A real rift in the midcontinent

In the heart of the U.S. Midwest, basalt cliffs and lava flows point to a massive break in the continental crust that occurred a little more than a billion years ago, a feature known as the Midcontinent Rift. Splitting the strong, thick North American craton — the stable interior of the continent — would have required dramatic geologic events. Geologists have long suspected two leading scenarios: a plume of hot mantle rock that sat beneath the several-hundred-kilometer-thick lithosphere, something like the one that sits below Yellowstone today; or mantle material upwelling beneath a zone where the Grenville Orogeny had pulled the rigid continental crust apart as a new supercontinent formed.

But now, Carol Stein of the University of Illinois at Chicago and her colleagues have offered a new possibility. Stein and colleagues suggest the Midcontinent Rift was related to the breakup of a supercontinent and to the early stages of a young ocean basin opening — similar to what is happening today in East Africa's Great Rift Valley — that preceded the Atlantic. The findings could have implications for how geologists view early plate tectonics, and cast new light on the New Madrid Fault Zone, formed 500 million years later and home to earthquake-producing faults in Arkansas, Missouri and Tennessee that seriously rocked the region in 1811 and 1812.

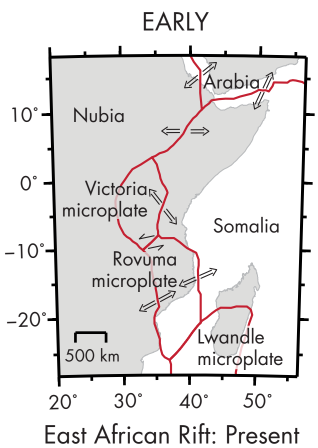
Making the connection to a larger continental breakup was not easy: Most of the rocks that tell the story are now buried beneath younger sediments or have been subducted into Earth's mantle. So Stein and her team turned to data on the wandering paths of the paleomagnetic poles, gravity anomalies, and seemingly unrelated outcrops of mafic rocks in Canada, the U.S., Bolivia and Brazil.

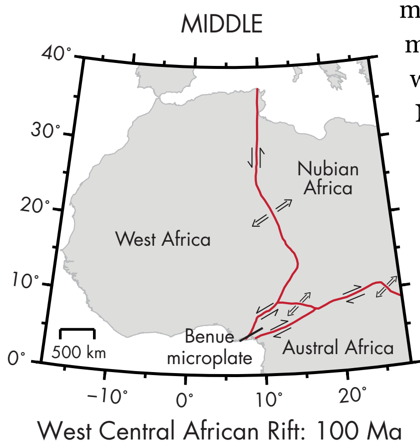
The team assembled paleomagnetic data from across the North American continent and several localities in Brazil. They calculated the paths of polar wander recorded in rocks on the continents, which translate to the movements of the rocks in time and space over millions of years, to show that the continents began pulling apart from one another about 1.1 billion years ago in a lateral motion. That means that what we know now as North America and Brazil were once part of the Laurentian and Amazonian continents, respectively, swinging past each other in opposite directions. The team also cites mafic igneous rocks, which are typically related to rifting, in southern Amazonia that are directly related to rocks in northern Appalachia, further linking Laurentia and Amazonia.

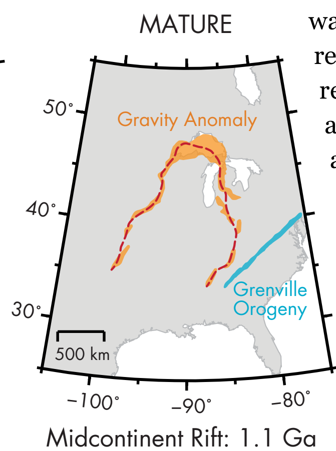
The team then took gravity anomaly data collected from North America and compared the very dense rocks of the Midcontinent Rift to similarly dense bodies nearby in the North American craton, including some to the southeast known as the Fort Wayne Rift and the East Continent Gravity High. These two likely rifts run along the edge of what's known as the Grenville Front, the western edge of the Grenville Orogeny, a mountain-building event that unfolded at about the same time that the Midcontinent Rift formed and the supercontinent Rodinia came together.

Taken together, the timing of the continental movements, the related outcrops and the similar gravitational anomalies across the Laurentia and Amazonia led Stein and her colleagues to suggest in Geophysical Research Letters that the Midcontinent Rift was likely the first in a series of rifts formed at that time. But it failed as the later rifts formed to the east, one of which eventually gave rise to an ocean, an antecedent to the Atlantic.

Stein's team's model shows that "Amazonia was the first straw to break, and once that happened, the rifting happened more easily," says Michael Wysession, a geophysicist at Washington University in St. Louis who wasn't involved with the new research. The strain from Laurentia and Amazonia pulling apart "went into Amazonia, and so the [Midcontinent Rift] shut down," he says. The timing of the cooling of the outcrops the team cites from North America and Brazil, and their similar coincidence with the paleomagnetic poles, are also persuasive, he says.







