Effects of different subsurfaces on impact sites on Mars

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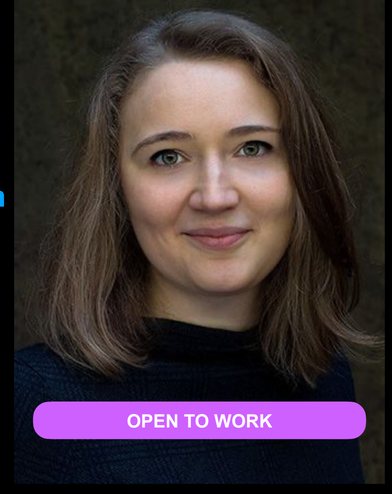

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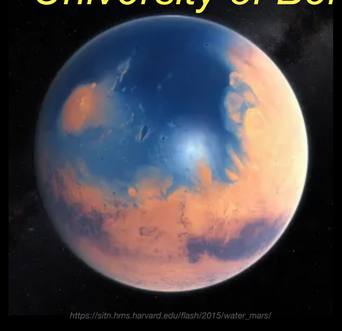

https://sitn.hms.harvard.edu/flash/2015/water_mars/

- Mars is a cold dry planet, yet there is ample evidence for fluvial activity on its surface, which paints a different picture for its past climate.
- If Mars has ever been covered by an ancient ocean or ubiquitous paleolakes, some old Martian impact sites should show signatures specific to the presence of water that differ from impact sites on dry land.

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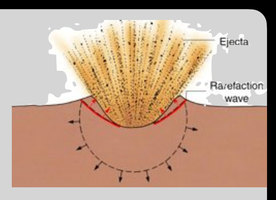
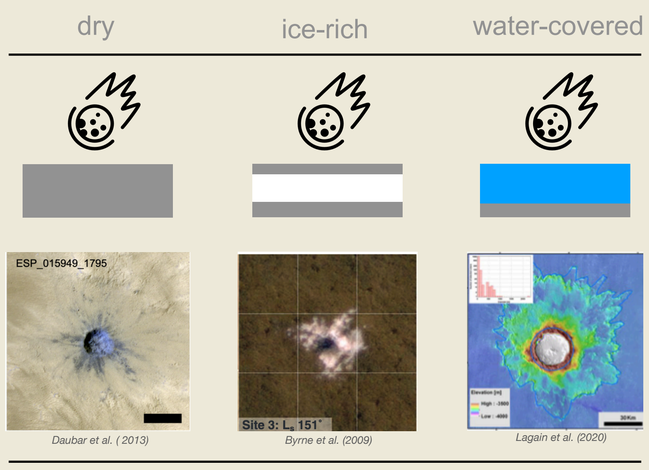
PHYSICS OF IMPACT CRATERING



- A projectile impacts the target (sub)surface with hypervelocity speeds. Material compressed by the shock wave is later released by the rarefaction wave which drives the excavation flow (ejecta).
- Thermodynamics of the flow depends on target material properties: e.g. its porosity, phase transitions, or yielding under stress (damage upon exceeding material strength).
- Crater profiles and ejecta distributions are thus dependent on the properties of the target material.

The **main objective** of this work is to test whether the difference between impact sites of water-covered, ice-rich and dry target subsurfaces is significant enough to aid the interpretation of remote sensing observations.



Daubar et al. (2013) | Byrne et al. (2009) | Lagain et al. (2020)

