MORPHOLOGIC, STRATIGRAPHIC AND MORPHOMETRIC INVESTIGATIONS IN EASTERN LIBYA MONTES, MARS: IMPLICATIONS FOR LONG-TERM FLUVIAL ACTIVITY. G. Erkeling[1], D. Reiss[1], H. Hiesinger[1], R. Jaumann[2,3] [1]Institut für Planetologie, Westfälische Wilhelms-Universität Münster, Germany, [2]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany. [3]Department of Earth Sciences, Institute of Geological Sciences, Planetary Sciences and Remote Sensing, Free University Berlin, Berlin, Germany. (gino.erkeling@uni-muenster.de/ Fax: +49-251-8336376)

Introduction: The Noachian highlands of Libya Montes, located at the southern edge of Isidis Planitia, represent one of the oldest regions on Mars [1] that have been degraded by intensive, long-term and repeated fluvial processes which led to the formation of "dendritic valley networks" [2-5]. Widespread "dendritic valley networks", particularly their extended branching were interpreted as evidence for atmospheric precipitation [2-5].

Within the Libya Montes, three distinct valley systems are defined by [2]: a western, a central and an eastern system. Here, we present our morphologic and stratigraphic investigations of the eastern valley system located between 87°E and 90°E and 5°S and 5°N. Our investigation of morphologic features resulted in a morphologic map of the drainage area in the eastern Libya Montes (Fig. 1). In addition, we performed crater counts for our morphologic units in order to determine their stratigraphic relationships and absolute model ages. Finally our morphometric analysis provides a comparison of quantitative parameters of the valley system and the corresponding drainage area with terrestrial analogues.

Morphology: Our morphologic mapping builds on the work of [2], but has been altered based on newer, higher-resolution data.

The "Noachian massifs" (Nm) are the oldest surfaces in the study area and are shown in dark-brown in the morphologic map. Adjacent to the basement material, unit NHf displays steep and heavily degraded slopes. Widespread within the NHf are small "dendritic valley networks" (Fig. 2), which are shown in dark green. The "longitudinal valleys" are long, stretched and broad in geometry (Fig. 2). They are shown in yellow color. Downstream and within their middle sections, the "longitudinal valleys" occur on broad plains (gray), furthermore cutting these. The "longitudinal valleys" are interrupted several times by "intermontane plains" (light blue) and "highland basins" (dark blue).

Stratigraphy: We used the current Mars cratering chronology model of [6] to determine surface ages. In total, we performed 141 crater counts on 70 homogeneous surface units. Our model ages [6-7] determined by crater counts vary between ~4.1 and ~3.3 Ga. This corresponds to the period from the middle Noachian to the upper Hesperian [6]. The oldest model ages were measured in the "Noachian massifs" (Nm) with a range from ~4.1 to ~3.8 Ga and an average age of ~4.0 Ga. The "dendritic valley networks" show the same average age of ~4.0 Ga, which corresponds to a formation within the middle Noachian. Our crater counts reveal that the formation of the dendritic drainage patterns occurred within ~300 My, between ~4.1 and ~3.8 Ga.

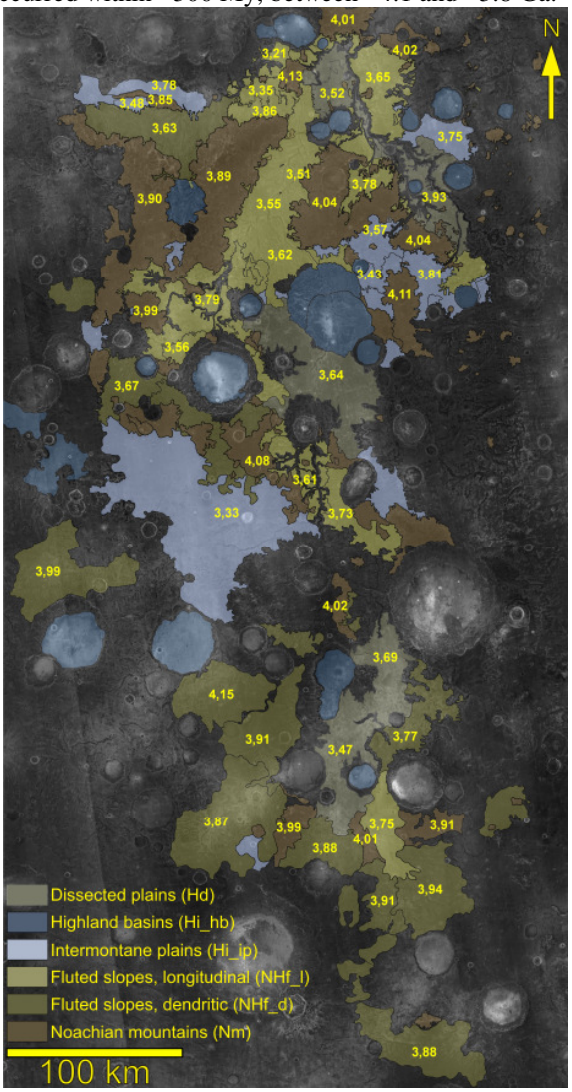

Fig. 1 Morphologic map and surface ages (THEMIS IR_night).

