

MISSOURI

resources

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GEOLOGY

director's comment



Missouri observes Earthquake Awareness month each February to promote preparedness and planning. Last year we experienced a magnitude 3.9 earthquake near Sullivan and a magnitude 3.6 earthquake near Poplar Bluff. These seismic events were felt by many Missourians, bringing the need to be prepared in sharp focus.

Until tragedy strikes close to home, we often forget that many Missourians are living and working in the New Madrid Seismic Zone, one of the most active seismic zones in the country. It was 200 years ago, when New Madrid and several areas in south-

east Missouri and neighboring states were shaken by one of the largest earthquakes ever to hit the continental United States. Three to five earthquakes, estimated at a magnitude of 7.0 or greater, altered the course of the Mississippi River, turned valuable farmland into fields of sand and destroyed most or all of the buildings in New Madrid and Little Prairie, now known as Caruthersville.

Geological studies indicate the potential for another damaging earthquake along the New Madrid Seismic Zone will likely occur – knowing when, however, is not predictable. Preparing and planning for such an event is essential. In addition to raising public awareness, the department's Division of Geology and Land Survey is actively conducting hazards mapping projects to better understand impacts from seismic events such as ground collapse, soil liquefaction, landslide and flooding.

The division, widely known as the Missouri Geological Survey, has been the primary resource for Missouri's

geologic information, interpretation and support for nearly 160 years. The division's geologists collect, interpret and distribute scientific information used by industry, developers, educators, federal and state governments, and local and regional planners, to name a few.

Geologic understanding is essential for protecting natural resources, cleaning up environmentally impacted sites, avoiding natural hazards, locating waste disposal facilities, making wise land use decisions, exploring for and developing mineral, fuel, and water resources, and developing science-based decisions regarding next-generation challenges.

This issue of Missouri Resources features many of the services the Missouri Geological Survey provides to all Missourians for professional, technical and educational purposes. To learn more about Missouri's geological history, visit the Ed Clark Museum of Missouri Geology in Rolla or visit the Web at: dnr.mo.gov/geology.

Sara Parker Pauley
Missouri Department of Natural Resources

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Mission Statement

The mission of the Missouri Department of Natural Resources is to protect, preserve and enhance Missouri's natural, cultural and energy resources.

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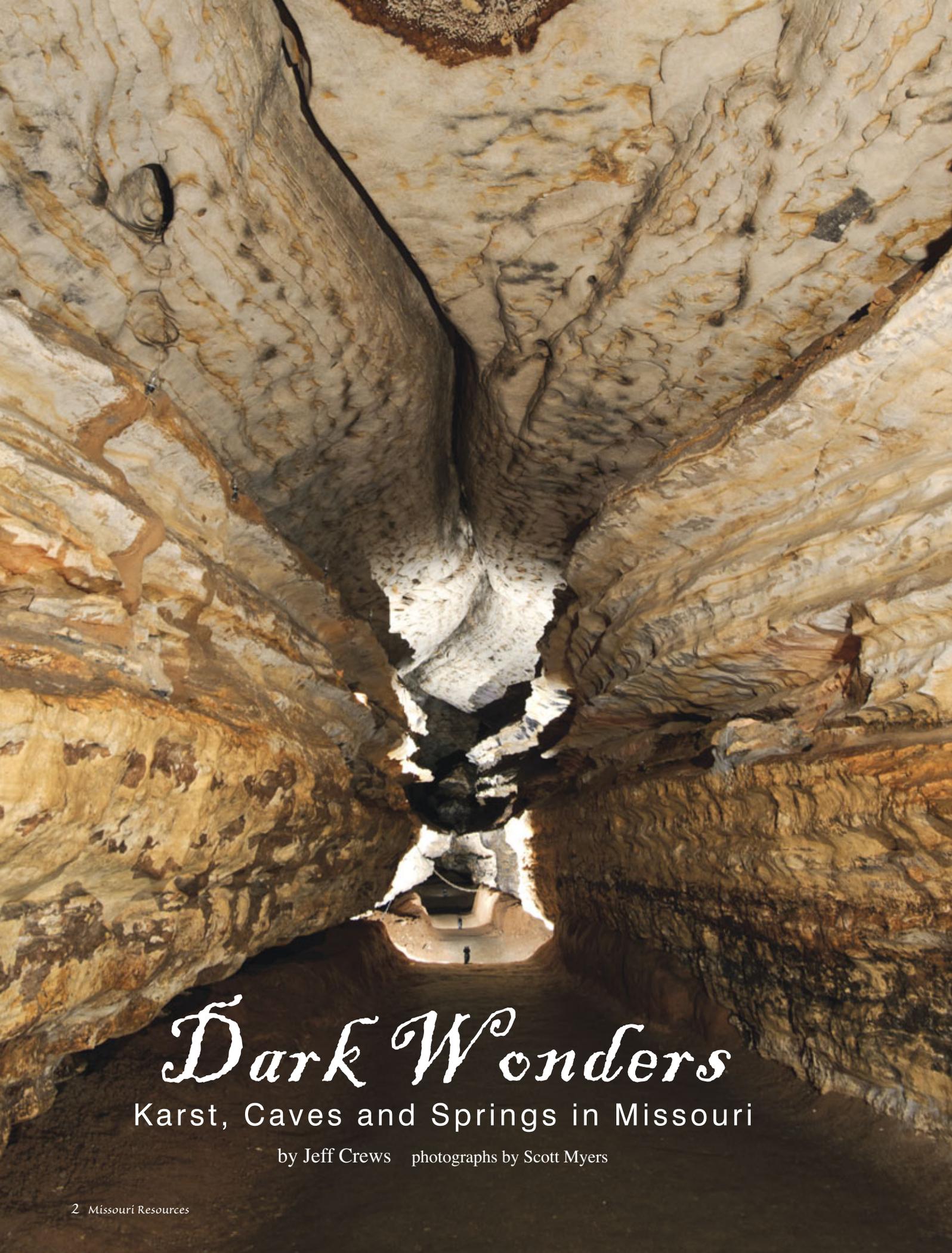
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Above: Mark Twain Cave, near Hannibal, is famous for its history and is an excellent example of a maze cave.

Front Cover: Elephant Rocks State Park, in Graniteville, offers an opportunity to explore one of Missouri's geologic wonders.

Back Cover: Multicolored lichens adorn many of the boulders at Johnson's Shut-Ins State Park.

DNR photos by Scott Myers.



Dark Wonders

Karst, Caves and Springs in Missouri

by Jeff Crews photographs by Scott Myers

“By-and-by the procession went filing down the steep descent of the main avenue, the flickering rank of lights dimly revealing the lofty walls of rock almost to their point of junction sixty feet overhead. This main avenue was not more than eight or ten feet wide. Every few steps other lofty and still narrower crevices branched from it on either hand — for McDougal’s Cave was but a vast labyrinth of crooked aisles that ran into each other and out again and led nowhere. It was said that one might wander days and nights together through its intricate tangle of rifts and chasms, and never find the end of the cave; and that he might go down, and down, and still down, into the earth, and it was just the same — labyrinth under labyrinth, and no end to any of them. No man “knew” the cave.” - Mark Twain, *The Adventures of Tom Sawyer*

Twain’s description of McDougal’s Cave near Hannibal, known today as Mark Twain Cave, may seem fanciful. In reality, the artful storyteller’s description of the maze of cave passages beneath and around Hannibal is an accurate description of this unique type of karst feature: a type of cave found nowhere else in the state and in only a few places in the rest of the country.

Karst is a term first used to describe the southwest region of Slovenia along the Gulf of Trieste in the Adriatic Sea. It is a landscape characterized by the presence of caves, springs, sinkholes and losing streams. Losing streams “lose” water into the groundwater system as they flow downstream. Missouri is rich in dolomite and limestone and since these rocks can be dissolved by water, springs and caves are prominent in the state. They also provide corridors for the movement of water that form the headwaters of many of our state’s rivers and streams.

There are five areas where karst is normally found in Missouri. They are the Central, Southeast, Springfield, Salem Plateau and Northeast karst regions.

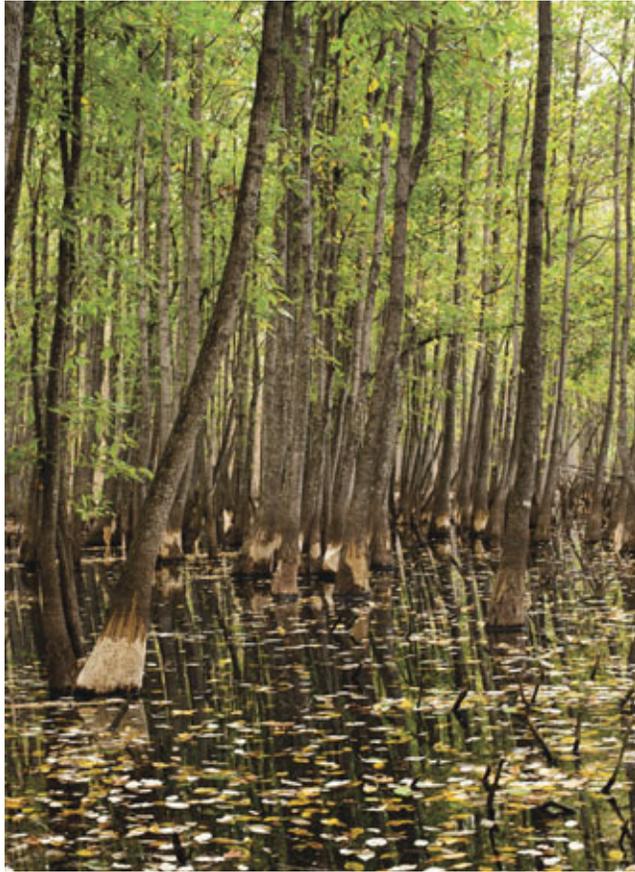
The Central Missouri Karst Region includes areas on the northern flank of the Ozark Plateau and is adjacent to the Missouri River in Boone, Moniteau and Cooper counties. Devil’s Icebox cave, located in Rock Bridge Memorial State Park near Columbia, is located in this region. Boone County boasts more than 418 documented sinkholes, most of them located near

Rocheport or Pierpont, which is just south of Rock Bridge.

