MODEL AGE OF GALE CRATER AND ORIGIN OF ITS LAYERED DEPOSITS. L. Le Deit[1], E. Hauber[1], F. Fueten[2], N. Mangold[3], M. Pondrelli[4], A. Rossi[5], and R. Jaumann[1], [1]Institute of Planetary Research, German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany (Laetitia.Ledeit@dlr.de), [2]Department of Earth Sciences, Brock University, St. Catharines, Ontario, Canada L2S 3A1, [3]Laboratoire de Planétologie et Géodynamique UMR 6112, CNRS, Université de Nantes, Faculté des Sciences et Techniques, Nantes, France, [4]International Research School of Planetary Sciences, Dipartimento di Scienze Università d'Annunzio, Pescara, Italy, [5]Jacobs University Bremen, Germany.

Introduction: Gale is a impact crater 150 km in diameter located along the dichotomy boundary of Mars and close to the Medusae Fossae Formation. The first age determinations of Gale suggested that it was formed during the Late Noachian/Early Hesperian Epoch [1], at the end of early Mars. Gale is partially filled by a central mound of layered deposits up to 5 km thick and 6000 km^2 in area [2] for which several origins have been proposed including volcanic [1, 3], eolian [1-4], and fluviatile and lacustrine processes [1, 2, 4, 5], precipitation as spring deposits [6], and a combination of several origins [4, 7]. The past presence of water is attested by the occurrence of fluvial channels and canyons carved into the deposits and the crater rim, and of phyllosilicates and sulfates located in the lowest part of the layered deposits [8]. Consequently, the layered deposits in Gale are of high interest to constrain the geochemical and climatic environments of the region prevailing during a key period of the planet history. We focus here on two major questions, which are the age of Gale and the mode of formation of its layered deposits.

Methodology: We estimated the age of formation of Gale crater by crater counts on the ejecta to the southeast of the crater on a mosaic of HRSC nadir panchromatic images (25 m/pixel). The ejecta to the north of Gale have not been taken into account because of resurfacing by fluvial processes. We investigated the origin of the layered deposits by mapping the sedimentary infill in Gale based on CTX images (~6 m/pixel) and HiRISE images (25-32 cm/pixel), and by measuring the geometry (attitude and thickness) of the layered deposits from HiRISE DEM.

Age of Gale: We counted 375 craters ranging from 88 m to 23 km in diameter on an area of 1.01x10^4 km^2 (*Fig. 1*). The estimated age of formation of Gale is ~3.61 $^{+0.04}/_{-0.06}$ Ga, which corresponds to Late Noachian with the size-frequency distribution of Hartmann [9, 10]. Taking into account that Late Noachian is ranging from 3.85 Ga to 3.57 Ga [9, 10] and the uncertainties of the measurement, we estimated the age of formation of Gale to be Late Noachian/Early Hesperian. This result is in agreement with [1, 4]. Consequently, the sedimentary infill of Gale is Late Noachian/Early Hesperian at maximum in age and probably younger.

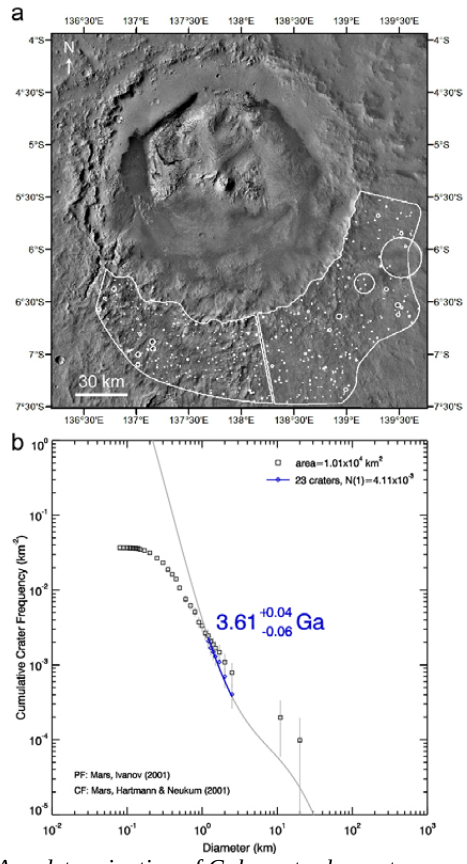

Fig. 1: Age determination of Gale crater by crater counts on its ejecta. (a) Crater counted and the counting areas (in white) on a mosaic of HRSC nadir panchromatic images. (b) Crater size-frequency distribution including an inferred model age (in blue).

Origin of the layered deposits: The central mound of layered deposits is constituted of several geological units, which have various albedo, erosion patterns, geometry, and mineralogical composition. The small yardang units (Syu$_{1-2}$) and the benched unit (Bu) are the main units of the mound in terms of volume (*Fig. 2*). At the base of the mound, the small yardang units (Syu$_{1-2}$) are moderate to dark-toned materials forming yardangs, which are indicative of cohesive materials. They are incised by wide canyons and consist of subparrallel layers of varying thickness ranging from <2 m to ~30 m for each layer or bundle of layers.

