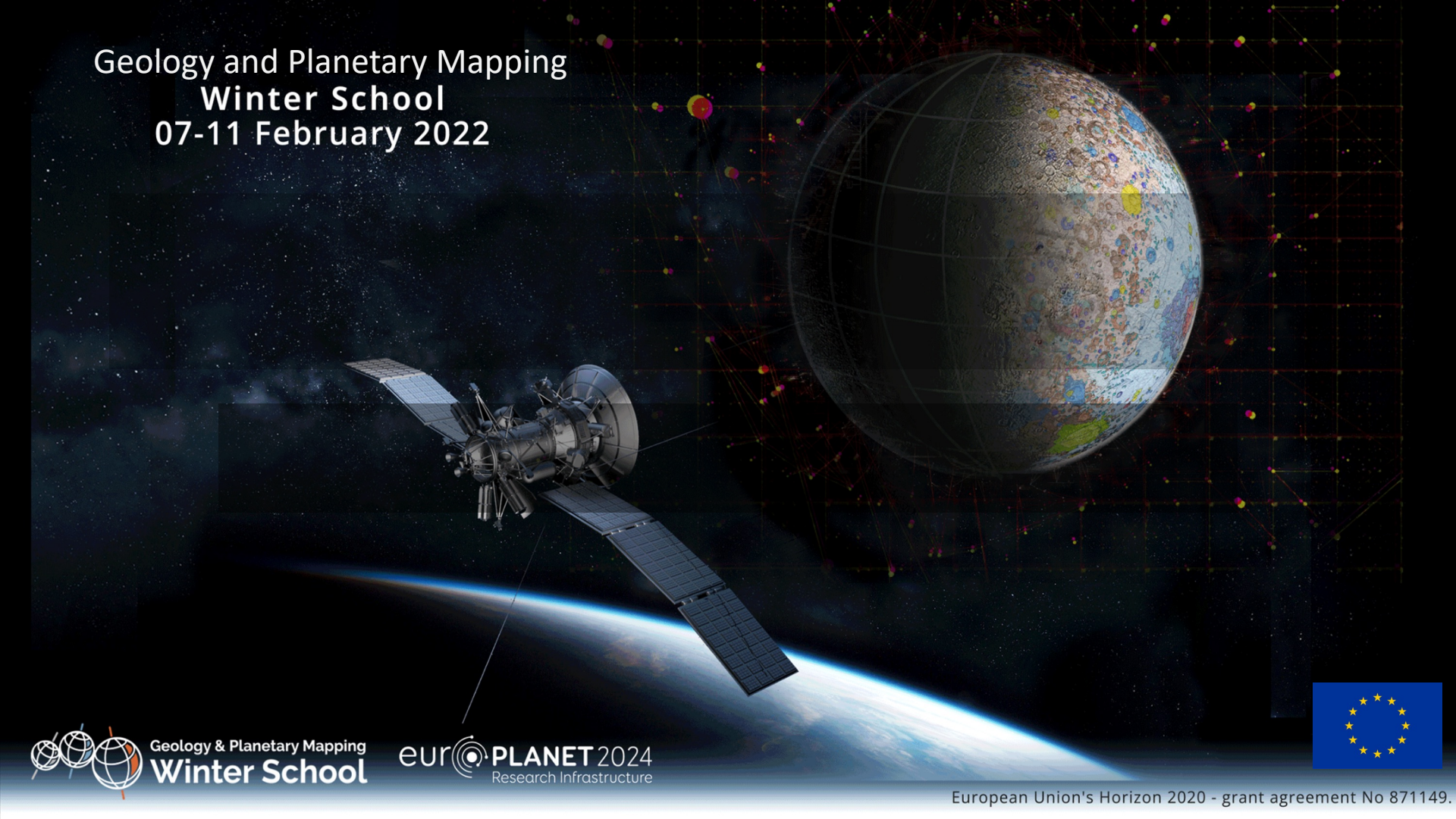

europlanet 2024
Research Infrastructure



Geology & Planetary Mapping Winter School

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European Union's Horizon 2020 - grant agreement No 871149.

Geology and Planetary Mapping
Winter School
07-11 February 2022

Creating geological cross sections

Matteo Massironi and Riccardo Pozzobon

Università degli Studi di Padova

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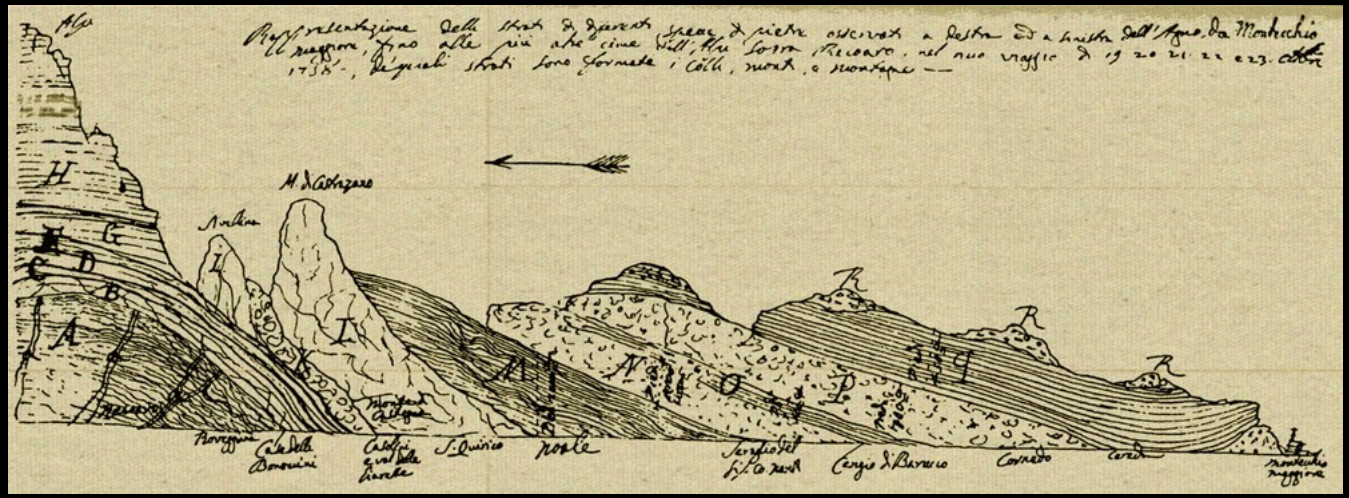
The first geological section



Giovanni Arduino (1758)

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William Smith (1815)

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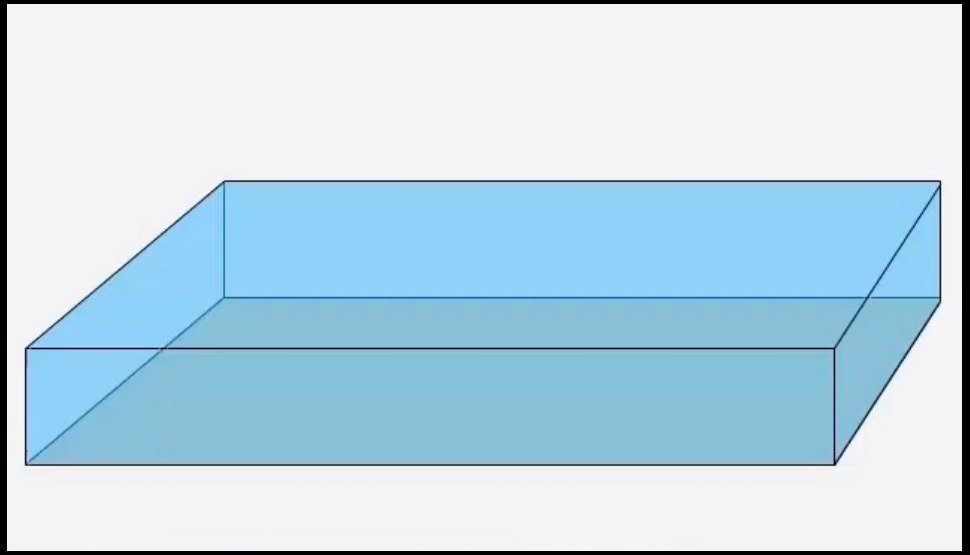
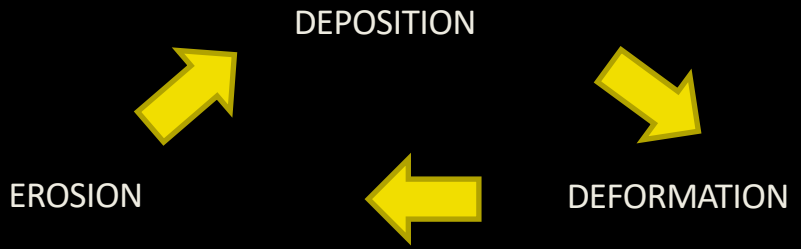
Geologic process





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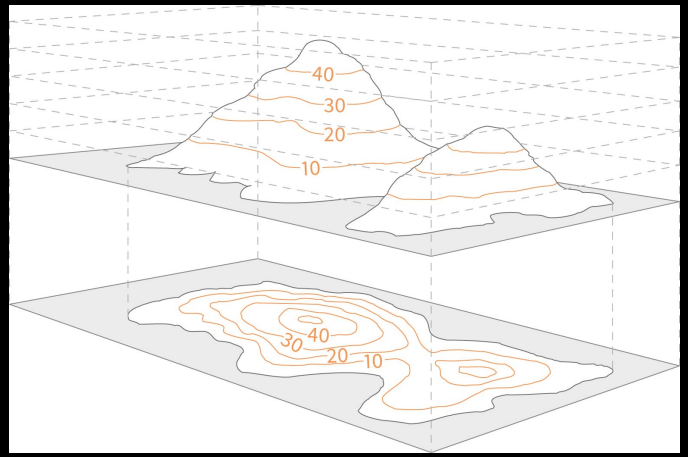
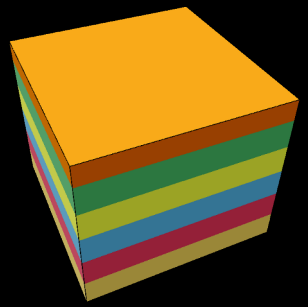
From geologic processes to geologic maps

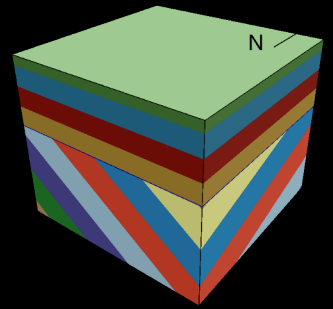


Source: ordnancesurvey.co.uk



DEPOSITION

DEFORMATION



EROSION
(and redeposition)

Visible Geology
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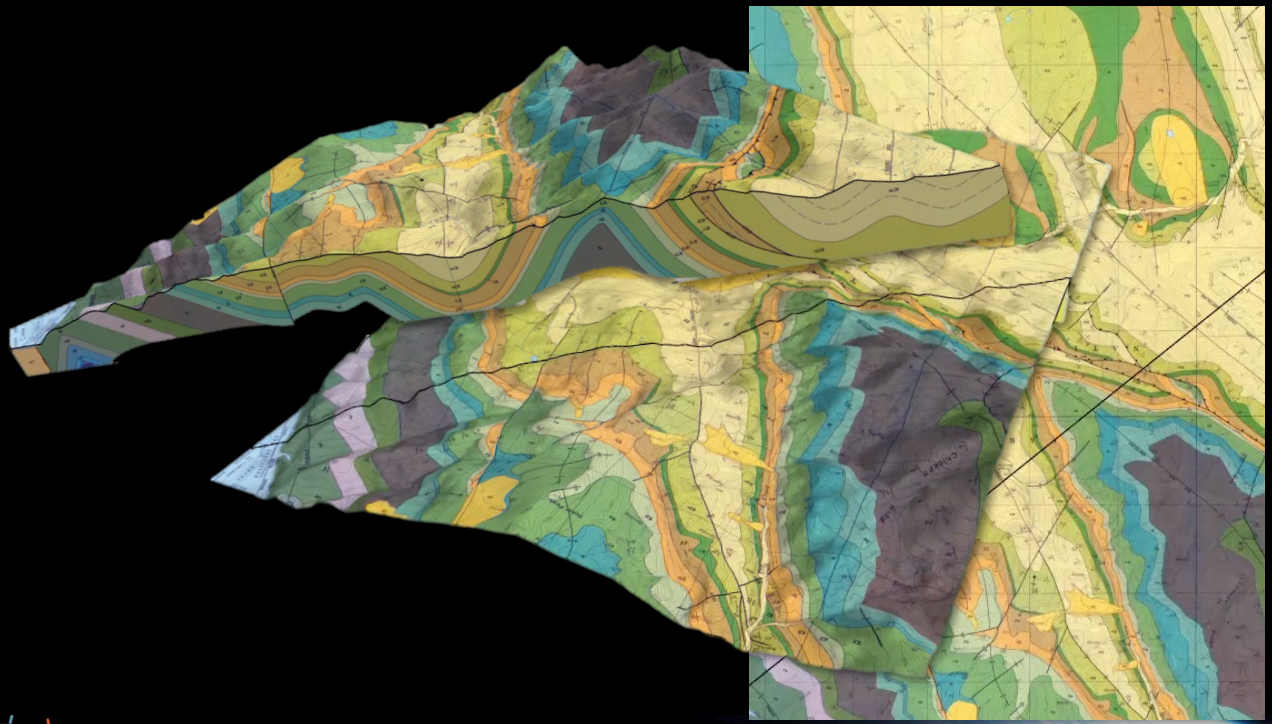
From geologic processes to geologic maps



