BRADBURY CRATER, MARS: MORPHOLOGY, MORPHOMETRY, MINERALOGY, AND CHRONOSTRATIGRAPHY G. Erkeling[1], M. A. Ivanov[2], D. Tirsch[3], D. Reiss[1], J. L. Bishop[3,4], L.L Tornabene[5], H. Hiesinger[1], R. Jaumann[3]. [1]Institut für Planetologie (IfP), WWU Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany (gino.erkeling@uni-muenster.de/ +49-251-8336376). [2]Vernadsky Inst. RAS, Moscow, Russia. [3]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany, [4]The SETI Institute, Mountain View, California, USA. [5]University of Western Ontario, London, ON, Canada.

Introduction:
The last decades of Mars research have revealed numerous observations of past flowing and ponding of water on the surface of Mars, including channels, valleys, paleolakes, seas, and, although subject of strong debate, oceans [1-5]. A region on Mars with the highest density of fluvial and lacustrine landforms is the Noachian-aged Libya Montes highland, which is part of the southern rim of the Isidis Basin [e.g., 5-9]. In particular, the 60-km Bradbury crater located at 85.8°E/2.7°N (Fig. 1) reveals a diverse and complex setting of fluvial and lacustrine landforms [5]. The crater is dissected by valleys, and contains fan-shaped deposits that are associated with aqueous mineral assemblages recording a complex history of flowing and standing water and provide significant insights into the aqueous geologic record of Libya Montes. The presence of multiple forms of hydrologic activity at Bradbury crater indicates great potential that past environments may have been favorable for life [5].

The complex geologic and geochemical nature of this site has encouraged multiple proposals for candidate landing sites for future rover missions to Mars [5,10,11]. Despite the difficulties of meeting the engineering requirements for past rover-based missions to Mars, the site continues to be studied for its potential as a future landing site. New HiRISE and CRISM images, together with an HRSC DEM, provide a means to decipher the complex geologic history of Bradbury crater and the surrounding region.

Proposed formation history:
Heavily degraded valleys represent the stratigraphically oldest units at Bradbury crater after its formation. They are partly dendritic and present only on some sections of the eastern and southeastern walls. They are comparable to the dendritic valley networks observed elsewhere in Libya Montes and represent earliest phases of fluvial activity characterized by what is interpreted to be precipitation-induced surface runoff [e.g., 5-8]. At that time (~3.8 Ga, [5]), water may have initially ponded in Bradbury crater. However, as the terrain declines toward the north, water appears to have spilled over the northern rim of the crater and resulted in a breach in the wall. The crater rim should have been initially intact to

