FINITE-ELEMENT MODELING OF THE VREDEFORT IMPACT STRUCTURE WITH IMPLICATIONS FOR THE COLLAPSE AND MODIFICATION STAGE OF LARGE CRATER FORMATION; E.P. Turtle and H.J. Melosh, Lunar and Planetary Lab., University of Arizona, Tucson, AZ 85721-0092.

While the morphology of large impact craters has been studied in some detail, the processes which generate structures such as central peaks, peak rings, and multiple external rings are still poorly understood. We are using finite-element modeling to investigate the collapse and relaxation phase of impact crater formation with the specific intention of determining the mechanisms necessary to reproduce the subsurface structure observed at Vredefort in South Africa. We have incorporated the rheologic parameters for a simplified stratigraphy into a mesh which has been modified to reflect the displacements that occur during the crater excavation phase. The modeling of the subsequent relaxation of this transient crater has generated up-turning of layers at stratigraphic boundaries similar to that observed at Vredefort. In addition the stresses produced are consistent with the collapse of the transient crater wall in the formation of a complex crater.

The 140km diameter Vredefort structure in the Witwatersrand basin in South Africa consists of a central granite core surrounded by a ~15km wide collar of sedimentary and volcanic deposits. Near the surface these layers typically display dips of up to and sometimes greater than 90° implying that the originally horizontal layers have been turned up and, in places, overturned. Although originally classified as a 'crypto-explosive' structure, substantial evidence (e.g. radially oriented shatter cones [1] and the presence of coesite and stishovite in the numerous pseudotachylite veins [2, 3]) suggests that the Vredefort dome is the deeply eroded remnant of a very large impact crater. Research by Therriault et al. [4, 5] indicates that the transient crater diameter was between 92 and 160 km and that the final crater was between 192 and 300km in diameter.

We are using the finite element code Tekton which was developed for use in geophysical problems. To model crater collapse we begin with a transient crater, 100km in diameter and 30km deep, which incorporates the excavation flow displacements predicted by Maxwell's Z-model [6]. In this empirical description of the cratering flow field, particles are assumed to follow individual streamlines. Particles along streamlines that break the surface inside the rim of the transient crater are ejected, the rest are pushed downward and outward into the surrounding material. We use this method to determine what material is ejected and what is displaced as well as to map the locations to which the stratigraphic layers are displaced during transient crater formation. The resulting mesh (Figure 1a) is used by Tekton as the starting point for modeling the crater collapse.

At this time we have completed runs of visco-elastic relaxation for a greatly simplified model taken from a reconstructed cross-section of the stratigraphy at the time of impact [7]. This three-layer model has a 20km thick quartzite layer on top of a 24km thick granite layer which rests on the mantle. The rheologic properties used are those given by Kirby and Kronenberg [8] for wet quartzite and granite. We have found up-turning of the more mobile granite layer around the edge of the quartzite (Figure 1b). We have also followed the evolution for the surface stress field external to the transient crater (Figure 2). The stresses there are typically extensional and are sufficiently large to induce normal faulting. Moreover, the maximum extensional stresses occur at radii roughly between 100 and 150km. This range is consistent with the distance at which slumping of the transient crater wall is expected for the formation of a 200-300km diameter complex crater. To further investigate the consequences of this stress field we will be incorporating faulting and plastic deformation in this region of our model.

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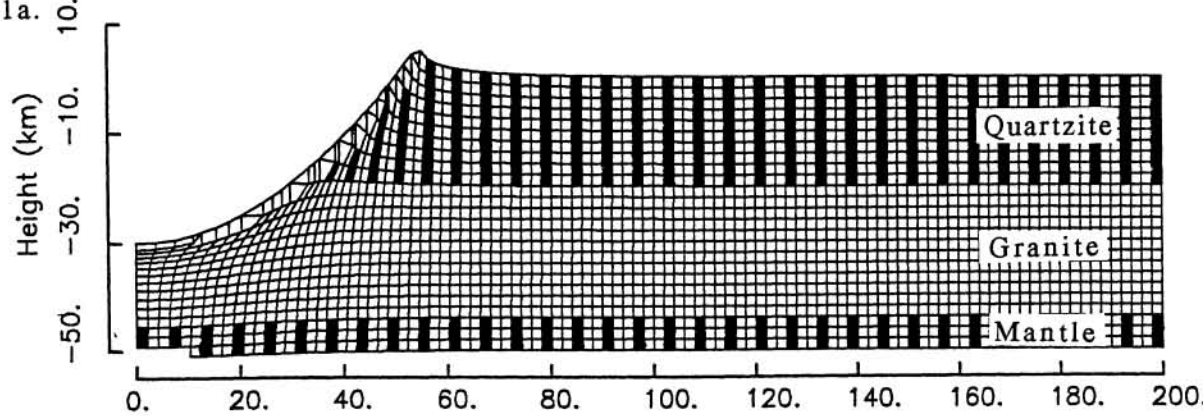
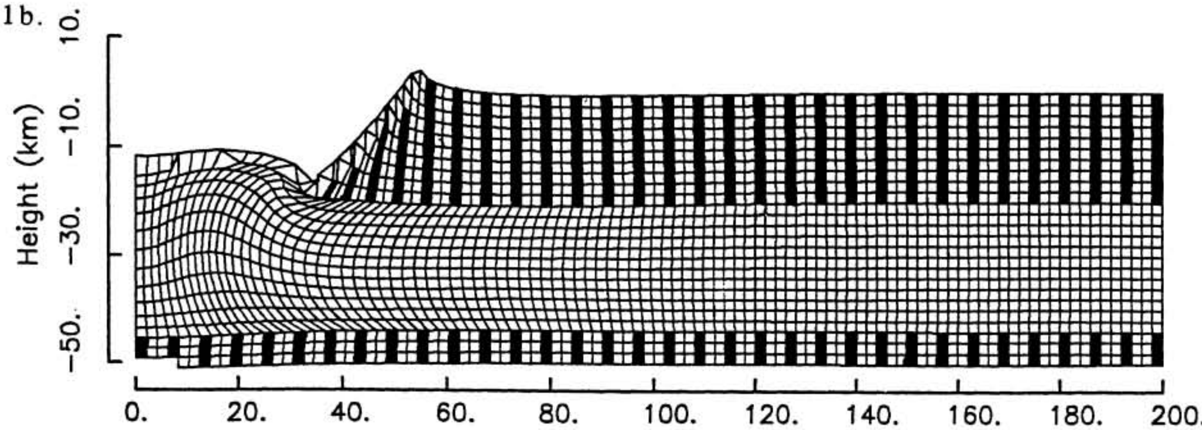
Figure 1: Finite-element mesh a) after application of the Z-model, b) after some relaxation has occurred. Turning up of the more mobile granite layer around the edge of the stiffer quartzite layer is apparent.
Figure 2: Plot of radial stress vs. distance from the center of the crater. Curves are shown for four different times. The solid curve corresponds to the time of Figure 1b.

1a.




1b.




2.