Analogs for the various life stages of the Midcontinent Rift can be seen today. The early rift looked like today's East African Rift, with major plates pulling apart, separated by microplates. At middle age, it was similar to the West Central African Rift, where faulting during the opening of the South Atlantic during the Mesozoic created four microplates. Looking at the progression could help geologists understand how the Midcontinent Rift evolved, says co-author Seth Stein, a geophysicist at Northwestern University.

Credit: Kathleen Cantner, AGI

The model is the first "that links the formation of this particular continental rift to the opening of the major ocean at that time through plate tectonic processes," says Anke Friedrich of the Ludwig-Maximilians University in Munich, Germany, who has worked with some of the co-authors but was not involved in the study. By piecing together the missing geologic record, she adds, "they are reaching into a black box and raising very fundamental questions" about plate tectonics. Friedrich says the team's findings will factor in the current debate over how rifts begin, particularly in strong continental crust that composes a craton. Breaks might rip along older faults that are weaknesses in that crust, or other characteristics like the presence of water might come into play, weakening the crust.

"It's rather common for rifting to initiate over a broad region and for only some rift faults to be successful, while others are abandoned," says Stephen Marshak of the University of Illinois at Urbana-Champaign, who also has worked with some of the researchers on projects through EarthScope. The new proposal implies similarities between the Midcontinent Rift and the system in the eastern U.S. during the Mesozoic, where early phases of the rift that pulled apart the supercontinent Pangaea stalled as rifting "stepped eastward."

The study raises the question, Marshak adds, of whether other rifts in the Midwest — such as the Reelfoot Rift, of which the New Madrid Fault Zone is a part — represent reactivation of still older rifts.

Naomi Lubick

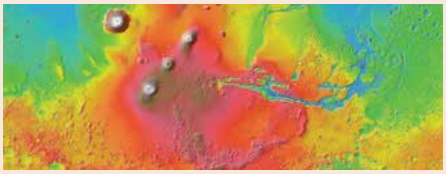
Mars Monthly

As Curiosity and Opportunity rove around Mars, the Mars Reconnaissance Orbiter (MRO), Mars Express and Mars Odyssey orbit above, and scientists on Earth study the Red Planet from afar, new findings are announced almost weekly. Here are a few of the latest updates.

- Thousands of kilometers across and bulging to elevations of almost 10 kilometers, the Tharsis region on Mars hosts several massive volcanoes and straddles the border between the planet's northern lowlands and southern highlands. Some scientists have postulated that the bulge resulted from a stationary hot spot, or plume, of warmer-than-normal mantle rock beneath it, but a new study supports a competing idea that the hot spot migrated to its present position. Karina Cheung and Scott King of Virginia Tech University identified a plume pathway, based on measurements of crustal thickness and surface topography, from Mars' south pole to the current Tharsis bulge. The pathway is characterized by thick crust underlying a relatively smooth stretch of surface that stands out from the surrounding pockmarked surface, and which may have resulted as plume-powered volcanism wiped out craters as it traveled north. The researchers noted in the Journal of Geophysical Research: Planets that the presumed Tharsis hot spot track resembles the path left by the Yellowstone plume as it has migrated under the western U.S.

- East of Tharsis, the 7-kilometer-deep Valles Marineris scars Mars' surface for more than 4,000 kilometers. The massive canyon's origins have remained a mystery to scientists, although various explanations have been suggested, including that it was carved by flowing water, that it is a huge tectonic fault, or, perhaps most commonly, that it is a crack that resulted from stress on the crust due to heavy volcanic activity in the Tharsis region. But in a new study in the Journal of Volcanology and Geothermal Research, Giovanni Leone of ETH Zurich in Switzerland has hypothesized that Valles Marineris and the nearby area of spider-webbed valleys known as Noctis Labyrinthus originally formed as subsurface channels funneling lava away from Tharsis. When the pressure of lava in these tubes subsided, he suggested, their thin ceilings gave way. Subsequent lava flows along the same routes then incised the canyons further, resulting in the features we see today. In a statement, Leone, who analyzed satellite imagery collected by MRO for the study, noted that he expects "a spirited debate" with other scientists over the lava-tube notion.

- Construction of NASA's next Mars lander, InSight, is set to begin after the project passed its Mission Critical Design Review in mid-May. Scheduled for launch in March 2016, InSight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) will study Mars' internal structure and investigate the formation of rocky planets using instruments that can detect seismic waves and heat flow through the planet's subsurface. "We now move from doing the design and analysis to building and testing the hardware and software that will get us to Mars and collect the science that we need to achieve mission success," said project manager Tom Hoffman of NASA's Jet Propulsion Laboratory in Pasadena, Calif., in a statement. Like the Phoenix lander, with which InSight shares many design features, InSight will be built by Lockheed Martin in conjunction with NASA and the French and German space agencies.



The high-elevation Tharsis region appears in shades of red and brown in this topographic map produced with data from the Mars Orbiter Laser Altimeter aboard NASA's now-defunct Mars Global Surveyor.

Credit: NASA/JPL-Caltech/Arizona State University

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