A geologic map is the 2D representation of the interaction between

- Topography
- Geological contacts

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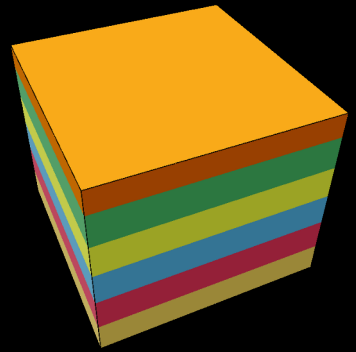
Horizontal contacts

Grand Canyon, Arizona



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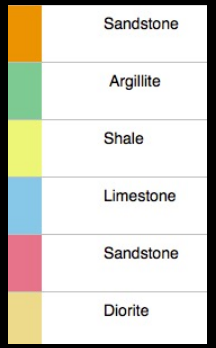
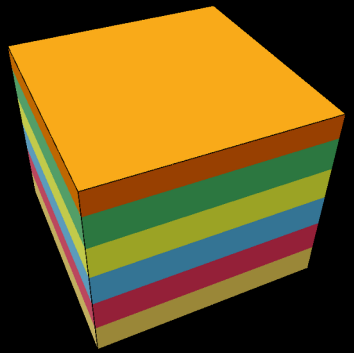
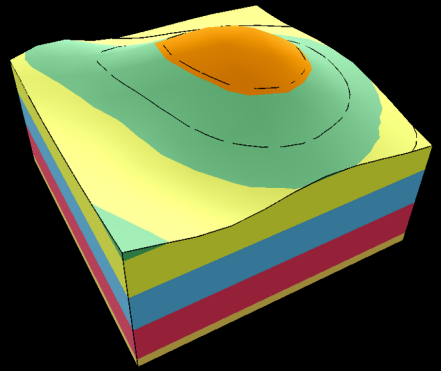
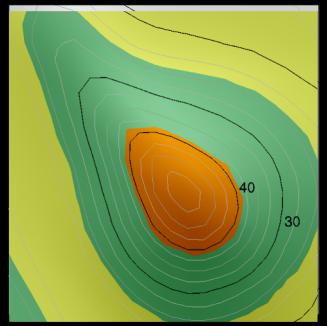
Horizontal contacts in map view









Horizontal contacts follow contour lines

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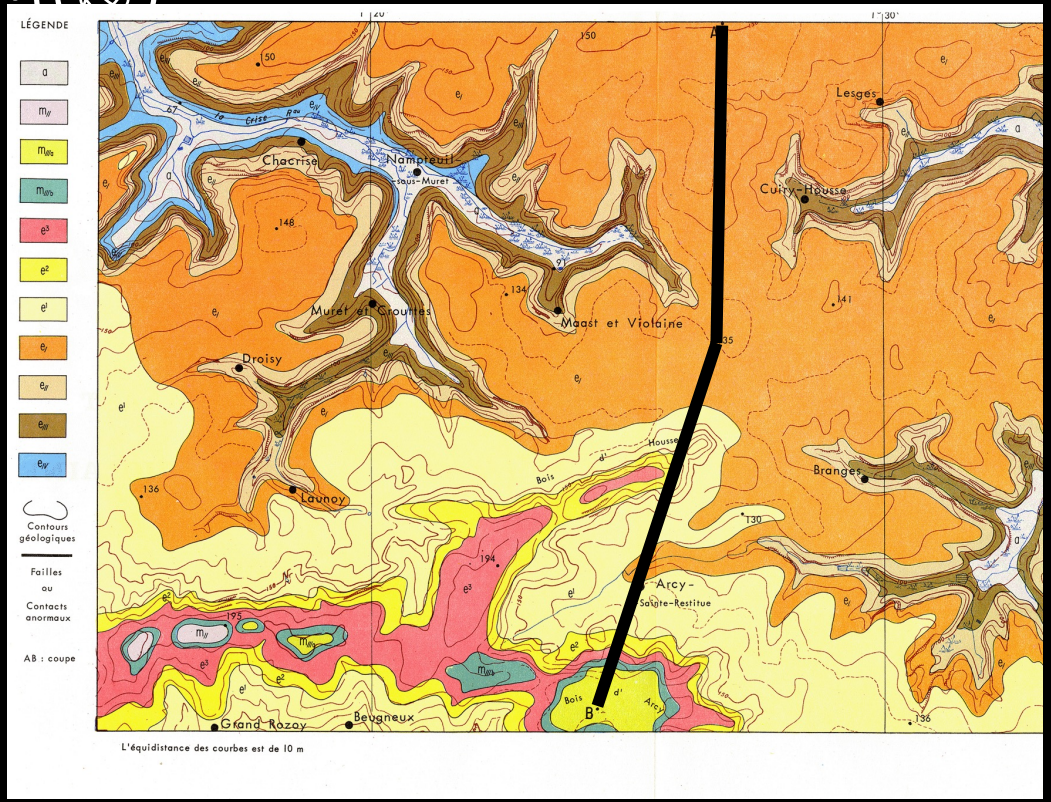
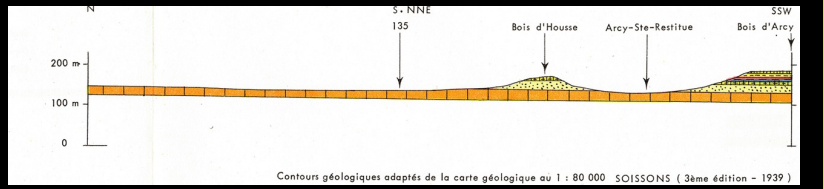
Geological map on a horizontal series





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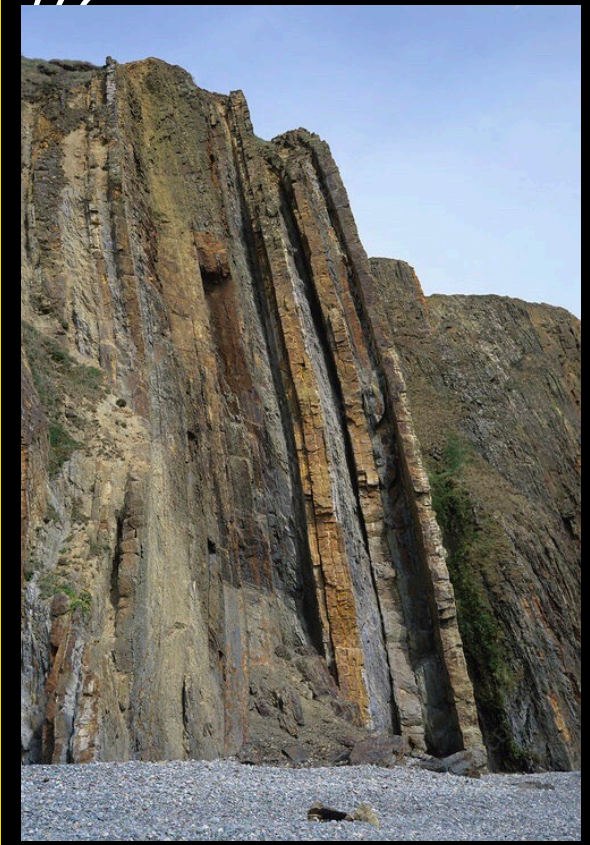
Vertical contacts



Type of geologic environments

- Magmatic intrusions
- Tectonic deformations

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Vertical contacts and topography

Martin crater, Mars

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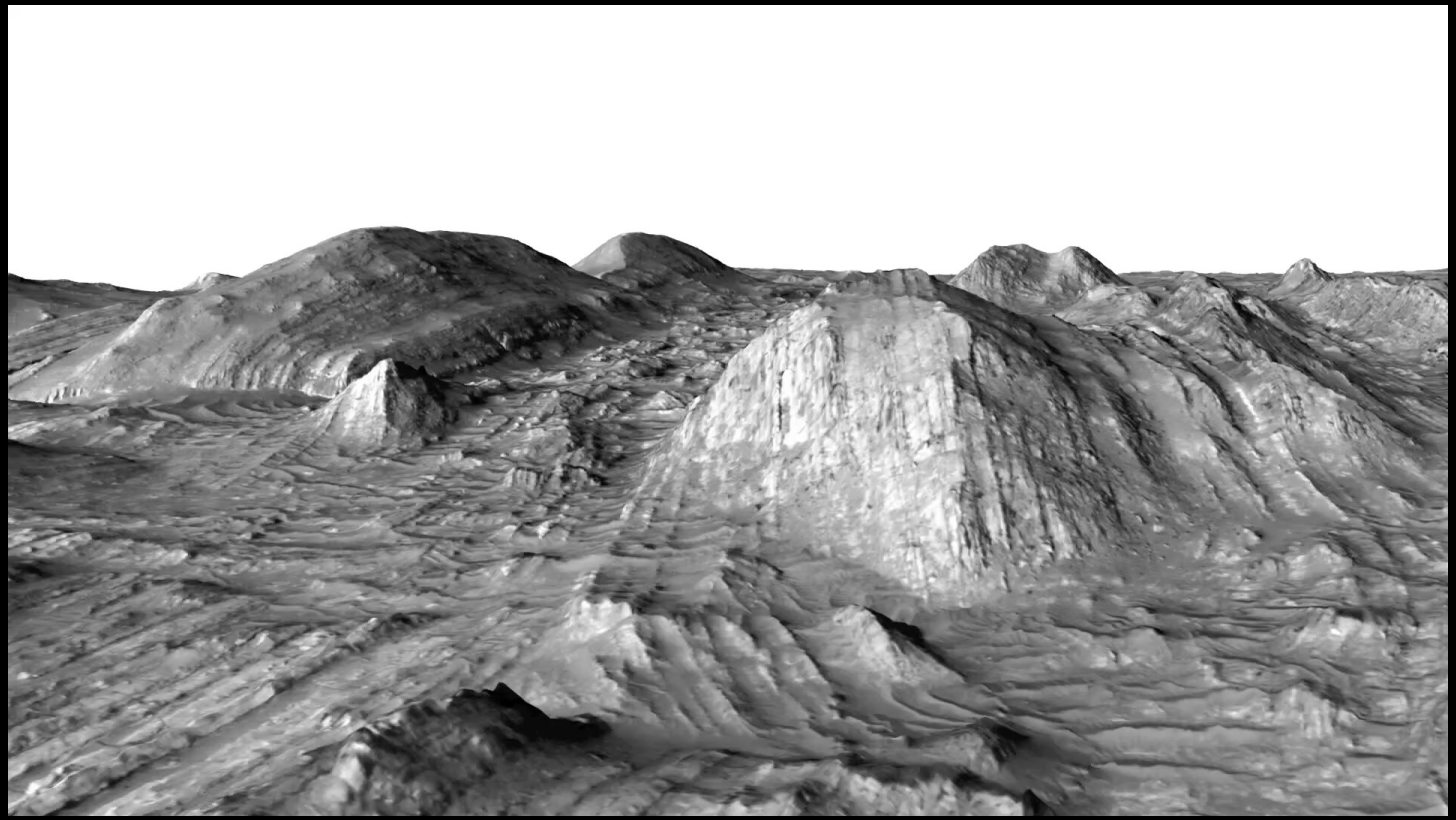
Vertical contacts and topography



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Vertical contacts and topography

