. The Warsaw formation is unique in that geodes can be found in this formation. It was deposited during a period of shallowing seas, and significant erosion occurred between the Warsaw and the Meramecian series.

The Meramecian series contains the Salem and St. Louis formations, and are known for having thick, uniform lateral facies located in the far southeastern corner of Iowa. The Salem formation is only found in very small section of southeastern Iowa and is believed to have occurred in the seventh transgression-regression cycle. The St. Louis formation is much better known in Iowa and lies unconformably on the Keokuk, the Warsaw, and the Salem formations. The St. Louis consists of four members, which consist of a variety of dolomite, limestone, carbonate breccias, gypsum, and quartz sandstones. The evaporates which occur in the first member of the St. Louis can be found in the subsurface in southeastern and south-central Iowa and the sulfates contained in them can adversely affect the drinking water, although these are mined in Marion county currently. The upper two members of the St. Louis can be distinguished by the types of fossils found, including scale trees, amphibians, snails, and several types of fish. The Waugh member of this formation has some of the best fossils of Mississippian amphibians in the world, and these can be found at a quarry near Delta, Iowa. These are the oldest and best-preserved amphibian fossils found in North America. The St. Louis occurred during the eighth and ninth transgression-regression cycles and the end of these cycles show a transition from marine to lowland coastal environment including, stream, lake, and swamp environments.

The Chesterian Series contains the Ste. Genevieve and Pella Formations, which belong to the Upper Mississippian period. These formations occurred during the tenth transgression-regression cycle, and the Pella is the last of the major Mississippian formations observed in Iowa. The Pella formation is known for calcareous shales containing fossils and can be found in southeastern Iowa. The limestone is the Pella is largely oolitic and skeletal , and represents a deepening sequence due to a marine transgrssions. An abundant variety of fossils can be found in the Pella. Mississippian rock is an excellent economic source of road aggregate and other commercial products for the state of Iowa.

## Pennyslvanian

A significant unconformity occurs between Mississipian and Pennyslvanian rock due to uplift, warping, and erosion, resulting in the Pennyslvanian period sitting on rock from a variety of periods. The majority of Pennsylvanian rock sits upon Mississippian rock, but in Eastern Iowa, it can be found resting on Silurian and Devonian strata. The Pennyslvanian period was one of shallow seas and coastal swamps, and coal deposits can be found parts of the state. In Iowa, the Pennyslvanian is characterized by a variety of shallow marine (Upper) and nonmarine environments (Lower and Middle). These nonmarine settings included coal swamps, deltaic coastal plains, and stream channels. Pennyslvanian rock was deposited as a rolling plain with a south to southwestward slope and varies up to 200 feet. This plain was modified by karst activity, and stream erosion. Pennyslvanian rock is best observed in two structural basins, the Forest City and the Illinois. These basins are separated by what is known as the Mississippi River Arch which is considered to be the same age as the Forest City Basin. The environment of this age is thought to be similar to today's Everglades or Louisiana Bayous, and transgressions and regressions of the seas can be observed in the depositions. These cycles are significantly shorter than previous ones and are believed to have been caused by the movement of continental glaciers in the Southern Hemisphere. The Forest City Basin was filled by sediment at the end of the Middle Pennyslvanian time, and Iowa was part of the Northern Midcontinent Shelf during the rest of the period, and cycles of limestones and shales can be observed. There are five series of Pennyslvanian rock in Iowa and more than seventy formations, providing a varied and complex geologic history.

