FIRST MINERALOGICAL MAPS OF 4 VESTA. M.C. De Sanctis[1], A.Nathues[2], E. Ammannito[1], F. Capaccioni[1], A. Frigeri[1], L. Le Corre[2], R. Jauman[3], E. Palomba [1], C.M. Pieters[4], V. Reddy[2], K. Stephan[3], F.Tosi[1], A. Yingst[5], F. Zambon[1], M.A. Barucci[6], D. Blewett[7], M.T. Capria 1, J.P. Combe[8], B. Denevi[7], H.U. Keller[2], S. Marchi[9], T.B. McCord[8], LA. McFadden[10], H. McSween[11], C.A. Raymond[12], C.T. Russell[13], J.Y. Li[14], J. Sunshine[14], M Toplis[15]. [1]INAF, Istituto di Astrofisica e Planetologia Spaziale, Area di Ricerca di Tor Vergata, Roma, Italy, mariacristina.desanctis@iasf-roma.inaf.it, [2]MPI for Solar System Research, Katlenburg-Lindau, Germany; [3]DLR, Berlin, Germany; [4]Dep. of Geological Sci., Brown University, Providence, RI,USA; [5]PSI, Tucson, Arizona, USA; [6]Obs. de Paris, Paris, France; [7]JHU-APL, Laurel, MD, USA; [8]Bear Fight Institute, Winthrop, WA, USA; [9]NASA Lunar Science Institute, Boulder, USA; [10]NASA, GSFC, Greenbelt, MD, USA; [11]Dep. of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, USA; [12]JPL, Pasadena, CA, USA, [13]Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA, USA, [14]Un. Of Maryland, College Park, MD, USA, [15]University of Toulouse, France.

Introduction: Before Dawn arrived at 4 Vesta only very low spatial resolution (~50 km) albedo and color maps were available from HST data. Also ground-based color and spectroscopic data were utilized as a first attempt to map Vesta's mineralogical diversity [1-4]. The VIR spectrometer [5] onboard Dawn has acquired hyperspectral data while the FC camera [6] obtained multi-color data of the Vestan surface at very high spatial resolutions, allowing us to map complex geologic, morphologic units and features. We here report about the results obtained from a preliminary global mineralogical map of Vesta, based on data from the Survey orbit. This map is part of an iterative mapping effort; the map is refined with each improvement in resolution.

Mineralogical background: 4 Vesta is known to have a surface of basaltic material through visible-near-infrared reflectance spectroscopy [1-4]. Vesta's spectrum has strong absorption features centered near 0.9 and 1.9 μm, indicative of pyroxenes similar to those of the HED (howardite, eucrite and diogenite) meteorites. Diogenite: is primarily composed of Mg-rich orthopyroxene, with small amounts of plagioclase and olivine, and it shows large crystals suggesting formation very deep inside the crust. Eucrite is made of Ca-poor pyroxene, pigeonite, and Ca-rich plagioclase, with smaller crystals than diogenite, which is consistent with formation closer to the surface. Howardite consists of eucrite and diogenite fragments intimately mixed in a breccia. This discovery led to the hypothesis that Vesta was the parent body of the HED clan. The data from Dawn VIR and FC [5] strengthen the Vesta – HED link and provide new insights into Vesta's formation and evolution. Vesta has a heavily cratered surface, with two large basins. The largest basin is at the South Pole and has been named Rheasilvia.

Data and Mapping Procedure: The Dawn spacecraft has acquired hyperspectral data for Vesta in more than 850 spectral channels from the ultraviolet (UV) to the infrared (IR) (0.25-5.1μm) allowing us to map the mineralogy of the surface. VIR has acquired data covering (> 65%) of the surface (fairly all the illuminated portion of the surface), while FC covered more than 80% permitting a nearly global view of Vesta's surface mineralogy. We here report about the first results obtained by means of the global map of Vesta, based on data from the Survey and Approach phases. FC color ratio images from Survey orbit with a spatial resolution of ~250 m/pixel and VIR hyperspectral images from Approach and Survey orbits with spatial resolutions of 1300 and 700 m/pixel, respectively, provided information on surface mineralogical and lithologic distributions and were used to define terrains and unit boundaries.

Vesta Global Mineralogy: Dawn VIR hyperspectral data shows that Vesta's surface is dominated by pyroxenes (Fig.1). Pyroxenes are everywhere on Vesta at the VIR pixel scale of hundreds of meters [6, 7] and no clear evidence for the presence of other pure minerals is observed at the scale of the present measurements. FC color data reveals that Vesta shows the largest color variation of any asteroid visited so far (see Fig. 2). Although the spectra are dominated by pyroxenes, variations at regional scale are evident and distinct color units have been identified. Both color and spectral variations are often correlated with geological, morphological and topographic features, demonstrating that Vesta has had a long and complex geological history. Several spectral parameters can be measured and evaluated in order to infer mineralogical composition, including band centers, depths, spectral slopes, and band ratios. Vesta's surface exhibits clear differences in the shape, depths and widths of pyroxene bands on a regional scale. Here we report the distributions of such parameters and their use in mapping the mineralogy of the asteroid's surface.

Vesta Terrains and Units: Spectral parameters show that Vesta can be divided very broadly into several major terrain types. The parameters are often correlated with geological structures and are geographically located in different regions on Vesta. Here we describe a first attempt to map the distribution of these parameters.