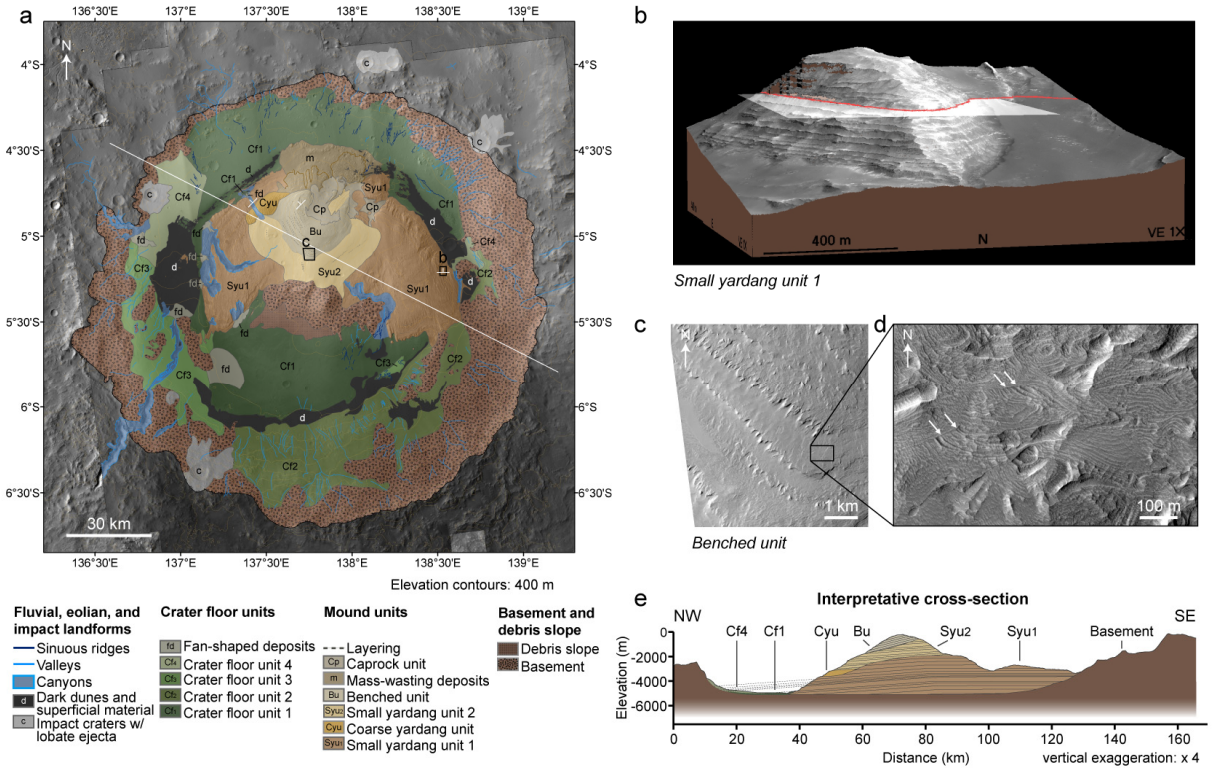

Fig.2: Spatial distribution and morphology of the layered deposits (central mound). (a) Geologic map of Gale crater on a CTX mosaic. (b) Perspective view of the Small yardang unit 1, which dips 3°N at this location (HiRISE ESP_016375_1750). (c) Cliff-bench morphology of the benched unit (HiRISE PSP_001620_1750). (d) Close-up view of (c) showing possible crossbeds (white arrows).(e) Interpretative section across the crater (topographic profile drawn from HRSC DEM).

They dip 3°N to the east of the mound (*Fig. 2b*) and ~3°NW to the northwest of the mound. Hence, the layers are not horizontal and appear to drape the pre-existing topography (*Fig. 2e*). No remnant butte of these units is visible out of the main mound that suggests that they never filled the entire crater. These observations indicate that a lacustrine deposition is unlikely. Instead, the small yardang units may result from an airfall deposition of volcanic ash and/or dust. Anderson and Bell [7] noticed the presence of polygonal ridges in the Syu_1 unit interpreted to be filled or cemented fractures consistent with fluid flowing through fractures. The identification of phyllosilicates and sulfates [8] in this unit provides additional evidence that alteration processes occurred in the Syu_1 unit.

The benched unit (Bu) is located in the upper part of the mound. It displays a cliff-bench morphology (*Fig. 2c*) and consists of subparrallel layers of roughly constant thickness ranging from <1 m to <5 m and dip 4-9°NW. No fluvial features has been observed in the benched unit implying that fluvial activity stopped before its deposition. Structures similar to crossbeds visible on benches of layers (*Fig. 2d*) [7] suggest that the benched unit may be aeolian material (remobilized volcanic ash/dust).

Conclusions: From our estimations, Gale crater formed ~3.61 $^{+0.04}/_{-0.06}$ Ga ago. The mound of layered deposits was mostly accumulated in an aerial environment by settling of dust particles and/or volcanic ash in air that have locally been remobilized by wind. The small yardang unit 1, at the base of the mound has been altered by aqueous processes that may have contributed to the lithification and cementation of the mound.

Acknowledgements: The authors thank the ISSI International Team "Mars Interior Layered Deposits" for fruitful discussions. This research has been partly supported by the Helmholtz Association through the research alliance "Planetary Evolution and Life".

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