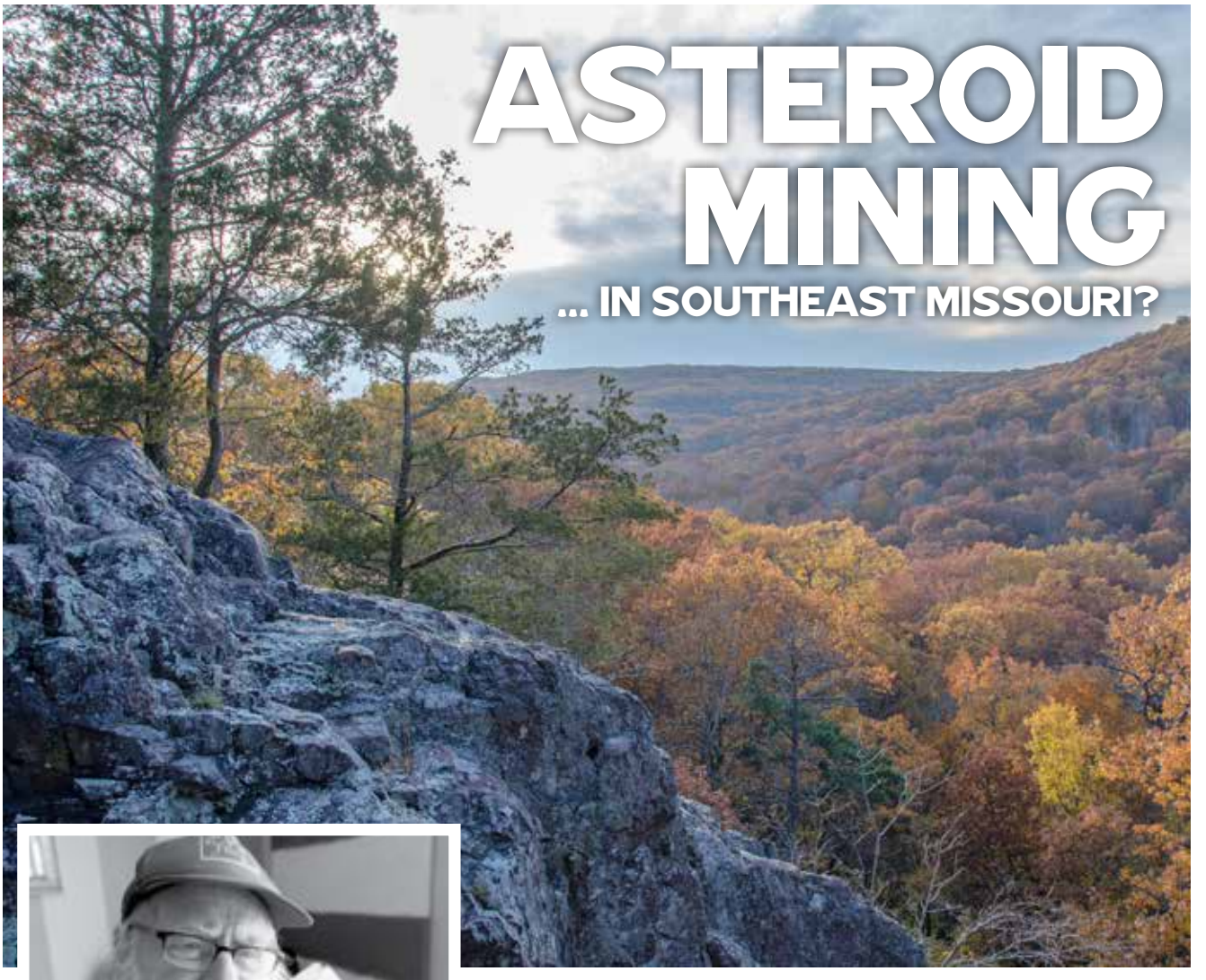
ASTEROID MINING
... IN SOUTHEAST MISSOURI?