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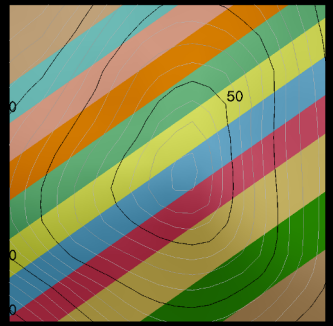
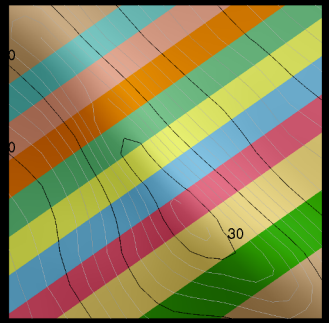
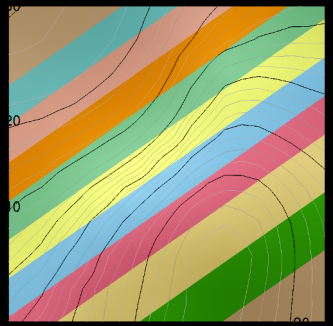
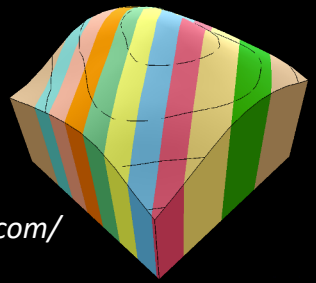
Vertical contacts

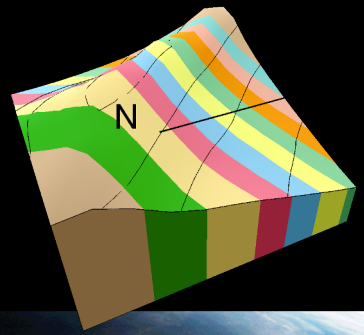


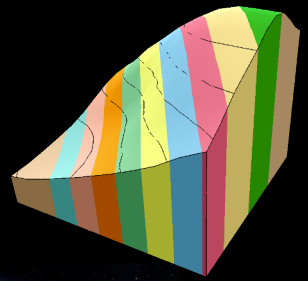




Vertical contacts/strata ignore contour lines







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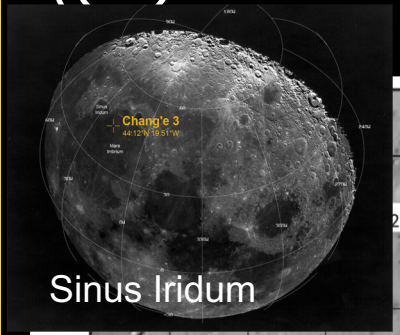
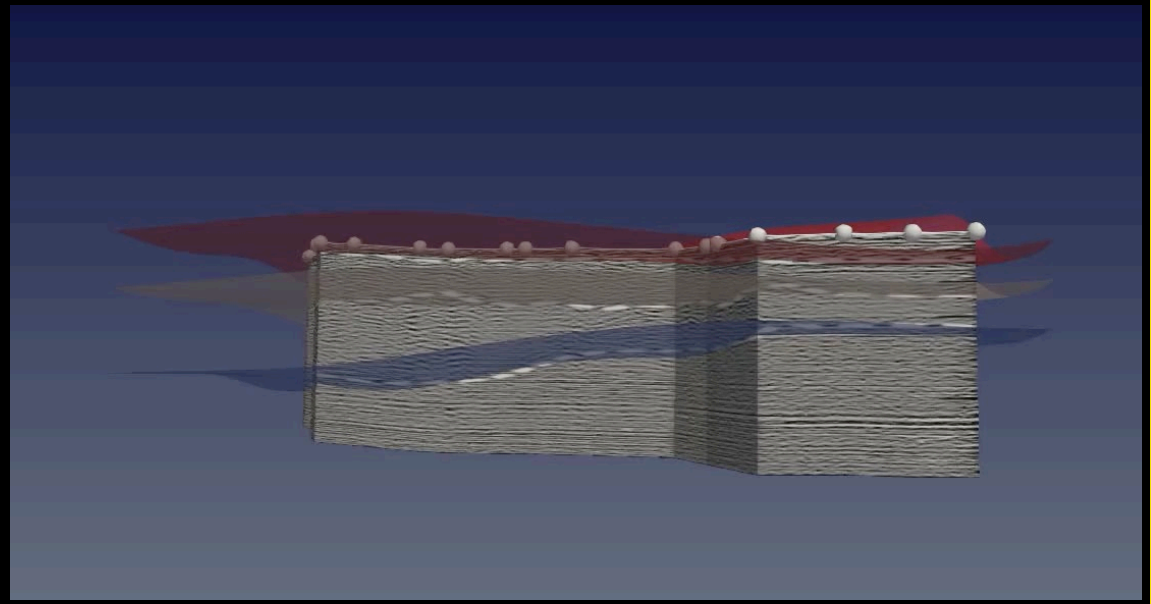
GMAP
Geological Mapping

Good news for some airless bodies planetary sub-surfaces





Penasa et al. in prep

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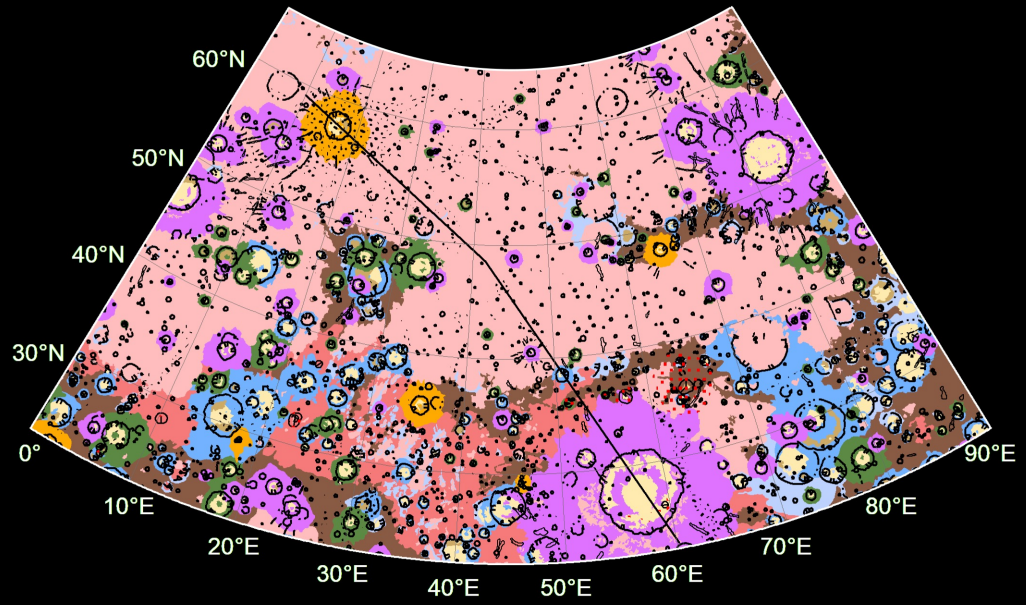
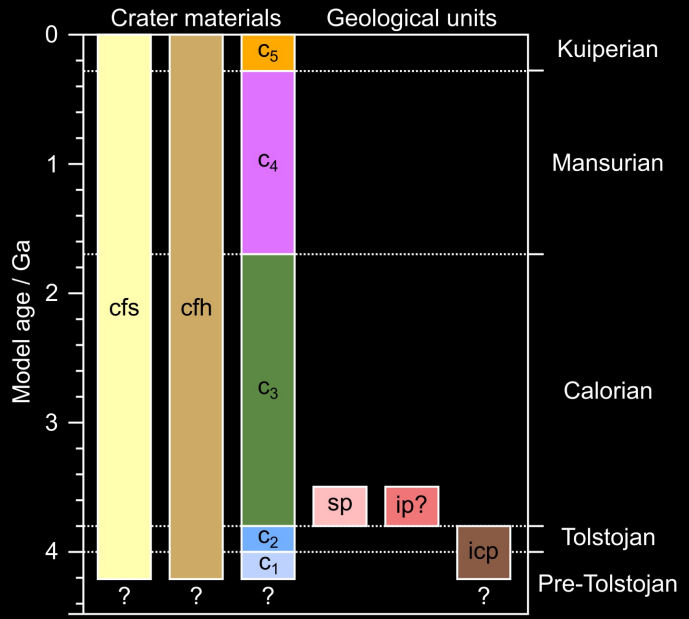
Planetary geological maps: Hokusai quadrangle





Wright et al. (2019)

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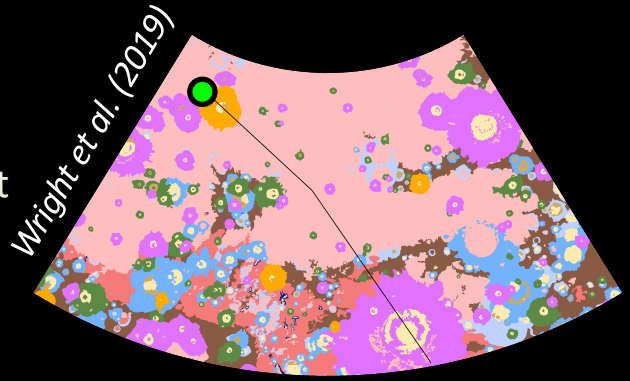
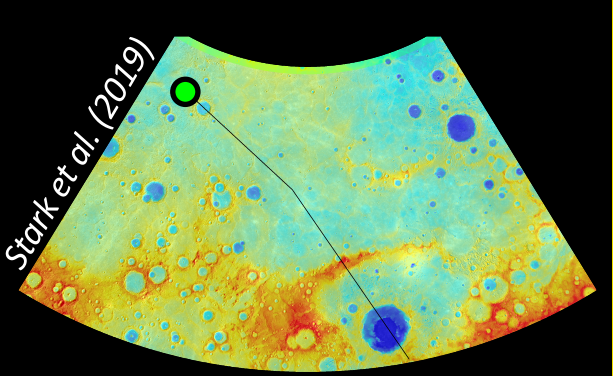
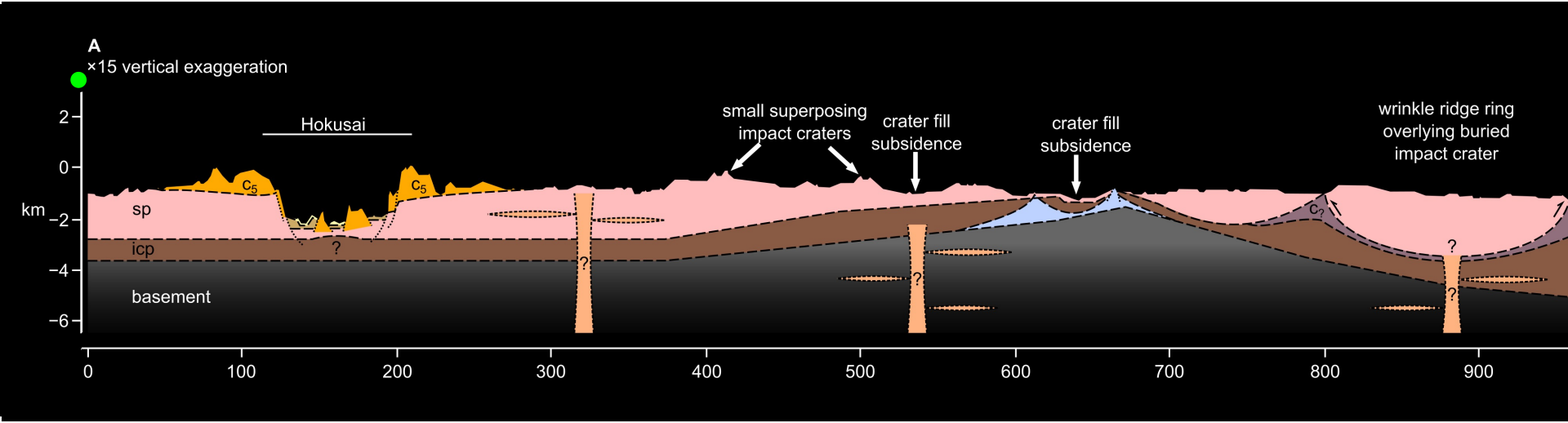
Cross section

Most planetary geological sections (and maps) are dominated by almost horizontal contacts and inferred vertical volcanic dikes.

