Lesson Plan

Comparing the surface of the terrestrial planets

Language(s): English

Domain: ICT>The Internet: searching and interpreting>Interpreting information, Science>Geography and Earth Science>Earth science>Geomorphologic phenomenon

Author(s)

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Description/ main idea

Using the same type of data and tools used by the planetary scientists, along this activity, students will experience the thrill of discovery while learning about the geological similarities and differences between the terrestrial planet's surface.

Students will use satellite images and topographic data to compare several geological landforms and feature that occur on Earth with those on the surface of the Moon, Mercury, Venus and Mars.

Phases & Activities

1. Activity 1 – Identification of geologic landforms using satellite images of surface of the terrestrial planets

Students will analyze a set of satellite images of the surface of different terrestrial planets. The analysis of these images will allow them to identify some geological structures and become familiar with the geological processes that originated them.

1.1 Preparation

Description

1. Ask the students to explore the surface of the terrestrial planets by observing and analyzing the image galleries available at the NASA website Solar System Exploration (if the class time available is limited, as an alternative, you can show them a compilation of satellite images of different geological landforms that occur on the terrestrial planet's surface – Supplementary Doc. 1).

2. Lead a brief discussion about the different types of geologic structures that can be observed from Space on the surface of the Earth, the Moon and other terrestrial planets. that can be studied from Space. Before starting the activity you may want to review the processes shaping the planetary surfaces (for a review see Carr et al., 1984 and Melosh, 2011).

3. Divide the class into groups. (*Tip: Each group of students may work as a team exploring the surface of a different planet.*)

Tools

Hardware Tools: Computer, Projector

Resources

Educational objects (as file):
1. Doc. 1

Duration

10 Minutes

1.2 Procedure

Description

1. Lead a brief discussion about the different geologic processes that create distinctive landforms or surface features. For example, circular depressions on a planet surface are easily identified as being

the result of the impact of asteroids, comets or meteorites. Use the NASA infography What's that Space Rock? to review the differences between those space bodies.

2. Take advantage of the discussion to ask the students how the geological structures identified by them on the images can be studied in more detail: from the surface or from space? (*Expected response: Both situations. Observations from Space allow the scientists to have an overview of a larger area, although with little detail, while the observations made from the surface allow detailed analysis of smaller areas.*)

3. Ask the students to explain the geological processes shaping the surfaces of the terrestrial planets and to mention the geologic landforms they create. The students should try to discover if those structures are identical when observed from Space or from the ground. (*Desired answer: Each geologic process is responsible for creating a specific landform/surface feature. Comparing the characteristics of those landforms with others, whose origin is known, one can deduce the origin of these structures. Moreover observation from the ground allows to have a three-dimensional perspective of the structures, while images obtained vertically from space are limited to two dimensions.*)

4. Hand-out copies of Student Worksheet 1. Student Worksheet 1 can be given as a homework assignment if you do not have enough class time. However, it is important to have the Discussion & Reflection as a class because the conversation will lead into Activity 2.

Tools

Software Tools: Web browsers
Hardware Tools: Computer

Resources

Educational objects (as file):
1. Student Worksheet 1

Duration

30 Minutes

1.3 Discussion & Reflexion

Description

1. Based on the observation and analysis of satellite images selected by the students one can ask them what they learned from those images and what are the advantages of using this method compared to the direct study on the ground. (Expected answer: Using satellite images scientists can study large geographical areas and have an overall perspective of the geological structures that occur on the surface of different planets. Some students may refer to economic and security issues regarding the deployment of robots and humans.). Students can also be encouraged to reflect on possible limitations of the exclusive use of images obtained by probes orbiting planets. (*Desired answer: In addition to the scale issues others like the*

lower resolution/quality/detail of the data obtained from Space by can be referred. Furthermore other necessary details to characterize the geological structures such as the altitude or the slope are not easily inferred from the analysis of two-dimensional images taken from Space.)

2. Ask the students what they learned about the geologic landforms other than just how to identify them (*Desired answers include: how landforms often relate to other features nearby and can be used to establish the chronological sequence of events and the geological history of a given area.*)

3. Explain to the students that this is how scientists studying other planets study the geologic processes operating on the surface of terrestrial planets. Students will use a similar approach throughout Activity 2 analysing topographic data obtained by different Space science missions.

Duration

10 Minutes

2. Activity 2 – Analysis of topographic data and comparison of geologic landforms and features on the surface of the terrestrial planets

The students will analyze topographic data from the surface of several terrestrial planets. The analysis of these data will allow them not only to identify some geological landforms and features, but also make quantitative analysis of some morphological characteristics of the planetary surfaces. The students will have the opportunity to visualize those structures (namely, impact craters and volcanic features) in 3D images, including anaglyphs that can be observed using glasses with red and blue lenses.

2.1 Preparation

Description

1. Download and install the free software Mirone (http://w3.ualg.pt/~jluis/mirone/) e iView4D (http://www.qps.nl/display/fledermaus/iview) needed for the students analyze and visualize the topographic data.

2. Download the topographic data and images needed for this activity (Supplementary Doc. 5). Some of these files are quite large, thus is essential to do this task before the class.

3. Divide students into groups and give them the files with the topographic data. (*Tip: Each group may work as a team exploring the surface of a different planet.*)

Tools

Software Tools: Web browsers
Hardware Tools: Computer

Resources

Educational objects (as file):
1. Doc. 2

2.2 Procedure

Description

1. Lead a discussion about the types of geological landforms and features that are more easily identifiable by exploring the satellite images used during the Activity 1 (*Desired answer: impact craters and volcanic features*).

2. Ask the students to think about the reason beyond the use of different technologies to obtain topographic data of the surface of the terrestrial planets (Supplementary Doc. 3). (*Desired answer: On Venus and Earth were used Radar images because of their thick atmospheres that prevent or hinder the use optical systems, such as the laser altimeters used on the Moon,*

Mercury and Mars that have very thin atmospheres).

Usually, female students are less enthusiastic with these kind of activities, but they can be encouraged to be more active enhancing the role of female scientists, like Maria T. Zuber, in the production and analysis of topographic data obtained with laser altimeters. That researcher led the team of scientists that recently published, in the prestigious Science magazine, the first results obtained from the laser altimeter aboard the MESSENGER spacecraft that continues to orbit the planet Mercury (Supplementary Doc. 4).

3. Ask the students to explore, autonomously, the topographic data (digital elevation models of the different terrestrial planets surfaces). Using the software Mirone they can identify geologic features, such as impact craters and volcanoes. The students will discover very quickly that those structures have different characteristics on the surface of each terrestrial planet (Supplementary Doc. 5 and 6 present a summary of the morphological characteristics of those geologic landforms).

