EGU General Assembly 2023

FlyRADAR

Expected Findings of a GPR onboard of a UAV on Mars

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA-RISE2020 grant agreement No 101007973

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Terre planètes Environnement

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26/04/2023

Main Characteristics of the FlyRadar Instrument on Mars

- Wavelength – centred at 80 MHz
  - Resolution
  - Depth of penetration

Radar Segment

- Autonomy (time and distance)
  - If fully autonomous -> less than 10 minutes
  - Attached by a cable to a rover – energy through the cable -> limited path to the length of the cable -> longer autonomy

UAV segment

- Flight conditions : close to the surface for optimization of S/N -> have a good idea of the topography
- Coupled with other instruments (optical cameras -> DEM and mapping)

FlyRadar Characteristics vs. Geology
What can we expect to visualize and measure ?

FlyRadar Instrument	Geology
Central Frequency : 80 MHz	Resolution : 0,5 to 1 m
Power and frequency	Penetration Depth : 10 - 30 m expected
Covered Surface : 500 x 500 m per flight with 5 m between flight lines	
Radargram	Interpreted Geological Sections
Permittivity estimation	Lithology/texture ?

Perfect to investigate
- Sedimentary features
- Volcanic features
- Regolith properties
- Cavity detection
- Subsurface Ice lenses

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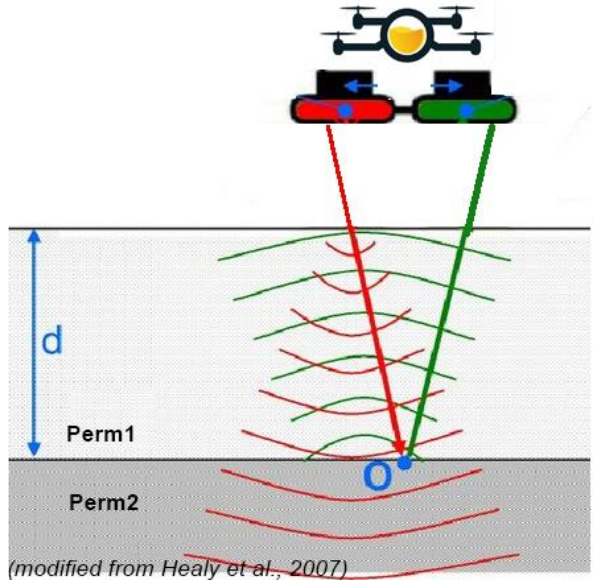
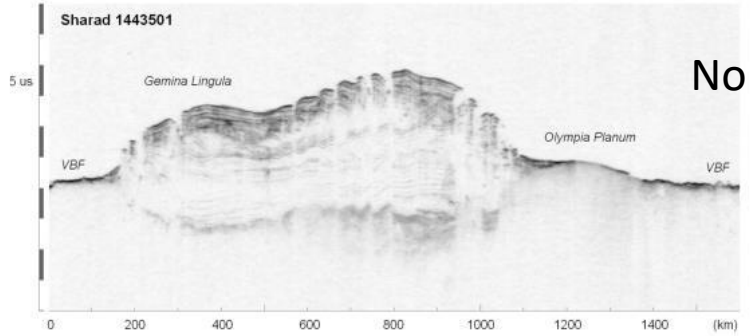
What do we measure ?
How do we interpret our measurements ?

- What is the observable of a Radar ? Time…….
- What controls velocity in a layer ?
  - Lithology
  - Porosity and rock texture
  - Possible impurities – conductive minerals,

  Magnetic minerals……
  - Interface roughness
  - Frequency of electromagnetic waves
  - Temperature…..

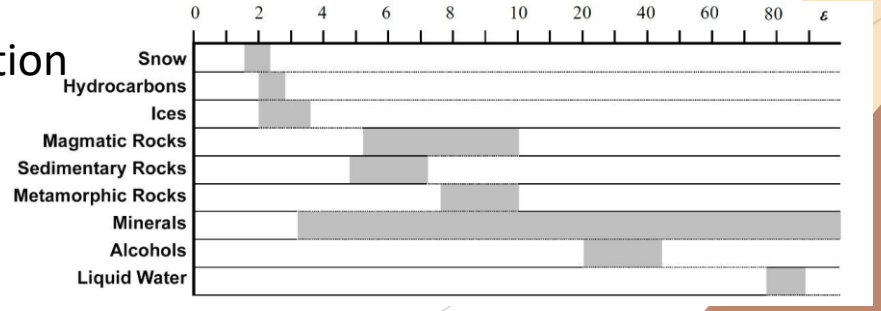




Sharad Radargram of the Martian North Polar Cap (in Grima, 2009)

No Univocal relation
????

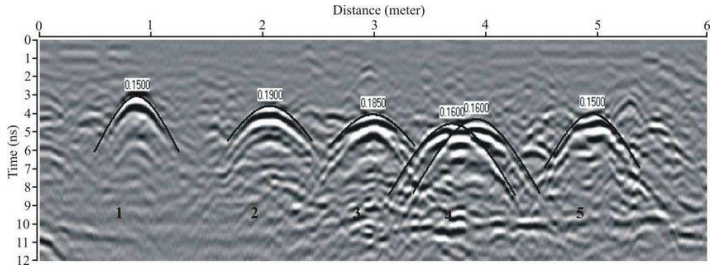
Relative Permittivity



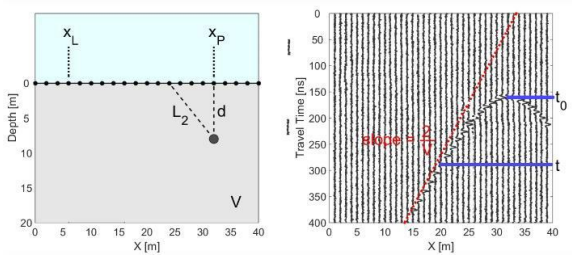
+ porosity, impurities, roughness …..

Inversion of Radar Signal

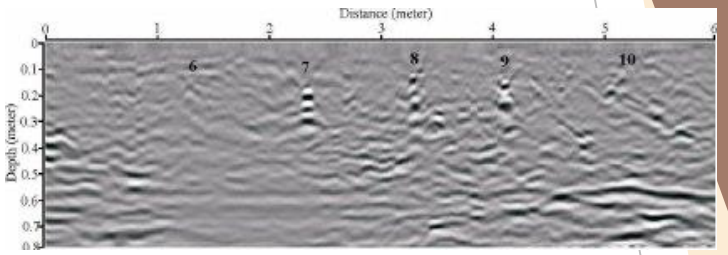
- Obtained dataset -> a Radargram…. To be interpreted in terms of lithology and geometry



Raw radargram
Vertical axis in time



Slope hyperbola inversely proportional to electromagnetic wave velocity



Migrated interferogram
Vertical axis in distance

Example of « inversion and migration » process of a radargram based on diffraction hyperbolas (from Metwaly et al., 2006)
We can estimate the « Relative Permittivity » of the underground

Other possible inversion methods

One can expect a uncertainty of 15 % on the estimation (Feng et al., 2016)

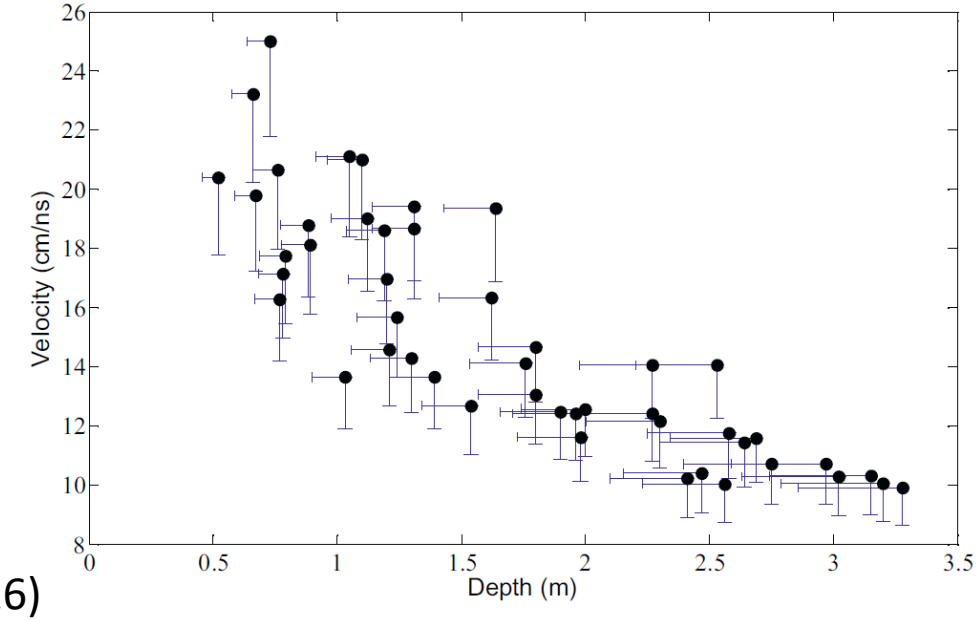
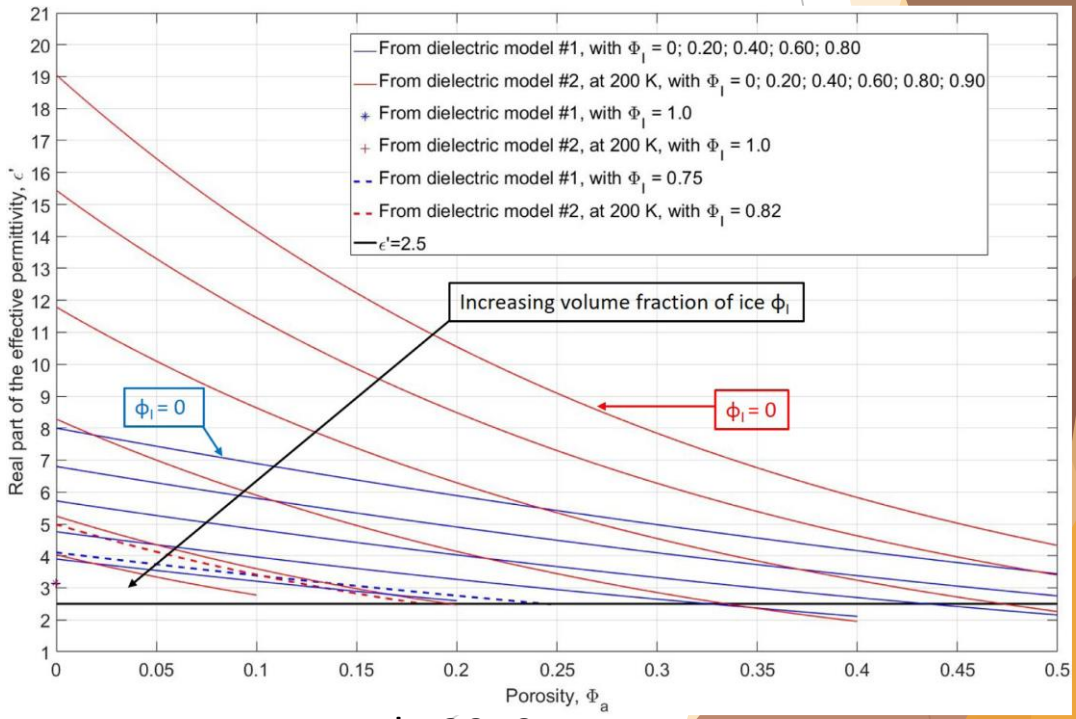


