BASIN FORMING IMPACTS: HETEROGENEITY as a UNIFYING CONSTRUCT,

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Basin Forming impacts. The Chicxulub crater is considered to be an archetype for basin forming impacts and is the object of extensive field measurements and modeling [e.g, 1]. We have new modeling results using the geologic strength/damage model, GEODAM, that reproduces the major features found in the Chicxulub field measurements. These include inverted stratigraphy, peak rings, terracing, Moho penetrating annular faults, Moho undulation, and melt layering (Fig.1). In support of this effort, we developed a Mohr-Coulomb scaling law, which explicitly accounts for the effects of internal friction and the brittle-ductile transition in the basin forming region.(Fig.2)

Heterogeneity as a unifying construct. Recent seismic imaging of craters such as Chicxulub [1], North Sea [2] and Mjolnir [3], illustrate the extensive faulting, damage and the ubiquitous heterogeneity of the cratering deformation process. This heterogeneity and complexity appears on all scales and is analogous to many process that occur with earthquakes. These processes, starting at the smallest scales include shock planar features, adiabatic shear bands, strain localization, fracturing, brecciation, comminution, suevite formation, Riedal shears, terracing/slumping, Moho penetrating annular faults…. .It is the heterogeneous deformation process in rock that enables weak average stresses in the case of earthquakes to localize strains and enable large displacements [4]. In earthquakes, the faulting process has been viewed as a percolation process in which multiple /complex initial faults evolve to a dominant fault that accommodates the major displacement. This is analogous to the terracing/slumping processes in which the strain localizes on multiple faults that subsequently evolve to a dominant major crater rim fault (Fig 1).

Approach. We developed a strength/damage model [5], GEODAM, that is an integration of the CTH geologic strength model with the Johnson – Holmquist damage model. It employs parameters for pristine and fractured rock obtained from standard laboratory measurements. We do not evoke other weakening mechanisms (e.g., acoustic fluidization [1]).. The model parameters and values are given in Fig. 1. This model is in constrast with typical impact calculations that produce smooth and homogeneous flow fields [e.g. 1,7] Our model addresses many of the heterogeneous process such as , fracturing, strain localization and faulting and mixtures flows of water saturated rocks. [5].

Results. For these Chicxulub simulations, we varied the 20 km/s velocity impactor radius from 5.0 to 7.5 km.(Fig. 1) Upon impact, the projectile lines the transient cavity and produces an associated melt layer. During the transient cavity collapse, the melt flows near the centerline and forms a thin layer on top of the peak ring (Fig 1). A peak ring forms as a result of the collision of the downward flowing transient central peak with the nearly vertically launched cavity flow [1,6], The radius of the overturned stratigraphy is a measure of the transient cavity size and thus the energy of impact [6].

The geometry and magnitude of the damage zone is a function of integrated strain to failure. The rock damage distribution, which is calculated during the impact evolution, is approximately an inverted cup saucer shape and has a maximum radius of approximately twice that of the 40 to 55 km radius of the transient crater cavity. This shape was found also for the damage zone in the Mjolnir [2] crater.

The terraced zone faulting is initiated during the over folding of the ejecta curtain and proceeds during the slumping of material in front of the ejecta curtain (Fig. 1LHS). This complex suite of faults evolves such that the crater rim fault accommodates the largest displacements. This is analogous to the earthquake process [4]. An asymmetric ring fault is formed that terminates the faulting in the terrace zone and also extens downward to the Moho. This ring is often designated as the crater rim. We calculate this diameter to be 150 km. We find ~ 20 km of central uplift of material above the Moho. and small positive and negative undulations of the Moho near the centerline. Finally a ~200 km diameter exterior topographic high ring is formed which is the result of the secondary impact of ejecta deposited upon the region of damaged surface material **.**

A Mohr-Coulomb scaling law for depth of penetration as a function of variation of internal friction is shown in Fig 2. The approach is an extension of that of Holsapple and Schmidt [7]. It shows the change in scaling for basin-forming impacts as the strength response evolves from Mohr-Coulomb to von Mises at the brittle ductile boundary

