**HEMATITE ON THE SURFACE OF MERIDIANI PLANUM AND GUSEV CRATER.** J. Brückner[1], G. Dreibus[1], E. Jagoutz[1], R. Gellert[1], G. Lugmair[1], R. Rieder[1], H. Wänke[1], J. Zipfel[1], G. Klingelhöfer[2], B. C. Clark[3], D. W. Ming[4], A. Yen[5], K. E. Herkenhoff[6], and the Athena Science Team, [1]Max-Planck-Institut für Chemie, J. J. Becher Weg 27, D-55128 Mainz, Germany, e-mail: bruecker@mpch-mainz.mpg.de, [2]Instit. f. Anorgan. Analyt. Chemie, Univ. of Mainz, Germany, [3]Lockheed Martin Corp., Littleton, CO, USA, [4]Johnson Space Center, Houston, TX, USA [5]Jet Propulsion Lab., Pasadena, CA, USA [6]U.S. Geological Survey Astrogeology Team, Flagstaff, AZ, USA.

**Introduction:** Meridiani Planum was selected as a landing side for the Rover Opportunity because of an indication of hematite observed from orbit [1]. Meridiani Planum consists of sorted sands with aeolian features like ripples and desert pavements. In impact craters, a high-albedo layered bedrock is exposed. The soil is a mixture of: (i) fine sand material in the size ranges of 50 to 150 µm, (ii) subangular, irregular particles of 0.5 to 5 mm size with submillimeter circular voids that are most likely vesicular basaltic fragments [2, 3], and (iii) spherules with a restricted grain size between 4 and 6 mm [3]. The Mini-TES on board the rover Opportunity identified a hematite signature at distance [4] resulting from mm-sized spherules as determined by the Mössbauer Spectrometer [7]. Small quantities of similar spherules (2 vol. %) were found in rock exposures in Eagle crater and were interpreted as concretions that formed by precipitation from aqueous fluids inside sedimentary rocks [5]. At Gusev crater no hematite was observed until sol 90 except for layering on a rock. Our investigations of hematite bearing materials, measured by the Alpha Particle X-ray Spectrometer (APXS), Mössbauer Spectrometer (MB), and Microscopic Imager (MI), provide a more integrated view of different occurrences of hematite on the martian surface.

**Chemistry of soils and rocks:** Chemical compositions of soils and outcrop rocks, as measured by the APXS [6], are remarkably uniform if normalized to the same low S concentration of 2 wt. %. In contrast, the MB [7] discovered a wide variation in mineralogy of soils and outcrops.

Ratios of Fe to Mn are compared with Fe concentrations (in weight %) for various samples (Fig. 1). Most samples cluster at a mean Fe/Mn ratio of about 50 and range in Fe from 13 to 17 wt. %. Exceptions are soils with very high Fe contents, such as targets dubbed 'JackRussell,' 'FredRipple', and 'Berry Bowl full' with a Fe/Mn ratio of about 110.

Similar observations as for the Fe/Mn system are made for Fe/Ti, Fe/Cr, and Fe/Zn: Mn, Ti, Cr, and Zn do not follow the increased Fe content. The only exception is Ni that shows a good correlation with Fe.

There is a significant difference in Fe mineralogy for Berry Bowl full, a bowl-shaped depression filled with spherules, and 'Berry Bowl empty', the spherule-free rim of the bowl. In Berry Bowl full, at least (depending on the areal coverage) 64 % of the total Fe content is associated with hematite as determined by MB. Based on the total Fe content of 24.1 wt. % from APXS, the hematite ($Fe_2O_3$) content is 22 wt. %. Assuming that pure hematite spherules in the Berry Bowl cover not more than 50 % of the field of view of the APXS in the bowl, the hematite of Berry Bowl full would increase to a value of 60 wt. % considering 13 wt. % Fe content of Berry Bowl empty. The measured Fe content of 24 wt. % would be off by a factor of 1.8. Either the spherules are not made of pure hematite or are covered by airfall dust. If such a thin dust layer was present, and there are indications in the APXS data, the Fe signal from the spherules could be a lower limit due to the lack of corrections for a layering model. Since the average sampling depth of the APXS measurement is about 20 µm for the Fe and Mn radiation, the high Fe/Mn ratio bearing material must be close to the surface.

It should be noted that for the hematite-rich soils like 'JackRussell' and 'FredRipple' nearly the same amounts of hematite as for Berry Bowl full were calculated.

**Discussion:** Because $Fe^{2+}$ and $Mn^{2+}$ have similar chemical characteristics, their ratio remains constant for most geochemical processes. In Fig. 2, the Fe/Mn ratio [6] is plotted versus Fe content in hematite [7] for Meridiani samples. A straight line can be closely fitted through the soil data points. The trench data are close to this line. The outcrop samples that have similar Fe/Mn ratios as the hematite-poor soils form a separate group with higher hematite contents than the soils. Except for Fe, S, and Br, the soils and outcrops show similar chemical compositions at Eagle crater. However, the MB results [7] indicate a different mineralogy between hematite-poor soils (high $Fe^{2+}$) and outcrops (high $Fe^{3+}$). On the basis of the similar Fe/Mn ratios in rocks and these soils, the difference in mineralogy can be explained by an isochemical change resulting from a change in the oxidation state of iron.

All high hematite bearing soils are top surface samples (e.g. crest of ripple dubbed 'FredRipple'), while corresponding subsurface soil samples and soils disturbed by rover wheels (near 'JackRussell' and 'FredRipple') have low hematite contents.

