MARS AND MOON ON EARTH: FORMATION OF SMALL TERRACED IMPACT CRATERS AND GROUND PENETRATING RADAR INVESTIGATIONS. M.A. Rappenglück[1], J. Poßekel[2] and K. Ernstson[3], [1]Institute for Interdisciplinary Studies, D-82205 Gilching, Germany (mr@infis.org) [2]Geophysik Poßekel Mülheim, Germany (jens.possekel@cityweb.de) [3]Univ. of Würzburg, 97074 Würzburg, Germany (kernstson@ernstson.de).

Introduction: Impact craters are generally distinguished between simple, bowl-shaped and complex craters with central uplifts and/or inner peak rings. The difference is size-dependent and is observed on Earth at a transition from roughly 4 km crater diameter. The difference in formation is strongly gravitationally dependent, which is why the transition from simple to complex craters on the Moon occurs only at much larger diameters. One was surprised therefore already some time ago, when one found on the moon very small craters with diameters of the order of a few 100 m or smaller, which show a rather complex form with a terraced interior instead of the simple bowl form (Fig. 1). A stratification of the subsurface into a loose regolith blanket over solid rock was quickly suggested as an explanation, with the propagation of the shock front initiating the excavation being controlled by the strong material differences.

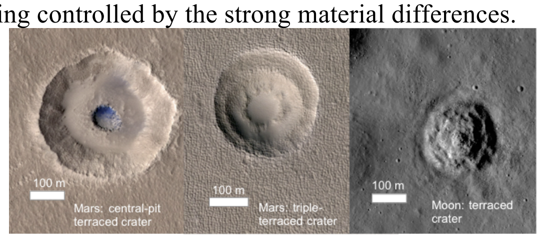

Fig. 1. Small terraced impact craters on Mars and Moon. Modified from NASA Open Domain.

Surprise was triggered by the finding that these very small terraced craters are also observed on Mars via Digital Terrain Model (DTM) measurements (Fig.1), leading to the discovery of a widespread ice sheet on Mars (Fig. 2). Here we report on very comparable, very small complex terraced impact craters on Earth that have since been studied by extensive GPR measurements, exactly what is currently envisioned on Mars with the Rover and the RIMFAX project.

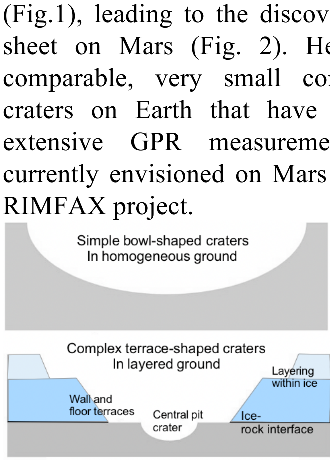

Fig. 2. Model for the formation of small terraced craters on the Mars ice sheet. Modified from NASA Mars Exploration Program.

Small terraced impact craters on Earth - the Chiemgau impact: In a roughly elliptically shaped strewn field more than 100 mostly rimmed craters with diameters between a few meters and a few 100 meters occur. The Chiemgau impact strewn field shows all and abundant evidence of impact signature as is required within the impact research community (impact melt rocks, impact glasses, strong shock metamorphism, and meteoritic matter [1, 2, and references therein]). The event happened in the Bronze Age/Iron Age as revealed from impact catastrophe layers and their archeological inventory [2].

The Digital Terrain Model (DTM) and the Chiemgau impact craters: The DTM is available and has been used in this study in highest resolution with a 1 m grid and a vertical resolution of 10 - 20 cm (DGM 1 in Germany), which via interpolation may even be reduced. In Fig. 3 we begin with two craters (diameters of about 300 m and 100 m), which in the DTM are perhaps the most similar to the Martian craters of Fig. 1.

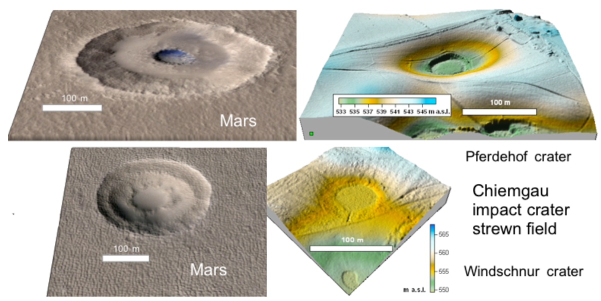

Fig. 3. Comparison of terraced craters on Mars (modified from Fig. 1) and terraced craters in the crater strewn field of the Chiemgau impact (DTM surface, after subtraction of a terrain trend field).

Figures follow for four other craters of varying sizes, where the complex topography is particularly prominent on profiles of the DTM. Terracing with a central pit crater becomes evident as on Mars. Undulating terraces (exemplified in Figs. 5, 7) around a central pit crater are observed for virtually all craters in the strewn field regardless of diameter [3-6]. The comparison between the Moon, Mars and the Chiemgau impact craters requires a consideration of the causes of the formation of small terraced craters, and it seems clear that, as with the Moon and Mars, subsurface stratification of sediments provides for terracing during cratering when the shock front of the impacted projectile encounters a stratification of strongly varying petrophysical parameters (cementa-tion, porosity, grain size, water content). Such a subsurface is common throughout the Pleistocene and

Holocene of the crater strewn field with alternating loess, moraine material, loamy-sandy deposits and gravel planes, which is also consistently evident in the radar measurements (Fig. 8).

