ORBITAL DETECTION OF SUSPECTED ALKALI-RICH FELDSPARS ON MARS.

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Introduction: Alkali basalts were observed in the Columbia Hills of Gusev crater by the Spirit rover [1] and trachytes and trachyandesites have been observed as float rocks by Curiosity [2]. Also observed by Curiosity were subalkaline rocks that could be deemed as "felsic" [2]. Orbital remote sensing evidence for alkaline and felsic compositions have been elusive and controversial [2-5]. We discuss here CRISM evidence from the 3 to 4 μm region, supported by shorter wavelength information, that indicates the presence of alkali feldspars in at least two areas on Mars.

Areas examined: The potential observations of alkali feldspars were serendipitous in that they were observed in the course of examination of areas of interest for other reasons. Domes in western Arcadia Planitia were cited in [6] as potentially being felsic on the basis of photogeologic evidence. Visible to short-wave infrared (0.35 to 2.6 μm) analysis with CRISM data provided evidence of rock-forming minerals that are associated with basalt [7] and more recent studies have suggested the presence of a 1.3 μm feature generally associated with plagioclase [8]. As part of a recent reexamination of this site, additional evidence suggests that alkali feldspars are present.

The NE Noachis Terra/southern Terra Sabaea area has been examined as an area with an abundance of exposed bedrock as well as containing extensive exposures of light-toned bedrock with an associated 1.3 μm feature [3, 9]. Spectral evidence from this region also suggests the presence of alkali feldspar exposures.

Spectrally Anomalous Exposures: In the examination of CRISM summary products [10] from CRISM targeted observations over both of these areas, spatially coherent relatively high values of the CINDEX2 parameter were observed (**Fig. 1** and **2**). This parameter is defined as:

$$\mathrm{CINDEX2} = 1-((0.62*\mathrm{R3450} + 0.38*\mathrm{R3875})/\mathrm{R3610}$$

and it is intended to detect the presence of carbonate minerals based on convexity between CO_3 absorptions near 3.4 and 3.9 μm [10]. However, carbonates were not expected in these areas, nor were other features characteristic of carbonates (e.g., absorptions just longwards of 2.3 and 2.5 μm) observed in CRISM spectra over these high CINDEX2 areas.

Analysis: To determine the identity of the phase responsible for the high CINDEX2 values in these regions, the CINDEX2 formula was applied to the CRISM spectral library [11] provided with the CRISM Analysis Tools (CAT) software with additional spectra drawn from the RELAB spectral library (since many entries in the CRISM library do not cover the 3 to 4 μm region). Out of 292 spectra (with carbonates excluded), eight of the fourteen library spectra with values of 0.09 to 0.19 (carbonates have values of ~0.1 to 0.9) were alkali-rich feldspars (oligoclase, albite, and microcline) with other relatively high values being gypsum and smectites. As with the exclusion of carbonates due to the lack of observed 2.3 or 2.5 μm features, gypsum or smectites did not seem like likely candidates due to the lack of features at 2.2 or 2.3 μm. Thus, the feature is attributed to alkalic feldspars.

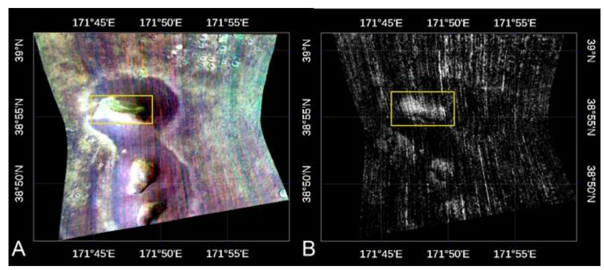

Fig. 1. CRISM scene FRT000171F6 from western Arcadia Planitia over domes. **A**. Composite of 3.3, 3.62, and 3.8 μm bands. **B**. CINDEX2 parameter image. Yellow box outlines area with highest CINDEX2 values.

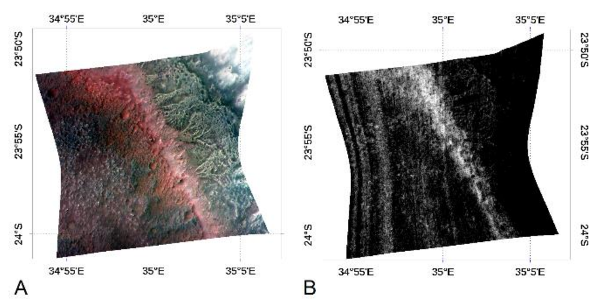

Fig. 2. CRISM scene FRT000085E2 from NE Noachis Terra. **A**. Composite of 2.5, 1.5, and 1.08 μm bands. B. Composite of summary products CINDEX2, BD1300, ISLOPE1. Green pixels have a stronger 1.3 μm band, yellow pixels have a weaker 1.3 μm band and stronger CINDEX2 response.