The sloped surfaces next to the "longitudinal valleys" exhibit model ages of approximately ~3.8 to ~3.5 Ga.

The main valley of eastern Libya Montes shows a model age of ~3.5 Ga. Hence, the surfaces are upper Noachian and lower to upper Hesperian in age. The average age of approximately ~3.7 Ga corresponds to the Noachian - Hesperian transition. The difference in age between the older middle regions of the "longitudinal valleys" and their younger downstream regions, amounts to nearly ~200 My. Our results are consistent with the ages of the western valley system, which has been dated to be ~3.7 - ~3.3 Ga old [4].

The age determinations for units Hi_ip and Hi_hb showed a formation period of about ~500 My within the range from ~3.8 to ~3.3 Ga. The average age amounts to ~3.6 Ga. We find that in this part of the Libya Montes, fluvial activity might have come to an end between ~3.5 and ~3.3 Ga ago.

Morphometry: In order to quantitatively define the original mode of fluvial activity, we calculated the "valley density" index [9,10] which was used to determine the maturity and integration of the "dendritic valley networks" [2-5].

We have identified an enclosed 100.000 km² drainage basin and ten secondary drainage basins with dimensions between 2.000 and 20.000 km² within our study area. We have identified 2976 valley segments within our study area, which show an overall length of 15,075 kilometers. The drainage basins show valley densities between 0.123 km^{-1} and 0.232 km^{-1}. The average valley density is 0.148 km^{-1}.

The calculated density values do not represent the original valley densities that were formed during the phase of fluvial activity and valley network formation but are only likely a minimum estimate of the valley density. We propose that the valley densities within the study area might have been significantly higher during the time of valley formation, because impacts have degraded the valley system to a large degree and reduced the valley density. Five well-preserved drainage basins with minimal impact modification and widespread and mature dendritic valleys were identified. They show a high drainage density of 0.57 km^{-1}.

Our results are consistent with densities of other "dendritic networks" elsewhere on Mars [2-5] and suggest a formation by surface runoff. Valley densities measured within the study area show significant differences to systems formed by sapping processes [3,11].

Conclusions: Based on our study, we conclude that the Libya Montes highlands are one of the oldest regions on Mars that have been modified by fluvial processes. The morphologic characteristics of the "dendritic valleys", especially the formation at local summits, are evidence for the initial formation by surface runoff due to atmospheric precipitation. The "longitudinal valley" systems have been formed and modified by groundwater induced processes.

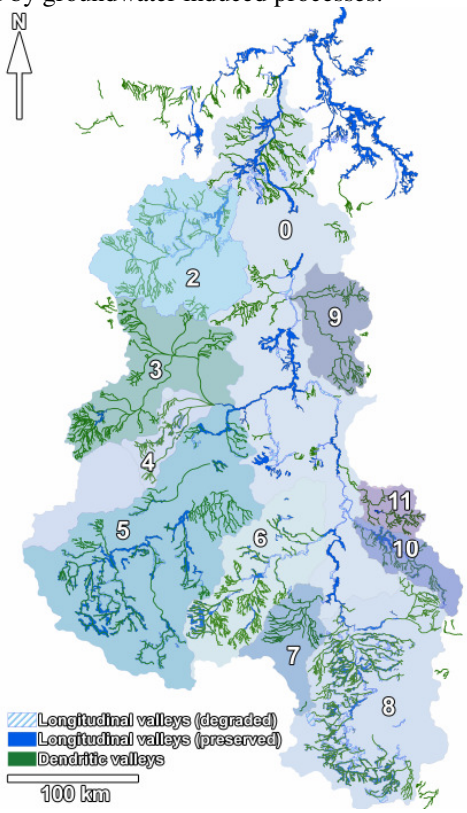

Fig.2: Drainage basins determined within our study area

Based on our age determinations, we conclude that the "dendritic valley networks" (average age ~4.0 Ga) have formed significantly earlier than the "longitudinal valley systems" (average age ~3.7 Ga). The Noachian "dendritic valleys" show maximum valley densities of 0.57 km^{-1} and indicate highly mature and integrated valley systems that are characteristic of a warmer and wetter environment. The ending of "dendritic valley network" formation around ~3.8 Ga is interpreted as evidence for an environmental change at the Noachian – Hesperian transition. Our results show that the fluvial activity within our investigation area lasted for ~800 My. The last fluvial activities likely occurred during the Late Hesperian, around ~3.3 Ga.

References: [1] Scott & Tanaka (1986) *U.S. Geol. Surv. Misc. Invest. Ser.*, Map I-1802-A. [2] Crumpler & Tanaka (2003) *JGR*, 108, ROV 21-1. [3] Carr & Chuang (1997) *JGR*, 102, 9145 – 9251 [4] Hynek & Phillips (2003) Geology 31, 757-760. [5] Mangold et al. (2004) *Science*, Vol. 305, 78-81. [6] Hartmann & Neukum (2001) *Space Sci. Rev.* 96, 165-194. [7] Ivanov (2001) *Space Sci. Rev.* 96, 87-104. [8] Jaumann et al. (2005) *GRL*, 32, 16. [9] Horton (1945) *GSA* 56, 275-230. [10] Schumm (1997) *Proc. Geo.*, 15-45. [11] Harrison & Grimm (2005) *JGR*, 110, E12S16.