Wright et al. (2019)







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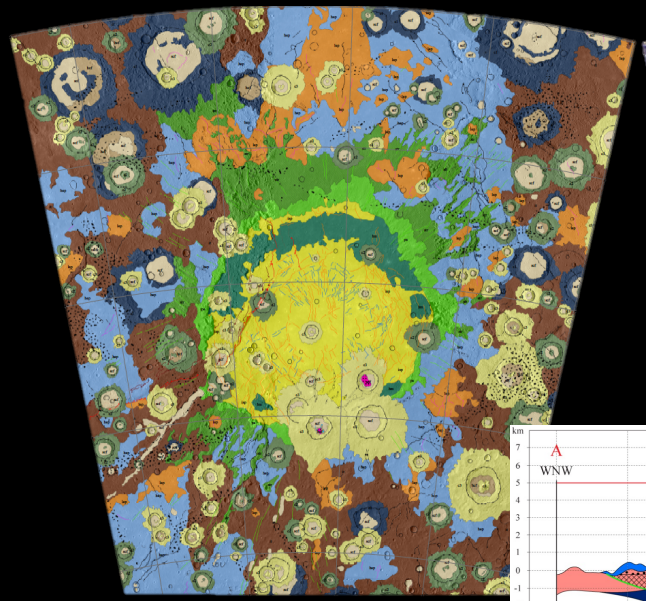
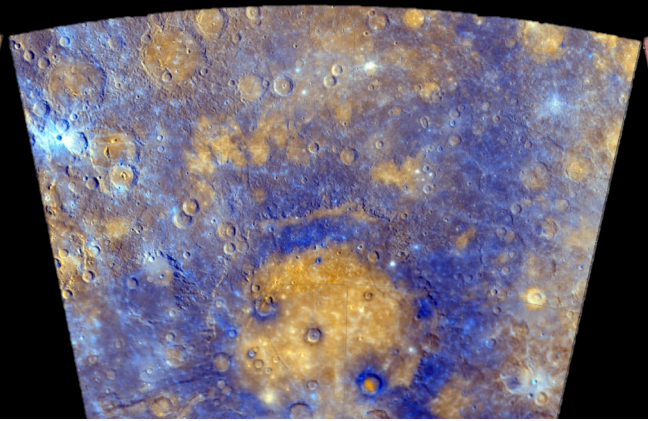
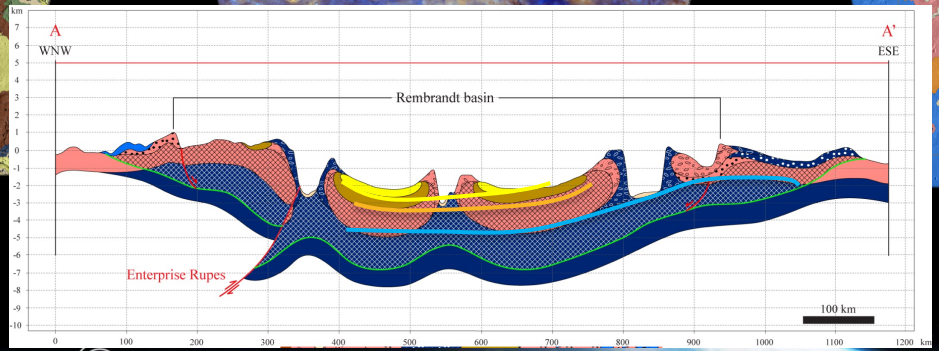
GMAP
Geological Mapping

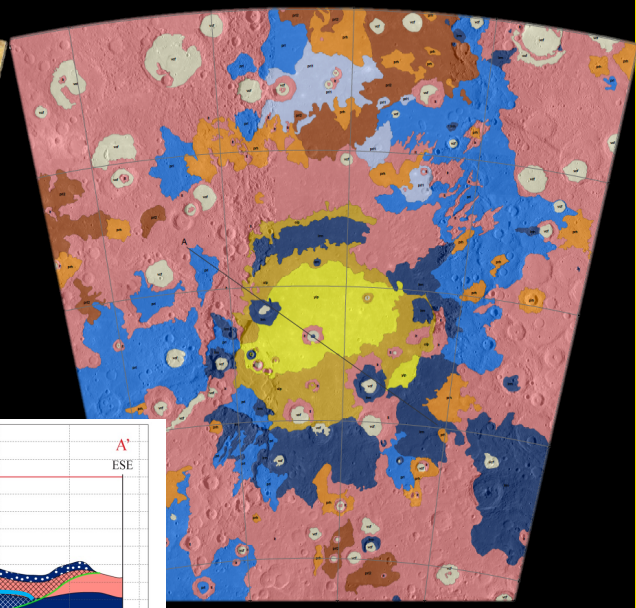
Planetarty geological maps: Rembrandt basin



Morpho-stratigraphic







Geo-stratigraphic

Semenzato et al. 2020

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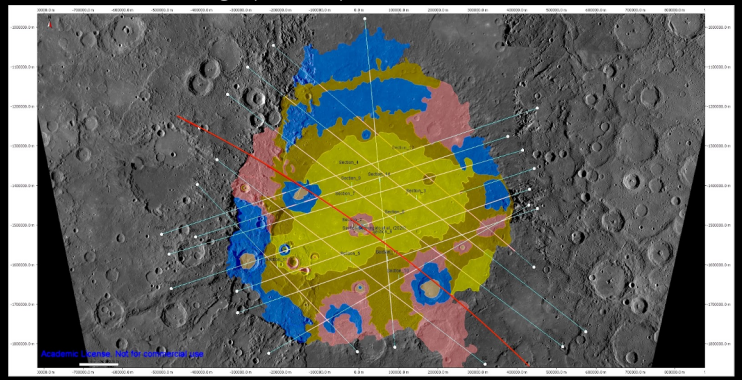
3D explicit modeling

GMAP Geological Mapping

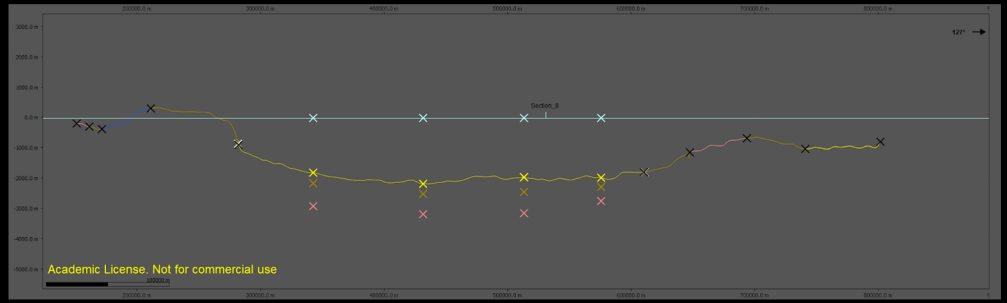
Inferring slightly from horizontal to slightly inclined contact planes

Model Inputs

Geo-stratigraphic map and cross sections

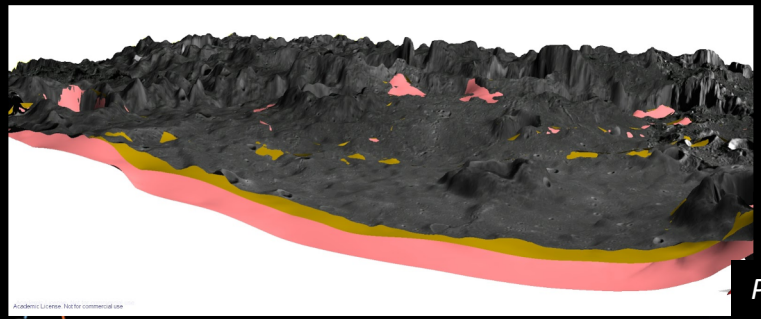


14 sets of parallel and intersecting interpreted cross-sections were used

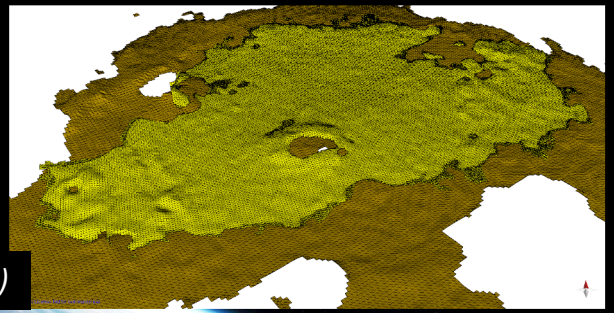


Model Outputs

Meshes obtained from cross-sections interpolation of the same horizons



Volumetric meshes were extracted modeling the Rembrandt basin's infilling



Pozzobonet al. (in prep)

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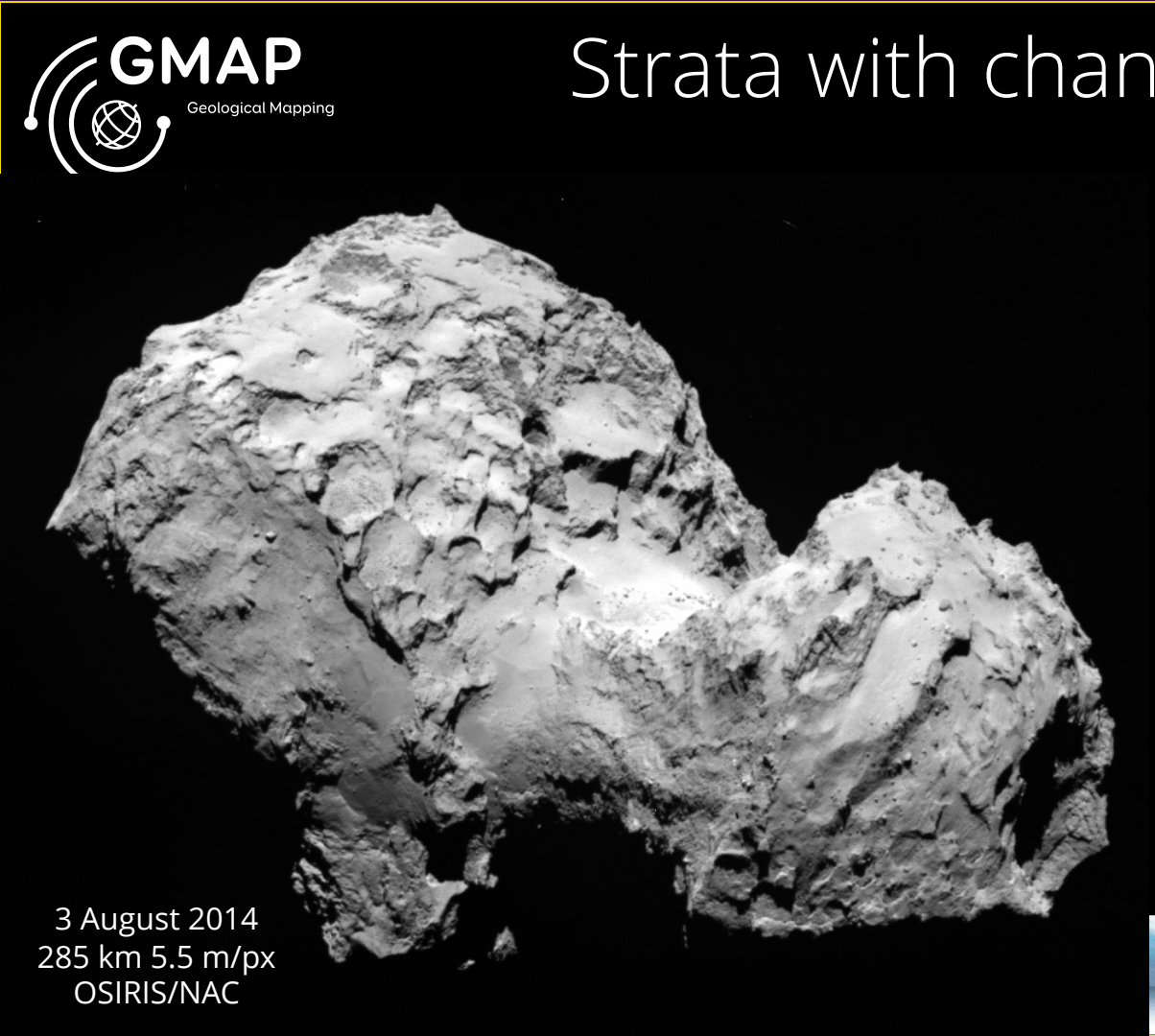
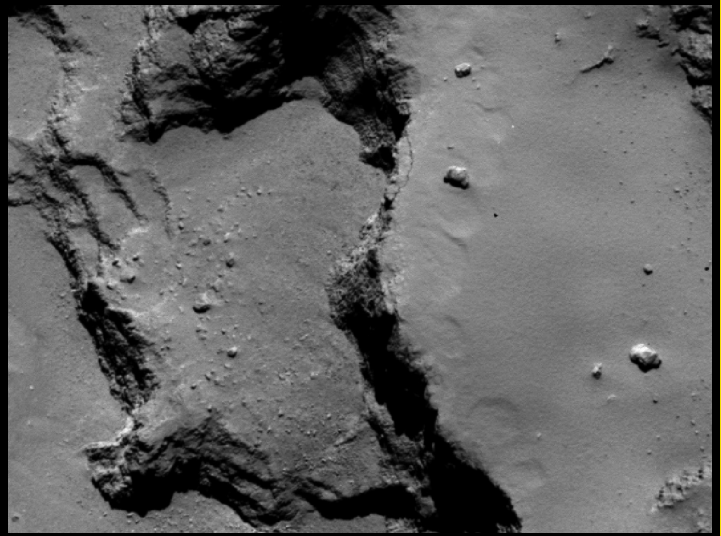
Strata with changing orientation: Comet 67P case



