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Mineralogical evidence for major aqueous activity in the northern Hellas province, Mars

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Abstract

The Northern Hellas province exhibits morphological and mineralogical evidence for a massive sedimentary depositional event, likely of fluvial origin. We present the result of our investigation of numerous hydrous mineral-bearing layered deposits, in particular the paleo-deltaic complex located in Terby crater.

1. Introduction

The northern rim of Hellas comprises some of the oldest crustal Noachian units on Mars [11] but has experienced extensive re-surfacing since it was emplaced by the basin-forming event. A number of morphologic features including buried landscape, layering in plains and crater infillings hint towards a massive sedimentary depositional event spanning the [-6 ; -1] km elevation range ([7], [8], [12]). The deposits may have an aeolian, volcanic ash or fluvial origin. In the latter case, the shear extent of the unit would have strong regional to global implications for the Noachian surface evolution and state of its hydrological system. Our investigation of the hydrous mineralogy in this region lead us to favour a fluvial origin for the deposits although much of the chemical alteration may have taken place in the sub-surface of the overlying Terra Tyrrhena highlands. One of the most compelling evidence is the hydrated mineral-bearing paleo-delta identified in 174 km-large Terby crater on the flank of the Hellas basin ([2], [5]). In this scenario, Hellas would have served as a major depositional sink where thick layers of salts and clays should have accumulated [1], perhaps in a sub-marine environment. The paucity of hydrous mineral features and morphological evidence that link this region with the Hellas basin remains puzzling.

2. Datasets

We conducted a joint morphological/mineralogical investigation by combining data from the OMEGA and CRISM imaging spectrometers ([3], [10]) to that of high-resolution cameras CTX and HiRISE. We focused on the region [45^{o}E,90^{o}E;-35^{o}N,-17^{o}N]. Primary sites of interest were identified using OMEGA and subsequently targeted at high resolution (18-36 m/pixel) with CRISM. We have processed manually the entire OMEGA and CRISM high-resolution dataset in this region and found hydrated minerals in 250+ sites (figure 1). $\sim$ 67% of the CRISM observations have hydrous mineral signatures, comparison to global mapping of these minerals [6] reveals that the northern Hellas province has the highest regional density of hydrous signatures, albeit scattered and small in size (typically $\lesssim$ km).

3. Mineralogy of the northern Hellas province

Hydrous mineral signatures are largely dominated by Fe/Mg-rich phyllosilicates spectrally consistent with mixed layered smectite-corrensite or smectite-vermiculite. Smaller occurrences of chlorite, Al-smecites/kaolins, prehnite, zeolites, Fe/Mg-micas and carbonates/lizardite are also reported. Mixed-layered smectites are dominantely a product of weathering of basaltic glass or the result of burial diagenesis. Most Fe/Mg smectites occur segregated from other hydrous mineral units altough Al-phyllosilicates have been occasionally found overlying them, suggesting possible weathering sequences.

4. Linking mineralogy to geomorphology

Most Fe/Mg smectite signatures occur in layered deposits exposed by erosion in sedimentary plains, crater infillings or highly eroded rims (see examples in figure 2). Spectral signatures are similar to the clays exposed as a shallow subsurface layer by all-sized impact craters in Terra Tyrrhena (*Loizeau et al., in preparation*, [4]). Numerous dendritic valley networks have been mapped in this region [9] but we found no clear direct morphological evidence for transport between the lower sedimentary vs. buried highland clays. Previous fluvial evidence may have been erased or the depositional event may have involved mud flows.

5. Terby crater as a tool to decipher the regional event

Terby crater is a flat, partially infilled crater with over 2 km-thick layered mesas exposed by erosion on its northern wall.

The stratigraphy suggests a deltaic origin [2] while mineral investigations have revealed an Fe-Mg smectite-rich strata, two stratigraphically distinct hydrated salt or zeolite units and hydrated silica (akin to opal) in knobs (figure 3). The smectites are likely detrital in origin, thus confirming a fluvial origin for the similar smectite-bearing strata in the region. The other phases may have formed authigenically or by burial diagenesis.

6. Conclusion

Coupled morphological and mineralogical investigation of the layered deposits in the northern Hellas province hint towards a massive lacustrine sedimentary event requiring stable liquid water in Noachian Mars, and governed by topography from the Tyrrhena Terra highlands to the Hellas basin, although few evidence for hydrous activity has been found in the latter region.

7. Figures

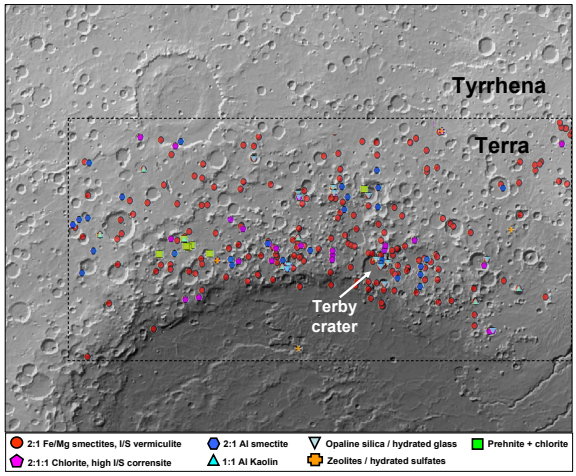

Figure 1: The northern Hellas region (MOLA background) with OMEGA/CRISM hydrous mineral mapping (in color).

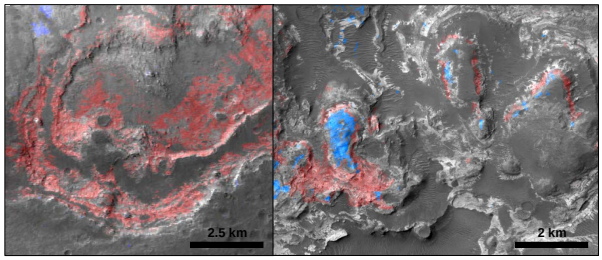

Figure 2: Examples of Fe/Mg- (*red*) and Al- (*blue*) smectite bearing layered deposits in northern Hellas.

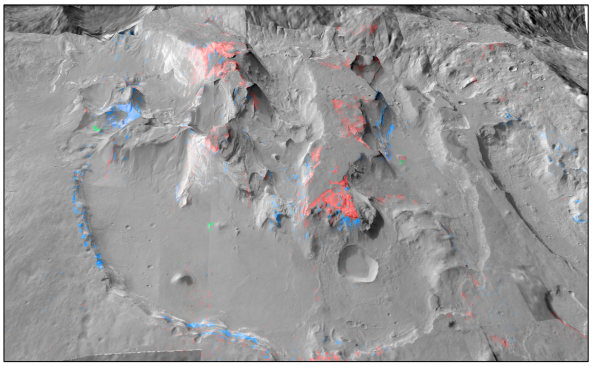

Figure 3: Mineralogical mapping of the Terby layered mesas with CRISM (CTX/MOLA background). *Red:* Fe/Mg-smectite, *blue:* zeolites/hydrated salt, *green:* hydrated basaltic glass.

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