WEATHERING RINDS ON GUSEV CRATER ROCKS: SIMULATION OF 6.4 AND 14.4 KEV BACK-SCATTER MÖSSBAUER SPECTRA AND IMPLICATIONS ON DEPTH SELECTIVITY I. Fleischer[1], G. Klingelhöfer[1], C. Schröder[1], D. Rodionov[1,2], [1]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität, Staudinger Weg 9, 55128 Mainz, Germany (irisflei@students.uni-mainz.de), [2]Space Research Institute IKI, Moscow, Russia

Introduction: The miniaturised Mössbauer (MB) spectrometers MIMOS II on both Mars Exploration Rovers obtained 6.4-keV and 14.4-keV backscattering MB spectra. Measurements on samples with a surface layer such as a weathering rind show significant differences in 6.4 keV and 14.4 keV: radiation of higher energy penetrates samples to a greater depth, so that a mineral which is enriched in the surface layer shows a higher relative intensity in a 6.4-keV-spectrum than in a 14.4-keV-spectrum [1]. To study the influence of surface layers of varying composition and thickness on Mössbauer spectra, lab measurements were done on samples composed of mineral thin sections on top of another mineral. Monte-Carlo simulations were conducted to model the scattering of Mössbauer radiation in different samples. A comparison of results from both measurements and simulations serves to determine the thickness of the surface layer, and its composition.

The Monte-Carlo simulation: MB spectra of layered samples are influenced by the composition, the density and the thickness of the layers. The influence of each of these parameters can be studied in a simulation, which allows the modelling of a sample composed of two homogeneous layers, each containing up to ten different minerals. For a given number of gamma quanta, the path from the source into the sample and back to the detector is modelled, taking into account the geometry of the experimental setup of MIMOS II. X-ray and γ-quanta interact nonresonantly through the photoelectric effect, Compton- and Rayleigh-scattering, only 14.4-keV MB γ-quanta can be absorbed resonantly via MB effect. Each interaction can alter the direction of movement as well as the energy of a photon.

Measured and simulated spectra: Samples composed of thin sections (TS) of pure minerals with thicknesses between 50 and 100 µm on top of other minerals were measured in backscattering geometry. Figure 1 shows experimental spectra and simulations of a sample composed of a TS of olivine (60 µm, 5 wt% iron) on top of pyrite. These minerals were chosen because their hyperfine parameters render them easy to distinguish in MB spectra. Agreement between measurements and simulations within a few percent is reached: The relative intensities of pyrite are 67% in the measured and 63% in the simulated 14.4-keV-spectrum, respectively, and 37% in the measured and 36% in the simulated 6.4-keV spectra.

Interpretation and simulations of spectra obtained at Gusev Crater: On the Adirondack-class rock "Mazatzal", a distinctive coating interpreted as a thin weathering rind was detected [2]. Therefore, Mazatzal is an ideal sample to investigate the influence of a weathering rind on Mössbauer spectra. Figure 2 shows the 6.4-keV- and 14.4-keV-spectra obtained on the brushed surface of Mazatzal and the corresponding simulated spectra. The possible weathering product nanophase oxide (npOx) shows a higher relative intensity in the 6.4-keV-spectra (~ 45% of total area) than in the 14.4-keV-spectra (~ 30% of total area). The composition of the interior of the rock and its coating used for the simulation is given in table 1. The coating has been modelled with a thickness of 10 µm. Iron-free minerals are taken into account by simulating an SiO_2-content in hematite, magnetite and npOx. This approximation is applicable, because the absorption coeffiecients of SiO_2 do not differ much from those of a more complex composition.

Table 1: The composition of Mazatzal used for the simulation. The composition of the minerals has been estimated using results presented in [3] and [4]. Values are given in wt %.

