Morphology and Mineralogy of Libya Montes Layered Delta Deposits, Mars: Implications for Long-term Aqueous Alteration G. Erkeling[1], D. Reiss[1], F. Poulet[2], J. Carter[2], D. Loizeau[2], H. Hiesinger[1], M. A. Ivanov[3], E. Hauber[4], R. Jaumann[4], [1]Institut für Planetologie (IfP), WWU Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany (gino.erkeling@uni-muenster.de/ +49-251-8336376) [2]Institut d'Astrophysique Spatiale (IAS), CNRS/Université Paris-Sud, Orsay, France [3]Vernadsky Inst. RAS, Moscow, Russia [4]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany.

Introduction: The Noachian highlands of Libya Montes, located at the southern rim of Isidis Planitia, have been affected by multiple and long-term aqueous activity [1-3]. The ancient highlands consist of mountainous massifs, ridges and individual peaks, which were mainly formed by Noachian impacts and heavily modified by intensive, long-term and repeated Noachian and Hesperian fluvial activity [2,3]. The aqueous activity led to the formation of (1) broad longitudinal channels, i.e. a western, a central and an eastern main channel system, that dissect the Libya Montes from S to N and (2) widespread dendritic valley networks that bear evidence for surface runoff [2,3]. The material that was eroded by the fluvial activity was likely transported into the Isidis basin [1-3]. The intensive and long-term fluvial modifications of the Libya Montes highlands resulted in high valley densities [2] and in the formation of highly altered lithologies, i.e. hydrated surface materials, Fe/Mg phyllosilicates [4].

We present the first results of our morphologic and mineralogic investigation of a possible delta or fan in Libya Montes, located between 85˚/86.5˚E and 1.8˚/5˚N, where our observations suggest that (1) Noachian cratered and crater-filling materials in an enclosed drainage basin were eroded by Noachian and Hesperian fluvial activity and deposited in layered delta-like deposits associated with a lacustrine system, (2) delta or fans show striking morphological similarity of layering appearance in delta with other delta-like deposits, e.g. Holden Crater or in Xanthe Terra [5,6], (3) Al-smectites are abundant in the stratigraphically lowest layers of the delta-sediments, (4) Fe/Mg-smectites are abundant in Libya Montes highland units, and (5) olivine-rich materials indicate the absence of aqueous alteration during the formation of plains units.

Morphology: Our study area (Fig. 1) is located at the boundary between the rough and cratered terrains of the Libya Montes and the smooth and low-lying plains of Isidis Planitia. The southern part of the study area is characterized by a Noachian crater with a diameter of ~40 kilometers. The crater is heavily degraded by impacts and bears evidence for intense fluvial activity. Numerous parallel channels are incised into a sloped plain in the western half of the crater and are likely the result of flowing water. The channels show exhumed and preserved morphologies in comparison to degraded valleys that are cut into crater-filling materials elsewhere within the crater. Both the degraded and the exhumed channels are converging toward the center of the Noachian crater.

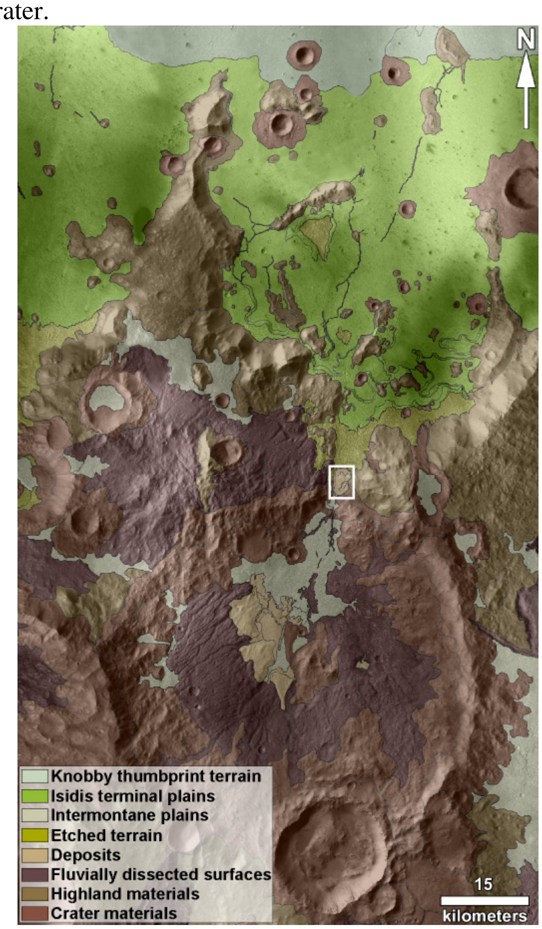

Fig. 1: Morphologic map of Libya Montes delta site. Dark units shown in the southern portions of the map, represent ancient, cratered and dissected highland terrains of the Libya Montes. Brighter units show the spatial distribution of intermontane plains and deposits. Morphologic units shown in bright green colors represent the Isidis exterior (terminal) and interior (thumbprint terrain) plains. Layered delta deposit shown in Fig. 2A is outlined by white box.

The material eroded by the channels is deposited in delta-like sediments and alluvial fans. Smooth intermontane plains that build the northern part of the crater interiors are cut by few channels that breached the northern rim of the crater.