Fig. 9. The fitting results of RMS velocity versus depth. Each point represents a fitting result.

Measurement of Geotechnical parameters ?

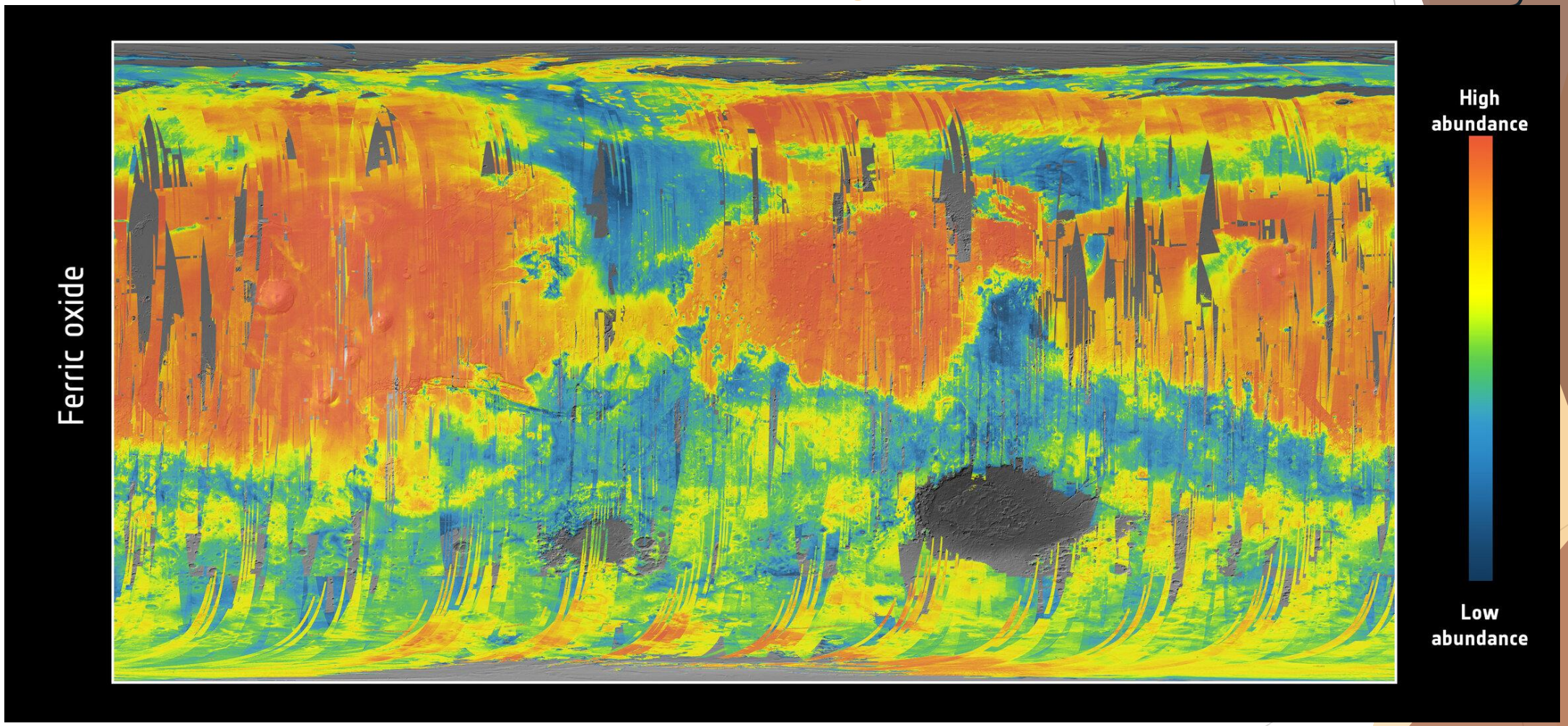
- Is it possible to estimate porosity variation with depth ?
- Very difficult if the composition of the regolith is unknown ?