Mineral and composition	Interior	Coating
Olivine ($45\%Mg_2SiO_4+55\%Fe_2SiO_4$)	40%	-
Pyroxene ($30\%CaFeSi_2O_6+30\%CaFeSi_2O_6$ $+15\%Mg_{1,35}Fe_{0,55}Ca_{0,1}Si_2O_6$ $+15\%MgFeSi_2O_6$)	30%	-
npOx ($50\%Fe_2O_3+50\%SiO_2$)	20%	80%
Magnetite ($50\%Fe_3O_4+50\%SiO_2$)	5%	10%
Hematite ($50\%Fe_2O_3+50\%SiO_2$)	5%	10%

Differences between 6.4-keV and 14.4-keV-spectra are not always due to the existence of a surface layer. Figure 2 shows spectra obtained on the abraded surface of "Humphrey" as well as simulated spectra in both 6.4 keV and 14.4 keV. In both cases, the relative intensity of olivine is higher in the 6.4-keV- than in the 14.4-keV-spectra, which can be explained with the different interaction processes of photons: 6.4-keV X-ray quanta interact only nonresonantly, while 14.4-keV γ-quanta can also be absorbed resonantly. After resonant absorption, the re-emission of a 6.4-keV X-ray quantum is more likely than the re-emission of a 14.4-keV γ-quantum. The largest fraction of all resonant absorptions occurs in the mineral with the highest relative intensity in a spectrum. This mineral should therefore show a higher relative intensity in the 6.4-keV than in the 14.4-keV spectrum. In the case of Humphrey, this mineral is olivine.

Summary: Monte-Carlo simulations of 6.4-keV and 14.4-keV MB spectra serve to determine the composition and thickness of thin weathering rinds (less than 100 µm). Differences between 6.4-keV and 14.4-keV spectra may also arise due to different absorption processes of 6.4-keV and 14.4-keV photons.

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References: [1] Klingelhöfer et al (2003) JGR 108 (E12), 8067; [2] Haskin et al (2005) Nature, 436, 66; [3] Morris et al (2006) *JGR* 111, E02S13; [4] McSween et al (2006) *JGR* 111, E02S10

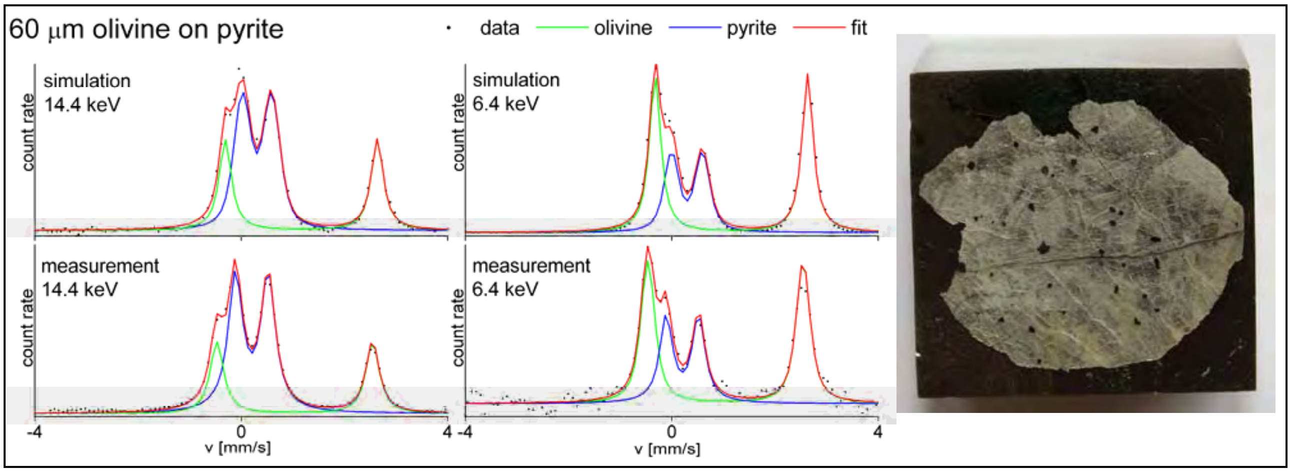

Figure 1: Spectra measured on a sample composed of an olivine thin section on top of pyrite and corresponding simulations.

