# HYDROCARBON RELATED BLEACHING OF STRATA AND HEMATITE DEPOSITION IN RED BEDS AT MOAB, UTAH: A POSSIBLE ANALOGOUS PROCESS THAT FORMED BRIGHT LAYERS AND HEMATITE DEPOSITS ON MARS.

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**Introduction:** The existence of large hematite deposits on Mars is now established, yet enigmatic [e.g. 1; 2]. In order to understand the processes behind their formation comparisons are often made with terrestrial hematite occurrences (e.g. Banded Iron Formations). In this study we are investigating an area near Moab, Utah, where large hematite concretions occur within Jurassic continental sandstones and exposed on the surface as weathered-out beds (Fig.1). A common appearance is cylindrical pipes and columns of hematite cemented sandstone that cut the surrounding, primary bedding of the sandstone. In some areas weathered-out pipes generate clusters of towers many meters high [3]. The occurrences are not nearly as extensive as the hematite deposits on Mars, but the process behind their formation is of interest as it provides a link between hematite deposits and hydrocarbons.

Fig. 1. Weathered-out hematite concretions at Moab, Utah, forming a bed on sandstone. The hat indicates the scale. Foto J. Ormö

Fig. 2. Rainbow Rock, Utah. Bleaching of strata along permeable layer. The bed is about 7 m thick. Foto J. Ormö

**Process of hematite enrichment at Moab:** Chan et al. [3] suggest the concretions at Moab to have formed when a reduced, low pH, high salinity brine moved up along a fault and percolated permeable sandstones where it met oxidizing meteoric water with higher pH. The brine dissolved iron from red-beds causing bleached layers (Fig.2). The iron was transported in a reduced state until it precipitated as hematite when encountering the oxidizing water. This has caused concentric structures where sometimes the flow direction of the oxidizing fluid is visible (Fig.3). The reducing conditions were due to hydrocarbons, methane, organic acids, or hydrogen sulfide in the brine. The bleached beds from where the iron was dissolved are clearly visible in the area. The Moab site was visited in 2001.

Fig. 3. Hematite cemented pipe in sandstone, Utah. Precipitation of hematite in concentric patterns indicate two directions of the groundwater flow. Foto J. Ormö

**Martian hematite occurrences:** Relatively high concentrations of Martian hematite deposits have been identified at Sinus Meridiani, Aram Chaos, and small areas within Valles Marineris [1]. The identified mineral is crystalline, coarse-grained (>10µm), gray hematite [1] and may be axis-oriented grains [4]. The friable layered unit in Terra Meridiani where hematite is concentrated (~10-15%) was interpreted to be sedimentary [1] or pyroclastics ([5; 2]. Thermal inertia data indicate that the unit is made of, or covered by, sand-sized materials. The hematite unit appears superposed on Middle to Late Noachian cratered terrain. Christensen et al. [1] assessed five different mechanisms of hematite deposit formation (1: chemical precipitation (a. low-temperature precipitation in Fe-rich water, b. laterite-style weathering, c. direct precipitation from circulating hydrothermal fluid, d. coating formation by weathering) 2: thermal oxidation of magnetite-rich lavas). 1a and 1b require an oxidative process to convert Fe-oxide/oxide assemblages to coarse-grained, gray hematite. They preferred chemical precipitation (1a or 1c) based on the geological settings assuming that the hematite-bearing unit is sedimentary. Hynek et al. [2], on the contrary, considered that the hematite-bearing unit is pyroclastic in origin and advocated thermal oxidation of volcanic ash or precipitation from circulating fluids. In the case of the latter hypothesis, the flow may have been under hydrothermal or ambient conditions, but the latter favored by the apparent lack of minerals typical in terrestrial hydrothermal hematite environments [2]. The observation that the hematite formed along a single stratigraphic horizon [2] indicates that precipitation may have occurred in a more permeable layer like in the Moab case. The Moab model does also not require a hydrothermally driven system. Instead the fluids were driven by differences in confining pressure between permeable near-surface layers where precipitation occurred and the deeper located fluid reservoir [3]. Hynek et al. [2] show some geological features in the Martian hematite areas that could favor mineral precipitation from groundwater flow (e.g. possible cementation along joints, and concentric ring patterns). The high albedo ring features (Fig. 4) that characterize the surface appearance of the smooth hematite unit have been shown not to relate to fossil craters, but to some other exogenic or endogenic mechanism [2]. Such features are consistent with the Moab occurrence (Fig. 3) although the Martian examples are several magnitudes greater in size.