4. A digital elevation model is a grid of georeferenced data (Supplementary Doc. 7) and that allows the students to explore them in more detail by comparing different types of impact craters and volcanoes. They can use the software capabilities such as shaded illumination, creating topographic profiles (Supplementary Doc. 8), measuring distances, heights, slopes and areas. Students can also explore the data interactively through 3D visualizations of those geologic structures (Supplementary Doc. 9), including features such as 360°rotation and vertical exaggeration and zooming of the images.

5. If you still have enough class time the students, with a single mouse click, can produce 3D anaglyphs (that can be visualized using glasses with red and blue lenses – Supplementary Doc. 10). The students usually like this activity because wearing these glasses it is quite fun.

If the school has a 3D printer the students also can produce 3D models of the geologic structures they are studying. That will allow that students with special needs (e.g. blind students) to explore the surface of the terrestrial planets using the touch.

6. Before the end of the class each group of students should present a summary of their conclusions and what they learned along this activity to the remaining students.

Tools

Software Tools: Presentation software Computer applications (Mirone | iView4D)
Hardware Tools: Computer, Projector

Resources

Educational objects (as file):
1. Doc. 3
2. Doc. 4

3. Doc. 5
4. Doc. 6
5. Doc. 7
6. Doc. 8
7. Doc. 9
8. Doc. 10

Duration

2 Hours

2.3 Discussion & Reflexion

Description

1. Ask the students what they learned from the analysis and visualization of the digital elevation models. Students should be encouraged to mention the advantages of using topographic data as a complement of the satellite images used during Activity 1. (*Desired answer: Students should refer to the possibility to explore in more detail other characteristics of the geologic structures, relating them to the processes that originated them. This allows scientists to reconstruct the geological history of the areas that they are studying*).

2. The discussion should be conducted so that the students come to the conclusion that the same geological processes that shape the Earth's surface also operate on the surface of other terrestrial planets generating geologic structures similar to those that can be seen on our planet. Students can also explore the relationship between the number of impact carters on a planetary surface and its relative age (Baldwin, 1964 and Supplementary Doc. 11). While analyzing volcanic landforms the students can also make correlations between the shape of volcanoes and the viscosity of their lavas.

3. Explain to students that it is through a similar approach and using the same type of scientific evidence that planetary scientists study and try to understand the geologic processes that shape the surface of terrestrial planets and try to reconstruct its geological history.

Resources

Educational objects (as file):
1. Doc. 11

Duration

20 Minutes

3. Activity 3 - Assessment

Strategies to verify what the students learned during and after Activity 1 and 2.

3.1 Self-assessment and hetero-evaluation

Description

The assessment of the activities undertaken by the students can be done through a global discussion about what they learned about this subject. As an alternative you may ask the students to make an oral or a poster presentation with a summary of the work they have done.

4. Recommended bibliography

See List of bibliographic references.

4.1 List of bibliographic references

Description

Baldwin, R. B. (1964) Lunar crater counts, Astronomical Journal, Vol. 69, N.º 5, 377-392, doi:10.1086/109289.

Carr, M. H. et al. (1984) The Geology of the Terrestrial Planets, NASA Special Publications, NASA-SP-469, 327p. (http://ntrs.nasa.gov/search.jsp?R=19850010579)

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Spray, J. G. (2002) Planetary science: Impacts in the round, Nature, 418, 487-488, doi:10.1038/418487a

Tran, T. et al. (2010) Generating digital terrain models using LROC NAC images, ASPRS/CaGIS/ISPRS/AutoCarto Fall Conference Proceedings.

Wieczorek, M. A. (2007) Gravity and topography of the terrestrial planets, Treat. on Geophysics, 10, 165-206, doi:10.1016/B978-044452748-6.00156-5.

Zuber, M.T. et al. (2012) Topography of the northern hemisphere of Mercury from MESSENGER laser altimetry, Science, 336, 6078, 217-220, doi: 10.1126/science.1218805.

Learning objectives
Cognitive - Process:
To understand: The students should be able to understand and describe different methods of explore and study the geomorphology of Earth's and other terrestrial planet's surface.

To think critically and creatively: The students should be able to: a) identify the main geologic processes shaping the planetary surfaces using satellite images and topographic data; b) explain how those data, obtained by remote sensing using satellites and space probes, can be used to study geologic landscapes and features on the surface of the terrestrial planets and help to determine the geologic history of a given area using those methods.

Grade & Age
15-18 years old

Keywords/subject
Planetology, geomorphology; digital elevation models, volcanism/volcanoes, impactism/impact craters

