THERMAL EVOLUTION AND MAGMATIC HISTORY OF VENUS

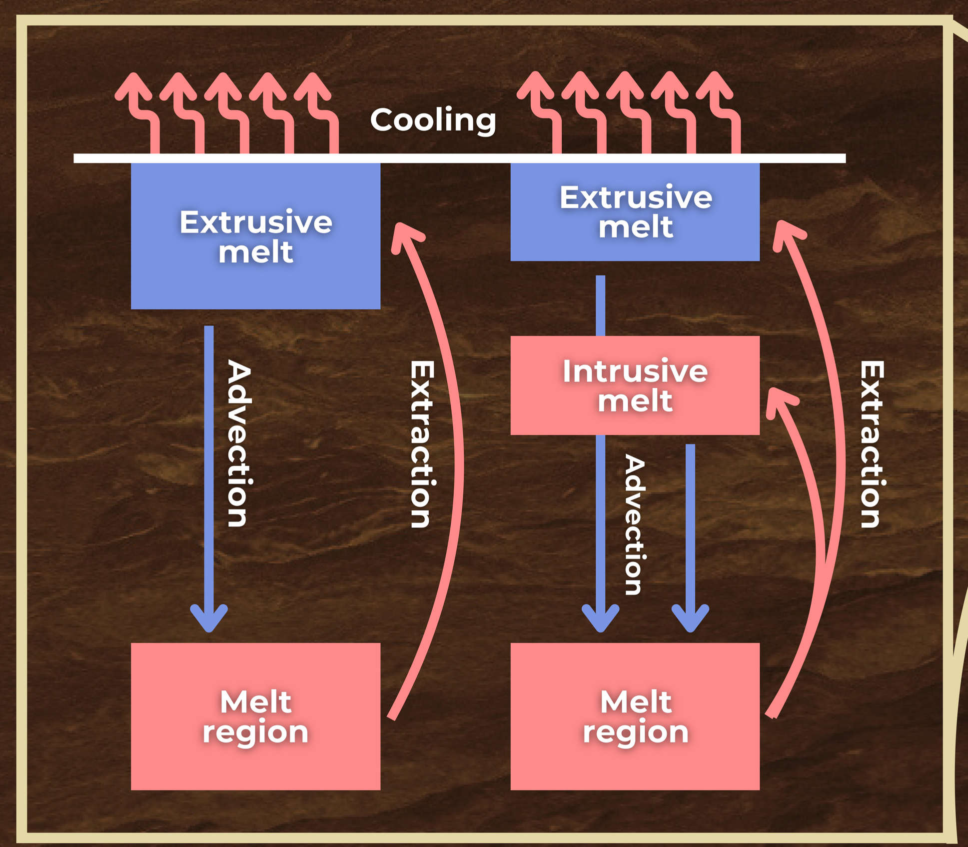
CARIANNA HERRERA[1,2], ANA-CATALINA PLESA[1], JULIA MAIA[1], STEPHAN KLEMME[2], AND LAUREN JENNINGS[2]
carianna.herrera@dlr.de

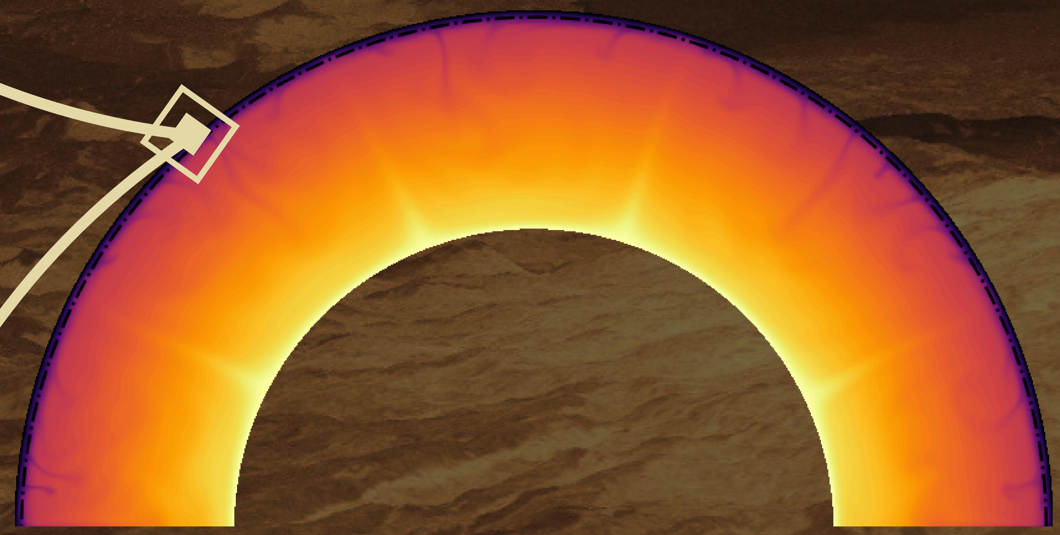
1: German Aerospace Center (DLR), Institute of Planetary Research
2: University of Münster, Institute of Mineralogy

EGU24-5946

Sharing is encouraged

Recent analysis of radar data from NASA's Magellan mission suggests that volcanic activity is ongoing on Venus [1], providing evidence that the planet's evolution and present-day state has been dominated by volcanic processes. Venus's geodynamics and tectonics seem to be well characterized by the so-called "plutonic-squishy lid" regime, where part of the melt that is formed in the interior rises to the surface but a significant part remains trapped in the crust and lithosphere magmatic intrusions [2]. These intrusions strongly influence the mantle's thermal evolution and the present-day thermal state of the interior.