Curiosity view, Nasa credit



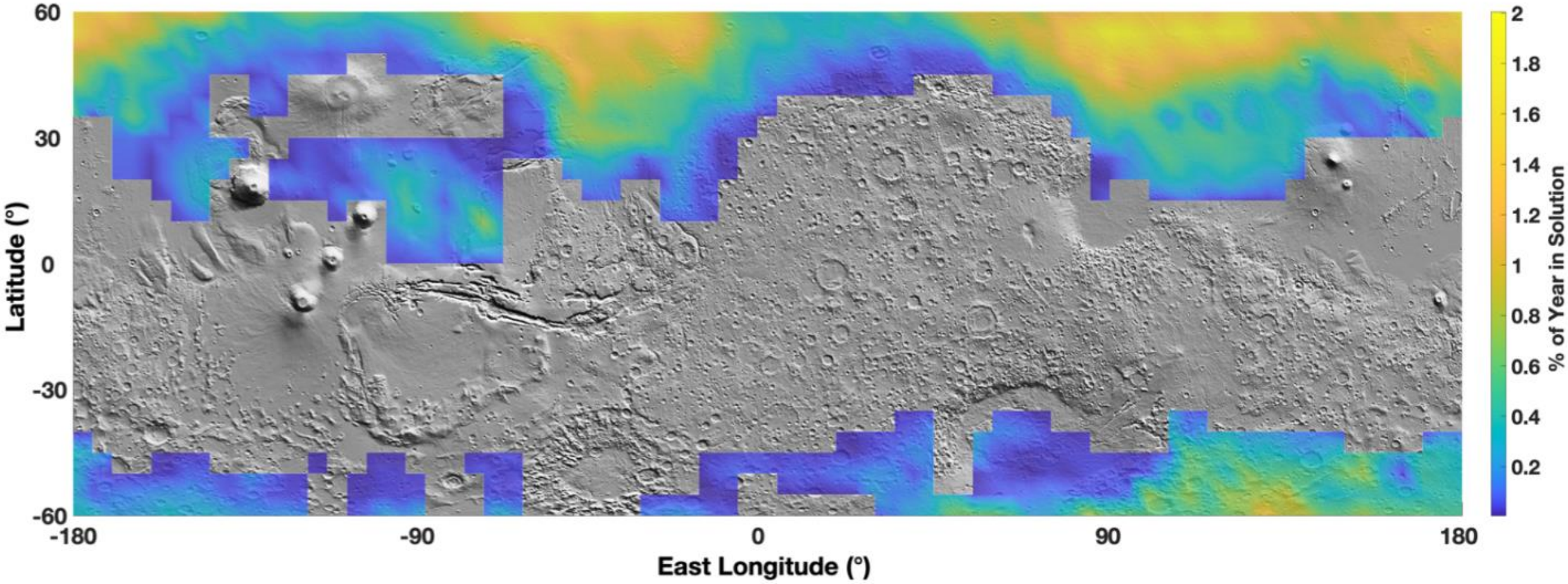
From Brouet et al., 2019

Factors that can affect signal



ESA/CNES/CNRS/IAS/Université Paris-Sud, Orsay;
Background image: NASA MOLA

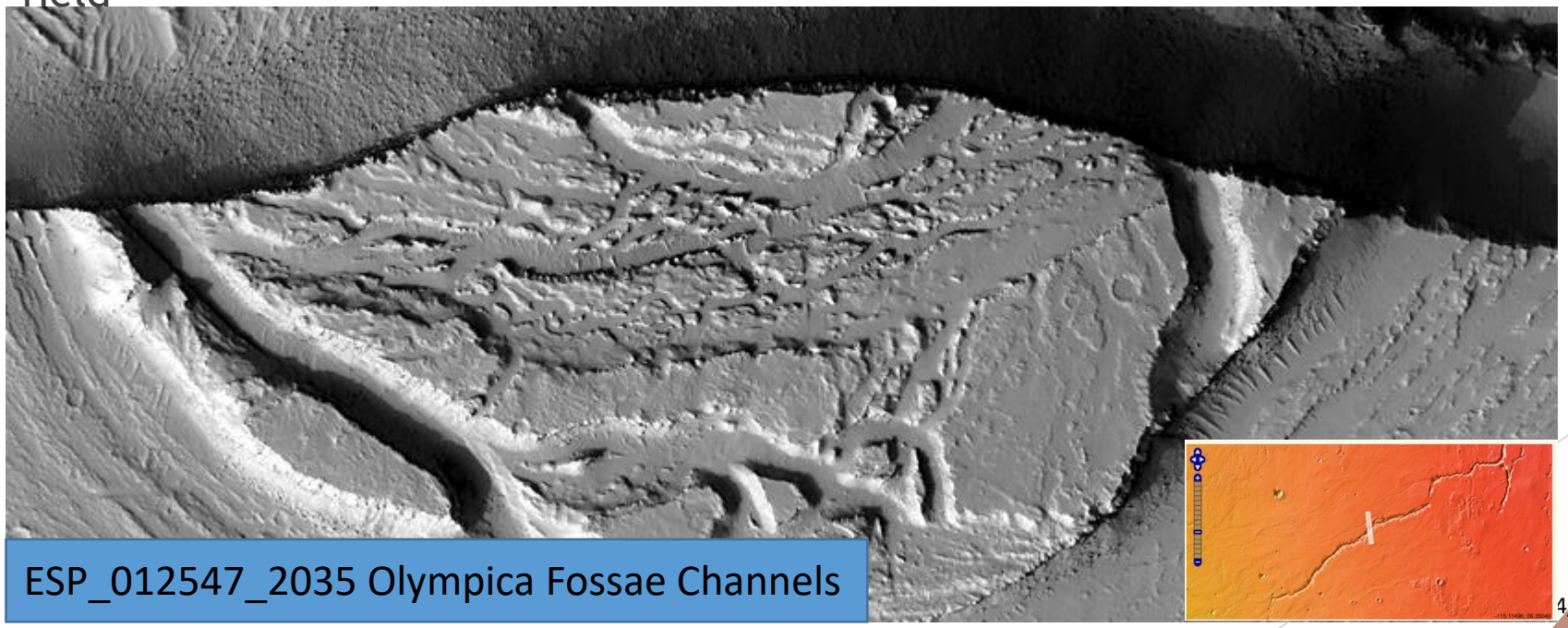
Factors that can affect signal - Brines



Distribution of (meta)stable calcium perchlorate brines on Mars (By Rivera-Valentin et al., 2020).

Exploration strategy – define the geological context as well as possible

- Direct lithologic detection not possible -> Permittivity is an ambiguous parameter
- Association with preliminary context studies – topography – structural geology- mineral characterization - surface roughness
- Modelling of the GPR response and comparizon with dataset obtained in the field



ESP_012547_2035 Olympica Fossae Channels

what question to address from the potential and limitation of FlyRadar Instrument ?

- These questions have to concern the structure and possibly the texture of the first 20 -30 m of the upper crust.
  - Questions regarding the definition of environment, environmental changes and possibly climate change -> Sedimentary organization
  - Questions regarding impact craters and landslide processes
  - Questions regarding the History of the upper crust -> regolith distribution and geometry; volcanic product organisation
  - Question regarding human exploration and habitability

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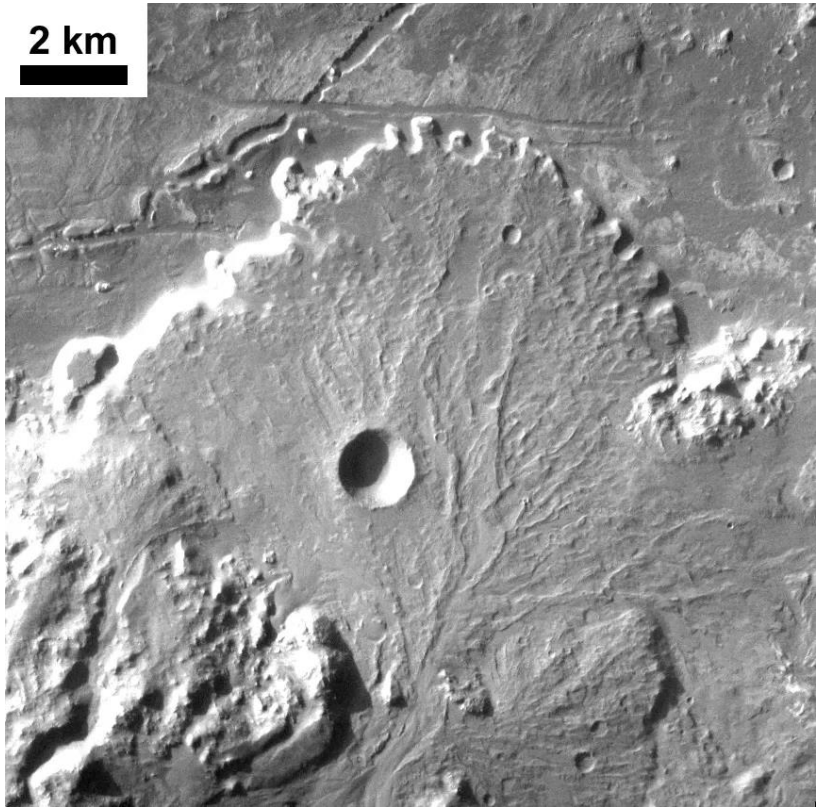
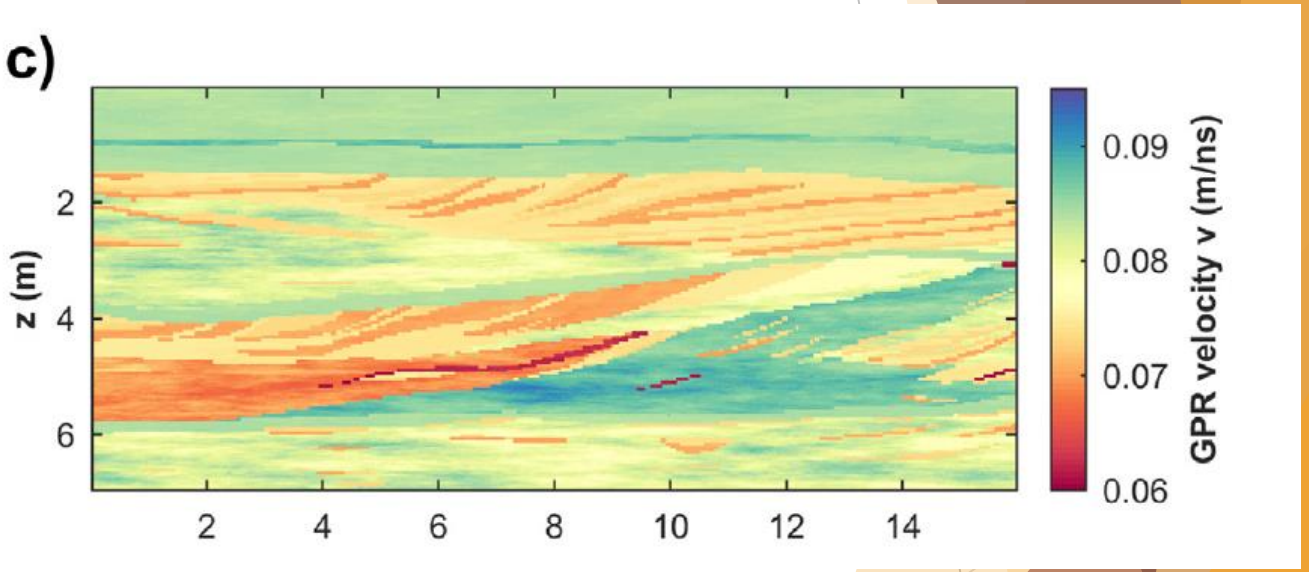
Questions regarding the definition of environment, environmental changes and possibly climate change