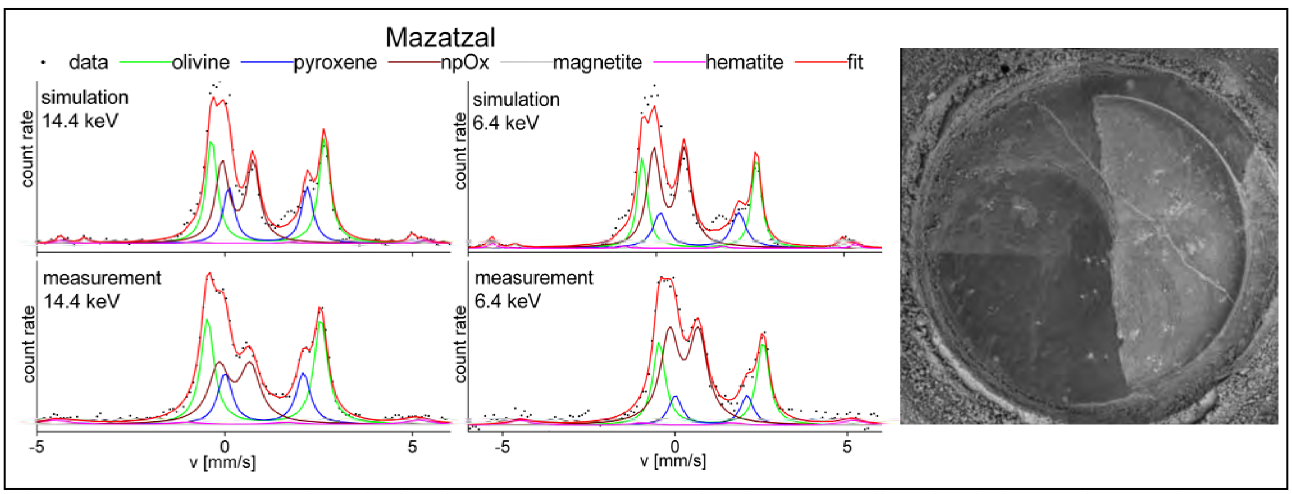

Figure 2: Spectra measured on the brushed surface of Mazatzal and corresponding simulations; Microscopic Imager mosaic taken on sol 82.

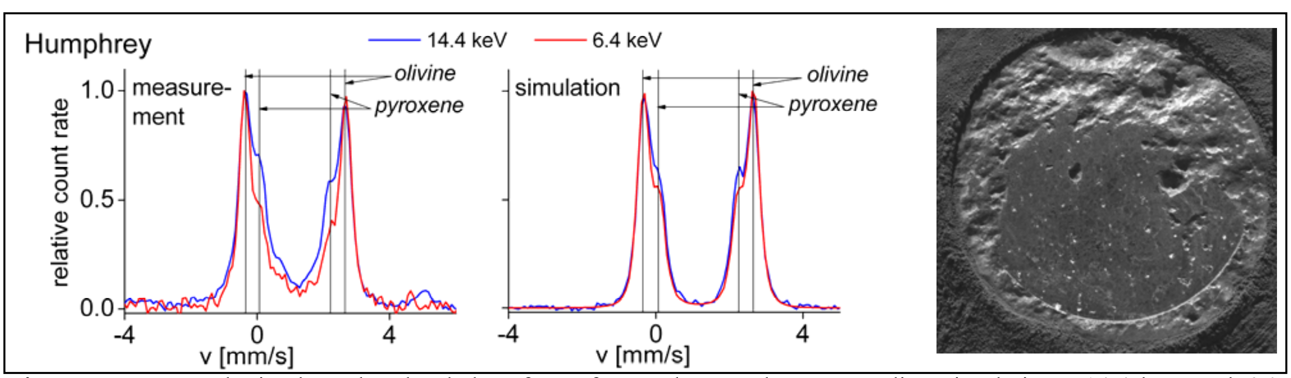

Figure 3: spectra obtained on the abraded surface of Humphrey and correpsonding simulations; 14.4 keV and 6.4 keV in direct comparison; Microscopic Imager mosaic taken on sol 60.