CONCENTRIC FRACTURING AROUND CRATERS ON CERES. K. A. Otto[1], S. Marchi[2], J. H. Melosh[3], A. J. Towbridge[3], [1]German Aerospace Center (DLR), Institute for Planetary Research, Berlin, Germany (katharina.otto@dlr.de), [2]Southwest Research Institute, Boulder, CO, USA, [3]Purdue University, Lafayette, IN, USA.

Introduction: The Dawn space craft is currently in orbit around the dwarf planet Ceres [1]. Ceres is believed to possess a relatively viscous mantle and mechanically strong crust that contains salts, clathrates, carbonates and ammoniated phyllosilicates [2, 3, 4, 5] mixed with up to 40% water ice in volume [4]. However, the detailed structure, particularly the properties of the heterogeneity of Ceres' crust [4], is still unknown.

High resolution Dawn images revealed a number of relatively young craters on Ceres exhibiting concentric fracturing beyond the crater rim [6]. This feature appears to be unique when compared to other planetary objects with high resolution image data available such as Mars, the Moon or asteroid Vesta. The fracturing may also be the cause for eroding crater rims on Ceres more efficiently compared to these bodies, potentially explaining the missing large craters on Ceres [7].

In this work, we will investigate the possible formation process of the circumferentially fractured craters as possible insights to subsurface material properties and the heterogeneity of Ceres crust, as well as their role in eroding crater rims.

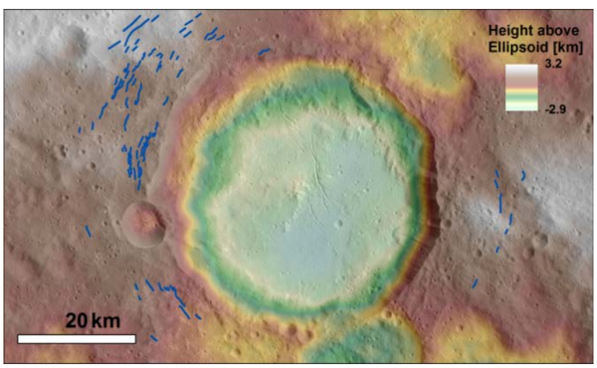

Figure 1: The crater Azacca is 50 km in diameter and located at 7° S and 218° E. Next to concentric fractures (blue lines) that cluster in the north west of the crater, it also possesses floor fractures. The elevation is referenced to a 482 km x 446 km bi-axial ellipsoid.

Observation: There are 16 craters on Ceres which exhibit concentric fractures surrounding the crater. The craters are between 20 and 170 km in diameter and are predominantly located in the mid latitudes. The fractures appear as elongated pit crater chains or narrow fractures with varying length in the order of a kilometer. They extend up to one crater radius beyond the crater rim and often cluster in specific regions around the craters (Figure 1). Craters exhibiting concentric fractures also commonly possess fractured floors, which are potentially caused by the uplift of the crater floor.

Theory: It is possible that the concentric fractures are a result of relaxation when the crater is located on top of a soft subsurface layer. Similar to observations made at the Canyonlands National Park, Utah [8], the spreading of a soft, possibly salt rich layer created by the overburden pressure yields the flexing of the viscous layer towards the crater cavity and subsequently the fracturing of the crust material.

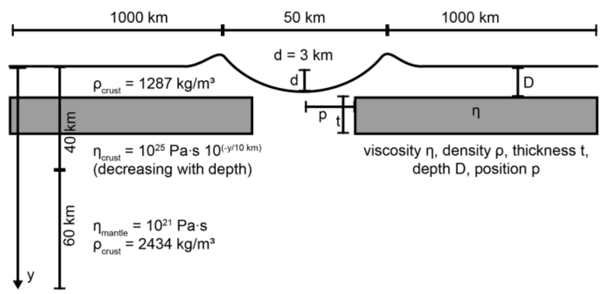

Figure 2: The modeling set-up for simulating the effect of a soft subsurface layer underneath an Azacca-like crater on Ceres.

