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Hellas Planitia as a potential site of sedimentary minerals

Natalia Zalewska (Andrzejewska)*

Space Research Centre, Polish Academy of Science, ul. Bartycka 18a, 00-716 Warsaw, Poland

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ABSTRACT

Demonstration of the existence of clay minerals and sulfates of Hellas brings us closer to the finding that water on Mars might have existed earlier and it may even exist now. Hellas Crater is a potential area where episodes of liquid water may appear. Infrared data from OMEGA and PFS installed on the Mars Express probe have been used for the investigation of the surface of Hellas for evidence of water. There are emissivity spectra from PFS and shortwave reflectance spectra from OMEGA. Only the most characteristic spectra indicating water have been chosen for presented studies. Additionally, high-resolution images from HiRISE installed on Mars Recconaissance Orbiter probe have been used for comparison. Some images from the HiRISE apparatus disclosed Hellas' area weathered surface possibly created by water erosion, that is confirmed by infrared spectra of the OMEGA apparatus. Wave number of 1160 cm^{-1} has been identified in the spectra of the PFS Mars Express probe, that fits very well to the band of sulfates. The band responsible for the occurrence of clay minerals associated with the presence of water in Hellas has been also found in the spectra obtained with the OMEGA instrument.

1. Introduction

Hellas Planitia is a roughly elliptic impact crater about 3000 km long by 1500 km wide located in the southern hemisphere of the planet Mars. The basin was probably formed when a large asteroid impacted Mars about 3.9 billion years ago during the Late Heavy Bombardment period of the Solar System (4.1–3.8 Ge). The topography of this broad crater slopes down from an average highland altitude of about 2 km above the Martian reference radius (3394.2 km) to an average depth of about 6 km. It reaches a minimum of—7.5 km in its NW corner, which is the lowest point on the entire surface of Mars (Richardson, 2002; Tanaka and Leonard, 1995; Leonard and Tanaka, 2001; Crown et al., 2009). The depth of the structure (7152 m below the standard topographic datum of Mars) explains the atmospheric pressure at the bottom: 1155 Pa (11.55 mbar). This is 89% higher than the pressure at the topographical datum (610 Pa, or 6.1 mbar) and above the triple point of water, suggesting that the liquid phase would be transient. It is interesting that PFS and OMEGA already determined the presence of minerals normally connected to the presence of liquid water, such as sulfates, carbonates, clay minerals and oxides (Bandfield, 2003; Bandfield et al., 2009; Hamilton, 2000; Lane and Christensen, 1997). However it is a difficult for investigation area because of thick atmosphere and presence of atmospheric dust.

The work is an attempt to analyze the very difficult data, not previously analyzed carefully because of the conditions on Hellas. Here, I have presented mineralogical investigation of PFS and OMEGA data from Hellas Basin. From significant amount of data I had to choose the most suitable parts of it for this investigation. The results are confirmed by the recent publication (Carter, 2011), where CRISM apparatus (Mars Recconaissance Orbiter) data have been analyzed.

2. Material description

The Planetary Fourier Spectrometer (PFS) installed on Mars Express spacecraft passing over Hellas and the surrounding terrain, such as valleys, recorded some infrared spectra with characteristic band. For ex121.1ample, one can see the band around 1160 cm^{-1} in emissivity, that could be assigned to sulfates (Fig. 1, for more details see Section 4).

The PFS-Planetary Fourier Spectrometer provides spectra in the range 200–8000 cm^{-1} with spectral resolution equal to 2 cm^{-1}. Such resolution improves earlier attempts of fitting the spectra of mineral mixtures to those measured (PFS for Mars Express, Planetary Fourier Spectrometer, IFSI-98-2., 1998). A lot of spectrum recorded by PFS over Hellas, apart from the deep CO_2 band with a minimum at 667 cm^{-1}, revealed a dust spectral shape at 1075 cm^{-1}. One can see the band around 1160 cm^{-1} which can be identified as sulfate spectra (Christensen et al., 2000a, 2000b) (Fig. 1). This is based on finding mineral-characteristic emission bands which do not belong to well known

* Tel.: +48 22 840 37 66.
E-mail address: natalia@cbk.waw.pl)

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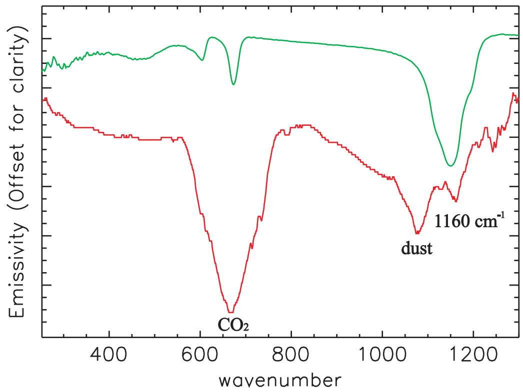

Fig. 1. PFS spectrum (red/bottom) of Hellas Planitia with band 1160 cm^{-1} which is interpreted as sulfates. A minimum of 1160 cm^{-1} of gypsum (green/upper) fits the spectrum with a minimum of Hellas from orbit 30th. Gypsum origin from ASU Digital Spectral Library (ASU Thermal Emission Spectral Library [http://speclib.asu.edu/] 2000). Other minima: CO_2 667 cm^{-1}, dust 1075 cm^{-1}, CO_2 1250 cm^{-1}. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

spectra of CO_2, at 667 cm^{-1} and H_2O about 900 cm^{-1}, ice crystals or dust which usually reside in Mars atmosphere (Grassi et al., 2007).

