TWO YEARS OF CHEMICAL SAMPLING ON MERIDIANI PLANUM BY THE ALPHA PARTICLE X-RAY SPECTROMETER ONBOARD THE MARS EXPLORATION ROVER OPPORTUNITY.

J. Brückner[1], R. Gellert[2], B. C. Clark[3], G. Dreibus[1], C. d'Uston[4], T. Economou[5], G. Klingelhöfer[6], G. Lugmair[7], D. W. Ming[8], R. Rieder[1], S. W. Squyres[9], H. Wänke[1], A. Yen[10], J. Zipfel[11], and the Athena Science Team, [1]Max-Planck-Institut für Chemie, J. J. Becher Weg 27, D-55128 Mainz, Germany, brueckner@mpch-mainz.mpg.de, [2]Depart. Physics, Univ. Guelph, Guelph, On, Canada, [3]Lockheed Martin Corp., Littleton, CO, USA, [4]Centre d'Etude Spatiale Rayon., Toulouse, France, [5]Lab. Astrophys. Space Res., E. Fermi Inst., Univ. Chicago, USA, [6]Instit. Anorgan. Analyt. Chemie, Univ. Mainz, Germany, [7]UCSD, Scripps Inst. Oceanogr., La Jolla, CA, USA, [8]Johnson Space Center, Houston, TX, USA, [9]Center Radiophys. Space Res., Cornell Univ. Ithaca, NY, USA, [10]Jet Propulsion Lab., Pasadena, CA, USA, [11]Forschungsinst. & Naturmuseum Senckenberg, Frankfurt/Main, Germany.

Introduction: For over two terrestrial years, the Mars Exploration Rover *Opportunity* has been exploring the martian surface at Meridiani Planum using the Athena instrument payload [1], including the **A**lpha **P**article **X**-**R**ay **S**pectrometer (APXS). The APXS has a small sensor head that is mounted on the robotic arm of the rover. The chemistry, mineralogy and morphology of selected samples were investigated by the APXS along with the Mössbauer Spectrometer (MB) and the Microscopic Imager (MI). The **R**ock **A**brasion **T**ool (RAT) provided the possibility to 'dust' and/or abrade rock surfaces down to several millimeters to expose fresh material for analysis. We report here on APXS data gathered along the nearly 6-kilometers long traverse in craters and plains of Meridiani.

Measurements: The APXS sensor head contains radioactive curium-244 sources to excite x-rays with alpha particles (**P**article-**I**nduced **X**-ray **E**mission, PIXE) and x-rays (X-Ray Fluorescence). A high resolution x-ray detector measures the induced x-rays emitted by the sample. The penetration depth of the APXS radiation is just several micrometers into a sample surface. For details see [2,3]. Regional variations in composition are illustrated by concentrations normalized to one sample.

Chemistry: The Meridiani samples can be divided into several distinct groups: basaltic global soils, iron-rich spherules, sulfur-rich outcrops, and erratic objects.

Soils. The undisturbed soil composition, e.g. soil in Eagle crater [4], resembles compositions found at Gusev crater and other landing sites [5]. However, Fe, Ni, and Cr contents and Fe/Si ratios are higher in Meridiani soils than in Gusev soils suggesting that there has been some admixture of debris from local rocks at Meridiani to an otherwise globally homogenized soil [4]. The enrichment of Fe results from an admixture of the mineral hematite as determined by MB [6]. In spite of the surrounding sulfur-rich outcrops at Meridiani, S and Cl contents of soils vary only by about 30% and are similar to the values found at Gusev (Fig. 1).

Spherules. One of the most intriguing features of Meridiani Planum is the large number of spherules (1 to 8 mm spheres, also dubbed "blueberries") that are mainly found on top of soils and bedrocks [1]. Small quantities of the berries (<2 vol.-%) were also discovered embedded in the light-toned outcrops [7]. In Eagle crater, several spherules appeared to be weathering out of the outcrop.

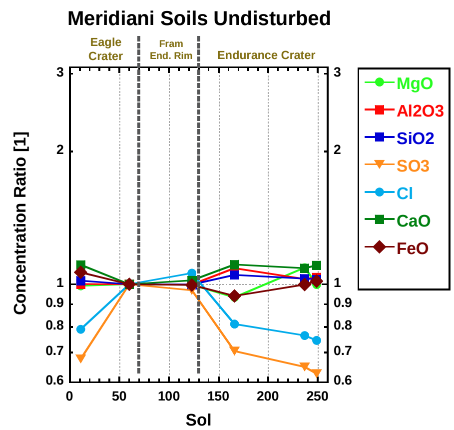

Figure 1 Concentration ratios of undisturbed Meridiani soils with low iron content normalized to soil 'MontBlanc' (Sol 60).

APXS and MB measurements confirmed that the berries contain high iron concentrations [4] mainly present as hematite [6]. Based on conservative estimates spherules probably consist of more than 50% hematite. However, angular fragments were also found on the surface that had similar Fe and hematite contents [8]. Hematite-rich samples were discovered all along the rover's traverse up to Erebus crater (Fig. 2). The formation of hematite is typically, but not exclusively, an indicator for aqueous activity under oxidizing conditions [6]. Erosional processes of the sulfate-rich rocks may be responsible for the accumulation of vast amounts of hematite-rich spherules and fragments just on top of the surface [9]. In addition, fine-grained hematitic material was discovered in the outcrops [6].

