Microscopic views of soil and dust at the Phoenix landing site, and how that relates to other landing sites. W. Goetz[1], S.F., Hviid[1], H.U. Keller[1], W.J. Markiewicz[1], M.B. Madsen[2], K. Leer[2], L. Drube[2], W.T. Pike[3], M.H. Hecht[4], D. Parrat[4], H. Sykulska[3], S. Vijendran[3], J. Marshall[5], R.V. Morris[6], R.E. Arvidson[7], and P.H. Smith[8], [1]Max Institute for Solar System Research, 37191 Katlenburg-Lindau, Germany (goetz@mps.mpg.de), [2]Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, [3]Department of Electrical and Electronic Engineering, Imperial College, London, UK, [4]Jet Propulsion Laboratory, Caltech, Pasadena, CA, USA, [5]SETI Institute, Mountain View, California, USA., [6]NASA Johnson Space Center, Houston, TX, USA, [7]Washington University, St. Louis. MO, USA, [8]University of Arizona, Tucson, AZ, USA

Introduction: The Phoenix Spacecraft landed on May 25, 2008 in Martian north-polar plains about 2000 km north of the shield volcano Alba Patera and about 20 km west-southwest of the 10 km diameter Heimdall crater. The material at the landing site is believed to be of multiple origin including ancient volcanic ash deposits (dating back to the Hesperian), impact ejecta from the 500 million years old Heimdall crater as well as aeolian material brought in from outside as saltation and suspension loads [1,2]. The data from the entire science payload contributed to the characterization of this material.

In this abstract we focus on Optical Microscope (OM) [3] data and address the question, how this material relates to other landing sites (MER-A, MER-B). Over the course of the mission, soil material was scooped up and delivered to 3-mm diameter substrates that were subsequently imaged by the OM (Figure 1).

Analysis: Figure 2 shows the very same substrate before and after delivery of Phoenix soil particles. These OM images are not unrepresentative among the OM images acquired during the mission. Therefore they have been selected for further discussion in the present abstract. Below the substrate surface is mounted a strong cylindrical magnet [4]. The fact that material sticks to the substrate prior to delivery is caused by the capture of magnetic particles during earlier deliveries to other substrates. The substrates are oriented vertically, whenever they are imaged by the OM (see g-vector in Figure 2). Figure 2 shows that both samples are clearly magnetic. Based on simulation experiments the *overall* saturation magnetization of these samples should be at least 0.5 A m^2/kg [4].

Figure 3 focuses on the spectral properties of these same samples. OM color images are composed of blue, green and red images that have been acquired during sample illumination by blue, green and red LEDs, respectively. These images do also provide 3-point reflectance spectra that are mostly of the reflectance type R* [5]. The spectra in Figure 3 suggest that there are at least three spectral types of particles: Brownish silt-sized (50-80 µm) particles (examples marked by (1)), black particles of similar size (marked by (2)) and fine-grained (clay-sized) orange material. The brownish particles have been chosen here as an example of a whole range of (apparently) glassy, colorless to brown particles that can be seen in the left part of Figure 3. Obviously these particles have a wide range of reflectance spectra (not shown in the present abstract). The orange material dominates the spectrum of the bulk material. Given the huge difference in scale the CRISM spectrum of a region nearby the Phoenix lander is in remarkable agreement with the OM 3-point spectrum. Note that these spectra have been independently acquired and not scaled in any way (as is commonly done in reflectance spectroscopy).

Figure 4 shows images of the MER-B Capture magnet. The Pancam images (to the left) have been acquired before and after events of strong wind. These events were able to separate the dust into a strongly magnetic dark and a weakly magnetic/non-magnetic bright subset. The B350 image reveals the concentric ring magnets that are mounted below the active (visible) surface of the Capture magnet [6]. The dark material is concentrated near the outer borders of each ring magnet (as projected onto the active surface), where the magnetic field gradient is largest. The image from sol B337 (acquired by the Microscopic Imager, MI) can be considered as a monochrome high-resolution version of the B350 Pancam image. The MI image shows that the dark particles are actually arranged as magnetic chains. From these images as well as from other data (Mössbauer, APXS) it has been concluded that these particles have a saturation magnetization that exceeds 7 Am^2/kg [7, 8, 9]. It turns out that the width of these magnetic chains coincides with the size of the black particles seen in OM images.

Figure 5 shows a high-resolution view of the El Dorado dune field in the Columbia Hills region in Gusev crater. The dark dunes are composed of weakly altered basaltic particles [10] that are well sorted by wind (220-300 µm). The right part of Figure 5 (Phoenix, sol132) shows a particularly large black particle (~ 160 µm). The particle sticks to the vertically oriented substrate surface indicating a substantial magnetization. A potential similarity between El Dorado grains and the black particles seen in OM soils is suggested. According to Pancam and CRISM spectra (not shown in the present abstract) El Dorado [11] has a red albedo of ~14% (near 600 nm), while "clean" black particles in the Phoenix soils generally have an albedo below 10% at the same wavelength. However, some black particles in Phoenix soils (including the one shown in Figure 5) have a rough texture, and therefore can potentially bind fine grained orange dust to their surface, thereby acquiring a larger albedo.

