BLOCKS AND MEGABLOCKS IN THE EJECTA LAYERS OF A DOUBLE-LAYER-EJECTA (DLE) CRATER ON MARS. G. Wulf[1], A. Pietrek[1], T. Kenkmann[1], [1]Institute of Earth and Environmental Sciences – Geology, Albert-Ludwigs-University Freiburg, Germany, gerwin.wulf@geologie.uni-freiburg.de.

Introduction: Martian impact craters are typically surrounded by layered ejecta deposits that terminate in ramparts [1]. The so-called "layered" or "rampart" craters are commonly classified as single-layer ejecta (SLE), double-layer ejecta (DLE), and multiple-layer ejecta (MLE) craters [2]. Several formation models have been proposed to explain the rampart formation process, generally assuming an underlying fluidization mechanism: (1) the interaction of ejecta with the atmosphere and involved ring vortices [3, 4]; (2) the interaction of ballistic ejecta with a vapor plume formed by an impact into a volatile-rich target, causing a ground-hugging flow [1, 5]; (3) a combination of both [6, 7]; or (4) as counter-example, a dry granular flow [8]. The existence of rampart craters on Ganymede indicates that volatiles in the subsurface are likely the dominant factor [9]. New results of the Bunte Breccia ejecta morphology of the Ries impact crater show striking similarities to double-layer ejecta craters [10] and demonstrate the importance of understanding the ejecta emplacement processes of DLE craters also for terrestrial issues. Here we analyze the block distribution and orientation of coarse materials exposed at the surface of the two distinct ejecta layers of a DLE crater on Mars.

Method: The Steinheim crater on Mars (190.65°E 54.57°N) is a relatively pristine 11 km diameter DLE crater in Arcadia Planitia. The excellent coverage of high-resolution image data, especially CTX and HiRISE, allows the detailed mapping [11] and analysis of surface structures of the crater and ejecta blanket. The data were processed by using ISIS (The Integrated System for Imagers and Spectrometers) to get the base data for further mapping in ArcGIS. Surface areas with a qualitatively estimated high block density were mapped with emphasis on block distribution and orientation (Fig. 1). Only areas with HiRISE coverage were suitable for mapping due to the small average block size (2-20m). The ratio of areas where relatively high block densities occur to that of the total ejecta blanket that was mapable with HiRISE was determined to get the radial trend of the block distribution in comparison to the position of the ramparts and moats.

Results: The distribution of the observed blocks differs significantly between the inner and outer ejecta layer (Fig.1). The blocks of the inner ejecta layer were mainly observed in its proximal part of the inner ejecta blanket (Fig. 1). They predominantly occur in radial oriented clusters or trains and partially show increasing block sizes with increasing radial distance (Fig. 2a).

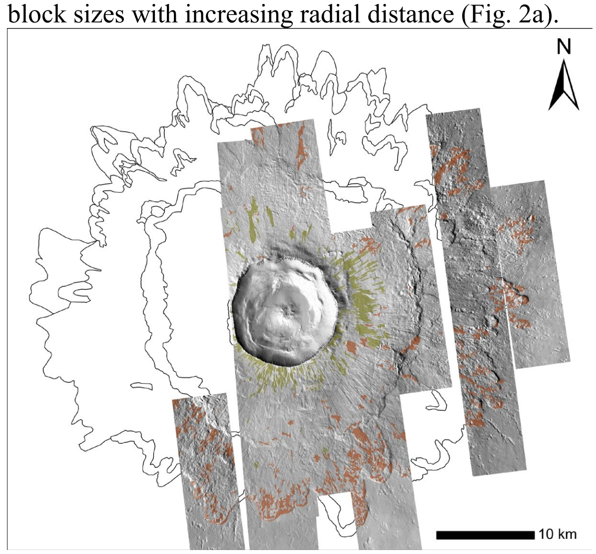

Fig. 1: Map of the DLE Steinheim crater shows several regions with high block densities (green = radial oriented clusters, brown = patchy and rampart related block clusters) on the basis of HiRISE imagery (contour lines from [11]).

They are stretched parallel to the grooves that characterize the surface of the inner layer. Blocks reach sizes of 2-20 m diameter. In contrast, blocks of the outer ejecta layer occur in irregular patches (Fig. 2b). They are concentrated on the outer edges of the outer ramparts (Fig 1). Their sizes range from 2 to 15 meters diameter. Exposed blocks of both the inner and outer layer are integral parts of the layers. They are not resting on top of the layers.

