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Occurrence of anorthosite on Mars in Xanthe Terra

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Abstract

Here we report the occurrence of an anorthosite body confined on the north rim of an unnamed crater in Xanthe Terra on Mars. The small identified exposure outcrops in a small area on the steep eastern bank of the feeding channel, that dissect the crater rim and creates a typical morphology of a fan shaped delta on the crater floor. Using CRISM spectrometer aboard MRO we performed a spectral analysis in the NIR, of the outcrop. Combining these results with other data sets we place the area in a geological context, the result of the analysis revealing a moderate sized body (probably a sill) with an area of a high Ca plagioclase content (in the bytownite-anorthite range). consistent with the presence of an anorthosite. This analysis makes the targeted outcrop the first identification of an anorthosite rock on the surface of Mars.

1. Introduction

Anorthosites are “exotic” rocks that are made of more than 90% of Ca rich plagioclases. Their importance is mostly concerned with the formation of the Moon, as anorthosites are found on the Moon highlands that stands as a proof for the lunar magma ocean theory that produced plagioclase by flotation crystallization [1, 2]. On terrestrial like planets anorthosite presence is rather rare in occurrence and are mostly related to Ti and PGE ore accumulations. Their surface presence is connected to a series of factors that make their presence on surface even more difficult to identify from orbit due to small outcrop exposures. The current identification is of a highly pure plagioclase phase within the northern rim of a martian crater in Xanthe Terra (Figure 1).

1.1 Method and data set

We used the NIR variable band centered in between 1.25-1.30 µm region (variation connected to the amount of Ca in the plagioclase structure) to identify and characterize the area where this anorthosite outcrops. This band is unambiguous and characteristic to Fe rich plagioclases substituting for Si and Al inside $[SiO_4]^{4-}$ tetrahedra [3, 4]. The band is clear and enhanced as of function of Fe concentration (better seen at > 0.4 % Fe substitution).

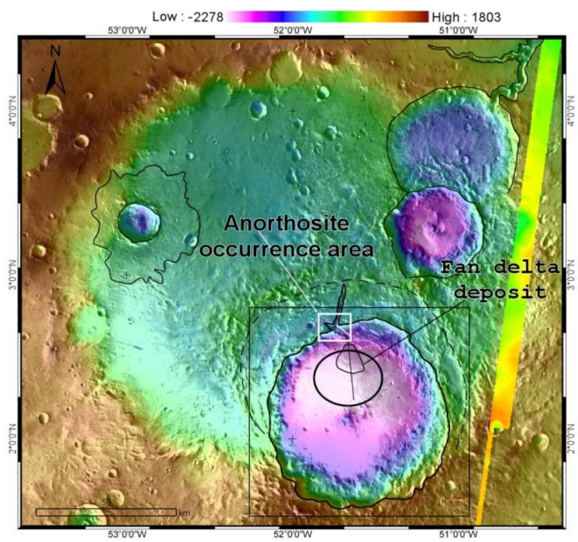

Figure 1: Position of the anorthosite outcrop relative to other units in the area. THEMIS global mosaic superposed on MOLA topography.

Using the CRISM available orbits we mapped the band depth around 1.25 µm and plotted on a map of the region. The presence of anorthosite unit seems to display a horizontal distribution, consistent with the presence of a sill with its maximum band depth on the eastern side of the crater rim dissecting channel. The steeper slopes on this side favors a good exposure of the unit free of gravitational sliding and mixing with other adjacent units (Figure 2). There is a slight band minimum variation, but generally within the small outcrop the band minimum is at 1.27 µm, that is consistent with the presence of bytownite member of plagioclase series (Figure 3).

The unit outcrops in three parts of the CRISM image area covered area, but could also cover areas not covered so far by high resolution spectral imagery following the crater rim most probably to the west and north along the channel bank.

The presence of the channel is testimony to the water presence in the area. Water is the agent that most certainly carved the channel and its presence is confirmed by the presence of various water derived phases in the area as well as traces of hydrous alteration in the anorthosite body itself.

