An overview of Moessbauer mineralogy at Gusev crater, Mars

R. Morris (1), G. Klingelhoefer (2), C. Schroeder (2), D. Rodionov (2,3), A. Yen (4), and D. W. Ming (1)

(1) NASA Johnson Space Center, Houston, TX, USA, (2) Johannes Gutenberg-Universitat, Mainz, Germany, (3) Space Research Institute IKI, Moscow, Russia, (4) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (richard.v.morris@nasa.gov)

The Mars Exploration Rover (MER) Spirit landed on the plains of Gusev Crater on 4 January 2004 [1]. The scientific objective of the Mössbauer (MB) spectrometer on Spirit is to provide quantitative information about the distribution of Fe among its oxidation and coordination states, identification of Fe-bearing phases, and relative distribution of Fe among those phases. The speciation and distribution of Fe in Martian rock and soil constrains the primary rock types, redox conditions under which primary minerals crystallized, the extent of alteration and weathering, the type of alteration and weathering products, and the processes and environmental conditions for alteration and weathering. We discuss the Fe-bearing phases detected by Spirit's MB instrument during its first 540 sols of exploration [2,3].

Spirit roved eastward across the plains from its landing site to the Columbia Hills during the first $\sim$150 sols. Rocks are unweathered to weakly weathered olivine basalt, with olivine, pyroxene (Ol $>$ Px), magnetite (Mt), and minor hematite (Hm) and nanophase ferric oxide (npOx) as their primary Fe-bearing minerals. Soils are generally similar basaltic materials, except that the proportion of npOx is much higher (up to $\sim$40%). NpOx is an oct-Fe^{3+} alteration product whose concentration is highest in fine-grained soils and lowest in rock interiors exposed by grinding with the Rock Abrasion Tool (RAT). Spirit explored the lower slopes of the Columbia Hills (West Spur) during sols $\sim$150-320. West Spur rocks are highly altered, even for interior surfaces exposed by grinding (Fe^{3+}/Fe_T $\sim$0.56-0.84). High concentrations of npOx, Hm, and Mt are present. One rock (Clovis) contains significant quantities of goethite (α-FeOOH; $\sim$40% of total Fe). The detection of goethite is very significant because it is a mineralogical marker for aqueous alteration.

For sols $\sim$320-540, Spirit explored Husband Hill in the Columbia Hills. This hill is characterized by both unaltered and highly altered outcrop rocks (Fe^{3+}/Fe_T $\sim$0.31-0.94) and scattered occurrences of unaltered float rocks (Backstay with (Fe^{3+}/Fe_T $\sim$0.23). Most outcrop rocks (e.g., Watchtower and Paros) are highly altered, with high concentrations of Hm and npOx. Only Peace outcrop, which has large quantities of Mt ($\sim$34% of total Fe), is unaltered according to MB. Ilmenite is detected in Wishstone, Watchtower, and related rocks (up to ∼8% of total Fe). With one exception, soils in the Columbia Hills are basaltic with the same general MB mineralogical composition as those on the Gusev plains. The exception is PasoRobles soil. Its MB spectrum is characterized by a oct-Fe^{3+} doublet whose quadrupole splitting is narrower than that for any other soil. The concentration of S in this sample is the highest reported on Mars to date (31.6% SO_3 [4]), implying that the doublet is associated with a ferric sulfate.

In summary, the Mössbauer spectrometer on the Spirit rover has identified 8 Fe-bearing phases on Mars through sol 540: olivine, pyroxene, magnetite, ilmenite, npOx, hematite, goethite, and probable Fe^{3+}-sulfate. Goethite and Fe^{3+}-sufate are mineralogical markers for aqueous processes, likely under acid sulfate conditions. The presence of magnetite in both rock and soil establishes the mineral as a magnetic phase in martian soil and rock.

[1] Squyres et al., *Science*,305 (2004) 794. [2] Morris et al., *Science, 305* (2004) 833. [3] Morris et al., *J. Geophys. Res.* 111, (2006) E02S13, doi:10.1029/2005JE002584. [4] Gellert et al., *J. Geophys., Res. 111* (2006) E02S05, doi:10.1029/2005JE002555.