Outcrops. Light-toned layered outcrops were discovered in Eagle crater and later in other craters, as

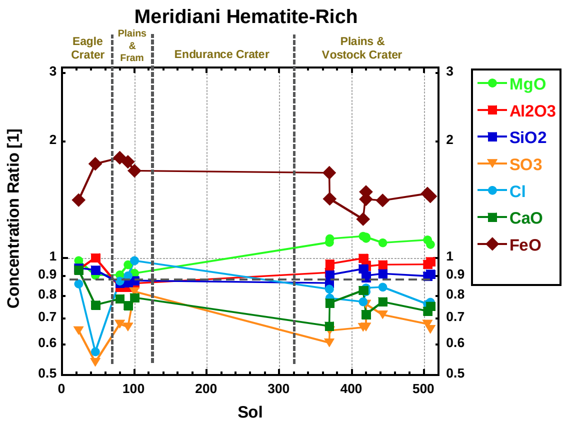

Figure 2 Concentration ratios of hematite-rich samples at Meridiani normalized to the hematite-poor soil 'MontBlanc'. Note the relative high Fe concentrations.

well as along the rover's traverse up to Erebus crater (Fig. 3). Compared to the soils most of these undisturbed rock surfaces have a mean S content of 6 weight-%, i.e. a factor of 2 to 3 higher S concentrations. Rock interiors exposed by the RAT showed even higher S contents of more than 10 wt-%. Assuming all SO_3 is bound to Mg and Ca sulfates and, according to MB data [6], to ferric sulfates, these rocks contain about 40 wt-% sulfates [10].

High concentrations of Br were also discovered in various outcrop samples abraded with the RAT. The high abundances of S and Br in these rocks point to an ancient occurrence of acidified water and the formation of brines, which later had been periodically evaporated. The acidic conditions during the formation of the hematitic spherules in the rocks as concretions allowed co-precipitation of Fe_2O_3 and NiO but not of MnO [4].

When the rover was climbing into Endurance crater, a stratigraphic sequence of the salt-rich silicic sediments was measured with all instruments. Large variations in Cl were not accompanied by enrichments of Br and S. Major elements varied within smaller ranges except for deeper parts of Endurance crater, where Mg is depleted together with S but Si and Al are enriched. These different layers provide further evidence of episodes during which temperature, acidity, and amount of water underwent significant change [10]. Survival of soluble salts on the outcrops points to a dry history of Meridiani since the time of crater excavation [10].

On the rover's journey to Erebus crater, more light-toned bedrocks below the top soil layer were encountered whose chemical compositions resemble those of the previous outcrops in the impact craters, indicating a broad lateral continuity of the outcrop exceeding several kilometers.

Erratic Objects. Two rocks on the plains can be related to known meteorite classes: 'Bounce Rock' is similar in chemistry and mineralogy to basaltic shergottites [11], a subgroup of martian meteorites. 'Heat Shield Rock' with high Fe and Ni concentrations is an iron meteorite. Small rocks sporadically strewn on top of the soil, so-called cobbles show varying chemical compositions.

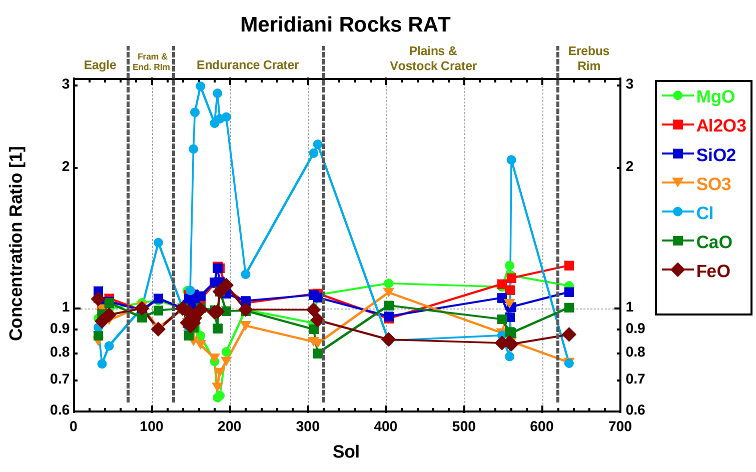

Figure 3 Concentration ratios of abraded rocks at Meridiani normalized to 'Tennessee', topmost rock measured inside the wall of Endurance crater (Sol 139).

References: [1] Squyres S. W. et al. (2004) *Science, 306*, 1698. [2] Rieder R. et al. (2003), *J. Geophys. Res., 108(E12)*, 8066. [3] Gellert R. et al. (2006), *J. Geophys. Res., 111*, doi:10.1029/2005 JE002555, in press. [4] Rieder R. et al. (2004) *Science, 306*, 1746. [5] Gellert R. et al. (2004) *Science, 305*, 829. [6] Klingelhöfer G. et al. (2004) *Science, 306*, 1740. [7] Squyres S. W. et al. (2004) *Science, 306*, 1706. [8] Brückner J. et al. (2005) *LPS XXXVI*, Abstract #1767. [9] Soderblum L. A. (2004) Science, 306, 1723. [10] Clark B. C. et al. (2005) *EPSL, 240*, 73. [11] Zipfel J. et al. (2004) *MAPS, 39*, A118, Suppl. S.

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