Structure
Linear

Interactivity Type
Active

Interactivity Level
High

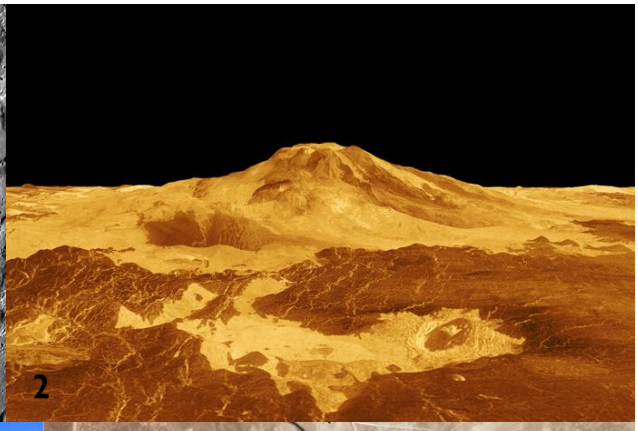
Semantic Density
—

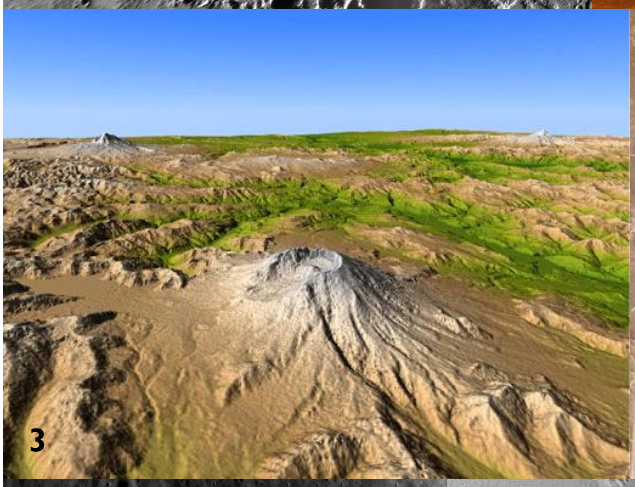
Cost
Use is free of charge

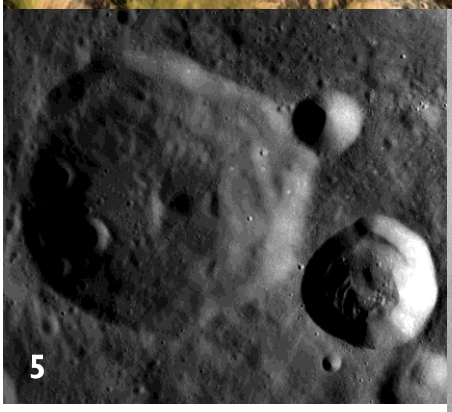
Copyright
No

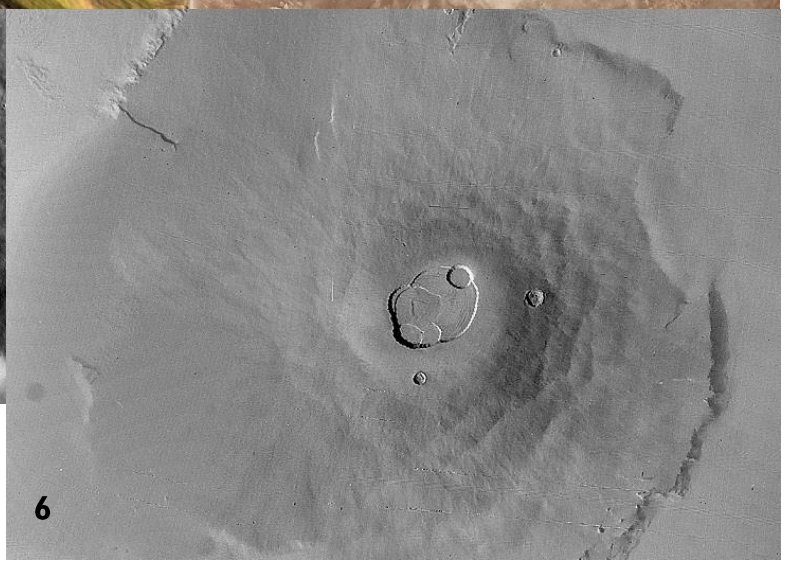
Comparing the surface of the terrestrial planets

Doc. 1 | Geological landforms on the surface of the terrestrial planets









1. Rembrandt impact basin (Mercury); 2. Maat Mons volcano (Venus); Mount St. Helens volcano (Earth); 3. Barringer impact crater (Earth); 4. Dante impact crater (Moon); 6. Olympus Mons volcano (Mars).

Images credits: 1. NASA/JHUAPL/Smithsonian Institution/Carnegie Institution of Washington; 2. NASA/JPL; 3. NASA/JPL-Caltech; 4. U.S. Geological Survey; 5. NASA/GSFC/Arizona State University; 6. NASA/MSSS.

Comparing the surface of the terrestrial planets
Activity 1 – Observation of geological landforms using satellite images

Your team elements:

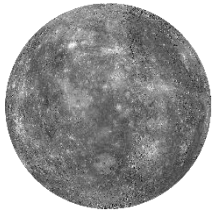
The geological processes which act on the surface of terrestrial planets can generate different landforms and structures that are studied by planetary scientists using various methods including satellite image analysis. Based on the exploration of the Solar System you did select some images taken by NASA that allow o identify those geological structures and the geological process that originated them.

Photo 1	Photo 2	Photo 3
Planet: Type of structure: Geologic process:	Planet: Type of structure: Geologic process:	Planet: Type of structure: Geologic process:

Photo 4	Photo 5	Photo 6
Planet: Type of structure: Geologic process:	Planet: Type of structure: Geologic process:	Planet: Type of structure: Geologic process:

Comparing the surface of the terrestrial planets

Doc. 2 | Topographic data (digital elevation models)



Mercury | MLA GDRs
http://pds-geosciences.wustl.edu/missions/messenger/mla.htm

Venus | MGN GTDR
ftp://pdsimage2.wr.usgs.gov/pub/pigpen/venus/Radar_properties/

Earth:

SRTM DEM
http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp

GMRT
http://www.marine-geo.org/tools/maps_grids.php

Bathymetry and Global Relief
http://www.ngdc.noaa.gov/mgg/bathymetry/relief.html

Open Topography
http://www.opentopography.org/index.php

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Doc. 2 | Topographic data (digital elevation models)

Moon:

LRO LOLA GDRs

http://pds-geosciences.wustl.edu/missions/lro/lola.htm

LROC NAC DTM

http://wms.lroc.asu.edu/lroc/rdr_product_select#_ui-id-6

Mars:

MOLA MEGDRs

http://pds-geosciences.wustl.edu/missions/mgs/megdr.html

HRSC DTMs

http://hrscview.fu-berlin.de/cgi-bin/ion-p?page=entry2.ion

HiRISE DTMs

http://www.uahirise.org/hiwish/maps/dtms.jsp

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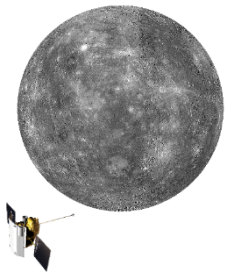
Comparing the surface of the terrestrial planets

Doc. 3 | Technologies used in missions that obtained topographic data

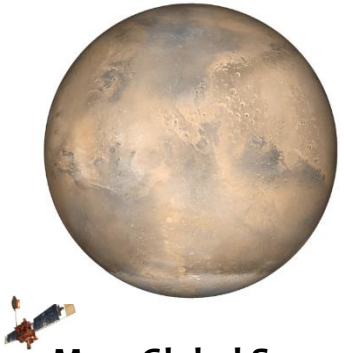


Messenger
MLA GDRs
Laser altimeter

Magellan
MGN GTDR
SAR (Synthetic Aperture Radar)

Shuttle Radar Topography Mission
SRTM DEMs
SAR (Synthetic Aperture Radar)

Lunar Reconaissance Orbiter
LOLA GDRs
Laser altimeter



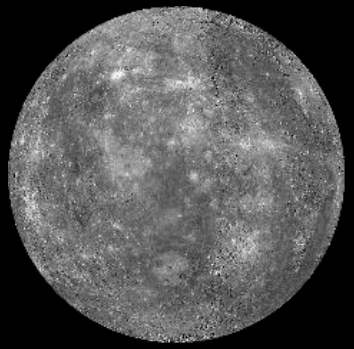
Mars Global Surveyor
MOLA MEGDRs
Laser altimeter