The Southeast Missouri Karst Region includes areas on the eastern side of the Ozark Plateau and is adjacent to the Mississippi River. It stretches from parts of Cape Girardeau County, north to St. Louis. This region contains more than 675 known caves and more than 2,700 sinkholes. Crevice Cave, the longest cave in Missouri, with more than 29 miles of mapped passageways, is located in Perry



(Above) At a depth of more than 300 feet, Blue Spring, part of the Ozark National Scenic Riverways, is the sixth largest spring in Missouri. Blue Spring discharges approximately 90 million gallons of water into the Current River each day. (Opposite page) Joint control maze caves, such as Mark Twain Cave, exhibit tall straight canyons among their many features.



(Above) Tupelo Gum Pond is a silted sinkhole that regularly holds water. The southern Missouri location and protected landscape create a micro-climate for Tupelo Gum trees to thrive outside their normal range.

(Below) Round Spring, within the Ozark National Scenic Riverways, stretches to a depth of approximately 55 feet. The spring was formed by a large sinkhole collapse above its conduit and near its outlet. On an average day, 26 million gallons of water flow from Round Spring.



County. Ball Mill Resurgence is also located in the region. Here, water flowing through the Berome Moore and Tom Moore Cave systems springs back to the surface during periods of heavy rain.

The Springfield Plateau Karst Region includes the western flank of the Ozark Plateau and stretches from Greene County south into Arkansas and west into Oklahoma. Marvel Cave, the deepest cave in the state, is located on the edge of the region near Branson. Also of note is Rader Spring, the major discharge point for water lost to the subsurface in and around most of southwest Springfield. Rader Spring is the largest spring in Greene County and third largest in the region.

The Salem Plateau Karst Region occupies the heart of the Ozark Plateau. This karst system showcases the large caves and springs familiar to most Missourians. World class karst features in this region are unique to the entire United States. Onondaga Cave, in Onondaga Cave State Park, near Leasburg in Crawford County, and Big Spring, near Van Buren, part of the Ozark National Scenic Riverways in Carter County, are two spectacular examples. The exceptional quality and abundance of helictites, cave pearls, shields and lily pads make Onondaga Cave one of the most beautifully decorated caves in the state. Big Spring is the biggest spring in Missouri in terms of average discharge, with a daily outflow of approximately 276 million gallons.

The Northeast Missouri Karst Region includes areas north of and adjacent to the Missouri River. It stretches from St. Charles County north to Clark County. In this region lie Mark Twain and Cameron caves, near Hannibal.

Northeast Missouri is usually mentioned in passing as a place where karst features are sometimes found, but rarely discussed. When scientists talk about Missouri karst and its importance, the focus is on the dramatic aspects that give the landscape beauty and inspire intrigue. We generally think of large springs and caves in the Salem Plateau, or the dramatic impact to manmade structures by karst processes in urban regions such as Springfield, Columbia or St. Louis. Another example is Perry County in southeast Missouri with its extensive cave

and sinkhole development that has more than 2,700 sinkholes in a 240-square mile area.

Why is northeast Missouri karst normally left out of the discussion? There are a couple of reasons. The first is aesthetics. Spectacular caves and large springs that feed clear-running rivers and streams don't exist on a large scale in this region. The second is location. Other karst regions are either part of, or adjacent to, three of the four most populated areas in the state. Karst features in these areas are often part of daily life for Missourians. They provide sources of fresh drinking water, recreation and natural scenery.

What do we actually know about karst in the northeast? There are nearly 800 documented sinkholes in this 13-county area. One sinkhole, located in Audrain County, is a recently reactivated paleokarst (pre-existing karst) feature. The sinkhole existed before the last ice age, was subsequently filled with glacial material and is now hydrologically active.

There are 240 known springs in the northeast but only seven have been measured for discharge. The largest has an average flow of 5,341 gallons per minute. This is small, relative to Big Spring's average discharge of 192,099 gallons per minute, but still above the average for the state.

Caves in Missouri can be divided into two patterns: maze and branch work. Whichever pattern a cave becomes mainly depends upon the movement of water through the subsurface. Most caves in Missouri are branch work caves that form when water moves through a single conduit and branches into tributaries, much like a surface stream. This sometimes creates natural bridges or larger abandoned upper levels.

Maze caves like Mark Twain and Cameron are the most unique karst features in the state. They were created when water was sandwiched between layers of shale and was only able to move along fractures in the limestone, dissolving out a network of passages in a regular pattern. These two caves differ from others because they are almost devoid of stalactites and stalagmites and contain 260 narrow, winding passages.



Only four of the 226 known caves in the northeast region have been explored for more than a mile in length. Most of the caves lie on the flanks of the Lincoln Fold that parallels the Mississippi River. The bedrock dips toward the river on the east side of this geologic structure and away from the river on the west. Several streams have eroded through the structure exposing older rocks that tend to form karst features in the center, while younger karst-forming rocks are still found on the flanks.

Here, karst is formed in different rock units in relatively close proximity to each other. Being close to the Mississippi River, there are several short, steep streams that flow from the relatively high Lincoln Hill to the low elevation of the Mississippi. Similarly, karst flow paths here usually have a higher gradient at the upstream end. Steep erosion within the bedrock creates vertical caves or caves with tall, narrow canyons.

In Mark Twain's day, McDougal's Cave remained largely unexplored. Today, both McDougal and Cameron caves have been completely explored and mapped. Guided tours of many of Missouri's caves are available for those wanting to experience the same wonders written about by Twain. Also in the hills and hollers close by are other caves just as complex with parts still unexplored by any man.

"By-and-by somebody shouted, 'Who's ready for the cave?'" - Mark Twain ☀

Jeff Crews is a geologist with DNR's Division of Geology and Land Survey.

This karst window on U.S. Forest Service land in Wayne County is known as The Gulf. It connects to a large underground lake that is at least 200 feet deep.



EXTRATERRESTRIAL VISITORS

by Division of Geology and Land Survey staff

Our solar system's dominant bodies we know as the sun, the planets and the moons, have their own characteristic positions and their near-circular orbital paths do not cross each other. In the wider reaches of space separating the inner planets from the outer planets, exists a planet-less gap between the orbital paths of Mars and Jupiter. Astronomers believe at least two planet-like bodies once orbited the sun. Their orbits were constantly altered by the strong gravitational pull of the giant Jupiter. Eventually, these planet-like bodies violently collided with one another and were blown apart. The resulting debris makes up what we know as the asteroid belt.

Since that time, the debris pieces associated with the asteroid belt have interacted with one another. Collisions, bumps and gravitational pulling between the pieces regularly cause pieces as small as a sand grain to those several miles in diameter to drop out of their orbits and fall toward the sun. Those that do not go directly into the sun, orbit it in highly elliptical paths that cross those of the inner planets. It is just a matter of time before one comes into contact with one of the inner planets or their moons. The collision between asteroid and planet happens at

great speed, from 20,000 to 45,000 miles per hour – seven to 16 times faster than the fastest speeding bullet.

A space rock smaller than approximately one yard across will likely burn up completely during passage through Earth's atmosphere. This is what we see as meteors (shooting stars) and fireballs. Larger space rocks up to approximately 10 yards across have a good chance of landing intact or in pieces on the Earth as meteorites. About 40,000 meteorites have been found on Earth. As many as 1,000 meteorites land on the planet every year. They are extremely difficult to find. Most will never be discovered, having landed in the oceans or in vegetated terrains.

A space rock larger than 10 yards across will slow very little as it shoots through the atmosphere in a blazing sun-bright fireball. It then impacts the Earth's surface creating a tremendous explosion that totally vaporizes the space rock and forms a crater. The smaller space rocks produce simple bowl-shaped craters, such as the one-mile diameter crater in Arizona known as Meteor Crater. Bigger space rocks produce larger and more complex craters. These craters can be more than 10 miles in diameter and are characterized by a circular, central uplifted area that

(Top) Meteors can be composed of iron, rock, or a combination of both. Patrick Mulvany photo.



Patrick Mulvany photo



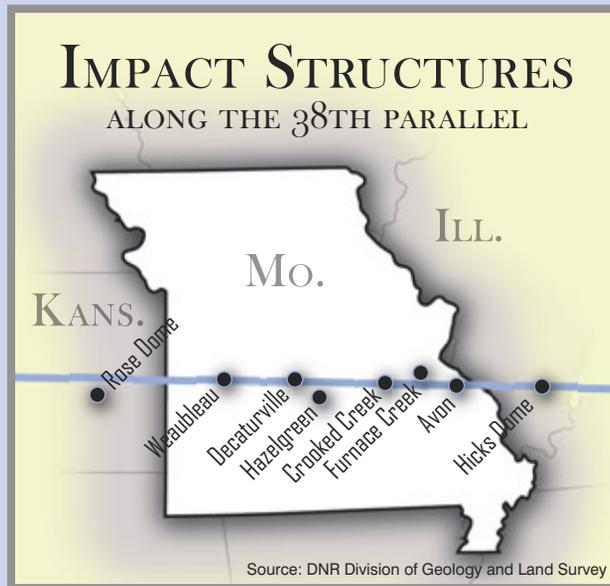
Patrick Mulvany photo

is surrounded by a ring-shaped down-dropped area. The Chicxulub circular geologic feature in the Gulf of Mexico, just north of the Yucatan, is an example of a huge complex crater.

