MISSOURI
Natural Areas
NEWSLETTER

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"...identifying, designating, managing and restoring the best remaining examples of natural communities and geological sites encompassing the full spectrum of Missouri's natural heritage"

Editor's Note

Missouri Geology from the Bottom Up

As with the rest of the world, Missouri's unique natural communities of the present are an expression of adaptation, evolution, extinction, and change in response to disturbance processes, climate, species dispersal/isolation, and (in the last 20,000 years) human influence. Stepping back at any point in time over the past 400 million years, one would have experienced a vast variety of different plants and animals. A natural community's distinctive assemblage of plant and animal species, vegetation structure, and degree of moisture is tied to topography, geology, and soil. Collectively, all make up definable, mappable environments containing associations of describable native plants, animals, and microorganisms. The Missouri Natural Areas Committee aims to identify our highest quality ecological natural communities (systems most often linked to an intact soil profile), and significant geologic features such as Elephant Rocks Natural Area.

For nearly 1.7 billion years, volcanism, plate tectonics, land uplifts, earthquakes, glaciation, inundation by oceans, and erosion have sculpted Missouri's rich and varied geology. Pressure and time solidified ocean sediments, river and

Sun setting on the Elephant Rocks Natural Area, Iron County, Missouri.

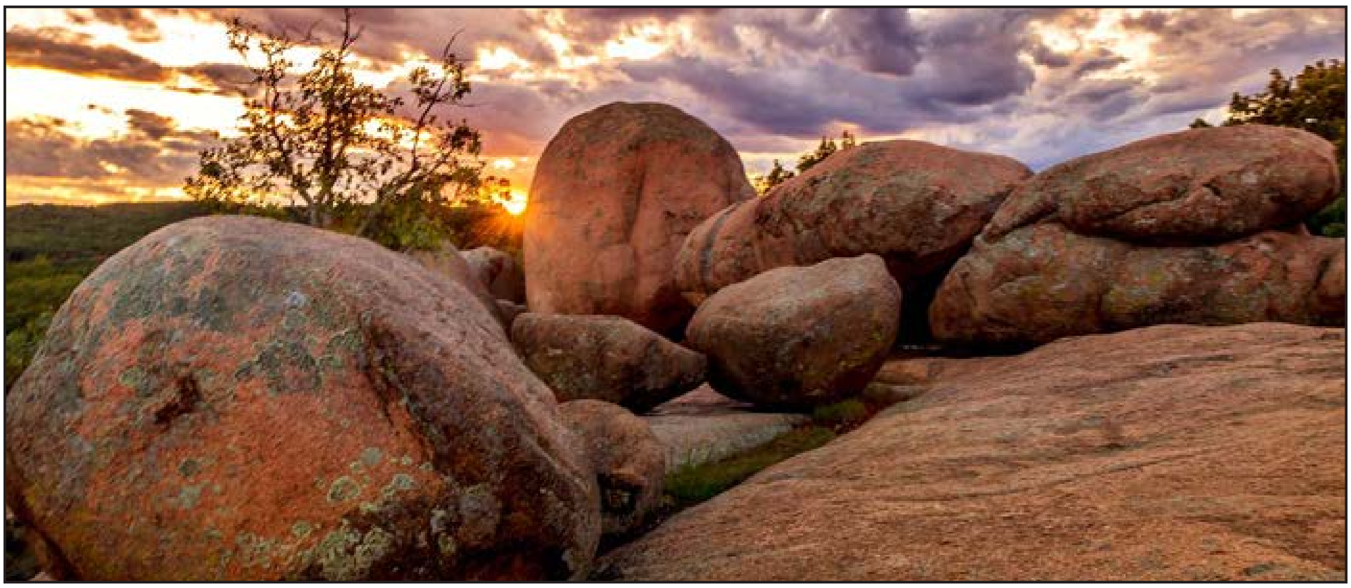

Photo by Andy Eckert

wind-driven sands, volcanic magma, ash, and lava into rock types. Most of Missouri's thousands of rock types are sorted into some form of sandstone, limestone, dolomite, granite, rhyolite, chert, and shale. These primary rock types and their unique physical, chemical, and water-holding capacity are major contributors in explaining where plant species often occur. It was not until 400 million years ago that vascular plants and animals evolved and adapted to fill distinctive niches of soil, substrate, and climate-all important keys in defining our terrestrial natural communities. The assemblages of native plants, animals, and microorganisms that developed through time and occur in repeatable patterns on the landscape are housed on often unseen bedrock geology and soils. While soils and geology do not singlehandedly define a terrestrial natural community, they serve as the foundation of the broad spectrum of communities that exist in Missouri.

The study of geologic processes, rock formations, and soil types is complex at best. In this edition of the Missouri Natural Areas Newsletter, we hear from various geologists and soil scientists about recent research in this technical field, and efforts to classify and categorize geologic features while providing examples for visitors to see these places with a better understanding of the underground forces that gave rise to them. We lead off the newsletter with a history of the geology mapping process in Missouri, a story of Missouri from the bottom up, and continue on with the various categorizations and groupings that help us organize geologic history. The story of the three distinct meteor impacts in the Ozarks is front and center of research, and we'll hear about new technological advances in dating. This edition will hopefully further one's understanding of our diverse geology and help us better appreciate the state's rich natural heritage this foundation gave rise to. — Allison J. Vaughn, editor

Allison Vaughn is the Natural Areas Coordinator with the Missouri Department of Natural Resources.

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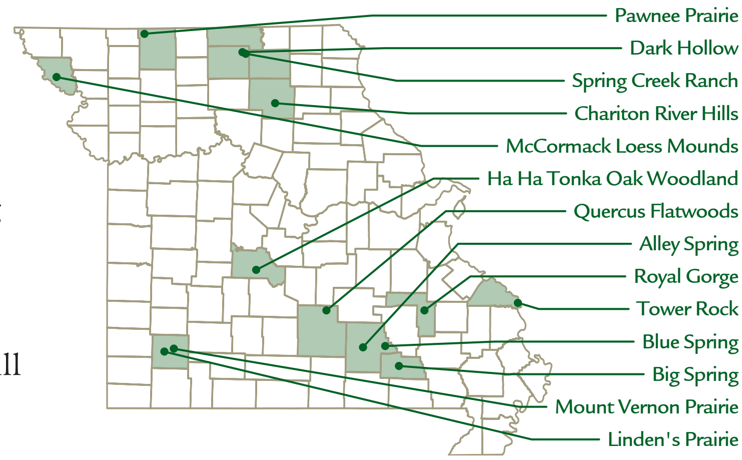
NATURAL AREAS FEATURED IN THIS ISSUE



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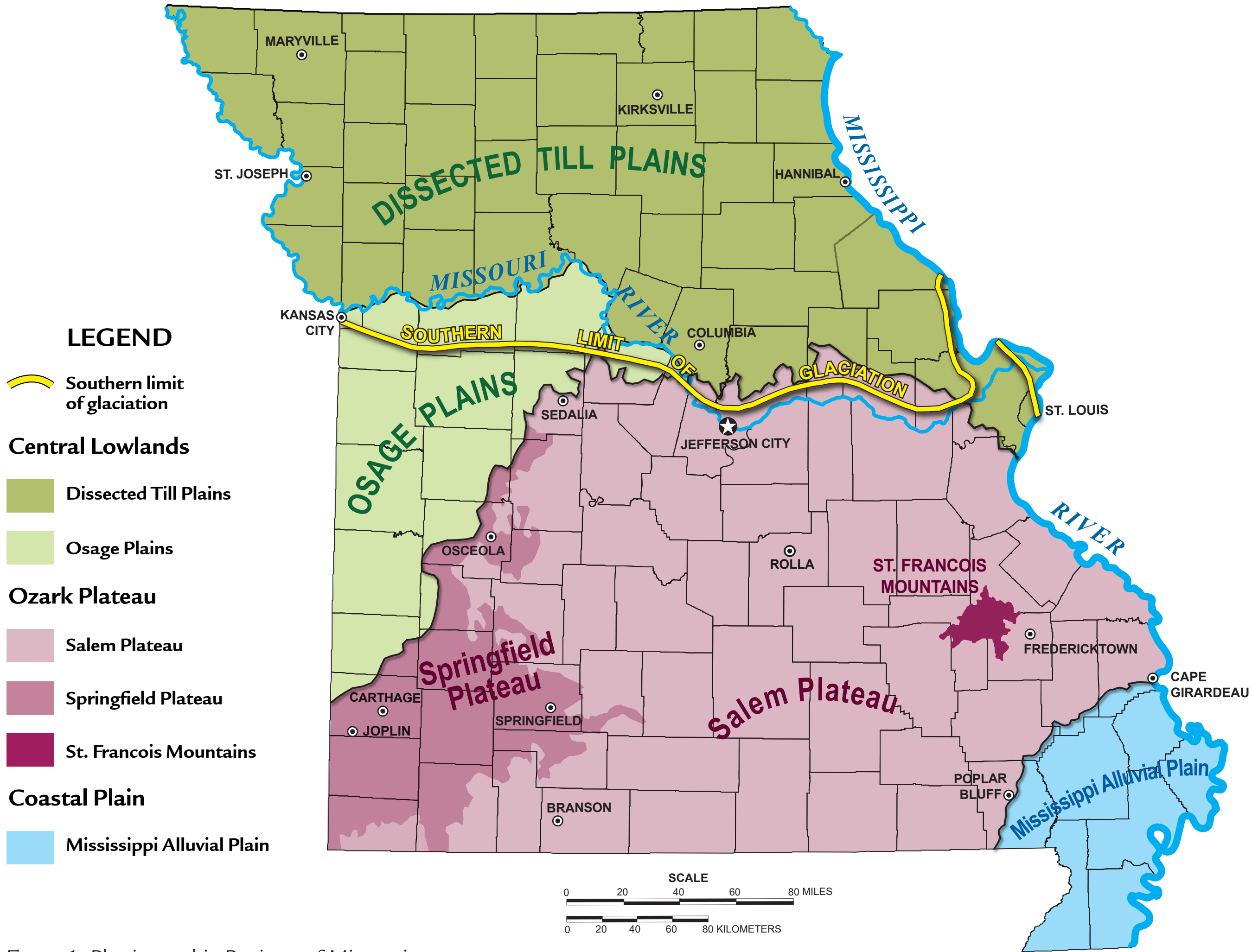
The Missouri Natural Areas Newsletter is an annual journal published by the Missouri Natural Areas Committee, whose mission is identifying, designating, managing and restoring the best remaining examples of natural communities and geological sites encompassing the full spectrum of Missouri's natural heritage. The Missouri Natural Areas Committee consists of the Missouri Department of Natural Resources, the Missouri Department of Conservation, the U.S. Forest Service, the U.S. Fish and Wildlife Service, the National Park Service and the Nature Conservancy.



