HIGH FIELD REMAGNETIZATION OF HEMATITE CONCRETIONS FROM UTAH, USA AND CZECH REPUBLIC.

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Introduction: Terrestrial hematite concretions of the Jurassic Navajo Sandstone in Utah, USA have been described and discussed [1, 2] as analogues to the hematite (blueberries) formation on Mars. We conducted initial magnetic investigation of iron-oxide cemented concretions from Utah, and for comparison, the concretions from Czech. The initial results are reported here.

Method: Natural remanent magnetization, NRM, was measured. Spheroidal concretions < 10 mm in diameter, with relatively weak NRM, were selected, and these concretions were oriented such that their magnetization vector had zero inclination and 360° declination with ±5 degrees for errors with respect to the laboratory coordinate system. This magnetization direction was used to orient the samples in the x-direction inside a one-axis alternate field (AF) demagnetizer, and inside a one-axis impulse magnetizer. First, concretions were demagnetized with alternating field from 2 to 240 mT. Second, they were remagnetized in the negative x-direction, and third, remagnetized in the positive direction.

Results: The NRM of various concretions ranged from 0.1 to 1.4 Am^2/kg (Table 1). AF demagnetization results were plotted in figure 1. Utah samples, L1 and M6 show almost the same results, and along O1 (Czech), they were hard to be demagnetized, except U1 showed low coercivity component that may indicate presense of low coercive component. Figure 2, A through D shows the results of remagnetization for the two from Utah, L1, M6; and the other two from Czech, U1 and O1. Both Utah and Czech concretions continued to saturate in fields exceeding 5 Tesla. The maximum measurable (with our 2G superconducting magnetometer) magnetization is around 400 Am^2/kg (mass of concretions ranged between 0.30 and 1.45 g, Table 1), and the impulse magnetizer can generate up to 5.2 T. The maximum Magnetization, M of Utah sample L1 was 88.0, and M6 was 85.0 Am^2/kg both at 5.2 T. The M of Czech concretions: O1: larger than 352 Am^2/kg at 5.2 T; and U1 went up to 415 Am^2/kg at only 2.8 T. Inflection points (red arrows) in the second remagnetization curve (pink) are different for each samples. Second remagnetization M of Czech samples were out of range and could not measured until remagnetizing filed of 150 mT. The remagnetization curve at the maximum field show steep increasing slope rather than flattening which means that the concretions saturate at fields far exceeding 5 Tesla field.

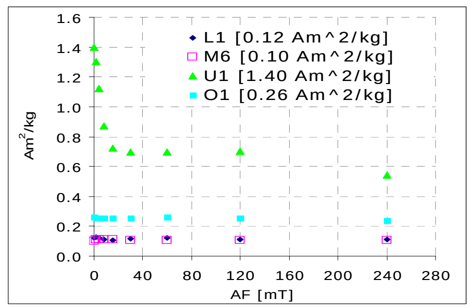
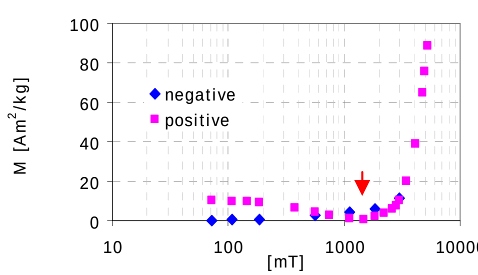
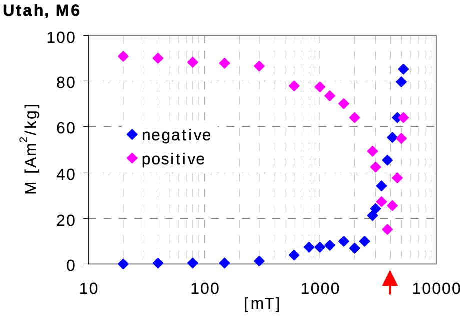


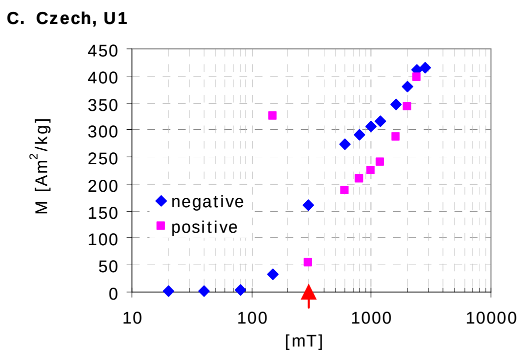
Figure 1: Results of AF demagnetization of Utah and Czech samples were plotted. The values in bracket next to the sample IDs are natural remanent magnetization, NRM before the AF demagnetization.

