MAX PLANCK INSTITUTE
FOR SOLAR SYSTEM RESEARCH

MPS

PLANETARY REMOTE SENSING

IN THE SOLAR SYSTEM

Urs Mall

Max Planck Institute for Solar System Research

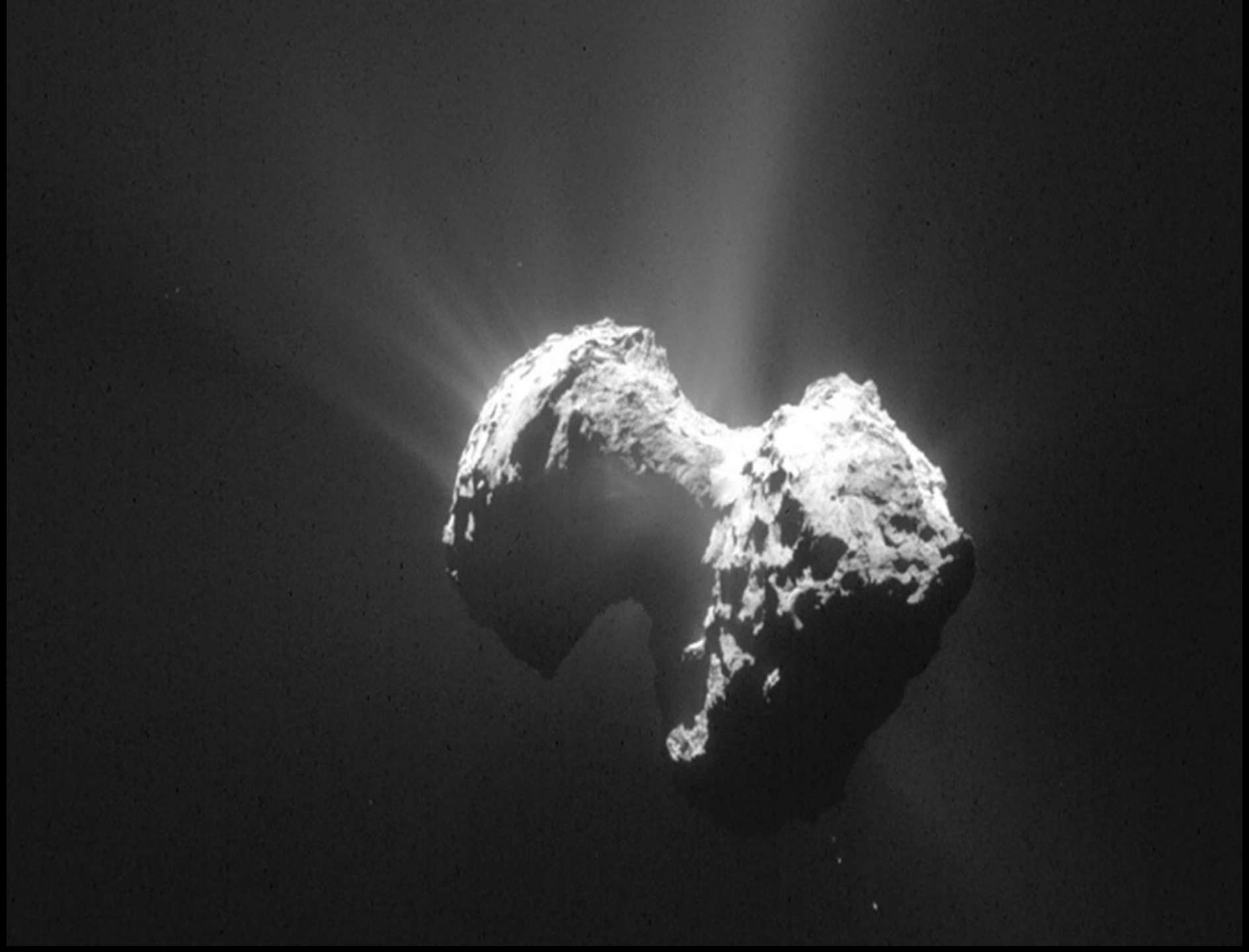
16.9.2022

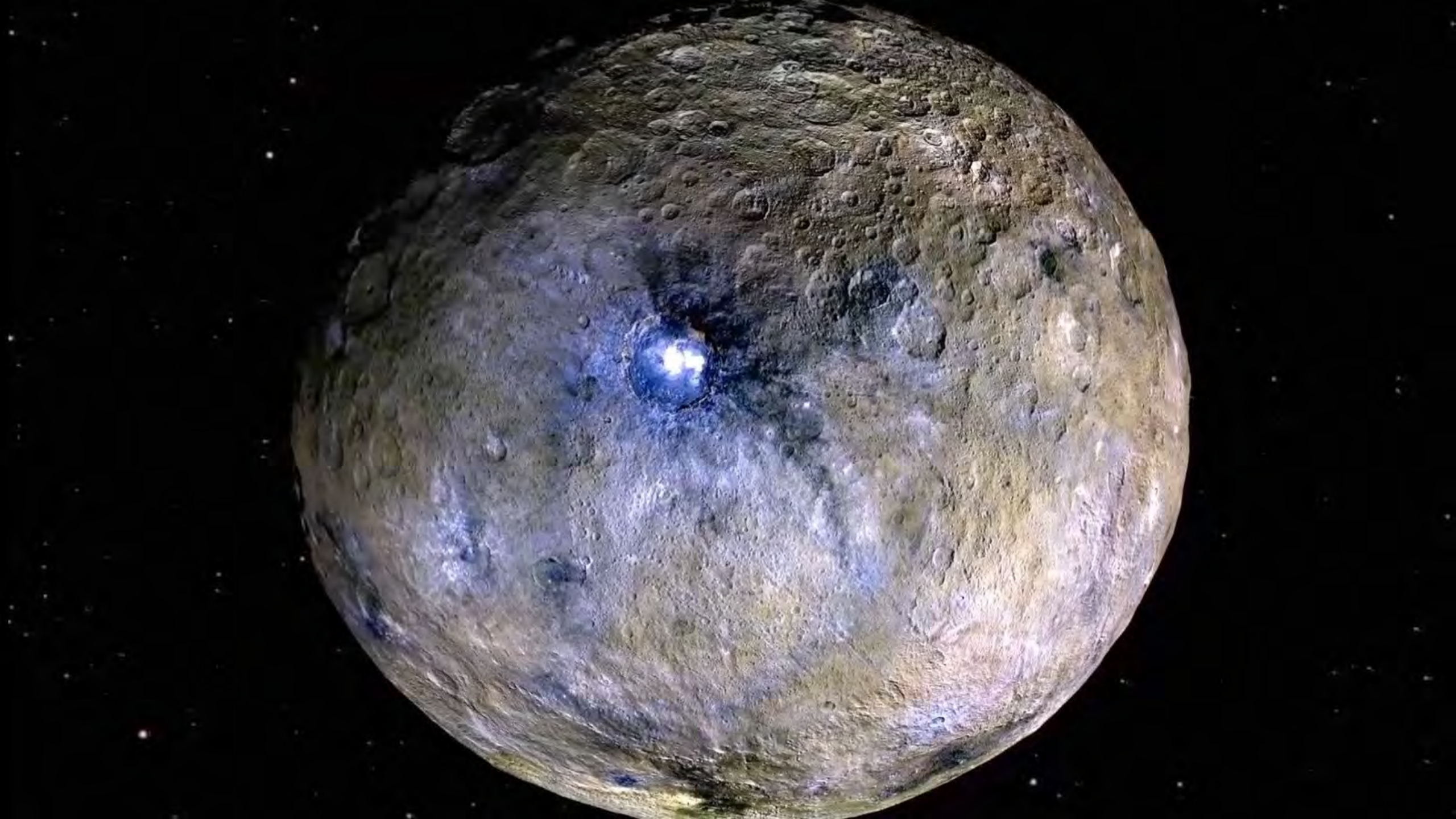
EON Workshop 2022, Oderbrück

MAX PLANCK INSTITUTE FOR AERONOMY
MAX-PLANCK INSTITUTE FOR SOLAR SYSTEM RESEARCH

Founded in 1957 in Kattlenburg-Lindau

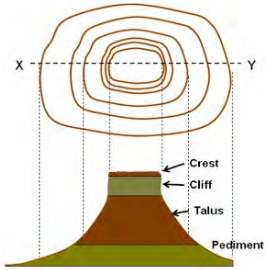
ab Februar 2014 in Göttingen





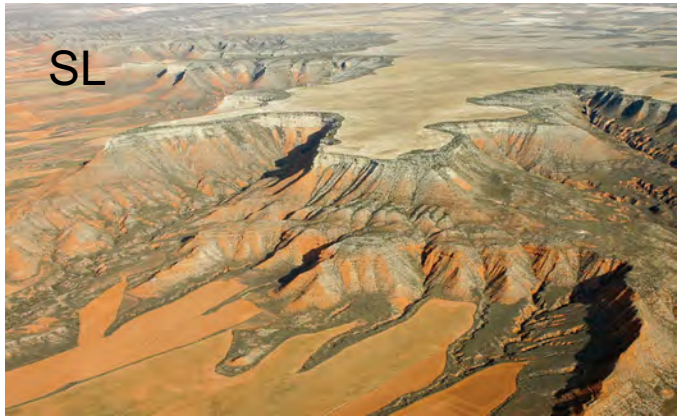
CONTENTS

WHAT NEEDS TO BE EXPLAINED?



The “development of slopes” refers to how slopes changes over time.

- **The form of the landscape: From flat surface to slopes**

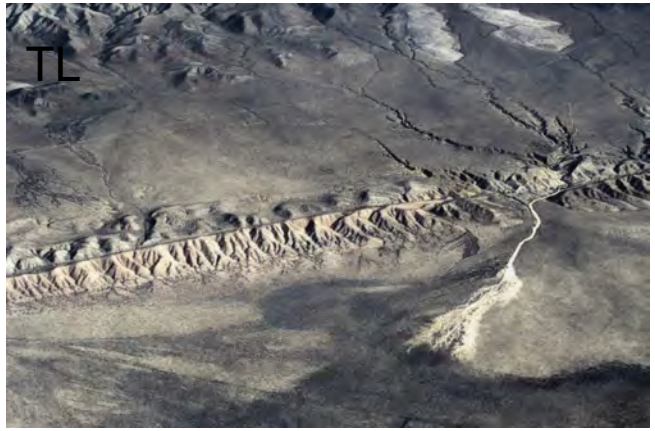


Flat-topped mesa (El Planerón, central sector of the Ebro Cenozoic Basin, NE Spain)

Butte in Monument Valley, Arizona

Chevrons developed on well-bedded Late Cretaceous limestones and marls, Bea village, Iberian Chain, NE Spain

Cueva del Viento lava tube, Canary Islands

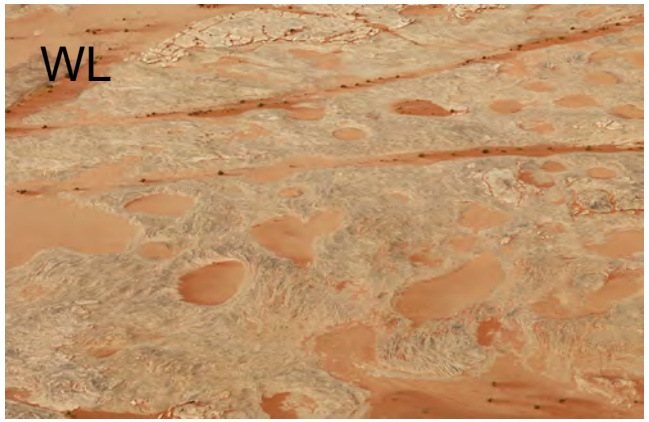


The San Andreas Fault

northern Sardona region, Switzerland

WHAT NEEDS TO BE EXPLAINED?

- **The form of the landscapes: From flat surface to slopes**



Weathering pits Hail area, Saudi Arabia

Jointed granite affected by spheroidal weathering, Brandberg, Namibia

incised meanders of the San Juan River at the Goosenecks State Park, Colorado Plateau, Utah

Large alluvial fan in the Gobi Desert, NW of Chijinpu, China

Sorted steps developed on slope deposits, western slopes of Løvehovden, central Spitsbergen

Pocket sandy beach at Langre, northern Spain

WHY ARE WE OBSERVING SOLAR SYSTEM BODIES?

PLANETARY MORPHOLOGY

Planetary morphology literally means the study of the landforms of planetary bodies.

Planetary morphology investigates landforms and landscapes addressing aspects, such as their

- genesis,
- morphometry (Measurement of the dimensions of landforms)
- chronology and
- past and future evolution.

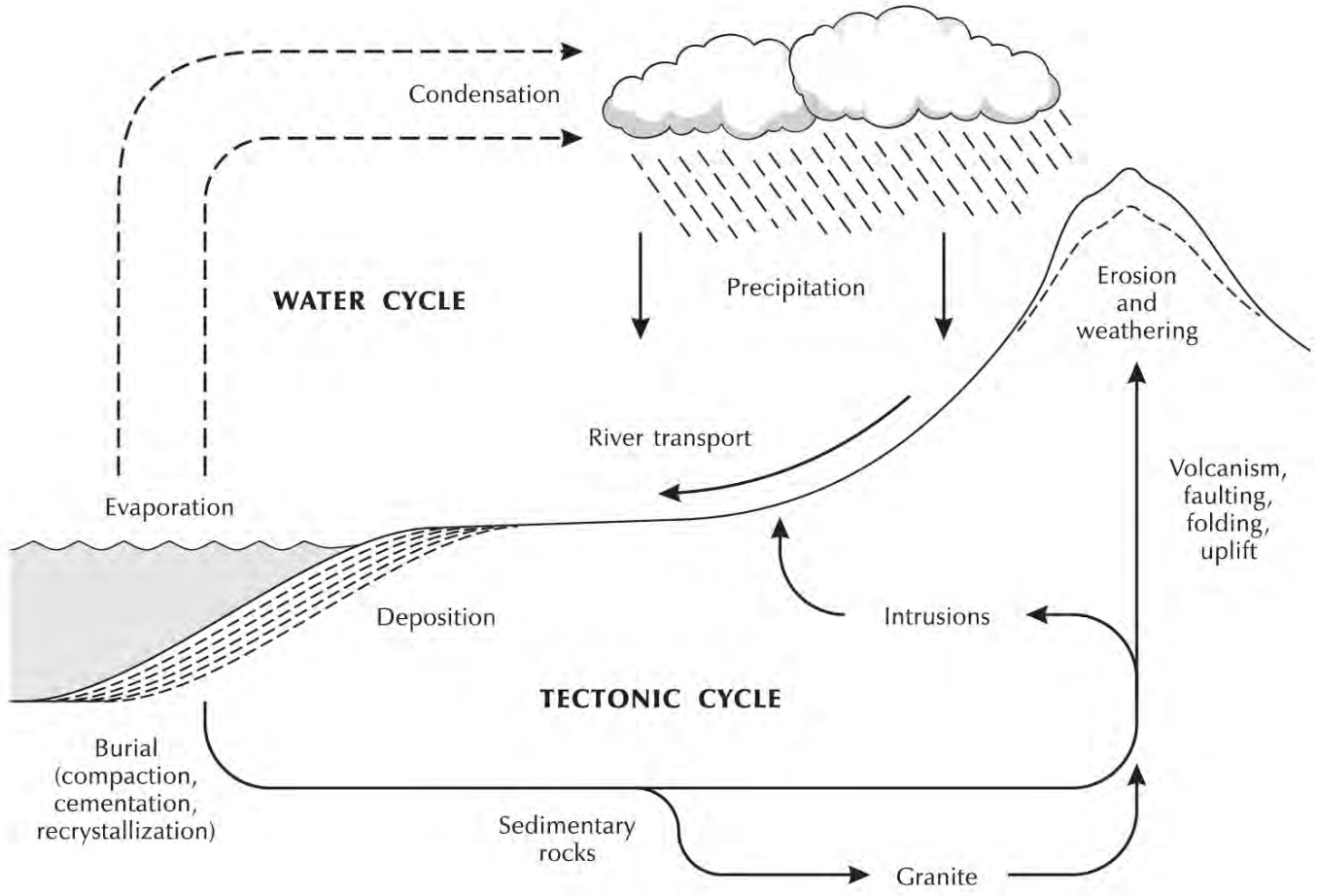
On Earth geomorphology investigates the Earth surface processes not only to understand their morphogenetic role, but also to gain a scientific basis for assessing and managing a great deal of environmental problems

There is a need to forecast the numerous impacts e.g. of the anthropogenic global warming on geomorphic systems, some of which will have significant detrimental effects for our society (e.g. sea-level rise, landslides, floods, geohazards etc). The current boom of geomorphology is most probably due to its social relevance.