Missouri Geological Survey Fact Sheet, Pub-2515

Figure 1. Physiographic Regions of Missouri

Major Geologic Divisions of Missouri

by Larry "Boot" Pierce

Missouri Natural Areas are defined as biological communities and geological sites that represent the natural character, diversity, and ecological processes of Missouri's landscape. For most natural areas, the ecological integrity plays a vital role in its designation, but underlying every natural area in the state is a set of factors which controls that ecology. Geology and climate, which includes the resulting geomorphic processes, both build and destroy the natural character of Missouri's landscape.

The continental United States of America is divided into 24 major geologic or physiographic regions. Missouri is included in three of those major divisions. These divisions, originally described for the country in Fenneman (1928) and further delineated in Fennemen and Johnson (1946) break down the geology of the nation into its broadest and most basic physiographic regions. The physiographic regions and subdivisions for Missouri are outlined on the Physiographic Regions Map (Figure 1.) Many scientists, including Thom and Wilson (1980) and Nigh and Schroeder (2002), have taken these broader physiographic regions and combined them with geomorphic, ecologic and climatic data to produce maps that outline the ecological or natural divisions of the state. These maps roughly coincide with the physiographic divisions of Missouri, however, as can be expected, the ecological and natural sub-regions are more diverse and a smaller in scale.

At their broadest, the geologic regions located within Missouri include the Central Lowlands subsection of the Interior Plains, Ozark Plateau subsection of the Interior Highlands and the Coastal Plain subsection of the Atlantic Plain. The geologic characteristics within each region are notably different and give each its unique properties. Based on these differences each of these regions are further subdivided into subregions which include:

- **Interior Plains**
  - Central Lowlands
    - Dissected Till Plains
    - Osage Plains
- **Interior Highlands**
  - Ozark Plateau
    - Salem Plateau
    - Springfield Plateau
    - St. Francois Mountains
- **Atlantic Plain**
    - Coastal Plain
    - Mississippi Alluvial Plain

Major Geologic Divisions of Missouri and Characteristic Topographies

Ozark Plateau

A. Salem Plateau

a. Dissected Salem Plateau: deeply and intricately dissected plateau, mostly Cambrian- and Ordovician-age cherty dolomite bedrock; area characterized by rugged hills with steep slopes and high local relief; sinkholes and karst features locally common. (Most of the central Ozarks; Ozark National Scenic Riverways, Shannon and Carter counties)

b. Undissected Salem Plateau: gently rolling upland plains with undissected plateau interfluves between major drainage systems; Mostly Ordovician-age dolomite and sandstone bedrock; sinkholes and karst features locally common. (Quercus Flatwoods Natural Area, Texas County)

c. Moderately dissected segment of Salem Plateau: masked by loess or glacial deposits; typically along border areas; Karst features locally prominent. (Apple Creek Conservation Area, Cape Girardeau County)

B. Springfield Plateau

a. Dissected Springfield Plateau: moderately to intricately dissected plateau, mostly cherty Mississippian-age limestone bedrock; area characterized by deep rugged valleys separated by rolling upland areas; karst features locally common. (Roaring River State Park, Barry County)

b. Undissected Springfield Plateau: gently rolling upland plains with undissected plateau interfluves between major drainage systems. (Mount Vernon and Linden's Prairie Natural Areas, Lawrence County)

St. Francois Mountains subsection of the Ozark Plateau (including the Precambrian outcrop area of Shannon County)

The St. Francois Mountains are an ancient volcanic complex dating back to between 1.5 to 1.2 billion years old. They are the largest exposure of Mesoproterozoic (Precambrian) aged rocks located in the mid-continent region. The mountains are series of exposed knobs that create part of the core of the Ozark Plateau. The chronological history of the St. Francois Mountains is of multiple sequences of large volcanic eruptions, with gaps of as much as 100 million years between major episodes. Most of the volcanic rocks are rhyolite flows or tuffs. After extrusion of the molten materials onto the surface, the volcanoes collapsed back into the emptied magma chambers, thus creating one of the five calderas (Day et al. 2016). The intrusive rocks, primarily granites with some minor mafic rocks, were later intruded into the complex. When we look at the St. Francois Mountains today, we are looking not at the large volcanic complex that was once there, but rather the highly eroded core of that complex.

The St. Francois Mountains Subsection covers several thousand square acres in an area roughly 30 by 50 miles. It is centered in northeast Iron County and crosses over into adjacent Washington, St. Francois, Madison and Reynolds counties (Figure 2). The actual

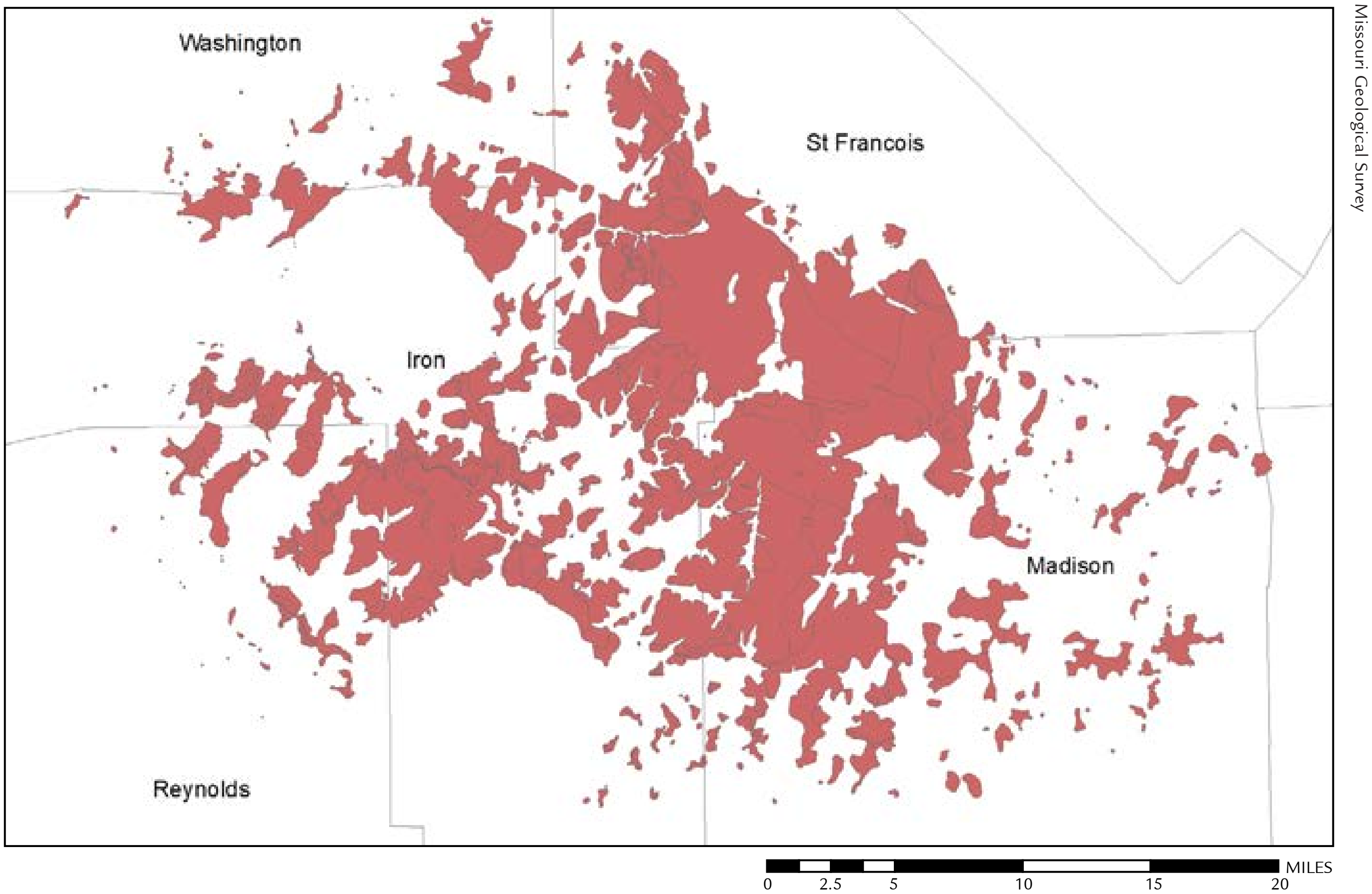


Figure 2. Outcrop map of the intrusive and extrusive igneous rocks in the central St. Francois Mountains.

extent of igneous exposures is approximately 560 square miles. Additional localized areas of igneous rocks occur in portions of Shannon and Carter counties along the Current River and in several locations of Wayne and southern Iron counties as well.

C. Rugged, highly dissected roots of ancient mountains:
Characterized by rounded igneous knobs, hills, and high local relief. (Royal Gorge Natural Area, Taum Sauk-Russell-Hogan Mountain area, Iron County)

D. Gently rolling intermontane valleys developed on sedimentary rock:
(Arcadia Valley, Iron County)

E. Rolling granite hills with relatively low relief:
(Silvermines National Forest Recreational Area, Madison County)

Central Lowlands

A. Osage Plains

a. Gently rolling plain: broad valleys and low relief developed on Pennsylvanian-age shale, sandstone, and limestone. (Prairie State Park area, Barton County)

b. Moderately dissected plains: characterized by development of knobs/mounds; Pennsylvanian-age bedrock. (Prairie View Farm Natural Area, Vernon County)

B. Dissected Till Plains

a. Moderately dissected glacial till plain: characterized by rolling hills and moderate relief. (Much of northern Missouri; Dark Hollow Natural Area, Sullivan County)

b. Undissected glacial till plain: areas of little relief developed on undissected plain interfluves between major drainage systems. (Chariton River Hills Natural Area, Macon County)

c. Moderately dissected glacial till plain with thick loess cover. (McCormack Loess Mounds Natural Area, Holt County)

d. Moderately to intricately dissected plains: uplifted Paleozoic strata along the Lincoln Fold with little or no till/loess cover: characterized by moderate to high relief, abundant bedrock exposures, and locally developed karst (Lincoln Hills Natural Area, Lincoln County)

Coastal Plain—Mississippi Alluvial Plain (Bootheel)

A. **Alluvial Plains:**

Nearly flat broad plain developed on alluvial deposits; no consolidated sediments. (Drainage has been greatly modified through construction of canals and drainage ditches). (Big Oak Tree Natural Area, Mississippi County)

B. **Crowley's Ridge:**

Moderately dissected erosional remnant ridges: Paleozoic, Cretaceous, and Tertiary bedrock; moderate relief and locally rugged; Portions are likely erosional remnant isolated from the Salem Plateau which may or may not be structurally controlled. (Benton Hills Area, Scott County; Holly Ridge Natural Area, Stoddard county)

Compared to many other Midwestern states, Missouri enjoys a wide variety of physiographic regions resulting in the great diversity of landscapes. Within a few hours' drive we can travel from the flat expanses of the Costal Atlantic Plain through the roots of a 1.4 billion year old volcanic complex (which marks the center of the Ozark Plateau) to the unglaciated prairies of the Osage Plains, and end up on the rounded Glacial Till Plains. With so much diversity it is easy to see why Missouri has nearly 200 designated natural areas.