Iowa's oldest Pennyslvanian rock is part of the Illinois basin and is known as the Caseyville formation. It contains a wide variety of rock, including sandstones, shales, and discontinuous coal beds (Anderson, W. I. Iowa's Geological Past, pg 237, 1998). The Caseyville is believed to have deposited in a deltaic or fluvial setting, and contains two formally mined coal beds, the Wildcat Den, and the Wyoming Hill. Well preserved fossils can be found in this area, including upright stumps of scale trees. The Cherokee Group followed the Caseyville, and covers much of central Iowa, and provides an array of information on the period. Significant coal resources are found in the Cherokee, which is a very thick deposit of rock. The Cherokee group indicates both alluvial and deltaic sediments deposited in swamps or coastal settings, and the accumulation of peat. This area is considered to have been one of the most extensive swamplands of all times. Besides these deposits of coal, the Cherokee is known for its sandstone, which has been used as a building material. The Forest City Basin contains a large deposit of cliff-forming sandstone, which can be observed at several state and county parks. Limestones from the Pennyslvanian are mined in southwestern and south-central Iowa and contain a variety of fossils, and shales from this period are used in the creation of brick and tile. Anderson spends a significant part of the chapter discussing the formation and importance of Iowa coal, which at one point employed a good number of people, but has since died out. Iowa contains bituminous and sub-bituminous coal, which was fairly high in sulfur and ash. However, since Iowa was second state west of the Mississippi to have commercial coal mines, it was considered to be the last place trains could be supplied before traveling to Colorado. A large number of underground mines were located in the Des Moines area (Iowa DNR, Iowa Coal Mines), making the area a prime candidate for sinkholes. Despite significant quantities of coal remaining in Iowa's Pennyslvanian strata, there are no plans on resurrecting the state's coal mining industry.

## Mesozoic

Much of the Mesozoic period is missing from Iowa due to an expansive unconformity, but evaporate deposits can be found can be found, and Jurassic strata can be found near Fort Dodge. During the Jurassic, lagoons are thought to have extended into central Iowa, and gypsum and red bed deposits can be found around the Fort Dodge area as well. Due to the nature of the period, fossils from the Jurassic period in Iowa are likely to be fish, although fossils of plesiosaurs have been reported in the Sioux City area (Anderson, W.I. Iowa's Geological Past, pg 298, 1998). Gypsum of this period is of great economic importance for the state of Iowa, and gypsum has been extensively mined in the Fort Dodge area. Due to this mining, it is estimated that these resources will be depleted in the next few decades. The gypsum of this period played a large roll in what could be considered one of the greatest hoaxes in United States history, the Cardiff Giant. Although the gypsum from this period is economically important, it is not the most interesting occurrence of the period.

During the Jurassic, a significant event occurred, creating the Manson Impact Structure which is estimated to have occurred 8-9 million years before the end of the period, so is not responsible for the mass extinction. The Manson Impact Structure is unique in that it is the only location in water where naturally soft water can be found. The structure is circular and is 23 miles in diameter and has been an area of significant study. Shocked quartz and ejecta are identifiers for impact structures and the original impacting body is believed to have completely vaporized as no evidence of meteorites has been recovered. The Manson Impact is not visible at the surface due to the glaciation in the Cenozoic period, and sits on top of Proterozoic basement rock.

Other important Mesozoic deposits include the Dakota formation of the Cretaceous rock record which has sandstone exposures near Sioux City, but mudstones, shale, and lignite beds can also be found. The sandstone of this formation is high in quartz and is thought to consist of Precambrian rocks. The Cretaceous time also includes the Windrow formation which is known for discontinuous iron-rich deposits, gravels, and alluvial sands. Due to the presence of iron, the rocks of period are typically red, yellow, or brownish limonites which were mined in the first half of the twentieth century and can still be found near Waukon in northeastern Iowa. Siltstone, shale, and mudstone sit on most of the Dakota formation, and fish are common fossils to be found in this layer, as well as occasional reptile fossils.

## Cenozoic

The early part Cenozoic was a major period of erosion in Iowa, but plenty of glacial activity occurred in part of the late Cenozoic. This period of continental glacial activity is known as the "Ice Age" and covered a large portion of northern North America. The majority of Iowa's landforms have been influenced by a series of glaciers that traveled over the state over a period of several thousands of years.

