A TRANSPORTED ORIGIN FOR ALTERATION MINERALS WITHIN THE JEZERO CRATER, MARS PALEOLAKE BASIN: EVIDENCE FROM CATCHMENT AND DELTA MINERALOGY.

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Introduction: Identified aqueous alteration minerals in ancient deposits on Mars have been used to hypothesize a warmer, wetter early Mars [e.g., 1,2]. However, recent work has suggested that these hydrated minerals may have formed in the martian subsurface, thus not requiring a substantially warmer, and wetter climate for prolonged periods [3]. Nonetheless, there is strong geomorphic evidence for at least a transient period of flowing liquid water on the surface of early Mars [e.g., 4-8]. Therefore, it remains an open question as to whether this period of fluvial activity is genetically linked to the formation of the alteration minerals observed on the martian surface.

Here we present new work addressing this question through the study of the catchment and delta deposit mineralogy of the Jezero crater (18.38°N, 77.70°E) paleolake system [7,9], which has previously been observed to contain alteration minerals in its delta deposits [10,11]. Previous workers have suggested that the alteration minerals observed within the deltas are primarily transported in nature [10,11], a hypothesis that is tested here using new observations.

Methods: To address the source to sink mineralogy hypothesis for these delta deposits, we have employed a combined approach of geomorphic mapping and compositional analysis with visible to near-infrared (VNIR) hyperspectral reflectance data. Geomorphic mapping was completed for the Jezero crater paleolake basin and watershed defined by modern, stereo-derived topography from High Resolution Stereo Camera (HRSC) images [12,13]. Mapping was completed at a 1:100,000 scale using a mosaic of ~6 m/pixel Context Camera (CTX) images [14]. The mineralogy of the major identified units was then determined with Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) VNIR reflectance data [15].

Major Geomorphic Units: *Intra-basin Units.* The primary units of interest within the Jezero crater paleolake are the two delta deposits (**Figure 1**), located at the mouths of the N and W inlet valleys [7,9], which have distinct spectral signatures [10,11] (**Figure 2**).

The N Delta deposit has a spectral signature with a broad absorption feature centered near ~1 μm, as well as an absorption feature centered near ~1.92 μm, and a paired set of absorptions centered near ~2.31 and ~2.51 μm **(Figure 2**). The ~1 μm absorption is interpreted to be due to a crystal field electronic transition from Fe^{2+} in olivine [16,17], while the paired absorptions at ~2.31 and 2.51 μm are interpreted to be due to an overtone of a fundamental vibrational mode of CO_3 in a Mg-carbonate [18,19]. The ~1.92 μm absorption is interpreted to be caused by a combination tone of the OH stretch and H-O-H bend in structural H_2O [20]. This spectral signature of a mixture of olivine and Mg-carbonate (**Figure 2**) is seen everywhere on the exposed portions of the N Delta deposit.

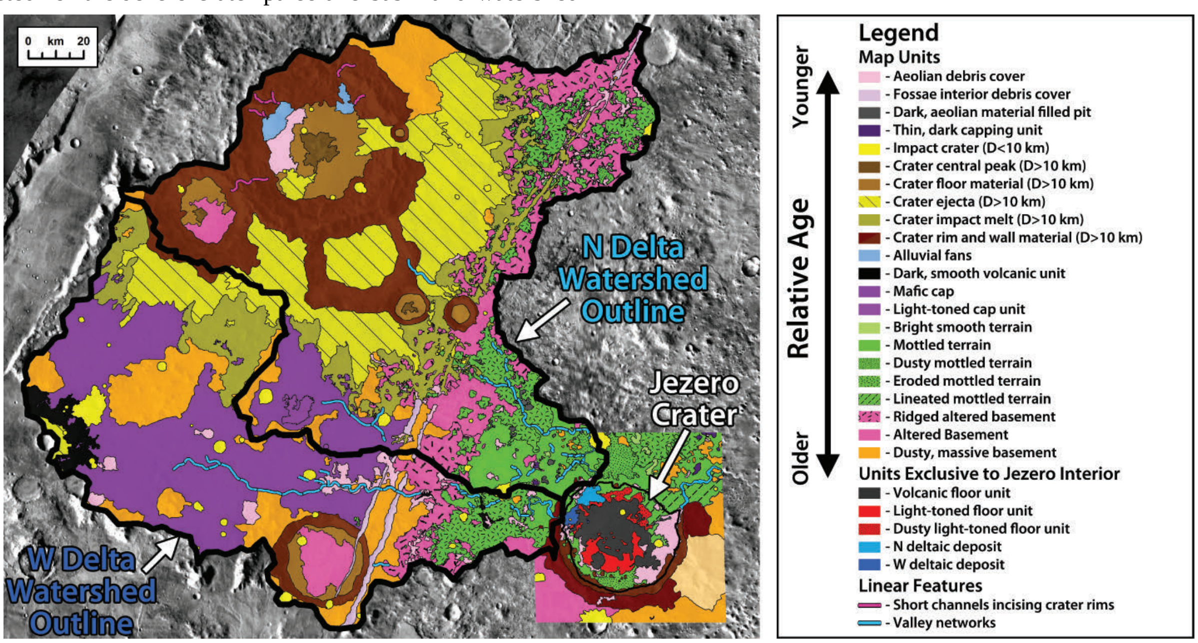

Figure 1. *Geomorphic map of the Jezero crater paleolake basin (indicated by labeled arrow) and its surrounding watershed (indicated by thick, black outlines). Watershed outlines shown are separated into the N Delta watershed and W Delta watershed, both identified by labeled arrows. Legend for all map units is shown on the right, listed in relative stratigraphic order with the youngest units at the top. Background is the global Thermal Emission Imaging System (THEMIS) 100 m/pixel daytime infrared mosaic [21]. See text for discussion of major units.*