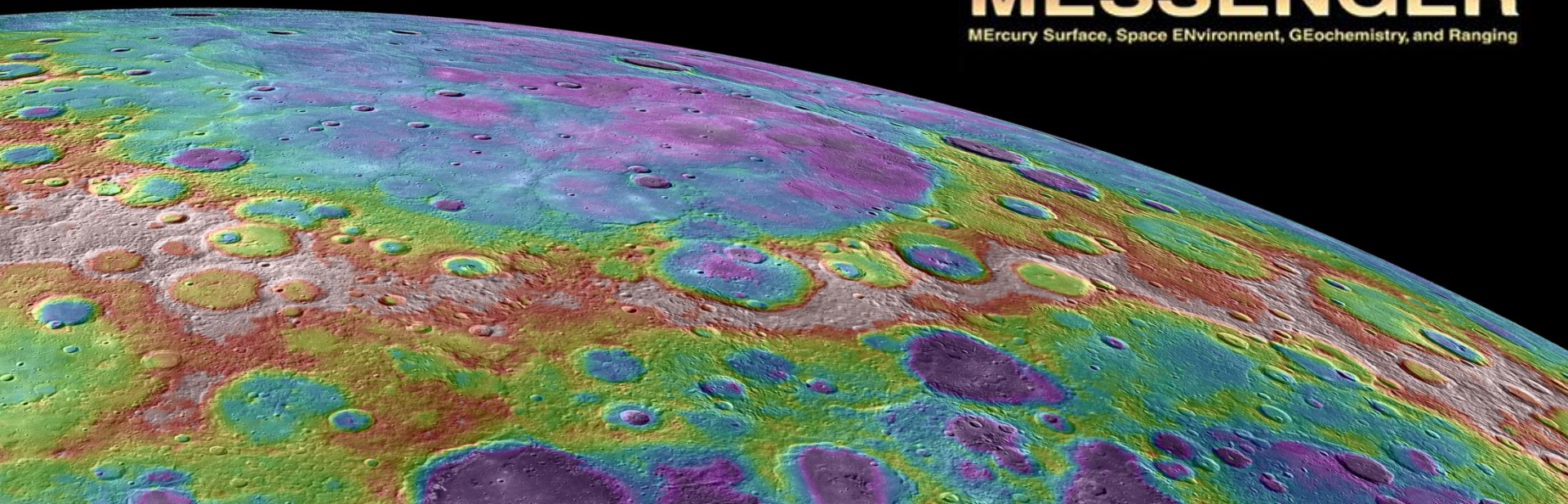
Comparing the surface of the terrestrial planets

Doc. 4 | Scientists leading the research about other planets characteristics

Maria T. Zuber

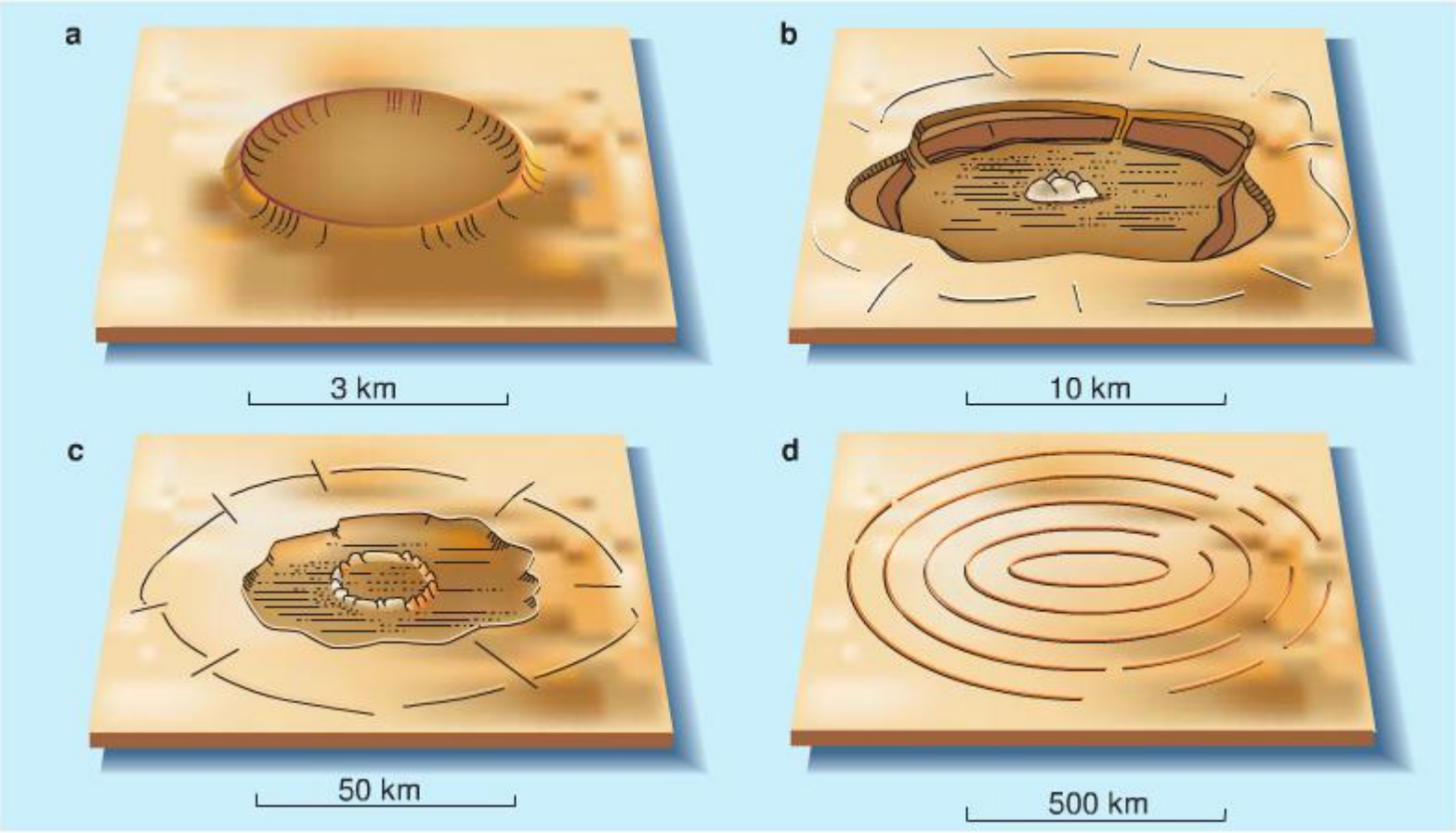
Zuber, M.T. et al. (2012) Topography of the northern hemisphere of Mercury from MESSENGER laser altimetry, Science, 336, 6078, 217-220, doi: 10.1126/science.1218805.