The geographic area that is now Missouri was hit at least twice and probably three times by crater-forming space rocks. The two confirmed meteorite impacts are the Crooked Creek structure (Crawford County) and the Decaturville structure (Camden County), both of which are several miles in diameter. The presence of shatter cones and shocked quartz in the rocks of these two structures is proof they were caused by meteorite impact. Shatter cones are conical fractures in the bedrock beneath meteorite impact craters or underground nuclear explosions. Shocked quartz grains are produced by the force of an impact on sandstone rocks. The crystal structure is different than standard quartz and is visible when greatly magnified.

Geologic maps of these structures reveal the characteristic central uplift portion that is encircled by a ring graben – a down-dropped block of the earth’s crust. The Weaubleau structure in Hickory County is likely an impact feature, as well.

Jerry Prewett, Geological Survey Program director, Missouri Department of Natural Resources, said, “The Crooked Creek and Decaturville impact structures are in



DNR photo by Scott Myers

line with at least six other localized structural disturbances that occur from southern Illinois and Missouri and extend just into eastern Kansas.”

From east to west, the disturbances are Hicks Dome, Avon, Furnace Creek, Crooked Creek, Hazelgreen, Decaturville, Weaubleau and Rose Dome. This line of structures defines what has been called the “38th parallel lineament” because it closely approximates the 38th parallel line of geographic latitude.

Remember that searching for meteorites and exploring impact craters are like other outdoor adventures: it is important to respect private and public property rights.

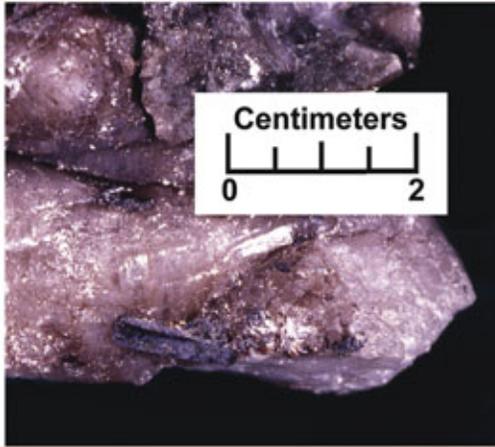
It is estimated that meteorite impact events such as Crooked Creek and Decaturville occur somewhere on Earth about every 90,000 years. The big space rocks are out there, and it is likely one of them and Earth will eventually be at the same place at the same time. 🌞

This story was a collaborative effort of staff from the department’s Division of Geology and Land Survey.

(Clockwise from upper left) This stony-iron meteorite found in Kansas has a rough, stony outer surface, while the cut surface reveals the beautiful, metallic pattern within. A locator map pinpoints impact structures in Missouri. The folding and fracturing of strata caused by a meteorite impact can be seen in this rock cutout that is part of the Decaturville Impact Structure. The rearrangement of rock layers occurs when meteorites impact Earth. Shatter cones in rock feature radiating fracture lines. They are found in only two places on Earth – at nuclear test sites and meteorite impact structures. These were found in the Crooked Creek impact structure in Crawford County.

MORE THAN IRON ON PEA RIDGE

by Cheryl Seeger



DNR photo by Cheryl Seeger



DNR photo by Scott Myers



(Above) A crystal of xenotime, a mineral that contains heavy rare earth elements, such as yttrium, and is important for green technologies and defense applications, such as laser systems and weapons.

(Above, right) Rare earth elements are used in many devices or products that people use every day, such as: cell phones, mp3 players, computer memory, DVDs, rechargeable batteries, car catalytic converters, magnets and fluorescent lighting, to name just a few.

Unless you work in the minerals industry, a mineral-related business or invest in mineral commodities, you may find it surprising that Missouri has historically been a major, international player in the production of minerals. For example, Missouri is ninth in the nation overall in mineral production – first in production of lead, fireclay and lime, fourth in the production of zinc, and eighth in silver.

The unique geologic setting in southeast Missouri is home to a former mine that operated for more than three decades and may soon reopen. It has the potential to help secure materials for emerging green technologies such as clean energy and the purification of water.

Located in Washington County, the Pea Ridge iron mine contains substantial reserves of high purity, high quality iron ores. Between 1964 and 2001, Pea Ridge Mine produced its primary product – magnetite. With a growing demand for the product, its extraction may soon be thriving again.

Magnetite has for many years been used for steel production, high power magnets and iron pigments. However, the high purity, high quality iron ore deposits at Pea

Ridge also contain chemical quality iron ores. These important ores have numerous environmental and “green” uses that include chemically and environmentally clean ways to desulfurize coal, purify water, and provide catalysts for cleaner air emissions. Currently, all iron ore for these uses is imported from Europe.

High-quality ores are not the only commodity at Pea Ridge. World-renowned rare earth mineral experts interested in Missouri iron deposits have visited with geologists at the Department of Natural Resources’ Division of Geology and Land Survey about the mine’s rare earth elements. Geologists with the department have studied Pea Ridge mine and other deposits in detail, and provide scientifically sound information related to mineralization, mining, permitting and environmental management at potential sites. The department provides geologic interpretations and data to interested companies and government agencies and officials. Rock cores collected during exploratory drilling in this area are stored at the department’s McCracken Core Library in Rolla.

It has been proven that Pea Ridge contains significant reserves of these elements.

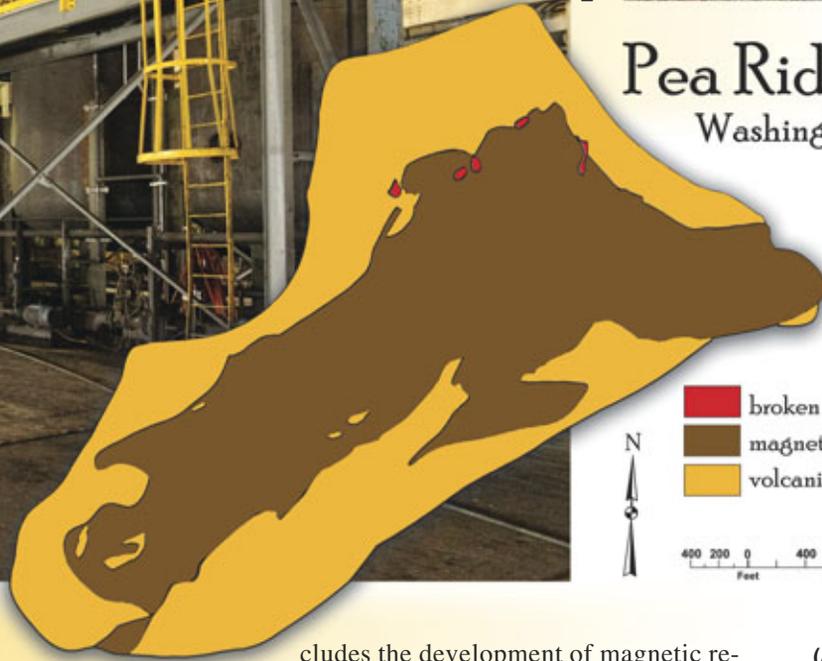


DNR photo by Scott Myers



DNR photo by Scott Myers

Pea Ridge Mine, Washington County



DNR map by Mark Gordon/Cheryl Seeger

- broken volcanic rock and magnetite
- magnetite and hematite iron ores
- volcanic rocks

The mine has the potential to produce at least 12 of the 15 rare earth elements. These include some of the rarest of the group, which have everyday uses, as well as those uses important to national defense. Samarium, for example, is needed for your headphones as well as for stealth technology and precision-guided weapons. Erbium is used to color glass pink and is required for fiber-optic data transmission. Neodymium is needed for welder's goggles, telescopes, laser range finders and guidance systems. And large wind turbines need more than two tons of rare earth elements to work, including neodymium, praseodymium, dysprosium, and terbium – all found at Pea Ridge.

Rare earths are part of our daily lives and help us keep our environment cleaner. They are essential in most of our electronic devices including cell phones, laptops, mp3 players, computer chips, fiber optics, catalytic converters, fluorescent lamps and lasers. Rare earth elements have important and diverse properties that include magnetic, optical, chemical, electrical, catalytic, metallurgical and nuclear. Research in-

cludes the development of magnetic refrigeration that will reduce energy consumption and CO₂ emissions.

Thorium, a potential energy source that could replace uranium used in nuclear power plants, is present at Pea Ridge Mine. While development work is still required, thorium reactors have the potential to provide electricity with less nuclear waste than current reactors that use uranium.

According to U.S. Geological Survey statistics, the United States is 100 percent reliant on rare earth imports, with 92 percent of those coming from a single country – China. Additionally, rare earths have an annual global impact in the billions of dollars. A quick Internet search will return a substantial number of articles discussing the numerous uses of rare earth elements, their lack of production in the U.S. and the devastating consequences to most technologies in the country if imports are restricted.

With the help of Pea Ridge Mine, the pricy importation of rare earth elements may someday drop substantially. ☀

(Above, upper left) An interior view of the processing operation at Wings Enterprises' Pea Ridge Iron Ore Mine, Sullivan, Mo. **(Above, map)** Vertical, cylindrical bodies of broken volcanic rock and magnetite (depicted in red) contain more than 591 thousand tons of rare earth elements at Pea Ridge Mine. Areas in brown represent more than 148 million tons of magnetite and hematite iron ores. Volcanic rocks are shown in gold. **(Above, right)** A massive magnetite ore found underground at the Pea Ridge Mine. Considered to be of high chemical quality, the ore has many clean uses.

Cheryl Seeger is a geologist with DNR's Division of Geology and Land Survey.



DNR photo by Hylan Beydler

DNR photo by Scott Myers

200 Years Later

THE NEW MADRID SEISMIC ZONE

by Hylan Beydler

Recent earthquakes in Virginia and Japan remind us the Earth is seismically active, and Missouri certainly has seen its share of shaking. Geologic studies tell us moderate earthquakes occur in the state about every 100 years and large earthquakes can be expected to occur about every 500 years.

Two hundred years ago, Missourians experienced powerful earthquakes in the southeastern region of the state. Although not recorded by modern instruments, the sequence of quakes that shook the area oc-

curred near the southeast Missouri town of New Madrid.