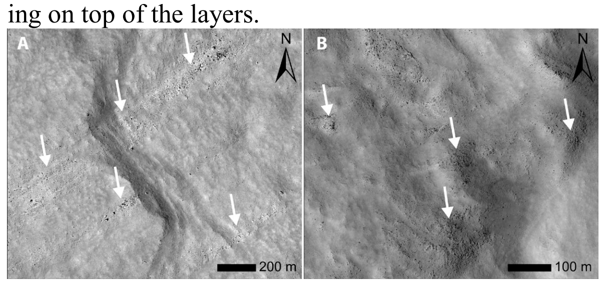

Fig. 2: Examples of the different block characteristics: A) radial oriented block clusters in the moat area of the inner layer, B) irregular patches of block clusters in the outer rampart area of the outer ejecta layer.

Figure 3 displays mean radial elevation profiles through the ejecta blanket averaged over the mapping area. The diagram also shows how much of the ejecta area is covered by blocks as a function of the distance

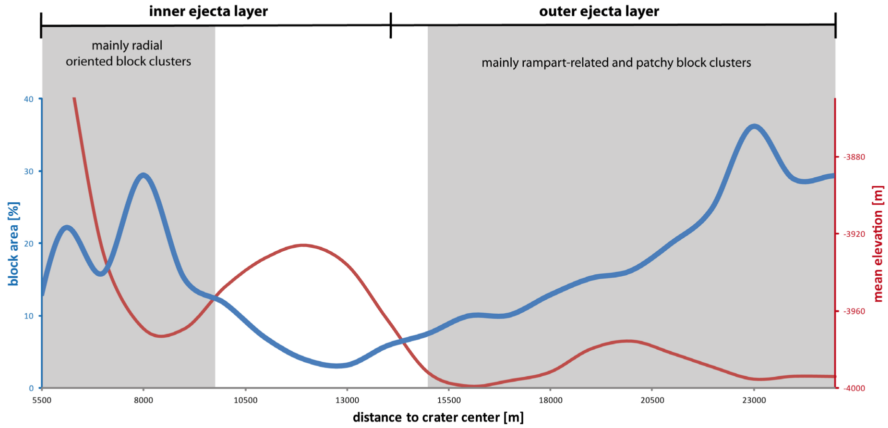

Fig. 3: Radial plot of the mean elevation of the inner and outer ejecta layer (red). Ratio of area with high block density to the the total ejecta area (blue) as a function of radial range. Note that only those areas with HiRISE coverage (see Fig.1) were analyzed. The real position of the rampart area of the outer ejecta layer (from 19-25 km) is extenuated in the elevation plot due to topographic effects.

to the crater center. Characteristic correlations exist between the elevation profiles and the occurrences of exposed blocks. The block clusters of the inner ejecta layer are predominantly distributed in the range from the crater rim (including debris from the crater rim) to the moat area. The broad rampart of the inner ejecta layer shows only minor amounts of blocks. The distribution of blocks in the outer ejecta layer can be correlated to the position of the outer ramparts.

Discussion: The configuration of blocks in the inner layer in linear arrays indicates that block fragmentation occurred during the radial outward flow. The strictly radial arrangement of the block trains suggests a laminar, and thus no turbulent, transport after deposition. Flow deviations by obstacles do not occur suggesting a high-speed flow. The apparent lack of block occurrences in the distal part of the inner layer reflects a primary lack of blocks deposited in this range and/or an effective flow-induced fragmentation of blocks to sizes that are beyond the resolution of the HIRISE data. The blocks could be originated by the incorporation of local substrate blocks into the ejecta. Another possible explanation for the radial block arrays is the excavation of larger blocks as part of the ejecta, accordant to so-called megablocks whose amount generally decreases with increasing distance to crater center. The blocks are disrupted at the moment of landing and/or during the following transportation. A simple fragmentation of the blocks during the passage of the atmosphere without a following transport can not sufficiently explain the block distribution because a radial trend from larger to smaller particles would be expected which is in conflict with our data. The radial extent of the clusters could provide evidence of the transport range and thus of the fluid-like behavior of the ejecta after landing. Some ejecta clusters (see Fig. 1) show radial extents of more than 2 km which allows a minimum estimation for the linear horizontal movement of the ejecta in the moat area. The existence of a broad rampart directly after the moat area indicates a relatively abrupt change in horizontal velocity.

The rampart-related block distribution of the outer ejecta layer gives likely direct evidence of the ejecta emplacement and rampart formation process (Fig. 3). The data confirm an ejecta emplacement of the outer layer as a fluid-assisted granular material flow of different grain sizes that (1) builds ramparts as a result of flow instabilities and (2) shows accumulations of coarse particles on the surface and the flow front due to kinetic sieving [9, 12].

Our future work will focus on fragment size distributions of blocks within the inner and outer ejecta layers as a function of radial range. This and compositional indications derived from CRISM data will provide further constraints on the provenance and emplacement process of the inner and outer ejecta layer in DLE craters on Mars and will probably help to better understand the rheological properties of both ejecta layers.

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