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References

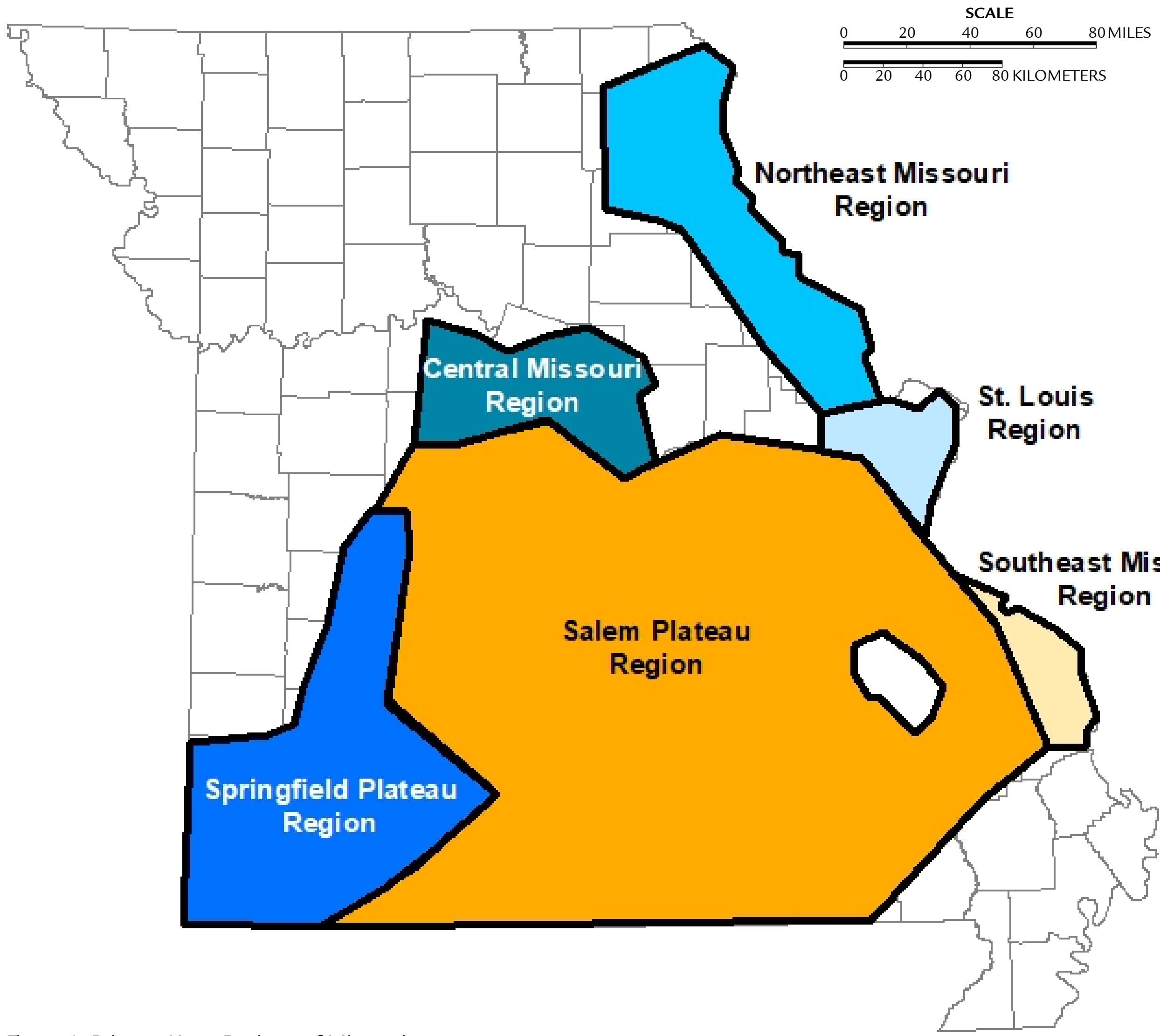
Day, W.C., Slack, J.F., Ayuso, R.A., Seeger, C.M., 2016. Regional geologic and petrologic framework for iron oxide ± apatite ± rare earth element and iron oxide copper-gold deposits of the Mesoproterozoic St. Francois Mountains Terrane, southeast Missouri, USA. *Economic Geology*, Volume III, no. 8, p. 1825–1858

Fenneman, N.M., 1928. Physiographic divisions of the United States. *Annals of the Association of American Geographers*, vol. 18, no. 4, p. 261–353., doi:10.1080/00045602809357034.

Fenneman, N.M., and Johnson, D.W., 1946, *Physiographic Divisions of the United States*, U.S. Geological Survey (USGS), Washington, D.C., http://water.usgs.gov/GIS/dsdl/physio.gz.

Nigh, T.A., Schroeder, W.A., 2002. *Atlas of Missouri ecoregions*. Missouri Department of Conservation, Jefferson City, Missouri. 212 p.

Thom, R.H., Wilson, J.H., 1980. *The natural divisions of Missouri*. Transactions of the Missouri Academy of Science 14:9–23.



Map by Larry "Boot" Pierce

Figure 1. Primary Karst Regions of Missouri

The Diverse Karst Regions of Missouri

by Larry "Boot" Pierce

Approximately two-thirds of Missouri is underlain by carbonate bedrock such as limestone and dolomite. When these types of bedrock units are located at or near the surface, they are prone to dissolution into groundwater, creating features such as sinkholes, caves, springs, and losing streams, which slowly begin to dominate the landscape. This terrane, called "karst" is best characterized as a landscape with discrete recharge and minimal surface water flow. In Missouri, karst terrane development can be divided into 6 distinct primary regions based on the underlying bedrock formations and the way in which the karst features developed.

A. **Salem Plateau Region**
   Deep groundwater circulation (phreatic), primarily developed in Lower Ordovician- (Roubidoux Formation and Gasconade Dolomite) and Upper Cambrian- (Eminence and Potosi dolomite) age bedrock units, large springs and associated recharge areas.

B. **Springfield Plateau Region**
   Shallow groundwater circulation (meteoric),

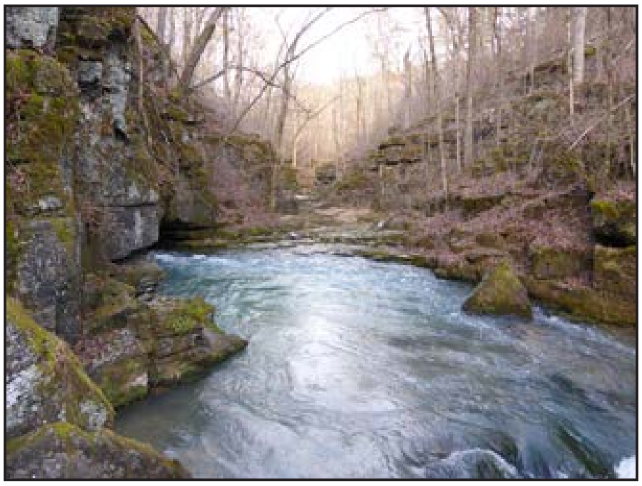


Photo by Bill Duley, Missouri Geological Survey

Large Spring in Ordovician-age bedrock of the Salem Plateau Karst Region: Upper discharge of Greer Spring located on Mark Twain National Forest, Oregon County.

Photo by Larry "Boot" Pierce, Missouri Geological Survey

Small spring in Mississippian-age bedrock of the Springfield Plateau Region: Clear Creek Spring, Greene County

Photo by Larry "Boot" Pierce, Missouri Geological Survey

Karst Window in upper Ordovician-age Joachim Formation located at the convent sanctuary of St. Joseph Catholic Church in Apple Creek, Perry County

developed in Mississippian-age bedrock units (Burlington, Keokuk, and Reeds Spring formations), mid-sized to small springs.

C. **Central Missouri Region**
Area draped with glacial till which partially covers karst features, shallow groundwater circulation (meteoric), developed in Mississippian-age bedrock units (Burlington and Keokuk formation), mid-sized to small springs.

D. **Northeast Missouri Region**
Shallow groundwater circulation (meteoric), developed in Mississippian- (Burlington, Keokuk, and Warsaw formations) and Ordovician- (Kimmswick Formation and Plattin Group) age bedrock units, mid-sized to small springs. Karst development in the confined Louisiana Limestone likely originated from deeper (phreatic) groundwater movement related to the nearby Lincoln Fold.

E. **St. Louis Region**
Shallow groundwater circulation (meteoric), developed in Mississippian-age bedrock units (St. Louis and Salem formation), small springs.

F. **Southeast Missouri Region**
Shallow groundwater circulation (meteoric), developed in Mississippian- (Ste. Genevieve and St. Louis formation) and Ordovician- (Joachim and Kimmswick formations, and Plattin Group) age bedrock units, mid-sized to small springs.

Three of these regions (Salem and Springfield Plateau and Southeast Missouri) developed on the unglaciated Ozark Plateau. The Northeast Missouri karst region is a buried karst terrane which was located under ice as recently as 20,000 years ago. The St. Louis and Central Missouri regions are also historical (buried) karst terranes located near the periglacial boundary. These latter three karst areas have only been revealed and rejuvenated with the erosion and removal of the overlying glacial till and loess deposits.

Several of Missouri's most beautiful and impressive karst features are recognized in the Missouri Natural Areas system, with the heaviest representation located in the Salem Plateau Region. Springs such as Alley, Big, Blue, and Ha Ha Tonka are all associated with adjoining natural areas. Grand Gulf and Cupola Pond natural areas are both examples of how sinkholes have shaped our landscape, but the award for most karst features for a natural area must be given to the former Ha Ha Tonka Karst Natural Area, which is now embedded in the 2,995 ac. Ha Ha Tonka Oak Woodland Natural Area in Camden County.