Three of the largest earthquakes to strike the continental United States, estimated at magnitude 7.0 or greater, occurred along the New Madrid Seismic Zone between Dec. 16, 1811 and Feb. 7, 1812. The zone is located in southeastern Missouri, northeastern Arkansas, western Tennessee, western Kentucky and southern Illinois. Hundreds of aftershocks followed for more than two years. Many were indicated by crude seismograph instruments and felt by people who record-

ed their experiences in personal journals. Thirty-one years old when the earthquakes shook the region, Eliza Bryan is one of the most important eyewitnesses to the New Madrid earthquakes.

Bryan related her experiences in 1816 to Rev. Lorenzo Dow, who published her account in his popular biographical book, *History of Cosmopolite*.

“On the 16th of December, 1811, about two o’clock, A.M., we were visited by a violent shock of an earthquake, accompanied by a very awful noise resembling loud but distant thunder, but more hoarse and vibrating, which was followed in a few minutes by the complete saturation of the atmosphere, with sulphurous [sic] vapor, causing total darkness. The screams of the affrighted inhabitants running to and fro, not knowing where to go or what to do – the cries of the fowls and beasts of every species – the cracking of trees falling, and the roaring of the Mississippi – the current of which was retrograde [sic] for a few minutes, owing as is supposed to an interruption in its bed – formed a scene truly horrible.”

New lakes, islands and streams appeared, and much of the topography in the southeastern corner of Missouri changed completely. Tennessee’s 15,000-acre Reelfoot Lake was created as a result of the shaking. Some reports stated that the Mississippi River flowed backward, which most likely can be attributed to huge swells of surging water, causing water to back up along the course of the river. Population was sparse, and due to a lack of census records and other reliable counts, it is undetermined whether people perished as a result of the quakes.

The 1811-1812 New Madrid earthquakes destroyed most or all of the simple buildings in New Madrid and Little Prairie – now Caruthersville. Buildings in St. Louis were slightly damaged. The damage mostly consisted of broken or collapsed stone chimneys and broken stone buildings – a type of unreinforced masonry construction that is especially susceptible to earthquake damage. Approximately 3.5 million

acres were also damaged by landslides, fissures, sand blows, lateral spreads, subsidence, submergence and uplift. Much of this land became unusable for the typical agriculture of the 1800s.

In recent times, lesser quakes of magnitude 4.6 or smaller occurred in 1990, 1992, 1998 and 2003 in areas ranging from central to southeastern Missouri. On June 7, 2011, a magnitude 3.9 earthquake occurred near the town of Sullivan, approximately 50 miles southwest of St. Louis. No injuries or damage was reported.

“The New Madrid Seismic Zone is the nation’s most active seismic zone east of the Rocky Mountains,” said Jerry Prewett, the Missouri Department of Natural Resources’ Geological Survey Program director. “Small earthquakes occur in the region daily. Earthquakes typically occur along plate boundaries. As these tectonic plates interact with one another ... they build up stresses within those plates.

“When those stresses are released suddenly, a mass of earth shifts and the result is an earthquake.”

The coast of California is a good example where the Pacific Plate and the North American Plate slide past one another. In Missouri and the central U.S., there are no plate boundaries.

“We are on a stable part of a continent or crustal plate,” said Prewett. “So the seismic

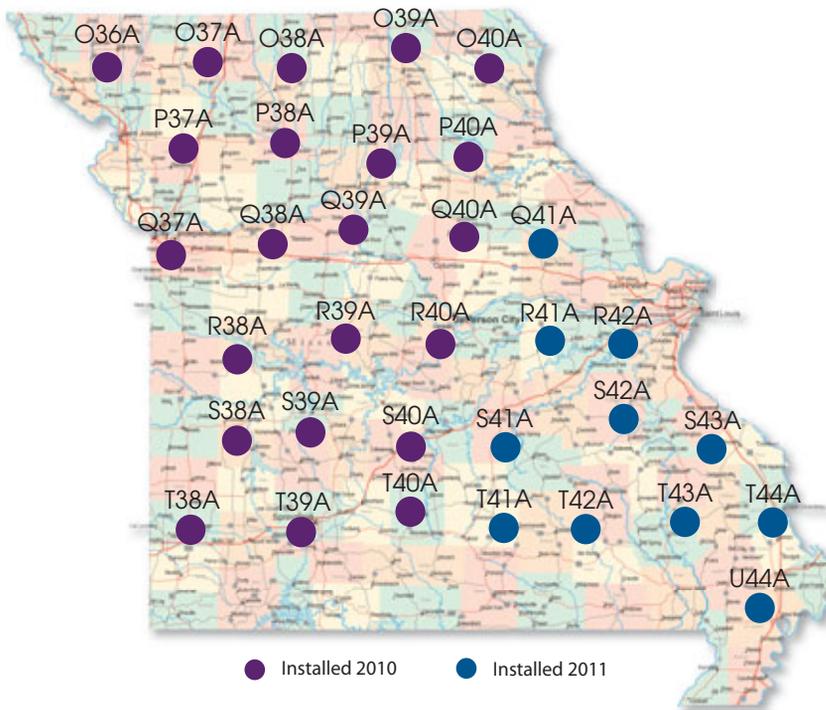
(Opposite page) Incorporated in 1808, New Madrid is the oldest U.S. city west of the Mississippi River. As a result of the 1811-12 earthquakes, New Madrid land certificates, good for public land elsewhere, were provided to quake sufferers by the 1815 U.S. Relief Act. These certificates benefited some residents, but mostly land speculators.

(Below) Not only did the topography in the southeastern corner of Missouri change as a result of the 1811-12 New Madrid earthquakes, Tennessee’s 15,000-acre Reelfoot Lake was created as a result of the shaking. Majestic cypress trees are a remnant of a once dense woodland.



DNR photo by Hylan Beydler

USArray Stations



USArray Stations located at (or near) these Missouri towns

O36A Bolckow	R41A Rosebud
O37A McFall	R42A Luebbering
O38A Galt	S38A Stockton
O39A Kirksville	S39A Bolivar
O40A La Belle	S40A Lebanon
P37A Lathrop	S41A Salem
P38A Dawn	S42A Caledonia
P39A Salisbury	S43A Patton
P40A Paris	T38A Diamond
Q37A Lee's Summit	T39A Clever
Q38A Concordia	T40A Mansfield
Q39A Nelson	T41A Mountain View
Q40A Auxvasse	T42A Van Buren
Q41A New Florence	T43A Greenville
R38A Montrose	T44A Benton
R39A Stover	U44A Portageville
R40A St. Elizabeth	

DNR map by Mark Gordon

(Below) This USArray Transportable Array (TA) station, R40A (see map above), located in St. Elizabeth, consists of a three-component broadband seismometer with signal processing, power and communications equipment. A vault buried beyond the solar panel continuously senses, records and transmits ground motions. The TA is a network of seismographs that are being placed in temporary sites across the conterminous United States.



Incorporated Research Institutions for Seismology photo

relationship is different in the mid-continent, where earthquakes occur less frequently than along the west coast.”

Scientists theorize that the New Madrid fault is an old rift that began to form millions of years ago but failed to split. Today, the rift is under stress as it is being pushed together both from the east and west.

Earthquakes are a natural hazard that no one can accurately predict. Based on this history of past earthquakes, the USGS estimates the chance of having an earthquake similar to one of the 1811-12 sequence in the next 50 years is about 7 to 10 percent, and the chance of having a magnitude 6.0 or larger earthquake in 50 years is 25 to 40 percent. Earthquakes that occur in the New Madrid zone have the potential to cause damage in the states of Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee.

Fortunately, there are things everyone can do to be better prepared. Geologists, seismologists and planners caution against developing heavily populated areas on land previously ruptured or shaken by

quakes, because these areas are likely susceptible to future earthquakes. The primary cause of damage and injuries in earthquakes is the destruction of manmade structures and their contents. Modern society is highly dependent on our manmade structures and infrastructure. Tall structures, structures with large open spaces, buildings made of brick and unreinforced concrete, and those with complex shapes and unanchored building contents are particularly susceptible to varying degrees of earthquake damage.

The Department of Natural Resources publishes geologic maps through the St. Louis Area Earthquake Hazards Mapping Project component of the National Earthquake Hazards Reduction Program.

“These maps provide characteristics of surficial material, which includes soil and several hundred feet of deeper unconsolidated material, depth to bedrock and depth to the water table, all of which influence the behavior of the surface due to earthquake-induced shaking,” said Prewett.

Scheduled to be completed by 2013, the hazards mapping project includes 21 maps in Missouri and portions of Illinois.

Last year, the Department of Natural Resources joined more than three million people who participated in a multi-state “ShakeOut” earthquake drill, which was the largest earthquake preparedness exercise in central U.S. history. The ShakeOut drill provided everyone a chance to practice the “Drop, Cover and Hold On” protective actions that should be taken in the event of a real earthquake.

In conjunction with the ShakeOut, the department invited Missouri K-12 grade students to enter the “Show-Me ShakeOut Video Contest.” Students from Ballwin, Dent County and Rolla were named winners in the earthquake preparedness video contest. All entries are available online at youtube.com/shakeoutmissouri.

The department also participated in a five-day national earthquake response training exercise focused on a coordinated local, state and federal response to a magnitude 7.7 earthquake. During the exercise, activities took place at state geological surveys, command posts, emergency operation cen-

ters and at other locations, including federal facilities in the Washington D.C. area and federal, regional, state, tribal, local and private sector facilities in the eight member states of the Central United States Earthquake Consortium.

Each February, Missouri observes Earthquake Awareness Month. Geologists with the department partner with local, state and federal agencies and organizations by participating in a number of public activities that provide scientific data about the New Madrid Seismic Zone, mapping for risk assessment and geologic information about earthquakes.

