FILLED CRATERS IN ARABIA TERRA: NUMERICAL MODELLING RESULTS FROM FIRSOFF CRATER
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Introduction: Comparing real crater with Hydrocode model outputs is particularly difficult on Mars due to strong crater degradation, due to a variety of geological processes. On the other hand, simulating a crater formation can also help to understand the entity of the geologic processes leading to the nowadays craters' shapes giving an estimate of the volume of materials involved in erosional and depositional processes.

In this work we present a case study of impact crater modeling on Mars. In particular, we analyze the Firsoff impact (90 Km in diameter), located in the equatorial southern highlands of Arabia Terra at 2.6° N – 350.8° E.

Firsoff crater: Arabia Terra is classically dominated by heavily cratered terrain, and some peculiar landforms, like pitted cones and mounds, can be found mostly in craters' interiors. The Firsoff crater is a complex crater characterized by a big central bulge located where the central peak should be and displaying a layered sequence [1]. In addition many mounds in its interior are interpreted to have worked as pathways for subsurface fluids [1] and their origin and timing of formation is still under investigation [2].

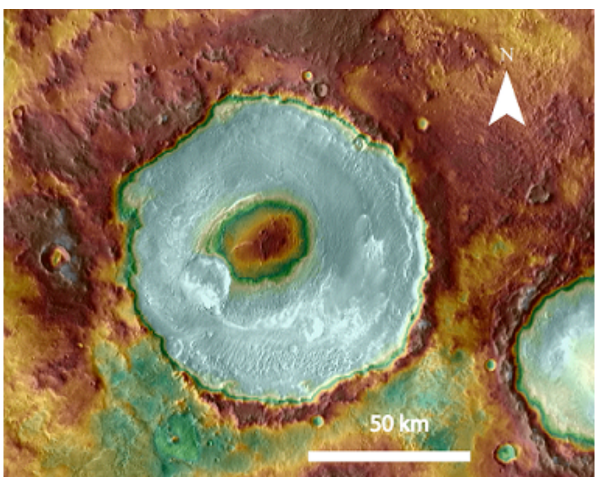

Fig 1. THEMIS daytime infrared image draped on MOLA 128px/deg DTM of Firsoff crater. The central bulge is clearly visible

Mounds inside Firsoff appear as sub-circular conical features going from 30 meters to 300 meters in diameter, often presenting a central orifice. Through HiRISE DTM analyses their height is roughly estimated to be tens of meters. These peculiar morphologies occur along the external margin of the crater, most of them concentrated and clustered on the south-eastern part [3]. Moreover, they seem to be genetically linked to the well bedded stratified deposits identified as *equatorial layered deposits* (ELD) ([1], [4], [5]). Sometimes they are aligned along fault traces and fractures.

Firsoff crater has been also strongly affected by degradation and before reproducing the right morphology of the crater by numerical simulations it is mandatory to estimate its original morphology. As testified by the numerous yardangs and dunes in the topographically lower parts of the crater and by the layered deposits in the central bulge, it appears that Firsoff crater has been strongly affected by eolian and water-related degradation and infilling processes. Moreover slumping and gravitational collapses of the crater walls along listric sliding planes faults are likely. Therefore, according to [6] we assume that the pristine diameter of this crater must have been 10% less than the current diameter. Adopting a pristine diameter equal to 80 km, we apply to the Firsoff case the morphometric relationships linking the diameter with the impact crater parameters such as rim high, central peak high and diameter [7]. In this way we have found the features of the crater at its formation time.

Therefore, the aim of the simulation is to reproduce the estimated parameters listed in the table below fixing the right size of the central peak and the real depth of the crater; this is necessary to obtain the volume of the material that covers the central peak of the Firsoff crater in order to understand the origin and the evolution of this feature.

Parameter		**Complex crater relationships**	**Firsoff crater case**
Depth	**D**	$d=0.36D^{0.49}$	3 km
Rim height	**H**	$H=0.02D^{0.84}$	0.8 km
Central Peak diameter	$\mathbf{D_{cp}}$	$D_{cp}=0.25D^{1.05}$	2.5 km
Central peak height	$\mathbf{h_{cp}}$	$h_{cp}=0.04D^{0.51}$	0.3 km

Table 1: Morphometric relationships derived from Garvin et al. 2004 [7]

Methods: For our purpose we are using the iSALE hydrocode ([8], [9], [10], [11], [12]) to model the formation of the Firsoff crater which is 90 Km in diameter and 1 km in depth. These values are obtained from the analysis of the high-resolution images taken by HIRISE (25cm/pixel) and CTX (6m/pixel) cameras. The depth is derived from MOLA and HRSC DTMs and its maximum depth is considered that of the crater floor. We based our simulation on a spherical basalt projectile 7-8 km in diameter, estimated by the comparison between the profiles obtained by the numerical modelling and by the DTM, with an impact velocity of 12 Km/s [13] and an impact angle of 90°.

The ordinary constitutive model accounting for changes in material shear strength [9] must be supplemented by a transient target weakening mechanism, called acoustic fluidization model, to facilitate the gravitational collapse characteristics of large impact craters [14].

Therefore, several model runs were done with various choices of the acoustic fluidization parameters to find an appropriate range of values for the oscillation decay time and viscosity.

We have modeled the Martian surface as a double layer made up by a damaged basalt layer passing to intact anorthosites at 8 Km depth. The choice of anorthosite is in agreement with the detection of this material on the Martian highlands [15].

We have used a density equal to 2700 Kg/m^3 and 2900 Kg/m^3 for anorthosite and basalt respectively neglecting the porosity of the target; while we have fixed a projectile porosity equal to 10 %. The thermodynamic behavior of both the projectile and the basalt layer of the target is described by the basalt ANEOS equation of state, while for the second layer made up of anorthosite we use the relative Tillotson equation of state.

Discussion and Conclusions: The main result of numerical modeling is shown in Fig. 3 where the red profile, derived from the simulation, corresponds to the morphology of the crater at its time of formation and the black profile is instead related to the nowadays topography derived from the HRSC DTM.

As mentioned above, these two profiles are very different because of the process of crater degradation.

The simulation is able to reproduce the diameter dependent parameters estimated in table 1, in particular the crater diameter, its depth and the rim height equal to 80 km, 3 km, 0.8 Km respectively. On the other hand the morphology of the central peak isn't well reproduced, but this is an open problem because this feature could have been modified by later processes. In particular the nowadays morphology of Firsoff crater is affected by later sedimentary layers and from the geological analysis alone is not possible to understand which part should be attributed to the central peak and which to later processes of modification .

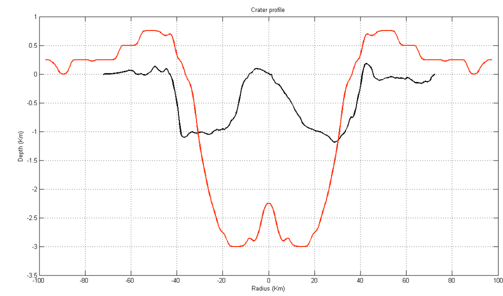

Fig 3: Crater profiles of the Firsoff crater: the red profile corresponds to the simulation result while the black profile to the HRSC DTM profile.

In any case, from our result we can raise the hypothesis that the Firsoff crater in 3.5 Gyr has been filled up of 60-70 %, in agreement with the model of crater degradation presented in [6]. Moreover material transport by fluids seem to have taken place following the fracture network and faults created by the impact itself, as testified by the small knobs and mounds identified inside the crater.

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