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Post-impact deformation of complex aqueous deposits in an impact crater in Aeolis Planum, Mars

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We have studied a collection of fan deposits in a 21 km diameter unnamed complex impact crater situated in Aeolis Planum that show a wide range of morphologies. Additionally, the fan deposits and the crater floor are affected by a prominent concentric fault system. The crater and the fans are embedded in and partly exhumed from the Medusae Fossae Formation (MFF) material that comprises the Aeolis Planum plateau [e.g. 1]. Our study area is interesting in different aspects. (1) It shows a complex stratigraphy of morphologically very different fans, and the large variety of fan shapes in such close proximity is very unusual. (2) The post-impact crater-filling deposits exhibit morphological features indicating sediment instability and subsidence caused by the reactivation of the impact-generated fault system.

We identified eight fan systems (fan-shaped deposit, associated feeder channel, and source area) along the western and northern crater rim. Based on geomorphic shapes and size the deposits were classified into four different types. Our preliminary results indicate a complex formation history. Based on cross-cutting relationships it appears that fan formation occurred in multiple (fluvial) phases. Type 1 fan systems formed first, followed by the more complex and larger type 2 fans (phase 1). Both types are interpreted to be alluvial fans possibly formed by the runoff of precipitation. Incised channels cutting through the type 1 fan deposits indicate ongoing fluvial activity after fan deposition. The deposits of type 3 and 4 fans superpose type 1 and 2 fans and are thus younger (phase 2). Their steep frontal scarps and stair-stepped topography might indicate that they formed as fan deltas in a standing body of water that formed as the results of the fluvial runoff during phase 1. Stratigraphic analyses with the surrounding geologic units indicated an interesting correlation with the emplacement of Hesperian-aged lava flows directly north of Aeolis Planum (see also [2]). Volcanic activity in the nearby Elysium region could have been a trigger of fluvial activity in the study area.

The interior of the crater is crosscut by prominent concentric faults which are well developed in the western part, but also prominent around the central uplift. Notably, also the fan deposits appear to be disturbed by faults. Our analysis shows that a fault system affected most of the fan deposits after their deposition. There are no morphological-structural signs that the deposition of these fans was going on during or after fault formation. This implies that there was no ongoing fault activity after deposition of these post-fan units. Post-impact deposits (e.g. fluvial/aeolian crater floor deposits) are also disturbed by the fault system.

The concentric fault system is typical for complex craters and reveals strong similarities in its structural signatures to known complex impact craters (e.g. [3] and [4]). The faults in the fan and crater floor deposits are interpreted as post-impact deformation structures due to reactivation of the impact-generated fault system. Especially the rim fault zone shows structural features suggestive of post-impact reactivation affecting the fan deposits. This fault pattern could be the result of a gravity-driven collapse of fan material along listric faults initiated by vertical movement along the rim faults during the post-impact burial of the crater structure. For example [4] described similar post-impact deformation processes caused by post-impact reactivation of rim faults and differential vertical movements at the marine Mjølnir impact structure, off Norway. According to [4] and [5] and the post-impact subsidence could also be related to the instability and the physical properties within the impact-affected MFF deposits, triggered by the upload of the prograding water-enriched post-impact deposits. In our view, the processes require the presence of water in the target rocks or in the post-impact deposits that fill the crater.

The proposed syn- to post-impact sequence is as follows. 1) Fault system formation by impact cratering processes. 2) Crater-influenced sedimentation by deposition of water-saturated fan material and other sedimentary deposits. 3) Deformation of fans and other deposits expressed by structural reactivation of the impact-generated faults along the crater periphery and differential subsidence of the crater floor caused by the loading of post-impact deposits. 4) The water is either pumped out due to deposit loading or vaporized into the atmosphere. 5) The volume left by the removed water finally collapsed, mainly controlled by the impact-induced faults.

References:

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