Outside of the Salem Plateau region, karst terranes within the natural area system are limited. The Lincoln Hills Natural Area in Lincoln County represents the Northeast Missouri Karst Region, and Ball Mill Resurgence Natural Area in Perry County represents the Southeast Missouri Karst Regions. While there are natural areas in both the Springfield Plateau and Central Missouri Karst regions, the karst terrane is not the primary feature of the natural areas. Nevertheless, representing these terranes with the best example of representation should be a priority among geologists. ❧

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Updated Geologic Bedrock Map Available

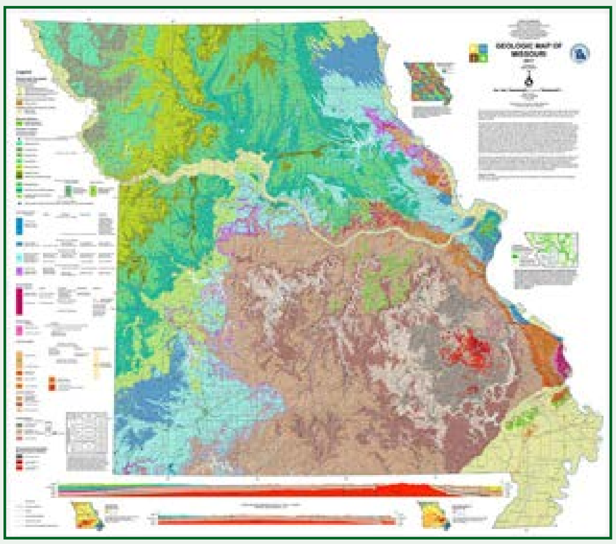
Published by the Missouri Department of Natural Resources

The Department of Natural Resources', Missouri Geological Survey (MGS) has completed its most recent version of a statewide geologic map. Last updated in 2003, the newer 2017 version of the map includes additional information from recent bedrock mapping projects of MGS geologists, United States Geological Survey's geologist and educational institutions.

The new state-wide geologic map provides an overview of the locations and distribution of the state's stratigraphic bedrock units. It also provides information about the distribution of consolidated rock types such as limestone, sandstone, shale and granite and the many structural features of the state by showing the many faults, folds and structures that may be present. Areas of recent updates include updated mapping in the Branson and Lake of the Ozarks area as well as the transition zone between the Ozark Plateau and Central Lowlands through the central part of Missouri stretching from St. Louis to Columbia. Inset maps include the major geologic structures of the state, Pre-Cambrian surface elevations, a magnetic anomaly map of the Pre-Cambrian basement rocks and a comparison of modern and pre-glacial stream channels across northwestern Missouri.

If you would like to obtain a paper copy of the new state-wide bedrock geologic map or any other 1:24,000 or 1:100,000 geologic map, visit the Missouri Geology Store at 111 Fairgrounds Road in Rolla, Missouri or call the survey at 573-368-2100.

For a digital copy of the maps you can visit our online web-based application **GeoSTRAT** at https://dnr.mo.gov/geology/geostrat.htm or visit our share point site at https://share.mo.gov/nr/mgs/MGSData/Forms/AllItems.aspx ❧



Bedrock Geologic Mapping in Missouri

By Edie Starbuck

The geology of an area comprises its consolidated bedrock, surficial materials and the soils developed on them. The term bedrock refers to consolidated sedimentary, igneous or metamorphic rock. A bedrock map depicts the uppermost layer of bedrock present in an area along with geologic structures (faulting and folding) that affect the pattern of bedrock outcrop. Surficial material refers to the regolith, unconsolidated material overlying bedrock that may be the products of bedrock weathering (residuum), unconsolidated wind-, glacier- or water-deposited sediment, or a combination of all three. Most geologic maps indicate whether the map is a surficial materials or bedrock map. Some geologic maps depict both, where the general intent is to map bedrock, but surficial materials are very thick over portions of the area. This article will focus on bedrock mapping.

The geology of Missouri is quite varied. This is reflected in the physiography of the state, from rolling prairies and rangeland to the flat farmland of the bootheel and from the rugged and karst Ozarks to the greater relief of the St. Francois Mountains. Soil texture and chemistry are affected by the materials on which they develop. Springs and losing streams in Missouri's karst areas are an obvious example of how bedrock affects hydrology. Geologic resources can be a major driver for economic development. Indeed, the geology of an area ultimately affects ecology and even culture. Geologic maps are an important resource for evaluation of issues ranging from landslide risk to the potential for a contaminant spill to migrate to groundwater.

From the viewpoint of a geologist mapping bedrock, Missouri, along with most of the eastern portion of North America, is cursed with

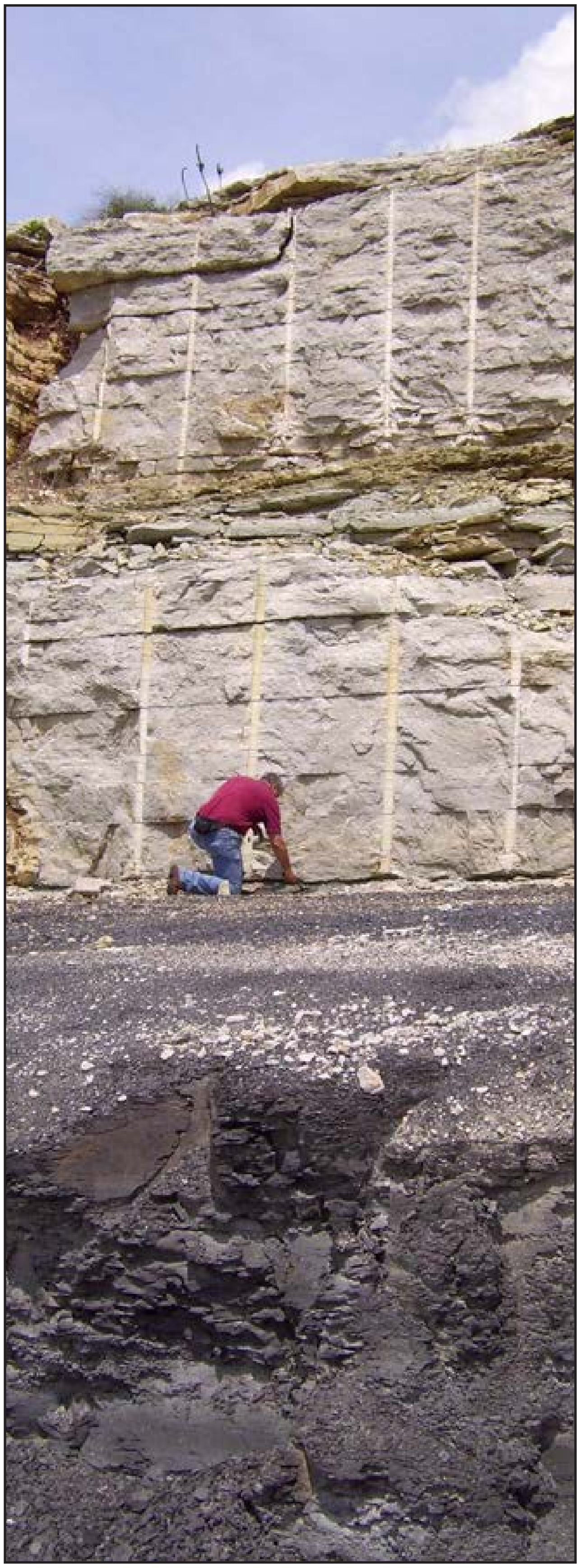


Photo by Edie Starbuck

A geologist examines a geologic contact in Southwest Missouri. The white Compton Limestone (Mississippian) overlies the black Chattanooga Shale (Devonian).

an excess of vegetation. A Missouri geologist visiting western states, where complex geology is often grandly exposed in continuous bedrock exposure, can feel a tinge of jealousy. This is because bedrock geologic mapping is highly dependent on locating and identifying bedrock exposures, both natural and manmade. This information is supplemented with information from water well logs which have been recorded and kept on file at the Water Resources Center of the Department of Natural Resources, bedrock core stored at the McCracken Core Library, historic notes and publications, existing aerial photography or LiDAR (remotely sensed elevation data) which is primarily used to search for lineaments that indicate geologic structures, and if we are lucky, additional coring or geophysical work is done. A seasoned geologist will also come to realize that the "cursed" vegetation will also give clues to underlying geology.

Most of the data collected for a new bedrock map comes from field work. Geologists look along roads, ditches, streams, quarries, bluff lines and hillsides to find exposures of bedrock. Loose rock and soil, and even vegetation, can also be a clue to the underlying bedrock. Geologists try to see as much of the study area as possible in order to locate a large number of control points that are evenly distributed. This requires the cooperation of landowners who allow access to their property. Data is collected along roads and on public property, but in many parts of the state, most of the property is privately owned and the cooperation of landowners contributes greatly to the effort to collect data.

As the geologist examines bedrock exposures, they will take notes on the rock type (lithology) and fossils (paleontology,) and also on the particular sequence of the bedrock layers (stratigraphy). Field identification of the bedrock formations is based on lithology, stratigraphic position and paleontology. The work of past researchers is invaluable in helping to develop the stratigraphic framework for the map area. To create a map at a scale of 1:24,000 mappers have a goal to collect at least 11 control points per square mile, or about 660 control points per 7.5-minute quadrangle. A geologist will walk from 50 to 100 miles collecting data during a field season to prepare a geologic map for one 7.5-minute area. Because of the variation in availability of bedrock exposures, geologists pay a lot of attention to the number and locations of the exposures that are used to create a bedrock geologic map. For detailed mapping, produced at a scale of 1:24,000 or greater, an inset map showing the locations of the collected data is often included.

Other insets may include a stratigraphic column, indicating the sequence of bedrock units depicted on the map, unconformities and approximate thicknesses, and a cross section to graphically depict geologic structures. A table called "Correlation of Map Units" should be included to show how the map units correlate with each other as well as the geology of the state and the geologic time scale.

The basic map units are usually formation names. Formation is the term for the fundamental lithostratigraphic unit. A formation is lithologically distinct and mappable. Formations are sometimes combined into groups or divided into members. Though several of the bedrock formations occurring throughout the Ozarks are made up primarily of the same rock type, dolomite, they weather differently and this can have a dramatic effect on the hydrology of an area. For example, the Jefferson City Dolomite and Gasconade Dolomite are both composed primarily of the rock type, dolomite, as their names imply. However, large springs, such as Meramec Spring and Bennett Spring have developed in the Gasconade Dolomite. Only relatively small springs have developed in the Jefferson City Dolomite. The two formations also look distinctly different in outcrop.

Two formations that often do not look distinctly different, The Jefferson City Dolomite and Cotter Dolomite, are usually mapped

Photo by Edie Starbuck

Fossils in Decorah Group limestone. The fossils in this view include brachiopods, bryozoans and trilobites.

together as one unit on geologic maps. The lack of continuous vertical outcrop in Missouri, combined with the fact that several beds within each of these formations look similar to each other, account for the difficulty in distinguishing these two formations. The combined map unit is called the Cotter-Jefferson City Dolomites.