A geologic search for the buried remnants of Precambrian celestial impacts

BY WILLIAM JUD

There is growing interest in mining asteroids in space, a venture that could one day prove profitable. Rare asteroids such as 16 Psyche — a Maryland-sized rock in the main belt between Mars and Jupiter — are believed to be rich in platinum-group metals and other high-value materials, potentially worth more than the enormous costs of space mining.

But the challenges are significant. Over the past few decades, the cost per pound of getting something into orbit has ranged from $10,000 to tens of thousands of dollars. SpaceX can now reach low Earth orbit for about $1,500 per pound, but that's far from the 28-million-mile journey to a "near-Earth" asteroid. The operational difficulties of chasing a live asteroid through space, using robots to chip off 50 or 100 tons of rock, and bringing the catch back to Earth present a daunting list of difficulties and dangers.

There might, however, be a better way — mining "fossil" asteroids already on Earth.

As a professional geologist, I've developed a theoretical model based on empirical and circumstantial evidence that about 1.5 billion years ago, a massive asteroid or perhaps even a comet — possibly 10 to 12 miles in diameter— impacted the Precambrian supercontinent Columbia, blasting a zone of fractured rock through the crust into the underlying asthenosphere.

The impact's immense force instantly created porosity and permeability in the Earth's crust, opening a low-pressure pathway that allowed local mantle plume circulation. The upwelling of very hot, semi-molten asthenospheric material then melted the base of the Earth's crust, feeding sticky, high-silica rhyolitic magma to the erupting Precambrian volcanoes of what now form the St. Francois Mountains in southeast Missouri, where I live and study rocks.

A quick geological lesson: About 1.3 billion years ago, the Precambrian continent Laurentia broke away from the supercontinent Columbia. As Laurentia

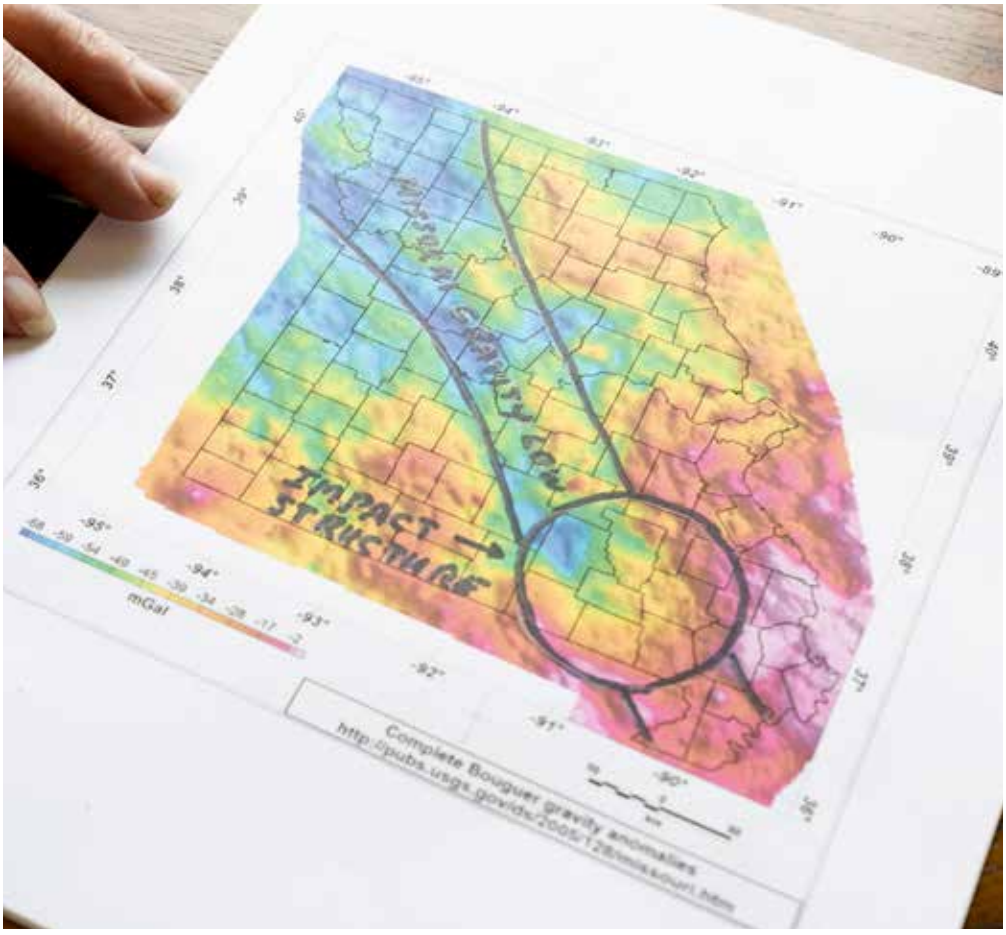
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Page Turners Book covers courtesy of the publishers; St. Francois Mountains by Keith Yahl, William Jud photos courtesy of *573 Magazine*