Alluvial fan in Holden Crater – Themis view

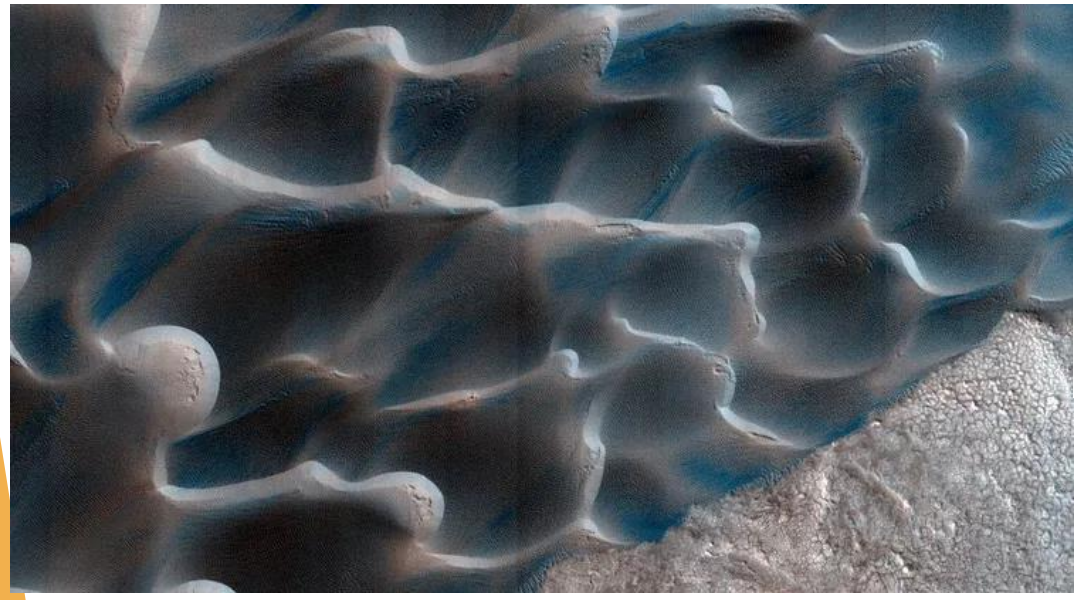


GPR modeled response of an alluvial fan – Koyan and Tronicke 2020

To visualize major discontinuities inside sedimentary series and internal organization of strata

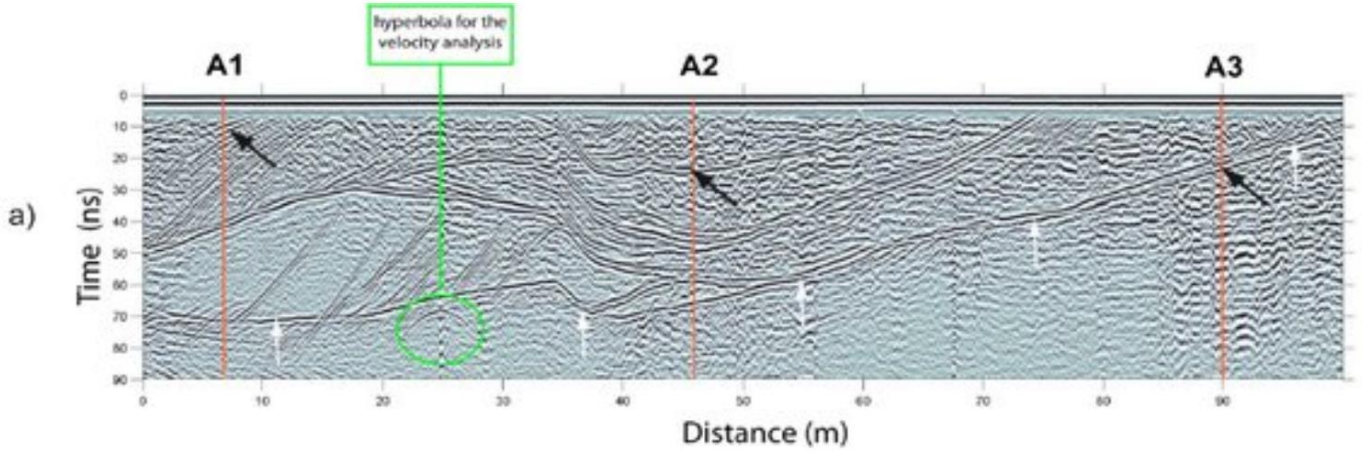
History of water level and sediment inputs – How ends the activity of intracrater lakes?
Connection with climatic changes or local changes?

Questions regarding the definition of environment, environmental changes and possible climate change

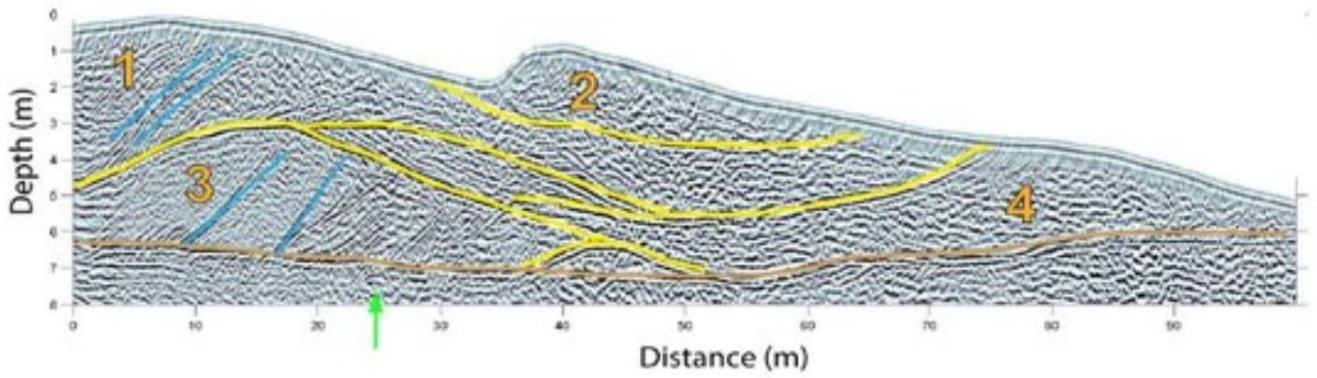


(Image credit: NASA/JPL/University of Arizona/USGS)

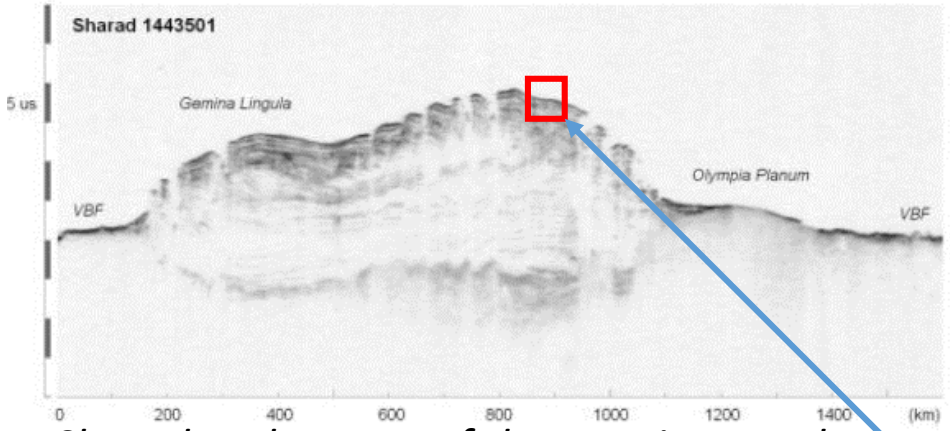
What is the internal organization of the dune ?
Is it compatible with the topography and thus with current wind field ?



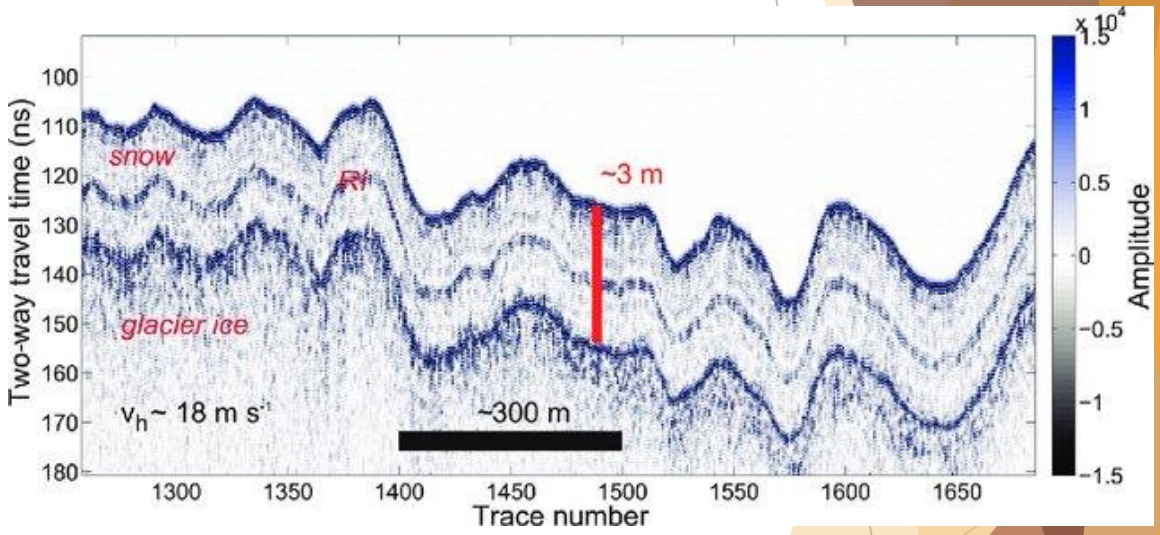
GPR section collected in a dry sand dune in the Chadian desert using shielded antennas of 450 MH; Guillemoteau et al., 2012



Questions regarding the definition of environment, environmental changes and possibly climate change