The three major periods of glacial advances are the Pre-Illinoian, the Illinoian, and the Wisconsinan. The Pre-Illinoian engulfed the entire state during its advance, the Illinoian can only be seen along the Mississippi River in Eastern Iowa south of the state's nose, and evidence of the Wisconsinan can be observed in the north central portion of the state. The Yarmouth and Sangamon are periods of interglacial stages, and are the best known periods in the state and soils can be identified as coming from these two periods.

These periods of glacial advances carried frozen soils and rocks with them, gouging out others as they traveled. The glaciers basically bulldozed soil and rock from other locations to others, depositing soil and rock as the glaciers melted or retreated. A common thing to find as a deposit is a grayish clay consisting of boulders, sand, and pebbles, which were commonly left behind by the glacier's meltwater streams (Prior J.C., Landforms of Iowa, pgs 21-22).

There are eight significant landform regions that make up the state of Iowa. These regions possess a variety of loess, drift, alluvium, and bedrock, allowing one to identify how different portions of the state were affected by different geological events.

## Black Hawk County Geology

The majority of the area surrounding Black Hawk County is in the landform area of the Iowan Surface. This area is known for layers of thin, intermittent loam over glacial drift. Glacial deposits have been found with a thickness up to 240 feet and eleven bedrock outcrops exist in the county (Rowden, et al., Bedrock Geology of Black Hawk County, 2013). Bedrock appears near the surface and there are several areas of where areas of karst or potential karst can be found. Erractics are also a common feature found in this landform region, as well as the unique feature of the paha. This region is also known for have integrated drainage networks. (Prior. J.C. Landforms of Iowa, pg. 34). The Iowan Surface lacks many of the strong geological identifiers found in regions such as Des Moines Lobe, Loess Hills, and Southern Iowan Drift Plain. This region consists of subdued hills and valleys surrounding the many drainage networks found in this area. Erosion had a major role in the shaping of this surface in Iowa. Prior to the Wisconsinan glacier, the Iowan Surface had the same characteristics (Figure 4) and features of the Southern Iowa Drift Plain including moderate loess cover, weathered paleosols, and stepped erosion surfaces. The main components both regions have in common are the integrated drainage networks. When the erosional surface formed, it also left behind a stone line, or what is called the Iowan Pebble Band. (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 7, 1996).

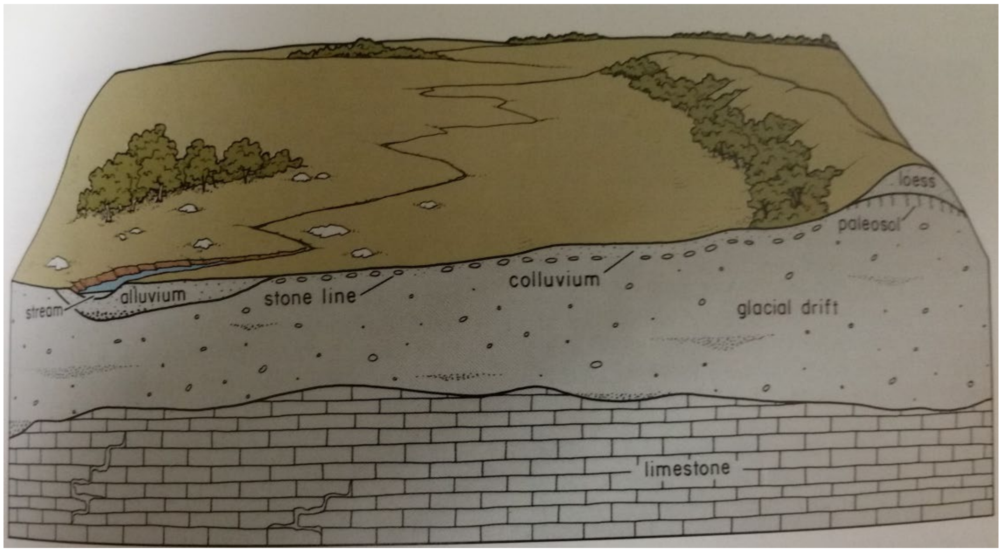


*Figure 4. The Iowan Erosion Surface (Prior, J.C.., pg 69, 1991.).*

The bedrock of Black Hawk county consists of Ordovician, Silurian and Devonian strata while exposed bedrock consists only of Silurian and Devonian (Figure 5). The Devonian Rock in the county have been assigned primarily to the Wapsipinicon and Cedar Valley Groups, and many of the Cedar Valley formations can/could be seen at the local quarries (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 10, 1996).