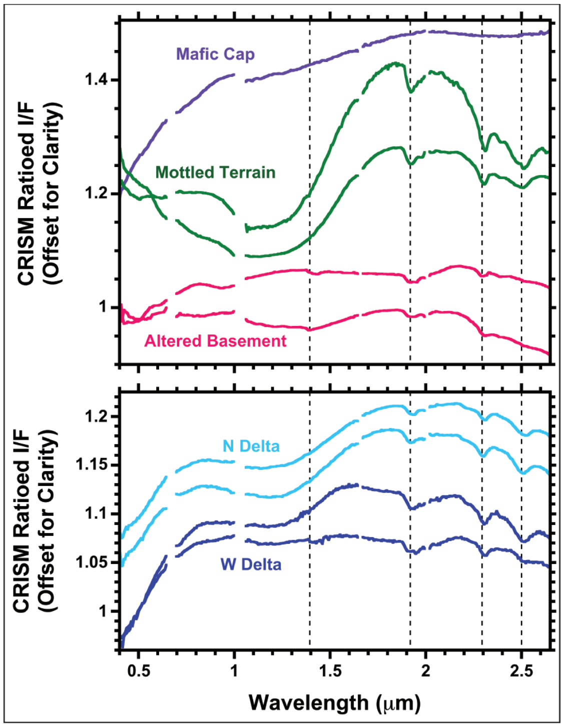

Figure 2: *Representative CRISM spectra of the major geomorphic units in the Jezero crater paleolake watershed (top plot) and of the two delta deposits in the Jezero crater basin (bottom plot). See **Figure 1** for spatial distribution of these units. Dashed lines are at ~1.4, 1.92, 2.3 and 2.5 μm.*

The spectral signature of the W Delta deposit varies across its surface. While some locations on the W Delta deposit show spectra indicating a mixture of olivine and Mg-carbonate, as is seen on the N Delta deposit, the main spectral signature observed is different (**Figure 2**). These spectra show narrow absorptions centered near ~1.42, 1.92 and 2.31 μm, interpreted to be due to the first overtone of the OH stretch, a combination tone of OH stretch and H-O-H bend, and a combination tone of OH stretch and metal-OH bend respectively, in an Fe- or Mg-bearing smectite, such as nontronite or saponite [20,22]. These spectra also show a subtle spectral shoulder near ~2.51 μm, which may be due to an overtone of CO_3 from minor amounts of carbonate. Therefore, the W Delta deposit is spectrally dominated by Fe/Mg-bearing smectites, with variable amounts of olivine and Mg-carbonate.

Watershed Units. The stratigraphically oldest unit of interest in the watershed is the Altered Basement unit (**Figure 1**), which has a spectral signature with narrow absorptions centered near ~1.41, 1.92 and 2.30-2.31 μm (**Figure 2**), and is interpreted to be the source of the Fe/Mg-bearing smectite observed in the delta deposits.

There are two units emplaced upon the Altered Basement unit that occupy the same stratigraphic position: the Mafic Cap unit and the Mottled Terrain unit (**Figure 1**). The Mafic Cap unit has a spectral signature dominated by broad absorptions centered near ~1 and 2 μm (**Figure 2**), interpreted to be a combination of bands due to Fe^{2+} in the mineral structures of pyroxene and olivine [16,17,23]. The Mafic Cap unit is thin, and in many locations the valley networks feeding the Jezero crater paleolake cut through this unit and erode down into the Altered Basement unit.

The Mottled Terrain unit has a spectral signature with a broad absorption feature centered near ~1 μm, as well as an absorption centered near ~1.92 μm, and paired absorptions centered near ~2.31 and 2.51 μm (**Figure 2**), and so is interpreted to be the source of the olivine and Mg-carbonate phases observed in the delta deposits.

Discussion: The two delta deposits within the Jezero crater paleolake have distinct mineralogies based on their VNIR spectral signatures. Therefore, if the alteration minerals contained within these two delta deposits are primarily transported in nature, it would be expected that this difference in mineralogy is also reflected in a difference in the mineralogy of the units present within the watersheds of the two respective deltas.

To test this hypothesis, we have looked at the distribution of the major identified geomorphic units in the different watersheds of the two deltas in the Jezero crater paleolake (**Figure 1**). We have put the major geomorphic units into two groups: an olivine- and carbonate-bearing group, and a smectite-bearing group. The olivine- and carbonate-bearing group contains the Mottled Terrain unit, and covers ~2275 km^2 in the N Delta watershed and ~725 km^2 in the W Delta watershed. The smectite-bearing group consists of the Altered Basement unit and the Mafic Cap unit, as this unit is thin and is eroded through by valley networks in many locations to expose the Altered Basement unit. This group covers ~3850 km^2 in the N Delta watershed and ~5365 km^2 in the W Delta watershed. It is apparent that the difference in delta mineralogy is reflected in the coverage and mineralogy of units within their respective watersheds. This supports a primarily transported origin for the alteration minerals within the two delta deposits, as has been suggested by previous workers [10,11].

Conclusions: Based on the geomorphic mapping and VNIR spectral analysis presented here, it appears that the alteration minerals observed within the two Jezero crater delta deposits are primarily transported in origin. Therefore, at this study site, the formation of the observed alteration minerals does not appear to be genetically linked to the fluvial activity that formed the Jezero crater paleolake.

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