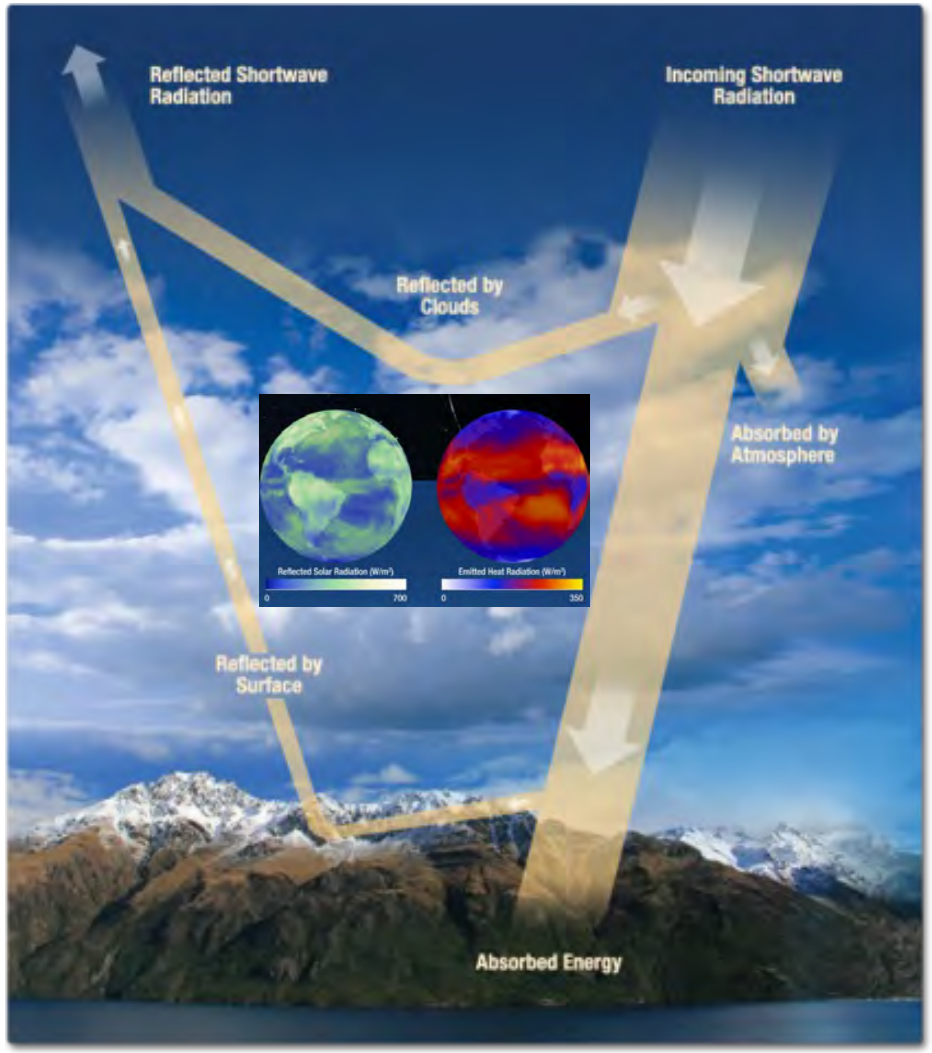
WHAT DO WE NEED TO EXPLAIN THOSE LANDFORMS?

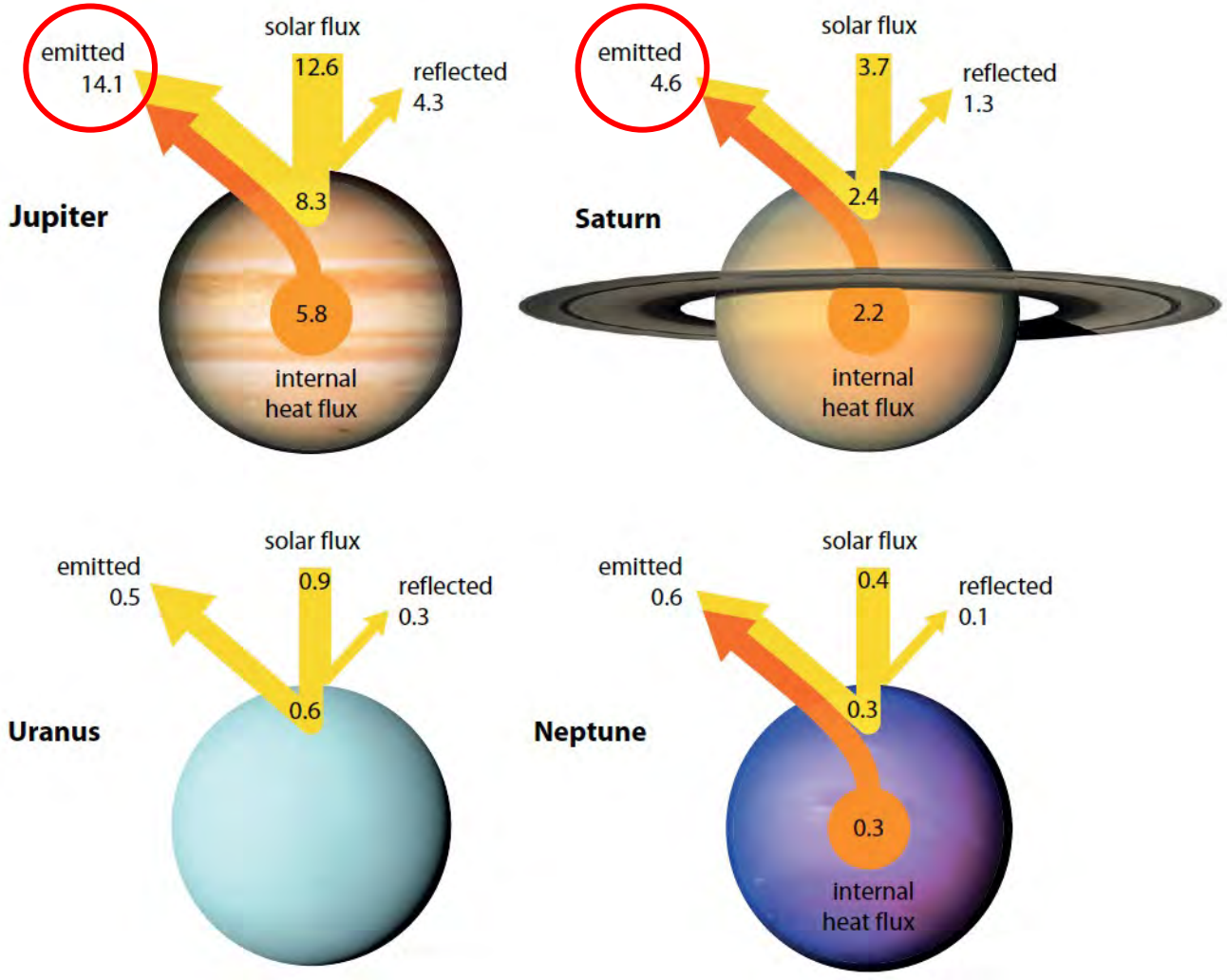
- **Processes**
- **What drives these processes ?**

Processes involve energy transfers. The work done in such transfers is the result of application of internally and externally applied forces (stresses) which are resisted in various ways.



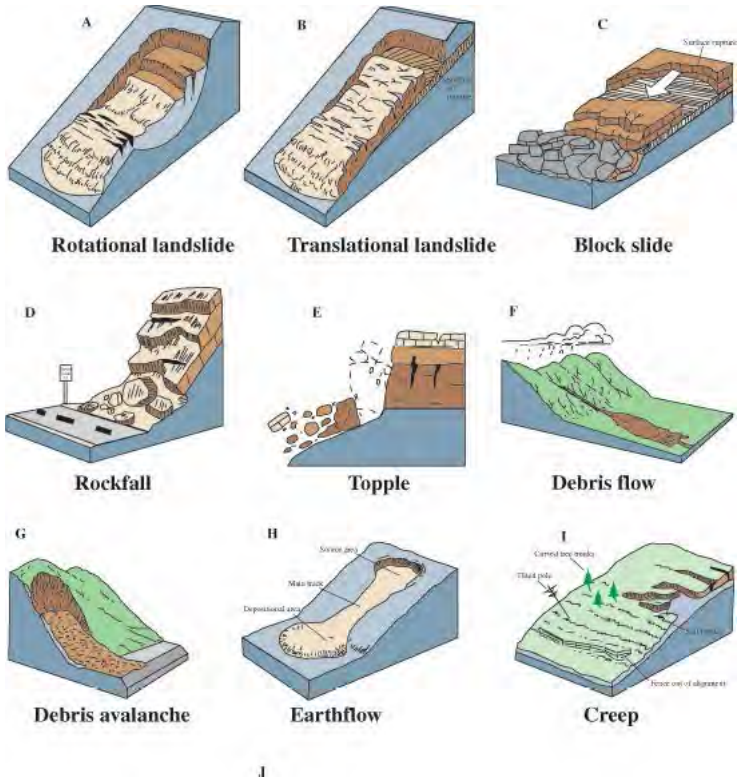
WHAT DRIVES THE PROCESSES: ENERGY BALANCE





MASS WASTING

Mass movement, often called mass wasting, is the downslope movement of a mass of surface materials, such as soil, rock, or mud. The most basic reason is the angle of repose, or slope of the hillside. Other causes of mass movements include earthquakes, lack of vegetation, abundance of water, geology, and gravity.



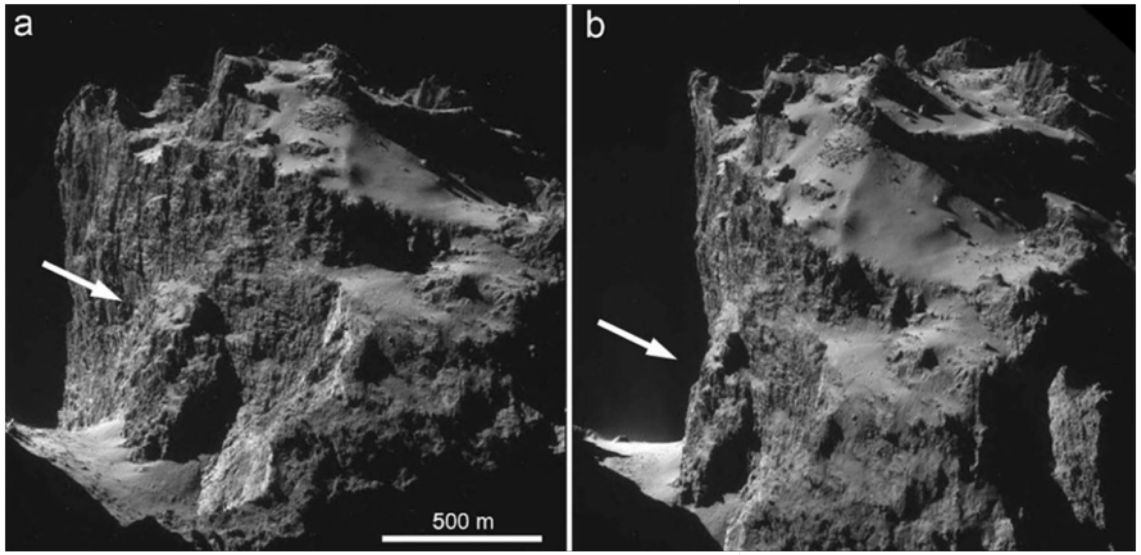
Taurus Littrow

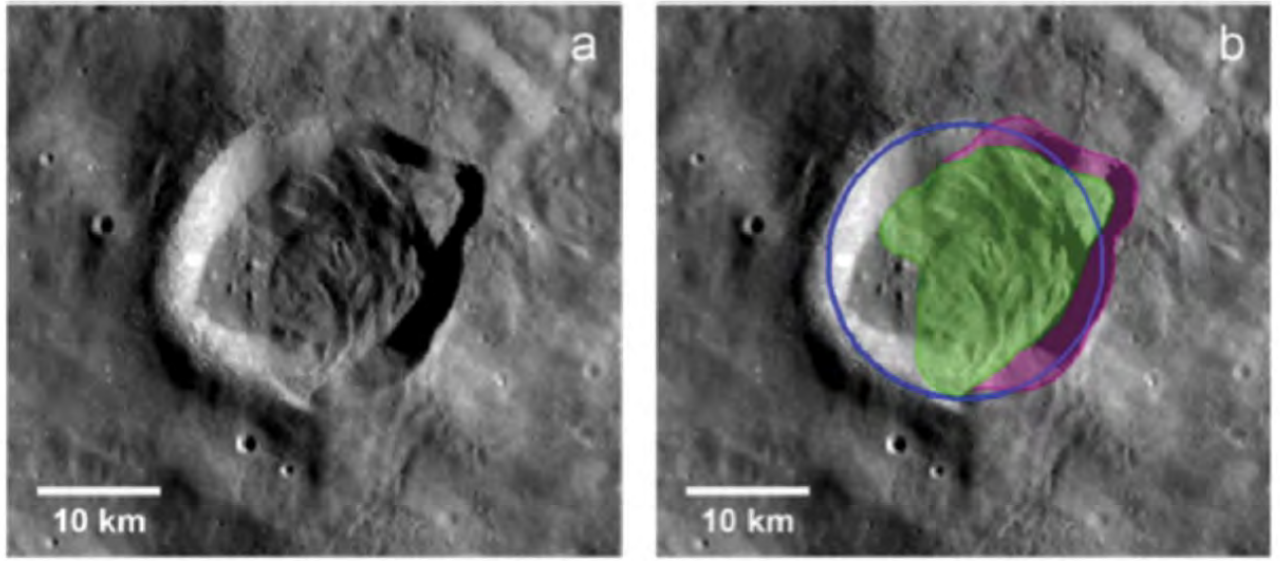
*14

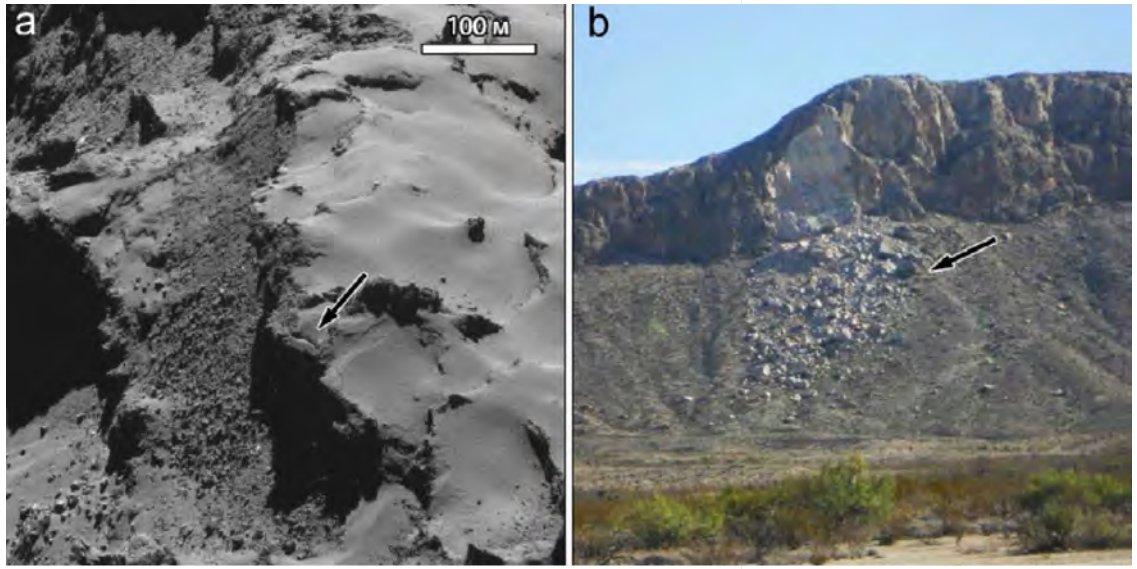
80 m

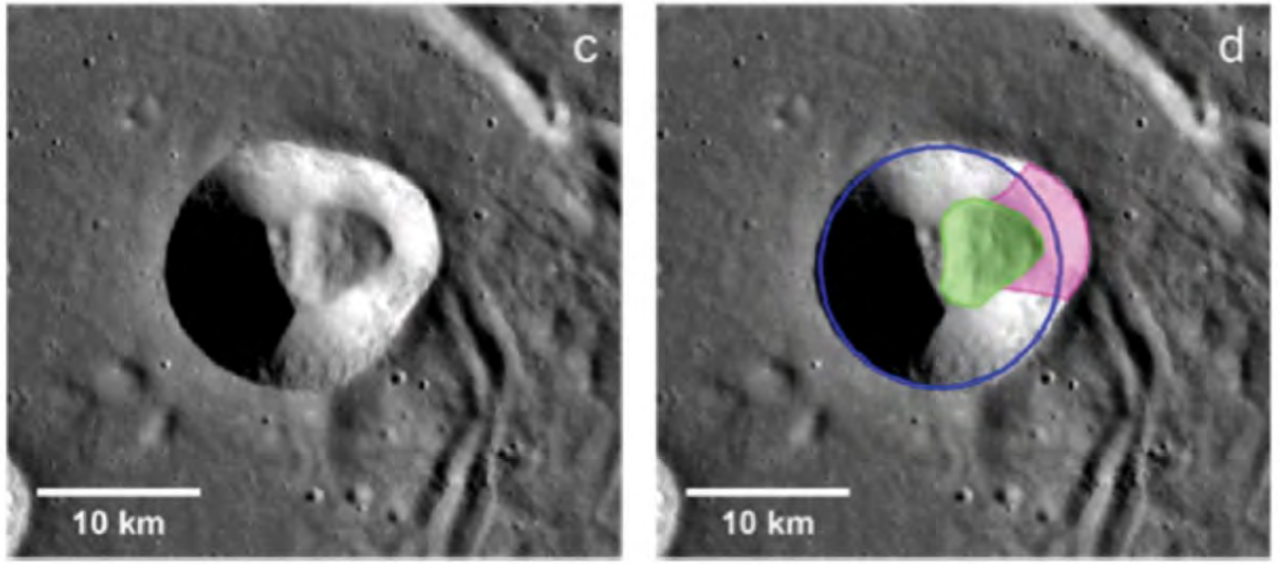
*17

MASS WASTING









Brunetti, M., et al., 2015

GEOMECHANICAL PROPERTIES OF THE REGOLITH (1)

