INFLUENCE OF TARGET YIELD STRESS ON CRATER DIMENSIONS: A NUMERICAL APPROACH BASED ON CHICXULUB. E. C. Baldwin[1], L.Vocadlo[1] and I. A. Crawford[1] [1]University College London, Department of Earth Sciences, Gower Street, London WC1E 6BT, e.baldwin@ucl.ac.uk.

Introduction: AUTODYN [1] is used to consider the effect of altering the yield stress of geological materials on the resultant crater dimensions. This investigation is part of a series of fundamental inquiries into the sensitivities of AUTODYN, in order to fully validate the code as an appropriate tool to study large planetary impact crater formation. The majority of current AUTODYN applications are for weaponry, defence and civil engineering problems. AUTODYN is extremely competent in analysing rapid events typical of this genre, and indeed is well suited to resolving peak shock pressure decay in the initial stages of large planetary impacts [2]. However, its potential for analysing the longer timescales required for the full impact process (i.e. to the end of the modification stage), which can require timescales on the order of hours, has been less widely explored.

Motivation for using Chicxulub: An imperative part of validating a numerical code is to assess its reliability at reproducing "real-life" data. A well-studied terrestrial crater was therefore selected for this study. An additional motive for investigating Chicxulub is its association with the impact event implicated in the demise of the dinosaurs, 65Mya. However, despite the plethora of data resulting from numerous intensive seismic, gravity and numerical studies, different authors have arrived at a wide range of dimensions for the crater (Table. 1). Furthermore, Chicxulub is classified as both a peak ring [3,7] or multi-ringed basin [4-5, 7,8] complex crater by different authors. Despite the agreement that there are three possible rings, the first of which is located at a diameter of 80km e.g. [5, 7, 8], estimates for the location of subsequent rings are varied. Rings two and three are inferred by [5] to be at 130km and 195km respectively; whereas [8] considers them to be at 200km and 250km. Modelling this crater with AUTODYN therefore also has the potential to constrain the parameters of this impact event.

Model initialisation: *Grid setup.* A 600x100km domain was defined, using axial symmetry, by an SPH grid (18945 particles) coupled to a Lagrange grid (42600 cells) and initialised with gravity (9.81m/s).

Material model. The success of a simulation relies strongly on the material data that are available. Any material model (i.e. equation of state, strength, failure) that is applied has many parameters, (e.g. yield stress, shear modulus, hydrodynamic tensile limit) and changing just one parameter could significantly affect the final results. In addition, yield stresses of typical geological materials can cover a range of several orders of magnitude [9].Therefore, to see whether crater dimensions are strongly affected by yield stress, a series of test simulations were executed. Preliminary tests configure the materials with identical yield stresses, to simply illustrate the affect of altering one parameter at a time. Subsequent investigation will examine other significant parameters. For results presented here, the linear Drucker-Prager strength model and hydro-dynamic tensile limit failure model was applied [10].

Materials. Materials chosen for the simulations imitate the idealised stratigraphy at the Chicxulub site: 100m water overlying 3km sediments, and a 27km thick crust overlying the mantle e.g. [11,12] Due to the resolution of the model, the water layer is considered negligible. Subsequent layers are represented as limestone, granite and dunite e.g. [11, 12]. Tillotson and Shock equations of state were used for limestone and granite, and dunite, respectively.

Reference	**Final Diameter, D (km)**	**Final depth, d (km)**	**Depth to Diameter Ratio (d/D)***
[3]	250		0.04
[4]	300		0.03
[5]	85	7-9	0.08-0.11
[6]	180		0.06
[7]	180	10	0.06
[8]	150	<10	0.07
Run #1 (YS=1E10)	65	20	0.31
Run #2 (YS=1E7)	117	13	0.11
Run #3 (YS=1E5)	144	5	0.03
Run #4 (YS=10)	137	9	0.07

Table 1. Comparison of quoted data from the literature for Chicxulub crater dimensions (km). Output from this study is included in the last four rows, where YS=Yield Stress (Pa)
*d=10 where otherwise undefined.

