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Evidence for widespread ongoing plume activity on Venus – clues from corona morphologies

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Talk outline

Corona structures on Venus

3D Numerical modelling of plume-induced coronae formation

Plume activity classification at large coronae on Venus

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ARTICLES
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Corona structures driven by plume–lithosphere interactions and evidence for ongoing plume activity on Venus

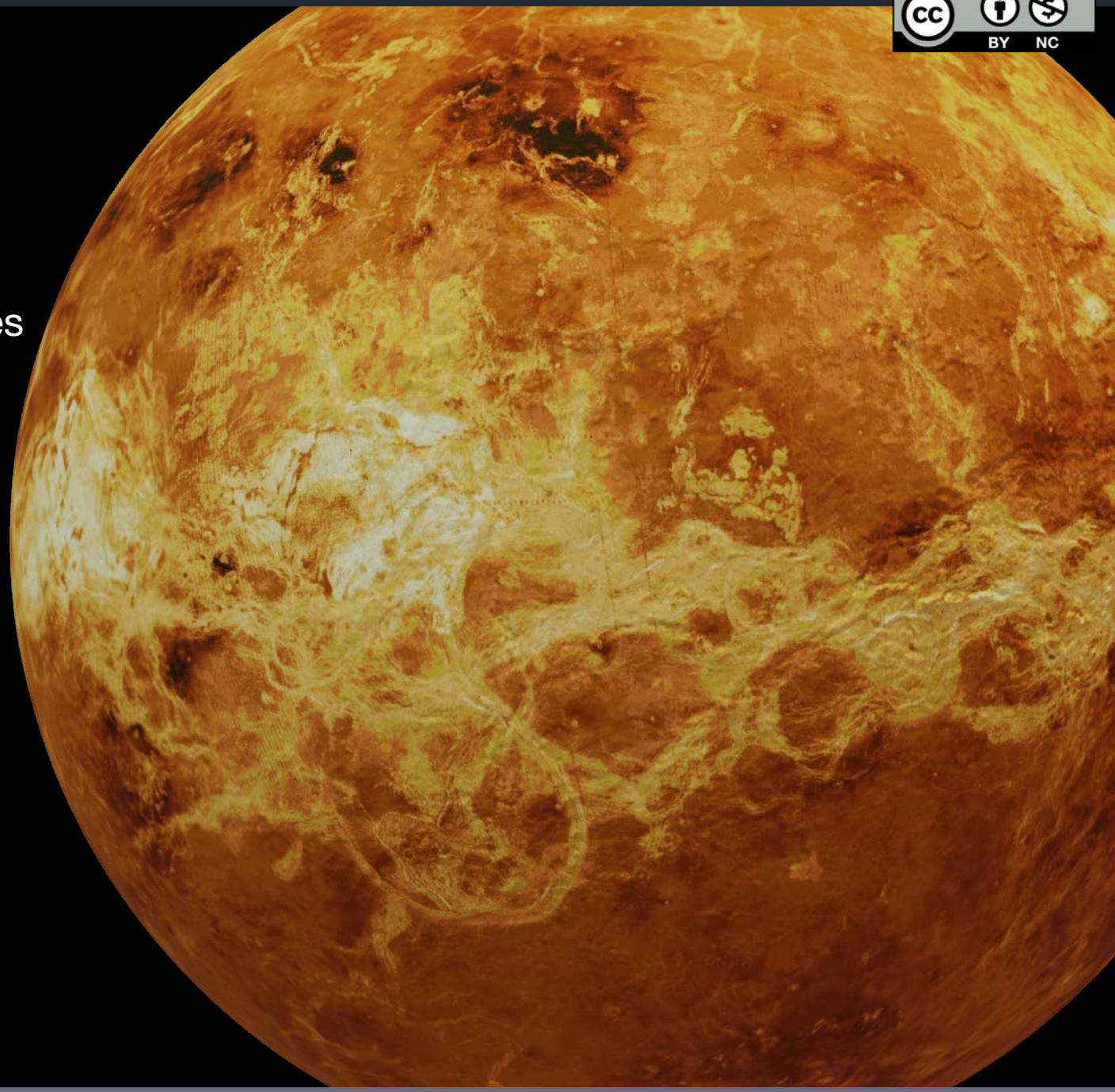
Anna J. P. Gülcher[1]✉, Taras V. Gerya[1], Laurent G. J. Montési[2] and Jessica Munch[1]

BEHIND THE PAPER

Evidence for a hotspot Venus - clues from mysterious coronae

The Venusian surface

- No plate tectonics
- Widespread volcanic & tectonic structures



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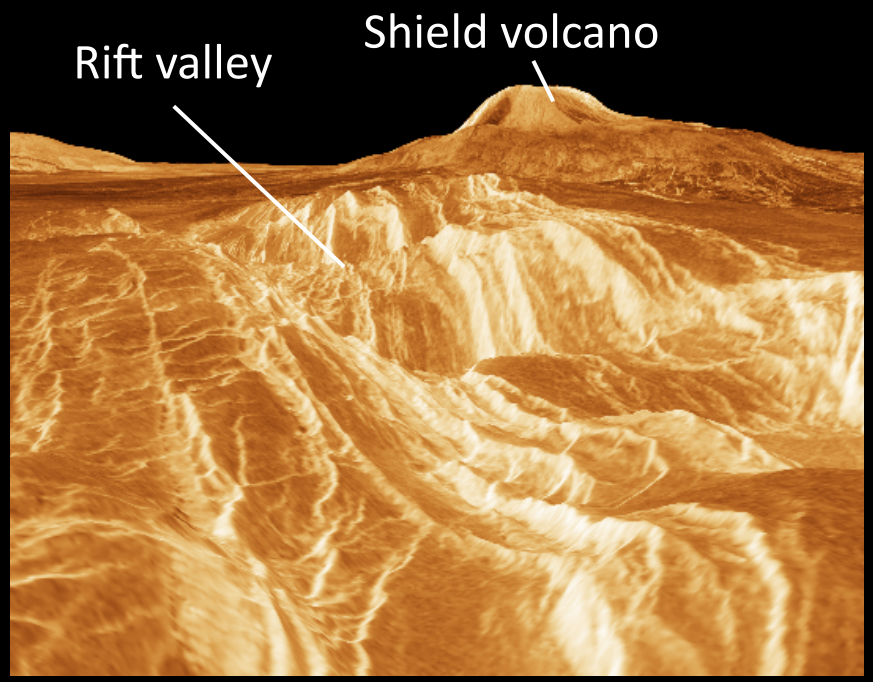
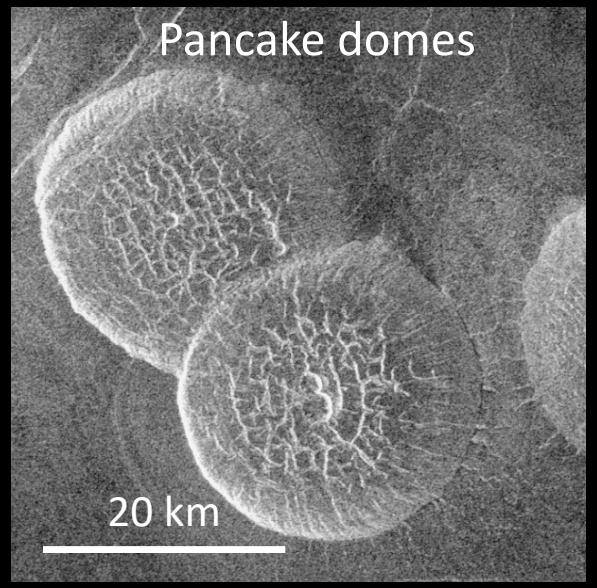
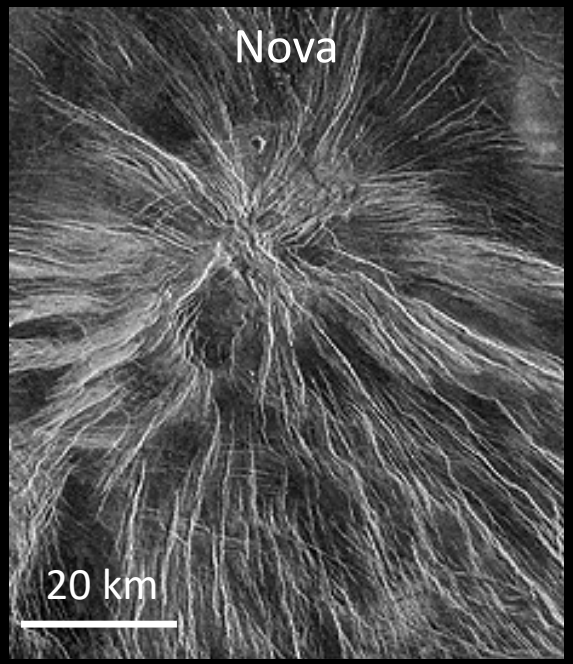
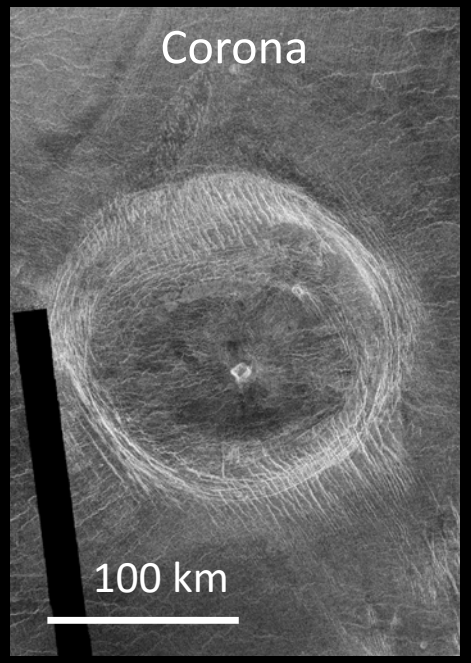
The Venusian surface

