MESSENGER: a tool to study Mercury beyond its operative life

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Introduction

Figure 1. Artistic representation of the MESSENGER impact into Mercury (*Credits*: Wayne Ferrebee, 2015, ink and coloured pencil)

- ❑ Impact crater morphology [1] can vary with
  - ✓ projectile kinetic energy (size: simple or complex craters)
  - ✓ target properties such as layering, material strength, porosity, and thermal state [2]

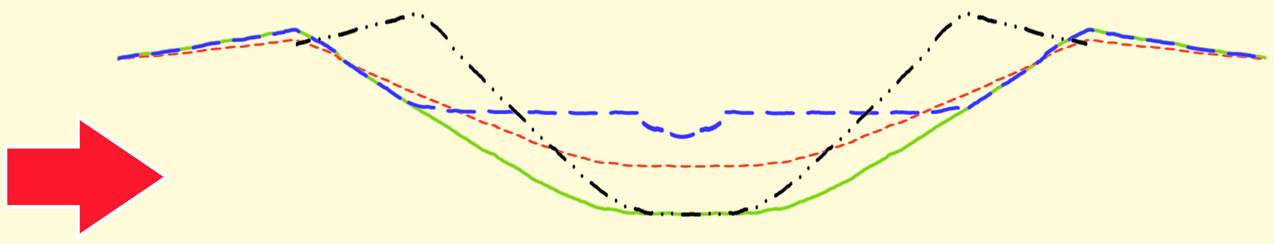


Figure 2. Profiles of small simple craters, which in homogeneous targets develop with a bowl-shaped morphology (green line). Any departure from such a shape provides insight into subsurface target properties, including changes in density and porosity (red line), strength (black line), and layering (blue line).

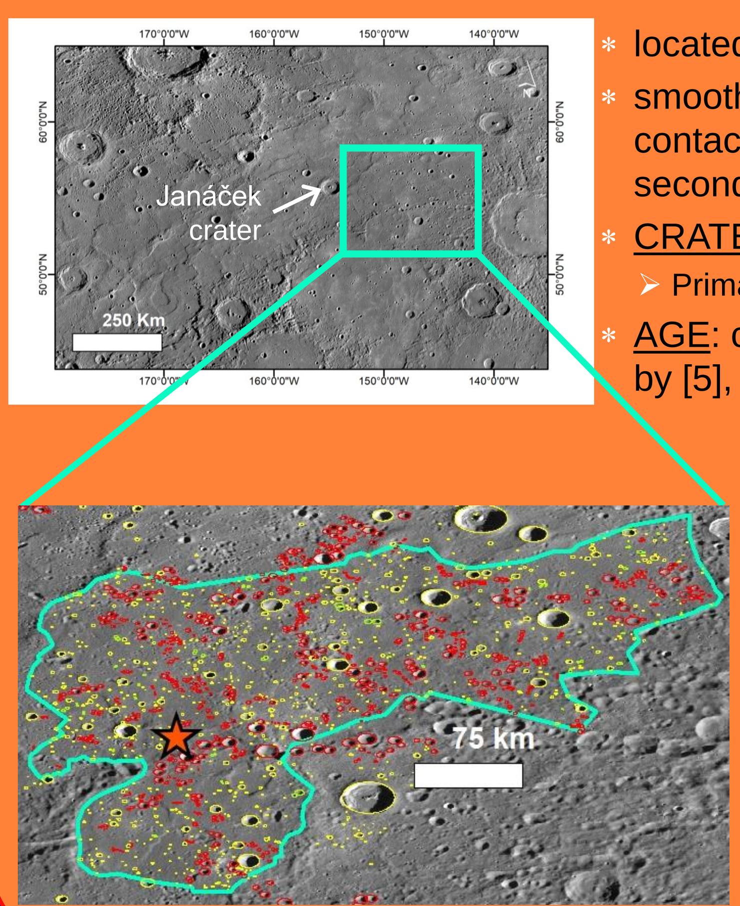
Goals

- ❑ impact experiments allows to decrease the number of unknown variables (projectile properties), **BUT:**
  - ✓ projectile sizes and velocities are far from the typical values at planetary scales
  - ✓ scaling-laws may fail in correctly "scaling" parameters like impact melt