3 August 2014
285 km 5.5 m/px
OSIRIS/NAC



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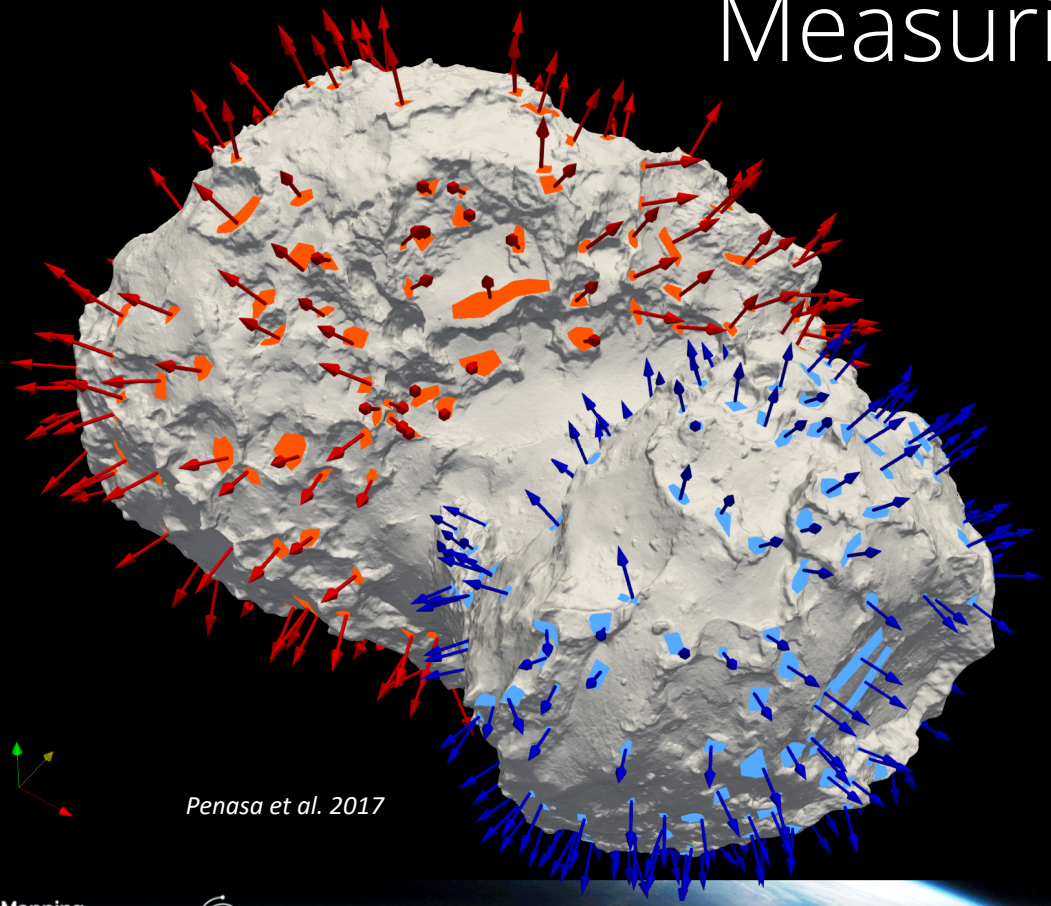
Measuring strata



Penasa et al. 2017

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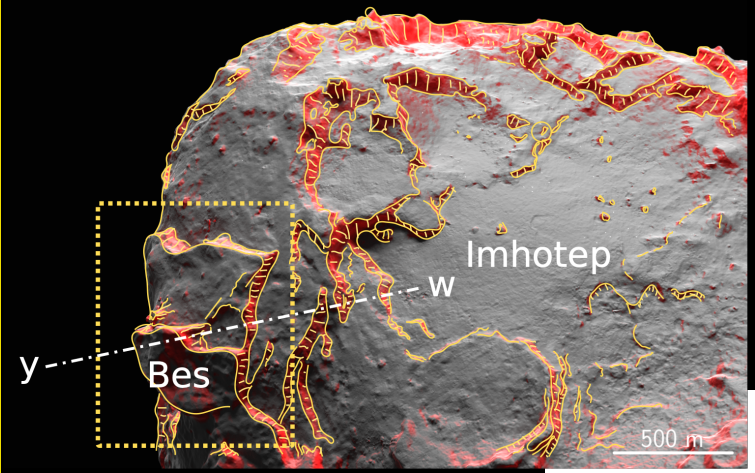
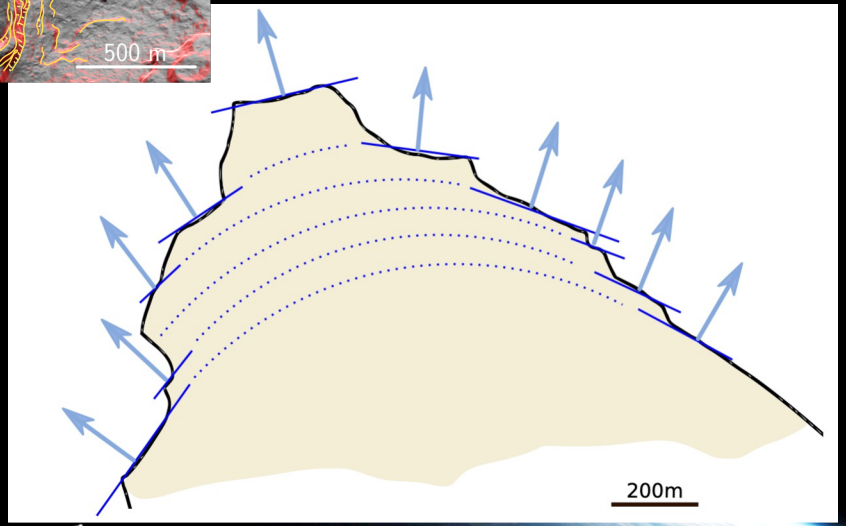
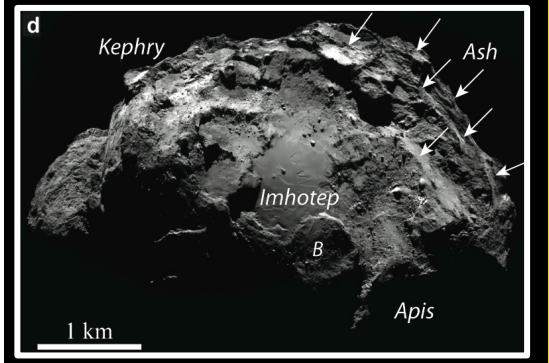
Cross Sections







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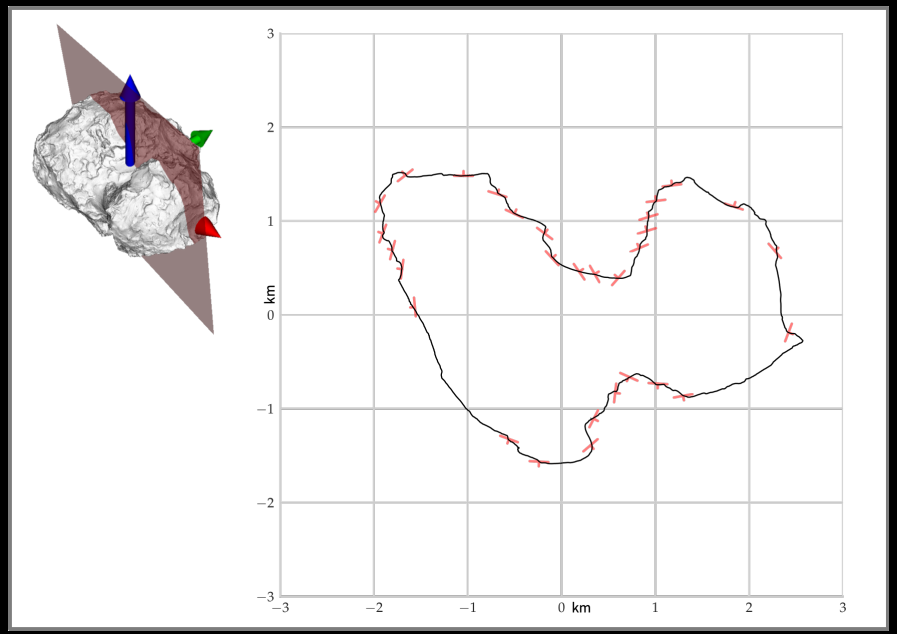
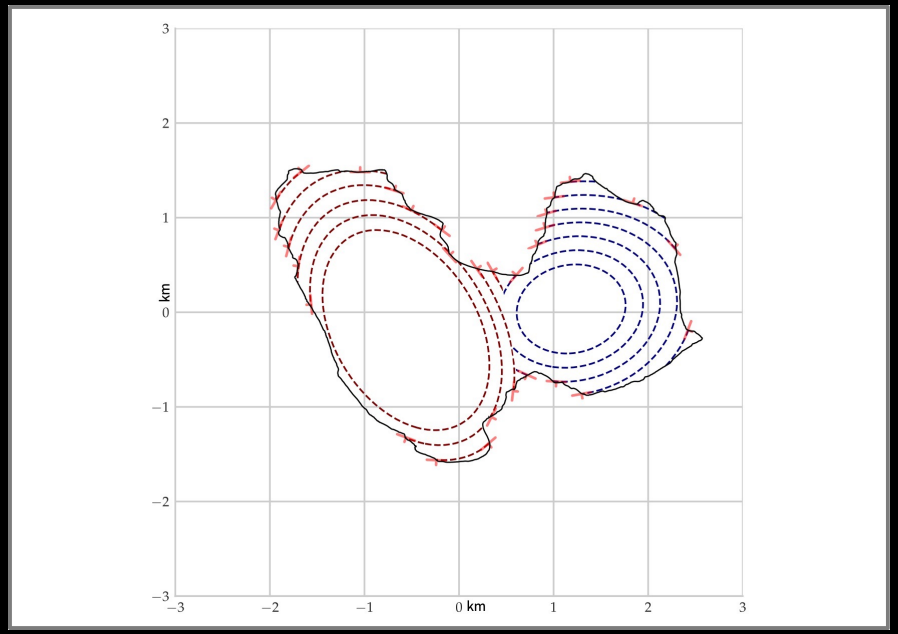
67P Geological Section