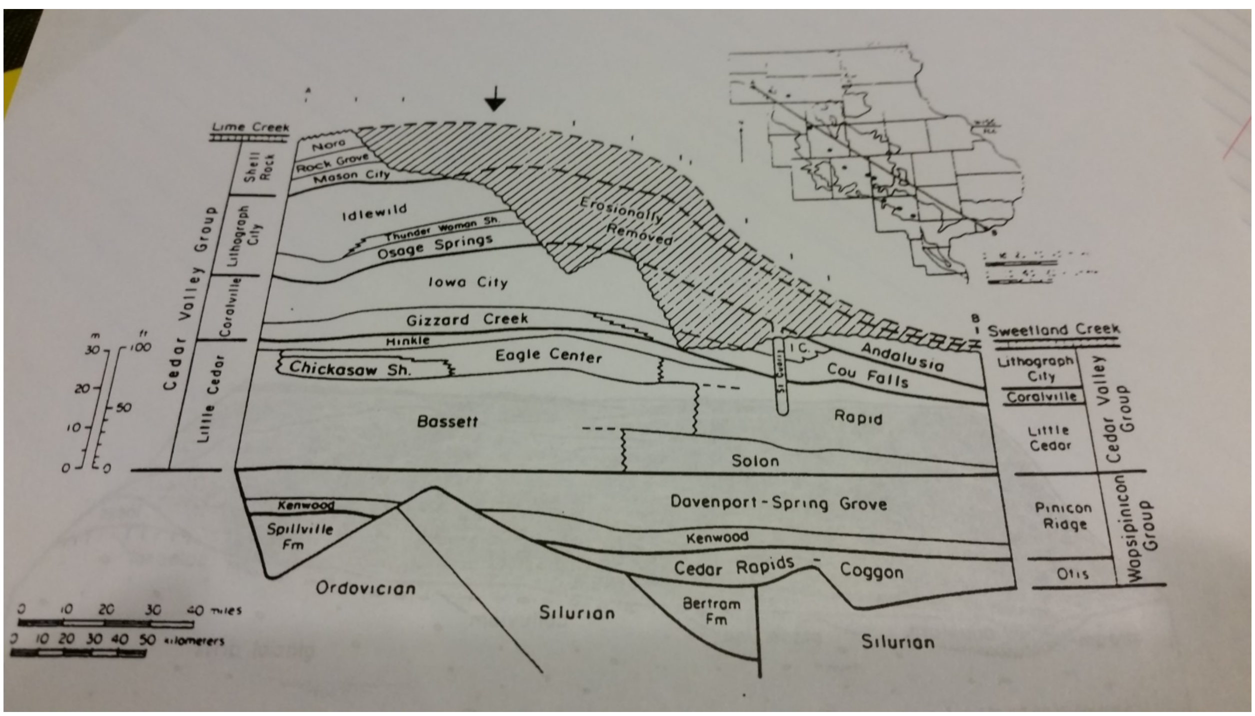


*Figure 5. Stratigraphic cross-section from north-central to east-central Iowa showing Wapsipinicon and Cedar Valley Groups. Obtained from Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 10, 1996 and Witzke, B.J., et. Al. " Eifelian through Lower Frasnian Stratigraphy and Deposition in the Iowa Area, Central Midcontinent U.S.A." CSPG Special Publications, pgs 221-250 1988.*

The Silurian-Devonian aquifer is of major importance to Black Hawk County and the surrounding area since nearly all of the water used in the County is provided by this aquifer. The aquifer in this area is very thick limestone and dolomite and in 1996 was estimated to contain between 30 and 60 million acre feet , with 20 million acre feet being considered to be quality water. Black Hawk County is estimated to withdraw roughly 5.4 billion gallons of water each year from this aquifer (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 12, 1996, citing Horick, 1984). Fossils of placoderms (armored fish) have been found in Devonian strata around Waterloo, as well as small mammals, molluscs, insects, plants and pollen from the Wisconsinan glacial period.

