PHYSICS TODAY

DOI:10.1063/PT.6.1.20200518a

18 May 2020 in Research & Technology

Pressure alters rock magnetization

A rock buried in Earth's crust or a meteorite compressed on impact may end up with increased magnetization.

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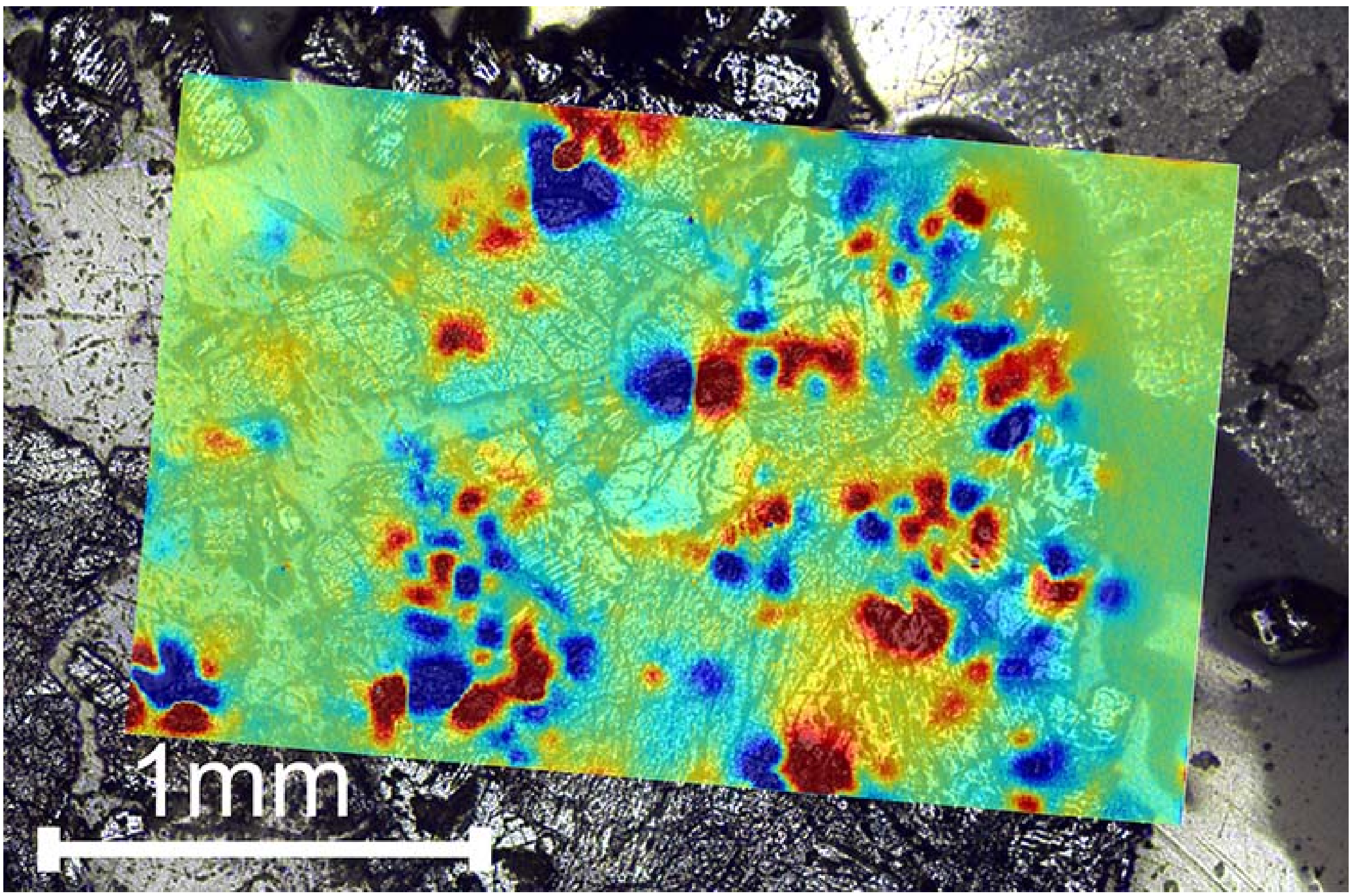
When molten ferromagnetic minerals such as iron cool and solidify, they form magnetized rocks that record the intensity and direction of the planet's magnetic field at the time of formation. However, a rock's natural magnetic remanence is not necessarily a fixed feature. When subjected to increased pressure in the absence of a magnetic field, a rock may lose some of its natural magnetization in a well-known relationship that depends on grain size (see the article by David Dunlop, *Physics* magnetic field present? Theories as far back as the 1960s propose that a rock may acquire stronger magnetization, but they remain untested. Michael Volk and colleagues at Harvard University and the University of Minnesota's Institute for Rock Magnetism have now shown in a series of experiments and calculations that pressure changes alone may replace up to 30% of the rock's natural magnetic remanence. That's enough to influence the results of paleomagnetic studies that infer the strength and direction of a planet's ancient magnetic field based on remanence.



A microscope image of a roughly 1.4-billion-year-old Martian meteorite is overlaid with a magnetic map of the sample. Credit: Courtesy of Michael Volk, Josh Feinberg, and Roger Fu

The researchers started with synthetic magnetite powders, which they mixed with cement to form nonmagnetized synthetic rocks, each with a single grain size. Those synthetic rocks allowed control over grain uniformity that would not be possible in a natural rock. Each synthetic rock was placed in a pressure cell surrounded by a 300 μT field. The researchers gradually increased the cell's pressure to 400 MPa—representative of the pressure experienced by a rock buried as deep as 70 km in Earth's crust. They then measured the sample's magnetic moment, which increased with increasing pressure and showed no dependence on grain size. To understand how that additional magnetization might add to the original thermal magnetization of a natural metamorphic rock, Volk and colleagues used an established scaling law to estimate a thermal magnetic remanence for the synthetic rocks based on the measured magnetic moments. Those calculations led them to conclude that the extra magnetization due to pressure could be as high as 30% of the rock's original magnetization.

The megapascal pressures in the Volk team's experiments could help researchers evaluate paleomagnetic models of rocks from Earth's crust. But studies of objects that originated beyond Earth, such as magnetized meteorites used to estimate when Mars lost its magnetic field, involve samples that experienced gigapascal pressures during impacts. The researchers are exploring the use of a quantum diamond microscope combined with diamond anvil cells to investigate the magnetization in samples at pressures up to 30 GPa. By understanding how pressure influences the magnetic remanence of an ancient Martian meteorite, scientists may be able to determine when the planet's dynamo ceased. (M. W. R. Volk, J. M. Feinberg, *Geochem. Geophys. Geosyst.* **20**, 2473, 2019; M. Volk, R. Fu, J. Feinberg, EGU General Assembly 2020, EGU2020-915.)

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