FILLED CRATERS IN ARABIA TERRA: NUMERICAL MODELLING RESULTS FROM FIRSOFF CRATER

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INTRODUCTION

We analyze through numerical modelling the Firsoff degraded crater (90 km in diameter), located in the equatorial southern highlands of Arabia Terra at 2.6° N - 350.8° E and characterized by the presence of a central bulge. We present two different scenarios depending on different composition of the Martian surface in order to find the best solution and give an estimate of materials involved in erosional and depositional processes.

GEOLOGICAL CONTEXT

Firsoff impact crater, located at 2.6° N - 350.8° E in Arabia Terra, is a complex crater with a diameter of 90 km, a depth of 1 km and characterized by a big central bulge of 30-40 km diameter (located where the central peak should be) displaying a layered sequence. [1] (Fig. 1, Fig. 2). MOLA (Mars Orbiter Laser Altimeter, Mars Global Surveyor mission) topographic data (128 px/deg) and HRSC (High Resolution Stereo Camera, Mars Express mission) derived stereo DTMs (100 m/px resolution) were used for our analysis.

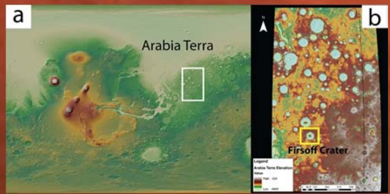
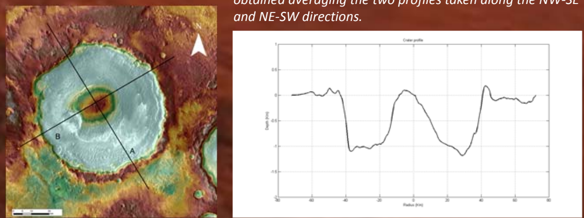


Fig. 1a) *MOLA (Mars Orbiter Laser Altimeter) global map and detail of Arabia Terra. In* ***Fig. 1b)*** *Firsoff crater is highlighted*

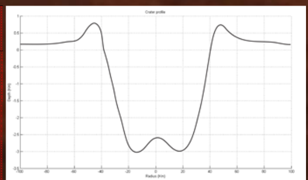
Fig.2 Left *THEMIS daytime infrared image draped on MOLA 128px/deg DTM.* ***Right.*** *Topographic profile obtained averaging the two profiles taken along the NW-SE and NE-SW directions.*



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. Therefore, according to the results of crater degradation simulation obtained by [2], that takes into account the processes of airfall deposition, eolian degradation, water interaction (erosion and sedimentation), we assume that the Firsoff pristine diameter must have been 10% less than the current diameter equal to 90 km.

Adopting a pristine diameter equal to 80 km, we use morphometric relationship defined by [3] to reproduce the original morphology of the crater at its formation time in order to have a comparison term with the results coming from the simulations. These equation, shown in Tab.1, were defined by [3] on the basis of MOLA topographic profiles of 6000 Martian impact craters.

Parameter		Complex crater relationship	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	D_{cp}	$D_{cp}=0.25D^{1.05}$	2.5 km
Central peak height	H_{cp}	$h_{cp}=0.04D^{0.51}$	0.3 km



Tab 1 Left *Morphometric relationships derived from [3]* ***Right*** *Reconstructed pristine profile from the parameters above.*

METHODOLOGY

We use the **iSALE shock physics code** ([4], [5], [6], [7], [8]), a multi-material, multi-rheology code, to model the formation of the Firsoff impact structure discussed above (Fig. 3).

• We have based our simulation on a spherical basalt projectile 7.5 km in diameter, with an impact velocity of 12 km/s and an impact angle of 90°.

• The target structure was modeled as two different scenarios fixing the depth of the first layer at 8 km depth according to [9]:
- a double layer made up by a damaged basalt layer passing to intact anorthosite. The choice of this composition is in agreement with the detection of anorthosite on the Martian surface [10] on the southern highlands.
- a double layer made up by a damaged basalt layer passing to compact basalt.

• The thermodynamic behavior of both the projectile and the basalt layer is described by tables generated using the basalt ANalytic Equation Of State (ANEOS). A Tillotson EOS for gabbroic anorthosite was used to represent the second layer of the target.

• The ordinary constitutive model accounting for changes in material shear strength [5] must be supplemented by a transient target weakening mechanism, called acoustic fluidization model, which is controlled mainly by the viscosity and the decay time The best fit crater is produced using a decay time of 115 s and a kinematic viscosity of 190000 m^2s^{-1}.

The main results of numerical modeling are shown in Figure 3.

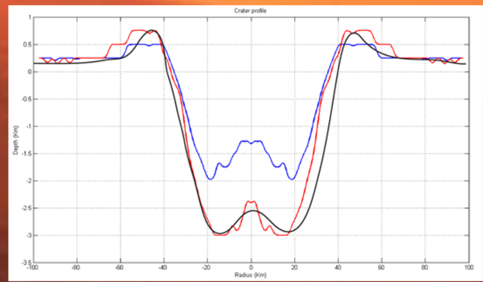


Fig. 3a *Comparison between the reconstructed pristine profile obtained according to [3] in black and the iSALE output profiles: the red profile corresponds to the double layer of basalt and anorthosite, while the blue profile correspond to the double layer of basalt.*

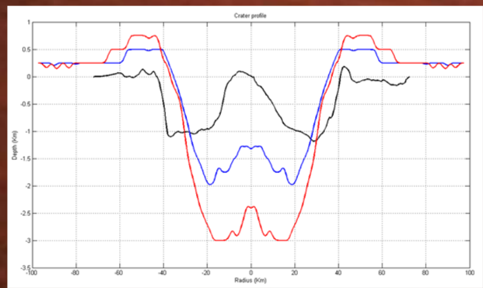


Fig. 3b *Comparison between the nowdays topography derived from the MOLA DTM and the iSALE output profiles.*

RESULTS AND DISCUSSION

Comparing the simulated profile obtained considering the fractured basalt/compact basalt layering and the fractured basalt/compact anorthosite layering both with the reconstructed pristine profile we obtained **two composition-dependent simulated endmembers**.
-The simulation involving the **anorthosite** layer, it appears evident that it has the best fit with the reconstructed profile using [3] (in respect to the basalt-only impact profile). The depth and the diameter are comparable and also the rim height that are equal to 80 km, 3km and 0.8 km respectively. Moreover, these obtained values are also consistent with a subsequent crater degradation, increase of diameter and rim dismantling that lowered their height.
- The profile involving only **basalt** (fractured/unfractured layering) seems to be the best choice taking into account the lithologies involved, but its morphology appears to be less realistic if compared with the pristine reconstruction of Firsoff.

The simulated morphology of the central peak is not well reproduced with respect to the reconstructed pristine one, but this is an open problem also because this feature is lying underneath the central bulge. In particular, the nowadays morphology of Firsoff crater is affected by later sedimentary layering 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.

Degrading the simulated profile involving anorthosite (in Fig 3b) , according to [2], by filling the crater with sediments and aeolic dust, increasing its diameter by 20% due to collapse of mass walls and mass-wasting and lower the rim height of 2/3, we can note that the obtained shape is in good agreement with the one observed by MOLA.

The best model output suggests that Firsoff crater is characterized by the presence of anorthosite below 8 km depth in the Martian terrain and from the comparison between the iSALE and the DTM profiles we observe that it has been filled up of 60-70% in 3.5 Gyr, in agreement with the model of crater degradation presented in [2].

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