Massironi et al. 2015, Penasa et al. 2021

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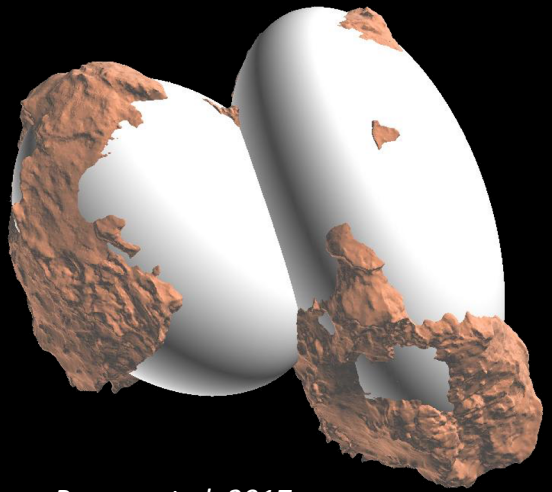
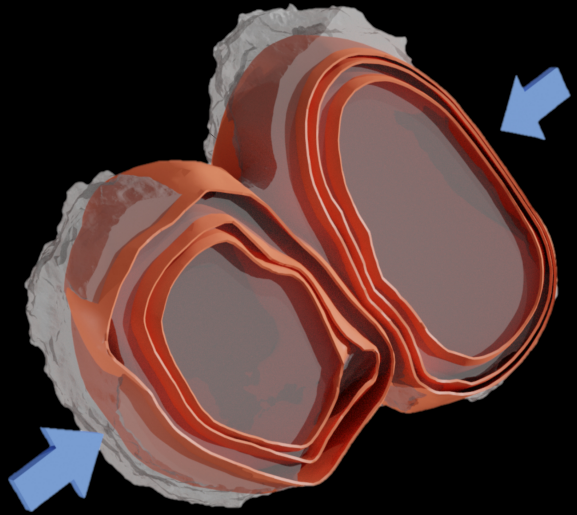
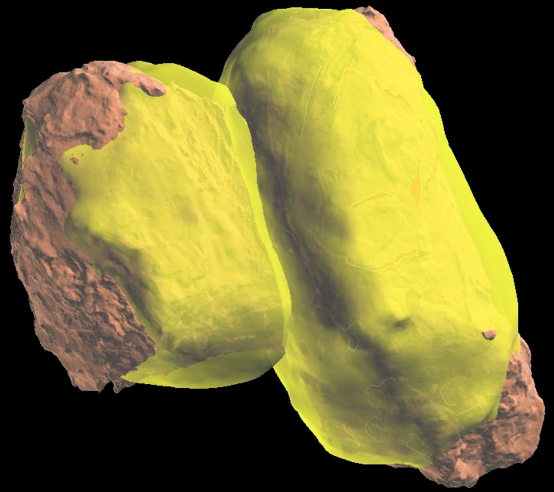
Comet nucleus 3D implicit modelling



Penasa et al. 2017





Franceschi et al. 2020

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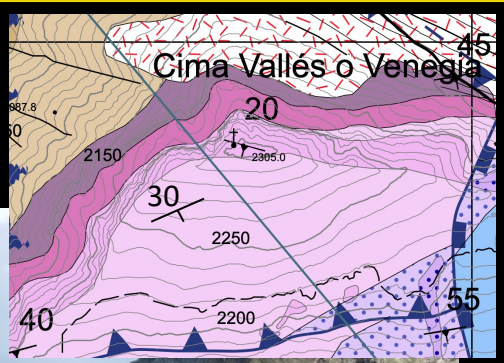
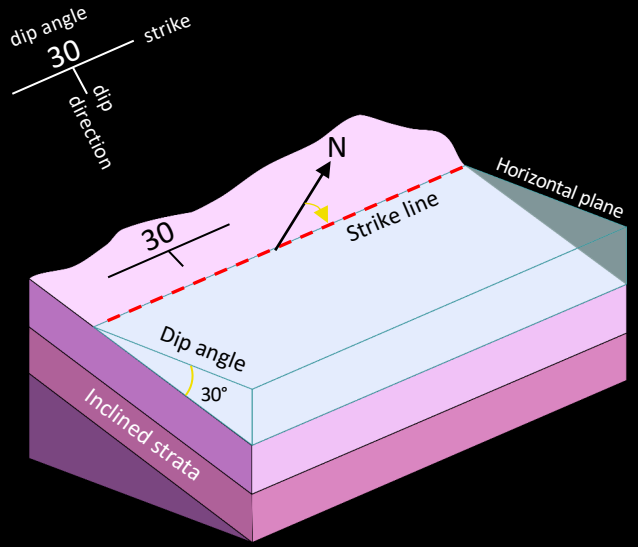
Geological Mapping

Inclined contacts



Werfen formation sequences (Cima Valles, Italy), Credits: Matteo Massironi



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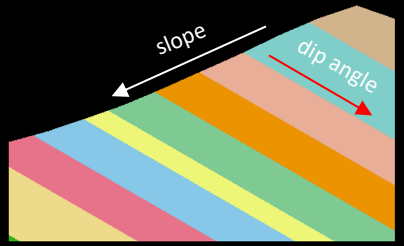
Anti dip slope

Scala dei Turchi, Sicily (Italy). Credits: Mattia Camellini

Dip angle opposite to the slope



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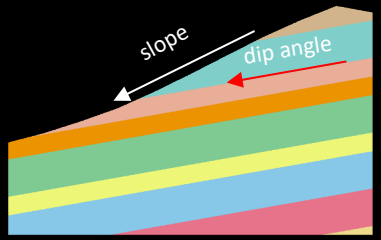
Dip angle less inclined than the slope



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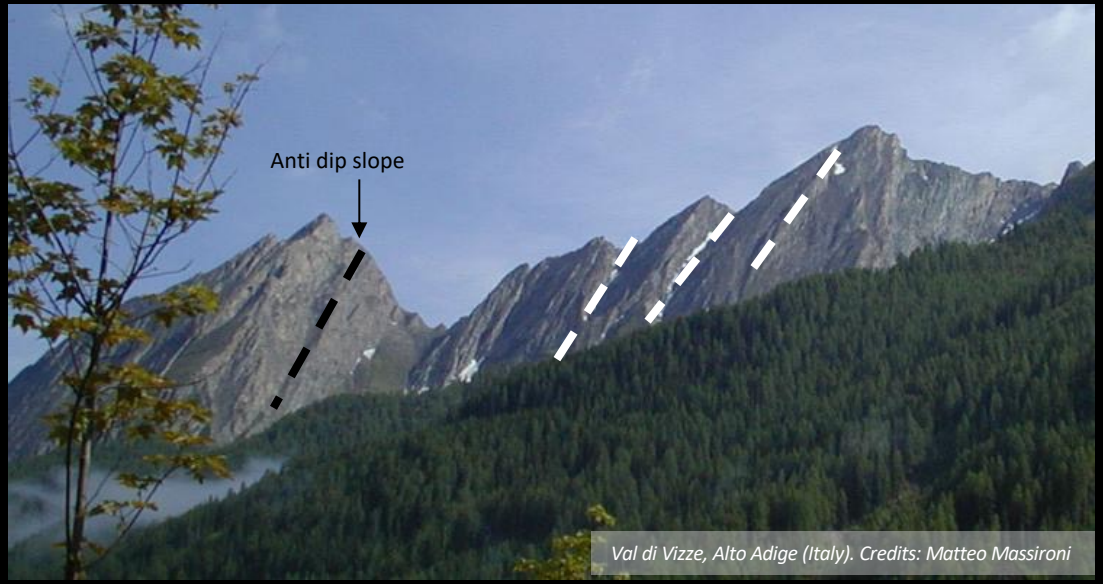
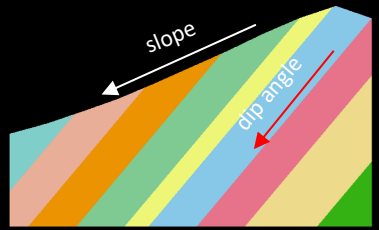
Dip angle more inclined than the slope



Val di Vizze, Alto Adige (Italy). Credits: Matteo Massironi



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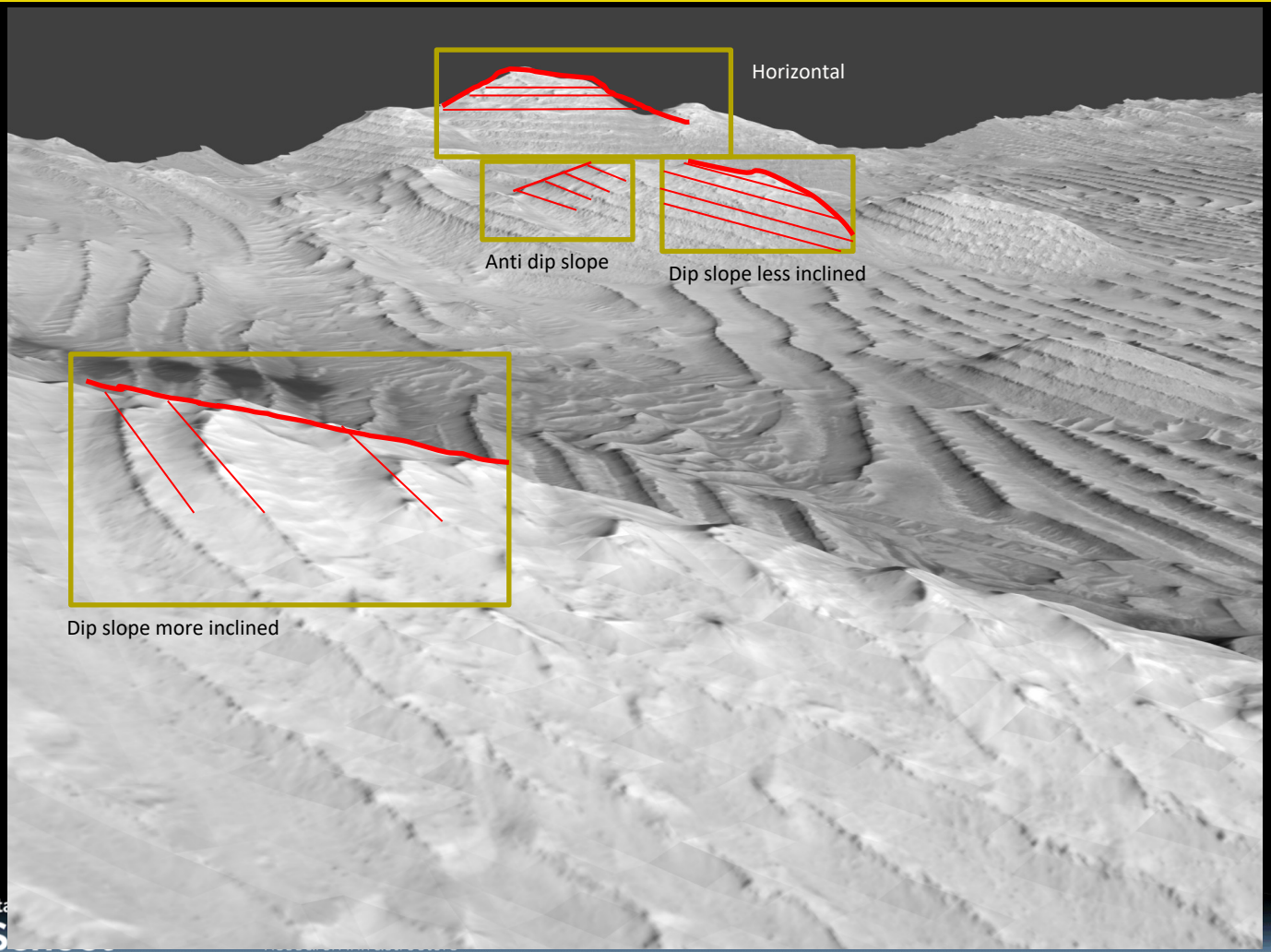
Danielson crater (Mars)