drifted on tectonic plates, it eventually became the "basement" rocks that now lie beneath much of North America. During its journey, Laurentia moved away from a still-upwelling column of magma rising through what I hypothesize to be asteroid-impacted rocks. This movement left behind a trail of slightly lower-density intrusive granite magma, forming a linear zone about 324 miles long with slightly lower gravity. This zone, known as the Missouri Gravity Low, is significant because such gravity anomalies can be clues to underlying geological structures, such as impact craters, that might have caused the magma to upwell in the first place. Our theoretical impact structure is a circular feature about 120 miles wide at the southeast end of this gravity low.

Big impactors tend to produce wide, flat craters like the ones you see on the moon. Typically, the crater diameter is about 10 to 12 times the size of the impactor itself. Using the asteroid impact conceptual model to interpret the circular geological structure and the 10:1 ratio of crater diameter to impactor diameter gives an asteroid diameter of 10 to 12 miles. Assuming a spherical shape and using the equation for the radius and volume of a sphere (4/3 pi) x (radius cubed) gives 523 cubic miles as a first approximation. That's a *big* rock.

The area's rhyolitic magma, which is a type of very hot, high-silica volcanic material, comes into play here because it can reach temperatures high enough to reset or even melt the usual indicators of an asteroid impact. These indicators typically include shocked quartz, coesite, stishovite, shocked feldspar, shocked zircons, and shatter cones. However, in this case, much of the evidence was likely destroyed due to the extreme heat. Shocked zircons, which have a higher melting temperature and are exceptionally durable, might have survived, but they would be rare and difficult to identify within their parent rocks.



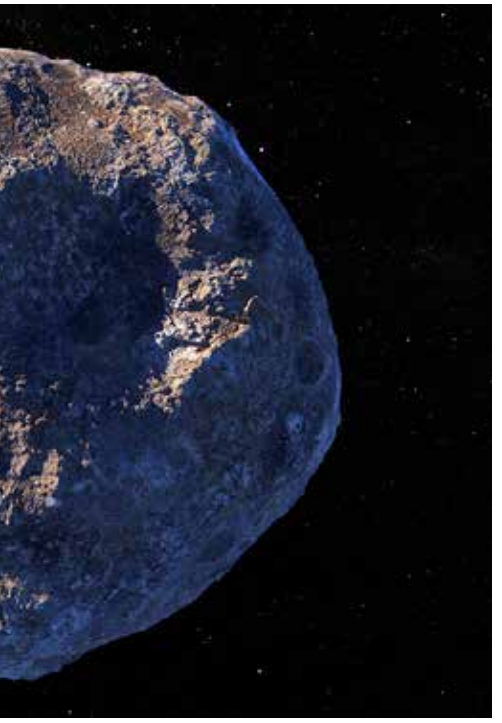
Missouri Gravity Low shown on the Missouri State Gravity map with suspected impact zone circled.



