

**HYDROCODE MODELING OF THE SIERRA MADERA IMPACT STRUCTURE.** T. J. Goldin<sup>1</sup>, K. Wünnemann<sup>1</sup>, H. J. Melosh<sup>1</sup> and G. S. Collins<sup>1,2</sup>, <sup>1</sup>Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA (tgoldin@geo.arizona.edu), <sup>2</sup>Department of Earth Science and Engineering, Imperial College London, London SW7 2AZ, UK.

**Introduction:** The Sierra Madera Structure (Pecos County, Texas, USA) is the result of a Late Cretaceous or early Tertiary impact into a thick sedimentary target sequence [1]. The crater is complex, with an intensely folded and faulted central uplift. The diameter of the crater, as defined by the outer limit of deformation and analogies with lunar craters and assuming the outer hills to represent the eroded rim, is 13 km [1, 2]. Impact breccias, shocked quartz, and shatter cones offer evidence for an impact origin and give shock pressure estimates as great as >20 GPa [1].

**Hydrocode Modeling:** We performed hydrocode simulations of the impact event using the SALE-3MAT hydrocode [3] to reproduce the observed target deformation, crater morphology, and pressure distribution of the Sierra Madera structure. SALE-3MAT is a finite-difference 2D hydrocode based on the code by Amsden et al. [4] that incorporates some major modifications e.g. stress- and multi-material extension [5, 6]. The strength model includes pressure and temperature dependent strength, shear failure, strain softening, brittle and ductile deformation, and acoustic fluidization [6, 7]. We approximated the sedimentary target lithologies using two layers of varying strength properties: a stronger lower layer representing Permian and older carbonates overlain by a weaker upper layer representing unconsolidated Lower Cretaceous limestones. We used the Tillotson equation of state and typical rock strength parameters for limestone.

Two possible scenarios were tested: (1) a smaller final crater with a rim-to-rim diameter of 13 km and ~700 m of erosion of 1-km-thick Cretaceous, consistent with previous interpretations, and (2) a larger final crater with a rim-to-rim diameter of 16 km and increased (~1.2 km) erosion of 1.5-km-thick Cretaceous strata. The smaller crater model uses a projectile radius of 340 m, as opposed to 500m for the larger crater model. Both employ an impact velocity of 17.8 km/s.

**Results:** Both the smaller crater and larger crater models, taking into account erosion of all but 100-300 m of Cretaceous strata, reproduce the observed crater geology fairly well. The smaller crater model fits with previous interpretations [1, 2], producing a transient crater ~8 km in diameter and a final crater ~12 km in diameter. Erosion of ~700 m of Cretaceous strata reveals a crater profile similar to observations. The modeled pressure contours agree with those estimated

from shocked quartz. The most significant problem that the smaller crater model experiences is that it predicts overturning of the upper Permian strata at the edges of the central uplift, which is inconsistent with geologic maps [1] showing no overturned stratigraphy.

The larger crater model produces a transient crater ~10 km in diameter and a final crater ~16 km in diameter. Erosion of ~1.2 km of Cretaceous strata also reveals a structure similar to Sierra Madera, with respect to the geometry of the central uplift and also that of the surrounding region. Although an overturned flap is expected, it is small and would be mostly removed by erosion. The diameter of the post-erosion “rim” is ~12 km, which is consistent with the low outer hills at Sierra Madera. However, this more energetic impact event creates potential problems. The model predicts that rocks exposed in the central uplift experienced pressures exceeding 40 GPa, which is greater than previous estimates. Additionally, the extent of damage is much greater for a larger impact and no evidence for impact related deformation has been described beyond the outer hills or deeper than a few kilometers.

Neither model can be ruled out at this stage. It is possible that the overturning of upper Permian strata in the smaller crater models may exist, but was not previously detected. It is also possible that the high maximum pressures in the larger crater model are due to highly shocked rocks being weaker and preferentially eroded. The extent of damage and strain at Sierra Madera may be greater than previously thought as estimates are based on disturbance of the stratigraphy [1]. Gravity mapping may help in this debate as a larger crater should be associated with a larger gravity anomaly. An unusually low impact velocity may also eliminate problems with the larger crater model.

**References:** [1] Wilshire H. G. et al. (1972) *USGS Prof. Paper 590-H*. [2] Howard K. A. et al. (1972) *GSA Bull.*, 83, 2795-2808. [3] Wünnemann K. et al. (2005) *GSA Spec. Paper #384*, 67-83. [4] Amsden A. et al. (1980) *Los Alamos National Laboratory Report LA-8095*, Los Alamos, 101 pp. [5] Ivanov B. et al. (1997) *Int. J. Impact Engin.*, 17, 375-386. [6] Collins G. S. et al. (2004) *Meteoritics Planet. Sci.*, 39, 217-231. [7] Wünnemann K. and Ivanov B. (2003) *Planet. Space Sci.*, 51, 831-845.