MI images of 'JackRussell' and 'FredRipple' show two places where fine sand is greatly reduced and spherules and fragments are paving the ground (Fig. 3). The area of 'JackRussell' is covered by about 30 % spherules and 'FredRipple' is dominated by about 60 % subangular fragments from basalts or spherules. However, both sites have almost identical concentration of hematite (about 22 wt. %) as also found for Berry Bowl full and same Fe/Mn ratios. Based on these observations, it can be concluded that the occurrence of hematite is not only linked to the presence of spherules [7].

Frequently we observed vesicular fragments by MI for which a basaltic composition cannot be ruled out. Therefore, we propose layering of fine-grained hematite to explain some of these observations. Mn-poor hematite coating could significantly contribute to the observed high fraction of hematite in undisturbed surface samples.

Observations by the Rover Spirit at Gusev crater also show a strong indication for hematite coating. The rock 'Mazatzal' was analyzed by MB and APXS [8, 9]: Hematite was only observed on its undisturbed outer surface with a Fe/Mn ratio of 56, whereas the abraded rock had no hematite and a reduced Fe/Mn ratio of 47. This suggests that Mazatzal's surface was also coated by Mn-poor hematite.

**Conclusion:** Taking these observations together, it seems that different hematite forming processes occurred at Meridiani. In the outcrops with the same Fe/Mn ratio, as found for the soil samples (Fig. 2), the formation of the main portion of fine dispersed hematite must be an isochemical re-crystallization process under strongly oxidizing conditions. Based on APXS measurements we cannot distinguish whether spherules consist of pure hematite or carry a thin layer of hematite. However, the very high Fe/Mn ratios of three undisturbed samples together with very high hematite contents suggest the presence of a hematite-rich top layer irrespectively of shape and area coverage of spherules or fragments. Meridiani Planum is a hematite-rich environment, where hematite is dispersed everywhere.

**References:** [1] Christensen, P. R. et al. (2000) *JGR, 105*, 9623-9642. [2] Herkenhoff, K. E. et al. (2004) *Science, 306*, 1727-1730. [3] Soderblom, L. A. et al. (2004) *Science, 306*, 1723-1726. [4] Christensen, P. R. et al. (2004) *Science, 306*, 1733-1739. [5] Squyres, S, et al. (2004) *Science, 306*, 1698-1703. [6] Rieder, R. et al. (2004) *Science, 306*, 1746-1749. [7] Klingelhöfer, G. et al. (2004) *Science, 306*, 1740-1745. [8] Morris, R. V. et al. (2004) *Science, 305*, 833-836. [9] Gellert, R. et al. (2004) *Science, 305*, 829-832. [10] Brückner, J. et al. (2003) *JGR, 108*, ROV 35 1-18.

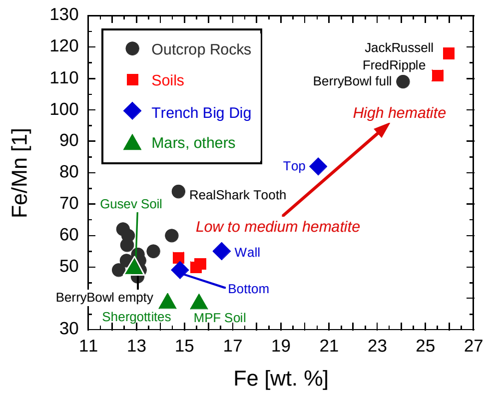


**Fig. 1** Ratio of Fe to Mn versus total Fe content (weight %). Full names 'feature, target' together with sol numbers (martian day of APXS integration) of Meridiani samples are: 'DogPark, JackRussell' (Sol 80), 'DogPark, FredRipple' (Sol 91), 'Berry Bowl, Empty' (Sol 48), 'Berry Bowl, Rubel' (full) (Sol 46), 'RealShark Tooth, Enamel1' (Sol 51), Trench: 'Hematite Slope, Hema2' (= Top) (Sol 23), 'Big Dig, Hematrench1' (= Bottom) (Sol 25), and 'Big Dig, Hematrenchwall2 (= Wall)' (Sol 26). 'MPF Soil' is Mars Pathfinder mean soil [10]. 'Shergottites' are martian meteorites.

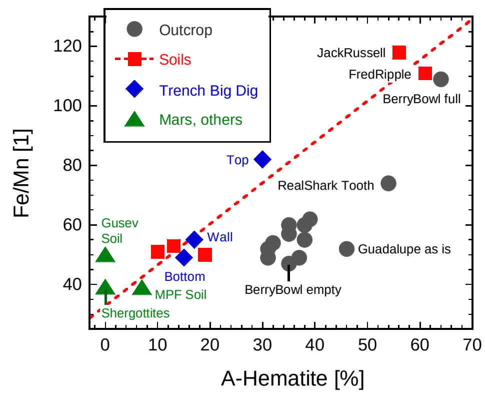


**Fig. 2** Fe/Mn ratio versus A-Hematite (percentage of iron in hematite compared to total Fe content). Samples as in Fig. 1.

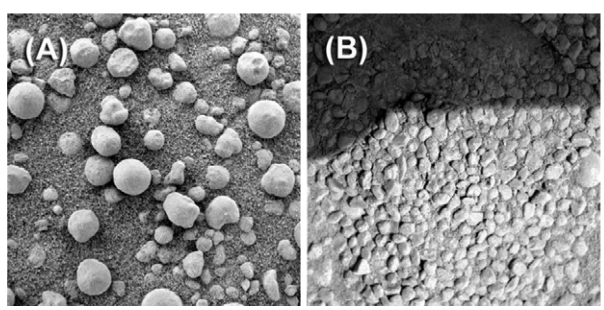


**Fig. 3** Surface texture of iron- and hematite-rich targets JackRussell (A) and FredRipple (B) measured by APXS and MB. Image by MI, width 3 cm.