Everyone is encouraged to participate in the 2012 Great Central U.S. ShakeOut at 10:15 a.m. on Feb. 7, and to attend any of the public events. Visit dnr.mo.gov/geology/eqaware.htm for information. ☀

Hylan Beydler is the information officer for DNR's Division of Geology and Land Survey.



DNR photo by Hylan Beydler

(Above) The New Madrid earthquakes of 1811-12 are well documented in the museum collections at the New Madrid Historical Museum. The museum is open daily. For more information, visit: newmadridmuseum.com/.

In the event ...

In the event a damaging earthquake affects Missouri, the Department of Natural Resources will activate the Post-Earthquake Technical Clearinghouse, which will coordinate scientific activities and facilitate collaboration between the emergency management and scientific communities. The clearinghouse will reside at the department's Division of Geology and Land Survey located at 111 Fairgrounds Road in Rolla.

Division of Energy Stakeholder Process

The Missouri Department of Natural Resources' Division of Energy started its Energy Stakeholder



Process in fall 2011. The division held a series of meetings on energy efficiency, tradi-

tional and renewable energy at venues across the state to elicit discussion on complex energy issues, trends, opportunities and challenges for the State of Missouri.

The goal of the Energy Stakeholder Process is to work with a diverse group of energy stakeholders such as utilities, energy consumers, state and local agencies, public policy groups, energy and environmental organizations and others to choose and prioritize key implementable recommendations for where the department's Division of Energy should focus its efforts and expend its resources.

The results of the stakeholder process will be used to develop an action plan for the division and provide direction for the division's strategic planning and resource allocation decisions. Participants worked with the division's project facilitator, The Cadmus Group, to build consensus on critical energy issues.

A small "core group" approach has been chosen to review how the Division of Energy might promote the best energy choices for the citizens of the state. The Energy Stakeholder Process will conclude in February 2012.

Cabins for Canines



If you want to take your "best friend" along on your best vacation, Missouri State Parks will provide both you and your dog a place to stay the night. With the new Cabins for Canines program, specific lodging units will be available for use by dog owners.

Beginning in January 2012, Missouri State Parks will make lodging units available to people who want to travel and vacation with their dogs. The program includes units such as outpost cabins, camper cabins, yurts, single-unit cabins, duplexes and fourplexes. The number of dogs allowed per cabin is limited to two, regardless of size.

For visitors bringing canines as overnight guests, there will be a minimum fee of \$15 per dog, per night collected at check-in time. The per-dog, per-night fee may vary depending on the type of unit chosen. An additional fee may be assessed when extra cleaning is required.

Dog owners are responsible for cleaning up after their dogs inside and outside the unit. Dogs should be attended at all times while inside the unit and at all locations in the park. When guests must leave the dog unattended, they must be placed in a crate or kennel. A crate or kennel will be provided for each unit free of charge as a courtesy to guests.

With the new program, dogs are allowed only in the designated lodging units and may not be taken in any other park building. This program applies to canines that are not considered service animals assisting guests with disabilities. Implementation of the Cabins for Canines program will begin Jan. 1, 2012, for state-operated facilities including outpost cabins, camper cabins and yurts.

Implementation of the program in lodging facilities operated by private concessionaires will be phased in during 2012 based on availability and fully implemented in 2013.

For more information on parks offering lodging facilities for dog owners, visit mostateparks.com.

MSD Gets \$39.8 Million for Plant Improvements



The Missouri Department of Natural Resources awarded the Metropolitan St. Louis

Sewer District a \$39.8 million low-interest loan to make improvements to its Missouri River wastewater treatment plant. Improvements include adding an activated sludge treatment facility and six final clarifiers.

Funding for the loan comes from the Missouri Clean Water State Revolving Fund, a joint effort between the department and the U.S. Environmental Protection Agency to provide cost-effective financing for clean water infrastructure improvements. Financing with a low-interest loan from the Department of Natural Resources will save the sewer district an estimated \$20.8 million in interest over a conventional loan. This loan will be used in conjunction with other district funding.

The project is estimated to cost \$141.7 million and is expected to be completed in 2014. For more information, contact the department's Water Protection Program, Financial Assistance Center, at 800-361-4827 or 573-751-1192 or visit DNR's website at: dnr.mo.gov/env/wpp/srf.

Drinking Water Funds Awarded to Cass County

The Missouri Department of Natural Resources has awarded Cass County Public Water Supply District No. 10 more than \$1 million in grant and loan funding to



make improvements to its drinking water storage and distribution system.

The department awarded the district a \$333,684 grant and a \$702,000 low-interest loan to add a new 300,000-gallon elevated storage tank and make improvements to the distribution system. The funding will likely cover the entire cost of the project, which is expected to be completed in September 2012.

Funding for the grant and loan comes from the Missouri Drinking Water State Revolving Fund. The fund provides significant funding to assist communities with their drinking water infrastructure needs. A portion of the



environmental notes

Salty Solutions for a Slick Sidewalk

Every winter, road crews spread approximately 22 million tons of salt onto icy roads in the United States. The environmental impact of road salting is hard to assess as it rests on trading human safety for ecological drawbacks. For this reason, special attention is given to selecting the proper materials and amounts to be spread based on factors such as cost, performance, environmental impact and corrosive

properties. When salt gets spread, care is taken to monitor road conditions and apply the least amount of material to get the job done. The aim is to use salt to keep frozen precipitation from sticking so it can be cleared with plows more easily.



Sodium chloride is the most common type of salt used on roads because of its natural abundance and low cost. It has been used for de-icing roads since the 1930s and continues to be the most popular method of keeping frozen roads clear and safe. Other salts, such as magnesium chloride and calcium chloride also are used, mainly when temperatures are so cold that sodium chloride is ineffective. Again, no matter which salt is used, the aim is to spread the minimum amount of material to get the job done without waste. The above philosophy can also apply to homeowners as they prepare to de-ice and shovel sidewalks and driveways around their dwelling.

Salt helps loosen ice and snow from sidewalks by creating a salt-brine layer of liquid between the ice and the sidewalk. Since salt water has a lower freezing point than non-saline water, sometimes it may even be useful to salt your sidewalks *in advance* of a winter storm. The layer of salt-brine that is created can act as an anti-ice layer and keep snow from sticking. This will make shoveling easier.

To make the most of your de-icing materials, make sure you select the right product for the job. If standard sodium chloride is your choice, keep in mind that it works five times better when the outdoor temperature is 30 F than at 20. If the temperature is less than 15 F, sodium chloride will not work at all. In extreme cold, salts such as magnesium chloride and calcium chloride will be more suitable as they keep water from freezing at temperatures down to zero degrees. Read the labels on the de-icing product before you purchase so you are sure which salt you are buying. Pre-wetting the salt can help it to stick better where it is tossed, which helps reduce waste that bounces off of the target area.

Finally, and most importantly, use as little salt as possible to get the job done. In many cases, a little salt can melt a lot of snow. Remember that salt can cause damage to concrete, soil and plants over time, so spreading more than what is needed is not only costly and wasteful, but it also can be harmful.

funding will be targeted toward green infrastructure, water and energy efficiency, and environmentally innovative projects. This funding will help the district protect residents and the environment by making necessary drinking water improvements.

The Department of Natural Resources' Water Protection Program will administer the grant and loan funds. The department is committed to working closely with communities to assist with funding efforts that support water and wastewater infrastructure improvement projects as well as provide a financial savings. For more information, contact the department's Water Protection Program, Financial Assistance Center, PO Box 176, Jefferson City, MO 65102-1076, call 800-361-4827 or visit the department's website at: dnr.mo.gov/env/wpp/srf.

Department Launches Our Missouri Waters Initiative

Our Missouri Waters is a new watershed-based approach that will change the way the department conducts water resource management. The new initiative will take a coordinated, holistic approach to watershed management across the state.

"Our Missouri Waters initiative will modernize and streamline the way the department conducts watershed planning to better target our resources and provide a greater environmental benefit to the state of Missouri," said DNR Director Sara Parker Pauley. "This will help the department maintain consistency and provides a framework to measure results and provide accountability."

Stakeholders, partnering agencies and the public will play a critical role throughout the initiative. The department established a Watershed Advisory Committee that will provide its expertise to the department as it works to develop this new approach. Working with these partners, DNR will work to improve watershed planning, identify issues within watersheds and use tools best suited to address those watershed-specific issues.

Citizen participation and cooperation is also crucial for successful watershed management. "Local citizen participation is key to the success of Our Missouri Waters initiative. When citizens better understand the issues within their watershed, they become

more invested in the future of their community and together we can develop the most effective solution to benefit the state's water resources for generations to come," added Pauley.

The department selected three pilot watersheds to be included in the de-

partment's first phase of the Our Missouri Waters initiative. The department evaluated all watersheds throughout the state and selected the Spring River, Big River and the Lower Grand River watersheds. When selecting the three pilot watersheds, the department examined issues such as water quality, water quantity, high-quality waters for preservation and local stakeholder interest.

The department will begin implementing the pilot projects in early 2012 and will continue the planning process into 2013. These pilots will allow the department to analyze how well this watershed-based approach works and to make adjustments be-

fore implementing a statewide effort expected to be launched in 2013.

Missourians Encouraged to "ShakeOut!" on Feb. 7



On Tuesday, Feb. 7, 2012, at 10:15 a.m., thousands of people across at least eight states will participate in the 2012 Great Central U.S. ShakeOut earthquake preparedness drill.

February is earthquake awareness month in Missouri and the Department of Natural Resources is again partnering with the Central United States

Earthquake Consortium, state and federal emergency management agencies, and others to promote awareness and to encourage people to be prepared in the event of an earthquake. Many other government agencies, businesses, organizations, and community groups are also promoting the ShakeOut to their members and constituents.