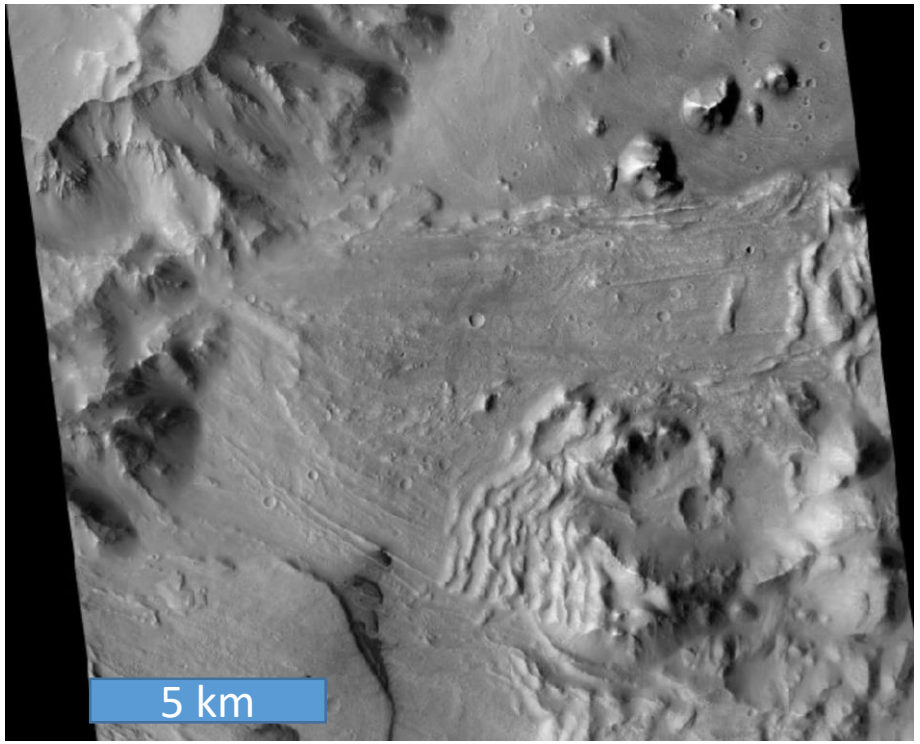
Sharad Radargram of the Martian North Polar Cap (in Grima, 2009)



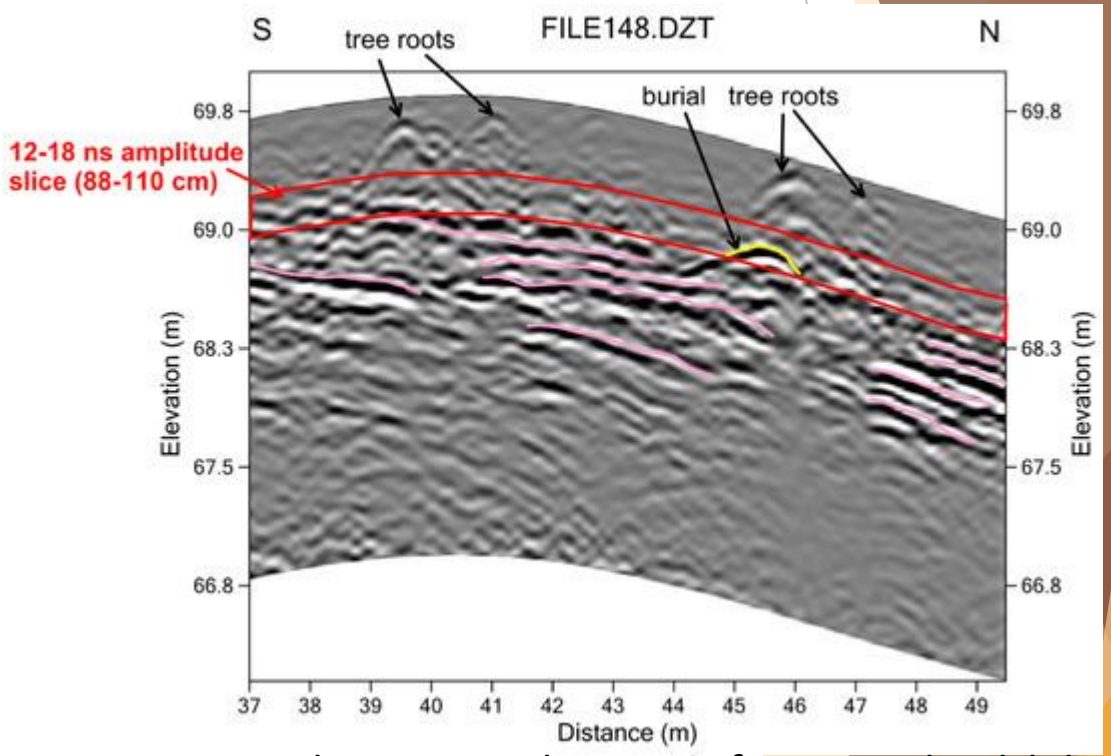
GPR image on the ablation area of Scott Glacier, Prince William Sound; Gusmerolli et al., 2013

Question about the recent evolution of martian climate registered in the polar caps

Questions regarding landslide processes and impact craters



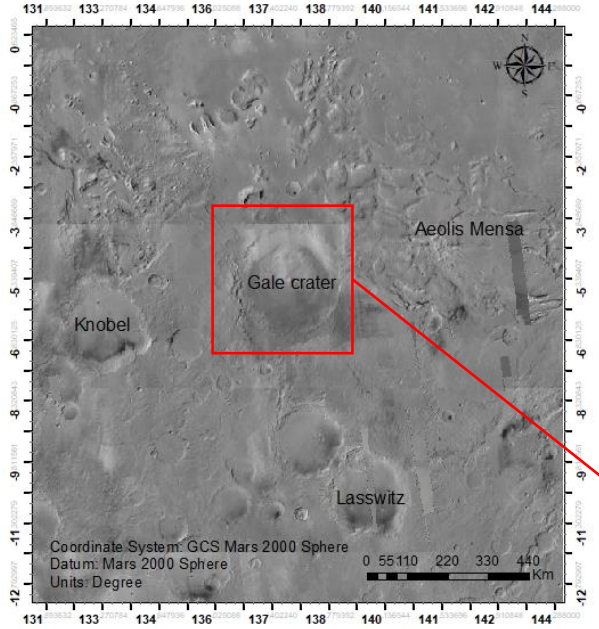
D05_029133_1802_XN_00N046W – M. Soldano

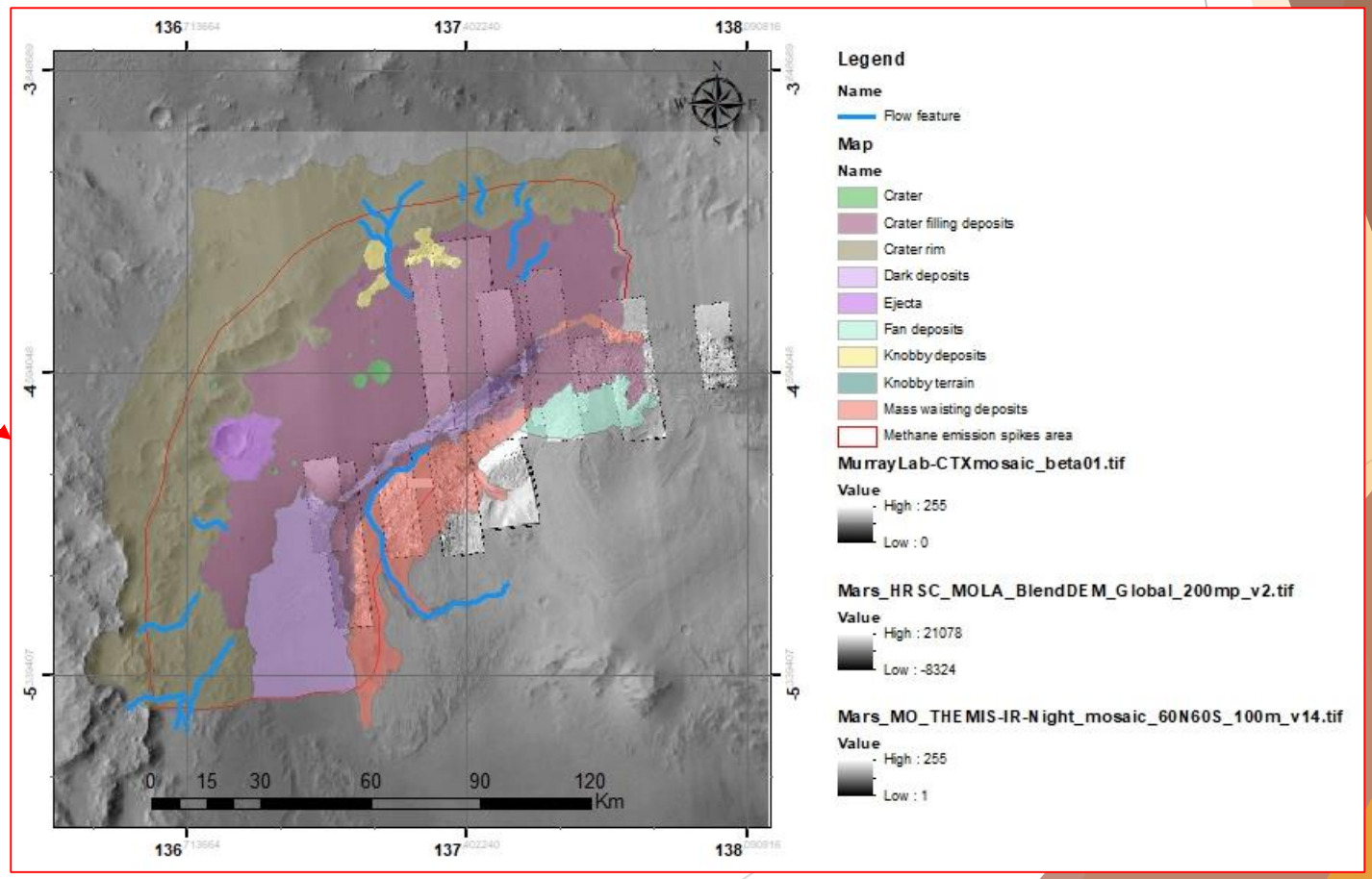


Conyers et al., 2019, Radargram of a recent landslide in Shadforth's Mounds, Australia

How does evolve the thickness of the landslide in space ? How does evolve the internal granulometry ?
Same questioon for crater ejecta

Questions regarding landslide processes and impact craters





What is the post impact History of a large impact crater ?
Relation with volcanisme ?
Relation with hydrothermalism ?