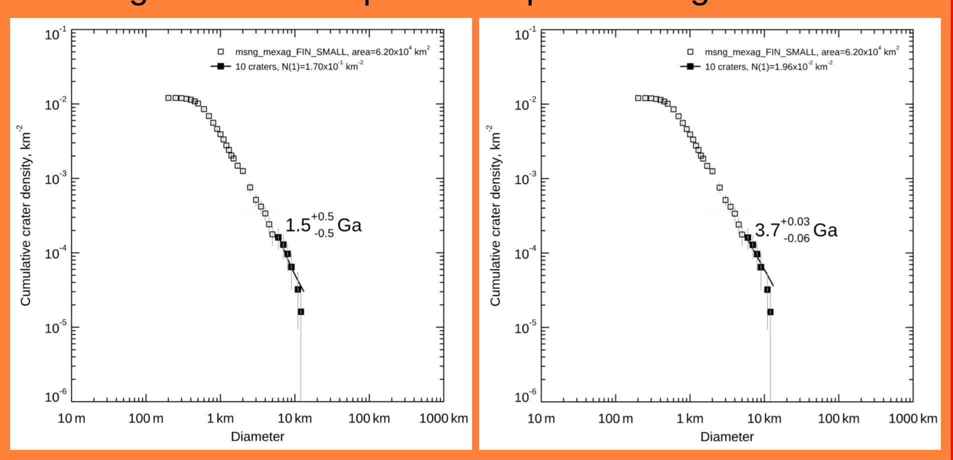
We aim to:

- ➢ model an "impact experiment at planetary scale", i.e. the impact of the NASA MESSENGER [3] spacecraft, which crashed on the Hermean surface in 2015
- ➢ analyse the crater morphology, at varying impact angle, testing different target properties
- ➢ evaluate whether we will be able to observe it by means of the SIMBIO-SYS instrument [4] onboard the ESA-JAXA BepiColombo mission, and in this case estimate the Hermean surface properties based on the crater morphology

SUISEI Planitia: Geology & Age Determination



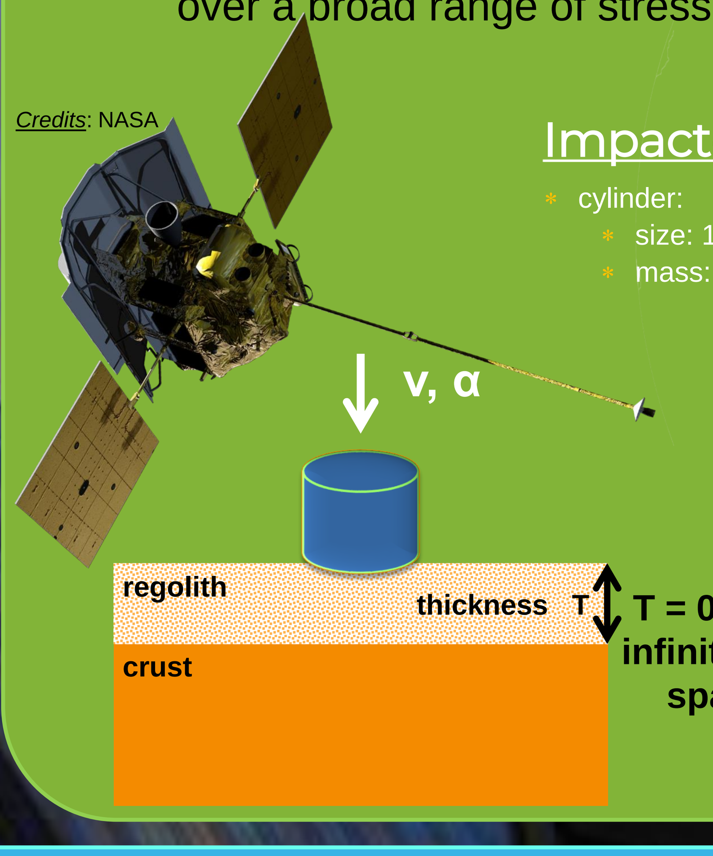
- located north-east of Caloris basin
- smooth plains: likely volcanic in origin, showing overlapping contacts, >50 km complex craters with their related field of secondaries, ghost craters
- CRATER COUNT:
  - ➢ Primary craters: yellow circles; Secondary craters: red circles
- AGE: crater age estimates are based on the chronology model by [5], assuming either a non-porous or porous target