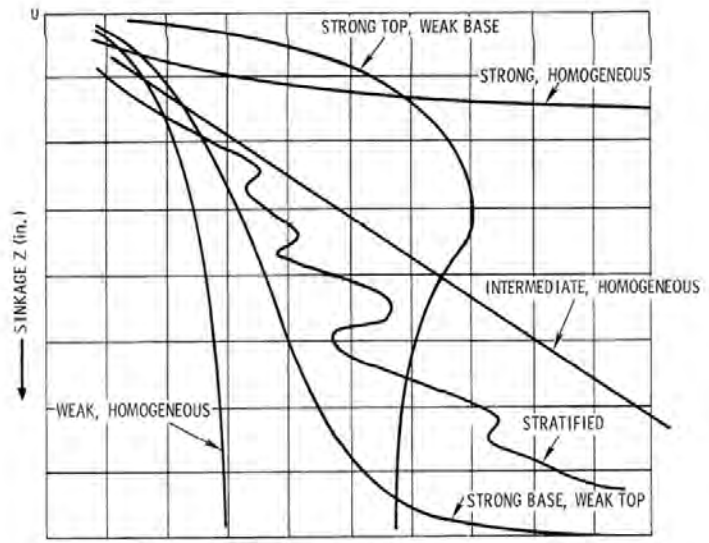
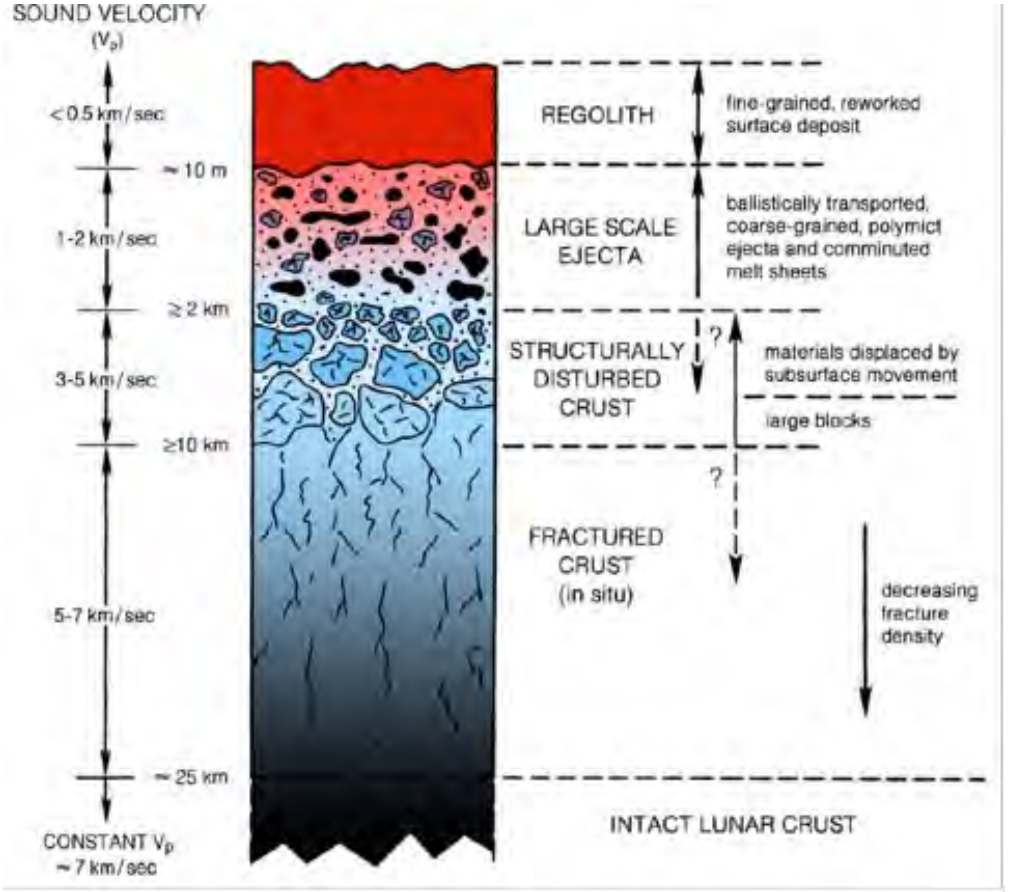


Figure 1.13 Typical pressure-sinkage curves (Bekker 1969).

Hoenicke, L., 2021

REGOLITH


SOUND VELOCITY
(V_p)
< 0.5 km/sec
~ 10 m
1-2 km/sec
≳ 2 km
3-5 km/sec
≥10 km
5-7 km/sec
~ 25 km
CONSTANT V_p
~ 7 km/sec
REGOLITH
fine-grained, reworked surface deposit
LARGE SCALE EJECTA
ballistically transported, coarse-grained, polymict ejecta and comminuted melt sheets
STRUCTURALLY DISTURBED CRUST
?
materials displaced by subsurface movement
large blocks
?
FRACTURED CRUST (in situ)
decreasing fracture density
INTACT LUNAR CRUST

… GEOMECHANICAL PROPERTIES OF THE REGOLITH (2)

Fig. 1 - Usual model of pressure distribution under a sinking plate

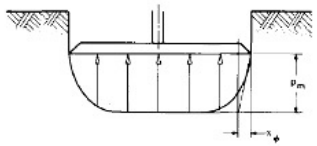


Fig. 2 - Typical pressure distribution measured under a plate sinking into frictional soils

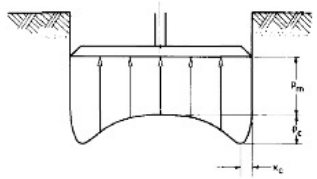


Fig. 3 - Typical pressure distribution measured under a plate sinking into cohesive soils

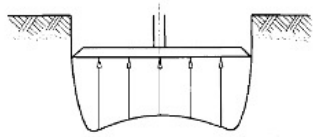


Fig. 4 - Typical pressure distribution measured under a plate sinking into a soil containing both friction and adhesion

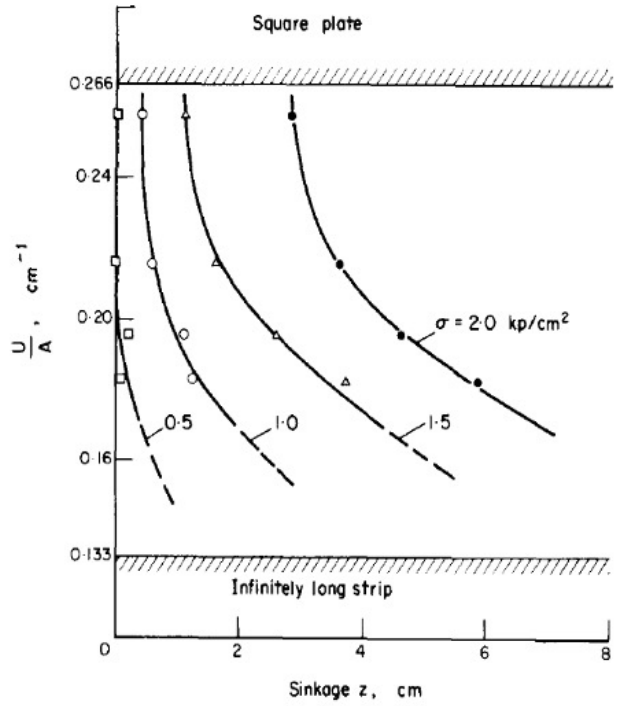


FIG. 4. Variation of sinkage of rectangular plates having different aspect ratios with ratio of plate perimeter to area.