Conclusions: Soils at the Phoenix landing site contain following types of particles: (1) Orange dust particles that make up the major part of all Phoenix soils, (2) black, silt-sized particles and (3) colorless-to-brownish glassy particles of similar size. Additionally the soils contain whitish (potential salt) particles in the percent range [12] as well as special particle types identified by the Atomic Force Microscope. Based on size, morphology and spectral properties it is suggested that analogues to type (1) and type (2) particles have already been observed at the MER-A and MER-B landing sites, either on the magnets or in particular dune fields. However, the glassy particles which occur in all colors and do not have a unique reflectance spectrum, are interpreted to be specific to the Phoenix landing site and may represent impact glasses from Heimdall crater and/or volcanic glasses from the Tharsis volcanoes, including Alba Patera.

References: [1] Smith P.H. et al. (2009) LPS XXXX. [2] Arvidson R.E. et al. (2009) LPS XXXX. [3] Hecht M.H. et al. (2008) JGR, 113, E00A22. [4] Leer K. et al. (2008) JGR, 113, E00A16. [5] Bell J. et al. (2008) JGR, 113, E06S18. [6] Madsen M.B. et al. (2003) JGR, 108, 8069. [7] Goetz W. et al. (2005), Nature, 436, 62. [8] Goetz W. et al. (2008), chapter 16 in: J. Bell (ed.), The Martian Surface, Cambridge Univ. Press. [9] Madsen M.B. et al. (2008) JGR (in print). [10] Morris R.V. et al. (2008) JGR (in print). [11] Arvidson R.E. (2008, personal communication). [12] Sykulska H. et al. (2009) LPS XXXX.

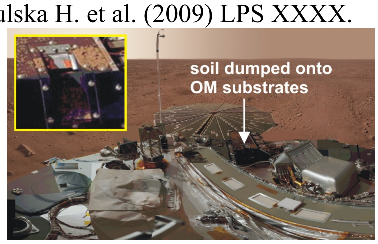

Figure 1. Instruments on the lander deck in a mid-Primary mission panorama. OM chute enlarged.

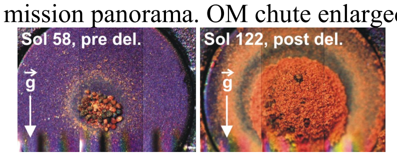

Figure 2. Magnetization of the Phoenix soil particles: The same substrate (circular, 3 mm in diameter) shown before and after soil delivery. The substrates are oriented vertically with the gravity vector (g) pointing downwards. All particles are noticeably magnetized, as they stick to the near-center of the substrate.

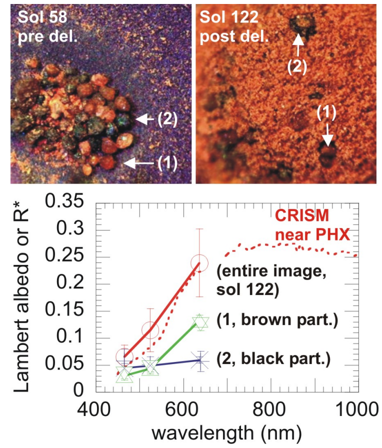

Figure 3. Spectral properties of various soil particle types. Both images are 1 mm wide.

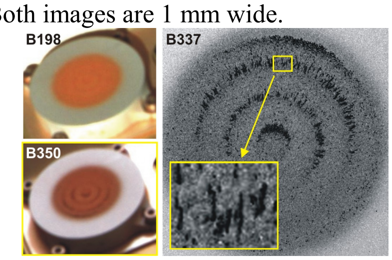

Figure 4. Images of the MER-B Capture Magnet from Pancam (left) and Microscopic Imager (MI, right) before (B198) and after (B337, B350) events of strong wind. The B337 image (25 mm wide) can be considered as a zoom up of the B350 image (~ 50 mm wide). Airborne dust is separable into a dark and a bright subset of particles. Some dark particles are sufficiently magnetic so that they can form magnetic chains. The inset (~ 2 mm wide) shows a zoom of the magnetic chains that are about 50-80 μm wide. This width is very similar to the size of most black particles imaged by the Phoenix OM.

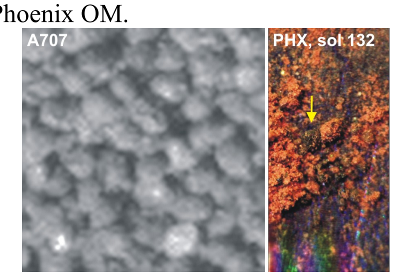

Figure 5. Left: Dark particles from the El Dorado dune field (MER-A). Right: Phoenix, sol 132. The black particle (yellow error) is about 160 μm large. Thus it is somewhat larger than average black particles (50-80 μm) in the Phoenix soils, but only slightly smaller than average El Dorado grains (220-300 μm, left image). Both images are at the same scale. The right one is 1 mm wide.