## Natural Resources of Black Hawk County

George Wyth Memorial State Park is the only state park in the county. It occupies 909 acres and is a designated National Urban Wildlife Sanctuary. It is known for its lakes and rivers, which are an excellent habitat for several species of fish, and for its forest. Black Hawk County also possesses several publicly owned tracts of land that the Conservation department manages. These include Black Hawk Park, Brett Klima Wildlife Area, Hickory Hills Park (technically established in Tama County) and Hartman Reserve Nature Center. Black Hawk Park is known for its waterways, fish, prairie and floodplain forest, while the Brett Klima Wildlife Area possesses forests and wetlands. The Hartman Nature Reserve is unique in that it possesses an upland bluff and is located within the heart of the Cedar Falls/Waterloo metropolitan area. A variety of landscapes can be found in the 300 acre Reserve and include forest, prairie, gravel pits, waterways, and an open meadow. Hickory Hills Park is known for its forest, waterways, and the geographical Paha feature which can only be found in the Iowan Surface portion of Iowa.

Casey’s Paha within Hickory Hills Park is one of three state recognized preserves located within the county. The preserve features only half a mile of the two and a half mile long paha, and its accumulations of loess have been found to be up to forty feet deep in places. Cedar Hills Sand Prairie northwest of Cedar Falls contains a small fen, a sand prairie, and a sedge meadow and is located between the Cedar River and Beaver Creek. Cedar Hills has been managed by the University of Northern Iowa since the time of its discovery in 1969 and is a useful educational tool for numerous biology classes. A number of locally recognized preserved areas also exist, and include open prairies, wetlands, forest cover, wildlife habitat and native prairie. Many of these preserves are privately owned and the owners have worked with various departments at both the county and state level, as well as private groups such as Ducks Unlimited.

At one point in time, there were a number of quarries within the county, but most of them have since closed. Pint’s Quarry was a favorite spot for many geologists, primarily for the array of minerals that could be found, but closed in the 1990s and is no longer open to collectors. BMC Aggregates L.C. purchased Waterloo South, Yokum, Morgan quarries in 1982 as well as several other quarries throughout northeast Iowa. Raymond Quarry was purchased in 1984 and they have slowly been adding quarries from around the area to their business. BMC is known for maintaining strong ties with the community and for working with UNI on education. They donated the Finchford (Yokum) Quarry to the county in 2006 to turn into a preserve (BCM Aggregates L.C. , 2016).

### Toxic Waste and Bedrock

For around 40 years, Black Hawk County had no official landfill and a handful of companies collected batteries, transformers, and scrap metal at the Blackhawk Iron and Metal site on the east side of

Waterloo. This site is located on Lafayette Street between California and Zuma Streets, bisected by the railroad line, and is currently fenced off to deny access. Initially the site was owned by the Blackhawk Iron and Metal Company, and then changed hands a few times before the facilities were destroyed by a fire in 1991 and the site was abandoned. (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 31, 1996). In 1993 the site was brought into the public spotlight when some children discovered elemental mercury onsite, triggering a massive clean-up. During the clean-up, high levels of lead, mercury, polychlorinated biphenyls and copper were found. This lead to the thorough testing of the on-site soils by the EPA in late 1993 and early 1994, and it was discovered that high levels of other hazardous metals were present as well. Despite the clean-up done, this area is still contaminated and potentially hazardous to the public and remains fenced off to this day. The groundwater was also tested during this time period and concentrations of all hazardous components were found to be under the EPA established maximum levels (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 35, 1996).