Lunar Source Book

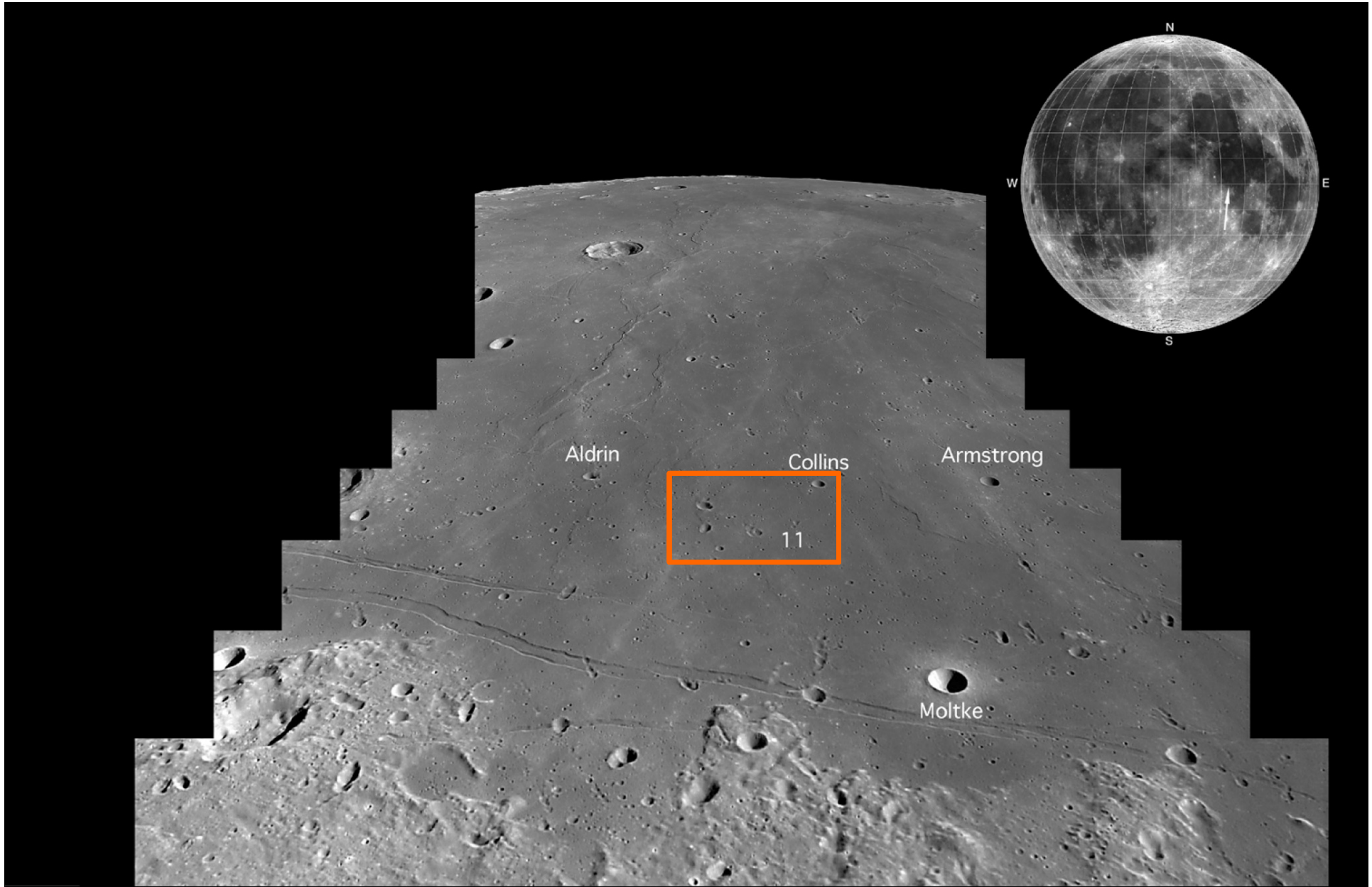
Remote Sensing the lunar surface

LRO Mission

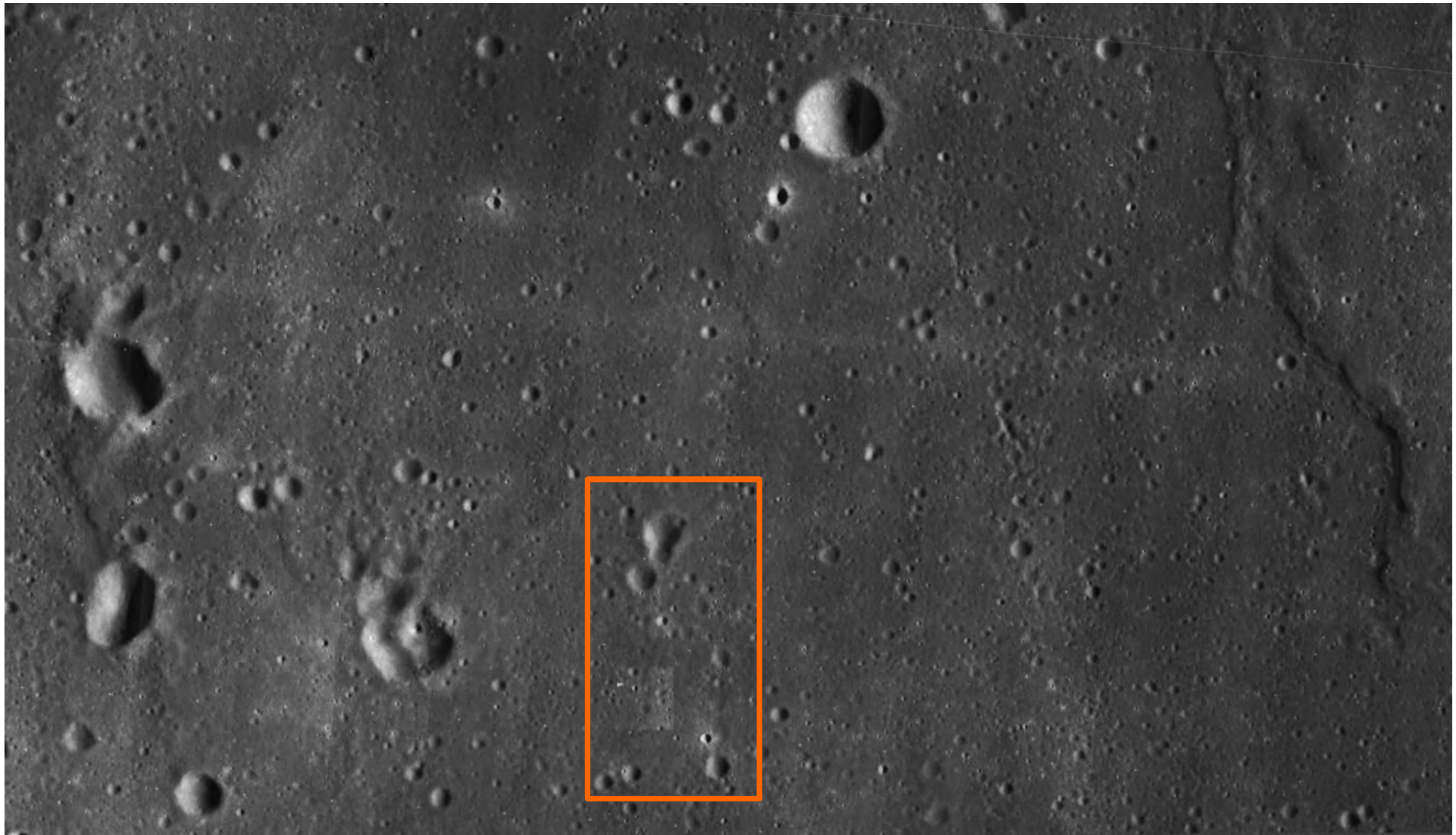
2009 - present

1 Satellite

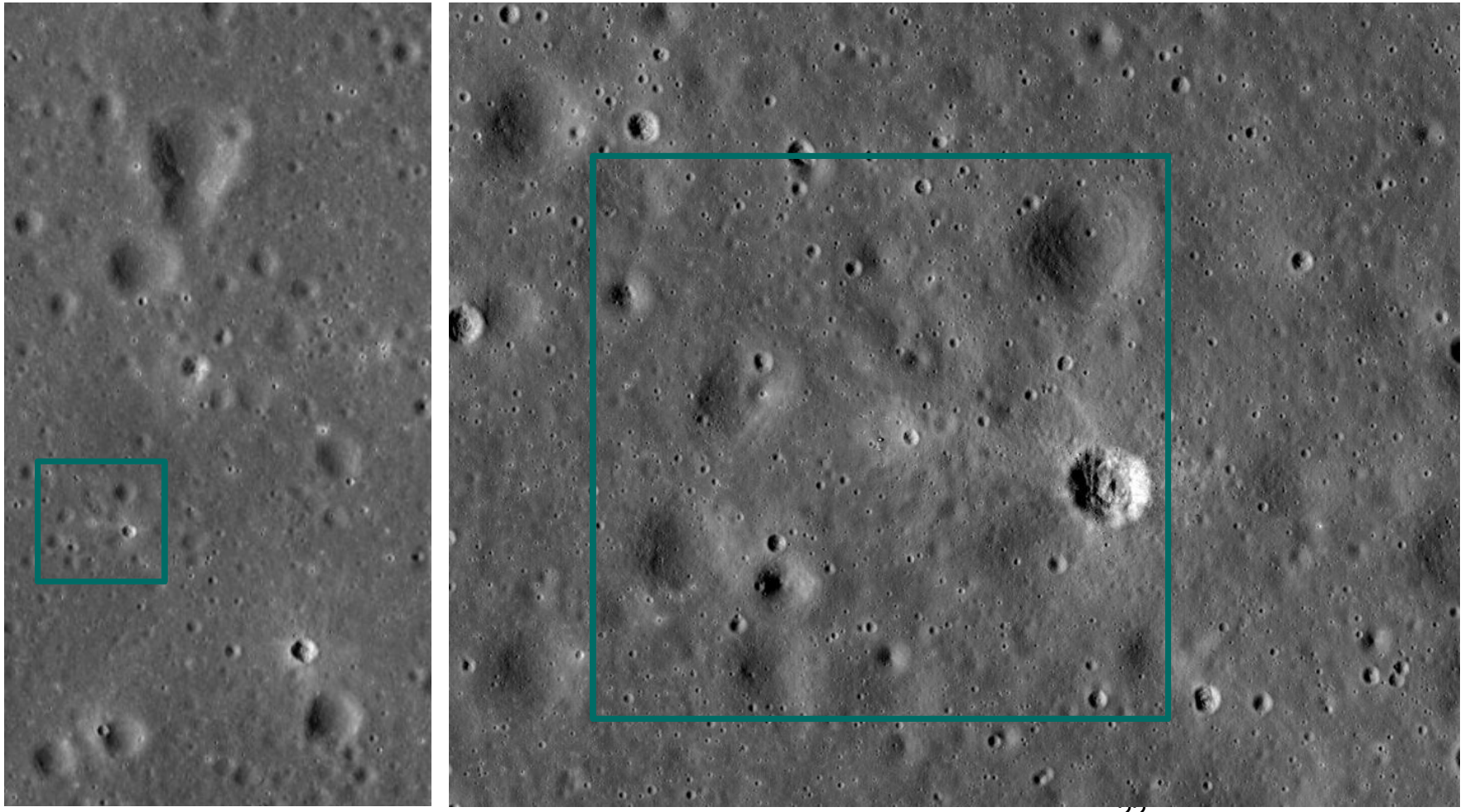
LET’S LAND ON THE MOON



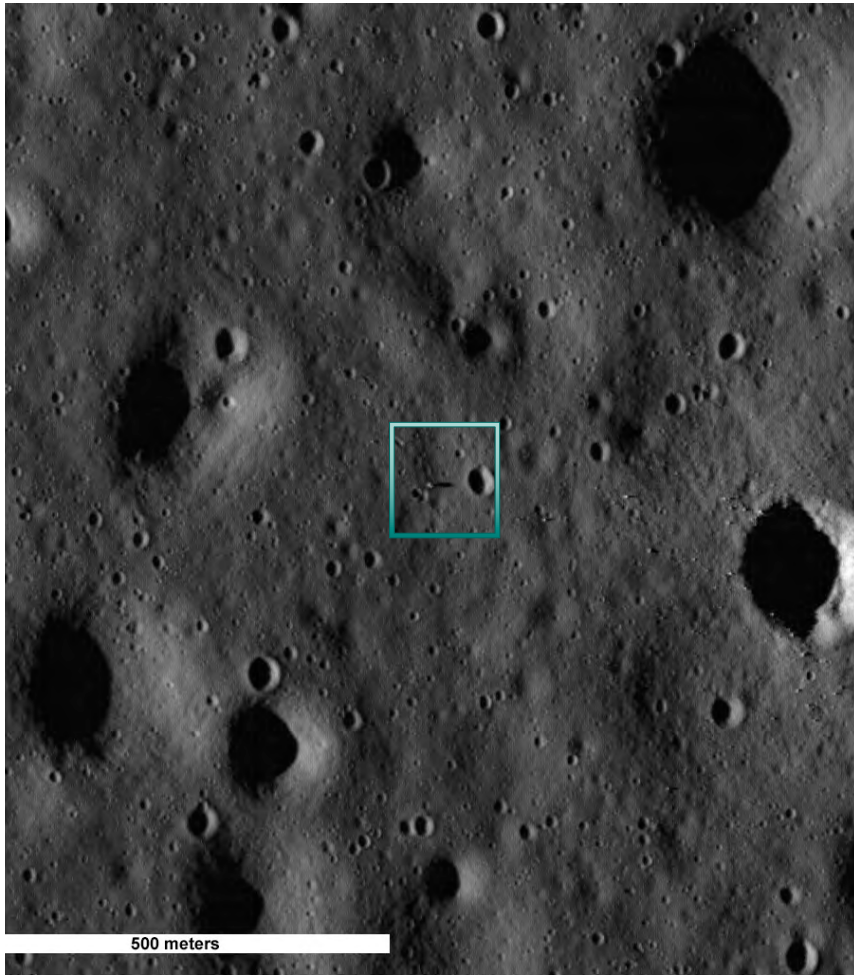
ZOOM 1

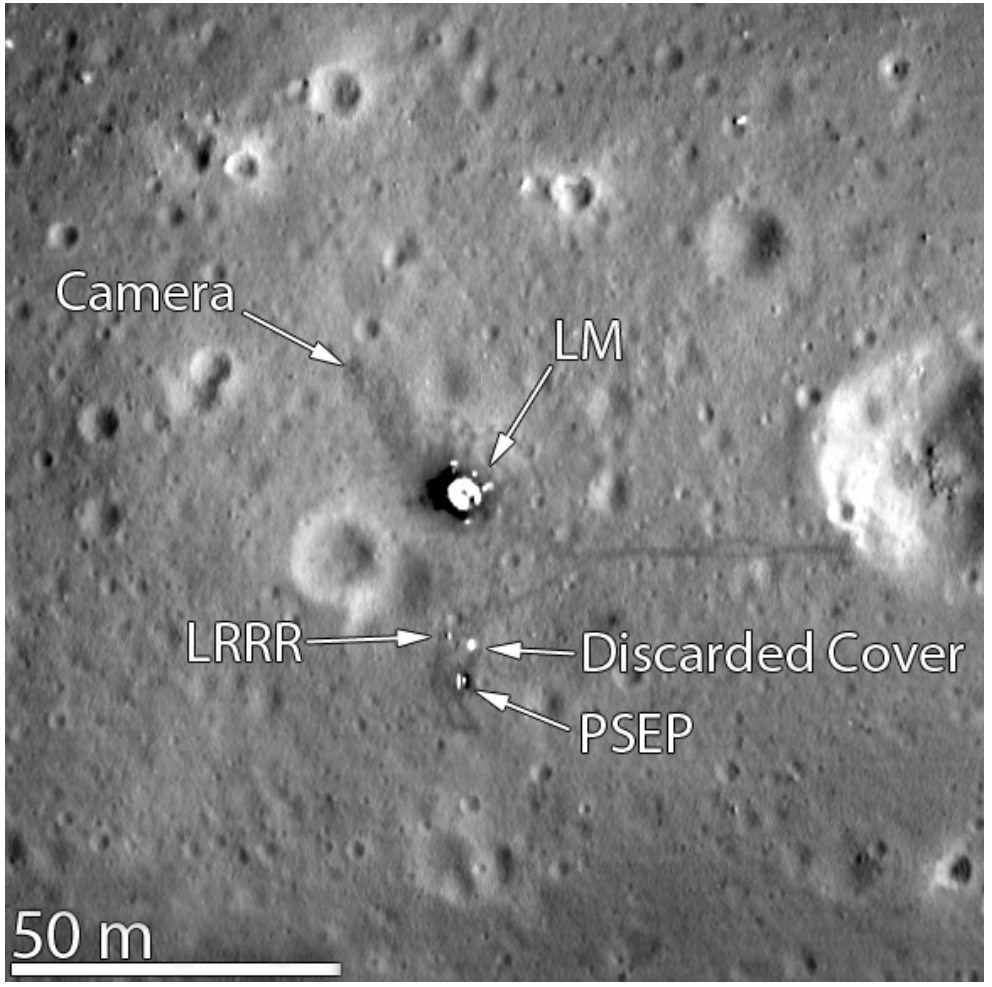


ZOOM 2



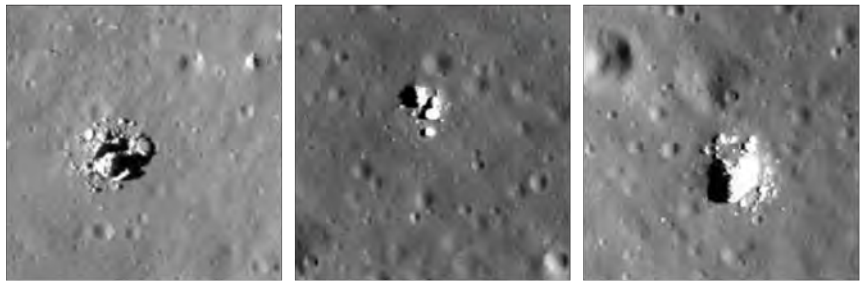
APOLLO 11

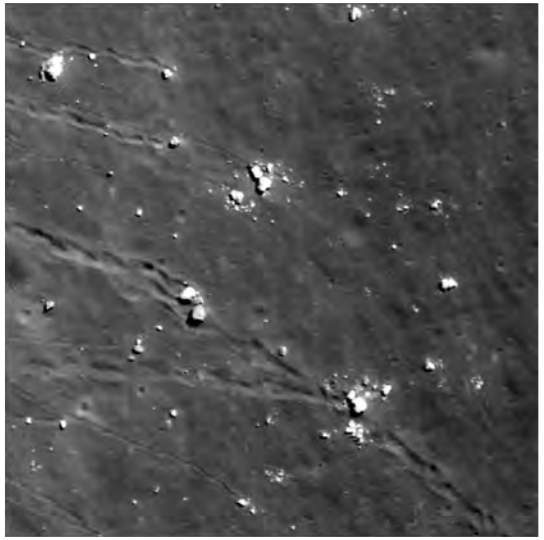




MASS WASTING

.... Erosional processes and age related processes

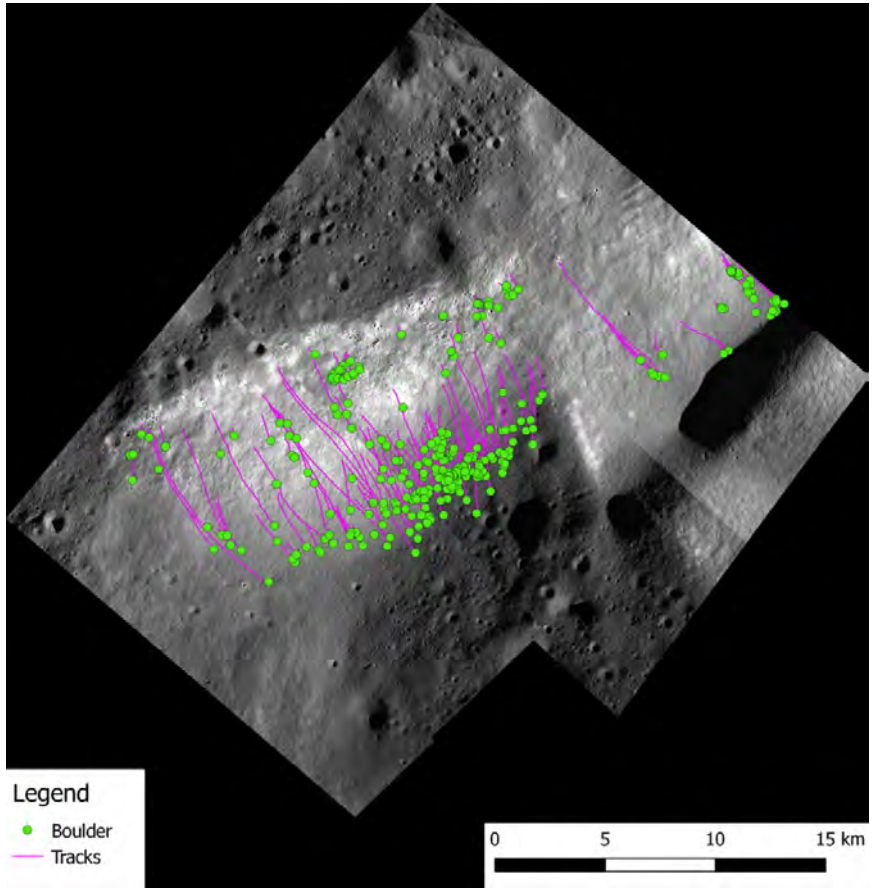


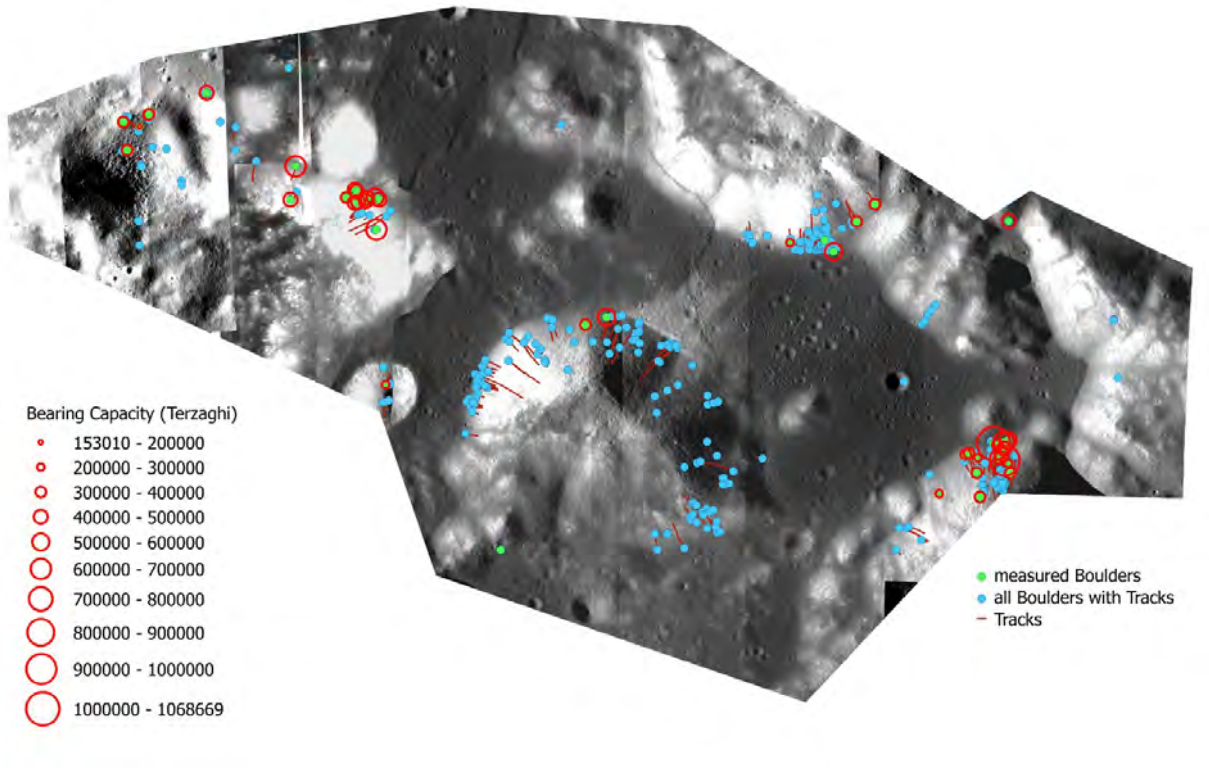


Images: LROC

GEOMECHANICAL PROPERTIES OF THE REGOLITH (3)

Sampling geomechanical properties through remote sensing





Mall et al, 2019, unpublished

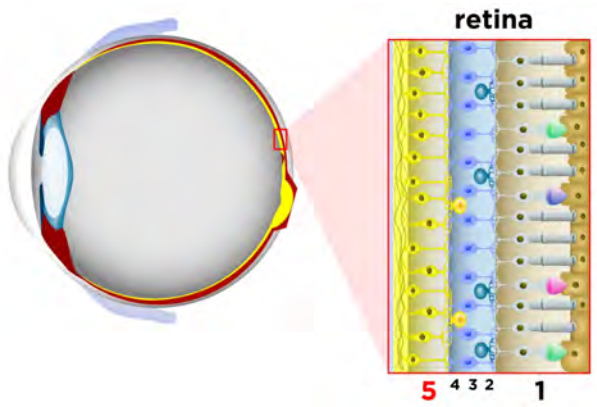
CONVOLUTIONAL NEURAL NETWORKS (2)

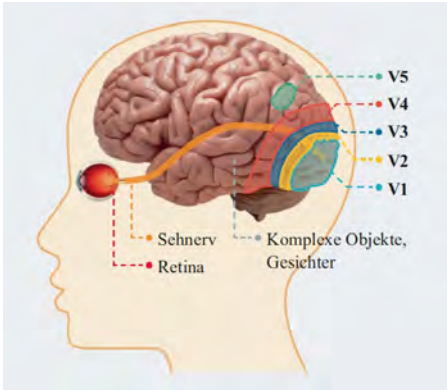
RECEPTIVE FIELDS OF SINGLE NEURONES IN THE CAT'S STRIATE CORTEX

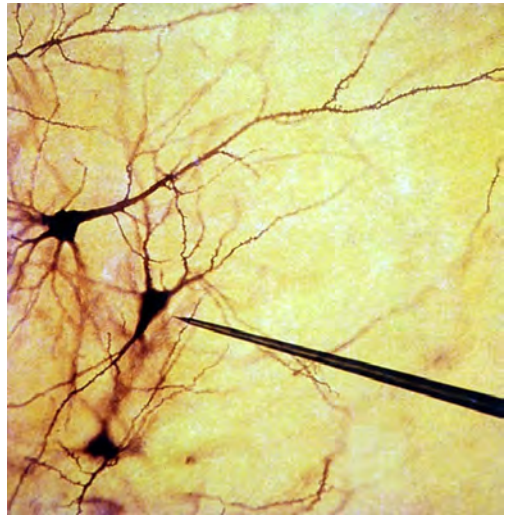
By D. H. HUBEL* and T. N. WIESEL*

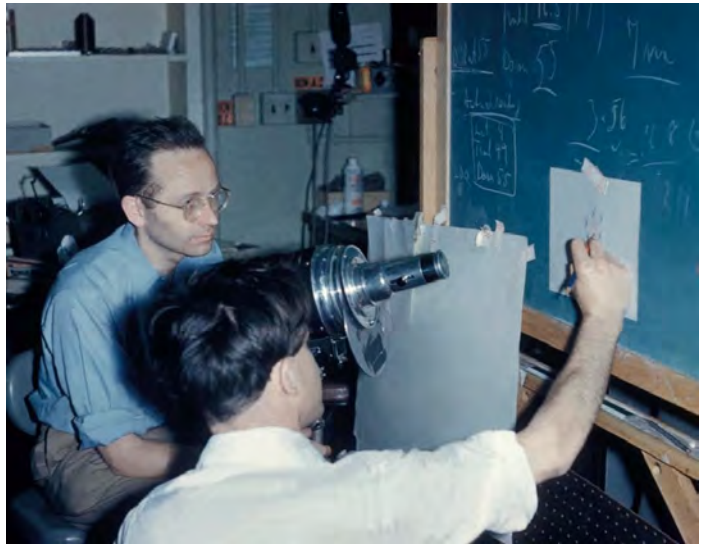
From the Wilmer Institute, The Johns Hopkins Hospital and University, Baltimore, Maryland, U.S.A.