Modelling Approach: We use the Abaqus software package to simulate a number of subsurface layering scenarios and explore their influence on crater relaxation. We simulate an Azacca-like crater with 50 km diameter and 3 km depth in a 40 km thick crust with decreasing viscosity with depth on top of a 60 km mantle (Figure 2) [5, 9]. In this set-up we place a softer layer of varying thickness, depth and extend. Once the run reaches steady state, we calculate the location and strength of the stresses that develop near the crater rim and infer where concentric fracturing may be possible.

Results: We have conducted preliminary models for an Azacca-like basin. Our current best model was conducted with an 8 km thick low viscosity layer at a depth of 15 km, which did not extend beneath the inner crater (Figure 2 with t = 8 km, D = 15 km, p = 20 km). The uplift in this run was concentrated along the inner crater walls. The stresses were outputted along the free surface so that the vertical stresses could be treated as zero [10]. At ~25-40 km from the crater center, both the radial and hoop stresses are positive, and the radial stress is greater than the hoop stress (Figure 3); this stress field preferentially produces circumferential normal faults [10]. The location of this stress field matches closely with observed concentric fractures associated with Azacca crater (Figure 1).

A same dimensional run with the low viscosity layer extending underneath the crater center did not produce the stress field in the observed location.

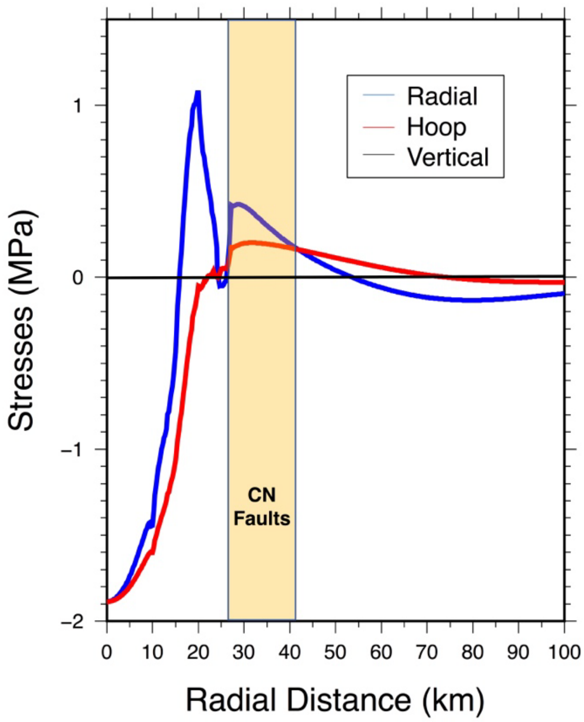

Figure 3: Stress field along the free surface for Abaqus run. The black line represents the vertical stress, which is zero along the free surface of the model. The tan box marks the area where concentric normal (CN) faults are the most preferable faults to form. This area is in agreement with the location of the concentric fractures around Azacca crater on Ceres (Figure 1).

Summary: We identified and characterized concentric fractures around 16 craters on Ceres and modelled the relaxation of Azacca crater as a representative crater with concentric fractures on Ceres. We were able to reproduce the location of the fractures by assuming a soft subsurface layer that partly extends underneath the crater. With this set-up, the area around Azacca where normal faulting forms most preferentially is in agreement with the area in which concentric fractures are found.

References: [1] Russell, C. T. et al. (2016) Science, *353*, 1008-1010. [2] De Sanctis, C. M. et al. (2015) Nature, *528*, 241-244. [3] De Sanctis, C. M. et al. (2016) Nature, *536*, 54-57. [4] Bland, M. et al. (2016) Nat. Geosci., *9*, 538-542. [5] Fu, R. R. et al. (2017) EPSL, *476*, 153–164. [6] Buczkowski, D. L. et al. (2017) Icarus, *in press*, 1-12. [7] Marchi, S. et al. (2016) Nat. Commun., *7:12257*, 1-12. [8] Walsh and Schultz-Ela (2003) Geol. Soc. Am. Bull., *115*, 259-270. [9] Ermakov, A. I. et al. (2017) JGR: Planets, *122*, 2267–2293. [10] Freed, A. M. et al. (2001) JGR: Planets, *106*, 20603–20620.