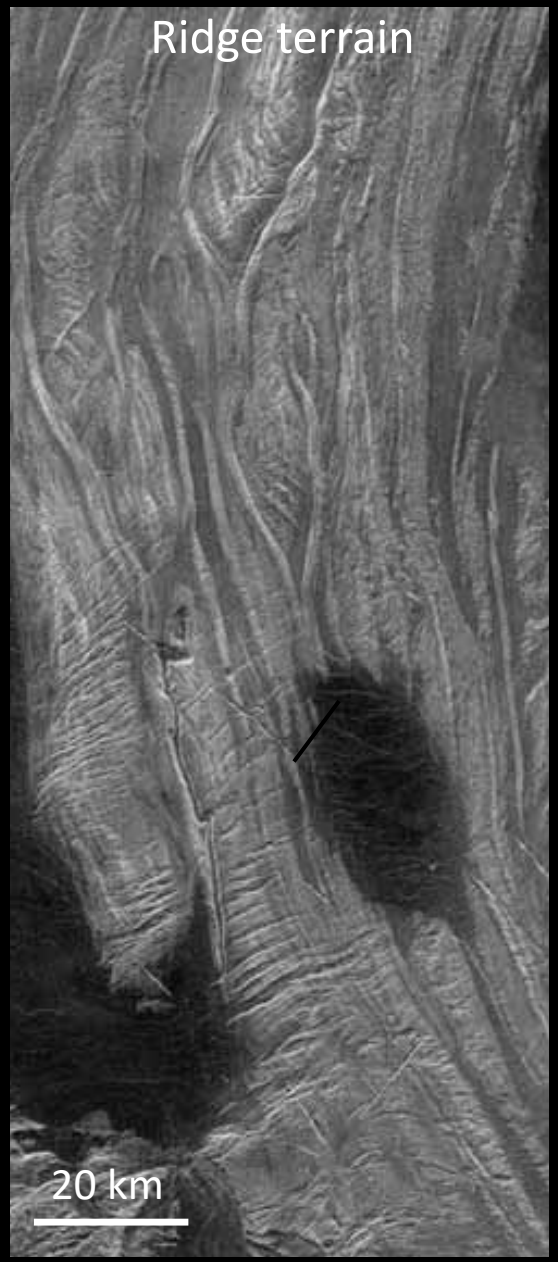
- No plate tectonics
- Widespread volcanic & tectonic structures











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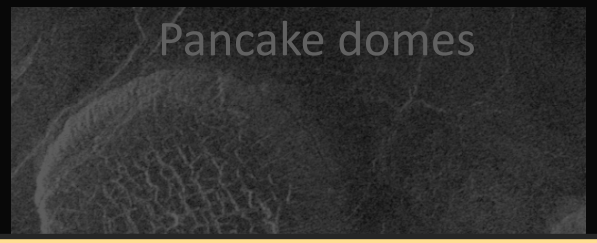
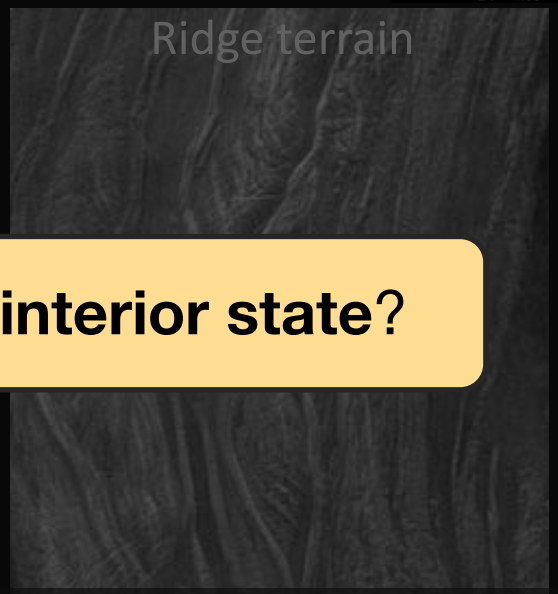
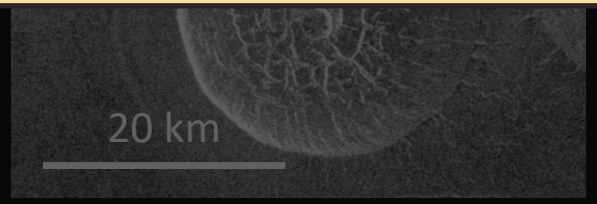
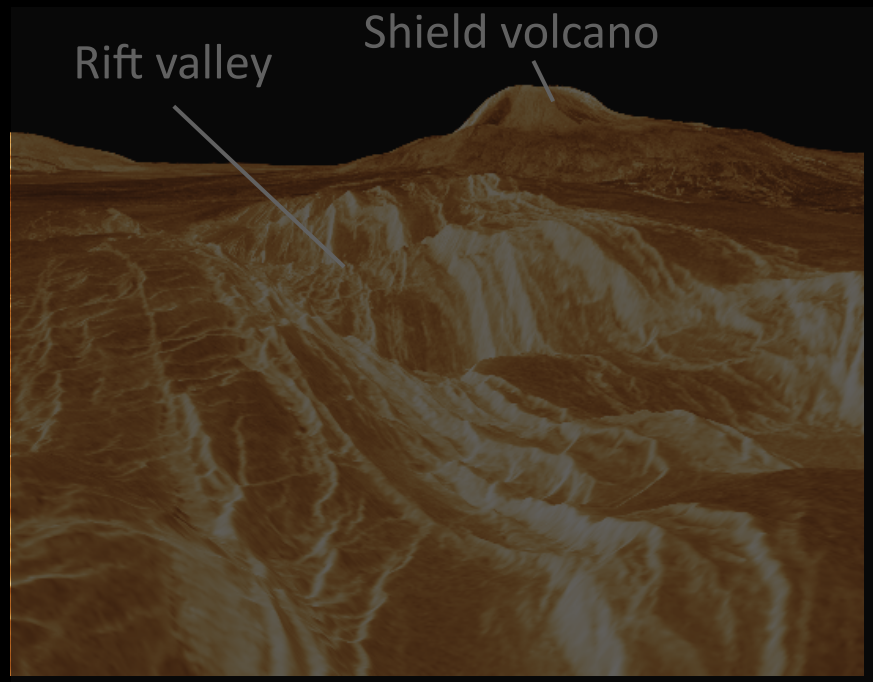
The Venusian surface

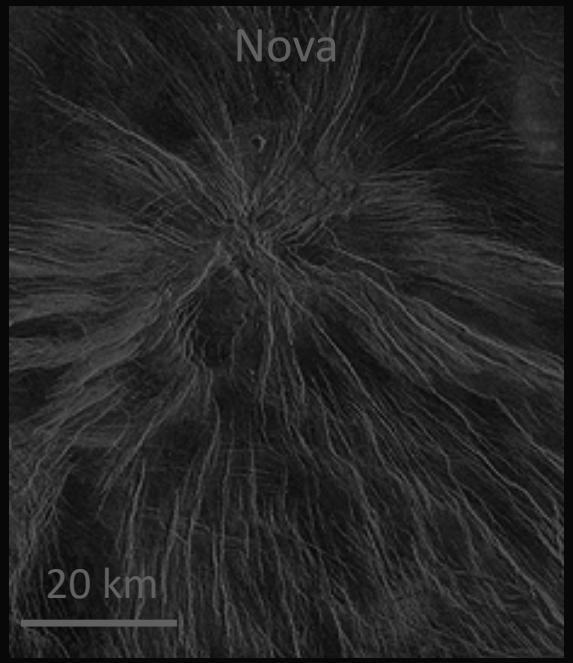
To what extend do **surface structures** reflect Venus' **current interior state**?

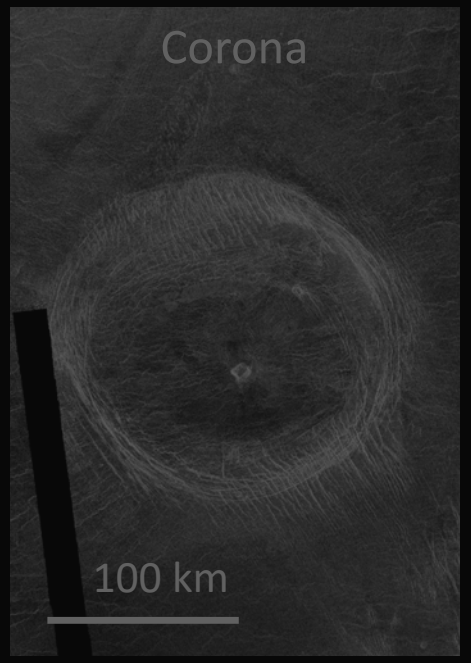


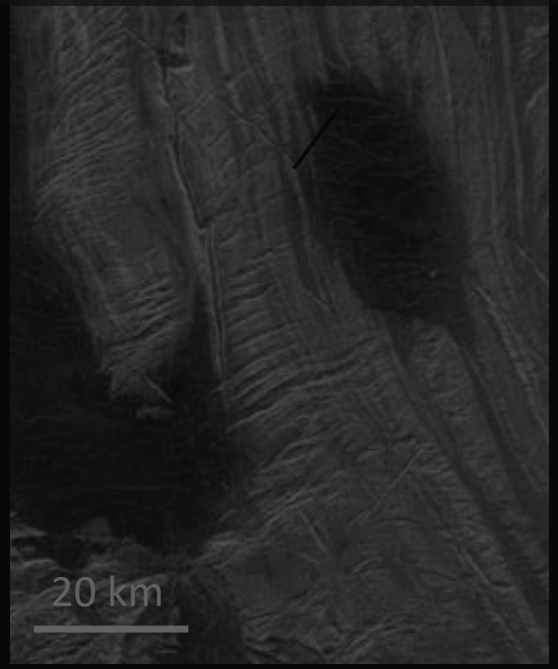












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The Venusian surface

To what extend do **surface structures** reflect Venus' **current interior state**?