The commonly used practice with CRISM data of dividing the region of interest (ROI) of a spectrally distinctive area by that of a spectrally bland area (from anywhere in the image for a CRISM MTRDR file or from within the same columns for a standard TRDR scene) was used here with caveats. The issue for the caution being that 3 to 4 µm is a crossover region with influence from both reflected solar and emitted thermal radiance. However, it is assumed that areas with similar temperatures, based on daytime IR observations from THEMIS, can be used in a ratio effectively. With the foregoing caveat, a ratioed spectrum from Arcadia scene FRT00017600 is shown in **Fig. 3A**. Applying a spectral angle metric against this spectrum with the aforementioned CRISM/RELAB library spectra finds top matches with several oligoclase spectra. In **Fig. 3B** are representative plagioclase and alkali feldspar spectra in the CRISM L spectrometer range.

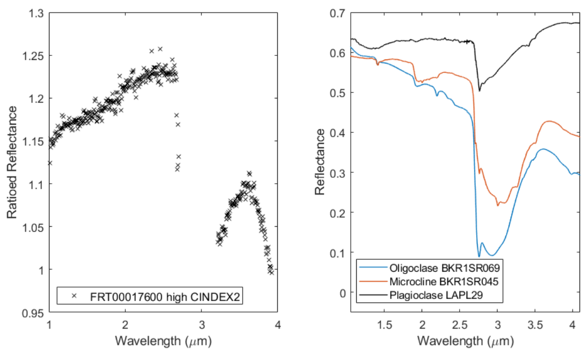

Fig. 3. A. Ratio spectrum of high CINDEX2 area in CRISM scene FRT00017600 from dome in Arcadia. **B**. Representative library spectra of feldspars. Alkali feldspars contain a reflectance peak at ~3.6 microns that is lacking from plagioclase spectra and is present in the CRISM ratio spectrum.

Spectral Discussion: While both the western Arcadia domes and the NE Noachis Terra bedrock unit have clear exposures of materials with elevated values of the CINDEX2 spectral parameter, definitively assigning an identity to the causative phase is challenging. The derived ratioed reflectance of the unit is only as good as the denominator spectrum used. In the western Arcadia region, plains that are relatively spectrally featureless in the 1 to 2.6 µm range surround the domes that display the high CINDEX2 values; thus ratioed reflectances in the 1 to 2.6 µm range are confidently used; however, the effects of thermal emission could still be affecting the shape of the spectrum in the 3 to 4 µm range although a convex shape is clearly present.

The NE Noachis Terra region, is spectrally more diverse. A spectrally neutral dark mantling unit is present that could be used as a denominator spectrum, but it clearly has different thermal properties than the high CINDEX2 materials. Thus work to obtain a reliable ratioed reflectance spectrum is on-going. Also noteworthy from this region is the presence of light-toned bedrock with a 1.3 µm commonly attributed to calcic plagioclase. However, spectral libraries have examples of alkali feldspars with a 1.3 µm band, nominally attributable to Fe^{3+} substitution for Al^{3+}.

Discussion of Geologic Significance: In the western Arcadia region, the presence of alkali rich feldspar (either oligoclase plagioclase or even an alkali feldspar such as microcline) lends credence to the hypothesis that these are felsic volcanic domes [6]. This idea is also supported by the observation that the high CINDEX2 areas on the Arcadia domes are associated with light-toned boulders (**Fig. 4**).

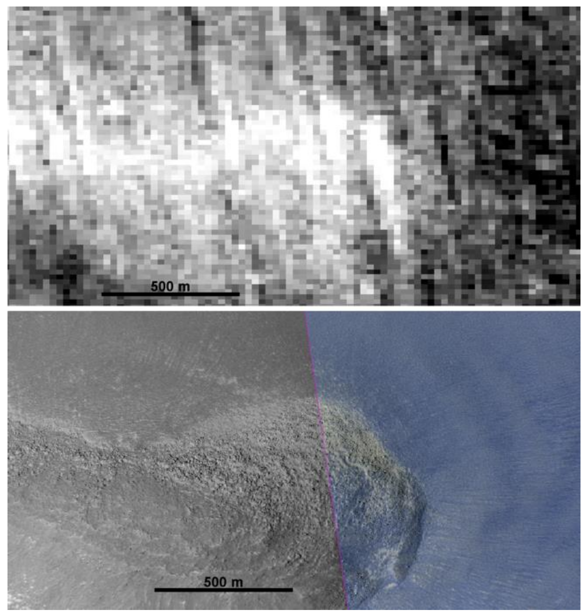

Fig. 4. (top) Subsection of CINDEX2 image from FRT000171F6. High values overlap with light-toned, boulder-rich surfaces in subsection from CRISM red and color imagery from HiRISE.

Felsic rocks have been proposed for the light-toned unit in the NE Noachis Terra region [3] and alkali-rich feldspars would be consistent with felsic compositions; however, thermal IR data from THEMIS [4, 9] is still contradictory to the proposed presence of felsic rocks.

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