Comparing the surface of the terrestrial planets

Doc. 5 | The main types of impact structures

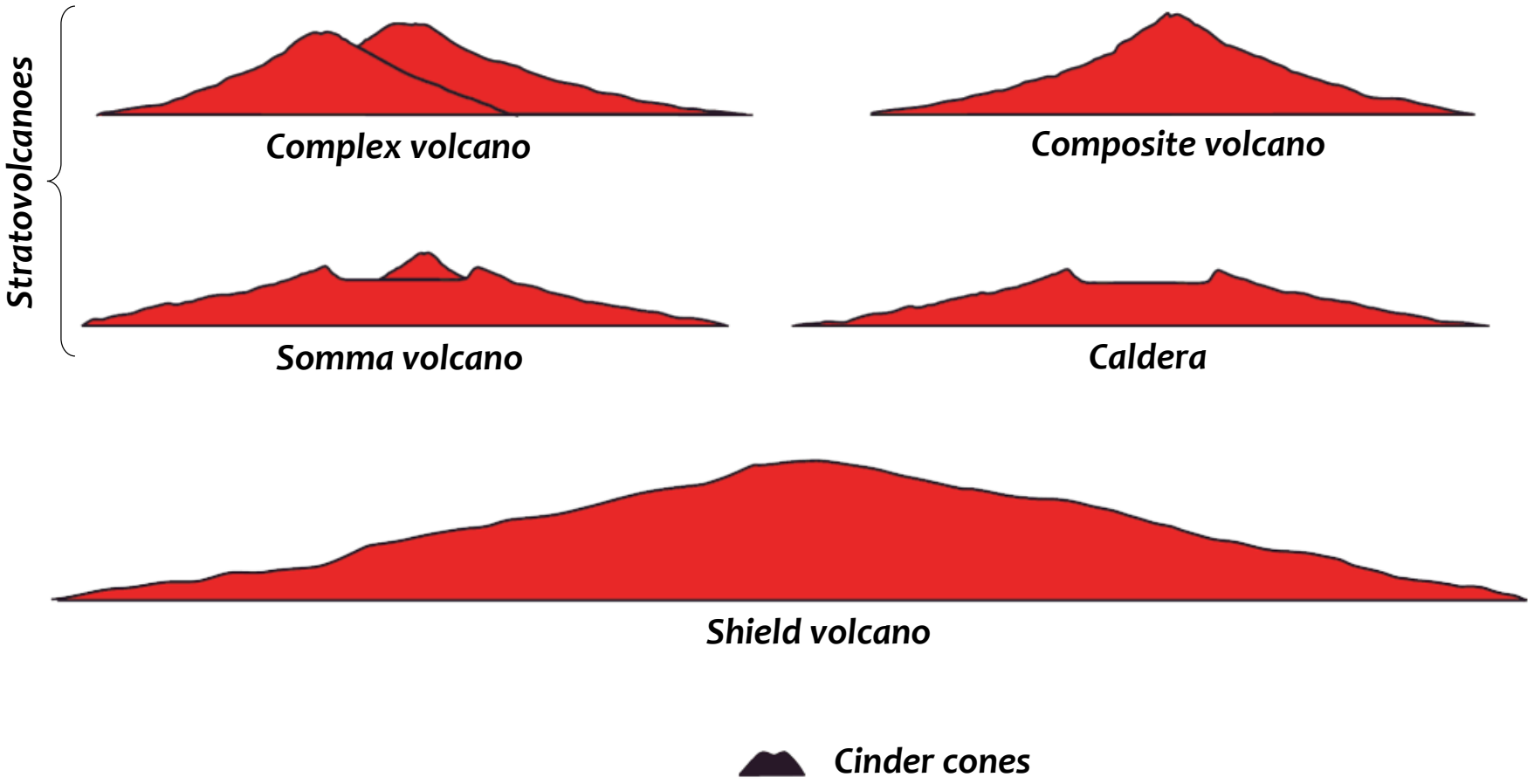


The main types of impact structure, as currently defined from studies of the Earth and Moon. **a,** At the smallest scale is the simple bowl-shaped crater. **b–d,** At larger scales, more complex structures are evident. **b,** Central peak; **c,** peak ring; **d,** multi-ring.

Image credit: Spray (2002)

Comparing the surface of the terrestrial planets

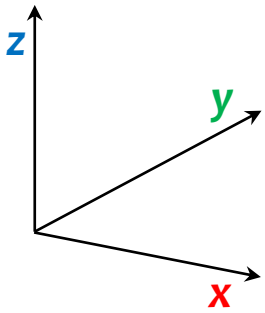
Doc. 6 | Main types of volcanoes on Earth



Types of volcanoes (Simkin and Siebert, 1994). Schematic profiles are vertically exaggerated by 2:1 (red) and 4:1 (dark) from the data of Pike (1978). Relative sizes are only approximate, as dimensions vary within each group.

Comparing the surface of the terrestrial planets

Doc. 7 | Digital elevation models (DEM)



Matrix of georeferenced topographic data

x = longitude, y = latitude, z = altitude or depth

430	420	410	390	370	350	360	365	370	375	380
420	410	390	370	350	360	365	365	370	375	380
410	420	410	390	360	350	355	365	370	380	390
420	410	400	390	370	350	360	365	370	380	390
420	410	390	380	370	355	350	360	365	370	380
410	400	380	370	360	350	360	365	370	375	380
390	395	400	390	370	340	350	360	370	380	380

z Value

DEM extension in latitude (y)

DEM extension in longitude (x)