- Catastrophic resurfacing? (e.g. Turcotte, 1993; Strom et al., 1994)
- Equilibrium resurfacing? (e.g. Herrick et al., 2011; Bjonnes et al., 2012)

ACTIVE?

Recent Hotspot Volcanism on Venus from VIRTIS Emissivity Data

Suzanne E. Smrekar,[1*] Ellen R. Stofan,[2] Nils Mueller,[3,6] Allan Treiman,[4] Linda Elkins-Tanton,[5] Joern Helbert,[6] Giuseppe Piccioni,[7] Pierre Drossart[8]

www.sciencemag.org SCIENCE VOL 328 30 APRIL 2010

THE ASTROPHYSICAL JOURNAL, 880:82 (8pp), 2019 August 1

The Physical Origin of the Venus Low Atmosphere Chemical Gradient

Daniel Cordier[1], David A. Bonhommeau[1], Sara Port[2], Vincent Chevrier[2], Sébastien Lebonnois[3], and Fernando García-Sánchez[4]

Geophysical Research Letters Published online 17 JUN 2015

Active volcanism on Venus in the Ganiki Chasma rift zone

E. V. Shalygin[1], W. J. Markiewicz[1], A. T. Basilevsky[1,2,3], D. V. Titov[4], N. I. Ignatiev[5], and J. W. Head[3]

AGU **Journal of Geophysical Research: Planets**

Pyroclastic flow deposits on Venus as indicators of renewed magmatic activity

Bruce A. Campbell, Gareth A. Morgan, Jennifer L. Whitten, Lynn M. Carter, Lori S. Glaze, Donald B. Campbell

First published: 11 July 2017 | https://doi.org/10.1002/2017JE005299

RESEARCH ARTICLE | PLANETARY SCIENCE

Present-day volcanism on Venus as evidenced from weathering rates of olivine

Justin Filiberto[1,*], David Trang[2], Allan H. Treiman[1] and Martha S. Gilmore[3]

Science Advances 03 Jan 2020: Vol. 6, no. 1, eaax7445
DOI: 10.1126/sciadv.aax7445

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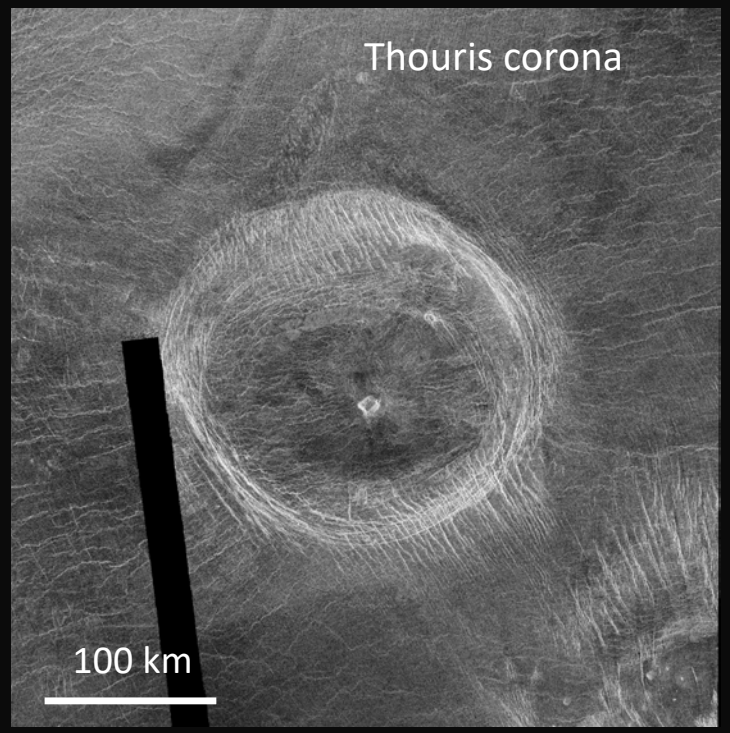
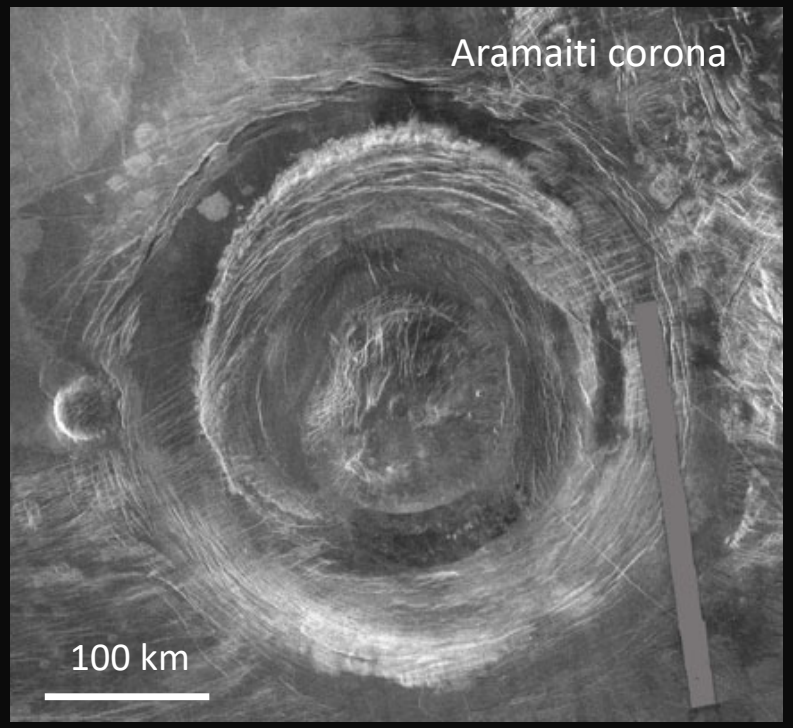
Coronae ("crowns")

- Large (quasi-)circular volcano-tectonic features
- Various dimensions (60 to over 1000 km wide)
- Various morphologies





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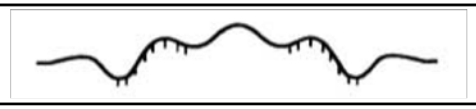
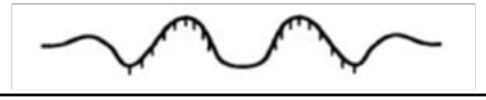
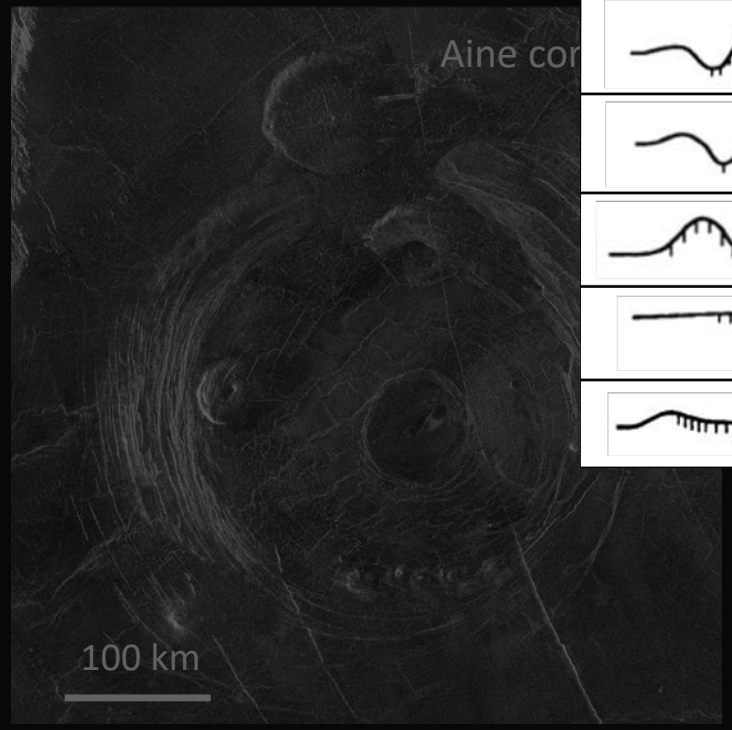
Coronae ("crowns")

- Large (quasi-)circular volcano-tectonic features
- Various dimensions (60 to over 1000 km wide)
- Various morphologies

Topographic profile	Description	% of coronae
	Dome	10
	Plateau	10
	Rim surroundig interior high	21
	Rim surrounding interior dome	
	Rim surrounding depression	25
	Outer rise, trough, rim, inner high	5
	Outer rise, trough, rim, inner low	1
	Rim only	7
	Depression	7
	No discernible signature	14

Smrekar and Stofan, 1997



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Formation of coronae

- Crustal stresses above an (upwelling?) mantle plume
- Plume-bounding subduction *(e.g. Sandwell & Schubert, 1992; Davaille et al., 2017)* and/or litospheric delamination *(Stofan et al., 1991; Smrekar and Stofan, 1997)*?
- Plume-induced crustal convection (novae and small coronae) *(Gerya, 2014)*
- Underplated plume and volcanic loading *(e.g. McGovern et al., 2013)*

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3D modelling of **coronae formation** by plume-lithosphere interactions, and assess the **reason** behind their **morphological diversity**