Preliminary Results: Initial runs simulate the impact of a 10km diameter sphere of dunite traveling at 20 km/s, as by [12]. Models were run to approximately 100mins until all large scale motion and collapse under gravity within the simulation had ceased. Preliminary results are presented alongside published data in Table 1 and also in Figure 1.

Typical complex craters have a depth to diameter (d/D) ratio of 1/10-1/20 [12]. Transient craters have a d/D ratio of ~1/3 [14]. From Table 1 we see a published range of 0.03 to 0.11 for the actual crater. The modelled d/D ratios lie in the range between 0.03 and 0.31, with the upper value being typical of the d/D ratio expected for a transient cavity. This is achieved with the highest yield stress tested in this study.

Peak rings? Current numerical resolution precludes the ability to resolve any peak ring location; however subsequent refinements to the model will concentrate on resolving this. This is an important consideration given that Chicxulub is classified as either a peak ring or multi-ringed basin by different authors. Moreover, this highlights the difficulties in modelling the phenomenon of large crater forming events.

Future Work: This investigation is in its infancy, and further exploration into the sensitivities of AUTODYN is required in order to constrain the preliminary results further. The yield stress of the material is just one of many parameters that define the material model within AUTODYN. Other parameters that may affect the crater dimensions (either independently, and/or separately) include shear modulus, hydro tensile limit, and of course the equation of state used. Where ranges of values are quoted in the literature for parameters such as these, upper and lower limits of the effect of this spread will subsequently be defined. In addition there are a number of different strength models available within AUTODYN, and currently only one (Drucker-Prager) has been implemented in this study. The combination of altering all of these parameters will conspire to make a more refined and more accurate model.It is important to re-emphasis the fact that AUTODYN has not been widely used to examine the complete impact process. Therefore, a lot of ground work has been covered to define the most appropriate model initialisation (solvers and resolution). In addition, the lack of readily available material data, particularly for geologically important materials, and how they respond in AUTODYN to the extremely high pressures involved in such events has caused some delay in calculations. These considerations have necessitated close collaboration with AUTODYN code developers to expand the software, in order to cope with the problems arising from modelling planetary scaled impacts. This has been a limitation to the study, but has allowed suitable advances to be made to the code.

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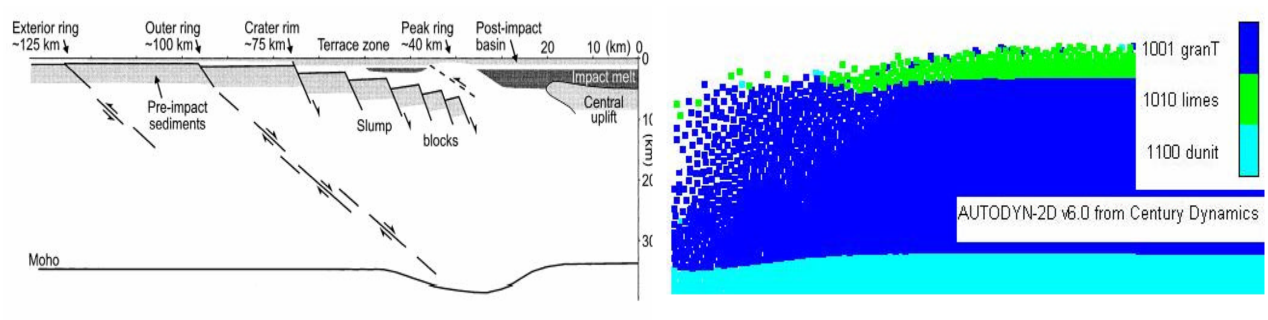

Figure 1: Cross section of Chicxulub, showing main structural elements interpreted from seismic data by [15] (left) compared with example of AUTODYN model (right) of Chicxulub event at 600s from impact. (NB. Not to scale).