Nature of Magnetism Recorded in Utah Concretions – relation to Mars?

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Introduction: Terrestrial Fe-oxides (e.g., hematite, goethite, and magnetite) growth rate in sedimentary deposits may vary. Sometimes iron deposits form cemented concretions from aqueous diagenetic solution in sandstones.

Mass transfer processes and fluid chemistries control the water/rock interactions during the concretion formation history in a sandstone [3]. This is why concretions may contain the diagenetic evolution of a sandstone rock units. This process may delineate a possible analog model of diagenetic processes in planetary settings similar to the Burns formation containing hematite spherules in Meridiani Planum, Mars [4] as well as to other potential analog models [5.6].

The formation of marine ferromanganese nodules (MFC/N) on deep-sea floor contains morphologies due to the migration of manganese and iron, directed by reducing to oxidizing environments [7]. The continuous slow growth (as slow as 1 cm/Myr) MFC/N appears to contain fairly long-term changes of its environmental conditions, for example, the evolution of bottom-water [8] and potential magnetic reversal record [9]. MFNs [7] provide an interesting opportunity of tracing the long-term environmental evolution.

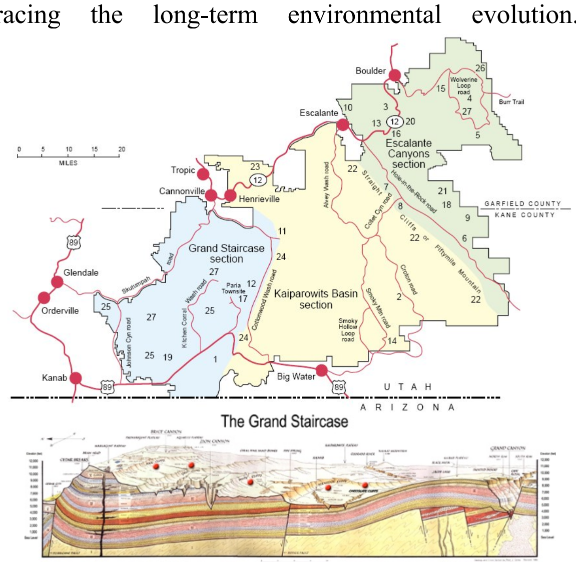

Fig. 1, A, B: Adopted geologic stratigraphic units of the Grand Staircase. Snow canyon samples are 50 km west from Orderville in similar stratigraphy.

Material and methods: Geographically distinct location in Grand Staircase-Escalante National Monument, southeastern Utah was used to collect iron deposits in form of concretions (Fig. 1). Weathering of the Grand Staircase occurs in a distance of several hundred kilometers long in west to east and at 2.8 km elevation above the sea level at the northern most plateau to southernmost at approximately 1.2 km above the sea level. A series of terraces descending from north to south, is such a way that each step of the staircase outcrop is distinctive with their hues. Sampling site was in the White cliffs (Jurassic Navaho Sandstone). The concretions were picked from the weathered horizons.

Three concretions RB01, RB05, RB10 were analyzed. Demagnetization by alternating magnetic field between 5 mT and 100 mT was performed on RB01, while measuring the magnetic remanence. For RB05 we used a completely new approach of physical abrasion of the outside surface and measured at several steps the resulting magnetic remanence. Concretion RB10 was split into three sections: top, middle and bottom. Magnetic remanence was obtained. Additionally we employed Finite Element Magnetic Modelling (FEMM) of three distinct concentric reversed magnetization volumes.

Results: Reconstruction of magnetic field variations resemble the geomagnetic record. The concretions contain a stable and isotropic natural remanent magnetization (NRM) that is about two orders of magnitude more intense than the surrounding sandstone. The appearance of three magnetically reversed volumes supports growth rates on the scale of magnetic reversal time scale.

Concretion RB01 contained both soft and hard magnetic coercivities. In addition, soft and hard magnetic coercivity components showed magnetically diverse directions.

One concretion (RB05 ~2.5 cm in diameter) was used to cut away the top and the bottom and the middle section (~2.5 cm in diameter and ~ 1 cm in thickness). The sample was abraded little by little from the outside, using abrasion tool containing diamonds. This was done in 13 steps, each time reducing the diameter by one ~1mm and magnetically measured each time. Magnetization of RB05 increased its intensity with few initial steps of physical abrasion. After several mm of abrasion, the magnetic intensity suddenly reduced. The observed intensity reduction was replaced by the magnetic intensity enhancement with continuous abrasion until, again, intensity dropped. When about 1.3 cm in diameter, sample.

RB10 was cut parallel with the sedimentary layers Each of the 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:

The magnetic directions of RB01 fluctuated by significant fraction possibly showing magnetic reversals. To test this, we assumed that the age of different layers of the concretion formed at different time. If we remove the outside, we may see magnetization signal reversed. To test this 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 supported by FEMM modelling.

Magnetic reversals on Earth last order of millions years. It is possible that Utah concretion formed on the millions of years' time scale? Our data support this possibility. Similarity of the Utah's concretions to the Mars blueberries may invoke that Mars concretion may contain magnetic record on the similar time scale, possible recording the once existing magnetic dynamo on Mars.

Magnetic record of a concretion from the Jurassic Navajo Sandstone, Utah [1], may 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.

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