FELDSPAR-RICH TERRAINS IN TERRA SIRENUM/CIMMERIA, MARS: AN EVOLVED CRUST IN EARLY MARS? V. Payré[1], M. R. Salvatore[1], and C. S. Edwards[1], [1]Northern Arizona University, 527 S. Beaver St, NAU PO Box 6010, Flagstaff AZ 86011, valerie.payre@nau.edu.

Introduction: Thought as homogeneously basaltic, the nature of Mars' crust is now questioned following the discovery of intermediate (SiO_2=52-63 wt.%) and felsic Noachian rocks (SiO_2>63 wt.%; >3.8 Ga) in Gale crater by the *Curiosity* rover [1] and the analyses of 4.47 Ga zircon grains in martian meteorite NWA 7034 and its paired meteorites, which suggest the existence of an andesitic crust formed as soon as 20 Myr after solar system formation [2]. Feldspar-rich (>60 vol.% [3]) terrains of Noachian age have been observed by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) onboard Mars Reconnaissance Orbiter [4-5], but their petrographic nature remains controversial [3]. The observations of evolved and feldspar-rich ancient rocks suggest that the martian crust is complex and raises questions about its chemical composition, especially in early Mars [1]. The Terra Sirenum/Cimmeria (TSC) region has been established as being the oldest crustal block (>4.2 Ga) preserved at the surface of Mars [6] and it presents geochemical and magnetic anomalies with K- Th- rich signatures that could indicate an evolved crustal component. We thus (1) explored the potential presence of feldspar-rich outcrops in this region using CRISM and (2) evaluated their nature based on thermal infrared data (TIR) that can constrain the SiO_2 concentrations of these terrains [4] in order to test whether the oldest crustal component on Mars is evolved.

Identification of Feldspar-Rich Terrains using CRISM: The detection of feldspar using visible/near-infrared (VNIR) spectroscopy is challenging due to the weak spectral signatures associated with the feldspar crystal field absorption in CRISM spectral range (0.4-3.9 µm). Yet, with low amount of mafic minerals and high amount of feldspar within the given regions of interest (<5 vol.% and >60 vol.%, respectively) [4]) and with the presence of Fe^{2+} impurities in feldspar crystals, a broad diagnostic absorption band at 1.25-1.30 µm becomes apparent and can be detected. We used a combination of spectral ratioing and parameterization to identify abundant plagioclase feldspar based on this unique absorption feature and the near absence of other mafic signatures. We used spectral parameters including BD1300 characteristic of feldspar and LCPINDEX2 diagnostic of LCP [7] to distinguish between true feldspar signals and complications from the presence of mafic phases. Ten locations in TSC have been identified as feldspar-rich terrains (Fig. 1a) and investigated here.

Silica Concentration of Feldspar-Rich Terrains using TIR: Thermal infrared spectroscopy is useful to constrain the silica content of terrains since the absorption center of emission spectra is shifted to shorter wavelengths when igneous materials of the targeted region are silica-rich (Fig. 1b). Hence, felsic and mafic terrains can be distinguished using emission spectra of the Thermal Emission Imaging System (THEMIS) aboard the Mars Odyssey orbiter.

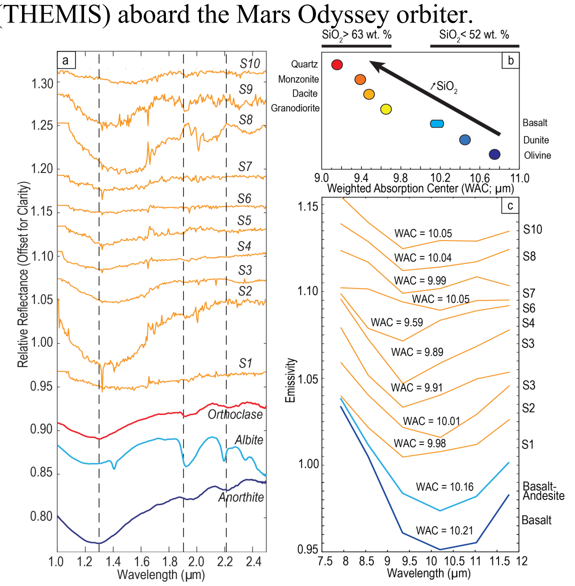

Fig. 1. (a) CRISM spectra of feldspar-rich terrains (orange lines) and feldspar-endmembers (blue and red lines) showing the diagnostic absorption band at 1.25-1.30 µm. (b) Weighed absorption center (WAC) for laboratory and modeled derive emission spectra. WAC is calculated according to [8]. (c) Averaged emission spectra from THEMIS of feldspar-rich terrains (orange lines) and modeled emission spectra of a basalt-andesite clast 77 from NWA 7034 [9] and a basalt [10].