Everyone is encouraged to register to participate in the drill, which will highlight "Drop, Cover and Hold On," and other protective actions people should take during an earthquake. Registered ShakeOut participants will be counted in this earthquake drill and will receive updates about ShakeOut

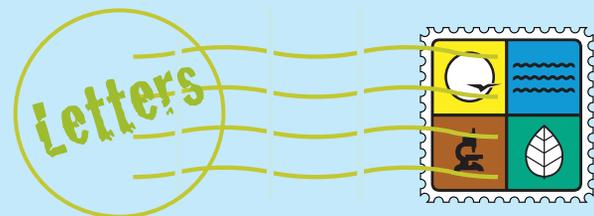
Just wanted to let you know that 48 members of Folks on Spokes just finished an eight-day ride on the Katy Trail. We became acquainted with this group of mostly retired campers when we were in Gulf Shores, Ala., last November. Like us, they visit the warmer states during the winter and bring their bikes along on the camping trips. For one of their summer trips, they chose the Katy Trail, so, being from the area, we assisted as guides. The participants came from eight states and were impressed with how well maintained and scenic the trail was. This confirmed what they had heard about the Katy Trail and was the reason they chose it for their summer trip. The riders stayed in a campground north of Columbia and rode different sections every day. Keep up the good work.

Parker and Edyth Jenkins
Ashland

Editor's Note:

The Jenkins' and their Folks on Spokes guests completed an ambitious itinerary, including St. Charles to Machens, downtown Columbia on the MKT Trail, and a North Jefferson, Rocheport, Hartsburg and Cooper's Landing trip.

I would like to express my sincerest gratitude for all of the assistance that we as an organization have received over the last two years from everyone that has worked in conjunction with the State Parks Youth Corps. By placing area youth in these positions to learn skills that benefit the communities they live in, they also will inevitably learn skills that benefit them for a lifetime. Some of the simplest lessons, such as: working regularly, managing money, learning teamwork and focusing on their individual successes redirect them along a path they will follow for life.



Our current adolescent substance/alcohol abuse and school-based prevention programs consistently work to assist the youth in finding ways to better themselves and give back to their communities. Programs such as the State Parks Youth Corps create the exact types of opportunities they need.

The entire staff at Cuivre River State Park not only assisted us with the SPYC, but always helps provide local youth with a positive outdoor experience. Naturalist Bruce Schuette, Stephanie Scoggins, Dan Smith, Ronnie King, Jeff Bonney, Andy Vanderbos and the others that were involved in this program continue to support the youth in Lincoln County. Ryan Mueller of the DNR Water Resources Center originally told me about the program and explained the need for youth staffing in certain areas of the state.

I hope that programs such as these do not go unnoticed and that they continue to receive the support and attention that they deserve. All that it takes to put many of the kids that we work with on the right track is a reason and the motivation to maintain positive changes in their lives.

Nathan Teague
School Teams Coordinator
Lincoln County, Preferred Family Healthcare

Letters intended for publication should be addressed to "Letters," *Missouri Resources*, PO Box 176, Jefferson City, MO 65102-0176 or faxed to (573) 522-6262, attention: "Letters." Please include your name, address and daytime phone number. Space may require us to edit your letter. You also can email *Missouri Resources* staff at moresdnr@dnr.mo.gov.

news and information about earthquakes and preparedness. Learn more and register to participate in the ShakeOut at: dnr.mo.gov/shakeout/. More than three million people in 11 states practiced "Drop, Cover, and Hold On" in April, 2011, as part of the First Annual Great Central U.S. ShakeOut.

This year marks the 200th anniversary of a series of three earthquakes believed to have been magnitude 7.0 or larger that occurred near the southeast Missouri town of New Madrid.

Find information about activities and events planned for Earthquake Awareness Month at: dnr.mo.gov/geology/.

Scrap Tire Grants Awarded for Joplin Playground Projects

The Missouri Department of Natural Resources has awarded \$635,000 in grants to the Joplin School District and Joplin Parks and Recreation Department for 11 playground projects necessary because of damage caused by the May 22, 2011 tornado that hit the city.



Earlier this year, Gov. Jay Nixon announced the department's Scrap Tire Surface Material Grants were available for public schools, parks, non-profit day care centers, other not-for-profit organizations and some local governmental organizations to submit applications for the grant funding.

The scrap tire grant funding by DNR will help rebuild playgrounds in the Joplin area damaged by the violent tornado that struck last spring.

"Children are especially vulnerable after a disaster of this scale," Nixon said. "Schools and playgrounds help return a child's sense of security and normalcy by providing a stable, familiar environment."

The Joplin School District will receive \$517,720 of the funds being awarded. Many of the elementary school projects include multiple play areas to meet each school's individual needs based on their number of stu-



Stream Team Notebook

It Takes a Team to Save Otoe Creek

Lisa Adams, the recipient of the 2010 Volunteer Water Quality Monitoring Ambassador Award, is a shining example of determination and teamwork. Adams, a Water Quality Supervisor with Missouri American Water, has worked with Missouri Western University, the Department of Natural Resources and the gifted students from the St. Joseph School District. They have formed a partnership whose main goal is to improve the water quality in Otoe Creek, which runs through the university campus.



Lisa Adams

DNR photo by Anna Nowack

"I was especially interested in Otoe Creek because it is very near my home," Adams said of her project. "I could see the challenges in that watershed every day and decided to try to do something to make a difference."

Adams, who has worked for Missouri American Water since 2005, has 30 years of lab experience including working with herbicides, insecticides, pesticides, meats and water. While her employer encourages all employees to be involved with environmental groups, Adams says she found her perfect fit with the Stream Team Program.

"It is very important for us to protect our watersheds and educate people in ways they can help, Adams said. "Through Stream Team, I have been able to engage dozens of students from fourth grade through college age, to share the water quality monitoring experience."

What Adams has accomplished in the short time since she attended her first water quality workshop in 2008 is amazing. Twice a year, students assist with monitoring the stream and a big campus-wide trash clean-up project is planned. A large trash dump has been located on Otoe Creek and plans are underway to remove it from the stream and install No Dumping signs.

"Currently, the water quality rating of the stream is poor," Adams said. "But my hopes are to implement changes and educate more people so that we eventually see better water quality in Otoe Creek."

Adams formed the Missouri American Water Stream Team #3681 and remains an active member.



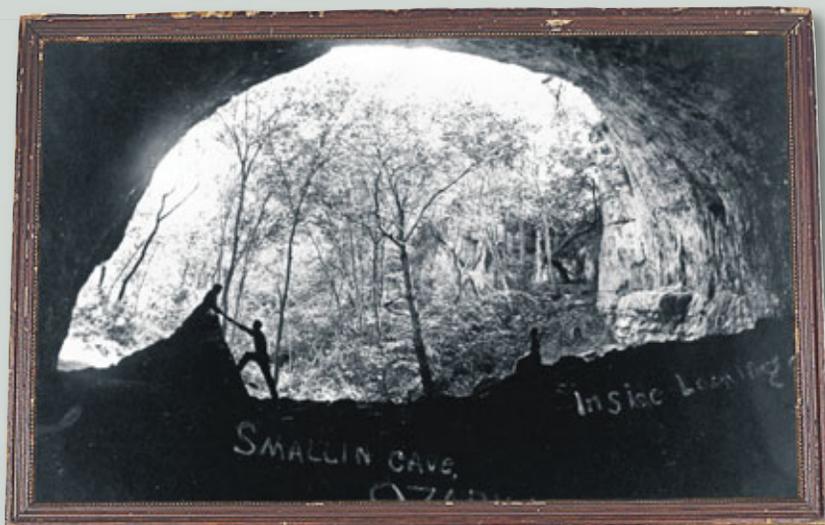
dents and to allow for age-appropriate play areas for those students.

The Joplin Parks and Recreation Department is receiving \$117,080 of the grant funds for the playground surfacing material projects. The grants announced today are in addition to \$22,288 awarded in September for a

playground project being built on land between the Hope Haven Mobile Home Park and the Jeff Taylor Memorial Mobile Home Park for children and families displaced by the tornado and currently living in FEMA housing.

The Department of Natural Resources is able to provide these

TIME EXPOSURES



Smallin Cave, located in Ozark in Christian County, was the first cave documented in the Missouri Ozarks. In 1818, English explorer and geologist Henry R. Schoolcraft happened upon the cave by accident while exploring the Louisiana Purchase.

The cave entrance is the largest in the state, stretching a spectacular 10 stories in width and 55 feet in height. The front section of the cave runs approximately 1,400 feet until narrowing to a small crawl space. Beyond the crawl space is a room with a 30-foot-high ceiling and many cave fauna, such as the blind cave crayfish, *Cambarus setosus*. Numerous cave formations adorn the cave's rear chamber, including a giant onyx flow stone that has been polished on one side, probably from use by Osage Indians.

The cave has played a background role in much of the local history. Osage Indians were thought to have used it for shelter for many years. In 1861 it was also rumored to be a munitions warehouse used by the Union forces under Gen. Nathaniel Lyon. These munitions were believed to be stockpiled for the Battle of Wilson's Creek that took place approximately 12 miles to the west.

This undated Victorian-era photograph shows the immense size of the cave entrance, with the silhouette of cave visitors giving scale to the opening. This image is part of a digital photo collection donated to Drury University by Dr. Bruce Pegram, who owns the original.

Send your photo to "Time Exposures," c/o Missouri Resources, PO Box 176, Jefferson City, MO 65102-0176. Original photos will be returned via insured mail. Pre-1970 environmental and natural resource photos from Missouri will be considered. Please try to include the date and location of the picture, a brief description and any related historic details that might be of interest to our readers.

sources' Solid Waste Management Program at 800-361-4827 or 573-751-5401, or visit the website at: dnr.mo.gov/env/swmp/tires/tirefinassistance.htm.

Winter Hiking in Missouri State Parks

Missouri state parks are a great place to visit – even in the winter. And winter hiking is a great way to experience your state parks.



Our parks system has trails for everyone. Visitors can find smooth, level, paved trails that provide for a nice leisurely stroll. Or experienced hikers can seek out some of the rugged, backcountry trails. Most trails are well marked so you can easily find your way on snowy days.