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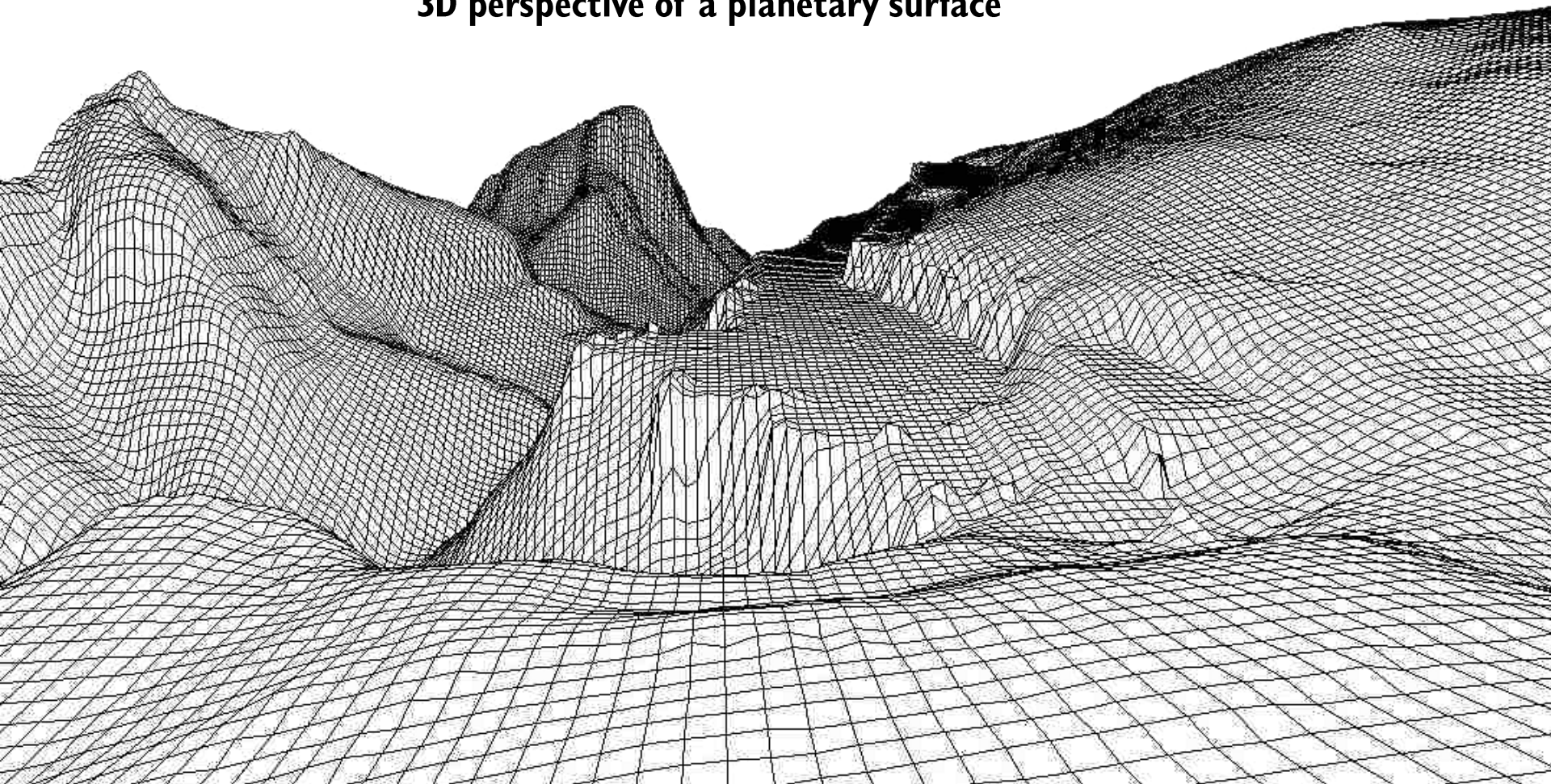
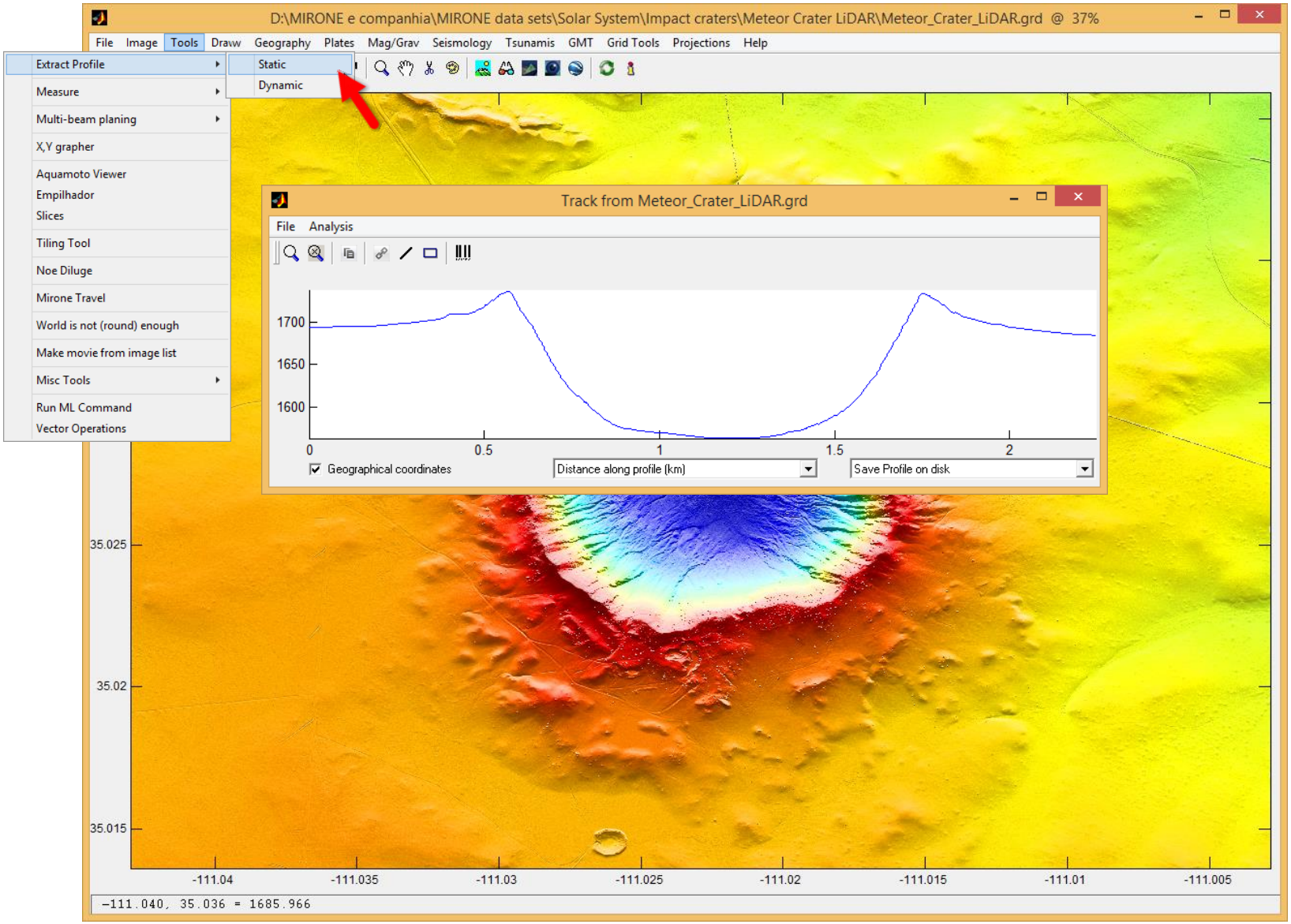
Doc. 7 | Digital elevation models (DEM)

