

WATER AND OTHER VOLATILES ON VESTA AFTER THE LUNAR CASE. J.-Ph. Combe¹, T. B. McCord¹, E. Palomba², M. C. De Sanctis², T. H. Prettyman³, C. M. Pieters⁴, E. Ammannito², F. Capaccioni², M. T. Capria², C. A. Raymond⁵, C. T. Russell⁶, and the Dawn Team. ¹Bear Fight Institute, 22 Fiddlers Rd., Winthrop WA 98862 USA, ²INAF-IAPS, Via del Fosso del Cavaliere 100, I-00133 Rome, Italy, ³Planetary Science Institute, Tucson, AZ, USA, ⁴Brown U., Providence RI USA, ⁵Cal. Inst. Tech Jet Prop. Lab. Pasadena CA USA, ⁶University of California, Los Angeles ,CA, USA, jean-philippe_combe@bearfightinstitute.com

Introduction: The Dawn spacecraft entered orbit in July, 2011, about 4 Vesta, the second largest object in the asteroid belt. Recently, hydroxyl, water and other volatiles have been reported on and in the surface of the Moon. Vesta is in some ways similar to the Moon and might be expected to harbor volatiles, according to some of the mechanisms proposed to be responsible for them in the Moon. Thus, a search for volatiles is underway using the Dawn data. This article is a report of the results so far, and emphasizes OH and H₂O because sufficient data for detection of other volatile species is not yet in hand.

Background: OH and other volatiles, both on the surface and within the Moon, can come from three sources: 1) indigenous from the original material forming the Moon, 2) in-fall of meteorite and cometary material containing water or hydroxyl, and 3) from processes associated with the solar wind irradiating the surface material that can actually produce such compounds. (See [1] *Lucey*, 2009 and [2] *Lucey et al.*, 2006 for background and reviews.)

Evidence for “water” on/in the Moon comes from a number of sources. Two spacecraft observations of hydrogen at the poles [3,4], three spacecraft measurements of OH/H₂O IR spectral absorptions [5,6,7] and observation of volatiles in the impact plume by LRO [6]. Further, there are a growing number of laboratory studies revealing water in lunar samples from deep sources within the Moon in quantities up to that thought to exist in the Earth’s mantle. These multiple observations probably are detecting several different deposits of volatiles, in different locations on and in the Moon, and from a variety of sources.

Vesta is in many ways similar to the Moon, in that it is an airless, differentiated, basaltic body in the inner Solar System. Some of the same process should have operated. For example, the IR spectral evidence is thought to be due to solar wind proton implantation and OH formation using dangling O⁻ bonds in the damaged surface soil grains [8]. This process might also work on Vesta. The solar wind also strikes Vesta with about the same energy, but with approximately 1/4.5 less flux. Volatile-rich materials must strike the surface, often with less velocity than for the Moon. The interior evolution of Vesta might also have pre-

served some residual water, as in the Earth and Moon, and Vesta’s surface is colder than the Moon’s.

Dawn has the instrumentation to detect lunar-like volatiles and is presently in orbit. So, a search is underway, the results so far of which are reported here, following our earlier report [9]. Dawn carries two instruments critical for the search for volatiles. The GRaND (Gamma Ray and Neutron Detector) can detect the presence of hydrogen but not its molecular form. It is sensitive to about the first ½ meter of the surface material. It builds global maps of certain elements over time but will not have sufficient SNR until near the end of the present low altitude mapping orbit (LAMO). The VIR (Visible and IR) mapping spectrometer can detect absorptions due to OH (at 2.8 μm) and H₂O and OH (3.0 μm region) and other volatiles. VIR observes high quality spectra on a pixel by pixel basis that can be immediately interpreted, but it can build up spatial coverage only over time, and it is sensitive only to the upper mm or so of surface material. In addition the framing camera (FC) might detect features associated with volatiles and their processes. Combining the results of these observations will be powerful in this search.

Analysis of VIR spectra: A global average reflectance spectrum for Vesta from the Dawn Survey orbit phase is shown in Fig.1.

