Circumferential Fractures around Craters on Ceres and their Implications for the Properties of the Subsurface

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Abstract

Based on image data from the Dawn Framing Camera (FC), we investigate craters with circumferential fracturing beyond the crater rim on dwarf-planet Ceres. Finite element modeling of a subsurface layer of low viscosity beneath a characteristic crater (50 km diameter) was conducted. The results show that the relaxation of such a subsurface layer introduces stresses that may be responsible for concentric normal faulting around craters on Ceres.

1. 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] together with up to 40 vol % water ice [4]. However, the detailed structure, particularly the properties of the heterogeneity of Ceres' crust [4], is still unknown.

FC images acquired from Low Altitude Mapping Orbit (LAMO; 35 m/px) revealed several relatively young craters on Ceres exhibiting small scale fractures beyond the crater rim that circumferentially surround the crater [6] (Figure 1). These features appear 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 cause erosion of crater rims to occur more efficiently on Ceres compared to other bodies, potentially explaining the missing large craters on Ceres [7].

Here, we present a possible formation process of the circumferentially fractured craters that leads to possible insights to subsurface material properties and the heterogeneity of Ceres crust.

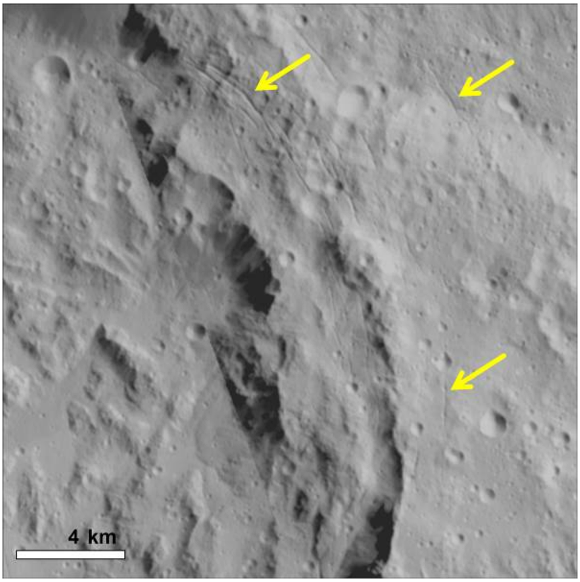

Figure 1: Circumferential fractures around the 50 km diameter crater Ikapati on Ceres. The yellow arrows point at some of the fractures. The crater rim is visible as the curved structure cutting through the image. Some of the fractures are directly on the crater rim, whereas others are located beyond it.

2. Modelling

It is possible that the concentric fractures result from crater relaxation on top of a low viscosity subsurface layer. Similar to observations made at the Canyonlands National Park, Utah [8], the overburden induced deformation of a low viscosity layer allows the surface rocks outside the crater to glide inward toward the crater cavity, opening concentric cracks and/or graben in the terrain immediately surrounding the crater.

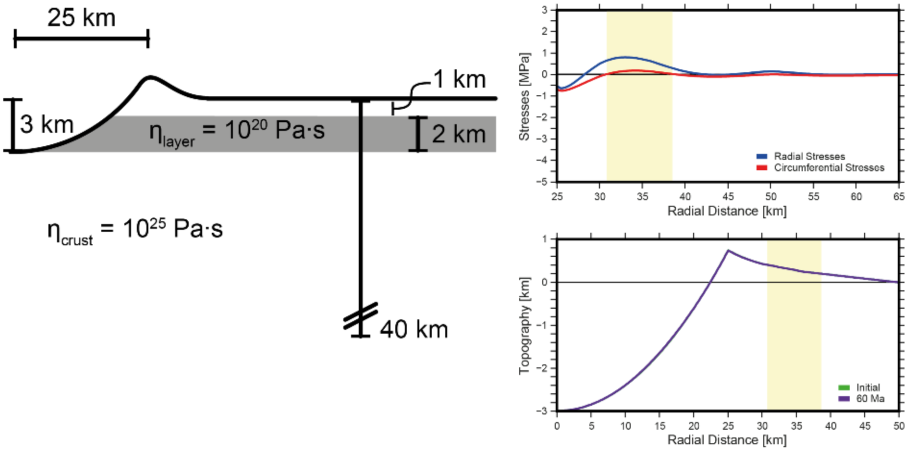

Figure 2: Left: Example of a simulation set-up to explore the effects of a low viscosity layer in Ceres subsurface. Right top: the radial and circumferential stresses that developed around the crater after 60 Ma. Right bottom: The Topography of the simulated crater. The yellow shaded areas on the right hand side mark the position where circumferential fracturing is possible.

Using the the finite element modelling software package Abaqus (Dassault Systèmes), we simulate a 50 km diameter crater with 3 km depth and a parabolic shape. This crater was placed into a 40 km thick and 1287 kg/m^3 dense crust with a viscosity of 10^{25} Pa·s corresponding to the maximum observed viscosity [5]. The crust covers a mantle with a density of 2432 kg/m^3. To estimate the effects of a potential subsurface ice-rich layer, we simulated crater relaxation in the presence of a layer with a viscosity of 10^{20} Pa·s and varying thickness and depth in the shallow crust. Figure 2 shows an example of the simulation geometry and results.

After 60 Ma, simulation set-ups with relatively thin (~2 km thickness) and shallow (~1 km depth) low viscosity layers generate positive radial stresses that exceed the circumferential stresses and thus allow normal faulting (Figure 2).

3. Summary and Conclusions

The concentric fracturing around some crater on Ceres may be a result of a relaxing low viscosity subsurface layer. Finite element modelling suggests that a crater of 50 km diameter may form concentric normal faulting after 60 Ma in the observed location when a low viscosity layer of 2 km thickness is buried 1 km below the surface.

Acknowledgements

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