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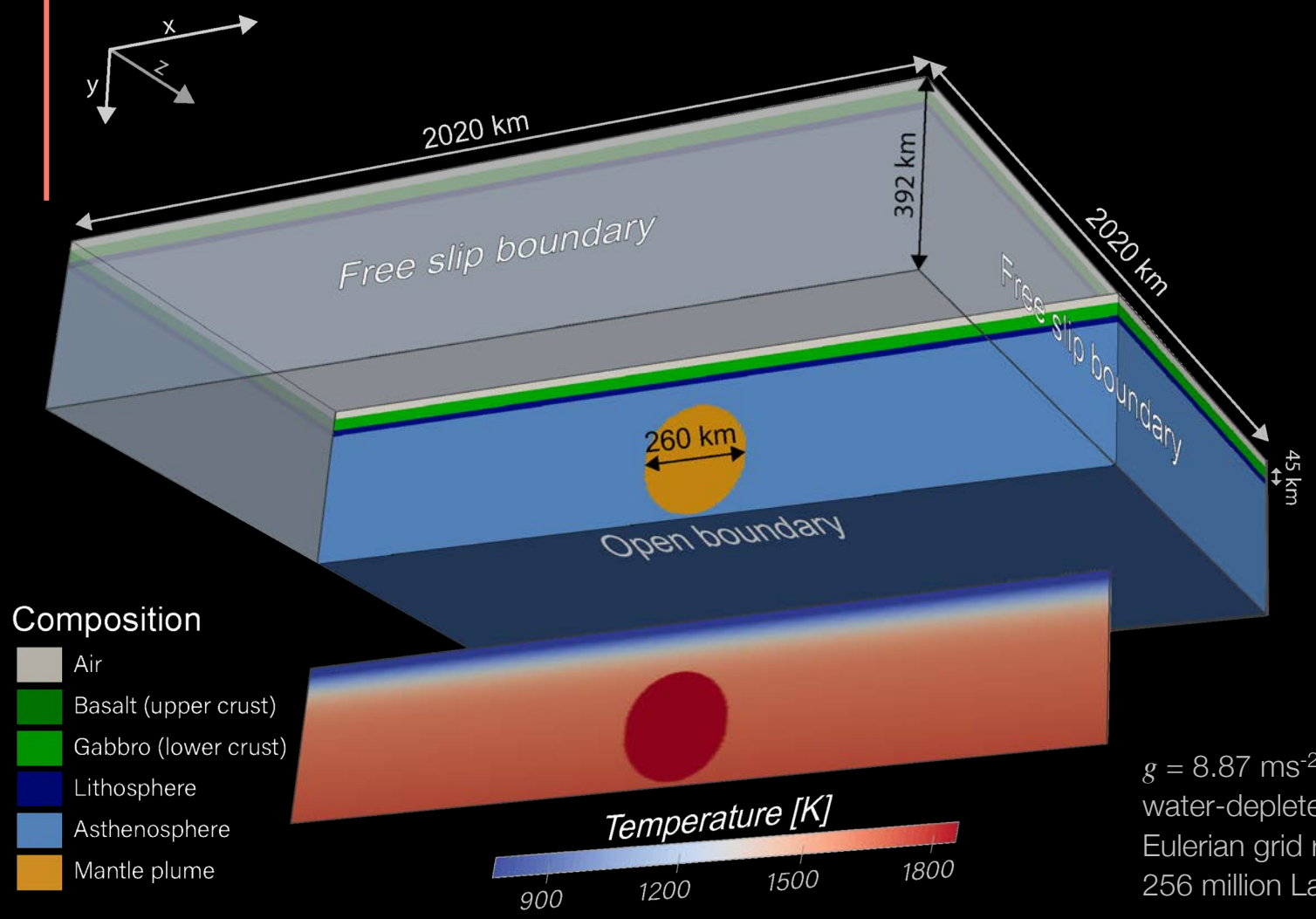
3D models – I3ELVIS (Gerya, 2010)



- *See Gülcher et al. (2020) for details*
- Melting, crustal accretion and phase change (eclogitization) implemented
- Visco-plastic rheology
- 21 numerical models, varying

Plume buoyancy

plume temperature; size

Lithospheric configuration

lithospheric strength, crustal thickness

$g = 8.87\ ms^{-2}$
water-depleted
Eulerian grid resolution: 5 · 2 · 5 km
256 million Lagrangian markers

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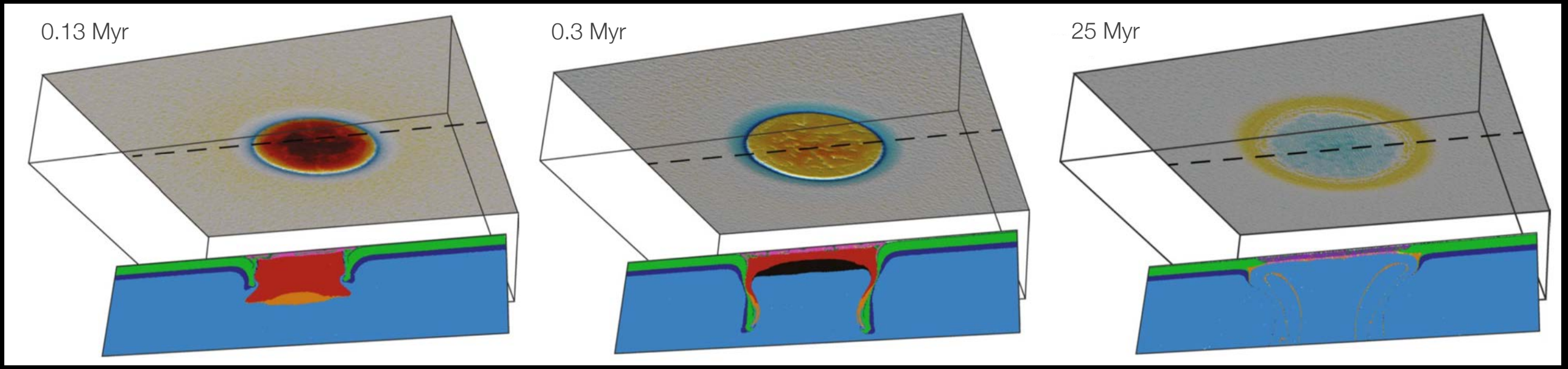
3D models - *reference model evolution*

Plume penetration into lithosphere → Lithospheric dripping at plume margins → Plume cooling and topographic inversion



Composition

solid/molten
Upper crust (basalt)
Lower crust (grabbro)

solid/molten
Newly formed crust
Lithosphere

solid/molten
Mantle
Mantle plume

Topography [km]
-3 -2 -1 0 1 2 3

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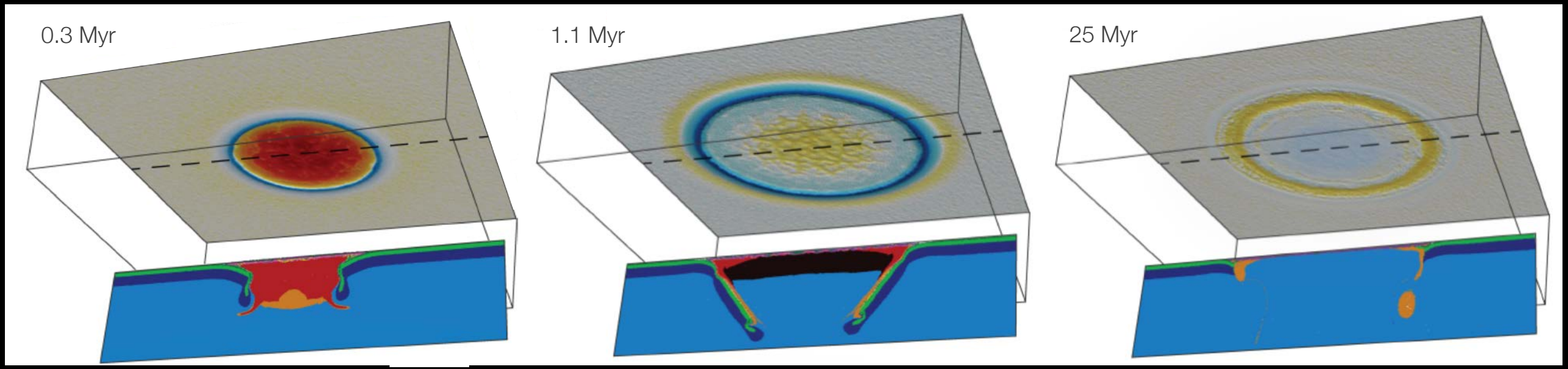
3D models - *stronger lithosphere / thinner crust*

Plume penetration into lithosphere → Slab retreat at plume margins **Short-lived subduction** → Plume cooling and topographic inversion