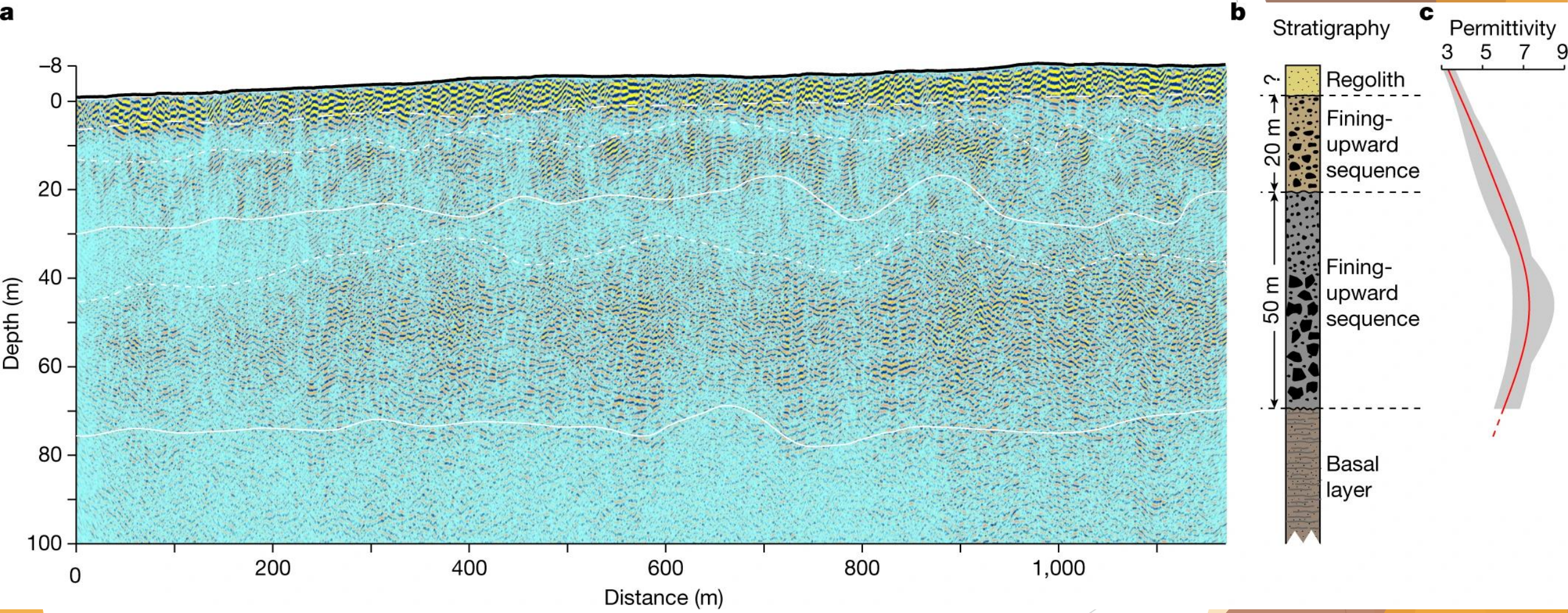
By E. Mariani

Questions regarding landslide processes and impact craters

ESP_017950_2205, Possible mud volcano in Acidalia Planitia – E. Mariani

How does connect such structure with basement ? Implication for methane emission on Mars ? Hydrothermalism ?