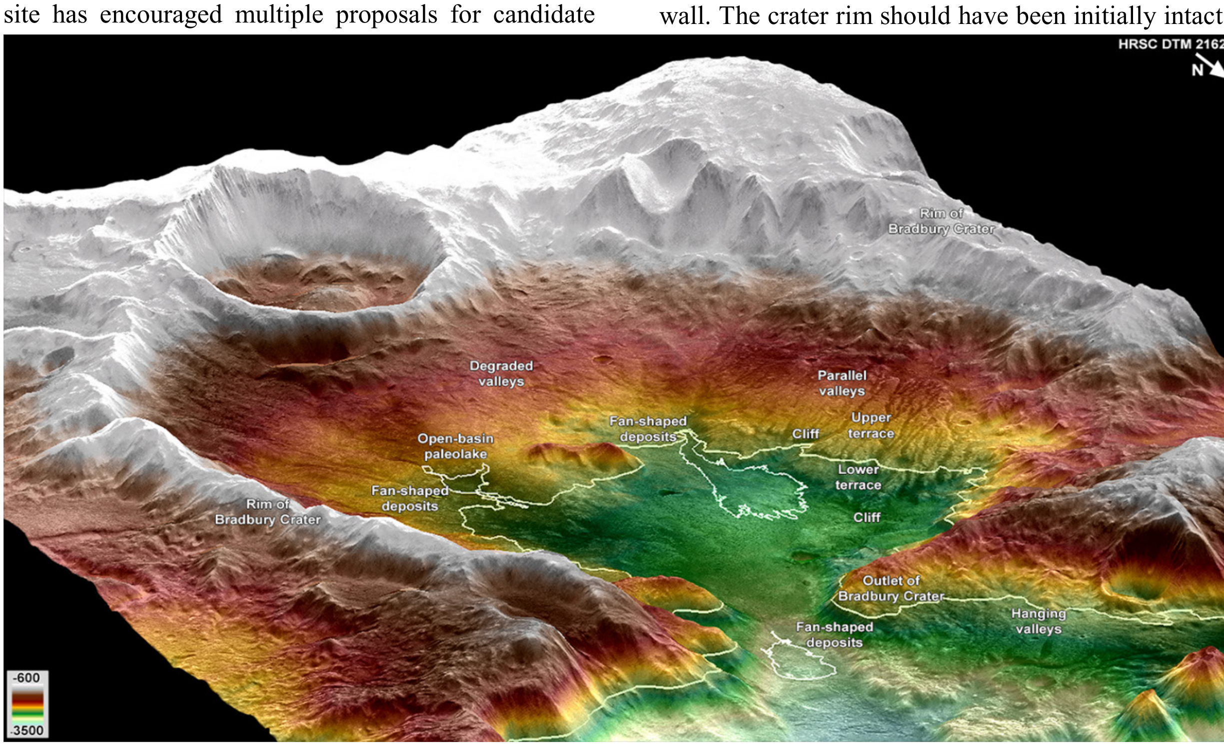

Fig. 1: Perspective view of Bradbury crater at south Isidis Planitia. The crater-lake site hosts a complex diversity of fluvial, lacustrine and possible fluvio-glacial landforms, in particular degraded valleys, parallel (tunnel) valleys, two cliffs and a terrace, an outlet cut into the northern rim of Bradbury crater, a delta with associated Al-rich phyllosilicates, a small-scale open-basin paleolake with another delta, widespread bright, polygonally-fractured Fe/Mg phyllosilicates, and an alluvial fan. Color-coded HRSC h_2162 DTM on CTX mosaic.

an elevation above -2500 meters. This is supported by fluvial and lacustrine landforms at Bradbury crater, which terminate at elevations of above -2500 meters and suggest later and repeated ponding events.

We propose that a second lake-sized standing body of water is present in Bradbury crater in cliffs near -2500 and -2800 meters elevation where the majority of valleys terminate. A terrace between the cliffs may also be related to a past lake-sized standing body of water and suggests, together with the cliffs, variations of the lake-level and distinct still-stands. Further evidence for subsequent fluvio-lacustrine processes distinct from those that formed the degraded valleys and the initial breach are the parallel valleys and a few individual valleys that appear stratigraphically higher than the degraded valleys. One of the individual valleys drains as the inlet channel into a small-scale open-basin paleolake (Fig. 2). We observed fan-shaped deposits, including typical morphologies such as a topset lobe with numerous distributary paleochannels, a heavily degraded foreset and the degraded and buried remnants of the bottomset. We interpret this feature as a delta, given the morphology of the lobe, the likelihood that the topographic setting represents an open-basin crater-lake site and the strong evidence for hydrous alteration.

Possible overspill events of the second lacustrine phase may have contributed to the erosion of the breach in the northern rim and deposition within Bradbury crater to its present state at -3100 meters elevation. In a depression immediately north of the outlet, another fan-shaped deposit is a result of a possible third phase of lake formation (Fig. 3). The deposits consist of three individual topset lobes with decreasing extent from oldest to youngest, suggesting that the amount of water availability was also decreasing during formation. Abundant bright-toned polygonally-fractured materials are observed to contain Al-rich smectites [5, 9,12]. The topographic setting in a closed basin, the lobe morphologies and strong evidence for hydrous alteration also support the interpretation of this feature as a delta.