A delta-like deposit, located immediately north of the crater, shows layered morphologies and bears evidence for aqueous alteration (Fig. 2A). At the front of the delta-like deposit, the lowest layers consist of polygonally fractured, bright material (Fig. 2B). The northern part of the delta forms a half-circled edge and shows eroded and layered morphologies.

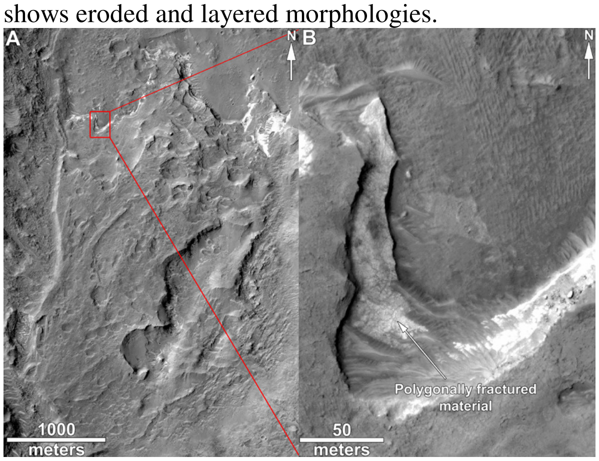

Fig. 2: A. HiRISE image PSP_008808_1830 showing layered delta deposit in Libya Montes (85.93˚E and 3.18˚N). B. Close-up showing the stratigraphically lowest layers of polygonally fractured bright material located at the front of the deposit.

Another ~10 kilometers to the north, etched surfaces represent the topographically lowest parts of the Libya Montes highlands. The contact between the Libya Montes and the smooth terminal plains [1] of Isidis Planitia is well defined and appears as a series of cliffs that show layered morphologies. The northward-sloping terminal plains are cut by small channels that trend downstream to the north. Few patches of etched and rough terrain located within the terminal plains indicate that the terminal plains are likely to be a thin layer that overlies Libya Montes rough terrain. In the northern parts of our study area, the terminal plains materials are superposed by the Isidis knobby interior plains, which contain the Isidis thumbprint terrain [7].

Mineralogy: The geologic and mineralogic setting, including the spatial distribution and abundance of alteration minerals at the delta site, is characterized by the occurrence of specific mineral assemblages, which are associated with three distinct surface units: 1) Highland units show widespread occurences of Fe/Mg-clay minerals, e.g. mixtures of saponite and vermiculite (Fig. 3, red color). Fe/Mg-smectites appear as the dominant alteration mineral in the study area and are most abundant in rough units of the Libya Montes highlands, including cratered and degraded terrains, as well as dissected and dendritic surfaces. 2) Intermontane plains, etched surfaces and smooth plains of the Isidis basin show olivine-rich materials (Fig. 3, green color). Mixtures of olivine and Fe/Mg-smectites (Fig. 3, yellow color), are the result of materials eroded from the highlands and incorporated into the plains. 3) Al-smectites (montmorillonite) appear exclusively within the stratigraphically lowest layers of the delta deposit (Fig. 2A,B and 3, blue color) and usually occur within the polygonally fractured bright unit at the front of the delta and within eroded parts showing bright layers, located at the eastern and western edge of the deposit. Upper layers with darker and polygonally fractured material are spectrally neutral or show weak Fe/Mg-smectite spectra, which are associated with material shed from the surrounding highlands.

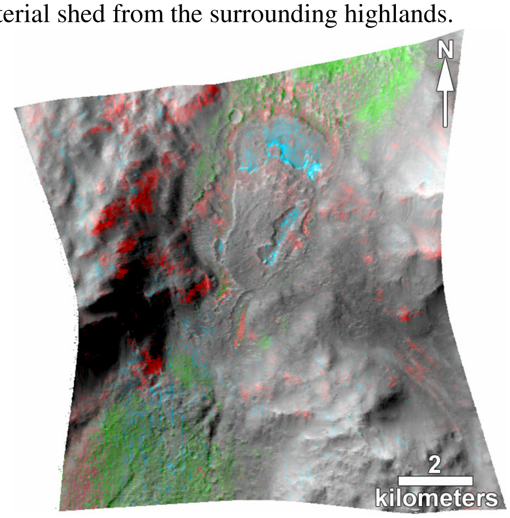

Fig. 3: Layered delta deposit as observed in CRISM image FRTB0CB. Fe/Mg-smectites (red) and Al-smectites (blue) indicate long-term hydrous alteration of oldest terrains, whereas olivine-rich (green) materials represent non-altered overlying (younger) plains.

Summary: Based on the morphology and the mineralogy we propose that,

1) aqueous activity resulted in the erosion of the Libya Montes cratered terrains as well as in the formation of fluvial morphologies and associated Fe/Mg-clay minerals, which are evidence for long-term availability of water and aqueous alteration,

2) layered morphologies of exhumed delta and fans are likely the result of water level fluctuations

3) Al-phyllosilicates identified in the lowest (oldest) layers of delta deposits indicate lacustrine environments,

4) olivine-rich materials, abundant in intermontane plains, represent late stage end or absence of aqueous alteration,

5) the geologic setting and associated mineral assemblages are the result of environmental changes over time towards decreasing water availability.

We propose this site as a new candidate landing site for potential future missions after MSL Curiosity.

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