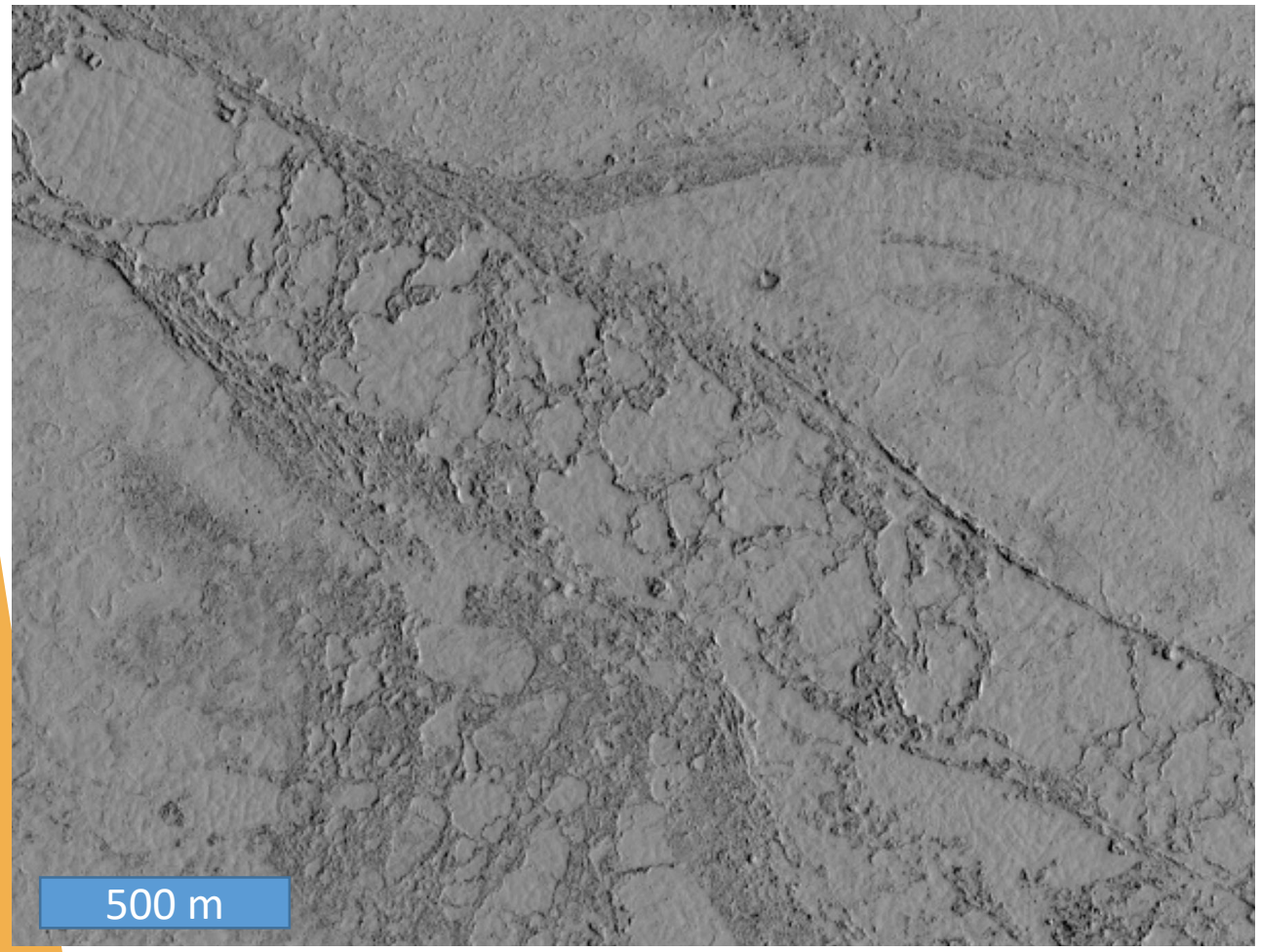
Structure of the upper crust



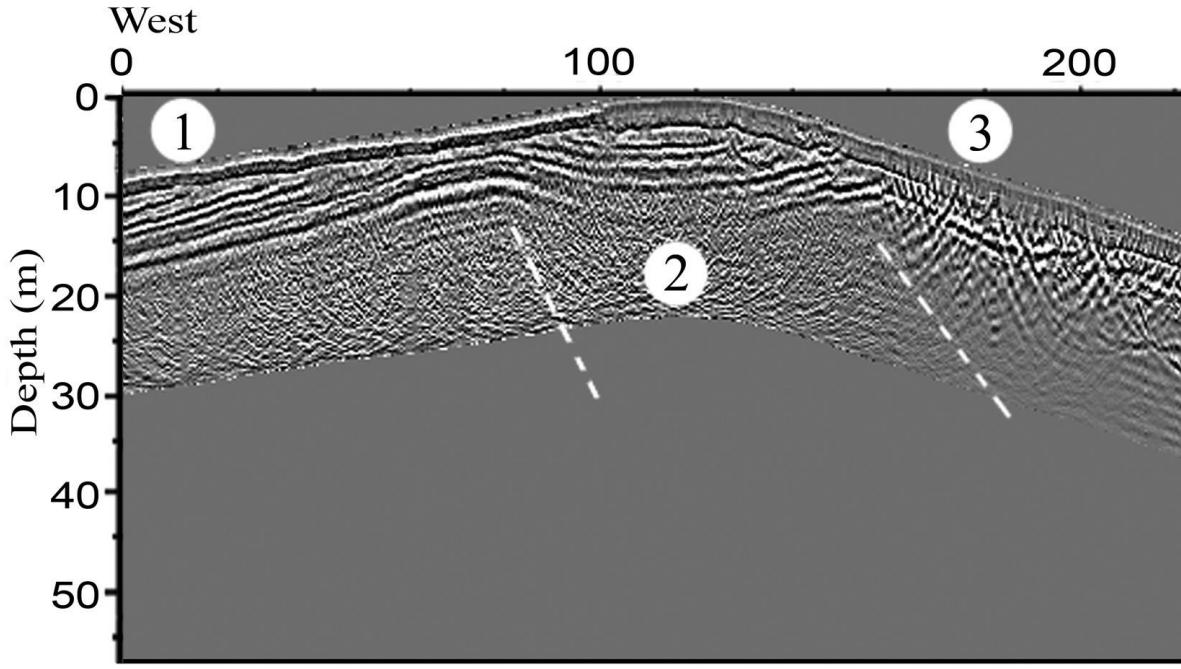
(Li et al., 2022) Radargram and interpretation of a traverse in the Utopîa basin realized by **Zhurong rover radar**

What's the strucure of the upper crust ?

Structure of the Upper Crust – Volcanic environnement



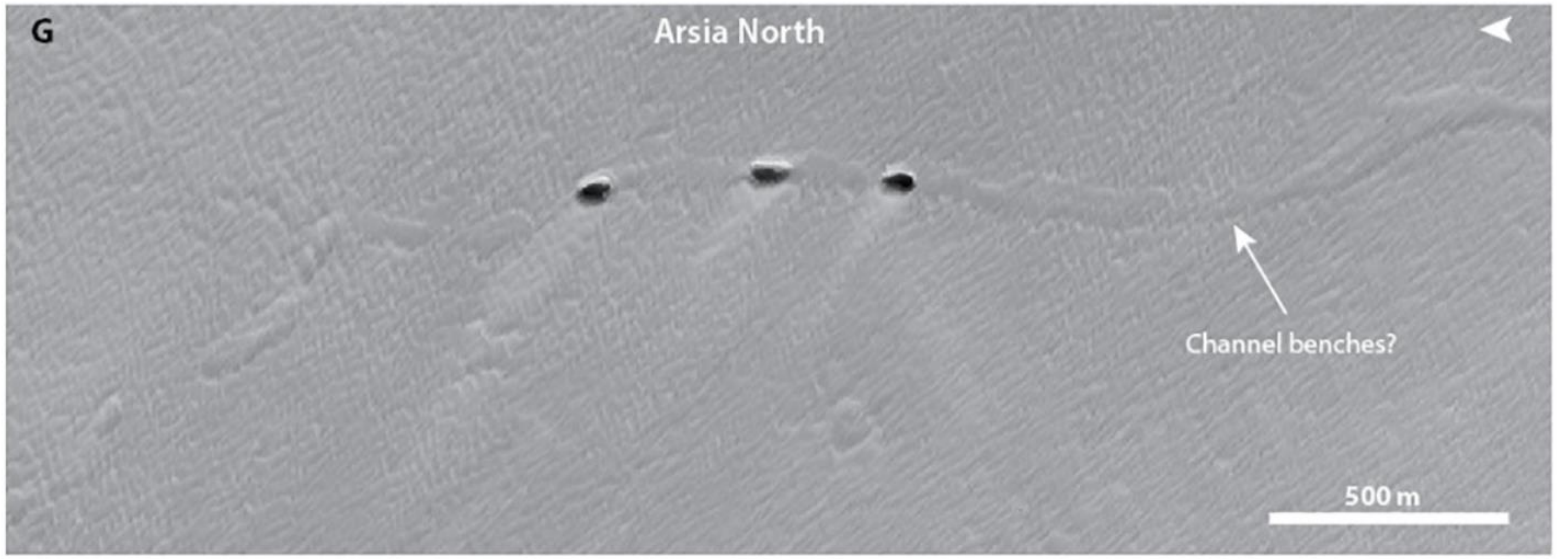
ESP_011614_1830 Hirise - Lava Flows in Elysium Planitia



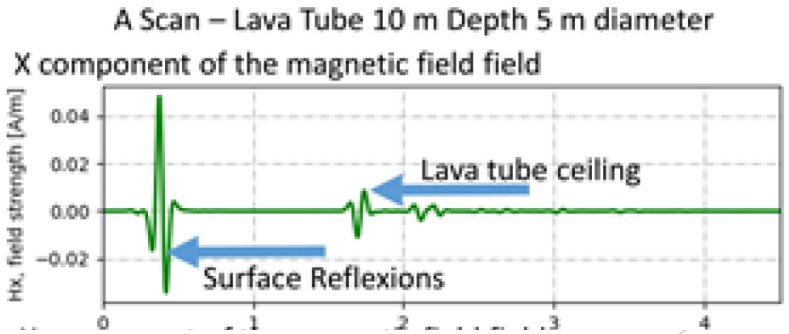
Marshall et al., 2015. GPR section of a volcanic environnement -Arizona

History of lava flow, texture estimation, Volume estimation

Habitability – Lava tube detection

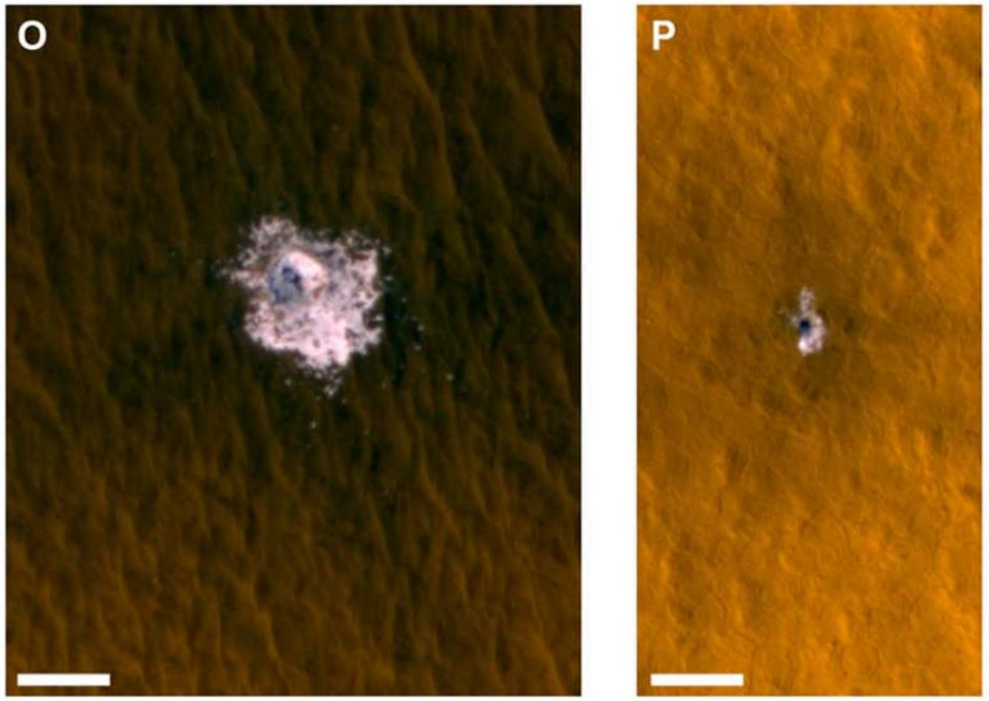


(Sauro et al., 2020)