Regardless of the trail you choose to hike it is important to be safe. You must be prepared for the varying conditions you can encounter during the colder months. Following are a few tips to ensure a successful hike.

It is important to understand map reading. This will help you find your way. Be sure you understand the distance you are hiking. It is important to realize that it will take you longer to hike than walk on a sidewalk. Always inform someone where you will be going and when you will return. And always dress in layers to accommodate the change in body temperature. These safety tips will help keep you safe on the trail.

Now that the leaves have fallen and the trees are bare, winter provides a unique perspective of our state parks. For more information on trails in state parks, visit our website at: mostateparks.com.

For news releases on the Web, visit:

dnr.mo.gov/newsrel/index.html.

For a complete listing of the department's upcoming meetings, hearings and events, visit the department's online calendar at: dnr.mo.gov/calendar/search.do.

grants through the state's 50-cent-per-tire fee collected on new tires sold at retail in Missouri. These fees are also used to finance cleanup of illegal scrap tire dumps, inspections and enforcement activities. The department has

awarded more than \$2 million to 319 organizations since the surfacing material grants became available in 1994.

For more information on the Scrap Tire Surface Material Grants, please contact the Department of Natural Re-

In Memoriam **John Drew**

John Drew, a hydrologist with the Missouri Department of Natural Resources' Water Resources Center, passed away on Tues., Dec. 27, as the result of an automobile accident.

John was with the department for more than 23 years and served as the state hydrologist and expert on interstate water issues for the state of Missouri. John worked closely with many DNR employees and numerous external stakeholders including the U.S. Army Corps of Engineers, state and federal legislators and those serving on various associations and groups working to protect the Missouri River. John was a skilled and dedicated employee and possessed a wealth of knowledge for Missouri River issues including flood control and navigation.

"Those fortunate enough to work with John over the years know what a profound loss this is to the Department of Natural Resources, the State of Missouri and to those who considered John a friend," said Sara Parker Pauley, DNR director. "His dedication and skill were unparalleled and irreplaceable."

Despite being recognized as the state's foremost authority on Missouri River issues, his congenial nature and gentle demeanor provided him with the rare ability to translate the technical information into terms understood by the layman.

"John Drew was a great person," said Missouri State Representative Randy Asbury, of Higbee. "He was the backbone of our Missouri River efforts with such knowledge about every aspect of the river – from biology to hydrologics. John was a great sounding board, a stellar strategist and a policy tactician. At the same time, he was unassuming and humble. He will be missed and the state has lost a tremendous friend and asset."

Beyond John's skill at his job, he was an amazing person and friend to those who knew him, as well as a wonderful husband, son and brother.

The Department of Natural Resources has set up an email address where you can send any remembrances of John, or simply express your condolences. The department will share anything provided with John's family, as well as with the people who worked with him most closely. Go to JohnDrewMemoriam@dnr.mo.gov.



John Drew

DNR photo by Scott Myers

Rock Matters



Meteorite

Meteorites are the recoverable pieces of rocks from space that have fallen to Earth's surface. How and when meteorites formed is a subject of scientific theorizing. Most are from the Asteroid Belt that contains lots of leftover rock debris from the formation of our Solar System. Photos by Patrick Mulvaney

Space rocks, like planets, orbit the sun. But many have elliptical orbits that cross the almost circular orbits of the planets. Therefore, it is just a matter of time until these rocks meet up with planets and are captured with great speed, from 20,000 to 45,000 miles per hour (seven to 16 times faster than the fastest speeding bullet).

To become a meteorite, a space rock cannot be too small or too large. Those smaller than approximately one yard across are likely to completely burn up as they pass through Earth's atmosphere. They make meteors – often called shooting stars or fireballs. Those larger than roughly 10 yards across are likely to slow very little as they shoot through the atmosphere in a blazing sun-bright fireball and then impact the surface with a tremendous explosion that vaporizes the space rock to form a crater.

Meteorites are divided into two groups: falls and finds. Falls are those that are recovered after a witnessed fireball or after having been seen or heard to land on the surface. Finds are those that are found with no historical record of a witnessed fall.

When fresh, meteorites have dark fusion crusts and rounded,

thumbprint-like indentations called regmaglypts. Prolonged weathering usually turns most of them into rough, rusty-colored rocks that are sometimes difficult to distinguish from Earth rocks. Most are attracted by a magnet, which helps identify them.

There are about 40,000 known and well-documented meteorite falls and finds. Probably 100 to 1,000 new meteorites land every year, but most will never be found, having landed in oceans or vegetated terrains.

Twenty-three meteorite finds have been confirmed in Missouri. Visit the department's Ed Clark Museum of Missouri Geology, located in Rolla, where you will find an impressive meteorite display. You also can visit dnr.mo.gov/geology/edclarkmuseum.htm.



Mark Twain State Park

by Tom Uhlenbrock

photographs by Scott Myers



On the borders of Mark Twain State Park rests an 18,000 acre lake, providing visitors with many recreational opportunities.

Mark Twain State Park received its name because of the well-known author born in the area, but many of today's visitors are drawn here for the water recreation and fishing, especially spring crappie fishing.

"In May, crappie fishing is explosive," said park manager Jim Griggs. "This year was a borderline record season; people were just slaughtering crappie out here." Fishermen were reporting they could catch a crappie anywhere they dropped a hook.

While water recreation is popular, the park has its roots in history. The park was established in honor of Samuel Clemens, the famous author and humorist known as Mark Twain who was born in 1835 in the nearby village of Florida. The Mark Twain Memorial Park Association purchased the cabin where Clemens was born and donated

it and 100 acres of land to the state in 1924. Mark Twain State Park, with its associated Mark Twain Birthplace State Historic Site, is the third oldest park in the Missouri state park system and the first one established north of the Missouri River.

During Mark Twain's childhood, the entire park landscape was wooded hills overlooking the Salt River valley. In the 1960s, the area changed dramatically when the U.S. Army Corps of Engineers began construction of the Clarence Cannon Dam across the Salt River. Completed in 1983, the dam generates power while Mark Twain Lake provides flood control and creates outstanding water recreation opportunities. The park borders the 18,000-acre lake and provides convenient ways to access the lake and its opportunities, including boating, fishing and swimming.



Much of the landscape around the lake remains as it did in Mark Twain’s day with a terrain that is more rugged and hilly than most of the other surrounding level terrain. With a topography that is reminiscent of the Ozarks to the south, the park provides a serene setting for relaxing and exploring history and nature.

The best place to understand that history is at the museum at the Mark Twain Birthplace State Historic Site. The museum’s centerpiece is the two-room cabin where Mark Twain was born. Museum exhibits interpret Twain’s remarkable life from his childhood through his adult life as an author and businessman. The museum preserves a handwritten manuscript of *The Adventures of Tom Sawyer* and furnishings from his Hartford, Conn., home.

Today’s visitors appreciate the history of the area while taking advantage of the recreational opportunities. “During April and May, we get a lot of fishermen who camp and fish,” Griggs said. “Then when school gets out, we get families.”

In addition to crappie, anglers fish for bass, bluegill, catfish and even a few wall-eye. The park has three concrete boat ramps and two fish-cleaning stations. Because there is no development on the shoreline, the lake features many quiet coves, perfect for an afternoon of fishing. But fishing is not the only water sport at Mark Twain State Park.

“You’ll see tubing, water skiing, a lot of pleasure boats, a lot of pontoon boats,” Griggs said. “I’ve seen sailboats out there.” Another popular activity is cooling off at the swimming beach.

For those wanting to spend the night, there are three types of camping at Mark Twain State Park. The park includes three campgrounds with a mix of approximately 100 basic and electric sites. The Badger, Coyote and Puma campgrounds have shaded sites in the woods, with views of the lake through the trees.

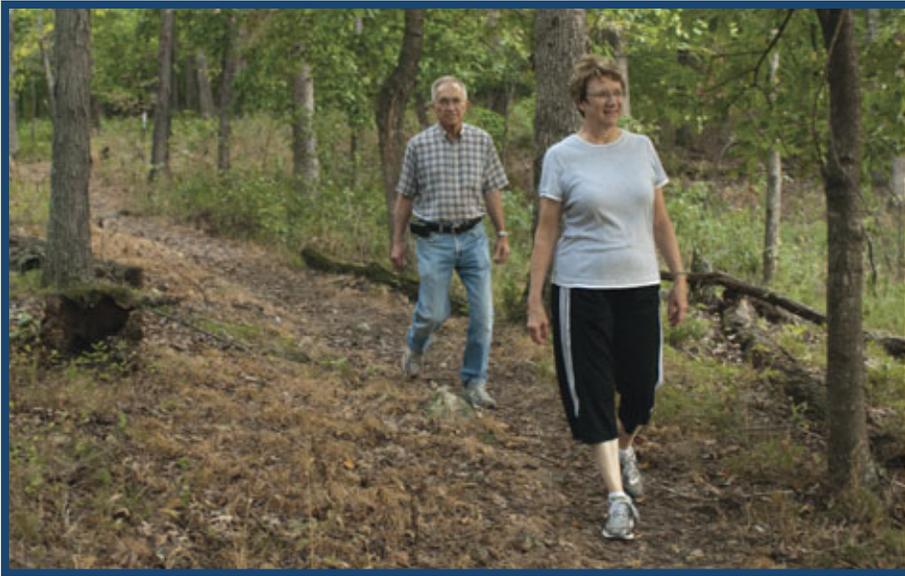
“It’s a nice area, especially when you catch the leaves just right,” said Jeff Crook, state park employee.

For another approach to camping, the campground includes six camper cabins. These cabins provide the experience of camping with some added conveniences such as electricity, heat, refrigerator and microwave. The cabins do not have water so campers have access to the shower houses and other amenities in the campground. Visitors need to bring their own linens. Located along the shore of the lake, the cabins provide great views of the water from a wooded, secluded setting.