(*Received* 22 *April* 1959)









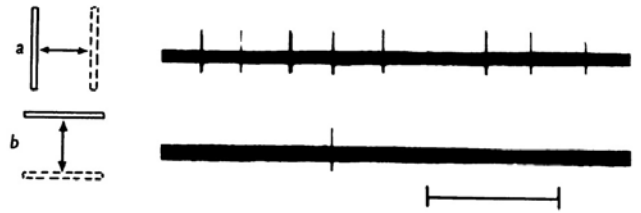


Fig. 5. Same unit as in Figs. 2 and 3. Receptive field shown in Fig. 2. Responses to a slit (1° × 8°) moved transversely back and forth across the receptive field. *a*, slit moved horizontally. *b*, slit moved vertically. Background and stimulus intensities as in Fig. 1; time, 1 sec.

CONVOLUTIONAL NEURAL NETWORKS (3)

Neocognitron: A Self-organizing Neural Network Model for a Mechanism of Pattern Recognition Unaffected by Shift in Position

Kunihiko Fukushima 1980

195

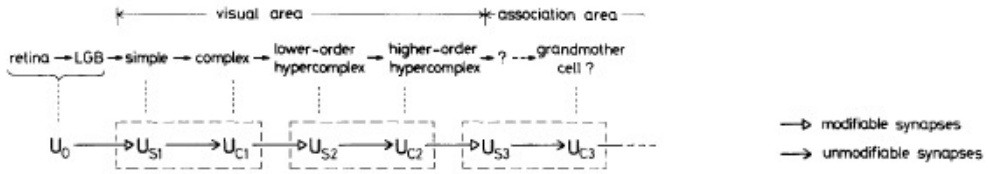


Fig. 1. Correspondence between the hierarchy model by Hubel and Wiesel, and the neural network of the neocognitron

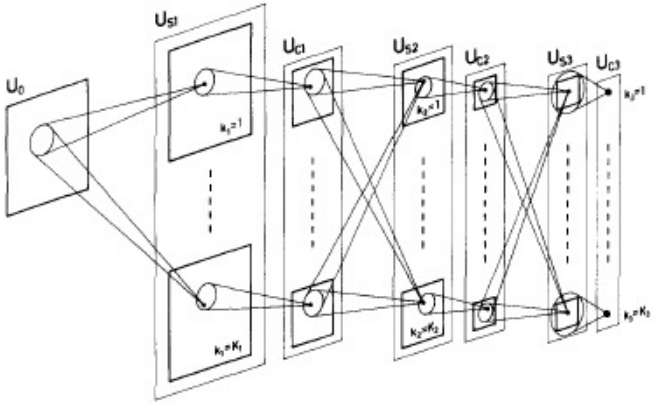
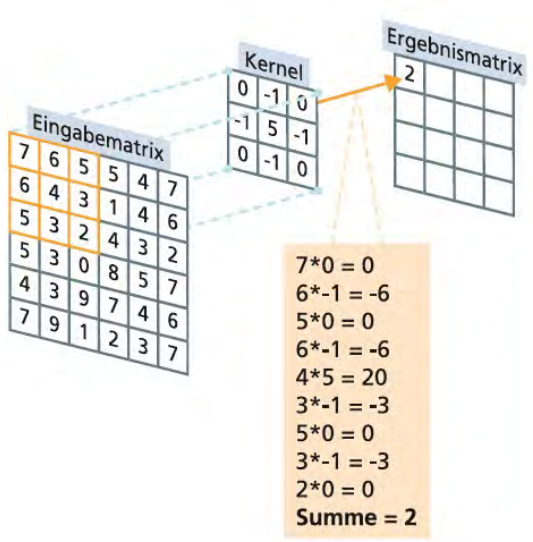
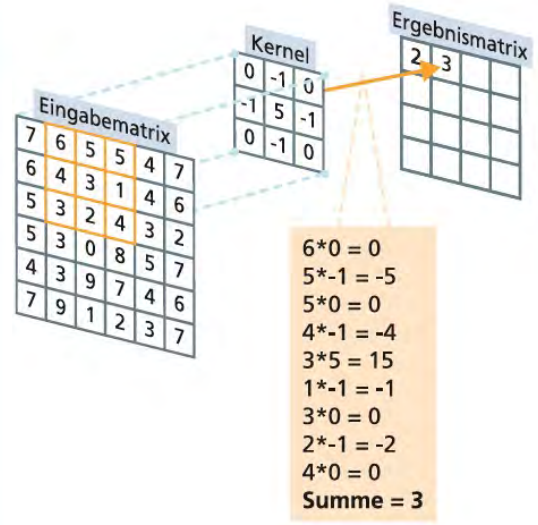
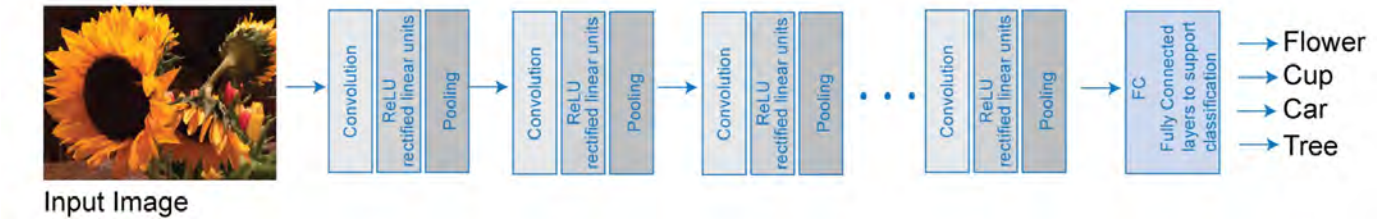
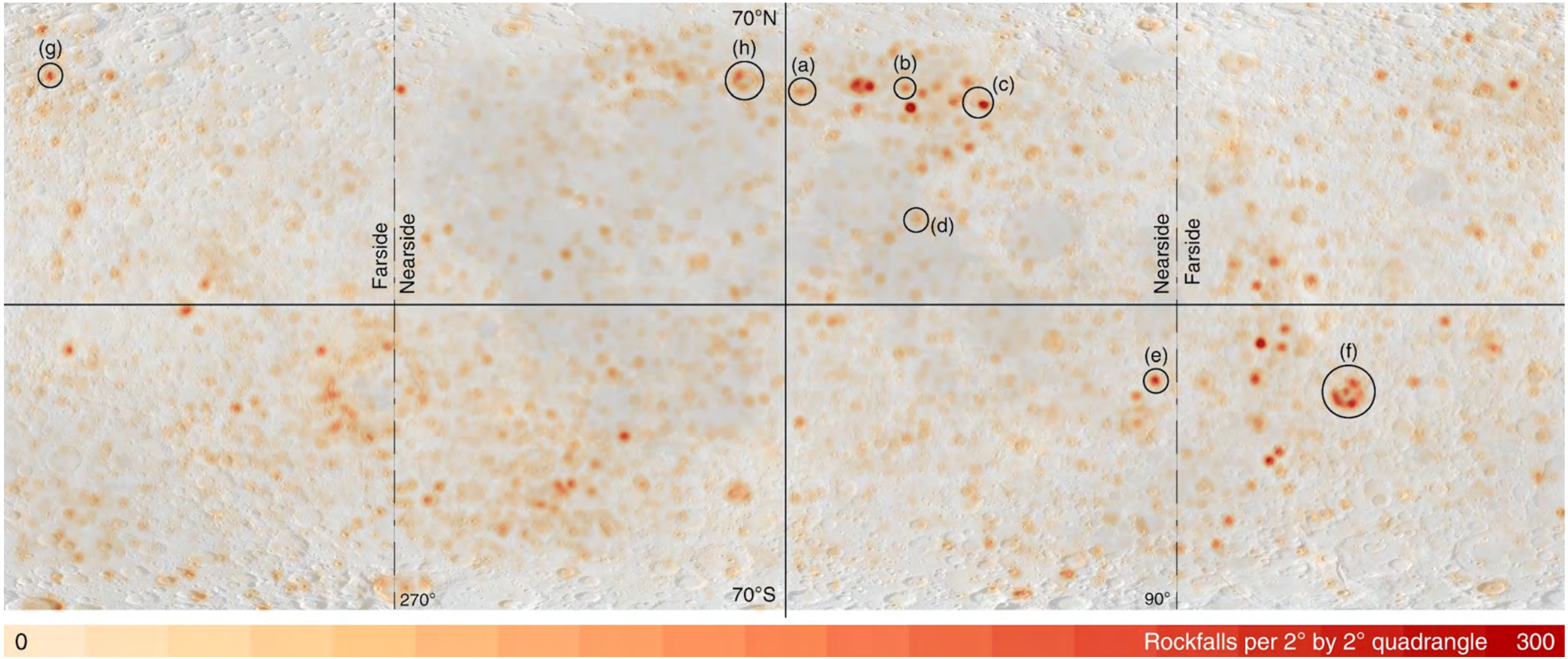


Fig. 2. Schematic diagram illustrating the interconnections between layers in the neocognitron

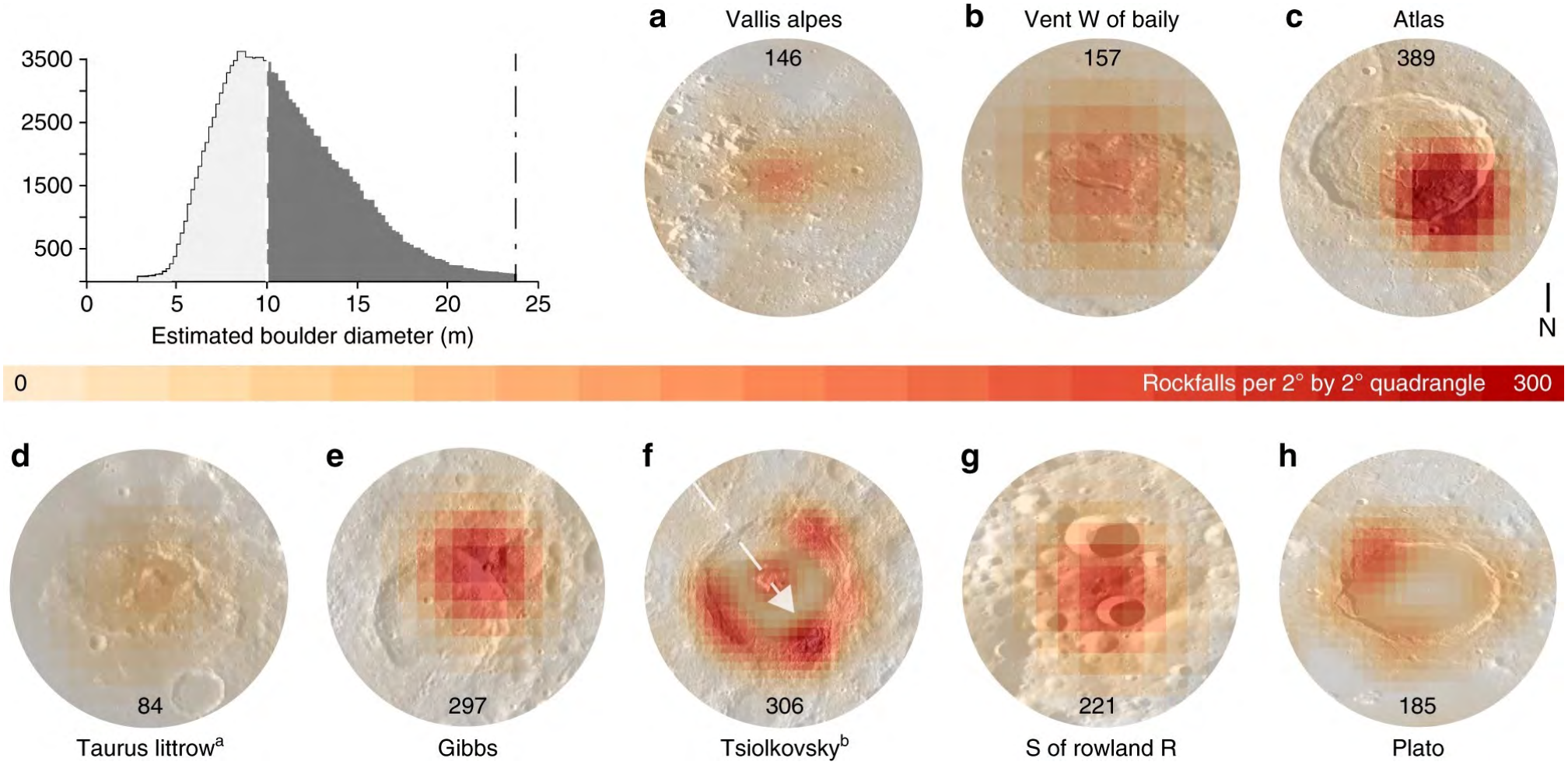








Bickel et al, 2020, Nature Communications



Bickel et al, 2020, Nature Communications

THE CONTROVERSY

Controversy is a state of prolonged public dispute or debate, usually concerning a matter of conflicting opinion or point of view.

Can the unreleased catalogue of boulders (138'000 locations) be used to make reliable statistical interferences on a variety of scientific questions?

JGR Planets

RESEARCH ARTICLE
10.1029/2021JE006824

Key Points:
- We study the drivers and transport mechanisms of lunar rockfalls on a local and global scale

Global Drivers and Transport Mechanisms of Lunar Rockfalls

V. T. Bickel[1,2], J. Aaron[2], A. Manconi[2], and S. Loew[2]

[1]Max Planck Institute for Solar System Research, Goettingen, Germany, [2]ETH Zurich, Zurich, Switzerland

6. Conclusions

We performed the first comprehensive and global study of lunar rockfall long- and short-term causal drivers and transport mechanisms using data about more than 130,000 rockfalls in combination with highly detailed local data about 687 rockfalls in 13 focus regions, covering volcanic, tectonic, and impact geomorphic contexts. Lunar rockfalls appear to predominantly occur on the slopes of N-S-facing, rocky impact structures that experience large thermal amplitudes over the course of the lunar day. We do not observe a qualitatively or statistically relevant relation between rockfall abundance, recorded Apollo-era shallow moonquake activity, and the distribution of visible tectogenetic features, indicating that moonquakes have not been a main, global driver of lunar rockfalls in the Moon's recent geologic past.

THE CONTROVERSY (2)

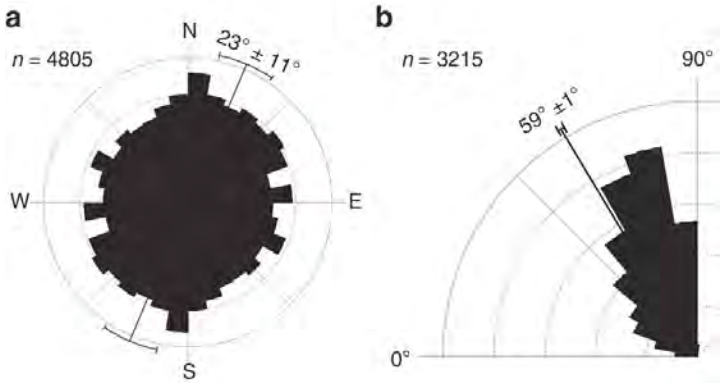
- How biased are our observations?
  1. How good is our coverage?
  2. Feeding Plane images to AI ?
  3. Observational effects (resolution, shadows etc) ?
- Use of CNN with ever changing training sets?

At which level are we with AI in morphological analysis to replace human classification?

WHY DOES IT MATTER?