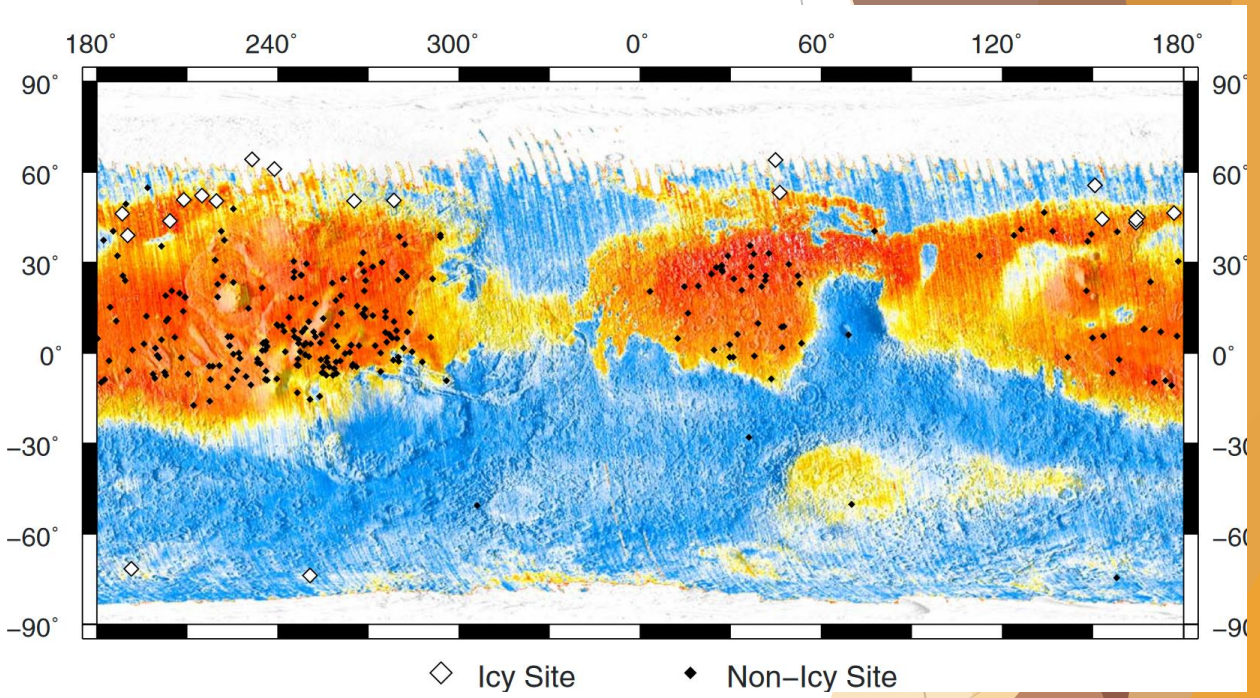
Are the lava tube suitable for human installation ?

Habitability - Water Ice detection



New impact craters exposing ground ice on Mars

Dundas et al., 2013



Map of new impacts. Icy sites are located from middle to high latitudes Dundas et al., 2013

Where is Ice ? How much ice is there?

Conclusions

- The FlyRadar instrument is suitable to investigate Martian underground with a vertical resolution around 0,5 m and a penetration depth of up to 20 – 30 m.
- The FlyRadar instrument will provide data that could be assembled to obtain a 3D model of the geometry of the underground
- Data have to be inverted to estimate relative permittivity and to translate the measured travel time into distance.
- The questions that can addressed from the FR instruments concern :
  - the definition of environment, environmental changes and possibly climate change
  - The dynamic of landslides and of crater ejecta – the volcanic, sedimentary and hydrothermal history of impact craters
  - Structure of the upper crust – regolith properties, lava flow organization
  - Habitability – ice lens detection, lava tube and cave detection

FlyRADAR

Thanks for listening

Disclaimer: This presentation reflects only the author's view.

The Research Executive Agency (REA) is not responsible for any use that may be made of the information it contains

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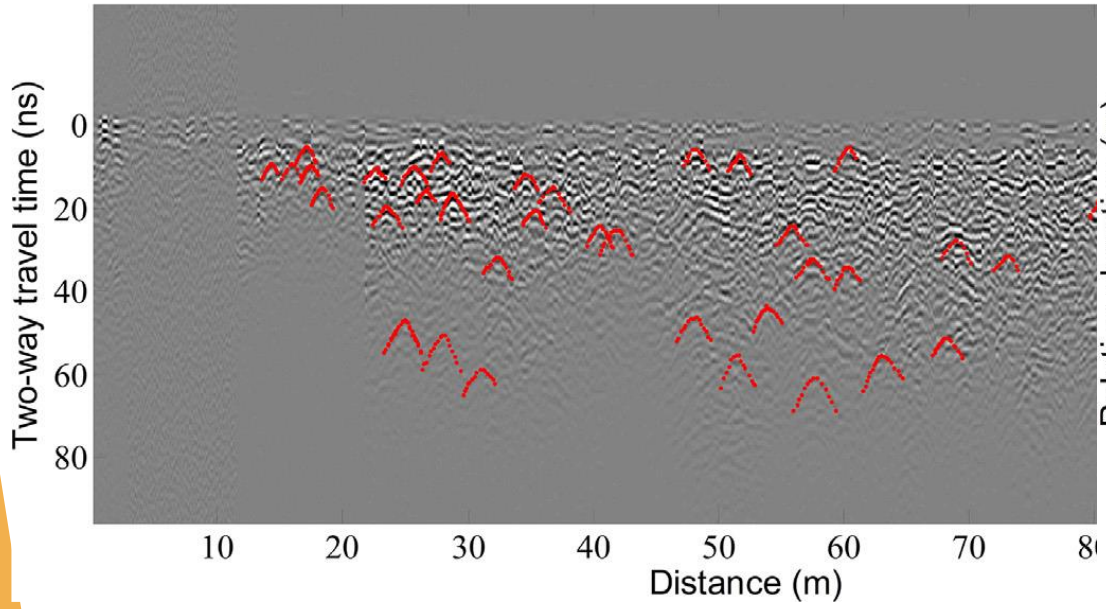
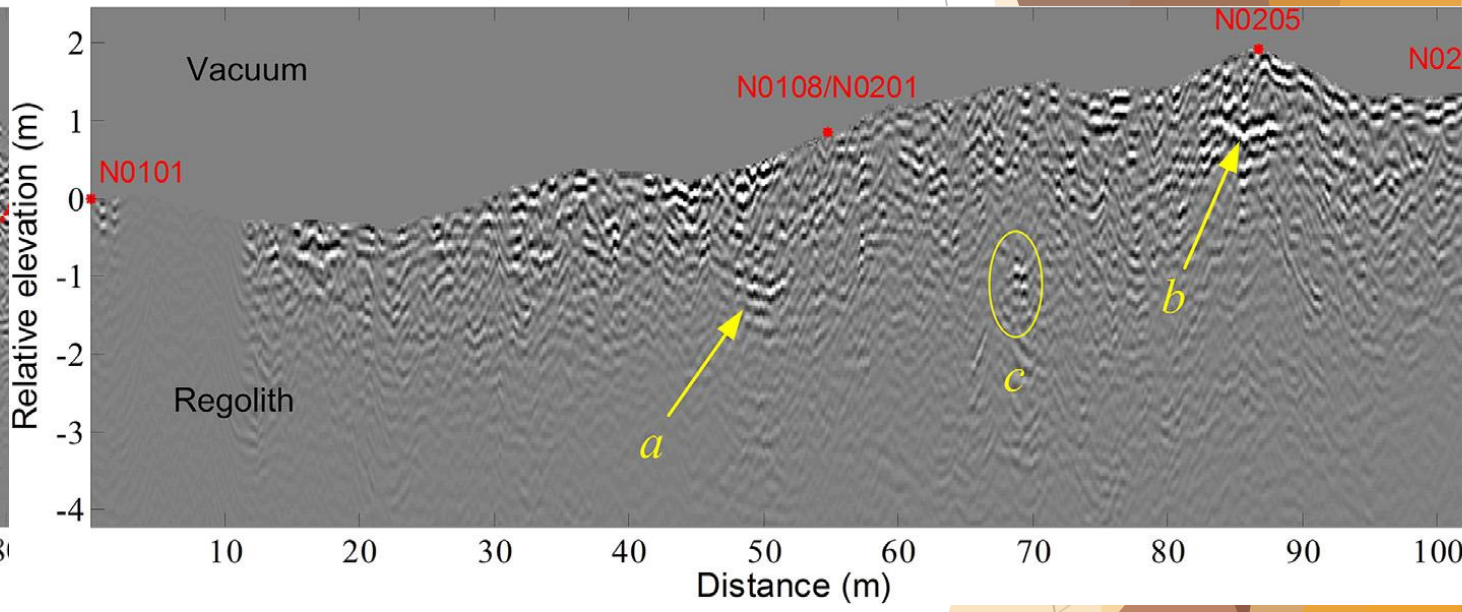
26/04/2023

Geometry of Subsurface
What's the thickness of the Regolith?



Mare Imbrium, GPR profile of CE-3, Feng et al., 2017



Migrated profile, Feng et al., 2017

Expected Findings of a GPR onboard of a UAV on Mars (10 minutes)

- Recall the characteristics of the system (GPR + UAV) and their consequences on exploration
  - Resolution, penetration, flight time, data processing and interpretation
  - => exploration conditions
- Finds for human settlement (within the geometry range of resolution and penetration)
  - Human habitability -> ice tunnel, thermokarst, karts -> cavity size
  - Human habitability -> Geotechnics via the porosity and density of materials
  - Human habitability -> detection of water in ice lenses -> demonstrate that potentially it is possible -> what size for these lenses?
  - Human habitability -> detection of mineral zones (metals)? Permittivity contrast
- Scientific discoveries -> synergy with other instruments
  - What is left to find in the 0 – 30 thick band?
  - Measurement of regolith thickness
  - Water detection
  - Architecture of sedimentary domains (rivers, delta, bottom of lakes) with aquatic transport
  - Architecture of wind depots
  - Shoreline detection
  - Imaging of tectonized areas
- Conclusion

- Questions about the climate change
  - Rivers and alluvial fans
  - Duricrust formation
  - Internal layering Dunes (recent climate)
  - Internal layering of polar caps and ice deposit
- Questions about impact craters and avalanche processe
  - Post impact evolution – interation between impact and volcanism
  - Hydrothermal evolution -> mud volcanoes
  - Landslides and craters ejecta -> geometrical parameter, internal strcuiture and bloc distribution
- Questions about the upper structure of the Crust
  - Regolith formation