MA'ADIM VALLIS, MARS: INSIGHTS INTO LATE-STAGE WATER ACTIVITY IN AN IMPACT CRATER THROUGH FLUVIAL DEPOSITS.

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Introduction: Martian impact craters altered by fluvial channels and deposits are a potential site to understand the aqueous history of the planet [1-4]. The craters with fluvial deposits either have a well-preserved rim [1, 2] or a breached rim [3, 4]. Breached rim craters, connected to inlet channels or valleys are of great interest as the source of water causing the breach lies outside the crater, and provides an understanding of surface water history on Mars.

This study focuses on the morphological, mineralogical, and chronological analysis of an unnamed impact crater (diameter ~ 22km), located on the banks of Ma'adim Vallis which is ~920 km long and ~ 15 km wide irregular flat floor valley filled with aqueous sediments [5-7], and hosts morphologic features and minerals implicative of fluvial activities. This crater impacted on the wall of Ma'adim Vallis, has a couple of rim breaches and typical fan deposits within it. Thus, this crater post-formation to Ma'adim Vallis will provide information about the late-stage water flow within the Vallis.

Data and Methods: We used MRO- CTX and HiRISE images with resolutions 6m/pixel and 25cm/pixel respectively for geomorphic mapping. For topographical analysis MGS MOLA- DEM of ~ 463m/pixel, MGS MOLA- MEX HRSC of ~ 200m/pixel resolutions were used. We used MRO-CRISM S and L spectral datasets for mineralogical analysis. Summary parameters [8] were generated for identifying the minerals. The spectra obtained from the regions of interest (ROIs) are normalized with the featureless spectra extracted from the same columns [9] to enhance the obtained spectra.

Fluvial Deposits: The unnamed impact crater shown in figure 1a comprises fluvial deposits on the crater floor that are mapped as two separate units. Both the units postdate the crater formation. The first unit, the sediment deposit unit, referred to as Crater floor has an areal spread of~ 135 sq km. This unit was the first to form within the crater. The second unit, the alluvial fan (figure 1c) superposes the sediment deposit unit. The alluvial fan extends~ 6km from apex to toe with a maximum width of 10km and has an areal spread of~50 sq km. It was formed by sediments transported from the western and southwestern breached rim and deposited in the region between the crater wall and elevated crater floor (figure 1a and figure 1b). The alluvial fan has several eroded ridges at its termini.

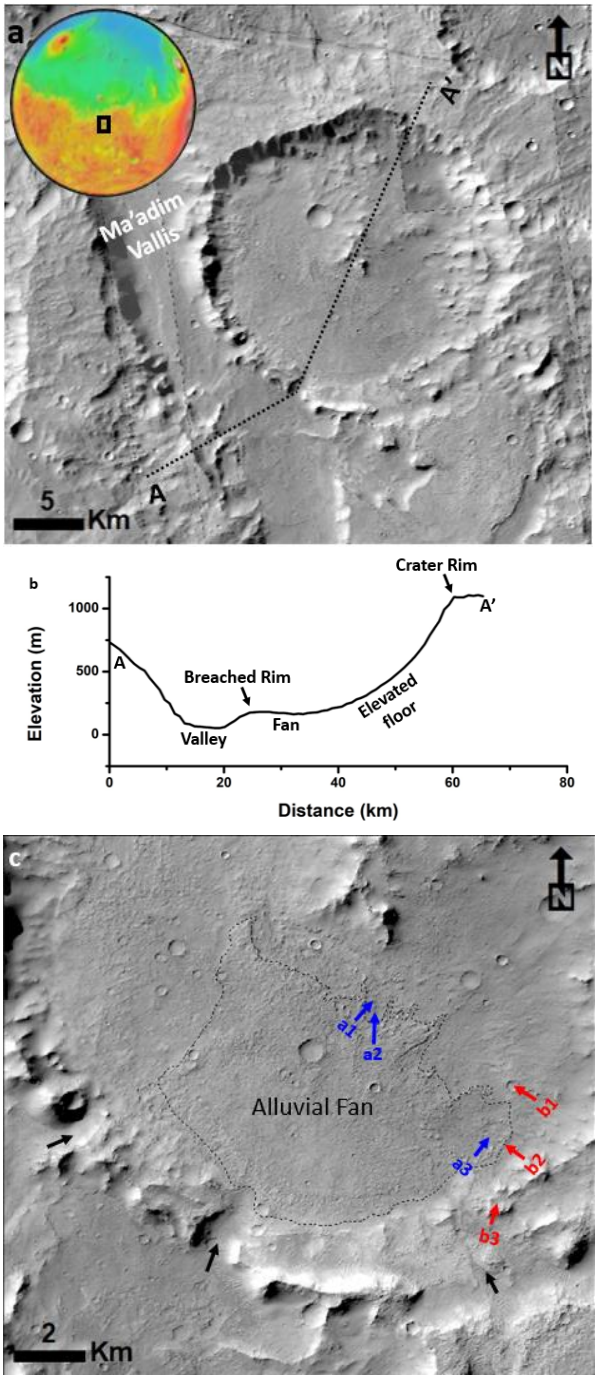

Figure 1: *a) The unnamed crater. b) Topographic profile taken along AA'. c) Alluvial fan within the crater, black arrows show breached crater rim. a1, a2, a3 - locations where Mg smectites are observed. b1, b2, b3 - locations where Mg olivine are observed.*

