

**VISIBLE-INFRARED REFLECTANCE AND EMISSIVITY SPECTRA OF A TERRESTRIAL KOMATIITE AS A GUIDE TO OBSERVATIONS AT MERCURY.** Alessandro Maturilli<sup>1</sup>, Jörn Helbert<sup>1</sup>, James St. John<sup>2</sup>, Mario D'Amore<sup>1</sup>, James W. Head<sup>3</sup>, William M. Vaughan<sup>3</sup> <sup>1</sup>Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, Berlin-Adlershof, Germany ([alessandro.maturilli@dlr.de](mailto:alessandro.maturilli@dlr.de)), <sup>2</sup>School of Earth Sciences, The Ohio State University at Newark, Newark, OH 43055, USA, <sup>3</sup>Department of Geological Sciences, Brown University, Providence, RI 02912, USA.

**Introduction:** X-ray fluorescence spectra obtained by the MESSENGER spacecraft orbiting Mercury show a planetary surface composition that differs markedly from that of the other terrestrial planets [1]. The X-Ray Spectrometer (XRS) on the NASA MESSENGER mission measures elemental composition for the topmost 0.1 mm of Mercury's crust. Relatively high Mg/Si and low Al/Si and Ca/Si ratios exclude a surface composition rich in feldspar, typical of the lunar highlands. On the other hand, the high abundances of sulfur detected (10 times larger than found on Earth and the Moon) and the low values for Fe suggest that Mercury formed from precursor material that was highly reduced (enstatite-chondrite-like objects or ice-poor systems enriched in anhydrous interplanetary dust particles) but not depleted in volatiles. Mercury's major element ratios are intermediate between those of typical basaltic compositions and more ultramafic compositions comparable to terrestrial komatiites [1].

Motivated by these findings, at the Planetary Emissivity Laboratory (PEL) at the German Aerospace Center (DLR) we have measured the visible and infrared spectra of a terrestrial komatiite sample under a range of environmental conditions.

**Komatiite sample:** The material used in the present study is olivine spinifex komatiite from the Paleoproterozoic-aged (3.481 Ga) Lower Komati Formation in the Komati River Valley area, Barberton Greenstone Belt, Kaapvaal Craton, northeastern South Africa. This is the type locality, known for the oldest well-preserved komatiites on Earth. It is an A2 facies komatiite. This facies is a zone of quickly chilled, feathery acicular olivine-clinopyroxene + glass, most likely a chilled margin below a flowtop breccia unit. The sample has been metamorphosed into black serpentinite, partly changing its mineralogy, but retaining the original spinifex texture.

The Lower Komati Fm. has five spinifex komatiite horizons interbedded with massive komatiites and komatiitic basalts [2-4]. Outcrop characteristics and geochemical data indicate that these komatiites were erupted on a seafloor lava plain [2, 3, 5]. The rocks in this area were altered by greenschist-facies to lower amphibolite-facies regional metamorphism in the late Paleoproterozoic, generally without affecting original igneous textures and without subsequent metamor-

phism [5, 6]. Some Lower Komati Fm. samples have small amounts of unaltered igneous material consisting principally of olivine, augitic clinopyroxene, and minor chromite [4, 5]. Moreover, the overall major element, trace element, and rare earth element compositions of Lower Komati Fm. komatiites indicate that serpentinization has not substantially altered most of the primary elemental constituents [4, 5, 7]. These attributes provide support for the premise that measurements may be relevant to unaltered komatiite.

**The PEL:** The key feature of the experimental facilities at PEL is the capability to measure the emissivity of materials from 1 to 100  $\mu\text{m}$  from low to very high (700 K) sample temperatures [8, 9].

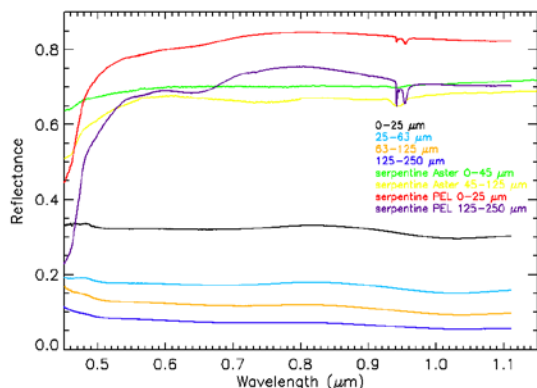
The Bruker VERTEX 80V Fourier Transform Infrared can be operated under vacuum to remove atmospheric features from the spectra. It is coupled to a planetary simulation vacuum chamber that allows measurements up to temperatures of 700 K. A Bruker A513 accessory is used to obtain biconical reflectance with variable incidence angle  $i$  and emission angle  $e$  between  $13^\circ$  and  $85^\circ$  at room temperature, under purge or vacuum conditions, in the 1 to 100  $\mu\text{m}$  spectral range.

The second instrument is the Bruker IFS 88 with an attached emissivity chamber for measurements at low to moderate temperatures [8, 9]. A Harrick Seagull<sup>TM</sup> variable-angle reflection accessory mounted in the Bruker IFS 88 allows measurement of the biconical reflectance of minerals at room temperature, under purging conditions in the extended spectral range from 0.4 to 55  $\mu\text{m}$ .