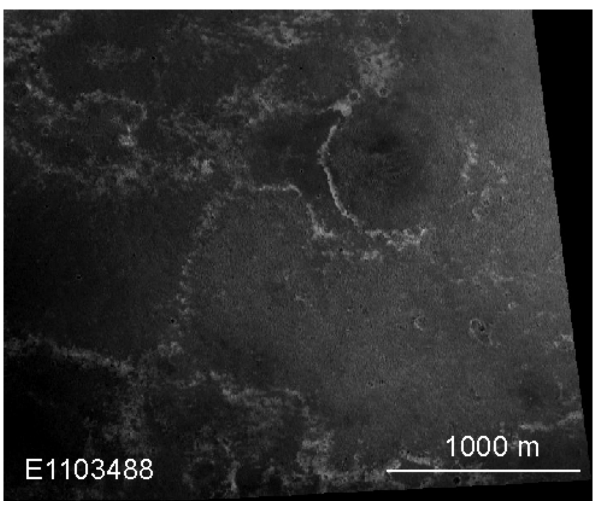


Fig. 4. Concentric, high albedo ring structures in Sinus Meridiani hematite area. Image courtesy Malin Space Science System.

**Comparative studies:** In this study we have focused on surface features in the Martian hematite region in Terra Meridiani, which may be analogous to the features in the Moab locality. Of special interest are the high albedo ring patterns, which may be related to bleaching of strata (i.e. the Rainbow Rock analog) and knobs and domes that may represent cementation along pipes (Fig. 5). The high albedo rings can sometimes be linked to subcircular depressions (Fig. 6).

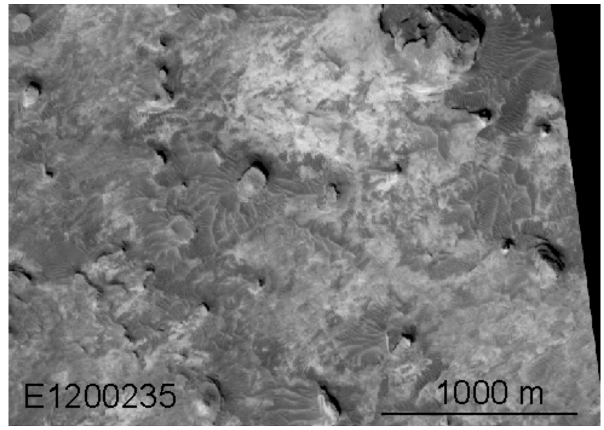


Fig. 5. Subcircular knobs and domes in the Sinus Meridiani hematite area. Possibly weathered-out pipes. Image courtesy Malin Space Science System.

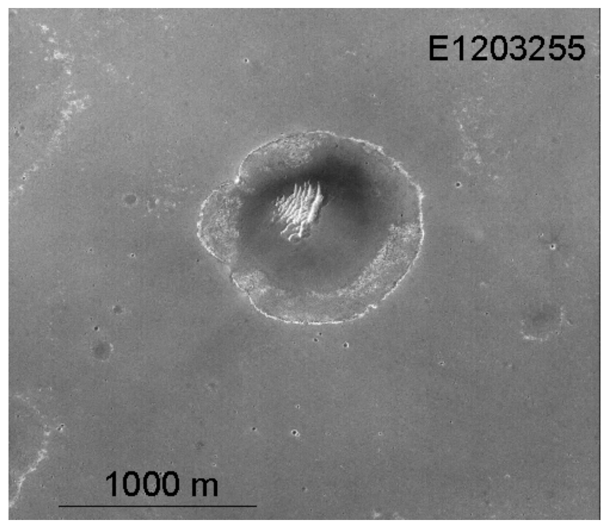


Fig. 6. High albedo ring surrounding a depression in Sinus Meridiani hematite area. Image courtesy Malin Space Science System.

The much fresher appearance of the ring than the depression in Fig. 6, and rings without depressions probably exclude that the rings formed in connection to impacts. We think that the depressions represent vents for fluids and the low albedo rings are zones of mineral (hematite?) precipitation. If the depressions are eroded or buried impact craters, the localized increase in fracturing may have provided an aquifer for later groundwater flows.

**References:** [1] Christensen P. R. et al. (2001) *J. Geophys. Res*., 106, E10, 23873-23885. [2] Hynek B. M. et al. (2002) *J. Geophys. Res*., 107, E10, (in press). [3] Chan et al. (2000) *AAPG Bulletin*, 84, 1281-1310. [4] Lane M. D. et al. (2002) *J. Geophys. Res.,* 107, E10, (in press). [5] Chapman, M. G. and Tanaka, K. L. (2002) *Icarus,* 155, 324-339.