Million year time scale magnetic record in Mars' Blueberries deduced from Earth's Navaho sandstone (Utah) concretions?

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Introduction: Terrestrial Fe-oxides (e.g., hematite, goethite, and magnetite) form cemented concretions from aqueous diagenetic solution in sandstones. We discovered that magnetic record of a concretion from the Jurassic Navajo Sandstone, Utah [1], contain, at least, three magnetic reversals. Reversals allow for the first time evaluation of the time scale on which iron concretions form. The similarities of terrestrial and Mars concretions [2] supports that similar formation process time scales may occur during the formation of Mars Blueberries found by the Mars rover Opportunity.

Mass transfer processes and fluid chemistries affect water/rock interactions during the concretion formation history in a sandstone [3] and therefore concretions may preserve information about the diagenetic evolution of a sandstone reservoir. This characterization provides a good analog model to reveal diagenetic processes in other settings like the Burns formation with hematite spherules in Meridiani Planum, Mars. The concretion occurrence offers novel diagnostic criteria for diagenetic concretion formation and compare well with similar characterization on the Burns formation spherules [4] as well as to other proposed analog models [5.6].

The formation of marine ferromanganese crusts and nodules (MFC/N) on deep-sea floor results in similar morphologies from the migration of manganese and iron, from reducing to oxidizing environments [7]. Due to their continuous albeit slow growth, usually less than 1 cm/Myr, MFC/N can record long-term environmental changes, such as bottom-water evolution [8] but also magnetic reversals [9]. MFNs abundance [7] are providing a potential opportunity to trace the long-term evolution of the environmental record.

Material and methods: Concretions were sampled from geographically distinct location in Grand Staircase-Escalante National Monument, southeastern Utah (Fig. 1). The Grand Staircase is a natural weathering feature several hundred kilometers long in west to east and nearly 2.8 km high from sea level at the northern most plateau to southernmost at approximately 1.2 km from sea level. The Grand Staircase consist of a series of terraces descending from north to south, and each steps of the staircase outcrop geological units from Mesozoic Era that are distinctive with their hues; our sampling site was located in the Jurassic Navaho Sandstone (White cliffs) where the concretions were formed. The concretions were picked from the weathered horizons of the sandstone.

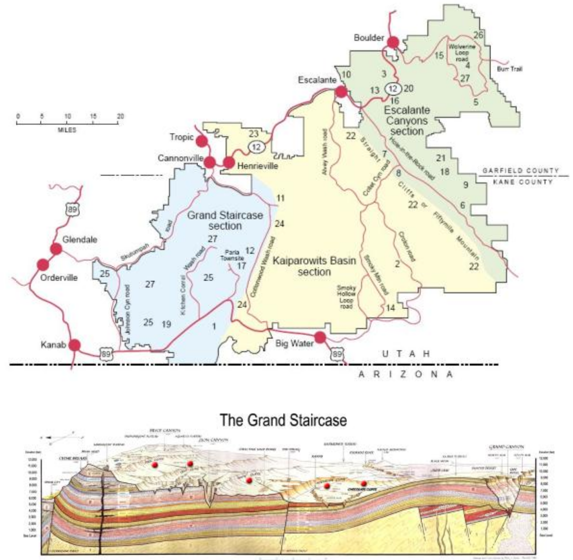

Fig. 1, A, B: Adopted geologic stratigraphic units of the Grand Staircase. Snow canyon samples are 50 km west from Orderville in similar stratigraphy.

We selected three concretions RB01, RB05, RB10. For RB01 we performed demagnetization by alternating magnetic field between 5 mT and 100 mT while measuring the resulting magnetic remanence. For RB05 we used physical abrasion of the outside concretion surface and measured the resulting magnetic remanence. Concretion RB10 was cut into top, middle and bottom sections and resulting magnetic remanence was measured. We used Finite Element Magnetic Modelling (FEMM) and modeled the concretion that had three distinct concentric reversed magnetizations

Results: Here, we use magnetic record of Navajo Utah concretions to reconstruct magnetic field variations. Based on polymetallic measurements and analysis, magnetic variations are derived from the dissolved oxygen-sensitive manganese/iron content, which can be correlated with the geomagnetic record. The concretions contain a reasonably stable and isotropic natural remanent magnetization (NRM) two orders of magnitude larger than the surrounding sediment. The recording of magnetic reversals in three Navaho concretions supports the slow overall growth rates.

RB01 magnetic analysis showed that this concretions contained both soft and hard magnetic coercivities. In addition, soft and hard magnetic coercivity components appeared to have magnetically diverse directions.

RB05: This concretion was about 2.5 cm in diameter. We cut the top and the bottom to obtain the middle cylindrical section about 2.5 cm in diameter and about 1 cm in thickness. The sample was abraded from the outside, using abrasion tool containing diamonds. The sample was abraded 13 times, each time reducing the diameter by one mm and magnetically measured. Magnetization of RB05 continuously grew with each step of physical abrasion of the outside layers. After several mm of abrasion, the magnetic intensity was suddenly reduced. However, this reduction was followed by the magnetic intensity increase with continuous abrasion to the point where the intensity again quickly dropped. When the concretion was about 1,3 cm in diameter, it disintegrated due to interaction of concretion´s sand core with water used for abrasion.

RB10 was cut parallel with the sedimentary layers in such way that we obtained top, middle and bottom of the concretion. Each of these fragments was magnetically measured. The top section was magnetically reversed relative to bottom section. The middle section direction was in between the top and bottom sections.

Discussion and conclusion:

RB01 contained both large and small magnetic coercivities as revealed by the alternating magnetic field demagnetization of increasing intensity. The magnetic directions fluctuated by significant fraction and suggested that the magnetic record of this concretion may contain magnetic reversals. In order to test this idea, we assumed that the age of different layers of the concretion formed at different time, and if we remove the outside, we may see magnetization reversal recorded in the concretion. For this test we used RB05.

RB05 showed that at least three magnetic reversals were recorded in this concretion.

RB10 concretion showed that that the overall magnetic signature is sensitive to the thickness of the layers magnetized in one direction. This was confirmed by FEMM modelling and supported existence of at least three magnetic reversals in Utah Navaho concretions.

Magnetic reversals on Earth last order of millions years. We conclude that Utah concretion formed on the millions of years' time scale. Similarity of the Utah's concretions to the Mars blueberries suggests that Mars concretion may contain magnetic record on the similar time scale, possible recording the once existing magnetic dynamo on Mars.

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