**Komatiite spectra:** We handled our komatiite sample following standard PEL procedures: we crushed the bulk rock into smaller particles, then sieved them to four particle size ranges. Figure 1 shows the visible spectra of the four samples, taken with the IFS88 instrument, equipped with a Si-diode detector and a quartz beamsplitter, at room temperature in a purged environment, with  $i = e = 13^\circ$ . For comparison, spectra of serpentine samples from the ASTER spectral library (PS-20A) and the PEL collection are included.

The first thing to note is that the four curves for the komatiite samples look very similar, and all seem to have the same slightly bluish slope. The finer-grained samples (as usual in this spectral range) have higher

reflectances, i.e., they are visually brighter than the larger. The bulk rock is very dark, so the low reflectance for the larger grain-size fraction is not surprising.



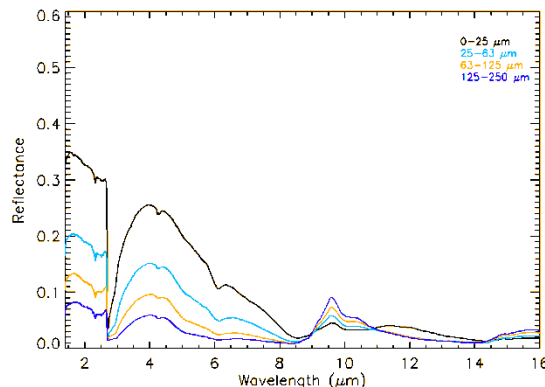
**Figure 1. Visible biconical reflectance spectra ( $i = e = 13^\circ$ ) of komatiite in four grain-size fractions, and comparison spectra of serpentines from the PEL collection and from the ASTER spectral library.**

A more detailed look shows that for the large feature between 0.7 and 1.0  $\mu\text{m}$ , the two smaller size fractions seem to group and to differ from the two larger fractions. The two groups of samples also differ from each other with respect to the small feature below 0.5  $\mu\text{m}$ , in that the larger grain-size fractions show a pronounced upturn toward the ultraviolet (UV). These differences should be taken into account when comparing with measured planetary reflectances, because they seem to be characteristic of the particle size ranges. The serpentine spectra for two different samples shown for comparison exhibit a strong downturn toward the UV, not seen for any size fraction of our komatiite sample. This difference is consistent with a determination that serpentinization of this komatiite sample has not strongly altered its spectral characteristics.

In Figure 2 we show the infrared (IR) reflectance spectra (from 1.4 to 16  $\mu\text{m}$ ) of the same four komatiitic samples, measured with the same set-up described above. The spectra show a larger variability, even if the trend observed for visible reflectance is followed up to 8  $\mu\text{m}$ . Although the measurements at visual and near-infrared wavelengths show no obvious serpentinization effect, the peak near 9.5  $\mu\text{m}$  could be attributed to a combination of serpentine and augite. The absorption band between 3 and 4  $\mu\text{m}$  is very close to features seen in augites. Note again the different intensities of the spectra and the differences in band depth and shape for the four size fractions.

Measurement of emissivity at low temperature under purging, followed by emissivity in vacuum ( $\sim 0.7$  mbar) at low and from moderate temperatures to 500 $^\circ$  C (typical of Mercury dayside), is underway for the komatiite samples. After cooling, we will remeasure

the reflectance of the heated samples, for comparison with fresh materials, to understand the importance of thermal shock on the observed spectral features.



**Figure 2. The infrared biconical reflectance spectra of komatiite in four grain-size fractions.**

**Summary:** We have measured visible and infrared reflectance spectra of a komatiite sample in four grain-size ranges. Like virtually all terrestrial komatiite, this sample has experienced some alteration. However, initial spectral measurements indicate that the effects of alteration may be limited. We seem to see less influence of the serpentinization in the spectra up to 1.1  $\mu\text{m}$  than in the IR spectra, possibly indicating that the former are more sensitive to texture while the latter are more sensitive to mineralogy. Therefore, this altered komatiite sample might provide guidance to the interpretation of spectral reflectance measurements of Mercury in the wavelength ranges covered by MESSENGER. In collaboration with Brown University, we will also be examining spectra of unaltered synthetic ultramafic material similar to compositions reported by MESSENGER and prepared in the experimental petrology lab. For all grain-size fractions, measurements of emissivity, at pressure and temperatures representative of surface conditions on Mercury, are underway.

Collectively, these measurements can provide support to the analysis of spectral reflectance data by MESSENGER using a clustering classification methodology [10]. They also might help to test the hypothesis that hollows form in magnesian crust in the course of removal of surficial sulfide deposits [11].

**References:** [1] Nittler L. R. et al. (2011) *Science*, **333**, 1847. [2] Dann J. C. (2000) *S. Afr. J. Geol.*, **103**, 47. [3] Dann J. C. (2001) *Bull. Volcan.* **63**, 462. [4] Parman S. W. et al. (2003) *Contr. Min. Petrol.* **144**, 383. [5] Chavagnac V. (2004) *Lithos* **75**, 253. [6] de Wit M. J. et al. (1987) *J. Afr. Earth Sci.*, **6**, 681. [7] Nesbitt R. W. et al. (1979) *Can. Mineral.*, **17**, 165. [8] Maturilli A. et al. (2006) *PSS*, **54**, 1057. [9] Maturilli A. et al. (2008) *PSS*, **56**, 420. [10] D'Amore M. et al. (2012), *LPS*, **43**, this meeting. [11] Helbert J. et al. (2012), *LPS*, **43**, this meeting.