Asteroid Psyche courtesy of NASA/JPL-Caltech/ASU

Southeast Missouri is part of an iron metallogenic province, an area where iron is notably more abundant than usual. The region's Precambrian rocks contain numerous occurrences of iron oxide minerals, including some ore deposits large and rich enough to mine profitably. Overlying Cambrian and Ordovician sedimentary rocks also contain filled sinkhole structures, many of which are mineralized with iron sulfide or oxidized iron sulfide deposits. The regional abundance of iron mineralization in southeast Missouri aligns with the possibility of iron transfer from a buried Precambrian asteroid.

The asteroid suspected of impacting the area is believed to have been a nonmineralized chondrite. These types of asteroids have a basic chemical composition generally similar to gneiss (pronounced "nice") and schist metamorphic rocks, meaning they might not generate noticeable geophysical anomalies, such as those related to



Using the Asteroid Conceptual Model to interpret the circular feature 120 miles wide at the south end of the Missouri Gravity Low shown on the Missouri State Gravity map and the 10:1 ratio of crater diameter to impactor diameter gives an estimate of asteroid diameter of 10 to 12 miles. Assuming a spherical shape and using the equation for radius and volume of a sphere = (4/3 pi) x (radius cubed), the asteroid volume was 523 cubic miles as a first approximation.

gravity and magnetism. However, buried asteroids enriched with metallic iron and other metals, such as nickel, can produce significant positive gravity and magnetic anomalies.

Magnetotellurics, a passive exploration method that uses Earth's natural electrical field to measure electrical resistivity distribution within the Earth, might be able to locate deep fossil asteroid fragments — particularly if these fragments are rich in metals and not obscured by overlying secondary metallic deposits.

MAGNETOTELLURICS, A PASSIVE EXPLORATION METHOD THAT USES EARTH'S NATURAL ELECTRICAL FIELD TO MEASURE ELECTRICAL RESISTIVITY DISTRIBUTION WITHIN THE EARTH, MIGHT BE ABLE TO LOCATE DEEP FOSSIL ASTEROID FRAGMENTS.

There is quite a mix of geological history in southeast Missouri. Proving the asteroid impact's conceptual model could be as difficult as identifying and removing a single egg from a pan of scrambled eggs. Drilling could provide proof if the drill core brings up asteroid rock or impact melt rock instead of the surrounding host rock.

But let's say the buried asteroid does exist and is at shallow enough depth to allow mining, generally 2 miles or less. Chondrite asteroids can contain as much as 25 percent metals. This could mean an entire cubic mile of metal in every 4 cubic miles of buried asteroid — a whopping amount of metals that could include iron, cobalt, nickel, copper, gold, rare earths, platinum group minerals, and others. A full cubic mile of metal from this buried asteroid could potentially double the currently known global resource of those metals.

If and when the asteroid hit, much of it exploded upward and outward, scattering large chunks throughout a wide area. Directly below the impact, asteroid fragments measuring many cubic miles could have been driven into the crater floor and survived as fossil asteroid fragments within the older Precambrian gneiss and schist now buried under younger volcanic rocks and much younger marine sedimentary rocks. Impact energy was instantly converted to heat and high temperature that melted a large volume of rock at the base of the impact. (Heat and temperature are related but not the same. Heat = energy *amount*. Temperature = energy *intensity*. A gallon of warm water contains far more energy than a match flame, but the flame has a much higher temperature.)

The huge fragments, ranging from 10 to 20 or more cubic miles in size, would have been widely scattered during the impact from the estimated 523 cubic miles of the parent asteroid. These fragments likely formed their own melted, fragmented, recrystallized mineral deposits and served as raw material for magmatic assimilation and hydrothermal transport, contributing to the creation of iron ore at the Pea Ridge mine in northern Washington County and other southeast Missouri "Olympic Dam-type" igneous/hydrothermal mineral deposits. The namesake Olympic Dam ore deposit is a massive, billion-plus metric ton hydrothermal/replacement deposit that features copper, silver, uranium, and a bit of gold, named after the original and still-operating Olympic Dam mine at Roxby Downs in South Australia.