Following atmospheric correction and conversion of THEMIS spectra to surface emissivity, the absorption centers of feldspar-rich outcrops identified with CRISM are found to range between 9.60-10.0 µm (Fig. 1c), i.e., at shorter wavelengths than basaltic and basalt-andesitic rocks (Fig. 1b-c), and at longer wavelengths than felsic rocks (< 9.6 µm; Fig. 1b). These values suggest that TSC feldspar-rich terrains are composed of intermediate compositions, being either andesitic/dioritic or trachy-andesitic/monzo-dioritic.

Geological Context: The feldspar-rich terrains observed in TSC are localized in various geological settings. Three exposures (S1-2, 10) are located on the edges of light-toned eroded blocks in Eridania basin.

The lack of layering and the presence of feldspar-rich signatures throughout these blocks are consistent with crustal materials excavated by erosion [11]. Five feldspar-rich exposures are associated with craters, occurring in crater rims (S3,8), in the wall of a fracture crosscutting a crater (S4), ejecta (S6), and within a central peak (S9). They are all likely crustal materials excavated by impacts. Note that although feldspar within crater central peaks could have formed through shock metamorphism, their precursor would likely be feldspar-rich, as observed on the Moon [12]. Feldspar signatures in S5 are found in boulders in the meanders of Mangala Valles, suggesting that feldspar-bearing materials from the river catchment were transported and deposited by fluvial activity. Finally, S7 is located within the eastern walls of a channel cross-cutting Garu crater, ~200 km east of Gale crater, suggesting that the feldspar-rich materials are crustal materials. Hydrated silica is observed at the toe of a delta that deposited materials from this channel [13], which is potentially an alteration product of feldspar weathering. Except for S5 that is ambiguous, feldspar-rich exposures in TSC are most consistent with a crustal origin that were excavated by impacts and erosion, suggesting that they are remnant of the early crust of Mars.

Discussion: Intermediate compositions of TSC feldspar-rich terrains echo a feldspar cumulate and trachy-andesitic and dioritic rocks analyzed by the *Curiosity* rover (Fig. 2). The estimated Noachian age [1] and location in Gale crater (at the NW border of the TSC region) suggest that these intermediate rocks might be related to feldspar-rich terrains observed by CRISM.

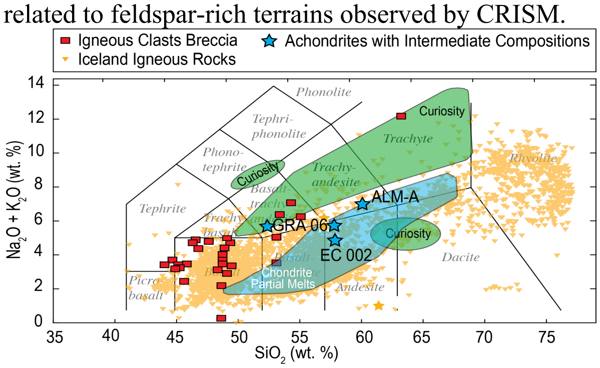

Fig. 2. Alkali versus silica concentration diagram of Gale crater igneous rocks (green patches [1]) and 4.47 Ga igneous clasts of NWA 7034 and its paired meteorites (red squares [9]) compared to Icelandic igneous rocks (orange triangles), achondrites with intermediate compositions (blue stars [14]), and melt obtained by partial melting experiments on various types of chondrites [15].

Intermediate compositions are also in line with the andesitic nature of the early crust formed on Mars in the first 20 Myr after solar system formation [2], potentially suggesting that these feldspar-rich materials are representative of this same early crust.

Several mechanisms could explain the formation of intermediate crustal rocks with abundant feldspar. (1) Fractional crystallization of basaltic melts at pressures <4kbars is a process that has been proposed to explain the felsic rocks analyzed in Gale crater, and such process could crystallize up to 90% of feldspar at intermediate melt compositions [16-17]. (2) As showed on Fig. 2 and suggested by [16], Icelandic igneous rocks have compositions similar to intermediate and felsic rocks in Gale crater. Icelandic rock formation process broadly consisting in the crystallization of melts formed by partial melting of a hydrated basaltic crust could have been similar to the mechanism that produced the feldspar-rich rocks in TSC, with a mantle plume partially melting the base of a basaltic crust. In these two scenarios, the feldspar-rich terrains are representative of a secondary crust that formed very early, potentially being an analog to the early Earth crust. (3) A third option is that they are the remnants of a primary crust on Mars. If so, an intermediate crustal block in the TSC region could not have been formed by a global magma ocean since a basaltic crust would have been extracted. Instead, partial melting of chondritic building blocks could form such intermediate compositions as suggested by partial melting experiments and andesitic feldspar-rich achondites (Fig. 2; [14-15]). In that case, although a magma ocean could have existed, at least one location on Mars, i.e., TSC would have undergone partial melting, leading to the formation of an evolved crust with intermediate compositions and abundant feldspar, as suggested by NWA 7034 zircons, seismic data [18], and the geoid-topographic ratios [19]. An evolved primordial crust on Mars would challenge our current knowledge of a homogeneous basaltic crust and highlight the complexity and diversity of planetary differentiation.

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