iSALE

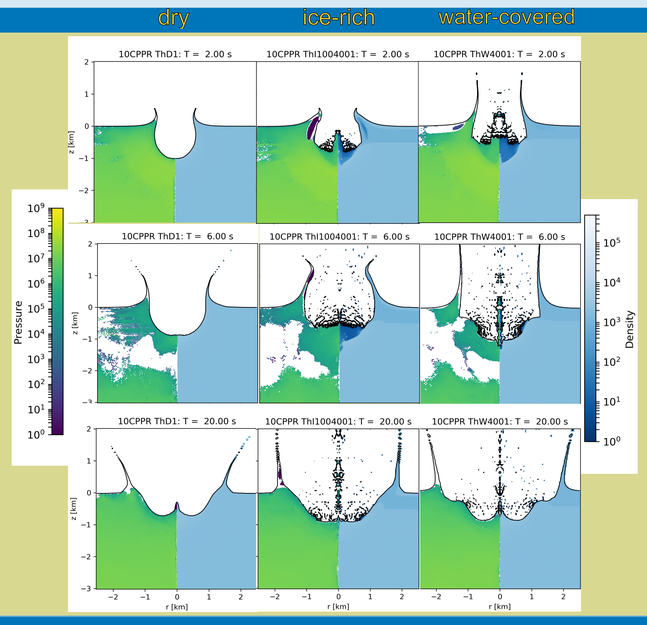
To simulate hypervelocity impact processes in solid materials, we use the iSALE-2D shock physics code (Wünnemann et al., 2006), which is based on the SALE hydrocode (Amsden et al, 1980). iSALE contains elasto-plastic constitutive model for multiple materials (Melosh et al., 1992; Ivanov et al., 1997), fragmentation and modified strength models (Collins et al., 2004), porosity compaction model, and various equations of state (EoS). Our simulations consider effects of porosity, acoustic fluidisation, and thermal softening.

Preliminary results

Simulated subsurface variations

Model	Bottom: basalt [m]	Middle: water ice [m]	Top: basalt [m]
ThI100200_1	2700	200	100
ThI200200_1	2600	200	200
ThI100400_1	2500	400	100
ThI0200_1	2800	200	0
	Bottom: basalt [m]	**Top: water [m]**	
ThW200_1	2800	200	
ThW400_1	2600	400	
ThW1000_1	2000	1000	
ThD_1	3000	0	

Example evolutionary sequences



Findings

- We simulate vertical impacts of 100m diameter projectiles made of basalt with speeds of 10km/s.
- The presence of water or water ice modifies the volume of the cavity during the entire excavation phase.
- Ice-rich craters are deeper than the "dry" cases. However, over time their depth would be decreased by the sublimation of subsurface ice.
- There are clear differences in the ejection angles and thus ejecta curtains between all 3 cases.
- The full trajectories and final distribution of the ejecta have to be quantified in post-processing due to the fact that high above the crater, ejecta enters the low-density regime where they become underresolved (to consider clumps "resolved", we require at minimum 10 cells).

Upcoming work

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Expansion of ejecta in vapour plumes

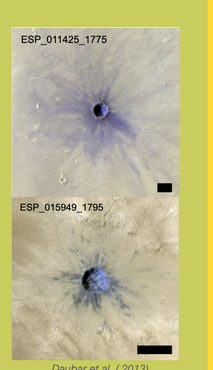
- In the absence of an atmosphere, ejecta from the excavation flow follow ballistic trajectories. However, due to the vaporisation of water and water ice, ejecta experience drag forces acting on them. We will post-process simulated data to account for this effect.

Hypervelocity experiments

- We are conducting a feasibility study, which involves firing a 2-stage light gas gun into dry and ice-covered basalt targets. The experiment will be done in collaboration with The Open University.

CaSSIS remote sensing data

- Over 1000 recent impact sites on Mars occurring in the period of spacecraft observation have been observed with HiRISE. Ejecta of some contained ice which underwent sublimation.
- Distributions of ejecta will be analysed and evaluated for follow-ups with CaSSIS camera onboard ESA ExoMars Trace Gas Orbiter.



Daubar et al. (2013)

References

- Images of impact sites:
  - Daubar et al. (2013): doi.org/10.1016/j.icarus.2013.04.009
  - Lagain et al. (2021): doi.org/10.1029/2020EA001598
  - Byrne et al. (2009): doi:10.1126/science.1175307
- iSALE references:
  - Wünnemann et al. (2006): doi:10.1016/j.icarus.2005.10.013
  - Amsden et al. (1980): doi:10.2172/5176006
  - Melosh et al. (1992): doi.org/10.1029/92JE01632
  - Ivanov et al. (1997): doi.org/10.1016/S0734-743X(97)87511-2
  - Collins et al. (2004): doi.org/10.1111/j.1945-5100.2004.tb00337.x
- CaSSIS:
  - Thomas et al. (2007): doi.org/10.1007/s11214-017-0421-1

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