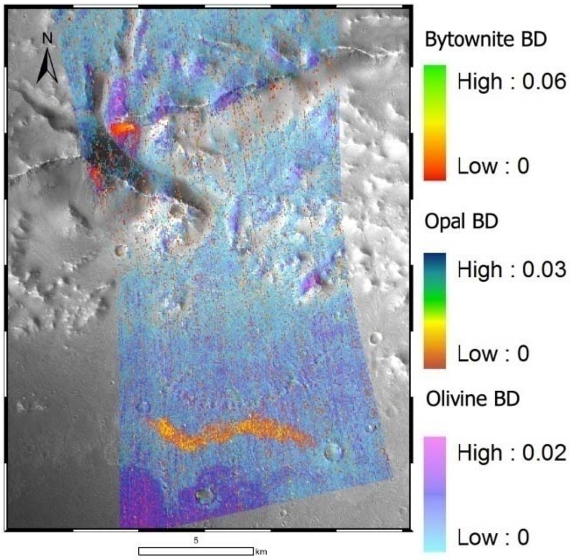

Figure 2: MRO CRISM superposed on a MRO-CTX image with color coding of three main mineral units in the area (scale bar below 5 km).

The main products of alteration are expressed in the area by the presence of Al and Fe/Mg phyllosilicates well correlated with the presence of plagioclase and mafic minerals in the area. The anorthosite alteration has probably occurred during the sapping event that produced the channel and is characterized by the presence of water related band at 1.9 and the 2.3 and 2.37 µm, consistent with the presence of Fe/Mg smectite, and small areas with kaolinite presence.

2. Conclusion

We present the first martian anorthosite occurrence in a complex geologic setting and a complex alteration pattern. The hydrothermal alteration occurred in the late Hesperian eon coeval to the outflow Channels formation in Xanthe Terra. The identification of this occurrence is probably strictly tied to the alteration pattern observed. The nontronite spectral match within the outcrop could mean that we deal with larger occurrence spreading horizontally over an undetermined area, and the pure anorthosite signature observed so far is due to the fact that this particular outcrop is depleted in mafics, probably by hydrothermal alteration. This depletion in (olivine mostly) permitted the enhancement of the plagioclase characteristic spectral band. It is known that this band is particularly sensitive in mixtures of plagioclases with very small quantities of mafic minerals [1].

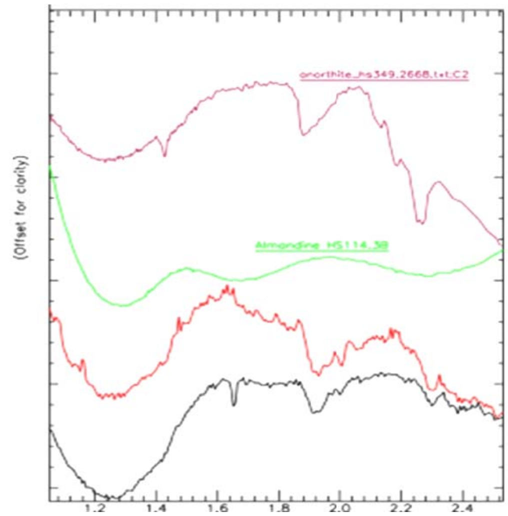

Figure 3: MRO-CRISM extracted spectra (red and black) vs. Spectral library (magenta anorthite and green almandine)

The areas with less alteration and stronger olivine spectral signatures are present to the north along the channel bank and crater rim, while the 1.2 µm fades away as we farther away from the main enrichment outcrop. This could mean that the anorthosite occurrence is spread on a larger area and its spectral signature is a convolution of Ca rich plagioclases and olivine as major and minor constituents respectively. The clear presence of the 1.27 µm absorption band demonstrates that the anorthosite unit preserves much of the crystal (phaneritic texture) and didn't suffered major diaplectic loss of structure by exposure at high shock pressures [5].

References

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