Mark Twain State Park also offers Camp Colburn, a group camp perfect for organized youth groups. Named after Si Colborn, a local newspaper editor, the camp can accommodate up to 75 people. The camp fea-



The Ridgeway family from Mexico, Mo., enjoys the panoramic view from Buz-zard’s Roost overlook and picnic area at Mark Twain State Park.



(Top) Charles and Kathy Riney of Hannibal take in the scenery on a quiet walk along one of Mark Twain State Park's many trails. (Bottom) Jenna Hurst and Jason Baynes of Hermann enjoy their evening campfire in the park campground. Mark Twain State Park hosts approximately 100 basic and electric campsites, six camper cabins and one group camp capable of hosting up to 75 guests.

tures four sleeping cabins, a group camp of-
 fice complete with staff quarters, a dining
 hall with kitchen, modern central restrooms
 with showers and a fully lighted and paved
 multipurpose court for basketball and vol-
 leyball games.

The 2,800-acre park has five hiking trails
 totaling 6.5 miles that offer views of the
 lake and the surrounding wooded hillsides
 of oak-hickory trees. In the spring, the dog-
 wood displays are impressive and in winter,
 bald eagles roost along the bluffs that line
 the lake.

One of the most popular areas in the park
 is Buzzard's Roost. This picnic area,

with rock walkways leading to an
 overlook on a towering limestone
 bluff, offers a panoramic view of Mark
 Twain Lake. The picnic area's open
 shelter is built of native limestone and
 has a large stone fireplace flanked by
 benches. The rock work was complet-
 ed in 1939-1942 by Civilian Conserva-
 tion Corps Co. 1743, an all-black com-
 pany that left an impressive legacy of
 buildings in the state park system. The
 enclosed shelter, known as Huck Hall,
 can be rented for family reunions and
 other gatherings.

With attractions for history buffs,
 fishermen, campers, hikers and those
 simply wanting to enjoy nature, Mark
 Twain State Park offers something for
 everyone. Its appeal continues

throughout the year, with spring offering
 crappie fishing, summer offering boating
 and camping, and fall featuring hillsides
 glowing with orange and yellow. Accord-
 ing to Crook, winter also is a good time to visit.

"You ought to come up in winter time,"
 Crook added. "It's really beautiful after a
 fresh snow."

Mark Twain State Park is off Highway
 154 at Stoutsville in Monroe County. For
 more information about facilities and activi-
 ties, call the park at 573-565-3440.

Tom Uhlenbrock is a writer for Missouri State Parks, a division of the Department of Natural Resources.





Roy Heimbeaugh

CONSTRUCTION VETERAN'S EFFORTS HARD TO OVERLOOK

by Sue Holst

photographs by Scott Myers

Every year, millions of people who visit Missouri state parks and historic sites hike on the trails, camp in the campgrounds and take in the views from an overlook perched on a bluff. For Roy Heimbeaugh, watching people use and enjoy these facilities makes his job worthwhile.

Heimbeaugh is the building construction supervisor for Missouri State Parks and he and his crew build many of the structures that enhance any visit to a state park. While state parks and historic sites are located in some of the state's most outstanding settings, the facilities make it possible for visitors to access the areas and enjoy them in comfort. Trails and boardwalks make it easier to explore the landscapes, picnic shelters provide shady areas for families to gather for a reunion, and campgrounds create convenient places to spend the night in a scenic setting.

Most visitors take those conveniences for granted, but Heimbeaugh considers it his calling to build them. Heimbeaugh, from Camdenton, was in the construction business when he was asked to do a couple of small jobs at Ha Ha Tonka State Park.

"I figured I would work for a couple of months, and here it is 28 years later. I don't regret it for a minute," he said.



Heimbeaugh leads the statewide construction crew that builds and remodels facilities in all of Missouri's 85 state parks and historic sites. He supervises a crew of nine with seven building construction workers and two heavy equipment operators. The state park system also employs three other construction crews located in the eastern, southern and northern areas of Missouri.

The construction supervisor says the variety of the work is one thing he appreciates about his job. He and his crew build trails, boardwalks, campsites, overlooks and picnic shelters; pour sidewalks and camping

(Above) The overlook at Ha Ha Tonka State Park is one of Roy Heimbeaugh's favorite projects because of the challenge it was to build and how much people use and enjoy it every day. Seeing people use his projects makes the job worthwhile for Heimbeaugh.

"I figured I would work for a couple of months, and here it is 28 years later. I don't regret it for a minute."

– Roy Heimbeaugh, parks construction supervisor

pads; and remodel cabins, shower houses and other facilities. The crew may be remodeling a cabin at Roaring River State Park one day and replacing shingles on a roof at Dillard Mill State Historic Site later that week.

“You never know what you will be doing next. That keeps it interesting,” he said.

Several overlooks stand out as special projects to Heimbeaugh and they can also prove to be some of the most challenging. He and his crew constructed the overlook and boardwalk that is anchored in the rock above the shut-ins at Johnson’s Shut-Ins State Park. At Trail of Tears State Park, they built the overlook that extends out from the hillside to provide spectacular views of the Mississippi River.

At Ha Ha Tonka State Park, the overlook providing sweeping views of the Lake of the Ozarks brought numerous questions and comments from the public.

“A lot of people stopped to ask what we were doing. I like it when I can explain what we are doing to the public,” he said.

Many times, the locations prove to be the most challenging part. In certain areas, the crews must clear paths and carry in all the material and tools by hand before they can even begin a project.

One of his favorite projects is preliminary development of the first section of the new Rock Island Trail State Park. Being constructed on the former railroad right-of-

Projects for Heimbeaugh vary from building new shelters, houses and trails to remodeling and renovating older structures. At Montauk State Park, Heimbeaugh and his crew remodeled the fourplexes to bring them up to today’s standards and provide even nicer places for visitors to spend the night.



way, the section of trail had to be cleared before the construction work could begin.

“I really enjoy this project because I am able to start it from scratch and will be able to see it through,” he said.

He is looking forward to the time when it is completed and he can see people enjoy the new trail section.

Another thing Heimbeaugh enjoys about his job is the crew. Based out of Jefferson City, the crew works four 10-hour days. Since they work all over the state, it is common for them to be away from home four days at a time.

“We spend as much time together as we do with our families, so we have become like family,” he said.

Heimbeaugh says anyone interested in working for a Missouri State Parks construction crew should have some construction experience. In addition to building construction supervisor, there also are positions available for building construction workers, capital improvement specialists and heavy equipment operators.

One quality applicants should have is a love of the outdoors and helping people enjoy it, like Heimbeaugh.

“I can’t think of anything else I would rather be doing.”



Sue Holst is a writer for Missouri State Parks.

Limestone: Missouri's Billion Dollar Industry

by Joe Gillman

photographs by Scott Myers

“It is hoped that this report will stimulate the lime and cement industries to such a degree that before many years Missouri will hold first among the lime and cement producing states of the Union.”

- E.R. Buckley, State Geologist,
in his 1907 report to Missouri Governor Joseph W. Folk

Well over 100 years ago, geologists understood the quality and economic value of Missouri's limestone resources. Missouri still hosts a robust limestone industry that mines rock and processes it into a variety of vital products for the state, the nation and the world. The annual economic impact of limestone mining equates to several billion dollars in Missouri.

Geologic history has endowed the Show-Me State with an abundance of limestone that occurs nearly everywhere in the state. During a geologic time span known as the Paleozoic Era, much of Missouri was repeatedly inundated by warm, shallow marine seas. In this type of environment, calcium carbonate precipitated out of seawater. This calcium carbonate then settled to the sea floor as a blanket of mud. Marine life that was capable of forming calcium carbonate shells also thrived in these waters and when they died, their shells and skeletons accumulated along with the mud. The result was a calcium carbonate sediment that was progressively buried and

compacted, eventually forming limestone rock. In some locations, these limestone deposits are several hundred feet thick.

Products derived from limestone are a critical component of many pollution control technologies. Lime is used to soften and clarify municipal water supplies and is also utilized to control pH, odor and pathogens in domestic wastewater. Lime also is used to control sulfur dioxide and hydrogen chloride emissions from electric utility and industrial plants and is widely used to treat and neutralize mine and industrial wastes. Lime is added to cropland to neutralize soil acidity, improve water and nutrient uptake and increase fertilizer efficiency.

Limestones that are durable and are not fractured may be cut into “marble” blocks that are used for dimensional building stone. Missouri limestone has been used as dimension and ornamental stone in many buildings across the United States including the U.S. Department of Commerce building, the Library of Congress, the National Archives and Missouri's own state capitol. Limestone known as “Carthage Marble,” perhaps the most widely recognized of Missouri's mar-



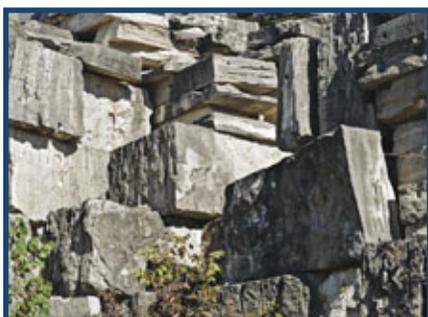
(Above and bottom) A large circular saw with a diamond segmented blade is used to saw slabs from limestone blocks at the Phenix Marble Quarry, near Springfield, Mo.

bles, has been extensively used across the nation.

Our understanding of Missouri's limestone resources continues to be refined. Understanding the properties and geographic distribution of these rock formations helps identify resources that have societal importance and commercial marketability. DNR's Division of Geology and Land Survey maintains a database of the chemical and physical properties of select stone resources in Missouri. That data is used to develop maps of the distribution of limestone deposits.

Buckley would likely be pleased to know that more than 100 years after his report, Missouri's robust limestone industry ranks as one of the nation's leading producers of lime and portland cement, the most active component of concrete.

Joe Gillman is director of DNR's Division of Geology and Land Survey and serves as Missouri's state geologist.



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