3D perspective of a planetary surface



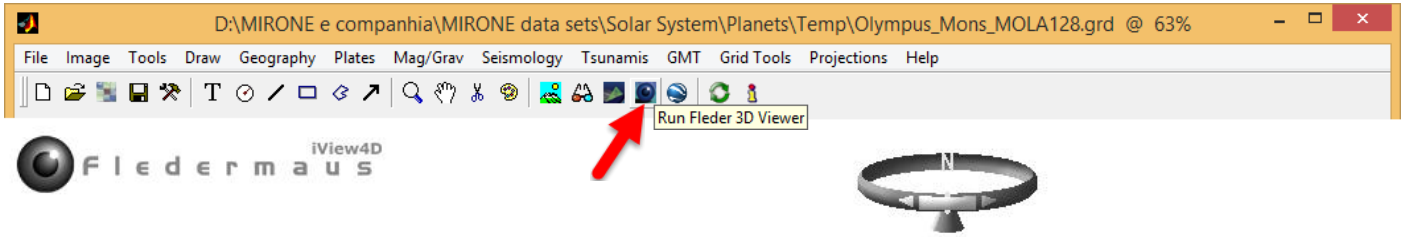
Comparing the surface of the terrestrial planets

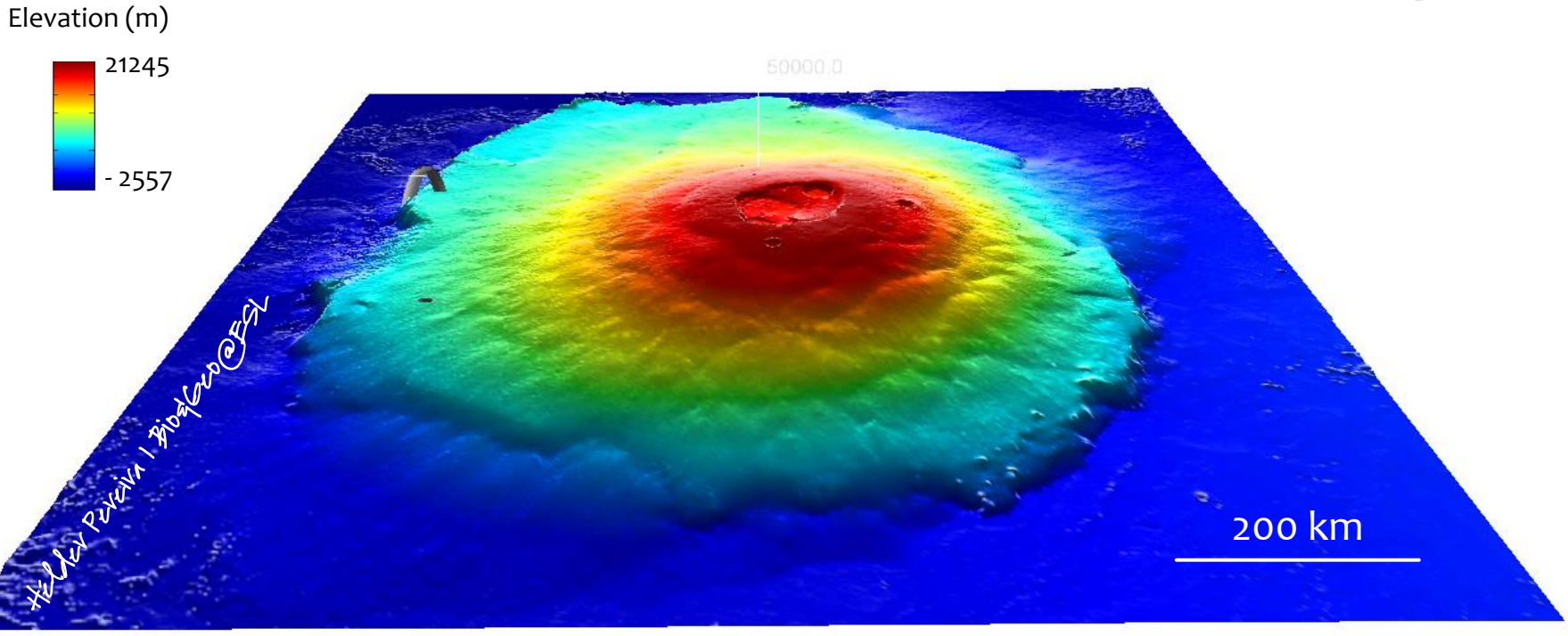
Doc. 8 | Creating topographic profiles



Comparing the surface of the terrestrial planets

Doc. 9 | Visualizing planetary surfaces in 3D

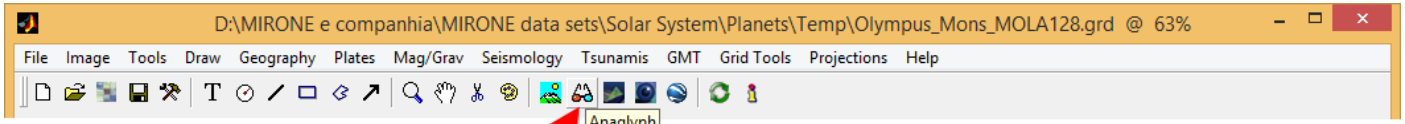


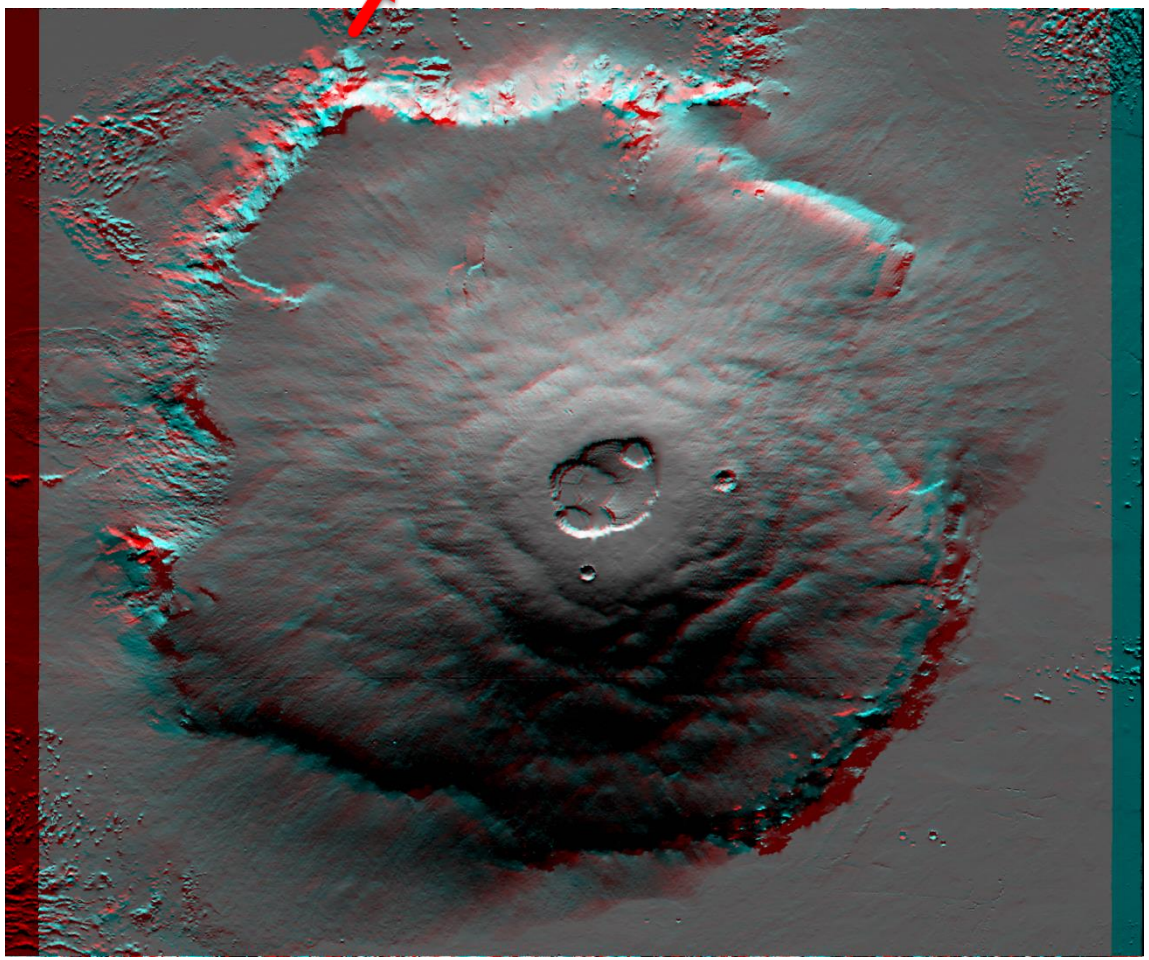


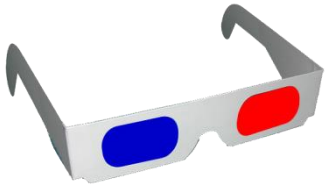
3D topography of the Olympus Mons volcano (VE = 3,5 x) | Mars