Non-porous target | Porous target

Numerical Modelling setup

- ❑ numerical modelling by means of iSALE shock physics code ([6], [7], [8], [9], [10])
  - ➢ quantitative simulation of the propagation of shock waves and of the behaviours of matter over a broad range of stress states and deformation rates



Impactor:

- cylinder:
  - size: 1.85 m x 1.42 m x 1.27 m
  - mass: 507.6 kg
- porous aluminum:
  - Tillotson EoS [11]
  - Strength Model by [12]
- impact velocity:
  - $|\vec{v}|$ = 3.91 km/s
  - angle α = 30°, 45°, 90°
    - ➢ tested v = $|\vec{v}| \sin\alpha$

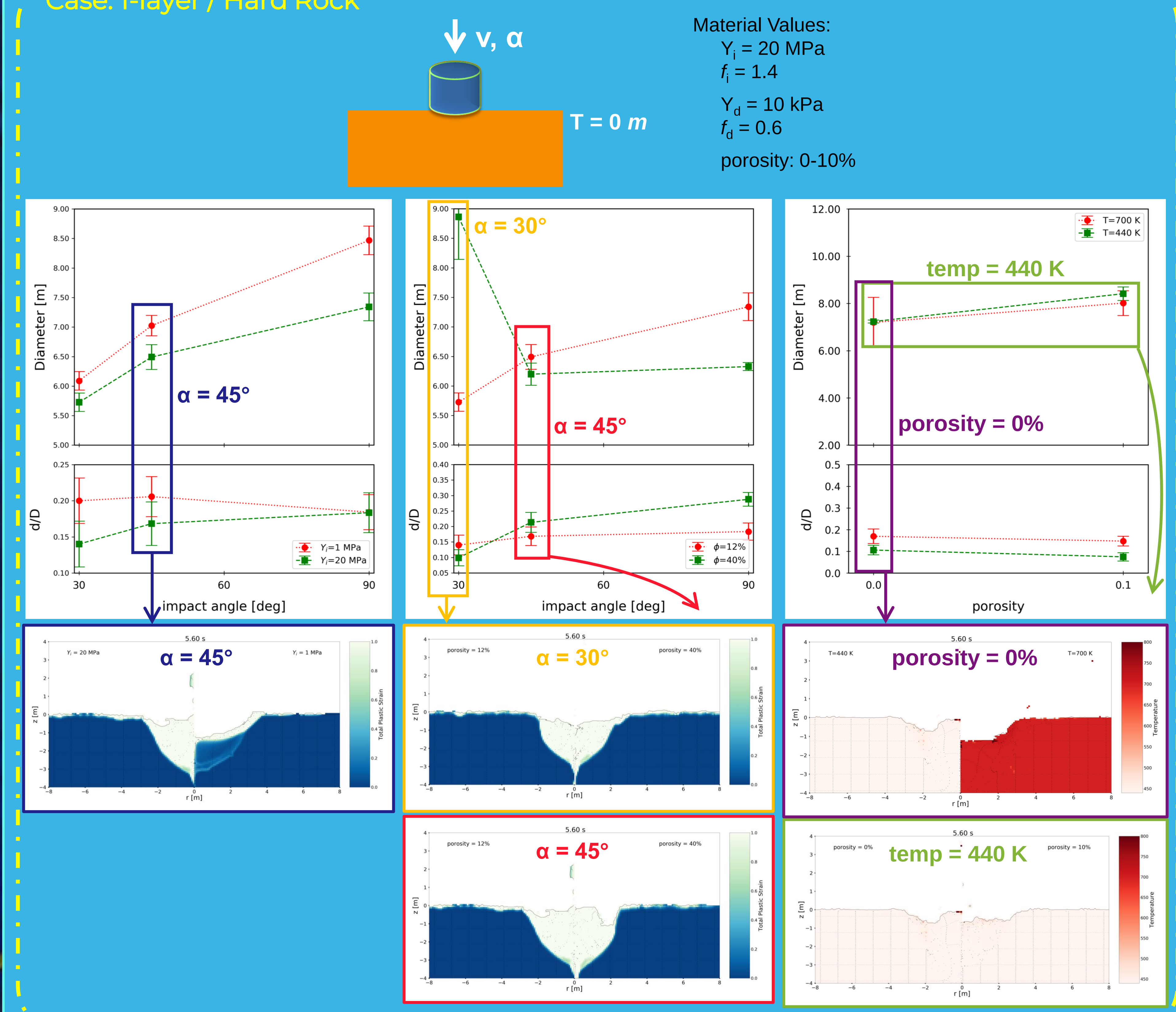
Target:

- 2D cylindrical symmetry
- g = 3.70 m/s^2
- basalt, 2 layers (regolith layer above a harder crust)
  - ANEOS for Basalt [11], [13]
  - Drucker-Praeger model for the regolith [14], Lundborg for the crust [15], and damage model by Collins et al. [8]
- Porosity: 40% for the regolith, 12% and 40% for the crust

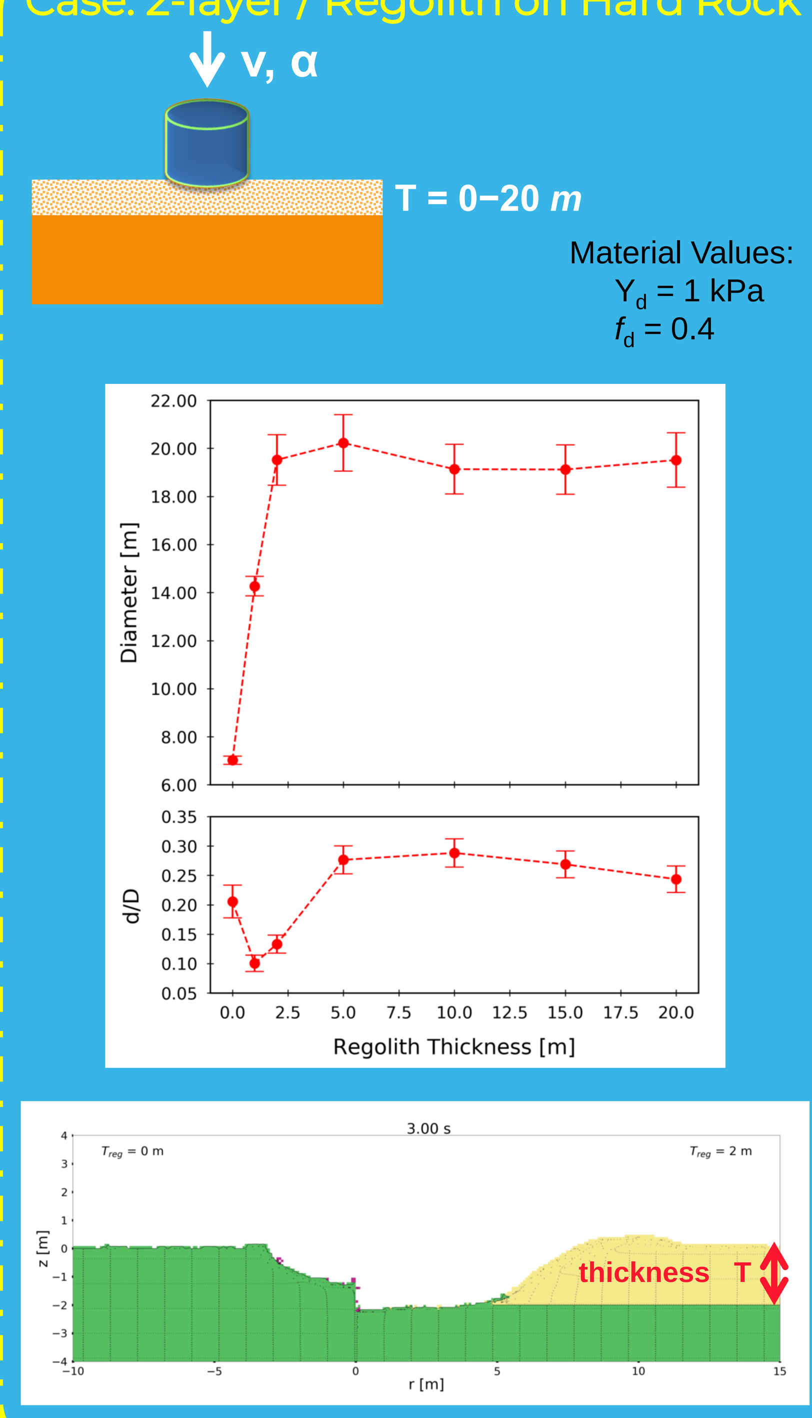
➢ **effect of material models, strength, friction coefficient, porosity, temperature, and layering**