Other issues encountered with waste in the county were the dumping of unwanted goods and materials in agriculturally undesirable areas. These areas included old quarries and sand pits, ditches, and low-lying areas near the Cedar River. This habit posed an environmental hazard very similar to the one caused by the Blackhawk Iron and Metal site. During periods of flooding, waste materials and leachate were frequently washed down stream or into the bedrock (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 95, 1996). Concerns over the soil and groundwater are what brought the Black Hawk County Landfill into being in 1974.

The Black Hawk County Landfill is located at -92.329114 and 42.414258 and is 1 mile south of Hawkeye Community College. This site was chosen because of its geology, as well as a near-central location. There are no alluvial soils present, and is not in an area of potential karst. Three feet of loamy sediment sit on top of an estimated 100 feet of glacial till which rests on bedrock from the Cedar Valley group. The till contains a high quantity of clay minerals and has low permeability, making the risk of leachate reaching the aquifer slim. The clay minerals also assist in adsorbing heavy metals that percolate from the collected waste (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 95, 1996). The nearest agricultural drainage well, major river source, major lake source and high quality water and high quality resource water are all more than a mile away from the landfill. The Black Hawk County Landfill is about 75 feet away from surface water. In order to be used as a sanitary landfill, the following components needed to be examined: soil permeability, depth to the bedrock, depth to a water table, flooding, ponding, slope, textures, boulders and stones, organic layers, soil reactivity, and sodium and salts content ( USDA et al. Black Hawk County, Iowa, pg 65, 2001). Unless noted otherwise, the ratings examined only apply to the first six feet of soil. The landfill has fifty-six wells used for monitoring water contamination and conducts sampling every six months.

The Black Hawk County Landfill officially opened in 1975 and was operated by Landfill Services Inc. from 1975 to 1985, which collected hazardous waste. When Landfill Services suggested taking in waste from all over the Midwest, the citizens of Black Hawk County voted to kick Landfill Services out in favor of the county taking over the landfill for a price of 2.2 million dollars. Once Black Hawk County took over, hazardous waste was no longer accepted (Wilson, L.J. et al. General and Environmental Geology of Cedar Falls/Waterloo and Surrounding Area, Northeast Iowa. pg 95, 1996). In the end, this has been favorable to county as both Waterloo and Cedar Falls offer "Hazardous Waste Collection Days" for the county in spring and fall. There are restrictions on what will be accepted, and occasionally fees apply. Volunteers are always requested, and in the fall of 2015, 65000 pounds of hazardous waste were collected (WasteTrac, http://www.wastetrac.org/springhhmdropoff.html, 2016).

# Sinkholes: The Effect of Pollution on Limestone

The Iowan Surface portion of Northeast Iowa has a large of number of locations where karst and the potential for karst have been found, and in parts of the state, large quantities of sinkholes have been found. Black Hawk County has several locations where karst or the potential for karst exist, however, only one known sinkhole exists within the county along the northern border with Bremer County near Janesville (Figure 6). Since many of the students at Hawkeye Community College live in the surrounding counties, the lab activity will examine how agricultural runoff and landfill waste could have an effect on the potential karst and the formation of sinkholes through a small scale lab exercise. This activity will be related to chemistry due to the backgrounds of the current instructors.

## Exploring Physical Science Lab Activity

Hawkeye Community College's Exploring Physical Science course is currently set up to cover six weeks each of chemistry and physics, and two each of geology and astronomy. This activity will be used to tie chemistry and geology together in a two hour lab period following one-two hours of lecture on Iowa's geology, following those on basic geology.

Due to the vast area Hawkeye Community College serves, the topic needs to cover something that will apply to the majority of the course's student population, which are often education majors with minimal background in science or math classes. This activity will be used to tie chemistry and geology together.

