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# Testing impact numerical model setups for simple craters

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## Abstract

To investigate the challenges in testing impact numerical model setups we selected three of the most common setups used in the impact cratering community. For each of these setups, we carried out simulations where the projectile diameters are varied. We focus only on simple craters on the lunar surface (i.e., craters with diameters smaller than 14-31 km [1]). Preliminary results are presented and discussed in the second part of this abstract.

## 1. Introduction

A crucial step in impact numerical modeling is to directly compare results with observations in order to test and quantify how well a model reproduces the processes and products generated through a natural impact. In most studies, this step is conducted with the help of a single observation, as they often focus on reproducing a particular impact structure on a certain planetary body. A problem that arises from such act is that single crater geometry (depth, diameter, wall slope and rim height, generally simplified to depth and diameter) can be reproduced by several numerical model setups. Numerical results may therefore be non-unique. The fact that neither the projectile diameter, composition, impact velocity nor angle that produces a particular impact structure are known adds another level of complexity in the testing of a model setup, as an impact with the same energy but different impact velocity may result in different geometry [e.g., 2]. The goal of this study is not only to test existing setups but to ultimately develop a single (or several) model setup(s) that will match the lunar observations over a large crater diameter interval.

## 2. Method

The iSALE-2D numerical impact code is here used [3-5]. This code gives us the versatility to choose in between routines (e.g., strength, porosity and dilatancy) to describe the material model, allowing us to test easily different model setups. The impact velocity is here held constant to a value of $U$ = 12.7 km/s, which is a rather reasonable average impact velocity for the Moon (including the vertical component of a 45$^{o}$ impact angle).

The three setups investigated are relatively different, the first one (#1) describes best granular or brecciated target [6], while the second [7] (#2) and third (#3) describes best the behavior of rocks [8]. Model parameters which might affect the most the final crater geometry and morphology are listed below. In addition, we list two other important factors: the crater diameter interval over which the setups have been used, and the datasets against which the setup have been tested. Readers are recommended to the references for a full description of each of those models. Note that the setups are sorted in increasing degree of complexities (from top to bottom, #1-3), and that strength model parameters in #2 and #3 have different values.

#1: **strength model:** completely damaged material, **initial porosity:** yes, **dilatancy:** no, **crater diameter interval:** 1 - 15 km (Moon); **tested against:** transient crater diameter scaling laws derived at laboratory-scale [6].

#2: **strength model:** intact and damaged material [9], **initial porosity:** no, **dilatancy:** no, **crater diameter:** 2.2 km (Moon); **tested against:** crater geometry of Linne crater [7].

#3: **strength model:** intact and damaged material [9], **initial porosity:** no, **dilatancy:** yes. **crater diameter:** 4.0 km (Earth); **tested against:** crater geometry, porosity gradient and gravity anomaly beneath Brent crater [8].

As computational resources increase considerably with decreasing projectile diameters, only simulations resulting in final rim-to-rim crater diameter $D_r$> 8 km have so far been investigated. Results are here compared against "fresh" simple impact craters on the lunar surface compiled in [10]. We compare the three different model setups not only to a single observation but to several observations with different crater diameters (Figure 1). By doing so, we also test whether a model setup performs well over a crater diameter interval. The three model setups are compared to elevation points obtained from the Lunar Orbiter Laser Altimeter data on-board the Lunar Reconnaissance Orbiter [11]. Both x- and y-axes are normalized with $D_r$ (Figure 1).

## 3. Results and discussion

Of the three setups, model setup #1 fits the best the different observations for $D_r > 8$ km on the lunar surface, with both a good representation of the depth, wall slope and crater diameter (Figure 1). We note that the rim heights seem to be more sensitive to asymmetries probably due to pre-existing topography. For setup #2, the wall slope is well reproduced, but the observed depth-diameter ratio $d_r/D_r$ is often underestimates by about 10% (depicted by the y-axis on Figure 1). In #3, $d_r/D_r$ is underestimated by 25%, certainly due to the fact that #3 is calibrated against Brent crater which have a $d_r/D_r$~0.15. The collapse observed at Brent crater seems to be larger than the collapse for craters with $D_r > 8$ km on the Moon. At last, we found that for a similar projectile diameter $L$ = 1000 m, different $D_r$ is obtained: $D_{r\#1}$ = 13.38, $D_{r\#2}$ = 17.28 and $D_{r\#3}$= 13.63 km. The largest difference is about 4 km, likely due to the fact that the effect of porosity is neglected in #2. All of these results clearly show that more work is required to develop a numerical model setup which will fit a larger crater diameter interval of observations.

## 4. Future work

Additional results will be presented at the conference, including the comparison to fresh impact craters with 100 m < $D_r$ < 8 km, and models including both strength and porosity gradients. In addition, different dilatancy and strength model parameters will be tested in model setups #2 and #3.


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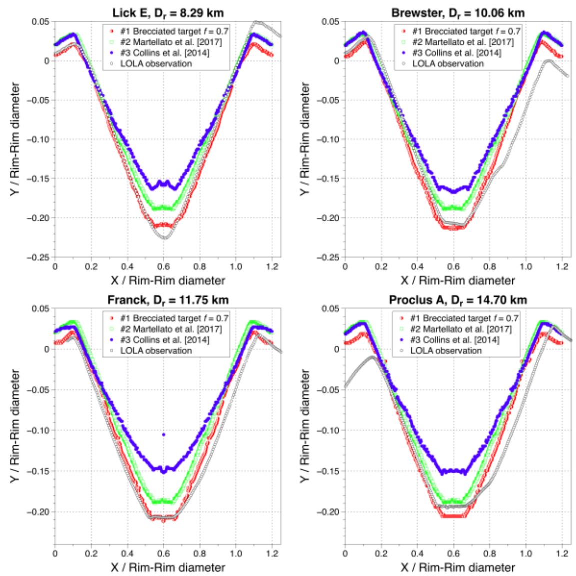


**Figure 1**: Craters from the three model setups are compared to four fresh simple impact craters on the Moon (Lick E, Brewster, Franck and Proclus A). LOLA altimeter elevation points are depicted in black and white circles.

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