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Shields Up: Magnetized Rocks Push Back Origin of Earth's Magnetic Field

Earth's churning interior produced a protective magnetic field as early as 3.45 billion years ago, closer to when life began

By John Matson

CLASSIC ROCK: Barberton Mountain Land in South Africa preserves relatively pristine rocks formed just a billion years after Earth took shape.
COURTESY OF J. TARDUNO

Earth's robust magnetic field protects the planet and its inhabitants from the full brunt of the solar wind, a torrent of charged particles that on less shielded planets such as Venus and Mars has over the ages stripped away water reserves and degraded their upper atmospheres. Unraveling the timeline for the emergence of that magnetic field and the mechanism that generates it—a dynamo of convective fluid in Earth's outer core—can help constrain the early history of the planet, including the interplay of geologic, atmospheric and astronomical processes that rendered the world habitable.

An interdisciplinary study published in the March 5 *Science* attempts to do just that, presenting evidence that Earth had a dynamo-generated magnetic field as early as 3.45 billion years ago, just a billion or so years after the planet had formed. The new research pushes back the record of Earth's magnetic field by at least 200 million years; a related group had presented similar evidence from slightly younger rocks in 2007, arguing for a strong terrestrial magnetic field 3.2 billion years ago.

University of Rochester geophysicist John Tarduno and his colleagues analyzed rocks from the Kaapvaal Craton, a region near the southern tip of Africa that hosts relatively pristine early Archean crust. (The Archean eon began about 3.8 billion years ago and ended 2.5 billion years ago.)

In 2009 Tarduno's group had found that some of the rocks were magnetized 3.45 billion years ago—roughly coinciding with the direct evidence for Earth's first life, at 3.5 billion years ago. But an external source for the magnetism—such as a blast from the solar wind—could not be ruled out. Venus, for instance, which lacks a strong internal magnetic field of its own, does have a feeble external magnetic field induced by the impact of the solar wind into the planet's dense atmosphere.

Magnetic measures

The new study examines the magnetic field strength required to imprint magnetism on the Kaapvaal rocks; it concludes that the field was 50 percent to 70 percent of its present strength. That value is many times greater than would be expected for an external magnetic field, such as the weak Venusian field, supporting the presence of an inner-Earth dynamo at that time.

With the added constraints on the early magnetic field, the researchers were able to extrapolate how well that field could keep the solar wind at bay. The group found that the early Archean magnetopause, the boundary in space where the magnetic field meets the solar wind, was about 30,000 kilometers or less from Earth. The magnetopause is about twice that distance today but can shift in response to extreme energetic outbursts from the sun. "Those steady-state conditions three and a half billion years ago are similar to what we see during severe solar storms today," Tarduno says. With the magnetopause so close to Earth, the planet would not have been totally shielded from the solar wind and may have lost much of its water early on, the researchers say.

Clues for finding habitable exoplanets

As researchers redouble their efforts to find the first truly Earth-like planet outside the solar system, Tarduno says the relationship between stellar wind, atmospheres and magnetic fields should come into play when modeling a planet's potential habitability. "This is clearly a variable to think about when looking at exoplanets," he says, adding that a magnetic field's impact on a planet's water budget seems particularly important.

One scientist in the field agrees that the results are plausible but has some lingering questions. "I think the work that Tarduno and his co-authors are doing is really exciting," says Peter Selkin, a geologist at the University of Washington Tacoma. "There's a lot of potential to use the tools that they've developed to look at rocks that are much older than anybody has been able to do paleomagnetism on before."

But he notes that even the relatively pristine rocks of the Kaapvaal Craton have undergone low-grade mineralogical and temperature changes over billions of years. "They're not exactly in the state they were in initially," Selkin says, "and that's exactly what has made a lot of paleomagnetists stay away from rocks like these." Selkin credits Tarduno and his co-authors for doing all they can to show that the magnetized samples have been minimally altered, but he would like to see more petrologic and mineralogical analysis. "I think that there are still things that we need to know about the minerals that Tarduno and his co-authors used in this study in order to be able to completely buy the results," he says.

David Dunlop, a geophysicist at the University of Toronto, is more convinced, calling the work a "very careful demonstration." The field strengths, he says, "can be assigned quite confidently" to the time interval 3.4 billion to 3.45 billion years ago. "It would be exciting to push back the curtain shadowing [the] onset of the geodynamo still further, but this seems unlikely," Dunlop says. "Nowhere else has nature been so kind in preserving nearly pristine magnetic remanence carriers."