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Upper crust (basalt)
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Newly formed crust
Lithosphere

solid/molten
Mantle
Mantle plume

Topography [km]
-3 -2 -1 0 1 2 3

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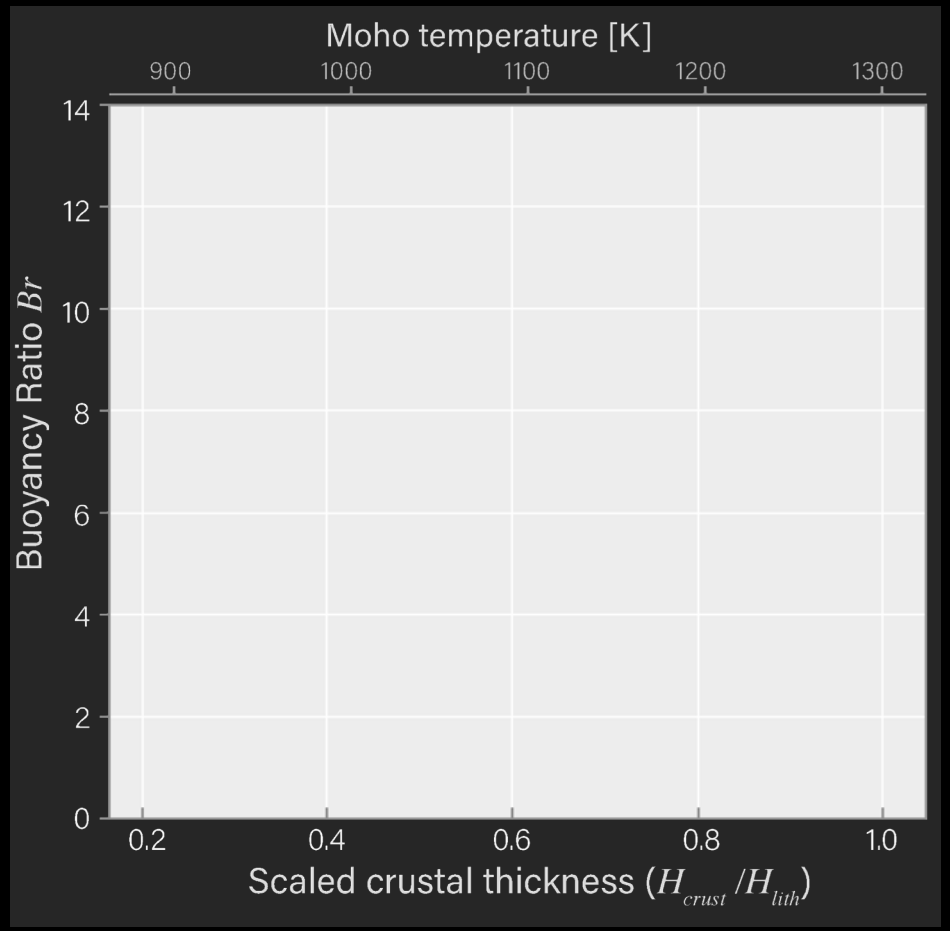
3D models - *plume-lithosphere interactions*

Buoyancy ratio *Br*

$$\frac{Plume\ buoyancy}{Lithospheric\ \ strength}$$

$$= \frac{\Delta\rho_{plume}\, g\, R_{plume}}{C + \rho_L g \varphi_{eff} H_L}$$



Moho temperature ($\propto \frac{H_{crust}}{H_{lithosphere}}$)

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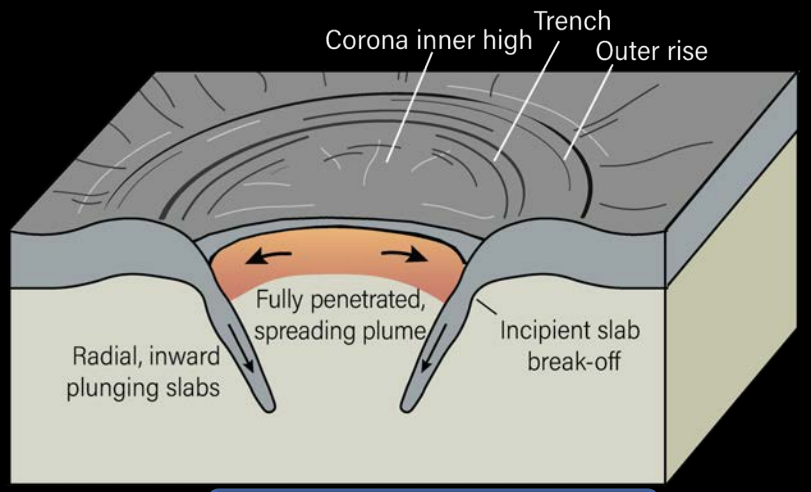
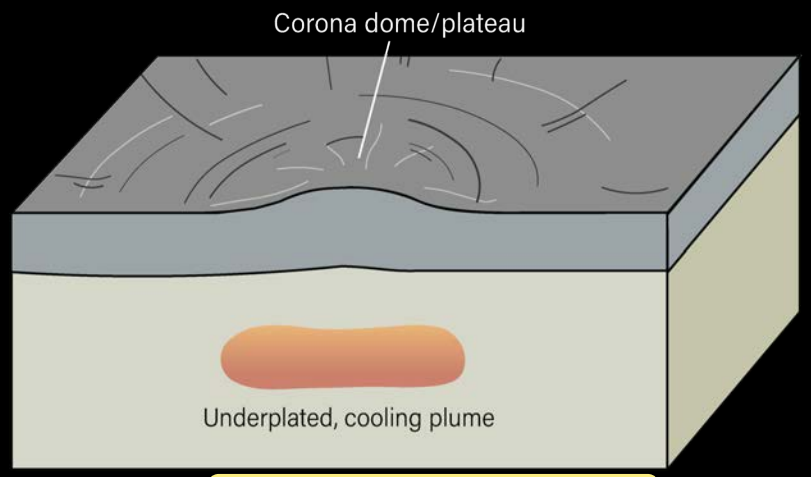
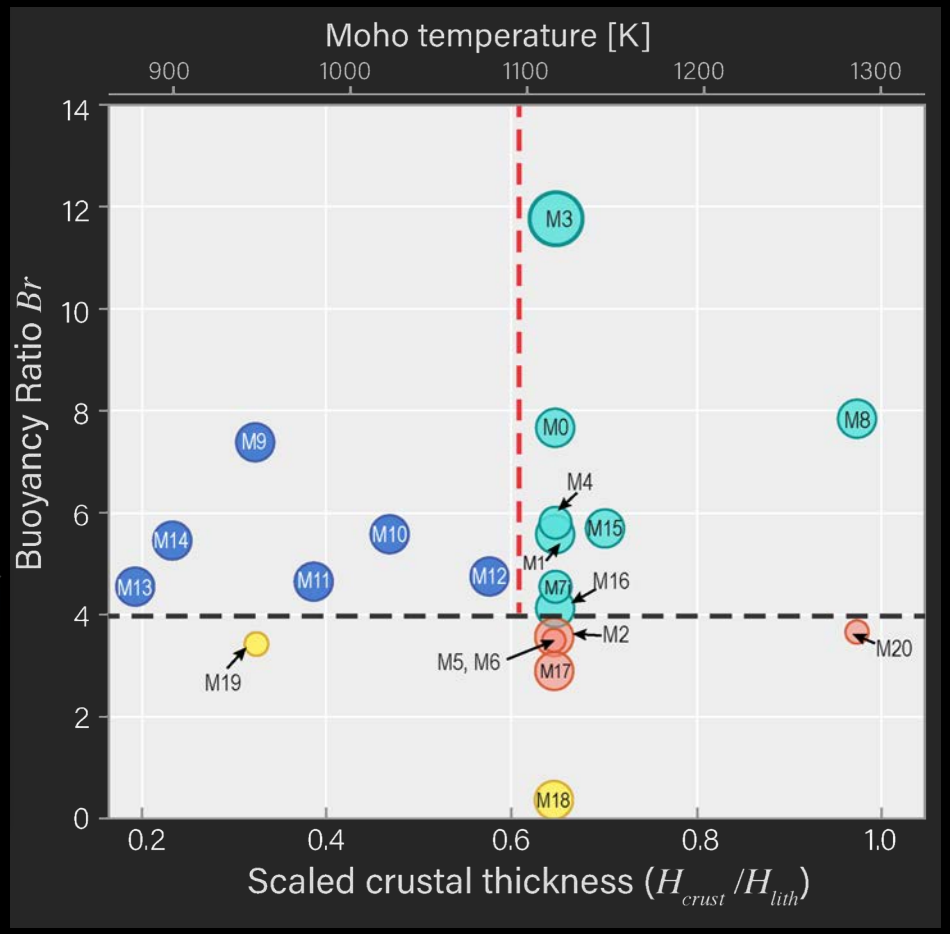
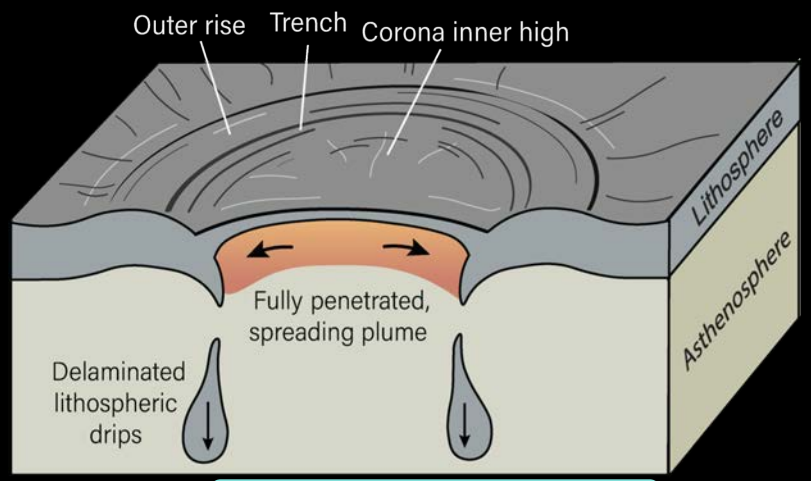