Chronostratigraphic terms, indicating the age of the rock, are also found on most geologic maps. They are found in the correlation of map units, but are sometimes used to name a unit on the map. This is most often the case on super-small-scale maps, such as a state-wide geologic map that fits on an 8.5”×11” sheet of paper. This is also done when a poorly identified unit is encountered, or when sedimentary units are encountered in an area where the emphasis of the map is on igneous units, or vice versa. This is sometimes seen on geologic maps of the St. Francois Mountains area.

The geologist also interprets the bedrock structures such as faulting and folding of the bedrock. These structures are formed when earth forces cause the bedrock layers to bend or break. Faulting can be an indicator of the likelihood of an earthquake, but often these features were formed hundreds of millions of years ago, and the area may no longer be a site of earthquake activity. Faulting and folding of bedrock has an effect on the present-day flow of groundwater and the distribution of mineral resources. Most geologic maps have associated text including a description of the bedrock structures indicating the location and nature of the structure. The description will say if the structure is a fault or fold, and how far the bedrock layers may be offset if there is faulting. Bedrock structures are also represented in a graphic form as a geologic cross section. A geologic cross section shows what a vertical slice through the earth would look like along a given line. Geologists usually choose to draw cross sections along a line that will help map users to better understand the geologic structure of the map area.

Unconformities are an important part of understanding the geology of an area, but are often overlooked because they are not well-represented on a geologic map itself. Unconformities are gaps in the geologic record that create interruptions in the normal sequence of rock units. This may be a time of non-deposition or erosion during the geologic record. A large unconformity explains why the St. Peter Sandstone plus several other upper Ordovician formations occur in the eastern part of our state, but are non-existent or found only in isolated blocks in the rest of the state. The "Great Unconformity," displayed so well in Arizona's Grand Canyon, is the same unconformity that we see here in Missouri between the Precambrian an igneous rock of our St. Francois Mountains and the overlying (or surrounding) Cambrian formations. The Precambrian surface we see exposed in the St. Francois Mountains is no more rugged than the buried surface that the sedimentary rocks rest on. Unconformities are indicated in the stratigraphic column as well as within the text descriptions of the map units and indicate that the thickness and extent of the units affected can vary unpredictably.

The Missouri Geological Survey is the best source for locating geologic maps for Missouri. This agency is responsible for most geologic mapping in Missouri, beginning in the nineteenth century, and it is also the repository for geologic mapping accomplished by other institutions. Much of the Ozarks and areas near major cities have been mapped at a scale of 1:24,000. Mapping for the rest of the state is available at smaller scales. The National Geologic Map Database, maintained by the United States Geological Survey, is useful for finding geologic maps across the country.

Edie Starbuck is retired chief of the Geologic Mapping Unit at the Missouri Geological Survey. She continues to volunteer with the Meramec Hills Chapter of Missouri Master Naturalists.

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Orthoconic (straight shelled) Nautiloid fossil from the Plattin Group, Cape Girardeau, County

Photo by Larry "Boot" Pierce

Photo by Sam Lord

This photo was taken from a swale within the south study area. This site is composed of the most intact portion of the restoration. Prominent plant species within this area of the restoration include Prairie Blazing Star *(Liatris pycnostachya)*, Sweet Brown-eyed Susan *(Rudbeckia subtomentosa)*, and relatively conservative species of Juncus and Carex. Three prescribed fires have occurred here in ten years, thus maintaining prairie structure and allowing germination of seeded species.

Seasonal Progression of Soil Health Metrics within Two Prairie-Savanna Restoration Sites at Mark Twain State Park

by Sam Lord

Before European settlement, loess/glacial till prairie and savanna spanning millions of acres dominated Northern Missouri. Located at the interface of vast open woodlands and ridgetop savannas, these natural communities once supported incredible biological diversity both above and below the surface. Rapid European settlement and the conversion to agriculture destroyed most of the native landscape, leaving only scattered small fragments, many degraded, as a legacy (Nelson, 2010). The best remaining examples of these historic natural communities in Northern Missouri include the largest intact savanna landscape of Spring Creek Ranch Natural Area and the rich Pawnee Prairie Natural Area. Prairie restoration projects on public lands in the past 30 years shows promise in bringing back the plant community structure and composition, but little is known about restoration of the soil profile, soil health, and associated microbial community composition of these remnant prairie and savanna landscapes. In 2019, while continuing restoration of a prairie and savanna remnant at Mark Twain State Park, I set out to help determine whether soil health conditions and soil microbial community composition restoration can aid in the restoration and management of the plant communities of degraded landscapes.

Soil disturbance causes devastating instability of natural communities. Our highest quality natural communities, those with rich native integrity—many of them designated natural areas—are linked to an intact soil profile. With that in mind, is it possible to determine the degree of damage to the soil profile in degraded systems, and can carefully implemented management practices reverse the damage? By comparing soil data points collected from multiple sites at Mark Twain State Park in remnant prairie and savanna with varying degrees of degradation, perhaps we can determine the degree of damage to the soil profile and relate it to the natural integrity of the sites (Heneghan et al., 2008). Two hypotheses are central to the progression of this research:

1. Prairie restoration management practices will increase subsoil biomass and carbon cycling resulting in increased diversity of soil microbial communities.
2. Increased diversity in soil microbial communities will show positive correlation to above ground plant community diversity and progression towards those standards held by remnant prairie/savanna communities.

If we can establish a correlation, we may be able to determine the conditions within the soil necessary to promote the growth of conservative prairie plant species without mechanical manipulation. Intact (unplowed) remnant prairie soils possess established nutrient flux cycles, well-developed upper soil horizons, and stability in regards to the seasonal processes that act upon them. In other words, these soils and associated natural communities developed a resilience and stability over millennia. By reinstating the natural disturbance factors that once shaped the Missouri landscape, and accounting for new threats such as invasive species encroachment, land managers may have the ability to effectively restore some semblance of the native resilience that once existed before settlement. Due to the disruption of historic edaphic processes by human activity, only time will tell if we have the ability to turn back the clock.

Located in the Central Dissected Till Plain and the edge of the Mississippi River Hills, Mark Twain State Park is situated in an area of broad ridges of prairie plain that intergrade between savanna and open woodland with increased dissection. The General Land Office (GLO) survey records offer further verification to the general structure of the area as an open landscape atop the broad plain moving north towards what is currently Monroe City, Missouri. The Salt River Basin trends south of the park, an area that according to the GLO records also possessed a canopy of variable openness correlating to the level of dissection on the landscape.

Agriculture has stripped most Northern Missouri landscapes of biological diversity, and the two areas of the park chosen for this research are no different. Both of these areas are historic prairie grading into savanna with varying levels of degradation; one area is significantly more degraded, seeming to have a more intense grazing history that included a historic planting of Smooth Brome *(Bromus inermis)* that persists today. In relatively recent years, this area has developed an issue with the encroachment of two dominant invasive species, Autumn Olive *(Eleagnus umbellata)* and Sericea Lespedeza *(Lespedeza cuneata)*. In comparison, the second area, located just south of the first beyond a powerline corridor, remains in better biological condition and was perhaps spared the intensive grazing that resulted in the damage of the first area. Previous managers indicated an abundance of prairie species here, and henceforth it was managed as such. These two distinct areas will serve the study to help determine what management practices may help reverse the effects of human disturbance on the landscape. Both sites share many of the same characteristics including soil series (Keswick), slope, and aspect, but key differences in previous land use and floristic composition will likely have a significant impact on the results as research progresses from season to season.

Methodology

Within both sites, we established soil pits to determine the soil series and baseline physical, chemical, and biological data to include pH, Phospholipid Fatty Acid (PLFA) markers, base saturation, aggregate stability, texture, structure, etc. We chose sample locations based on slope, aspect, and proximity between the two sites. We established and sampled a control pit in an adjacent woodland while the other two pits are located within prairie/savanna management areas. Subsequent, less invasive, sampling will take place four times a year to establish turnover rates and microbial community composition with seasonal change. Subsequent surface sample testing will monitor PLFA, soil respiration, soil temperature, gravimetric water content, total carbon content, and Carbon to Nitrogen ratio within the upper 7.5 cm of soil. We chose this series of tests in order to determine microbial community structure and activity (PLFA and Respiration), while also monitoring changes in the environment in which they live (temperature, water content, and carbon content).

The historic disturbance factors, primarily regularly occurring fire, drives the management practices on both areas. Considering that fire is responsible for the maintenance and structure of both herbaceous layer composition and overstory spatial variation, prescribed fire will be implemented on a 1–3 year interval to mimic historic disturbance (Kucera and Koelling, 1964). Due to natural and manmade firebreaks, fire may be implemented differently to coincide with the specific restoration needs between the two areas. While periodic low intensity grazing by large herbivores may be of historical significance, these areas are too small and still recov-

Right: NRCS Assistant State Soil Scientist Mark Abney dug this soil profile from the second analysis pit and series determination of "Keswick" by Ralph Tucker, also of NRCS. The prominent A horizon containing localized loess from later stage glaciation and the now flooded Salt River comprises the upper most 10 cm of the profile. At 10 cm, a prominent boundary separates the A and B horizons. The Sangamon paleosol, a buried soil that formed post-Illinoisan glaciation, is evident from depths of 10 cm to 117 cm from the surface. Localized loess from later stage glaciation (Wisconsan) is responsible for the burying of the paleosol. Early deposits of glacial till reside at 117 – 200 cm into the profile and consist mostly of heavy clays. The Sangamon paleosol was formed from different parent material than that of the glacial till it succeeded, therefore this profile is designated as having two B horizons.