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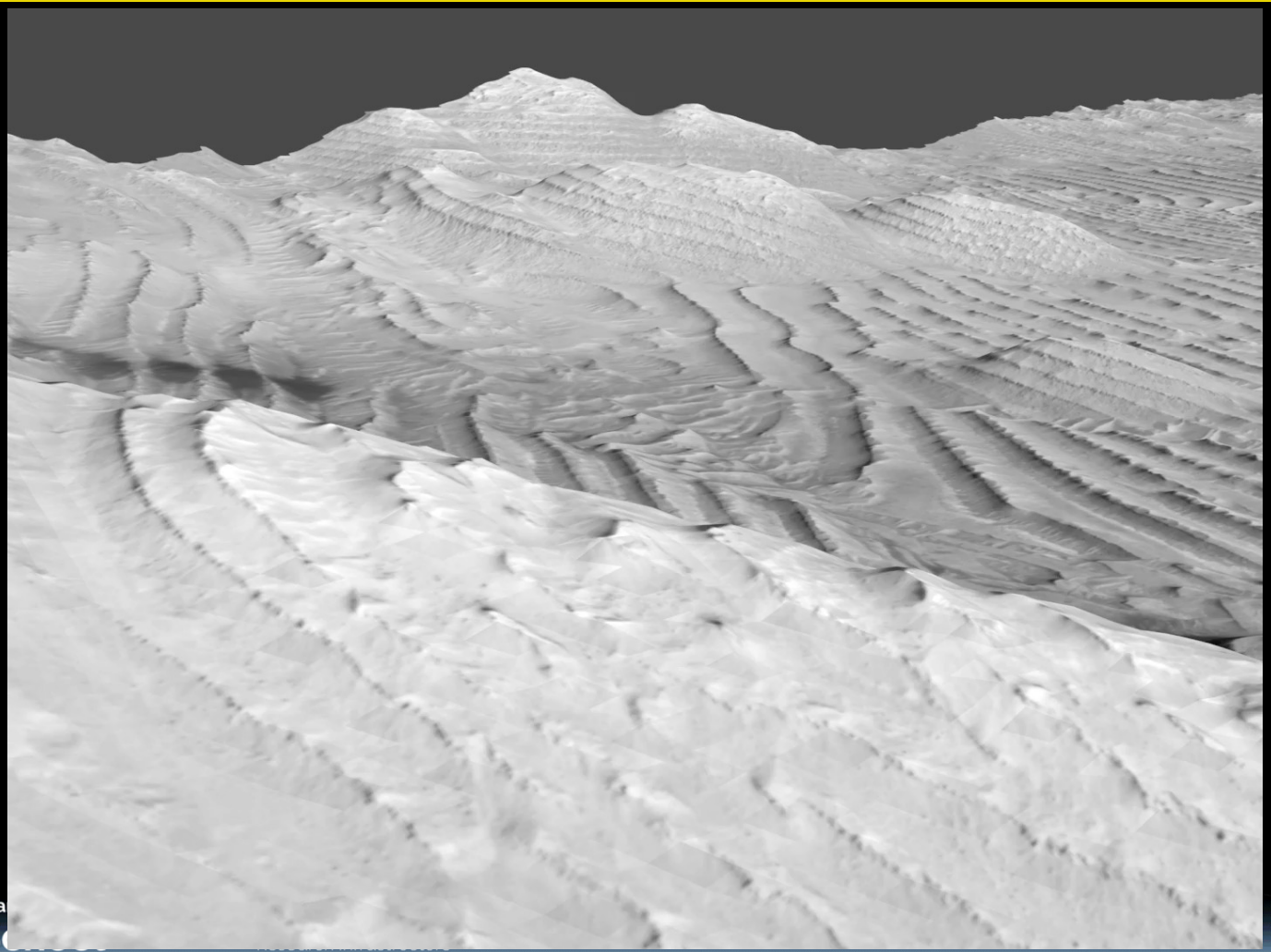

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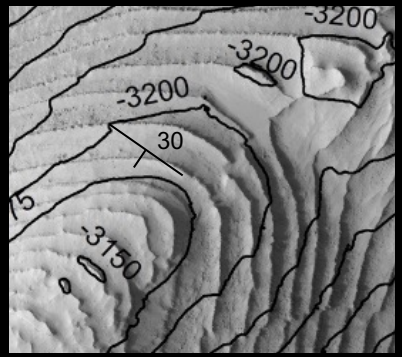
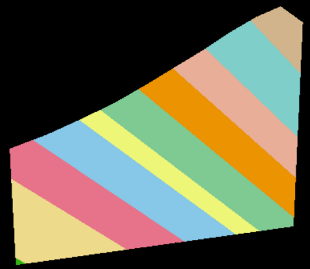
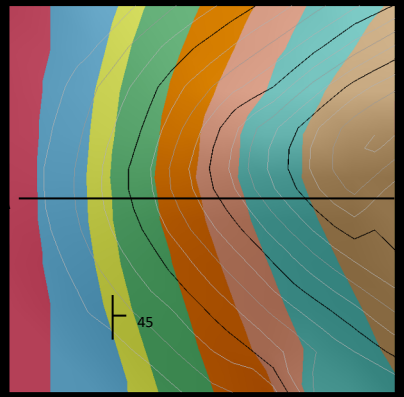
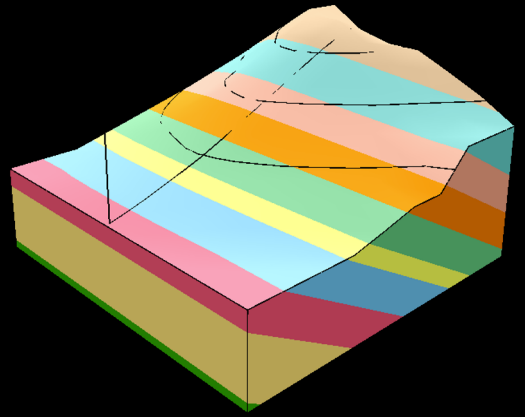
Anti-dip slope

Strata inclined with an opposite angle with respect to the slope
Geologic contacts/strata are **wider than contour lines**









Visible Geology
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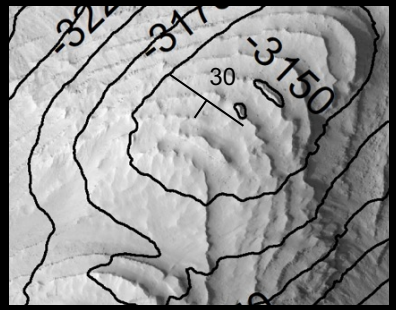
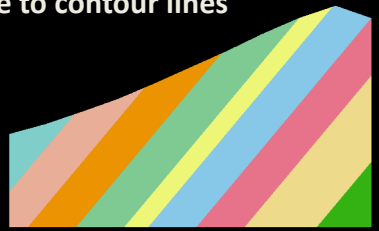
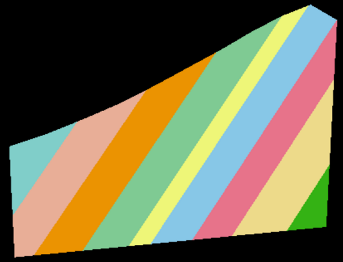
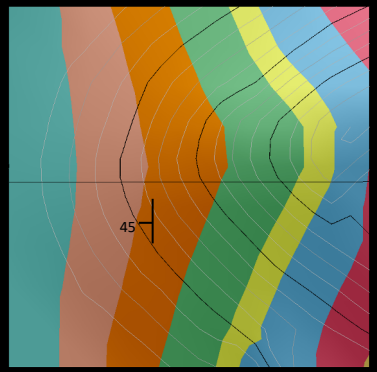
Dip slope: more inclined than the slope

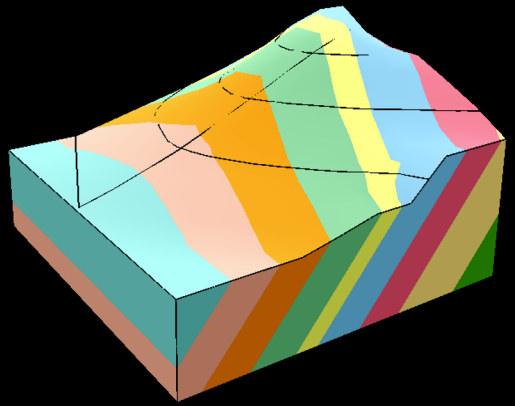
Strata inclined in the same direction of the slope
Geologic limits/strata patterns are the **opposite to contour lines**











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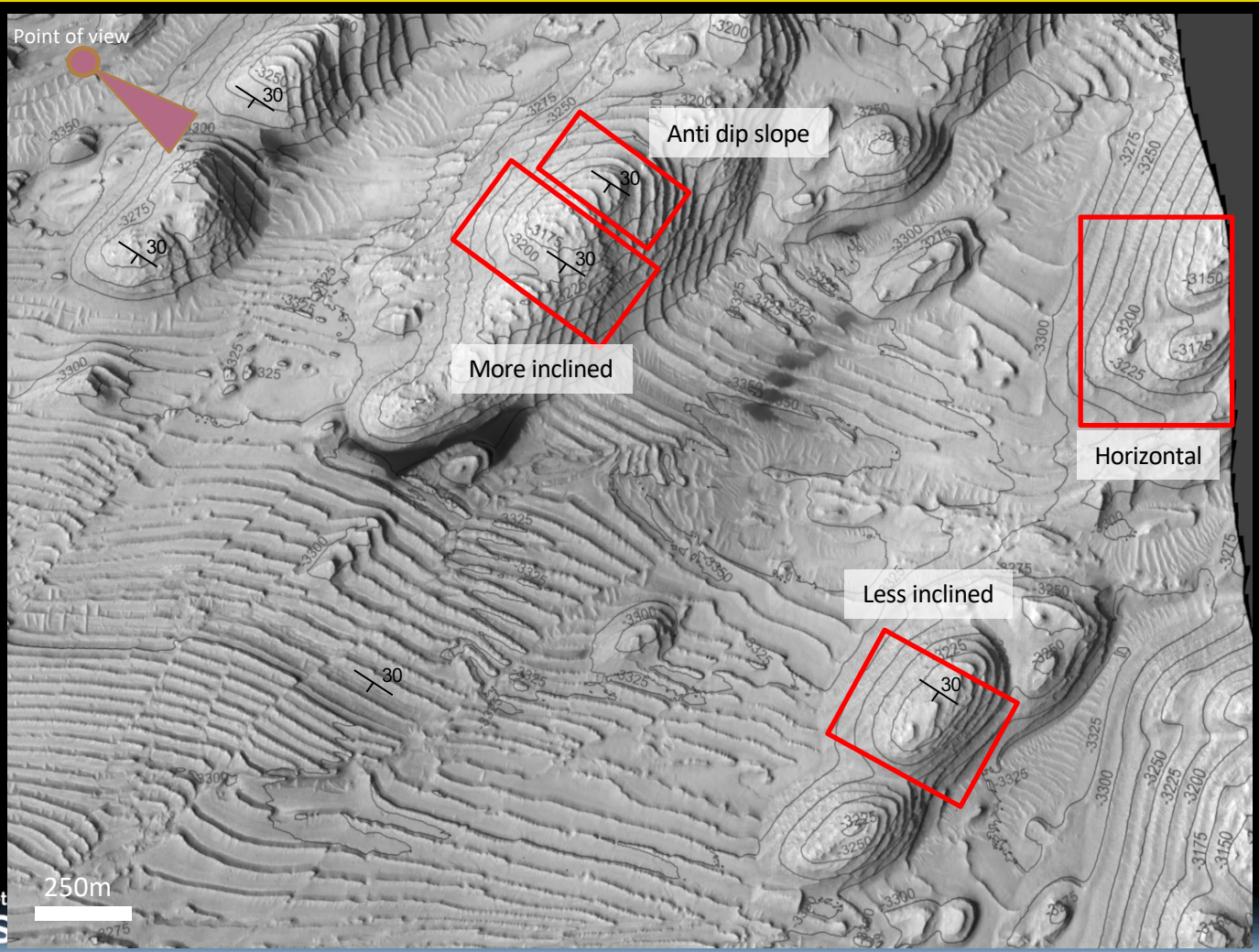

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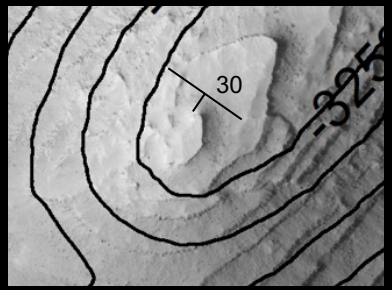
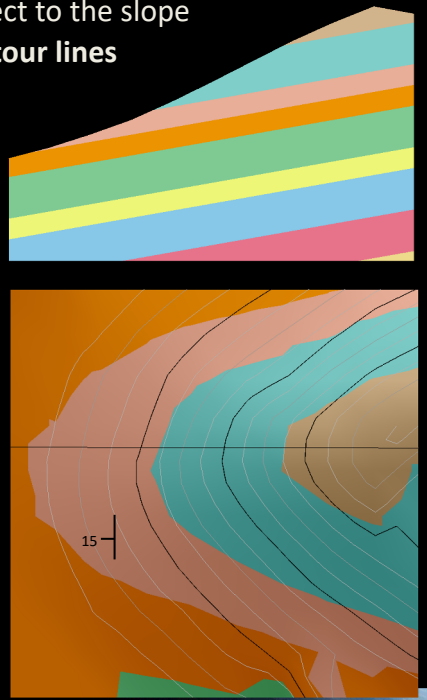
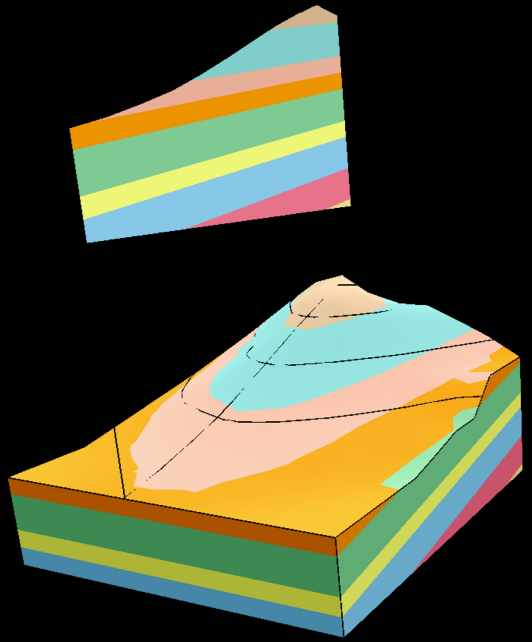
Dip slope: less inclined than the slope