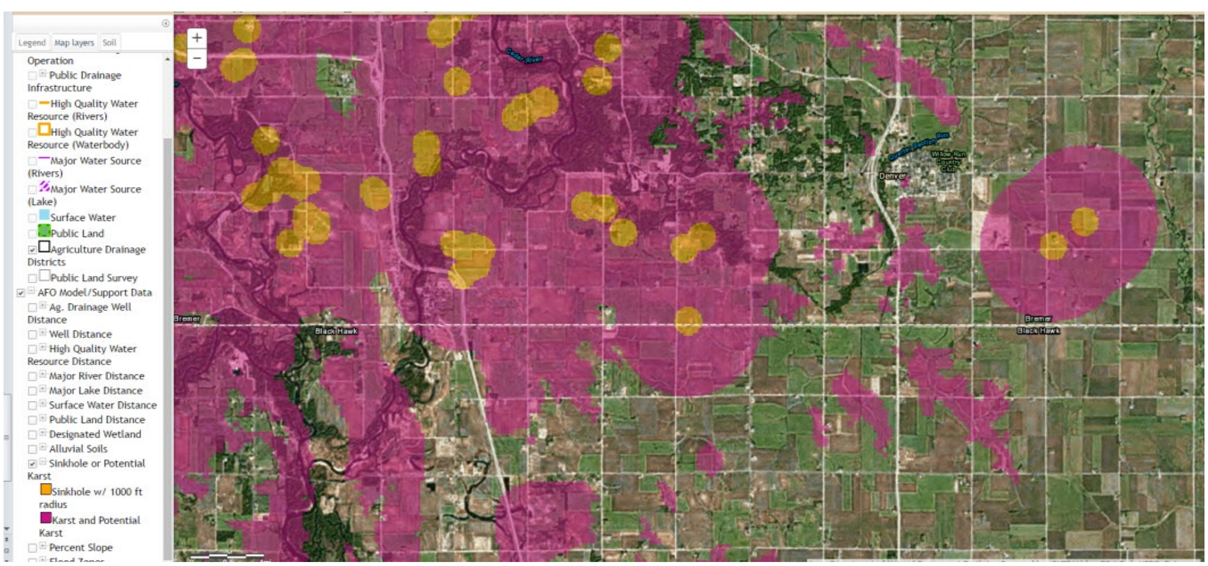


*Figure 6 Location of karst and sinkholes along the Bremer-Black Hawk border (Iowa DNR).*

Two weeks prior to lab, simulated rock samples will be made with soils and calcium carbonate, sandwiching the calcium carbonate layer between a clay/sand mix and topsoil from campus. The containers to be used are pneumatic troughs, which will allow for water to flow through. Once layers have been made and thoroughly soaked, they will be stacked and water will be allowed to evaporate off in fume hood. For the lab, students will be given diluted acids and fertilizers and will be able to test their land 'samples' to see what will happen when various waste and run-off chemicals react with soil and 'limestone'. "Leachate will be collected throughout the experiment and tested via chemical precipitation to see if sulfate or nitrate (brown ring test).

Students will add barium chloride to "leachate to test for sulfates. If precipitate occurs, sulfate is present.

Students will add iron (II) sulfate to fertilizer "leachate" then add concentrated sulfuric acid drop-wise until an acid forms a layer underneath the aqueous solution. If a brown ring is present at the junction of the layers, nitrate ions (fertilizer) is present.

The following questions will be asked for the students to fill in during the lab:

What happens to your land sample when acid is added?

What happens to your land sample when diluted fertilizer is added?

What happens if we flush a large quantity of water over and through your sample after adding fertilizer?

Does the sulfate from your battery acid show up in leachate collected from your "land"?

What about nitrates from the fertilizer?

Post lab questions:

Where is your county's landfill located? (Use ArcGIS)

What do you think would happen to the groundwater if your county did not hire a geologist to assist with deciding where to build a landfill?

What types of features occur around your county's landfill? Are there any areas of potential karst nearby?

How do you think disposing of waste improperly could affect aspects other than groundwater?

Students will then research any sinkholes and watershed projects going on in their home county and write a summary on the lab exercise and discuss how this may have affected any existing sinkholes. Students will also discuss what is being done to reduce agricultural and landfill waste and how they can make an effort to reduce these types of waste in their homes.

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