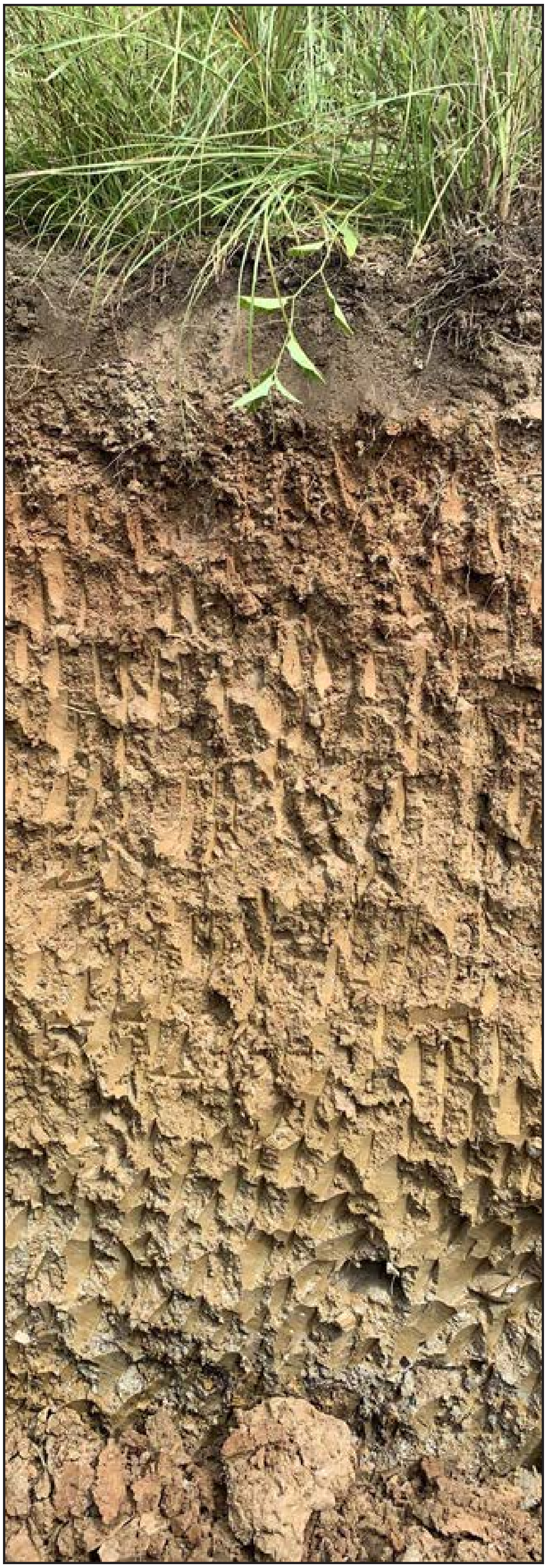

Photo by Sam Lord

ering from high intensity grazing from previous ownership. To reduce the negative impacts of deer browse on native vegetation in the study areas, park staff have conducted managed deer hunts frequently over the past decade and will continue to do so as needed. Finally, invasive species eradication efforts will continue with focus on those species determined to be most detrimental to the restoration of these landscapes. Sericea, Autumn Olive, and Smooth Brome remain the primary target invasive species for eradication and control.

To supplement soil data collection and to track recovery of the plant community, an annual floristic survey will take place to determine whether a positive correlation between soil health metrics and plant community composition exists. It is hoped that as we restore soil health through long-term management, that species richness and abundance will increase through time. I established three survey plots across the two areas. In 2019, we initiated the sampling event in twenty five permanent ¼ meter quadrats within a 400 square meter area to ascertain changes in plant species composition over time. Considering the previous land use history and the potential damage to the soil from a long history of fire suppression and overgrazing, I have located native prairie remnants in highway and railroad rights-of-way within a 45 mile radius of the park for collecting native prairie seed. To date, we have collected seeds of 56 species from these remnant areas, a testament to the history of destruction of native prairie in the area that only in spaces not converted to row crops or livestock operations can native prairie still exist. Dispersal of those remnant seed populations will be broadcast throughout both sites and tracked using GPS markers and stored in an online database to maintain records of introductions. Floristic quality and mean-C data is obtained for those species collected to supplement data for established species. The collection of seeds is determined by availability and determination of value to the restoration of the sites which includes Coefficient of Conservatism statistics and status as a native species with origins in the prairies and savannas of the local area. The restoration of these prairie and savanna remnants with the suite of matrix and conservative plant species accrued through time, management, and additional seeding may show that the concept that restoring soil health through the same natural disturbance factors can have a positive impact on the plant community.

Existing Data

Within the sampling plots, we documented over 130 species, while recognizing that outside of the plots and throughout the areas, general surveys indicate additional species. This number includes several non-native species that require removal, and that subsequently lower the mean-C value of the areas. Plot data indicates a striking degree of difference between the two areas. Native mean-C of the one site is 3.8, though including the non-native species brings that value down to 3.4 (Ladd and Thomas, 2015). The more degraded sites average 3.0 mean-C, though hopefully, through time, careful management, and invasive species control, these will gradually see an increase to a more stable system.

The initial soil data is still under collection and will be analyzed in coming months to establish a baseline data set. It is anticipated that this long-term research project will aid other land managers with prairie and savanna remnants by offering a management prescription to help restore soil health to promote a thriving ecosystem that was once represented across Northern Missouri.

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References

Nelson, Paul W. *The Terrestrial Natural Communities of Missouri.* Missouri Natural Areas Committee, 2010.

Kucera, C. L., and Melvin Koelling. "The Influence of Fire on Composition of Central Missouri Prairie." *The American Midland Naturalist,* vol. 72, no. 1, 1964.

Heneghan, L., et al. "Integrating Soil Ecological Knowledge into Restoration Management." *Restoration Ecology,* Vol. 16 No. 4, Dec. 2008.

Ladd, D. and J.R. Thomas. 2015. "Ecological checklist of the Missouri flora for Floristic Quality Assessment." *Phytoneuron* 2015-12: 1–274.

Calendar of Events

January 26–29, 2020
80th Midwest Fish and Wildlife Conference
Springfield, Illinois
www.midwestfw.org

February 4–6, 2020
Missouri Natural Resources Conference
Osage Beach, Missouri
www.mnrc.org

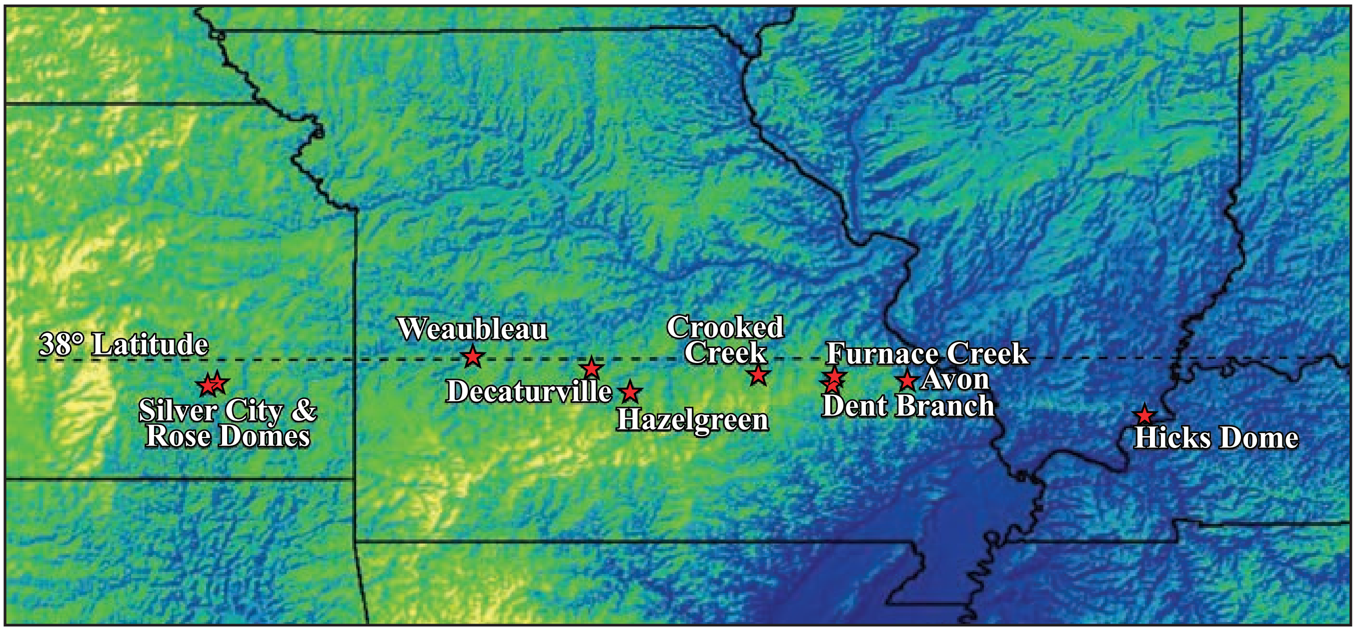
March 28, 2020
Grow Native! Plant Sale
Runge Nature Center
Jefferson City, Missouri
www.moprairie.org

May 5, 2020
Missouri Prairie Foundation: Evening Wilflower Walk at Linden's Prairie Natural Area
Mount Vernon, Missouri
www.moprairie.org

July 20–22, 2020
2020 North American Prairie Conference
Des Moines, Iowa
www.northamericanprairie.org

September 20–25, 2020
Biodiversity Summit 2020
Alexandria, Virginia
www.idigbio.org/content/biodiversity-summit-2020

October 13–16, 2020
2020 Natural Areas Conference
Reno, Nevada
www.naturalareas.org



Map by Marissa K. Spencer

Figure 1. Digital elevation map showing the location of the thirty-eighth parallel structures (Silver City and Rose Domes in Kansas, Weaubleau, Decaturville, Crooked Creek, Hazelgreen, Furnace Creek, Dent Branch and Avon in Missouri and Hicks Dome in Illinois).