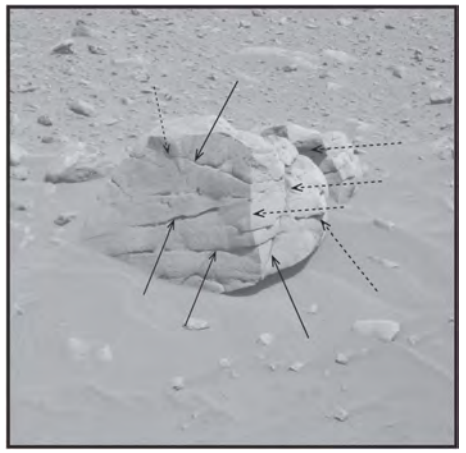
One example: Understanding the importance of thermal weathering on airless bodies.

Physical weathering is the primary, non-tectonic mechanism for the mechanical breakdown of rock into smaller particles.

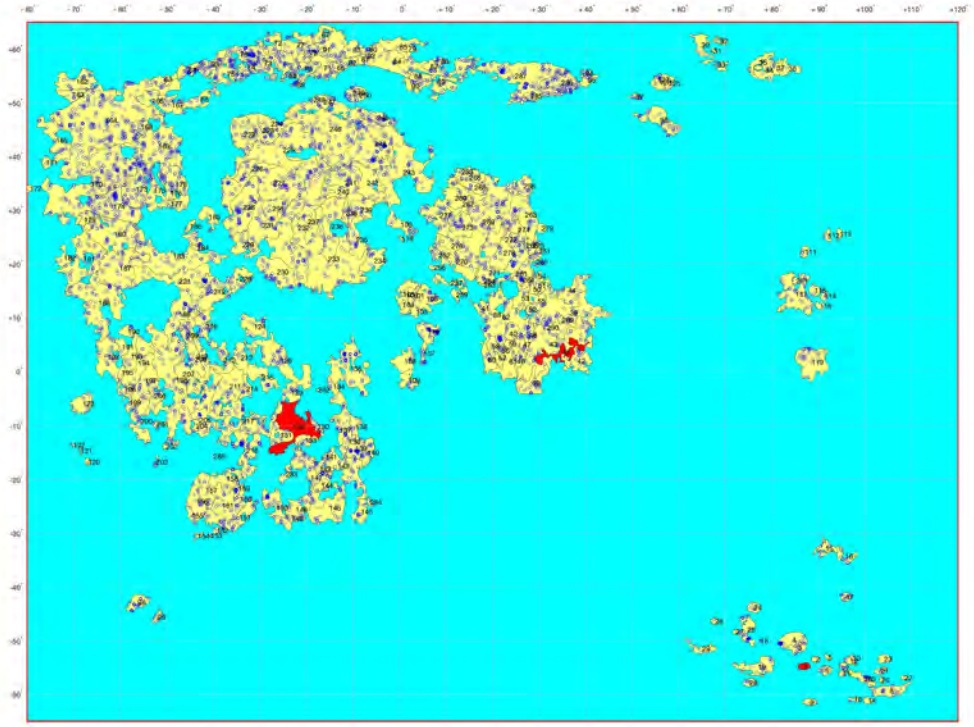


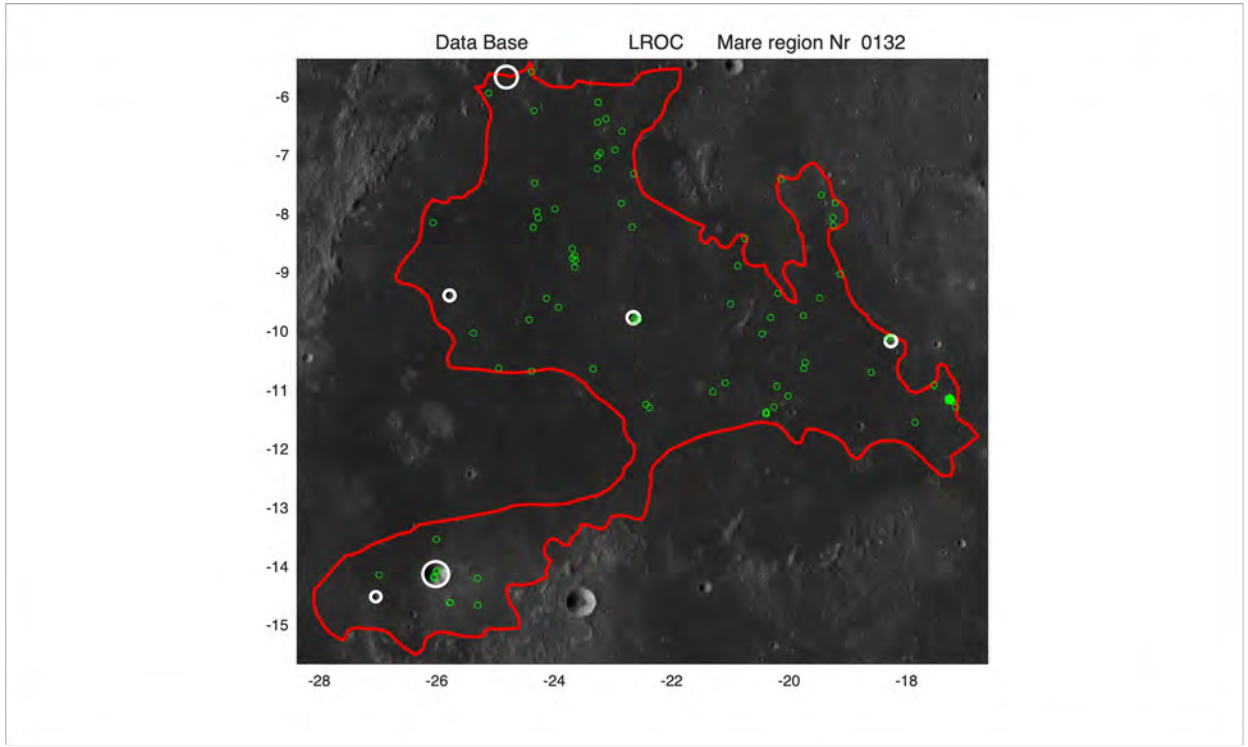
Eppes et al.,2015

Rocks found in the Mars Exploration Rover (MER) images of the Martian surface commonly exhibit fractures that are visible without magnification.



GUERICKE A

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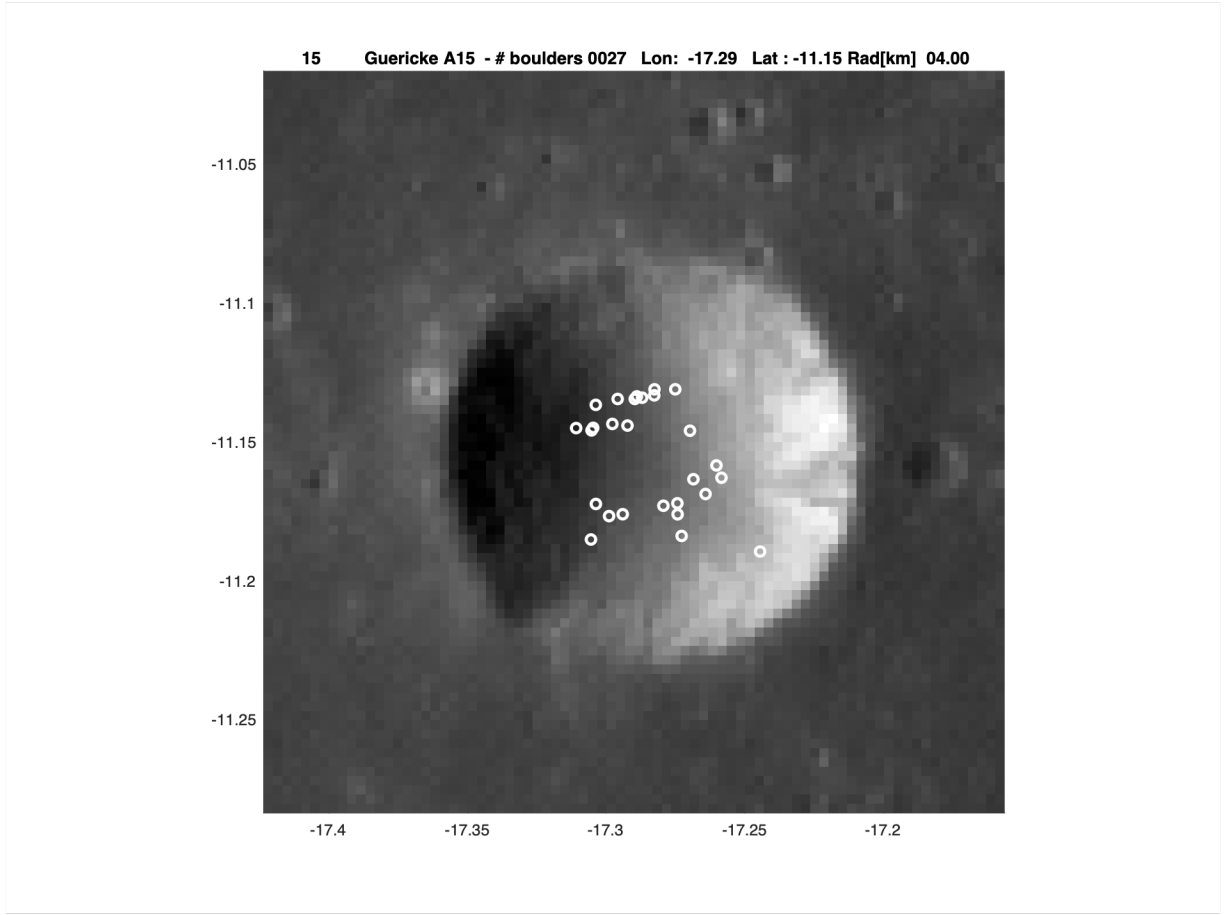
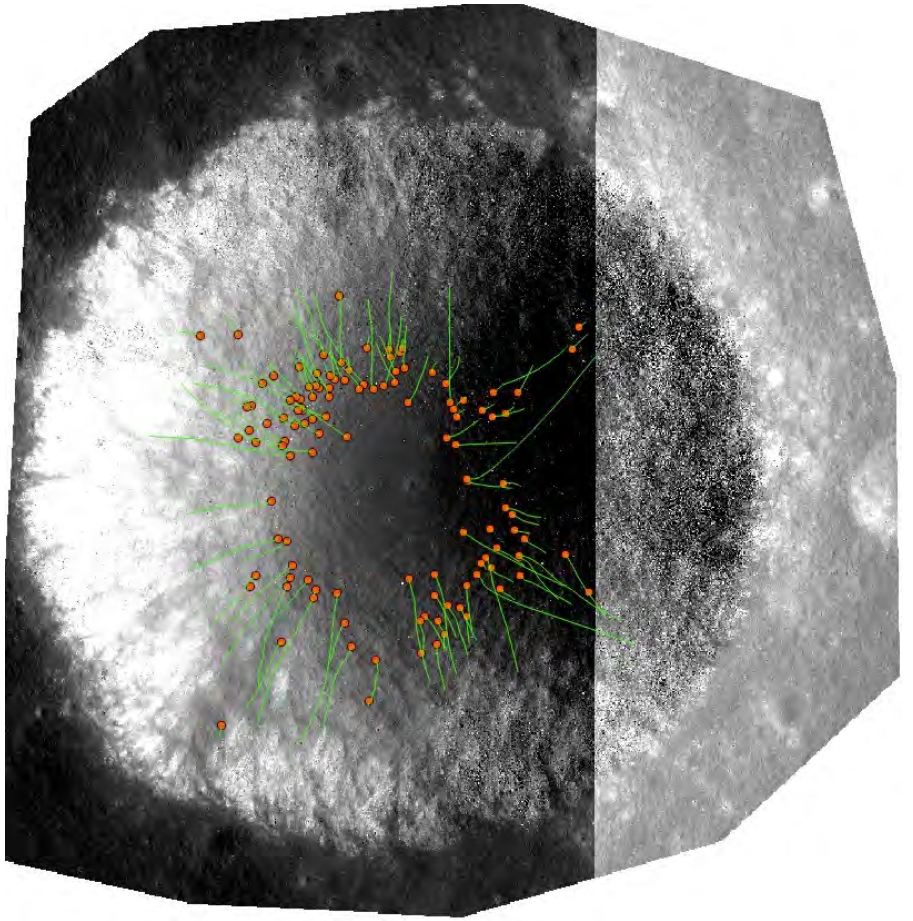
LROC
Mare region Nr 0132
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-28
-26
-24
-22
-20
-18

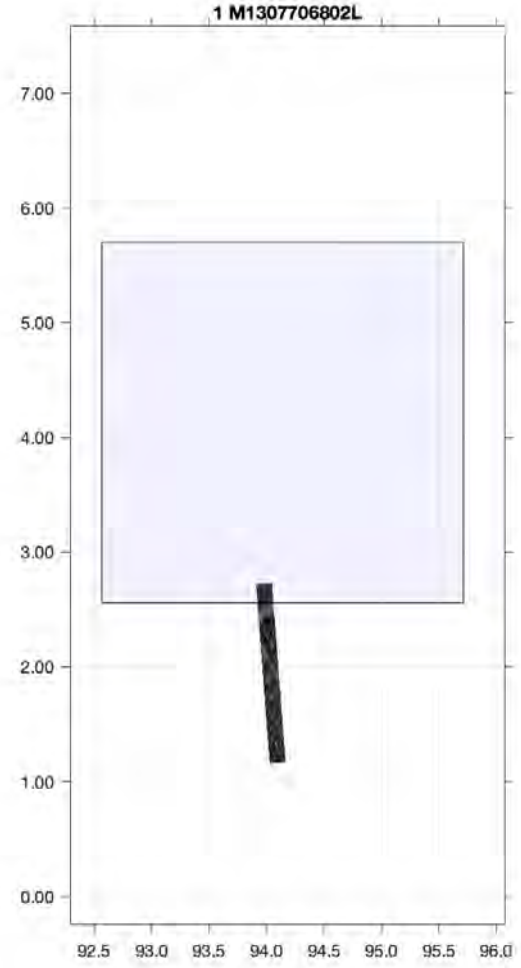
GUERICKE A



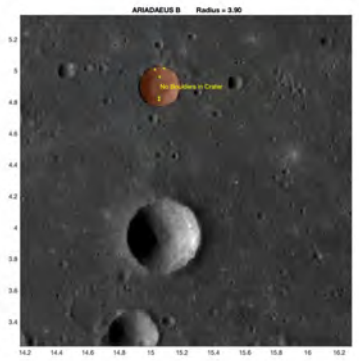


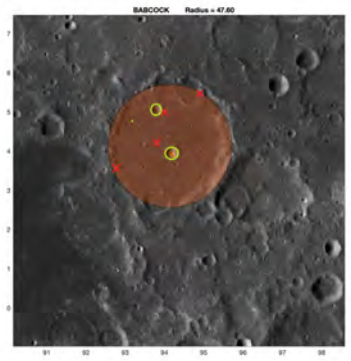
Mall et al, 2020, unpublished

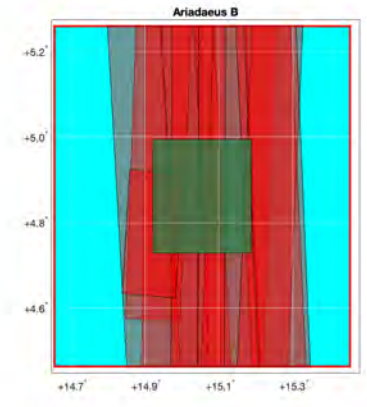
A MACHINE APPROACH

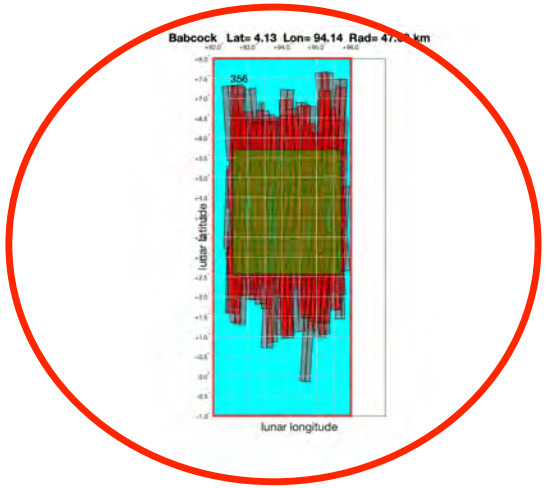


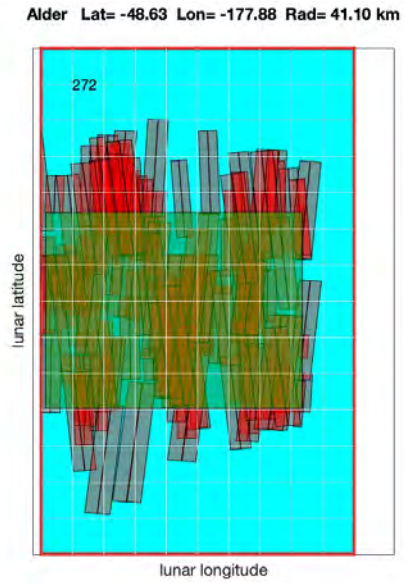
A MACHINE APPROACH (2)