PFS spectra were selected so that the atmospheric influences are minimal. It was difficult because of noise as the atmosphere over Hellas is the thickest on the whole planet due to the depth of the basin (7 km below the standard topographic datum of Mars), and additionally because of atmospheric dust (Christensen et al., 2000a, 2000b; Smith et al., 2000), (Fig. 1) is an example of PSF spectrum of Hellas Planitia around the 1160 cm^{-1} band.

The Visible and Infrared Mineralogical Mapping Spectrometer (OMEGA) (Observatoire pour la Minéralogie, l'Eau, les Glaces et l'Activité) was installed on Mars Express. This instrument is able to detect mineral compositions of the surface up to 100 m resolution. OMEGA has two channels, one for visible (0.5–1.0 μm wavelength) and the other for IR (1.0–5.2 μm wavelength).

Let's take into consideration OMEGA spectra. In the first spectral characteristic the influence of water ice and dust can be noticed. One can also find weathered basalt with minerals such as phyllosilicate minerals (Fig. A.3), (Gendrin et al., 2005; Bibring et al., 2006). Here, only data from the SWIR-C (1–2.5 μm) channel were therefore used for more detail interpretation as they have least noise.

Additionally, the infrared spectra from OMEGA were compared with High Resolution Imaging Science Experiment (HiRISE) installed on board the Mars Reconnaissance Orbiter (MRO) mission.

3. Methods of data analysis

In this investigation the following steps of PFS spectral analysis were involved:

Spectra were averaged from a dozen of single PFS measurements of radiance in order to eliminate incidental noise. There were orbits taken by PFS numbered from 1 to 2000 since the year 2009. Among them 300 were passing over Hellas, and from them 21 orbits that showed the last noise were selected. Each orbit contained typically 40 measurements scanning Hellas and surrounding areas. The least noisy measurements have been selected from each orbit, and then averaged. About 12 measurements have been selected from each orbit. These spectra were selected when measurement was done during Martian autumn on south hemisphere, because they contain less dust than spectra of other seasons. To achieve clear interpretation, spectra are calculated from radiance to emissivity through division by the spectra of a black body at a certain temperature selected in optical window. Averaged spectra are to be smoothed even more using the least-square method to eliminate noise.

In order to establish the exact temperature of the surface of Mars over which the infrared measurements were made, temperature in optical window had to be chosen so emissivity without minima should reach 1. Hence, the best optical window 320–370 cm^{-1} was chosen. Other suitable window is 1250–1350 cm^{-1}, but it is less useful to obtain good result.

Bands show well distinguished minima. High noise often blurs the picture of the spectra in emissivity. Noise is probably caused by apparatus or atmospheric influences. This is caused by temperature selection in the optical window of the atmosphere when dividing spectral radiance by the Planck curve for a certain temperature; then, the band range higher than 1200 cm^{-1}in emissivity becomes unreadable. This is the reason why spectra are interpreted only below the 1200 cm^{-1} band, in this analysis.

Spectra from OMEGA were interpreted after automatic removal of atmospheric influence using ENVI software. However the majority of spectra still showed some small atmospheric CO_2 influence because of thickness of the atmosphere over Hellas.

To remove these atmospheric influence from spectra, an estimation of atmospheric spectral thickness over Olympus Mons volcano has been used due to Spectral Hourglass Wizard installed on ENVI software (Bandfield and Christensen, 2000; Odden et al., 2009; Harris, 2006). Measured spectral reflectance over the peak of the volcano has been divided by spectral reflectance from its base, assuming that the volcano is made of solid rock, which yielded the spectrum of the atmosphere itself. Assuming that atmospheric influence is the same over the entire Mars, spectra from different areas of Mars have been divided by the spectrum of the atmosphere giving reflectance spectra of the surface alone. Unfortunately, for Hellas this method is not sufficient because of the thickness of the atmosphere, which results in noticeable atmospheric influence in Hellas spectra around 2 μm. (More details in Appendices)

4. Results

Resulting PFS spectra in emissivity were carefully observed to find interesting bands and then compared with infrared spectra of minerals. Spectra of minerals were taken from the ASU internet library and from measuring the spectra of various earth samples (ASU Thermal Emission Spectral Library [http://speclib.asu.edu/] 2000; Christensen et al., 2000a, 2000b).

I found that band around 1160 cm^{-1} may indicate a deep band of gypsum (Fig. 1). This band has been found in 12 orbits passing over Hellas. Sulfates could appear as products of evaporation when the Hellas basin was supposedly filled with water (Thomson and Head, 1999). Sulfates may also form at depth in the presence of sulfur-rich fluids in hydrothermal conditions. Layered deposits could have originated as volcanic ash or eolian deposits and later possibly altered to sulfates by acidic groundwater circulation. Finally, sulfates could result from alteration of mafic minerals by rain or frost acidified through volcanic outgassing (Gendrin et al., 2005; Peterson, 1978).

Other minerals which were found in PFS spectra (Table 1) are connected with occurrence of liquid water on the surface excluding some minerals from the phyllosilicates group like, muscovite and flogopite. These phyllosilicates are associated with magmatic and hydrothermal processes. They occur in rocks such as granitoids and pegmatites. The presence of such rocks is highly questionable on Mars. Nevertheless infrared spectrum of vermiculite in transmittance fit well to band 980 cm^{-1} and confirm the occurrence of this mineral discovered by OMEGA (Figs. 2 and 3).