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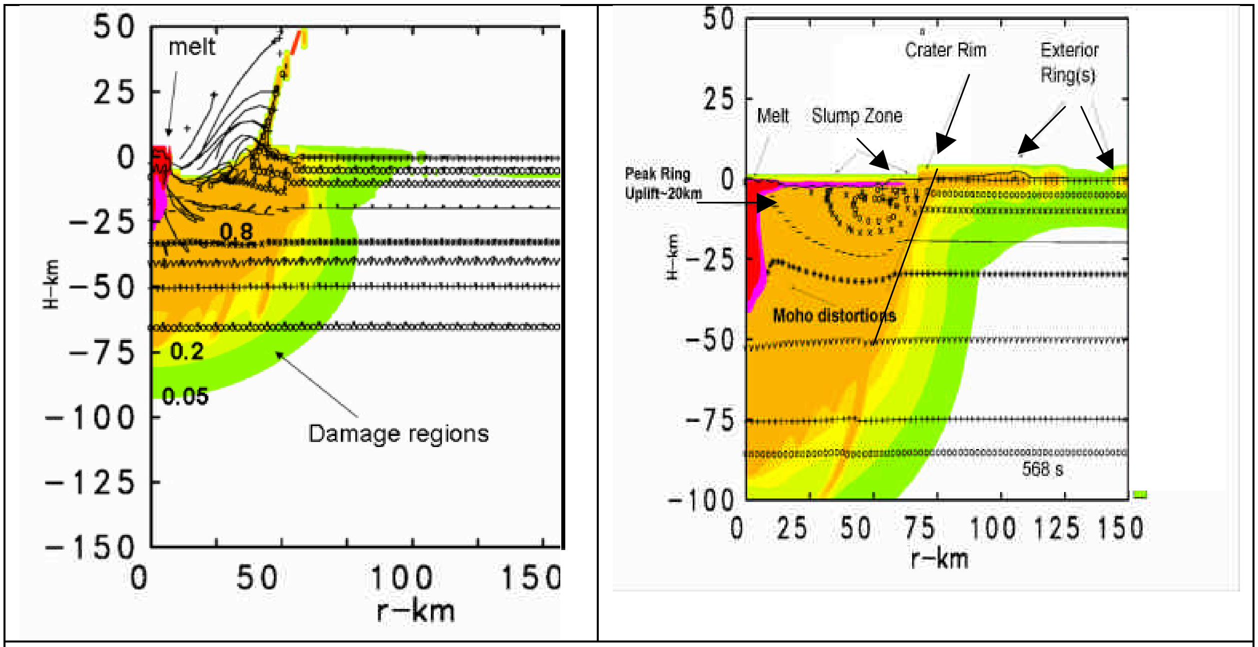

Fig.1 Chicxulub crater deformation fields.. Time = 88 s(LHS).and. 568 s(RHS). Impact velocity, U=20 km/s, radius, a = 7.5 km, cohesive strength, Y_c = 1.0e9, internal friction, μ = 0.75, internal friction-damaged, μ_d = 0.2, intergrated strain at failure, ε_f = 0.1 Note dips in damage region delineating faulting. and the heterogeneity of deformation field.. Terracing occurs in front of the ejecta curtain (LHS).. and is terminated by the crater rim fault (RHS).˙ Damage contour colors magnitudes are shown on LHS. Projectile and crust is granite and mantle (> 33km) is dunite.

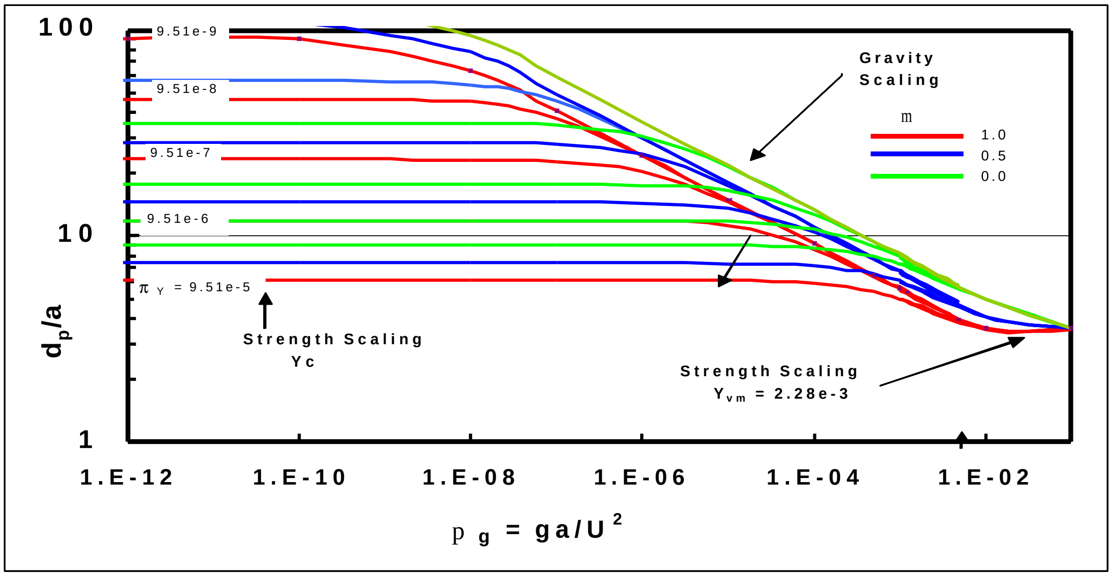

Fig. 2.**Mohr-Coulomb Scaling Law**., **Depth of penetration vs. gravity scaling parameter,** π_g , where g = gravity, a = impactor radius and U = impact velocity. and the material is granite. The effect of varying the internal friction, μ, from 0 to 1 is shown.. Note the transition from Mohr-Coulomb to von Mises scaling at the brittle/ductile transition and the resulting insensitivity to internal friction for π_g > 1.0e-2.