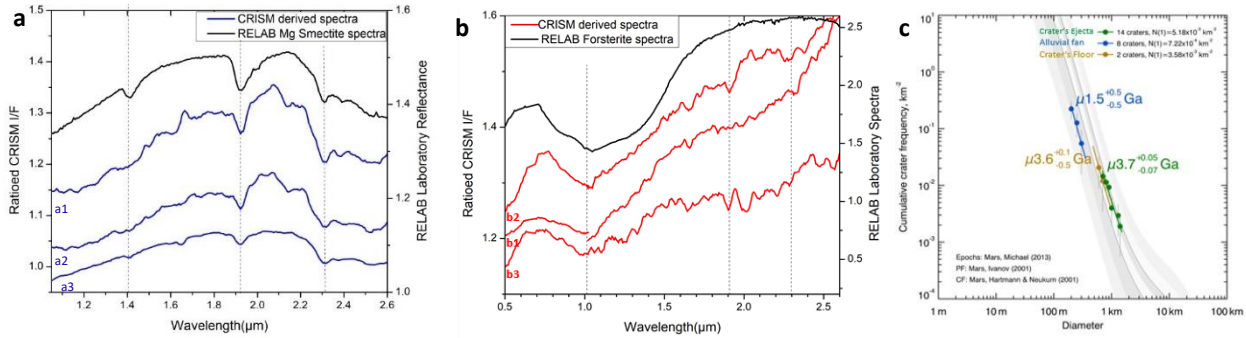

Figure 2: *a) Mg smectite spectra. b) Mg olivine spectra. c) CSFD curve derived age for crater's ejecta and crater retention age for floor and alluvial fan.*

Spectral Analysis: The spectra obtained from the unnamed crater show that the region was rich in Mg phyllosilicates and Mg-rich olivine.

Mg Phyllosilicates: The spectra derived from the fan show strong absorptions at 1.91 μm and 2.3 μm and weak absorptions at 1.4 μm (Figure 2a) which corresponds to Fe/Mg bearing phyllosilicates. The CRISM spectra show absorptions near 2.31-2.32μm which corresponds to Mg smectite [9]. Mg smectites are observed over and in the close vicinity of the alluvial fan (a1, a2, a3 in figure 1c and figure 2a).

*Olivine***:** The spectra derived from the floor and rim of the crater show a broad absorption around 1μm which indicates the presence of olivine in the region. The short wavelength (<1μm) band center, the presence of distinct absorption near 0.85 μm, and the absence of absorption between 1.2 μm and 1.4 μm suggest that the identified olivine is rich in magnesium [10-12]. The olivine detections found over the crater floor (b2, figure 1c and figure 2b) exhibit clay signatures indicated by slight absorptions near 1.9 μm and 2.3 μm and while almost pure olivine signatures are found over the rim (b3, figure 1c and figure 2b) and within a small impact on the floor of the crater (b1, figure 1c and figure 2b).

The unaltered olivine signatures on the rim suggest that the region was initially rich in mafic minerals and the observed smectites are possibly transported (e.g. [13]) through water in the Vallis or formed in-situ (e.g. [1, 13, 14]) by olivine to smectite alteration as both olivine and smectites are rich in Mg.

Chronology: The crater size-frequency distribution curve of the unnamed crater suggests an age of 3.7 Ga (figure 2c). The age was determined from the crater's visible ejecta and represents the crater retention age of the unnamed crater suggesting the crater was formed during the Noachian-Hesperian boundary period or earlier. The unnamed crater probably witnessed the last stage of water activity in Ma'adim Vallis. The crater retention ages derived for the crater's floor and alluvial fan are 3.6 Ga and 1.5 Ga respectively (figure 2c). We anticipate the obtained age for alluvial fan shows the ultimate activity of fan formation and erosion.

Discussion: This study provides one more evidence suggesting episodic water activity in Ma'adim Vallis. The unnamed crater impacted on the wall of Vallis, plausibly after the incision of the Vallis as the crater's rim clearly superposes the floor of the Vallis (figure 1a), and the presence of fan deposits and breached rim indicates another episode of water flow in the Vallis, implying that the unnamed crater saw at least two episodes of water flow. The source for fluvial deposits in the unnamed crater and the cause of rim breach is possibly water from Eridiana overflow [7], which traveled through Ma'adim Vallis. The timing of fluvial activities in the unnamed crater is also consistent with the lower bound age of the Vallis determined by [7].

Overall, this study provides evidence of water-involved activities during the Noachian - Hesperian period of Martian history through fluvial deposits and hydrated minerals in the unnamed impact crater in the Ma'adim Vallis region and has implications in understanding the hydrological history of Mars.

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