Ephemeral subduction

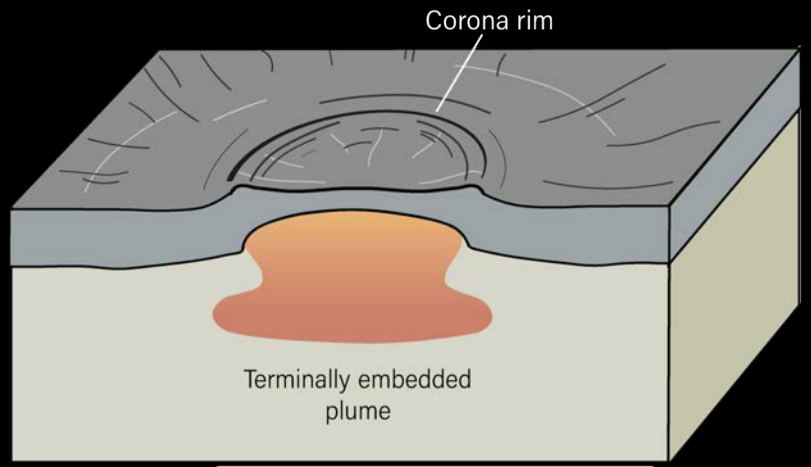


Underplated plume



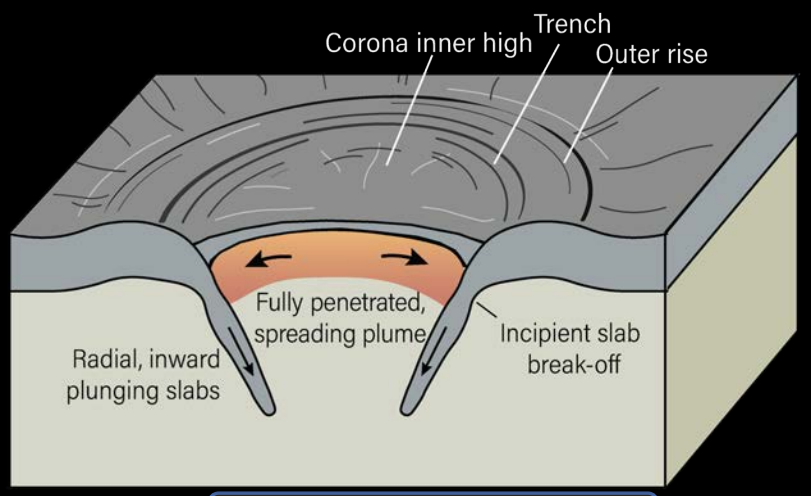


Lithospheric dripping

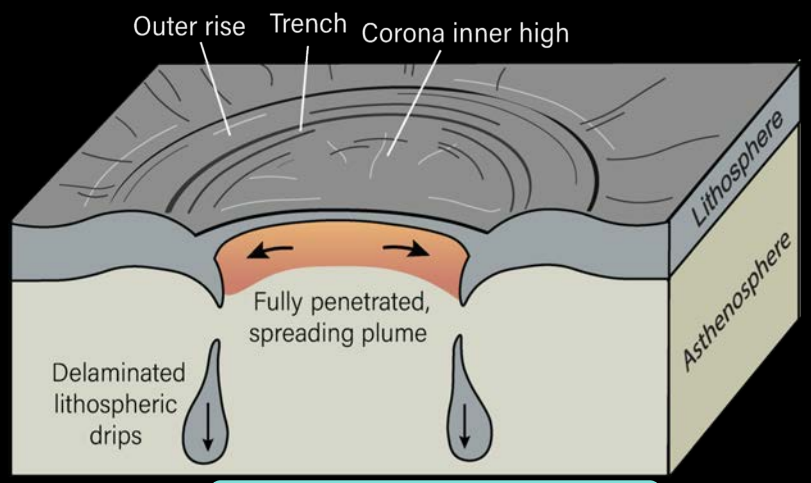


Embedded plume

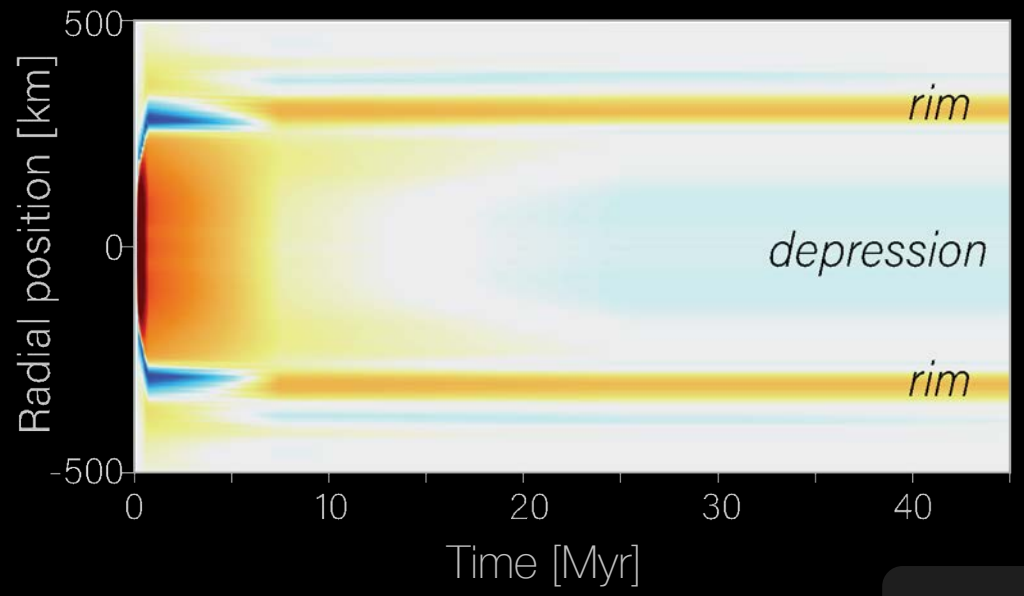
temporal evolution of topography

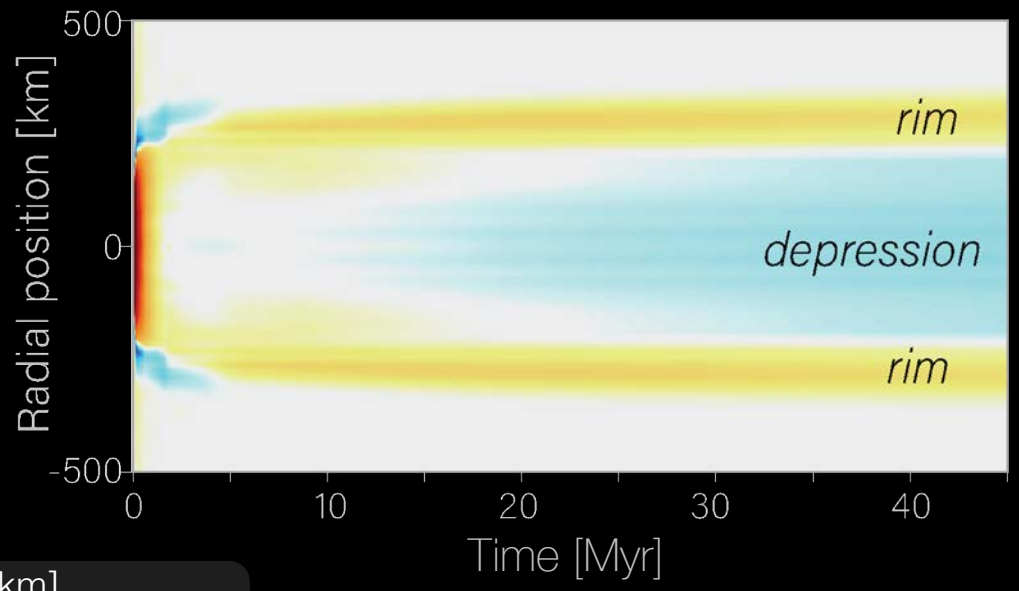


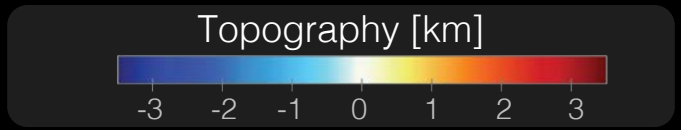
Ephemeral subduction



Lithospheric dripping







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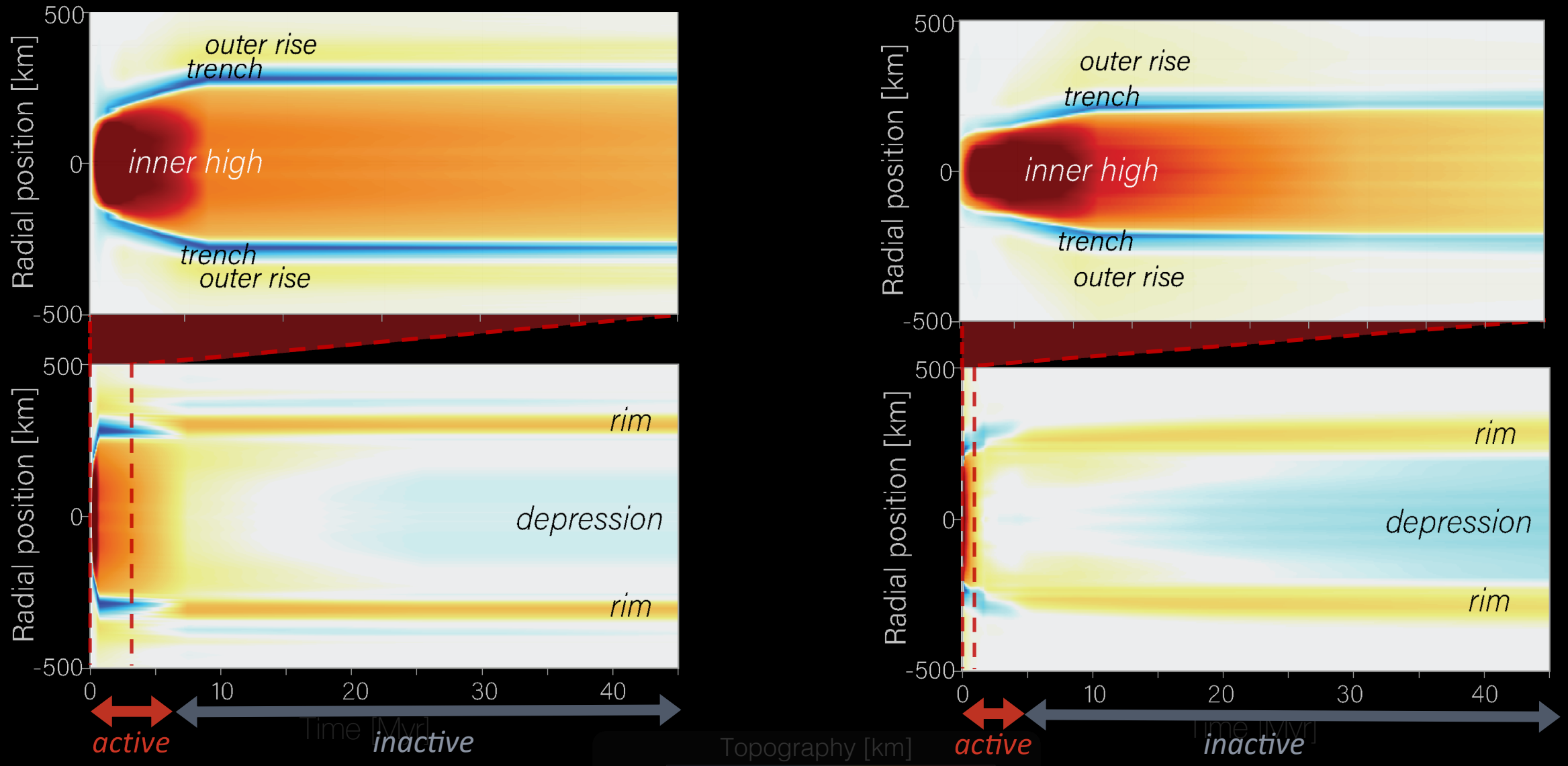
topographic inversion