A. Utah L1



B. Utah, M6





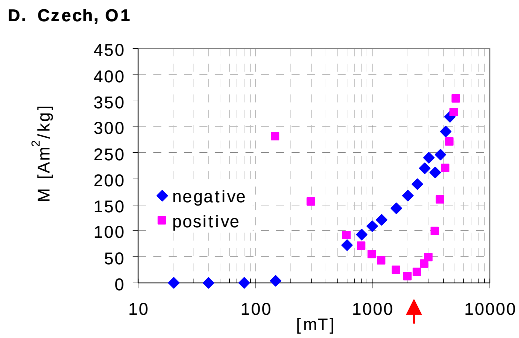


Figure 2A – 2D: Remagnetization in the negative (blue diamond) and positive directions (pink square) from initial (after AF demagnetization) upto 5.2 T. Magnetization, M in the x-axis and applied pulse magnetizaing field is in the y-axis. All four samples show the upward steep slope of the magnetization curve from the inflection point (red arrows) that indicates no saturation at 5.2 T.

	Sample ID	Mass [g]	NRM [Am²/kg]	Max. M [Am²/kg]	Max. field [T]
Utah	L1	0.304	0.1228	88	5.20
Utah	M6	0.219	0.1032	85	5.20
Czech	O1	1.447	1.3976	352	5.20
Czech	U1	1.195	0.2586	415	2.80

Table 1. : Parameters for the concretions from Utah and Czech.

Discussion: Hematite (αFe_2O_3) is antiferromagnetic with superimposed weak ferromagnetism, and its spontaneous magnetization is ~0.5 Am^2/kg [3]. The Utah concretions may contain ultra-fine-grained hematite cement derived from dehydration of weathering products like goethite (αFeOOH) [4]. Although hematite is antiferromagnet, ultra-fine-grained hematite along with the presense of goethite may be responsible for observed behaviors of remanent magnetizations. Bulk magnetization, M, when remagnetized in two opposing directions (1^{st}: negative, and 2^{nd}: positive), showed the inflection point in the 2^{nd} remagnetization (fig. 2, red arrows). The associated field indicates the coercivity of the minor hysteresis loop since the sample was not saturated. Interestingly, large increases in such remanent magnetization should be caused by the parasitic ferromagnetism or spin-canting phenomenon [4]. When these magnetizations were cooled down to 77K they showed significant increase in M (due to superparamagnetism), and when slowly brought back to room temperature, samples converged to magnetization around 100 Am^2/kg. This phenomenon needs to be validated with more data. Czech concretion U1 showed low coercivity component and suggests a presence of low coercivety mineral such as magnetite since the M became out of range (exceeding 400 Am^2/kg) only at the field, 2.8 T (Fig 1 and Table 1).

The Utah and Czech concretions showed unusual and complex behavior of antiferromagnetic hematite-goethite composition. Magnetite, hematite and goethite, or combinations of these can memorize past magnetization events. This has significant implication regarding the potential to interpret preserved paleomagnetic records within concretions both on Earth and Mars [5] and further shows the possible application of magnetic instruments on future payloads of Mars exploration vehicles.

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References: [1] Ormö et al., (2004), Icarus 171, 295-316; [2] Chan et al., (2005), GSA TODAY, 15 (8), 4-10, [3] Dunlop and Kletetschka (2001), GEOPHYSICAL RESEARCH LETTERS, 28 (17), 3345-3348, [4] Dunlop and Özdemir (1997), Cambridge University Press. [5] Kletetschka et al, Meteoritics, 35(5), 895-899, 2000.