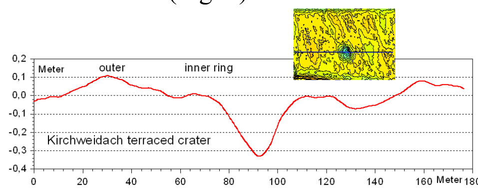

Fig. 4. The terraced Kirchweidach crater. Topography and profile from the DTM after subtraction of a terrain trend field.

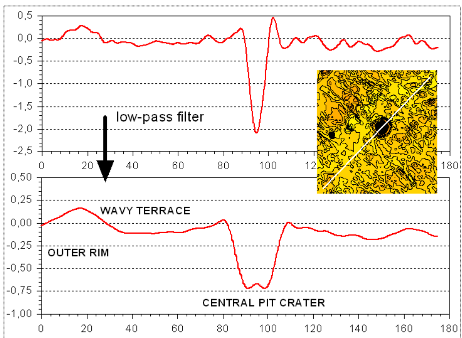

Fig. 5. The Einsiedleiche crater with a central-pit crater and surrounding wavy terrace, which becomes special evidence after strong low-pass filtering.

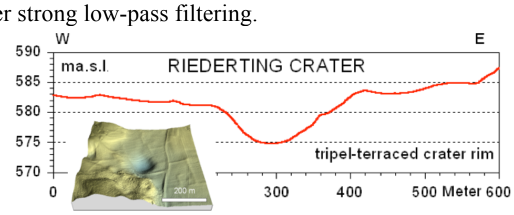

Fig. 6. The Riederting crater exhibiting a triple-terrace crater structure.

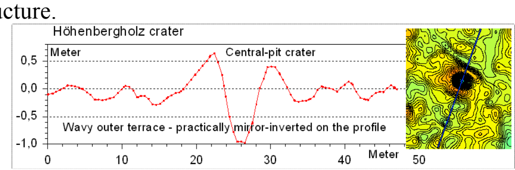

Fig.7. The Höhenbergholz crater with a distinct central-pit crater and a surrounding wavy terrace with remarkable mirror symmetry.

The GPR measurements: To date, GPR measurements have been made in the crater strewn field at 12 craters of various diameters using antenna frequencies of 200 and 300 MHz at a sampling rate on the profiles of 3 cm. None of the craters surveyed were found to have a simple bowl-shaped structure, and instead, in most cases, a quite complex structure was seen in the radargrams, with an apparent close relationship between the high-resolution DTM surface structure and the internal structure. Here, two typical findings are presented from the wealth of measured material to date.

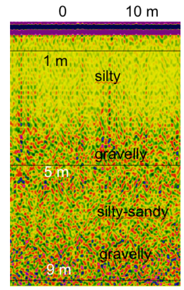

Fig. 8. A typical GPR radargram taken with a 200 MHz antenna near the Kirchweidach crater (Fig. 4). The interpretation sees a layering of changing lithology in the loose-sediment stratigraphy probably responsible for the impact crater terracing.

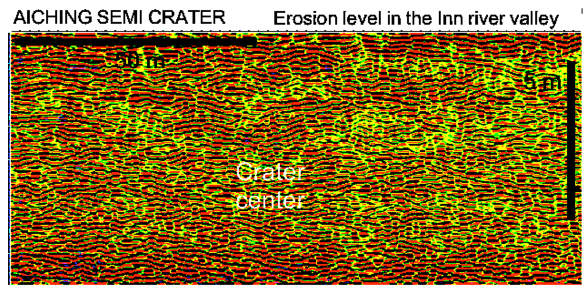

Fig. 9. Complex radargram across the Aiching crater [4].

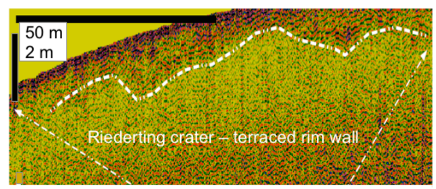

Fig.10. The Riederting crater (Fig. 6) terraced rim wall in a GPR profile.

Discussion and conclusion: We are listing: The small terraced impact craters on the Moon and Mars have more or less exact impact counterparts on Earth. # In the Chiemgau impact strewn field craters that have been scanned with high-resolution DTM show terracing in various shapes like on Mars. # Like on Moon and Mars the terracing can be ascribed to an underground layering. In the Chiemgau region changing lithology with varying compaction or cementation and probably a specific influence of the near-surface groundwater table are reponsible. # GPR measurements underline this model of terracing. # It would be interesting to see whether there are structural similarities between the Chiemgau GPR and the RIMFAX recordings on Mars.

References: [1] Ernstson, K. et al. (2010) J. Siberian Federal Univ., Engin. & Techn., 1,72-103. [2] Rappenglück, M.A. et al. (2017) Z. Anomalistik, 17, 235-260. [3] Poßekel, J. and Ernstson, K. (2019) 50th LPSC, 1204.pdf. [4] Ernstson, K. and Poßekel, J. (2020) https://agu 2020fallmeeting-agu.ipostersessions.com/?s=EF-E1-3-48-F6-1F-59-AF-56-E4-59-E3-0D-8E-DF-F8. [5] Poßekel, J. and Ernstson, K. (2020) 11th Planetary Crater Consortium, Abstract #2014. [6] Ernstson, K. and Poßekel, J. (2020): 11th Planetary Crater Consortium 2020, Abstract #2019.