Geology professor Gary R. Lowell at Southeast Missouri State University and R.W. Harrison of the U.S. Geological Survey published a study on the Eminence-Van Buren volcano located at the center of my proposed asteroid impact site. They noted that erupted materials, reaching up to 8,300 meters (5.15 miles or 27,230 feet) in thickness, are mostly volcanic ash with minor lava flows. The large amount of volcanic ash suggests a high gas content in the erupting magma, indicating intense hydrothermal mineralizing activity at depth. While this depth is far too great for conventional drilling and mining, it suggests that secondary Olympic Dam-type ore deposits might exist higher in the volcanic rocks, within reach of exploration drilling and mining.

This situation presents both opportunities and challenges. The good news is the potential for discovering Olympic Dam-type secondary ore deposits in Missouri's volcanic rocks that overlie the impact structure. These deposits could be within reach of exploration drilling and mining. The bad news is that much of the impact structure itself might be buried too deep for effective mining, except possibly around the perimeter of the volcanic rocks. However, in this type of geologic environment, many ore

THE EXPECTED MINERALS COULD SUPPORT THE PRODUCTION OF HIGH-TECH PRODUCTS AND LOW-TECH GOODS, CREATING A LONG-TERM BOOST FOR THE REGION'S ECONOMY.

deposits tend to occur around the thinner perimeter of a structure. So, the maximum 5-mile thickness of volcanic rock at the center of the volcano might not be as significant an obstacle to exploration as it initially seems.

To understand the scale and potential of such an impact structure, consider the Sudbury mining district in Ontario, Canada, which is remarkably similar to the proposed impact structure in southeast Missouri. At Sudbury, erosion removed the rock overlying the impact structure, exposing it and unfortunately eliminating the possibility of finding secondary ore deposits in those now-missing rocks. In Missouri, the proposed impact structure likely resembles Sudbury's but is buried under a thick and variable cover of Precambrian volcanic and Paleozoic marine sedimentary rocks.

For context, the Sudbury mining district, one of the world's most productive mining regions, has produced approximately 1.7 billion metric tons of ore since mining began in 1886, according to public records. This includes around 40 billion pounds of nickel, 35 billion pounds of copper, 70 million ounces of platinum and gold, and 283 million ounces of silver. These figures underscore the tremendous potential that a similar impact structure in Missouri could offer.

Hopefully, the proposed asteroid impact structure in Missouri will be similarly productive. Due to its extreme depth, the impact structure itself is likely beyond reach for direct mining. However, significant ore discoveries will probably consist of secondary, large, low-grade Olympic Dam-type and vein deposits within the overlying volcanic rocks. Given the geological differences, the ore in Missouri is expected to be richer than that of Sudbury in iron oxide, lanthanides (rare earths), gold, copper, uranium, thorium, and possibly vanadium. Additionally, gemstones such as topaz and colored varieties of quartz, including amethyst and citrine, are also likely to be present.

Should exploration confirm a fossil asteroid deposit and its ore body definition show sufficient inventory to justify mining, these operations could generate significant economic activity for the area — not just from mining and processing these materials but also from manufacturing with them. The expected minerals could support the production of high-tech products, such as military electronics, as well as low-tech goods such as bricks, lightbulbs, and even jewelry, creating a long-term boost for the region's economy.

If this asteroid impact model of mineralization proves true, it could be applied to geologically similar known ore deposits worldwide. Should even a few large, known ore deposits be found to overlie and derive their mineral wealth from exploitable buried asteroids, global mineral reserves might increase by a factor of 50.

In areas such as western South America where several large ore deposits and mines are clustered, some of the metallic mineral wealth could be attributed to scattered fossil asteroids arriving on sinking tectonic plate "conveyor belts." As each asteroid subducts into the asthenosphere, it adds its load of metals along the same narrow linear band, enriching the accumulating ore-rich magma created as the tectonic plate partially melts. These asteroids, melting at similar temperatures and depths, further enhance the metal-rich magma that creates the ore deposits.

The California Gold Rush of 1849 began with the discovery of a mere spoonful of gold by a laborer digging a ditch at Sutter's Mill on the American River. Sometimes, a different way of looking at things and a new conceptual model can lead to far-reaching effects, transforming entire regions and economies.

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