Strata inclined with an opposite angle with respect to the slope

Geologic limits/strata are **tighter than contour lines**







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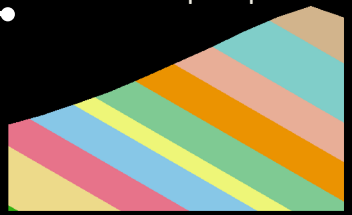
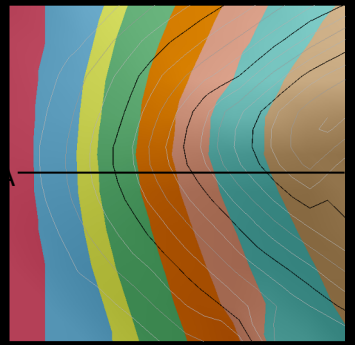
Dip slope wrap up

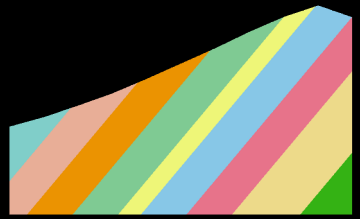
- Anti dip slope

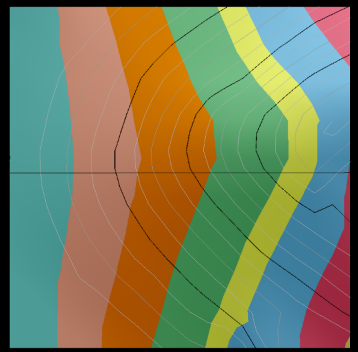




Contacts/strata are **wider** than contour lines

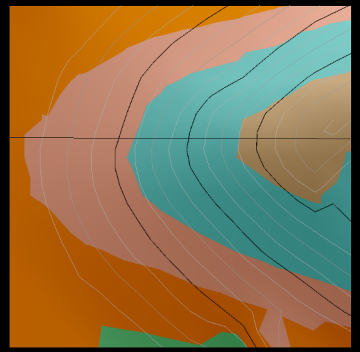
- More inclined



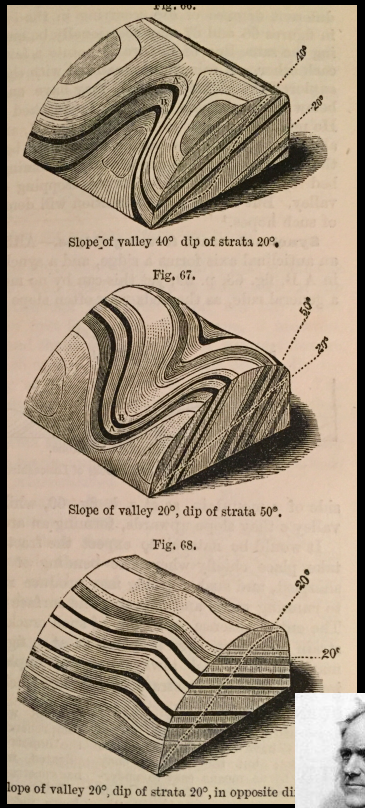


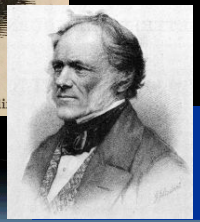
Contacts/strata are **opposite** to contour lines

- Less inclined



Contacts/strata are **tighter** than contour lines





Lyell 1874
Elements of Geology

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Piqiang and Keping fold and thrust belt, China

Piqiang and Keping fold and thrust belt, China

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Cross Section

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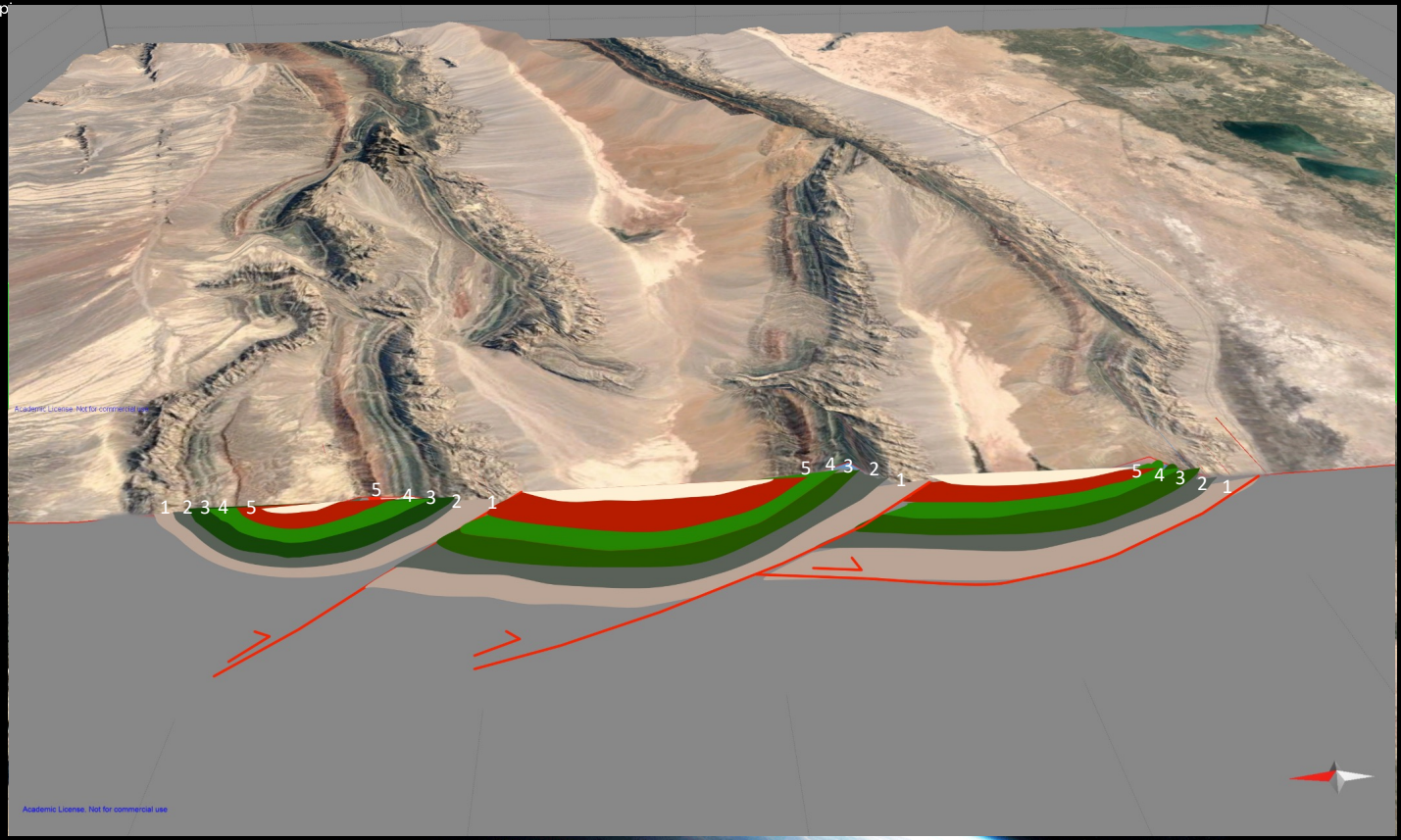
Cross Section



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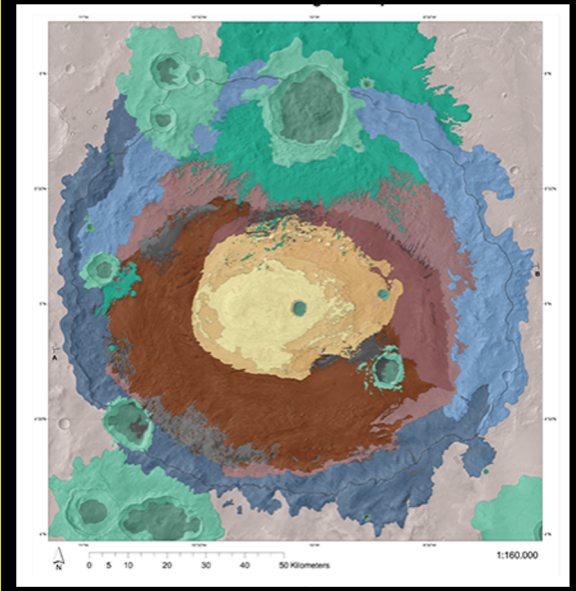
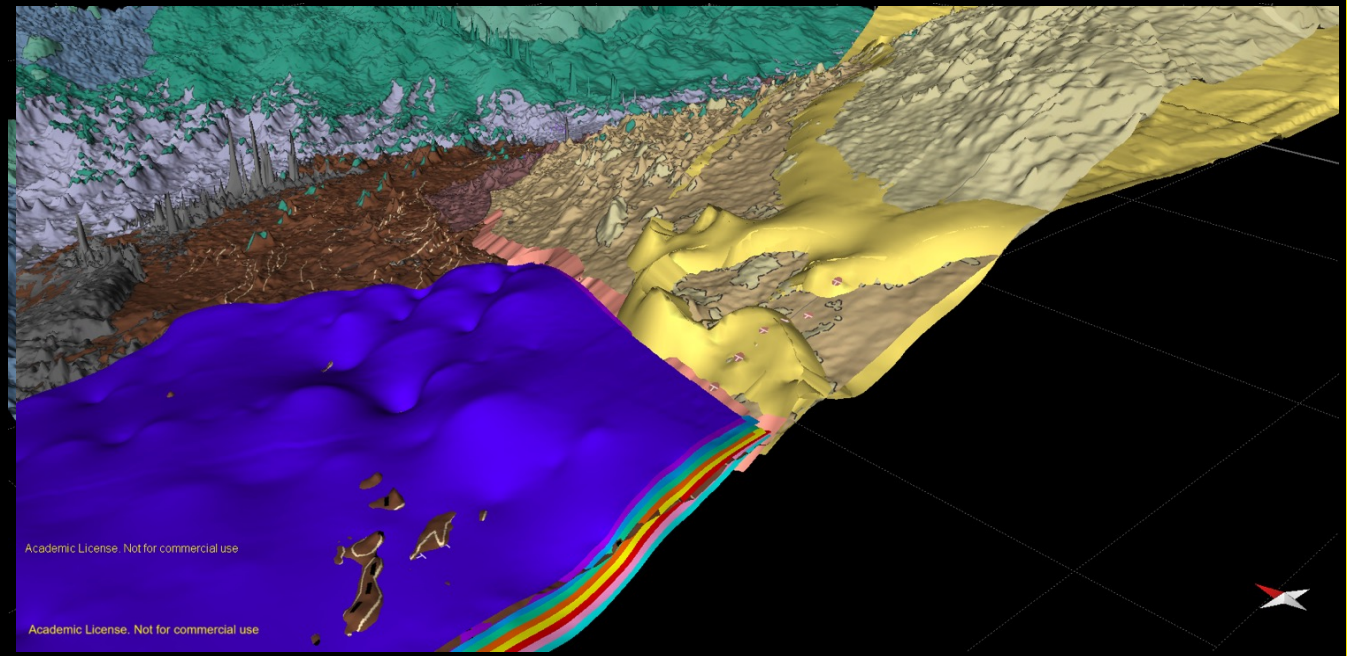
3D Explicit Modeling on Crommelin crater on Mars





Pozzobon, Pesce et al. (in prep)

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Conclusions

The interaction between geological contacts and topography allow to infer the subsurface prosecution of geological units and creating interpretative geological sections.

- Any geological section must strictly follow a clear stratigraphic chronology.
- Airless bodies are dominated by sub-horizontal or slightly inclined contacts between major units.
- Craters can constrain subsurface stratigraphy and unit thicknesses useful for geological sections and 3D volumetric models.
- Geological sections are pivotal for any explicit approach to 3D modelling which is also the only one applicable to date on the Moon and Mercury
- The sedimentary sequences on Mars allow deriving geological sections and 3D models well constrained by contact attitudes on a topographic surface and strata measurements.
- Implicit 3D modelling has been applied only on Earth and comet 67P but with rigorous stratigraphic constraints, high resolution DTMs and a good number of strata measurements could be potentially produced also on some Martian sites

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Credits: Carlotta Montagna/PLANMAP