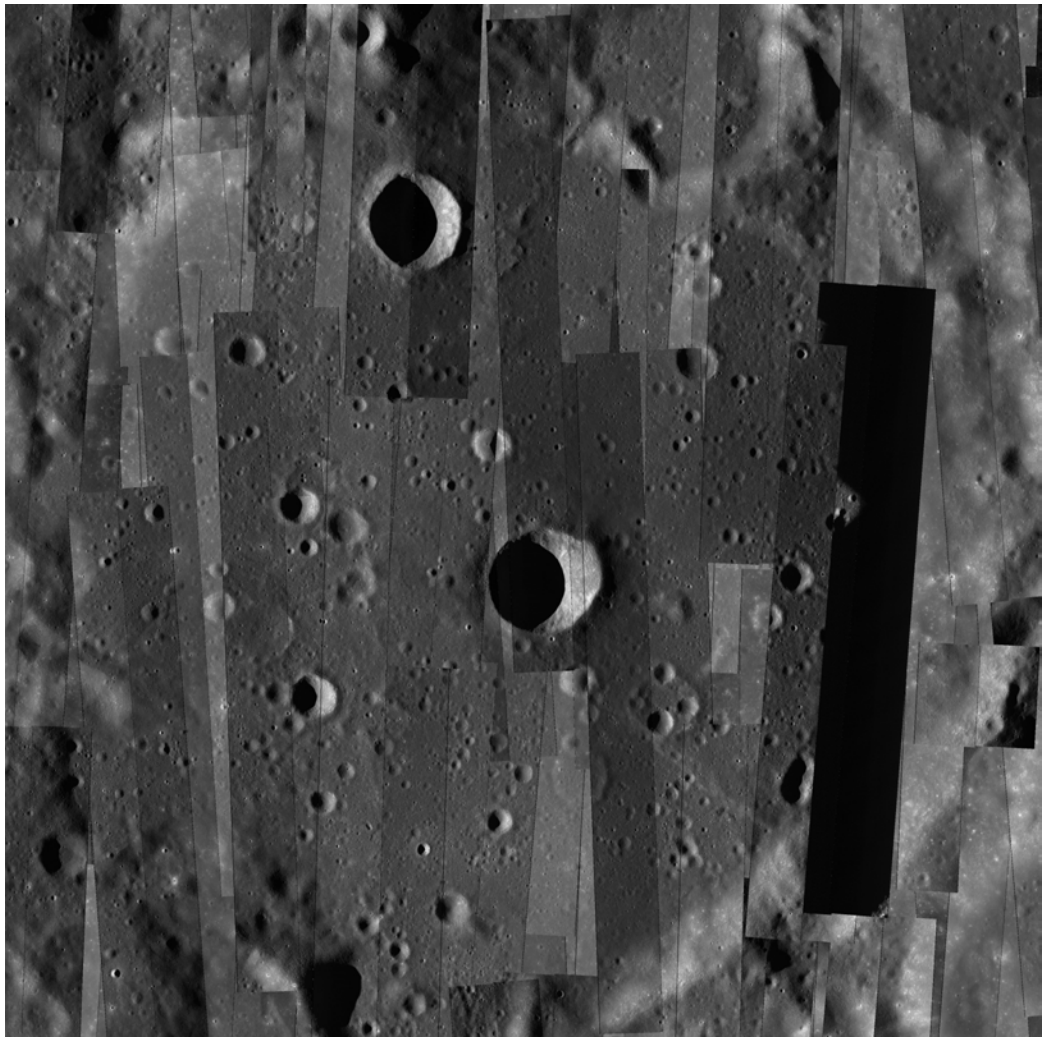


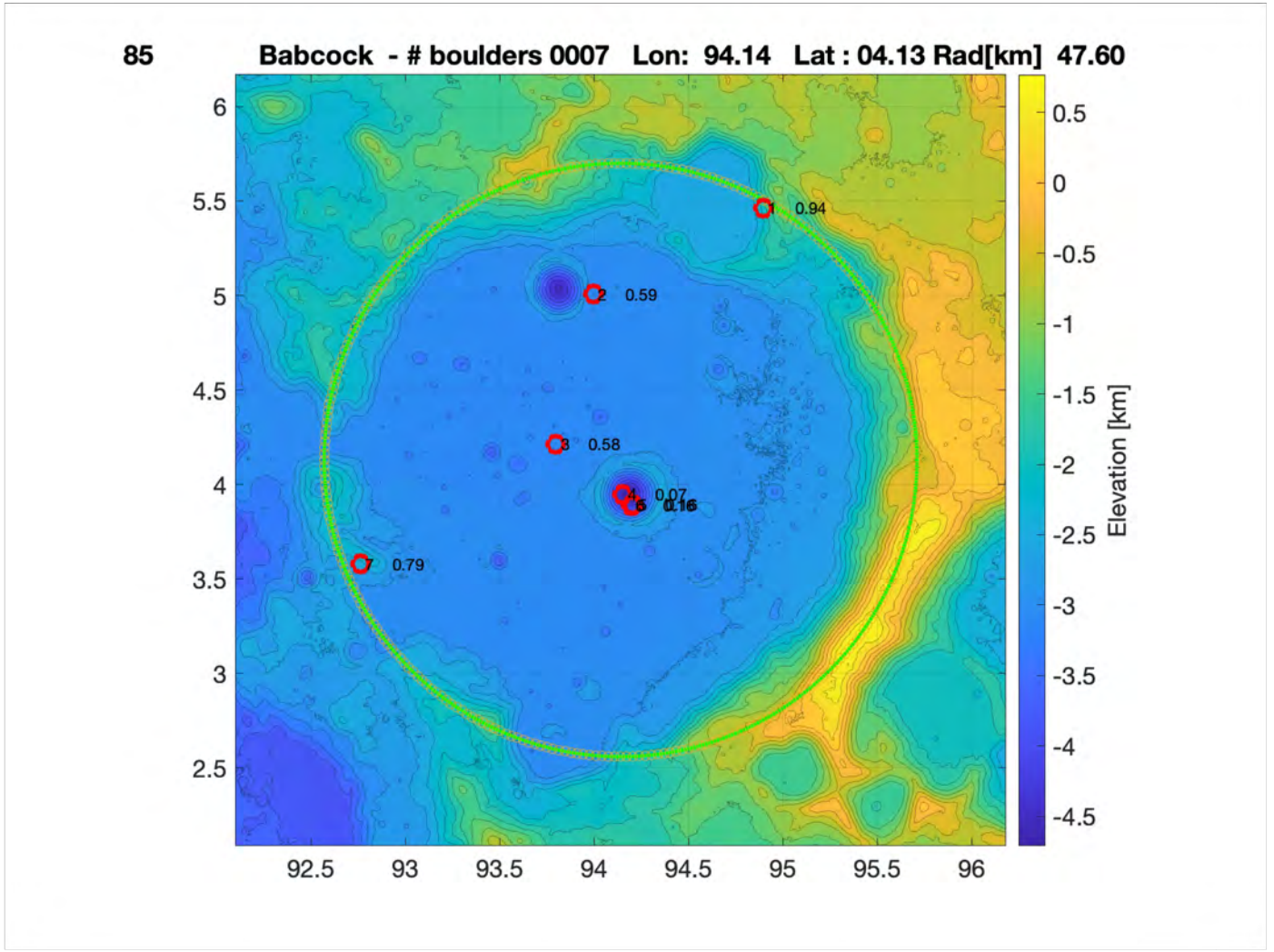




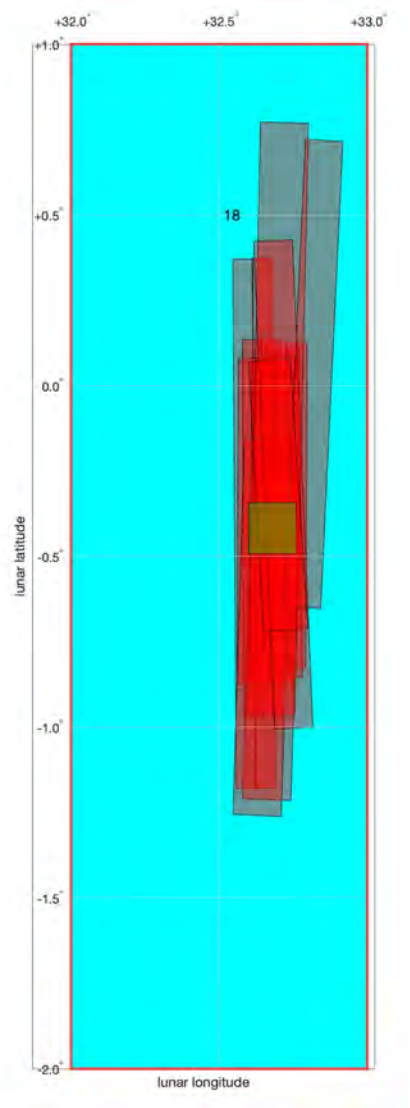


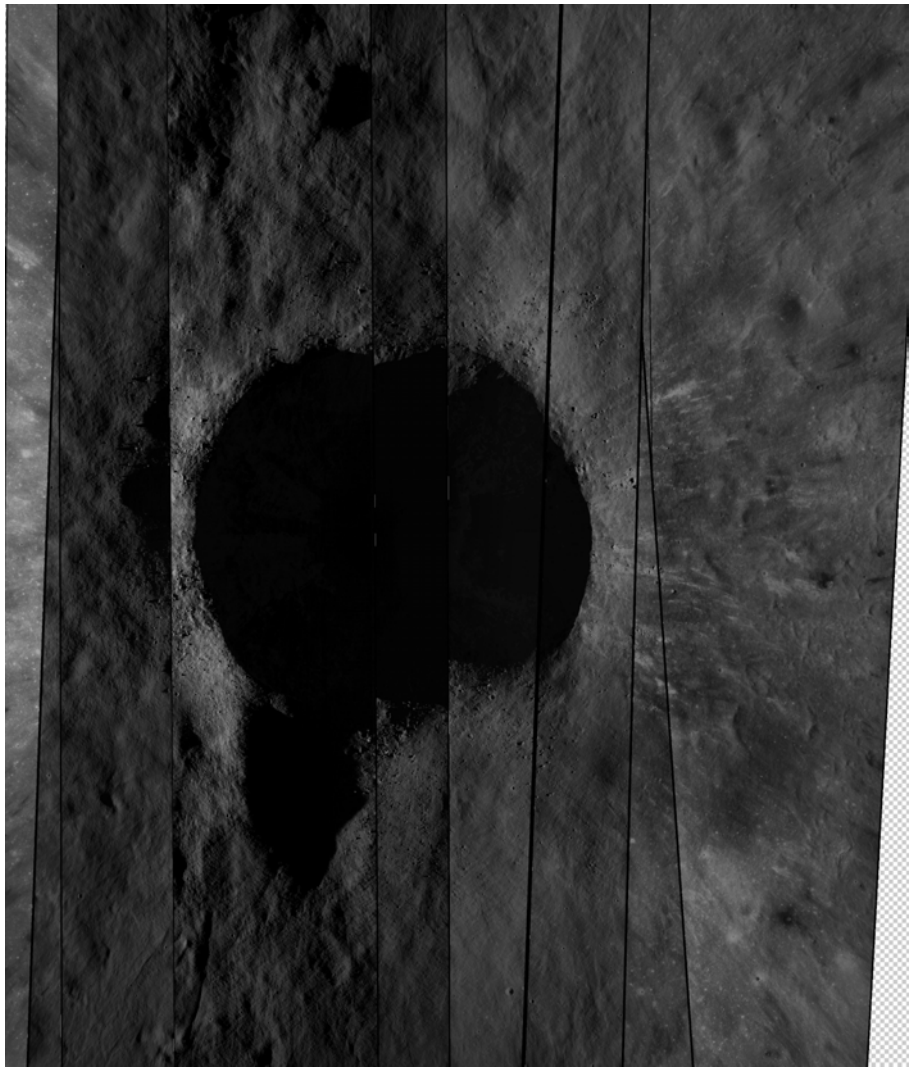
BABCOCK

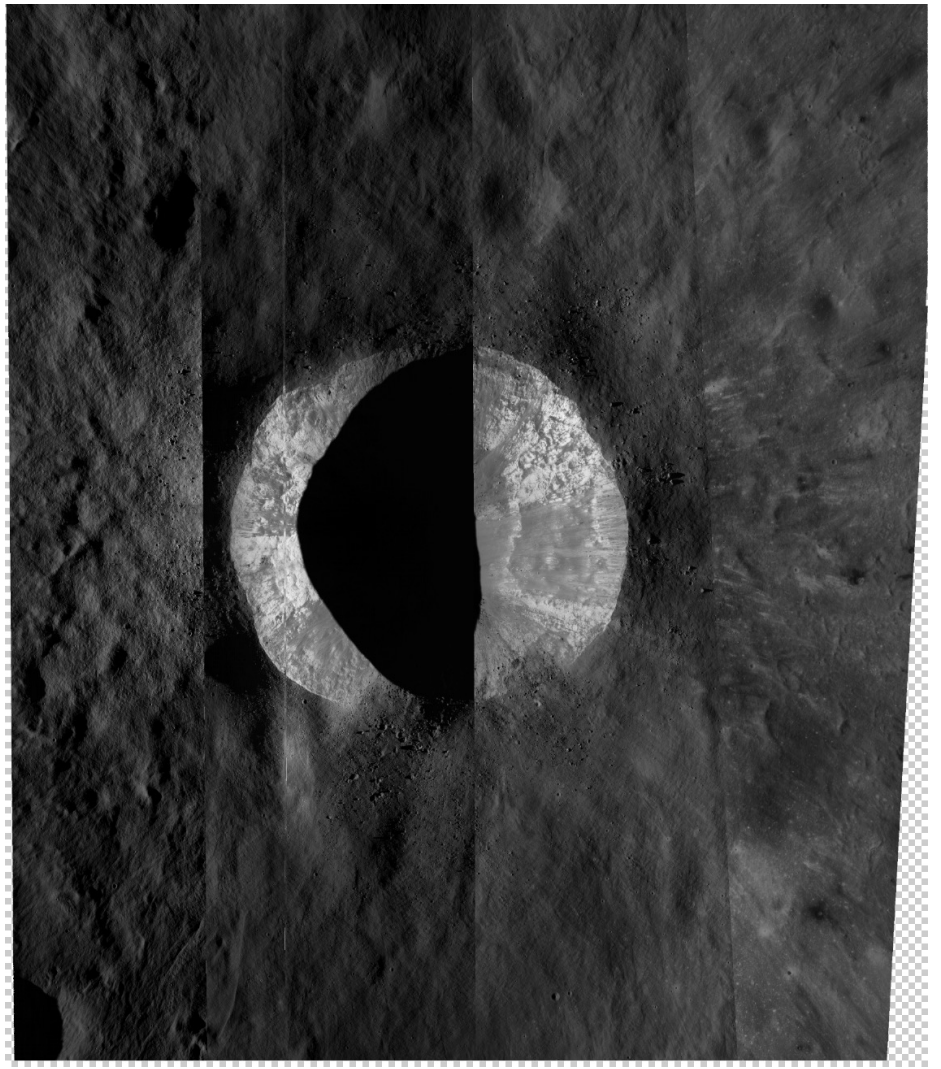



85
Babcock - # boulders 0007 Lon: 94.14 Lat : 04.13 Rad[km] 47.60
0.94
0.59
0.58
0.07
0.16
0.79
Elevation [km]
6
5.5
5
4.5
4
3.5
3
2.5
92.5
93
93.5
94
94.5
95
95.5
96
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
-4.5

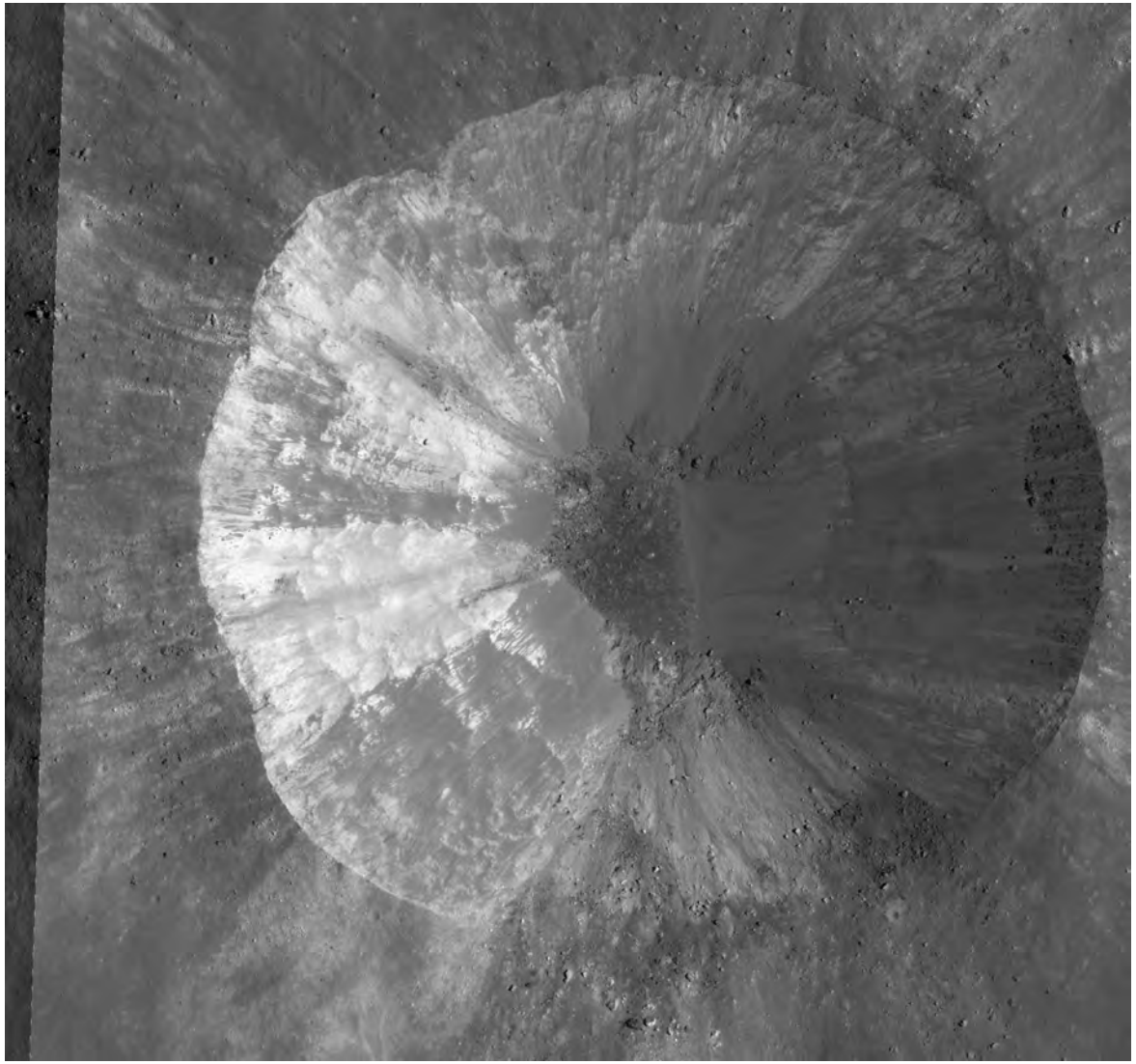
CENSORINUS


+32.0°
+32.5°
+33.0°
+1.0°
+0.5°
0.0°
-0.5°
-1.0°
-1.5°
-2.0°
18
lunar latitude
lunar longitude