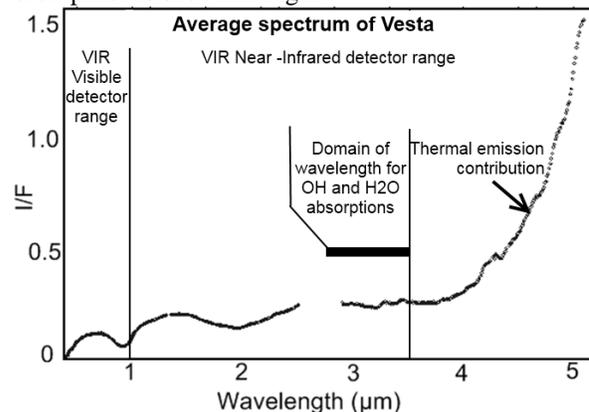


Figure 1: VIR average spectrum of Vesta.

Molecular absorptions from OH and H₂O exist in the near-infrared between 2.8 and 3.5-μm. Some weak spectral structure exists in this range in the global average I/F spectrum [9]. Unfortunately, the spectral

domain near the short wavelength edge of the OH-H₂O region is also affected by instrument artifacts and associated incomplete calibration that deter the full analysis of I/F signal. These issues are currently under investigation.

Therefore, we are focusing first on the variations of the signal at expected wavelengths for absorption bands of OH (2.8 μm) and H₂O (3.0 μm) by using normalized I/F. We divided all VIR spectra by the average spectrum of Fig. 1. Any depressed/raised spectral feature in ratio spectra represents an excess/reduced absorption with respect to the average.

Interpretation of spectral feature variations:

We have detected weak but clear variations at 2.8 μm that could be due to OH. There are indications that this detection could be due to surface properties because it matches the following criteria: 1) Areas of increased spectral feature occur as coherent spatial units; 2) different observations of the same area provide similar spatial distribution; 3) Similar analyses performed at other nearby wavelengths provide different results (no or little spectral variation). Because we are observing only the variations of spectral features across the surface, interpreting these spatial coherent spectral variations is less simple than if we were interpreting the absorption itself. The spectral variations measured at 2.8 μm with respect to the average spectrum of Vesta probably means a component that absorbs at this wavelength, such as OH, is present at the surface in different amounts, but it tells little about the absolute amount because we are analyzing variations from the average Vesta spectrum, only,

Origins and processes: While the strengths and locations of these spectral variations are being better defined, a search is also underway to identify the sources and processes responsible. Associations with

surface morphological features observed at high spatial resolution with the Framing Camera (FC) are proving complex. No significant correlation with temperature, also retrieved by VIR (see companion abstract [9]), or with illumination suggest that the formation of OH is not likely due to short-term surface processes, as might be the case on the Moon [5, 8]. The final objective will be to derive abundance estimates for OH and H₂O at the surface of Vesta, and to compare them with abundances found on the Moon. On the Moon, feldspathic areas such as highlands show stronger absorption bands of OH and H₂O. Vesta is less feldspathic than the Moon. The strong pyroxene absorption bands in VIR data indicate that Vesta surface particles are more crystalline. The crystal structure of Vesta's soils may have fewer defects than lunar soils, which is less favorable to proton implantation. Analysis of incoming data is underway, with more spatial coverage, higher spatial resolution and improved calibration.

Acknowledgements: The authors acknowledge the support of the Dawn Science, Instrument and Operations Teams. This work was supported by the NASA Dawn Project under contract from UCLA and by the NASA Dawn at Vesta Participating Scientist program.

References: [1] Lucey, 2009, Science 386. [2] Lucey et al., 2006. [3] Feldman et al., 2000, JGR. [4] Mitrofanov et al., 2010, Science 330. [5] Pieters et al., 2009, Science 386. [6] Sunshine et al., 2009, Science 386. [7] Clark, 2009, Science 386. [8] McCord et al., 2011, JGR. [9] McCord et al., 2011 EPSC.