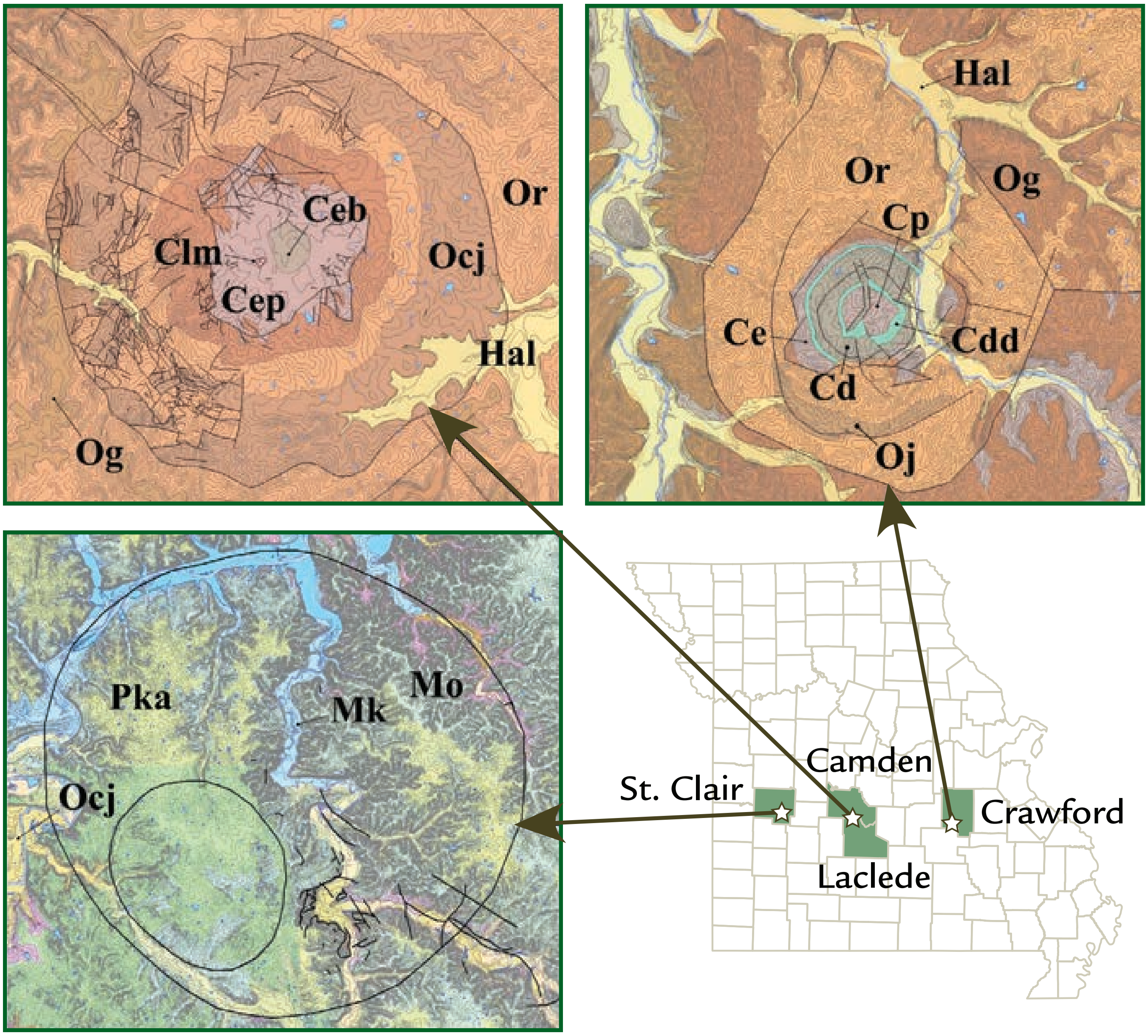
Enigmatic Structures along the 38th Parallel in Missouri

By Marissa K. Spencer and Dr. Francisca E. Oboh-Ikuenobe

The timing of and relationships between 10 geological structures situated in a line across the 38th Parallel in Kansas, Missouri and Illinois have long been a mystery to scientists (Figure 1). Clues from fossils and minerals, along with updated technology, may soon provide answers about these intriguing prehistoric structures. Three of the structures in Missouri are located near or in parts of natural areas: Crooked Creek (near Crooked Creek Conservation Area, Crawford County), Decaturville (near Ha Ha Tonka State Park, Camden County), and Weaubleau (Kings Prairie Access, St. Clair County).

The Crooked Creek, Decaturville and Weaubleau craters have been confirmed as meteorite impact structures based on characteristic fracture patterns in the rocks and minerals (e.g., shatter cones and planar deformation features in quartz) that are considered diagnostic of impact. Were these kilometer-sized structures the result of one body that broke up into pieces before hitting the Earth, similar to the Comet Shoemaker-Levy 9 that hit Jupiter in 1994? Or were these structures part of a meteor shower or series of impacts that occurred within a short time frame (geologically speaking), such as the widely separated Boltysh (central Ukraine) and Chicxulub (Mexico) craters? Research using fossils and radioisotopic dating of impact-affected rock and minerals in the three Missouri craters (Figure 2) may help to answer these questions and explain why they and the other structures occur in a linear fashion.

Impact structures are bowl-shaped depressions resulting from the collision of a meteorite with the Earth. The area of impact undergoes catastrophic change within seconds as the meteor traveling at cosmic velocity, or the velocity necessary for orbit (around 20 km/s), interacts with the Earth's surface. Rocks located at the surface at the time of impact are vaporized, melted, and the geological layers overturned, Map by Marissa K. Spencer



Quaternary		Pennsylvanian		Mississippian		Ordovician		Cambrian	
Hal	Holocene Alluvium	**Pka**	Krebs Subgroup, Atokan Stage	**Mo**	Osagean Series	**Ocj**	Cotter-Jefferson City	**Ce**	Eminence
				Mk	Kinderhookian Series	**Or**	Roubidoux	**Cep**	Eminence & Potosi
						Og	Gasconade	**Cp**	Potosi
						Oj	Joachim Dolomite	**Cdd**	Derby-Doe Run
								Cd	Davis
								Ceb	Bonneterre
								Clm	Lamotte Sandstone

Figure 2. Topographic map with geologic formation overlay of three of the 38th Parallel Structures (left to right: Weaubleau, Decaturville and Crooked Creek).

with bedrock from meters below sometimes displaced to the surface. The structural form of the resulting impact crater can be used to classify these geological structures as simple or complex craters. The Crooked Creek, Decaturville and Weaubleau craters can all be classified as complex craters. Complex craters are associated with larger impacts and may be characterized by raised rings with a bulls-eye appearance and areas of uplift in the center. Simple craters are generally deeper in depth, and smaller in diameter than complex structures with more regular bowl shapes. Both types of craters have complex stratigraphy and structures with numerous faults resulting from the chaotic energy and extreme force of impact. The structures also frequently have areas of spall near their rims (similar to other projectiles and their targets; i.e., bullets and armor). In these areas of spall, the overturned layers may result in repeated geologic formations.

In addition to the larger scale deformation caused by impact, simple and complex structures have distinctive products called impactites, which may include monomict breccia (one type of rock and possibly confined to one rock bedding plane) and polymict breccia (more than one type of rock). Breccias can be compared to chocolate chip cookies with the chips (angular fragments of rock) within the dough (a finer grained rock matrix cementing the rocks together). Other processes can form breccia, however, the types in these structures contain fragments from the different geological formations involved in the impact and occasionally other impactites like impact glass. Additional products of impact include tektites (glassy melt particles) and other impact-melt such as spherules (Figure 3). Spherules are formed during impact as the projectile hits and the rock is vaporized. As the vaporized particles fall back to the Earth, they cool and condense, forming sand grain sized particles of the rock they represent. These particles have a variety of shapes such as spheres and aerodynamic shapes like dumbbells, discs, teardrops, eggs, football, and diamond shapes. Collisions of particles also occur, forming agglutinated particles. The spherules sometimes have interesting textures. Some of the shapes are smooth and glassy; others have a rougher surface texture with schlieren, the flow texture produced from melt differentiation at very high temperatures. Additionally, spherules sometimes have hypervelocity impact pitting, or dents, formed from collisions with other particles. Spherules can be hollow, or have various inner structures (e.g., concentric rings, thin rims, crystalline, massive, and radial patterns). Spherules vary in color with composition. The colors noted in the 38th Parallel structures are yellow, orange, white, brown, red, black, gray, and variations of these.

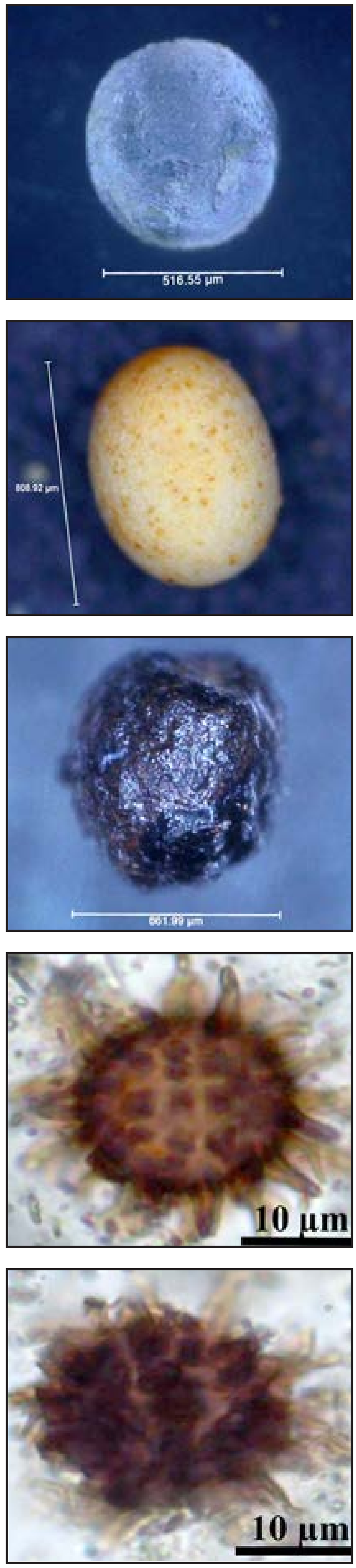
Other evidences of impact include: 1) fractures in rocks and minerals such as shattercones in rock, and microscopic fractures occurring at the atomic level of the mineral called planar deformation features (pdf's); 2) the formation of spinels in some structures are believed to be formed as part of the vapor cloud from impact; and 3), damage to organic-walled microfossils, also known as palynomorphs. Palynomorphs are fossil pollen, spores, fungi, dinoflagellate cysts, acritarchs, and other algae with very durable external walls that enhance their preservation in rocks over long expanses of geologic time. Some of the fossil pollen and spores in the Decaturville structure have uncharacteristic damage that is likely due to impact (Figure 3).

Changes related to meteorite impact are not only limited to the lithosphere. Other systems on the Earth such as the biosphere and atmosphere may also be affected. These effects vary with the size of the projectile and occur at local, regional and worldwide scales, with large impacts potentially affecting the climate. Meteorite impact is believed to be responsible for at least one of several mass extinction events occurring over geologic time. The Chicxulub crater located in the Gulf of Mexico has been dated to the same geologic time as the extinction of the dinosaurs and other marine and terrestrial life at the Cretaceous-Paleogene boundary 66 million years ago. Effects of the impact likely caused the total destruction of the ecosystem in the immediate vicinity. Regional and global effects of any impact event vary depending on the size of the impactor and conditions in the region of impact; impact in ocean or ice would likely have different results than in a terrestrial environment. A large impact could cause earthquakes, destructive winds (on the order of hundreds of km/hr) with a barrage of debris similar to a tornado or hurricane, landslides, mudslides, and wildfires from re-entry of hot ejecta both locally and globally. The resulting smoke and particulates from wildfires and dust from impact in the atmosphere would likely block sunlight, decreasing temperature and interrupting the photosynthesis of plants and, ultimately, the food chain, as well as resulting in increased rainfall. Meter-high tsunamis and flooding would potentially occur, as well as the release of heavy metals, greenhouse gases like carbon dioxide, water vapor, methane, and sulfur, and other toxic gases that would poison the wildlife and cause an initial global cooling followed by a global warming.