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3D models – *key points*

- The morphology of coronae is related to what processes are going on underneath it
- Crustal thickness variations eventually lead to an isostasy-driven topographic inversion:

  circular trench surrounding interior high → outer rim surrounding interior depression

- The topographic pattern of coronae is therefore indicative for plume (in)activity

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3D models – *key points*

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Address the **current state of plume activity** at large coronae on Venus

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Coronae classification

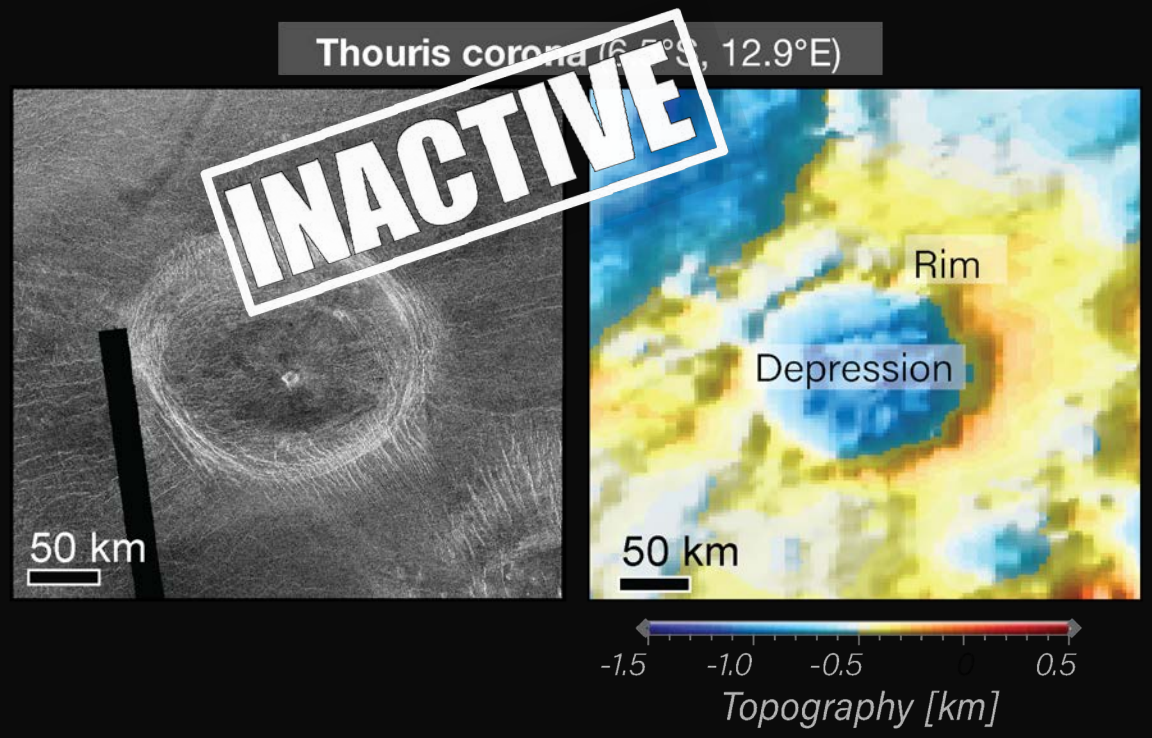
- Analyse topography of 133 largest coronae on Venus
- Classify plume activity

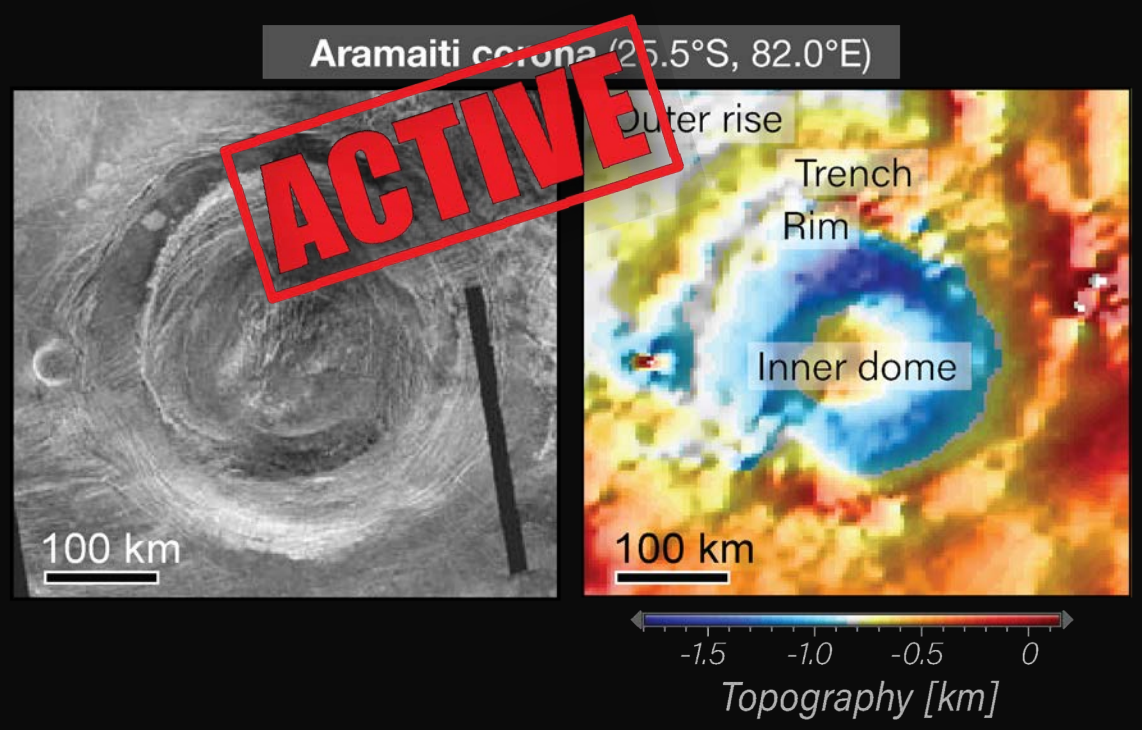
ACTIVE

- ✓ Outer trench
- ✓ Outer rise

INACTIVE

- ✓ Outer rim
- ✓ Inner depression





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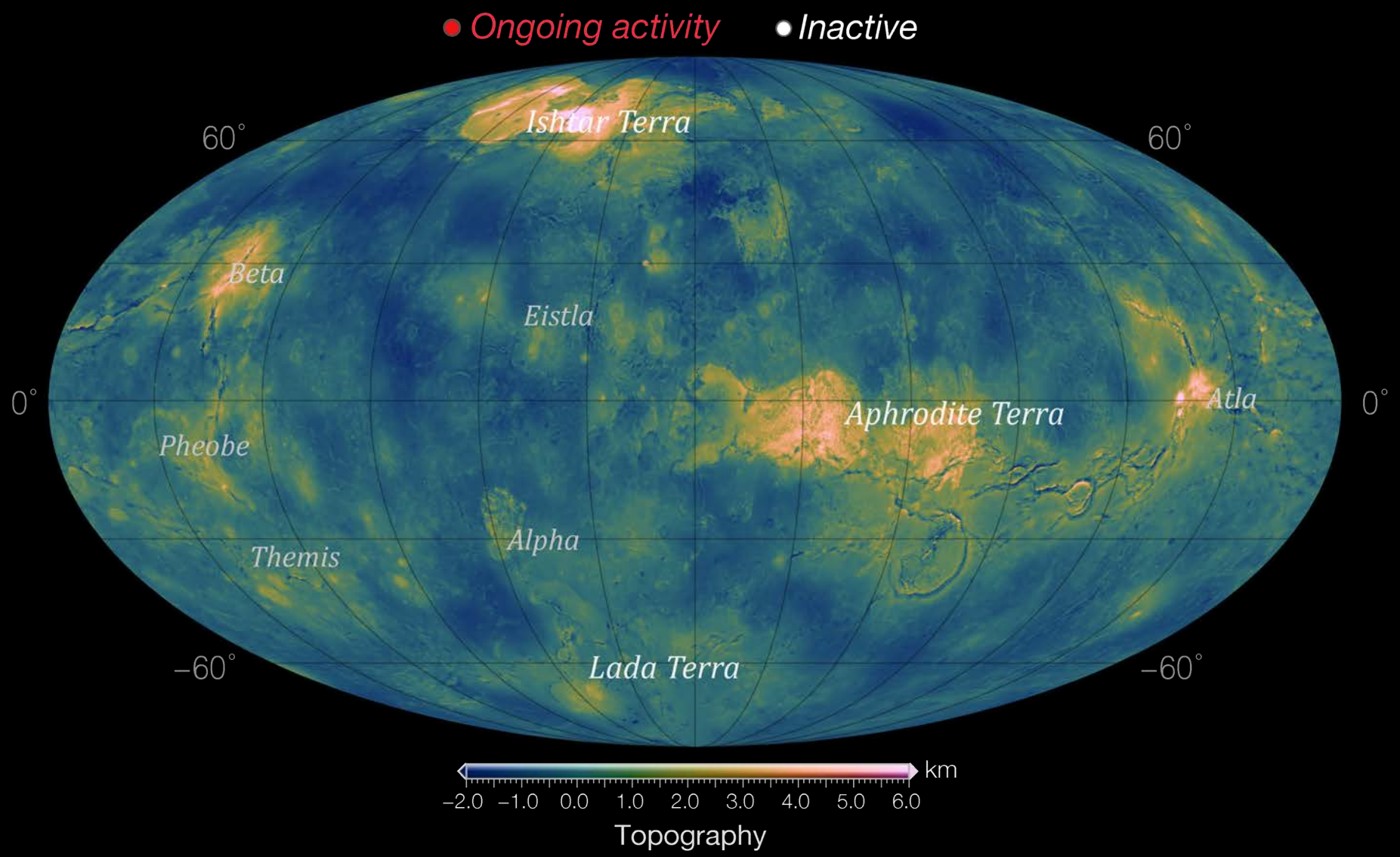
Coronae classification