Results

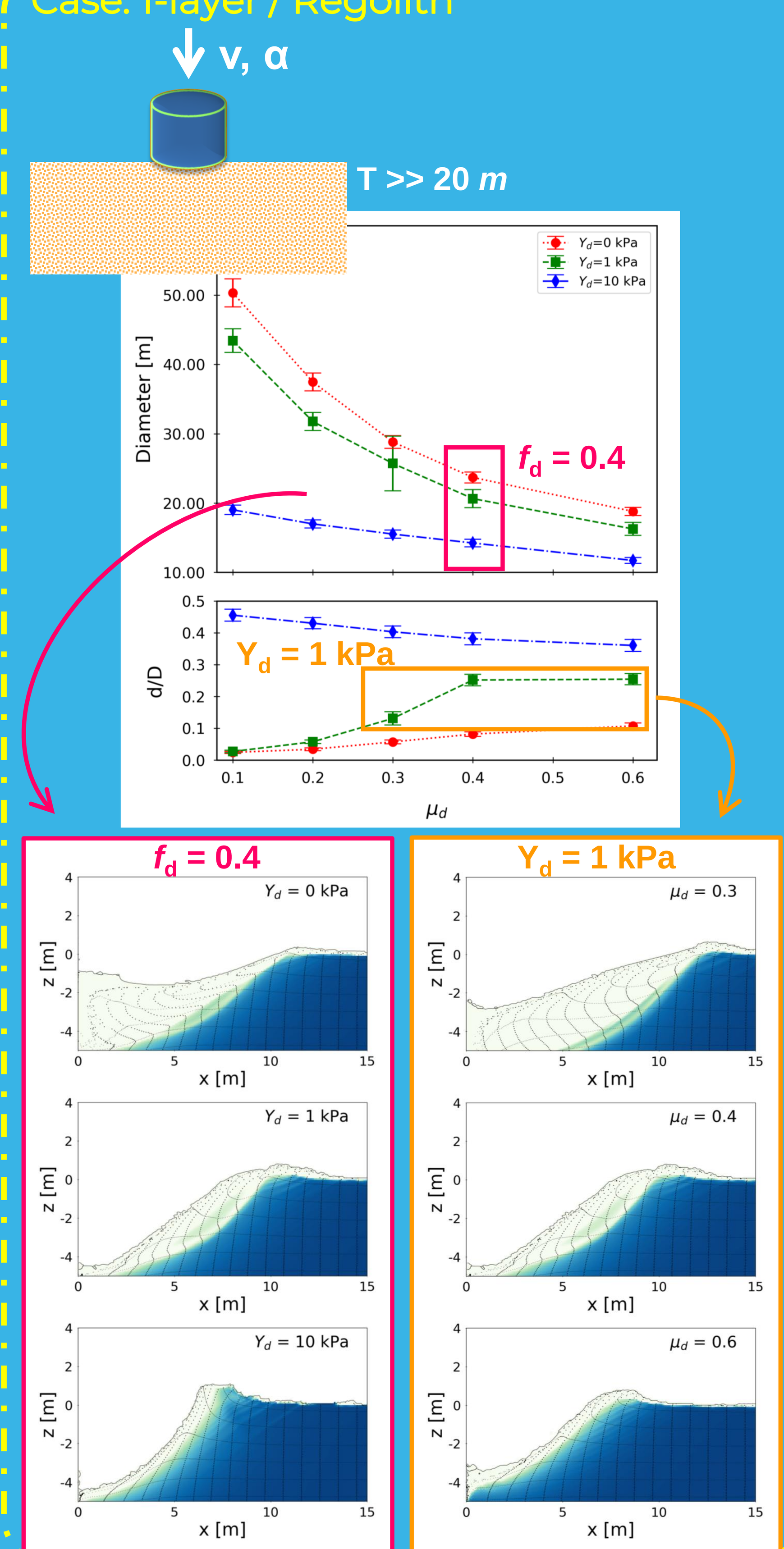
Case: 1-layer / Hard Rock



Case: 2-layer / Regolith on Hard Rock



Case: 1-layer / Regolith



Diameter Summary

D = 6 – 8 m

- material strength, porosity
- target temperature
- impact angle

D = 7 m (small T) → 20 m (large T)

- target temperature → still to be tested
- impact angle → still to be tested

D = 10 − 20 m → <50 m

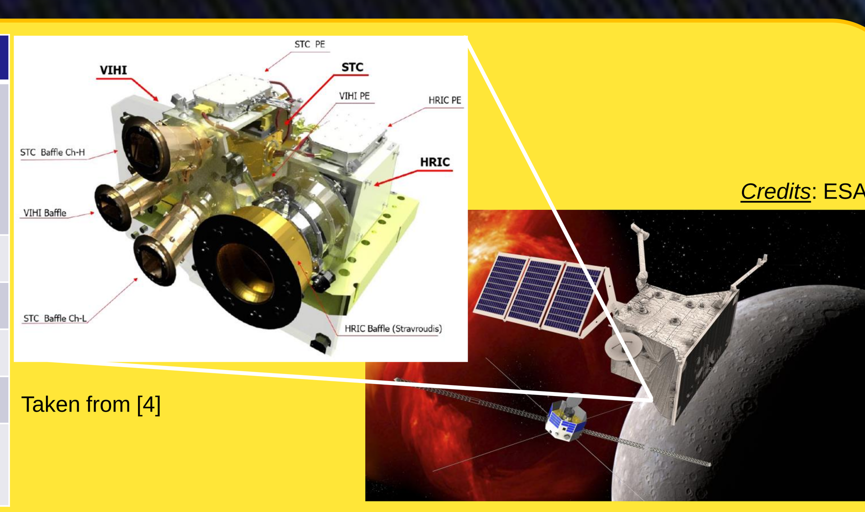
- material cohesion, friction coefficient
- target temperature
- impact angle → still to be tested

Discussion

Based on the first results of our numerical modelling analysis, we can argue that

- ➢ SIMBIO-SYS / STC will not be able to detect the MESSENGER crater,
- ➢ SIMBIO-SYS / HRIC might be able to detect the crater if the surface is covered by a thick layer of regolith,
- ➢ crater ejecta extension will serve as additional constraint for the Hermean region where MESSENGER impacted
  - ➢ the ejecta for shallow impacts will spread downrange (butterfly pattern)

Parameter	SIMBIO-SYS / STC	SIMBIO-SYS / HRIC
Optical concept	off-axis modified Schmidt, unobstructed	Modified Ritchey-Chretien with hyperboloid mirrors and 3 spherical lenses for dioptric correction
Maximum FoV	5.38°	1.47°
Focal length	95.2 mm	800 mm
Focal ratio	F/6.3	F/8.9
Spectral range	410–930 nm	400–900 nm
Pixel on ground	Periherm: 58 m Pole: 121.8 m	Periherm: 6.0 m Pole: 12.1 m ➡ 7 m/px @ impact point



Taken from [4]

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Acknowledgments

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