While the timing of the Missouri impacts is not yet known, the 38th Parallel structures are believed to have formed millions of years ago due to the range of time represented by the geological rock formations involved in the structures, which range from Precambrian to Paleozoic ages. The Weaubleau structure includes geological formations from the Proterozoic eon to the Mid-Mississippian period. The geological formations mapped within the Crooked Creek structure range in time from the Proterozoic eon to the Ordovician period. The Decaturville structure includes rocks with ages ranging in time from the Proterozoic eon to the Silurian period.

A potential relationship between these structures is not a novel idea. Evidences for their alignment and their relationships may be observed both extra-terrestrially and terrestrially, with extraterrestrial chains such as the aforementioned Shoemaker-Levy 9 occurring even in modern times. Impact crater chains have also been noted on two of the four largest moons of Jupiter (Ganymede and Callisto), as well the Davy and Abulfeda chains on Earth's moon. Linear arrangements of craters have been observed elsewhere on Earth, including the three craters making up the Aorounga chain located in the Republic of Chad in north-central Africa.

To solve this mystery, micas obtained from the impacted bedrock from the center of the Decaturville and Weaubleau craters and impact spherules from the Crooked Creek structure have been analyzed for the element potassium using a Helios 600 Scanning Electron Microscope (SEM) equipped



Micrographs by Marissa K. Spencer

Figure 3. Products of impact (top to bottom): glassy spherule from the Weaubleau structure with hypervelocity impact pitting; egg-shaped spherule of the Decaturville structure; black sphere from the Crooked Creek crater; and undamaged and damaged acritarch (organic walled microfossil) for comparison of palynomorph alteration.

with an Oxford SDD 50 mm2 electron dispersive spectroscopy (EDS) detector. Interaction between the electrons provided by the scanning electron microscope beam and the surface of the sample produces x-rays during analysis. These x-rays correspond to certain elements and the electron shells that generate them and are compared with a known library of spectral values within the EDS software (AZtec). In this study, electron dispersive spectroscopy was used to detect the presence of potassium to determine its suitability for 40Ar/39Ar radioisotopic dating. Since potassium (K) decays to argon (Ar) during the radioactive decay process, an appreciable amount would likely indicate that enough Ar is present for analysis. The radioactive decay of 40K is a branching process with a portion of the isotope decaying to 40Ar and the other portion to 40Ca (calcium).

Argon has three naturally occurring isotopes (36Ar, 38Ar and 40Ar). 36Ar comes from the atmosphere; 39Ar is derived from the decay of K in samples induced by irradiation; and 40Ar may be radiogenic, atmospheric or excess Ar that may be trapped in inclusions or within the crystal lattice of minerals.

40Ar/39Ar dating utilizes mass spectrometry to compare naturally occurring isotopes with reactor isotopes. The calculated age is based on the ratio of argon isotopes (36Ar /40Ar and 39Ar /40Ar). Since the ratio of 40K to 39K is constant in nature and the half-life of the 40Ar and 39Ar isotopes are known, an age can be calculated after carefully measuring all the argon masses and corrections made for other types of argon isotopes such as radiogenic, atmospheric and excess Ar. The date produced by the Ar/Ar technique reflects the time in which the radiogenic argon (from the decay of 40K) became trapped in the mineral and is related to temperature; this date may correspond to the time of formation of the mineral, or reflect the cooling period when the mineral was last altered.

Samples from each structure were sent off to a lab for analyses utilizing the step-wise heating method of 40Ar/39Ar measured by a mass spectrometer. This step-wise heating method of 40Ar/39Ar may be more telling than previous techniques used since it provides a thermal history for the minerals that may enable differentiation between the timing of the impact and older tectonic events in the mid-continent. After irradiation of the samples with a standard of a known age, the samples are subjected to incremental temperature increases with the measurement of gas released at each step. The stages of heating decrease in age with the youngest represented at the highest temperature step. Since any excess argon that may be trapped in inclusions or within the crystal lattice of the mineral is released during the lower stages of heating, the 39Ar can be distinguished from the radiogenic, atmospheric and excess Ar to target a more representative and accurate age. The 36Ar/40Ar and 39Ar/40Ar data can be used to create an isochron diagram and be used to calculate an age from a consistent area of the age spectrum.

There has been much discussion about the timing of the 38th Parallel structures. The questions raised include the potential occurrence of younger unaltered rocks within and in proximity to the structures. Other methods of dating these structures have met with limited success due to their complex stratigraphy and other geologic events that probably prevent a clearer picture. Although radioisotopic dating has been used on at least one of these structures previously, advances in dating methods in the last 20 years, specifically the step-wise heating method, will refine the accuracy of the dates. This study will constrain the age for the three-targeted impacts based on the approximate time that the micas and spherules were altered. The results will potentially provide important information about mineral resources, Earth and other planetary movements, and the effects of impacts on the biosphere, lithosphere and atmosphere.

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After Decades, the Namesake of Tower Rock Natural Area Actually Becomes a Part of the Natural Area

by Mike Leahy

In 2019, the Missouri Natural Areas Committee added the eponymous "Tower Rock" of Tower Rock Natural Area to the Missouri Natural Areas System. Tower Rock is an iconic geologic feature of Missouri and the Middle Mississippi River. It is an excellent example of a bedrock island formed from eroded Devonian-aged Bailey formation limestone and is one of the largest natural exposures of this rare formation in Missouri. Tower Rock is the largest remaining bedrock island in Missouri. In order to improve river navigation in the 1800s, the other bedrock islands along the Mississippi River in Missouri were destroyed.

Tower Rock formed during preferential erosion of the surrounding bedrock as the current Mississippi River channel developed, likely during the late Pleistocene. It is likely tied to the location of the Wittenberg fault zone. Continued uplift on the Ozark Dome during the late Pleistocene, coupled with bedrock impacted by the faulting probably allowed the river to cut the channel that it did, and eventually leave a stranded bedrock remnant that forms Tower Rock today. The rock itself is about 100 yards in maximum dimension at its base and around 60 feet high.

French missionary Father Jacques Marquette, along with Louis Jolliet, passed the rock in 1673 and provides the first written account of its existence. In 1871, President Grant authorized the U.S. Army Corps of Engineers to spare the destruction of Tower Rock, at which point it became part of U.S. property and eventually managed under the ownership of the U.S. Bureau of Land Management (BLM). Fast forward to 1971 when the Missouri Department of Conservation (MDC) acquired the 28 acres of land adjacent to Tower Rock in Perry County. MDC originally designated the land as Tower Rock Natural Area in 1972, and was subsequently grandfathered in to the inter-agency natural areas system in 1977. Ironically though, MDC did not actually own Tower Rock itself!

In 1978, upon MDC's hiring of Rick Thom as the agency's first natural areas coordinator, Thom visited Tower Rock. When he returned to the Jefferson City office and reviewed the file on this site, he eventually discovered that the ownership of Tower Rock was unclear. After a very circuitous route, involving a chance meeting with someone who happened to work for the BLM at a natural areas conference, in 1996 Thom secured the transfer of Tower Rock from the BLM to MDC. The official addition of Tower Rock's signature geologic feature to Tower Rock Natural Area waited for an additional 22 years. Sometimes the wheels of government move slowly. Today, visitors can enjoy Tower Rock from a viewing platform on land or by boat.

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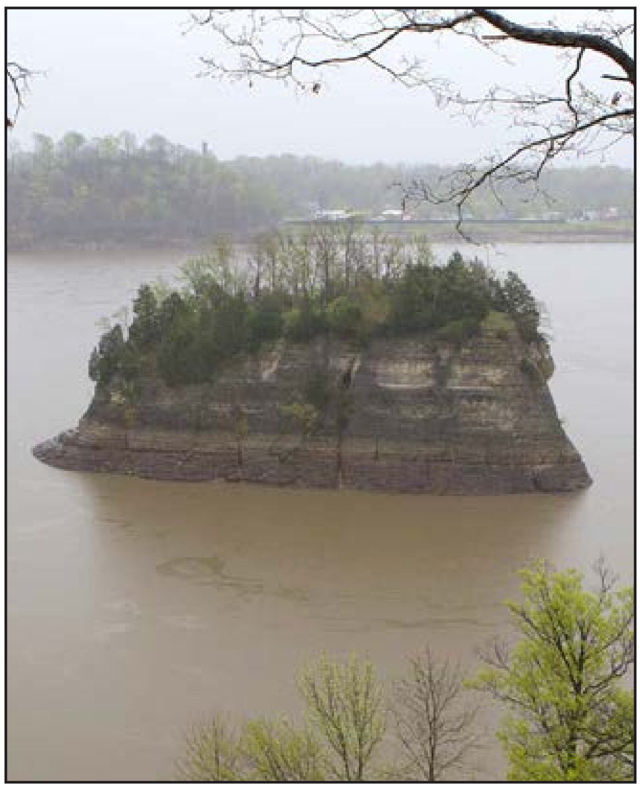

Photo by Jim Rathert

Tower Rock Natural Area in early spring.

Photo by Bruce Schuette, Missouri Prairie Foundation

Pale purple coneflower *(Echinacea pallida)* is abundant at Linden Prairie NA, along with Royal catchfly *(Silene regia)* and a panoply of other prairie obligates.

Linden's Prairie Natural Area Designation

by Mike Leahy

The Missouri Natural Areas Committee designated Linden's Prairie Natural Area in 2019. This prairie natural area conserves over 150 acres of high-quality dry-mesic chert prairie in Lawrence County.

Linden's Prairie was acquired by the Missouri Prairie Foundation (MPF) in 2014 and named for Ms. Linden Trial, an MPF member and dragonfly and damselfly researcher for the Missouri Department of Conservation. Funds from a generous bequest from Linden Trial and a grant from the Robert J. Trulaske Jr. Family Foundation made the purchase possible. Prior to MPF acquisition, the prairie was owned, protected, and managed for many generations by the Cox Family. Over 190 native plant species are documented on the property thus far, of which 41 species have a C value (coefficient of plant species conservatism, an indication of remnant dependence) ≥ 7.

The prairie supports a robust population of royal catchfly *(Silene regia)* as well as regal fritillaries *(Speyeria idalia)* and prairie mole crickets *(Gryllotalpa major)*. This prairie is a remnant of a larger tallgrass prairie system that stretched across the uplands of the Spring River watershed in the Springfield Plain ecological section of the Ozarks. Prior to MPF's ownership of the site, the prairie had been managed primarily for prairie hay. This prairie, like all of MPF's prairies, are open for public visitation (see moprairie.org).

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