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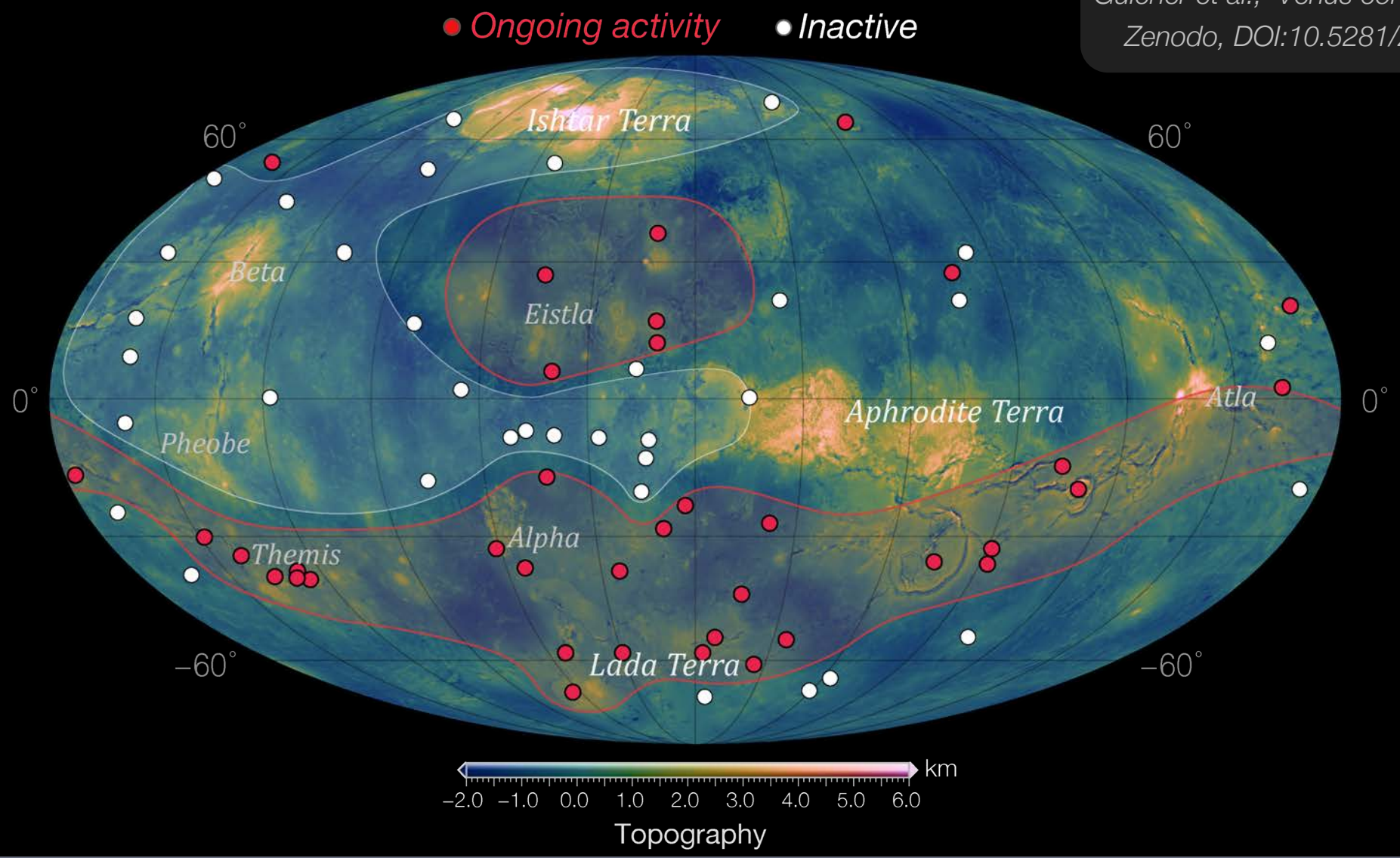
Coronae classification

Database freely available:

Gülcher et al., 'Venus coronae classification', Zenodo, DOI:10.5281/zenodo.3608692



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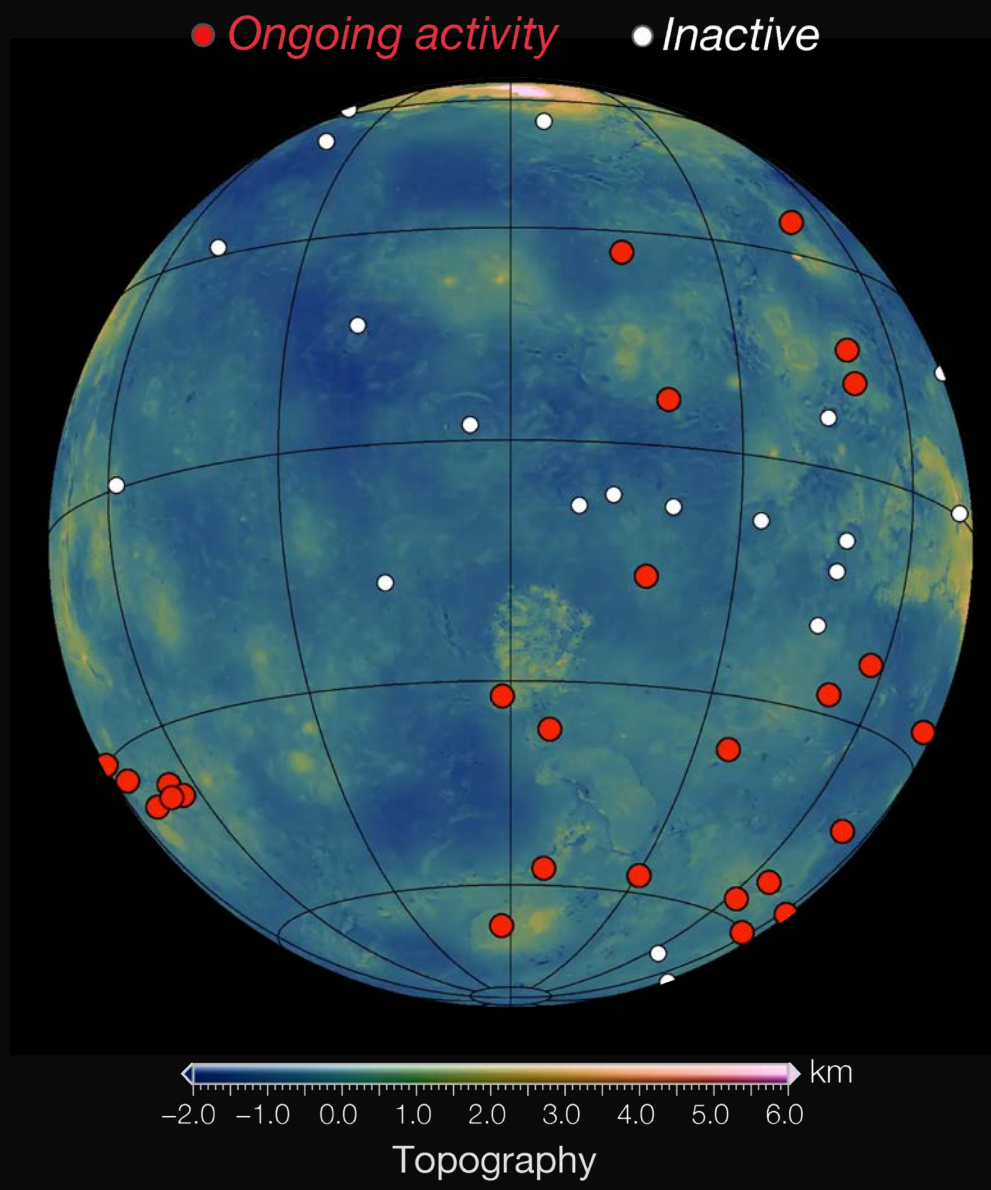
Key points

3D Numerical modelling of plume-induced corona formation:

- The morphology of coronae is related to what processes are going on underneath it
- The topographic patterns of coronae are indicative for plume (in)activity

- We identify 37 coronae whose structures are consistent with ongoing plume activity
- New evidence for widespread plume activity on Venus!
- Future studies should explore how this global distribution reflects circulation patterns of the deep interior



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