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Imaging spectrometry of meteorites to support interpretation of Dawn observations of Vesta

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Abstract

In order to support interpretation of the first observations of Vesta by Dawn, we have measured reflectance spectral images of Vestan meteorites (howardite, eucrite, diogenite) with an imaging spectrometer at the LPG in Nantes. We report on the first results of this analysis.

1. Introduction

Observations of Vesta by the Visible and Infrared spectrometer (VIR) and the Framing Camera (FC) onboard Dawn [2] have begun in May 2011 during approach phase. Interpretation of images and spectra at higher spatial resolution from orbit will benefit from reference spectra of known minerals, analogs, and samples and meteorites. Some meteorites, such as howardites, eucrites and diogenites (HED), are assumed to come from Vesta because of similarities of their reflectance spectra. Meteorite samples are generally breccias of heterogeneous composition, which suggests the need for either statistical analysis over many point measurements of each sample, or imaging and mapping of several samples. Recent developments of imaging reflectance spectrometry in the laboratory enable compositional mapping of optically thick samples. This provides an opportunity for developing and testing methods of visible and near-infrared spectral analysis as support for processing of remotely-sensed data, such as from Dawn. The possibility of using the same technique on samples (in the laboratory or in-situ) and on planetary surfaces (from orbit or from ground-based observations) makes comparative interpretation more direct and more reliable. One objective is also to test the origin of HED samples. Are they really from Vesta? We present the first results of spectral mixture analysis on HEDs in the context of the new observations of Vesta by Dawn.

2. Meteorite samples

Most of these meteorites come from North West Africa (NWA) and are part of the collection of Pr. Anthony Irving. Samples are opaque, thick sections (> 1 mm) with a smooth surface (unpolished).
The suite of meteorites we have analyzed includes a large variety: Eucrite-polymict, Mesosiderite, Dunite, Eucrite (basaltic), Olivine diogenite, Diogenite, Diogenite-polymict and Eucrite-plutonic.

2. Spectral reflectance images

2.1 Instrument characteristics

The HySpex imaging spectrometer is a push-broom system built by the NEO company. It uses three two-dimensional detectors (one spatial dimension and one spectral dimension) covering the spectral range 0.4-1 µm (VNIR), 1-1.7 (SWIR-i), 1.4-2.6 µm (SWIR-m). Each image is acquired independently, line by line, by translating the stage that supports the samples.

2.2 Image calibration and coregistration

Calibration into radiance is computed with customized software from NEO. For calibration into reflectance, a standard white, diffusive surface (Lambertian) is observed with the samples as reference. The images are then spatially coregistered by taking reference control points on the visible image for optical distorsion and misalignement of the cameras. A final radiometric adjustment between the detectors is performed by applying a single-value offset per detector in order to make the spectra match where they overlap.

3. Spectral analysis

The objective is to map the composition of each sample. This involves identification of the purest spectral components (spectral endmembers), calculation of their respective mixed contributions in each pixel in the image (Spectral Mixture Analysis or SMA [3, 4]), and precise characterization of the composition of each spectral endmember.

1) We use the strong linear correlation between reflectance values at all the wavelengths to automatically retrieve the darkest and the brightest spectral endmembers. 2) Then a variant version of the SMA, the Multiple-Endmember Linear Spectral Unmixing Model (MELSUM, [5]) is calculated. Results are image fractions for each component and model residuals. 3) Manual analysis of the residuals helps identifying additional spectral endmembers. Steps 2) and 3) are performed iteratively until the addition of one more spectral endmember does not improve the residuals. This follows the procedure to be used for Dawn data of Vesta.

4. Preliminary results

We have performed the SMA on meteorite sample NWA 5229, which is an ophitic-textured basaltic eucrite composed mainly of exsolved pigeonite and calcic plagioclase (probably ~An85) with accessory silica, ilmenite and troilite. As is typical, the pyroxene consists of high-Ca augite exsolution lamellae within orthopyroxene.

The spectral endmembers in Fig. 1 show mostly two absorption bands near 1 and 2 µm that are characteristic of pyroxenes.

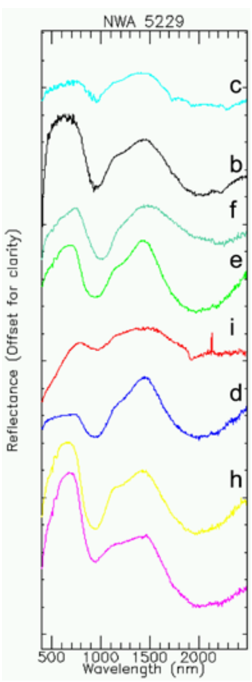

Figure 1: Spectral endmembers derived from MELSUM on sample NWA 5229. Labels correspond to image fractions in Fig. 2.

The position of the center of the absorption from long to short wavelengths is related to composition, ranging from high-Ca to low-Ca. The absorption band near 1.2 µm is characteristic of Fe^{2+} electronic transitions in M2 sites of pyroxenes [6], which implies rapid cooling during crystallization, and therefore formation close to the surface. Variations in spectral slopes still have to be investigated. An additional component, such as the one represented by the red curve, is spectrally similar to an iron oxide, which could be explained by terrestrial alteration of the minerals in fractures of the samples (Fig. 2).

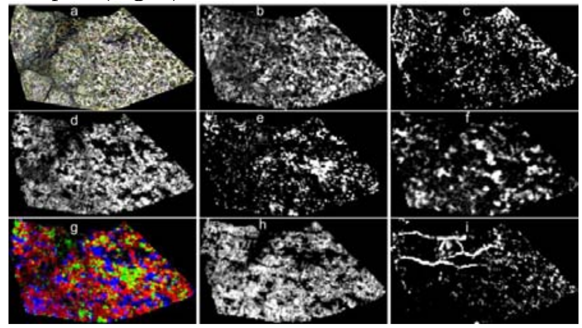

Figure 2: Eucrite-basaltic sample from NWA 5229 and image fractions from MELSUM. a – Visible color composite. b to i: Image fractions of spectral endmembers from Fig.2, except g: Color composite of d (red), e (green) and f (blue).

5. Perspectives

Preliminary results indicate that imaging spectrometry in the laboratory makes possible mapping image fractions of representative spectral endmembers of meteorite samples. The objectives are 1) to use these results to support similar analyses performed on spectral images of Vesta from VIR and FC, 2) to interpret the spectral components in more details, 3) to perform similar analysis on the other samples, and 4) to test the origin of HED meteorites using observations of Vesta by Dawn.

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