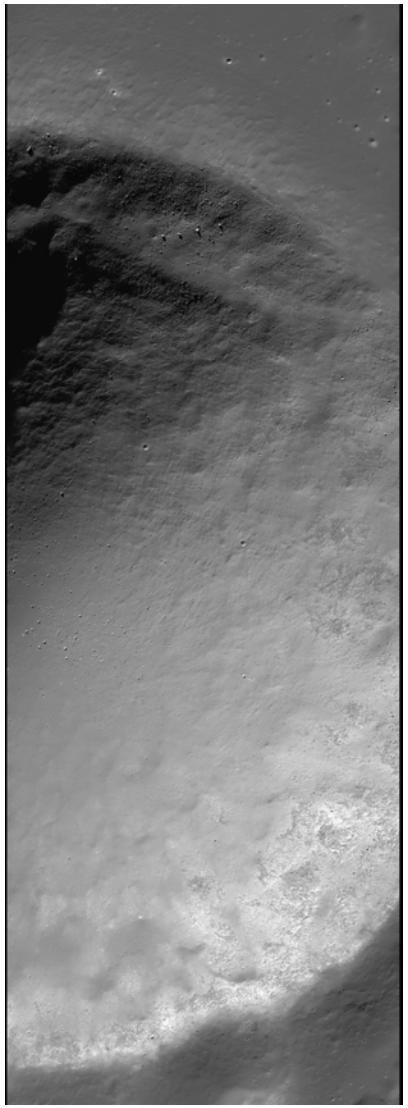


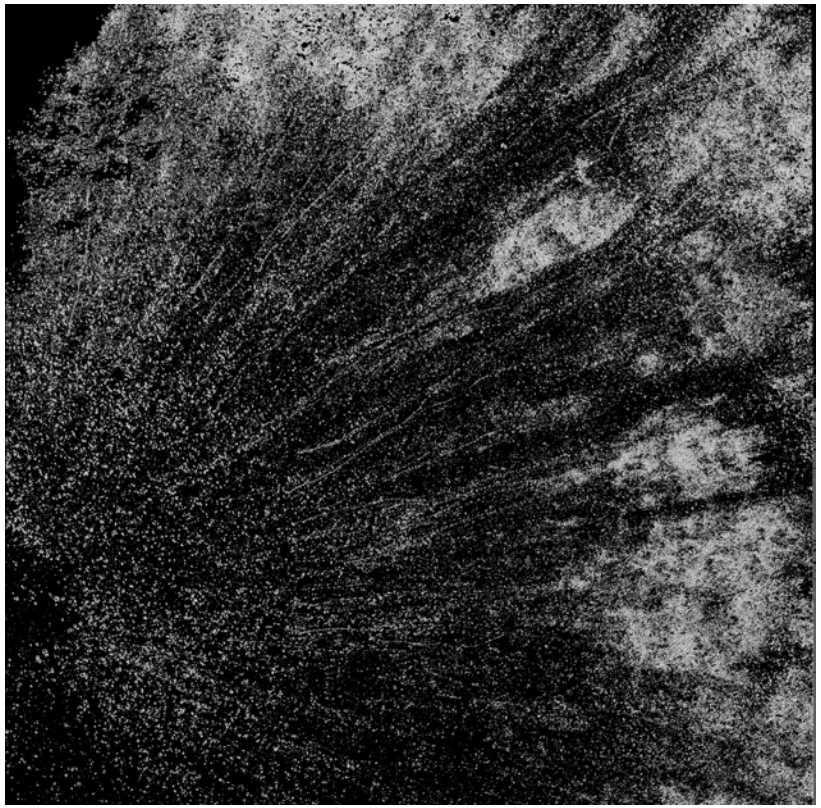


CENSORINUS(3)



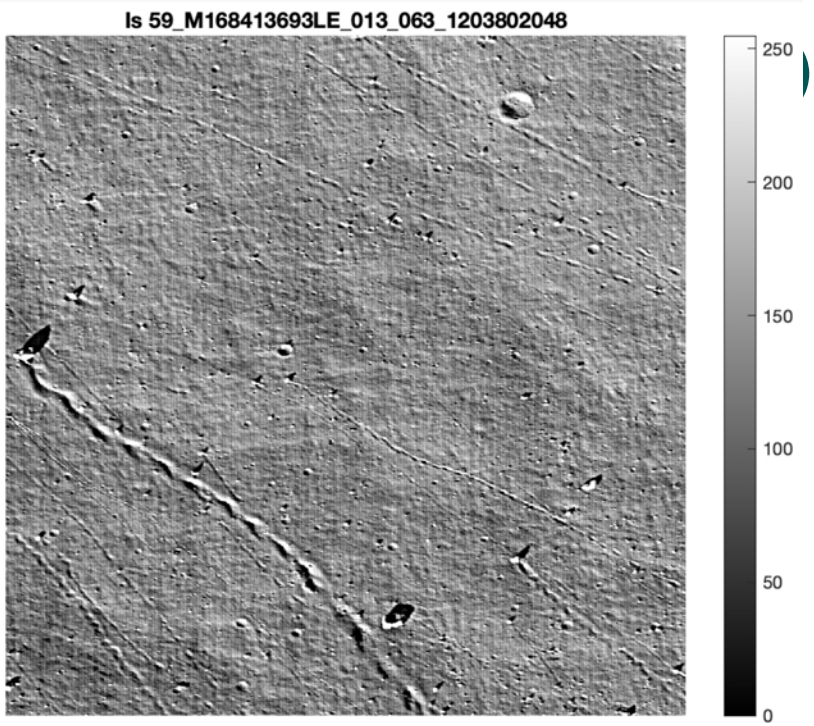
IMAGING APPROACH: ANALYZING INDIVIDUAL CRATERS IMAGES

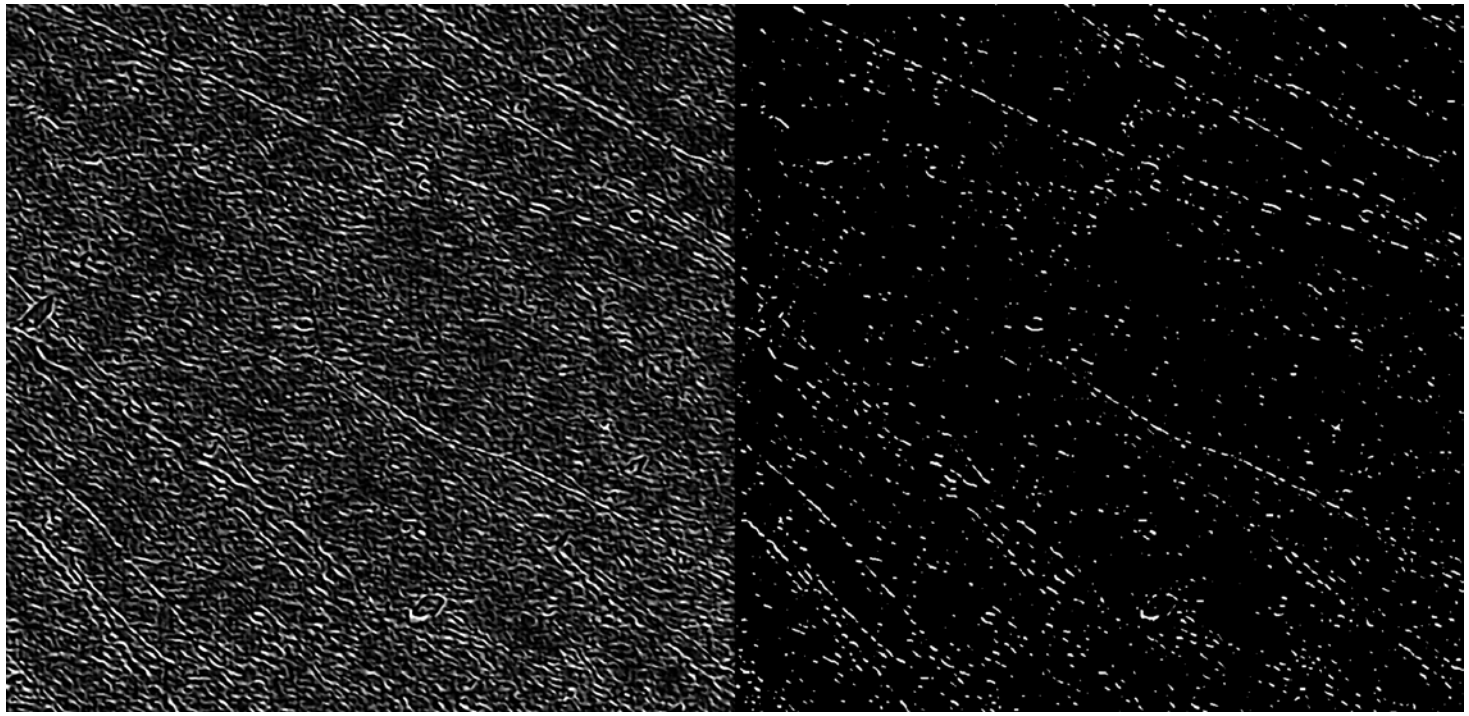




Mall et al, 2021, unpublished

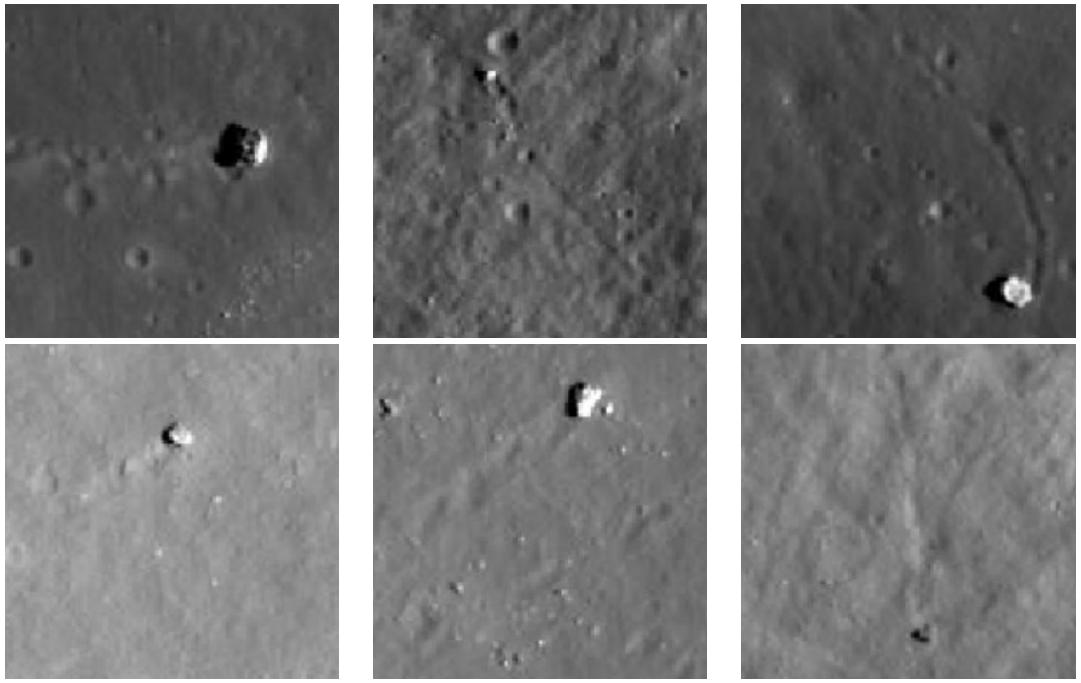
TR



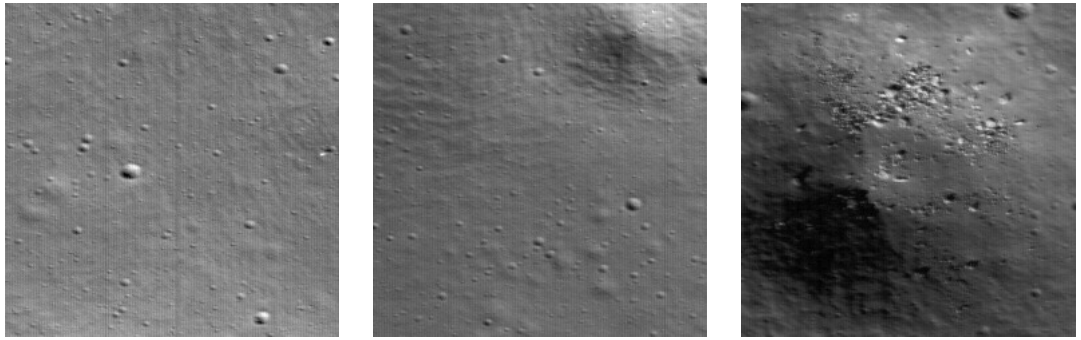


AI APPROACH

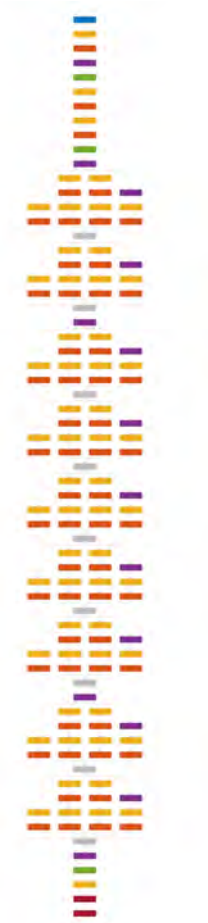
- Library of boulders with tracks

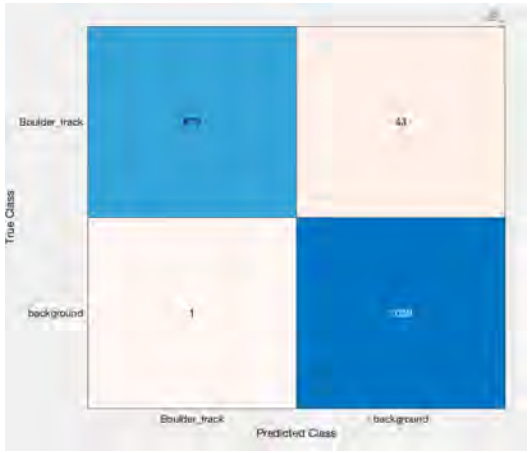


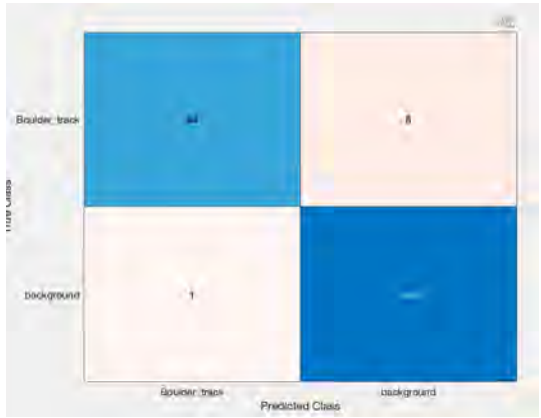
- Library of background images



A SIMPLE TEST WITH GOOGLENET







COMMENTS AND MY CONCLUSIONS

- The Moon is a fantastic laboratory to investigate many processes relevant for our understanding of geology.
- The accumulated datasets which we have from lunar missions is a rich field to investigate mass wasting processes.
- New missions which are being launched now very soon are going to provide abundant missing information.

- We have barely started to scratch the surface to understand many of the observed phenomena.

- AI in geomorphological investigations is a fantastic tool but we need to aware that it needs close collaboration between geologists, physicists, remote sensing scientists and the AI community.

- The existing boulder data catalogue of lunar rockfalls should be used with **uttermost** care.
- It is not true that AI is the only game in town to identify boulders in big data sets efficiently. Image analysis can do the job as well and should be used complementary.
- AI tools should not be used straight out of the box .