Fan-shaped deposits located in the center of Bradbury crater (Fig. 4) very likely represent late-stage depositional events at Bradbury crater. The general morphologic setting of the fan on a steep slope and not in a basin is comparable to an alluvial fan. The rim of Bradbury crater at -3100 meters elevation was already breached during formation of the deposits and did not allow ponding up to -2500 meters, the level of the alluvial fan. However, four distinct lobes of the fan-shaped deposit and Fe/Mg phyllosilicates present in the stratigraphically oldest lobes are possibly the result of repeated events of erosion, transport and deposition, and suggest a complex formation history. Finally, fluvial activity responsible for the formation of the alluvial fan was still active (~<3.6 Ga, [5]) but the lack of associated lacustrine deposits also indicates waning fluvial activity insufficient to form a lake.

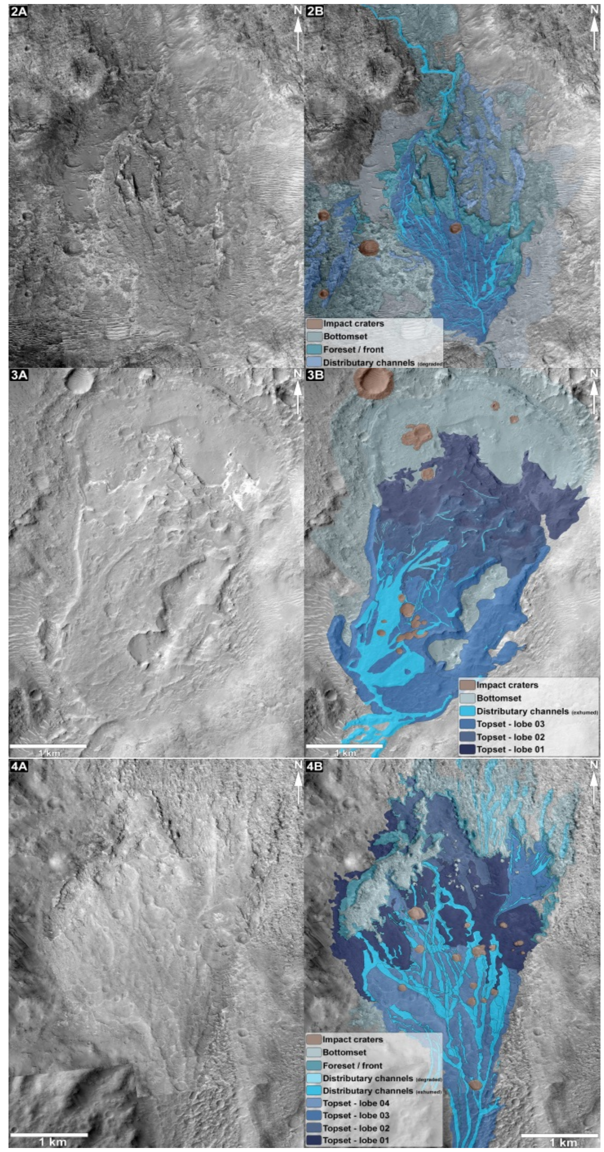

Fig. 2-4: HiRISE-based morphologic maps of a small-scale open-basin paleolake with fan-shaped deposits (2AB), deltaic deposits at the outlet of Bradbury crater (3AB), and an alluvial fan (4AB).

Conclusion:

We interpret the morphologic–geologic setting and associated mineral assemblages of Bradbury crater resulting from repeated fluvial activity, multiple lake-size standing bodies of water and an environmental change over time toward decreasing water availability.

References: [1] Baker et al., 1991, *Nature 352*, 589-594. [2] Parker et al., 1993, *JGR 98,* 11061-11078. [3] Head et al., 1998 *GRL 25,* 4401-4404. [4] Di-Achille and Hynek, 2010, *Nature Geosci. 3,* 459-463. [5] Erkeling, et al., 2012, *Icarus, 219*. [6] Crumpler and Tanaka, 2003, *JGR, 108*, ROV 21-1. [7] Erkeling, et al., 2010, *EPSL, 294*, 291-305. [8] Jaumann et al., 2010, *EPSL, 294*, 272-290 [9] Bishop et al., 2013, *JGR, 118,* 487–513 [10] Erkeling et al., 2011 *MEPAG*, RFP round VI; NKB-269-122010 CDP [11] Erkeling et al., 2014, *1st ExoMars 2018/2020 LSSW*, Madrid [12] Tirsch et al., 2015, *46th LPSC*, #1738.