Data: Mars Global Surveyor MOLA MEGDR 128

Comparing the surface of the terrestrial planets

Doc. 10 | Creating 3D anaglyphs







3D anaglyph image of the Olympus Mons volcano | Mars
Data: Mars Global Surveyor MOLA MEGDR 128

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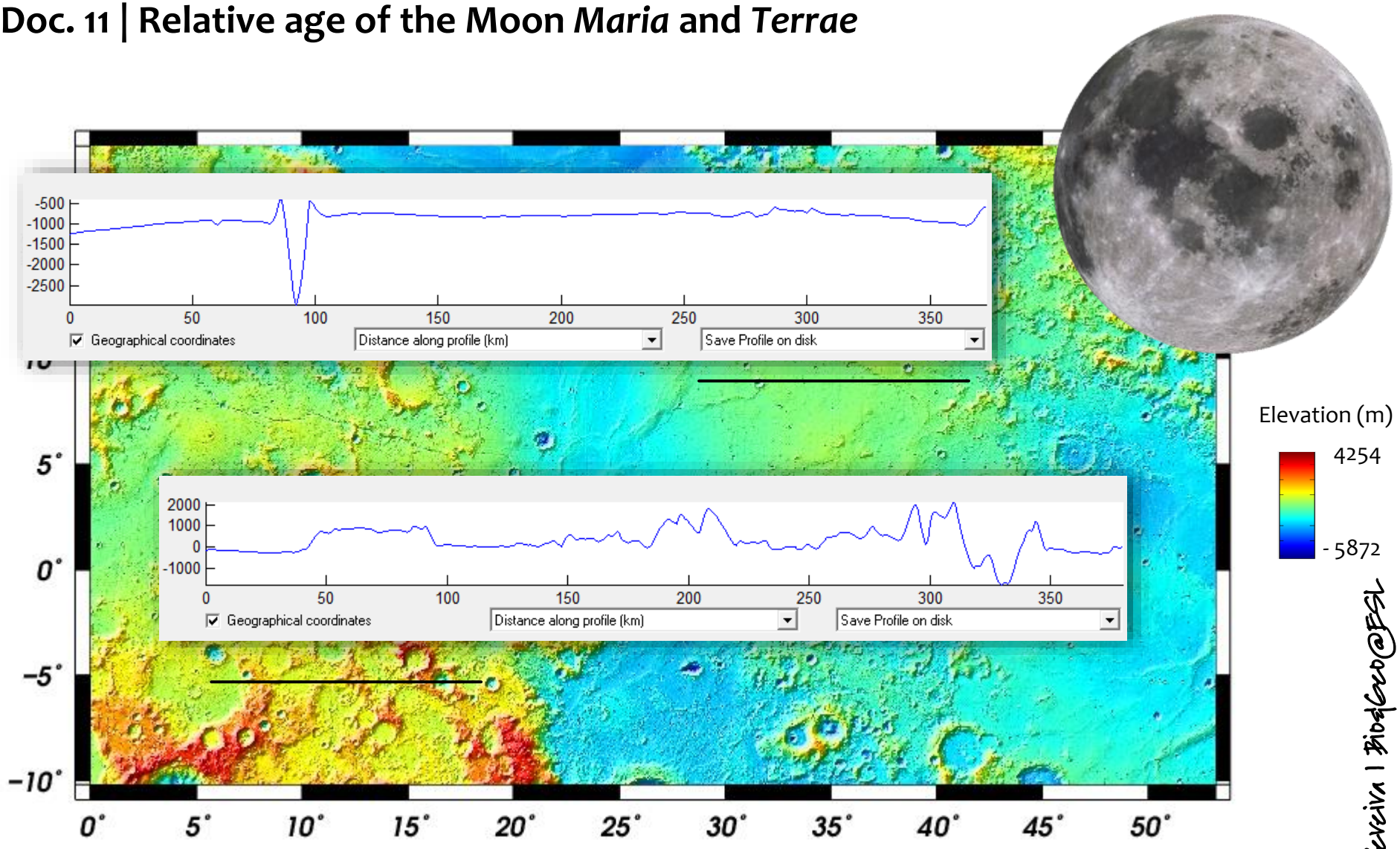
Doc. 11 | Relative age of the Moon *Maria* and *Terrae*



Topographic map of *Terra Sanitatis* and *Mare Tranquilitatis* | Moon
Data: LRO LOLA DEM 16

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