Band depths is one of the parameters that show clear correlation with surface structures and are uneven distributed on Vesta. Four main terrains based on pyroxene band depths can be identified (Fig.1):

- *ST - Southern Terrains*: These terrains are located mainly in the southern hemisphere, especially between latitude -50°, and -90°. The pyroxene bands are very deep (Fig.1 yellow spectrum).
- *MLT- Mid-Latitude Terrains*: These are located mainly in the southern hemisphere at mid-latitudes (between -20° and -50°). Similar terrains are found associated with specific geological structures in the northern hemisphere. These terrains are characterized by deep pyroxene bands (Fig.1 red spectrum).
- *ET - Equatorial Terrains*: these terrains are mainly in the equatorial regions and have intermediate band depths (Fig.1 green spectrum).
- *CET-Copious Ejecta Terrains:* are found in the continuous ejecta of certain large craters. These terrains are characterized by low reflectance in the visible and shallow pyroxene bands (Fig.1 blue spectrum).

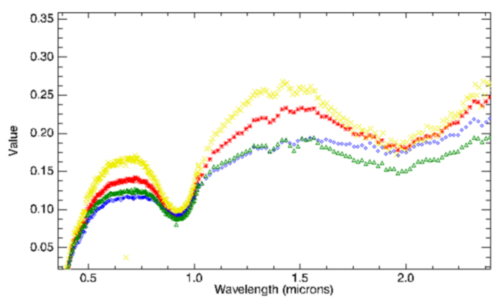

Figure 1. Vesta spectra of different terrains obtained during the Survey phase (yellow-ST; Red-MLT; Green-ET; Blue-CET). The feature at 1.4 micron is a calibration residual.

Band centers are the main parameters used to identify the mineralogy of the terrains. High-Calcium pyroxenes (clinopyroxenes) have the center of the absorption bands I and II shifted towards longer wavelengths, while Low-Calcium pyroxenes or pyroxenes without calcium (such as orthopyroxenes) have their absorption bands shifted towards shorter wavelengths [8]. There is a general trend for greater band depth to correlate with shorter wavelength band centers and shallower band depths with longer wavelength band centers, although exceptions occur.

The distribution of band centers indicates a large variability of Vesta mineralogy. We found that the band centers are often correlated with geological and topographical features, suggesting an intrinsic mineralogical superficial and sub-superficial variability on Vesta. Based on the analysis of VIR data [7], the general character of the surface is similar to that of howardite meteorites. However, some terrains can be interpreted to be enriched in diogenitic material and others appear to be consistent with the presence of eucrite-enriched howardite mineralogy.

In particular, VIR data indicates that the south polar region (Rheasilvia) has its own spectral characteristics: deeper and wider band depths, average band centers at shorter wavelengths, quite uniform spectral behavior of the central mound. These spectral behaviors can indicate the presence of Mg-pyroxene-rich terrains in Rheasilvia. By contrast, the equatorial areas have shallower band depths and average band centers at slightly longer wavelengths (Fig.1).

Conclusion: Vesta's entire surface is covered, at least at VIR resolution, with pyroxenes and large color and spectral variations are seen. Spectral and color variations often correlated with geologic and topographic structures suggesting mineralogical variation of Vesta's stratigraphy. Vesta shows clearly mineralogical distinct terrains and units, indicating a complex evolutional history involving basaltic magmatism, akin to that experienced by the terrestrial planets.

References: [1] McCord T.B. et al. (1970) Science 168, 1445-1447; [2] Binzel, R.P., et al., (1997) *Icarus, 128*, 95-103. , [3] Gaffey, M.J., (1997) *Icarus*, *127*, 130-157. [4] Li, J.-Y., et al., (2006) *Icarus*, *182*, 143-160. [5] De Sanctis et al., SSR, 163, (2011). [6] Sierks et al, SSR, 163 (2011). [7] De Sanctis et al, LPSC (2012). [8] Adams et al., 1974, JGR 79.

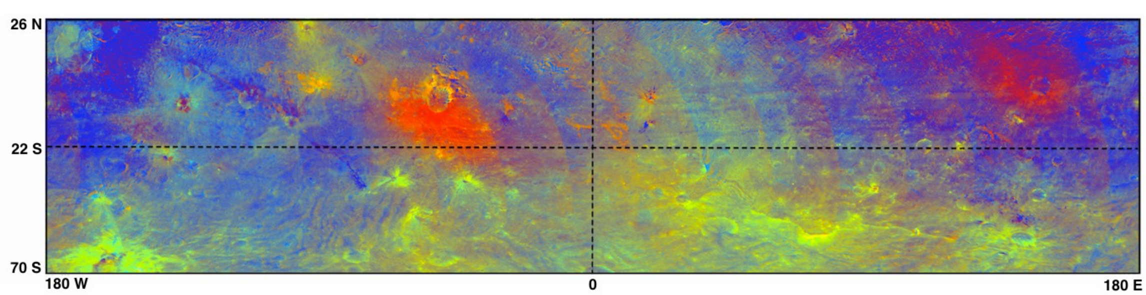

Figure 2. FC false color map (red: 750/430 nm, green: 750/920 nm, blue: 430/750 nm) from late Approach data. The map shows deeper pseudo 1-µm absorption band depths (green colors) for latitudes less than -20°.