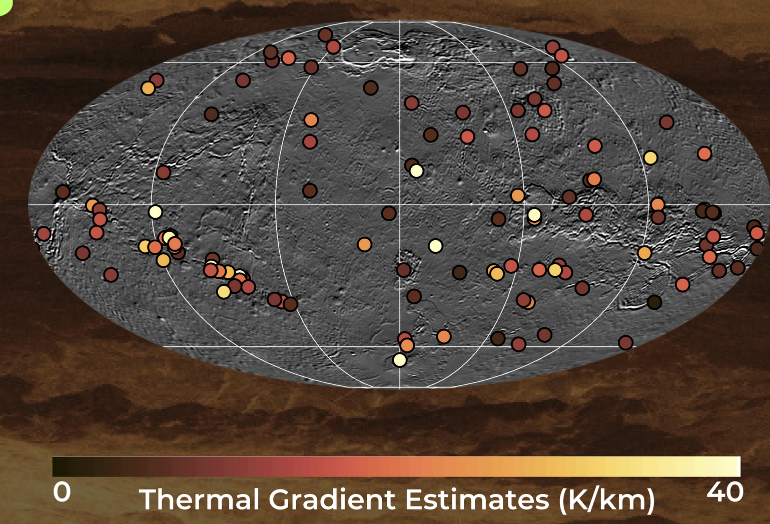


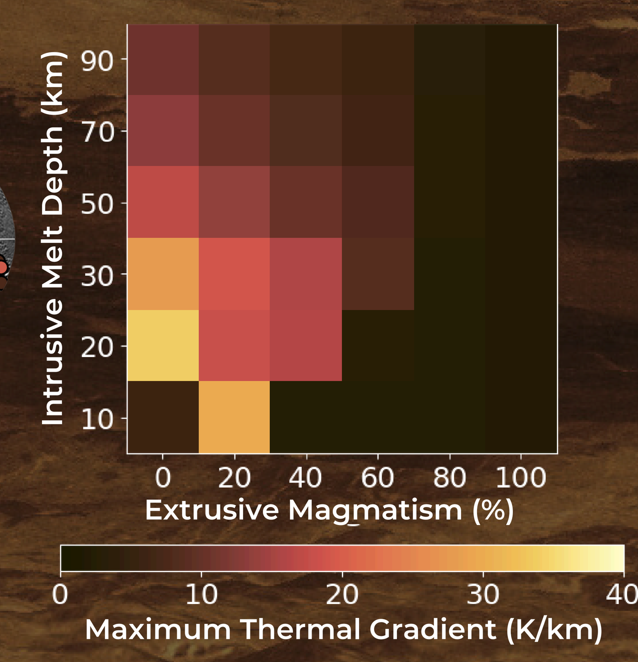


We study the effects of intrusive magmatism on the thermal evolution and present-day state of Venus. We use the geodynamic code GAIA in a 2D spherical annulus geometry [3,4]. Our models vary the intrusive-to-extrusive ratio from a fully intrusive case to a fully extrusive one and the intrusive melt depth from 10 km to 90 km.

CONSTRAINTS ON VENUS MAGMATIC STYLE

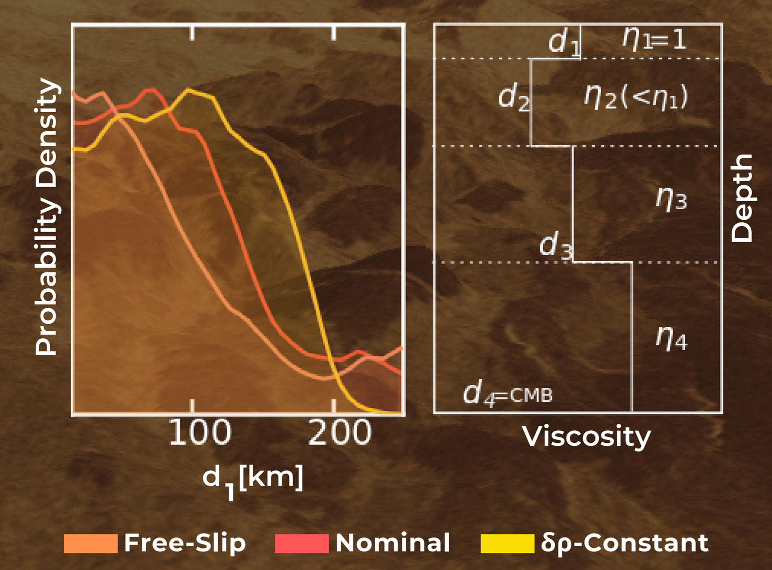
Depending on the percentage of extrusive melt and the depth of magmatic intrusions, the maximum thermal gradient goes up to ~40 K/km at the present day, with higher values obtained for higher percentages of intrusive melt and shallower magmatic intrusions.



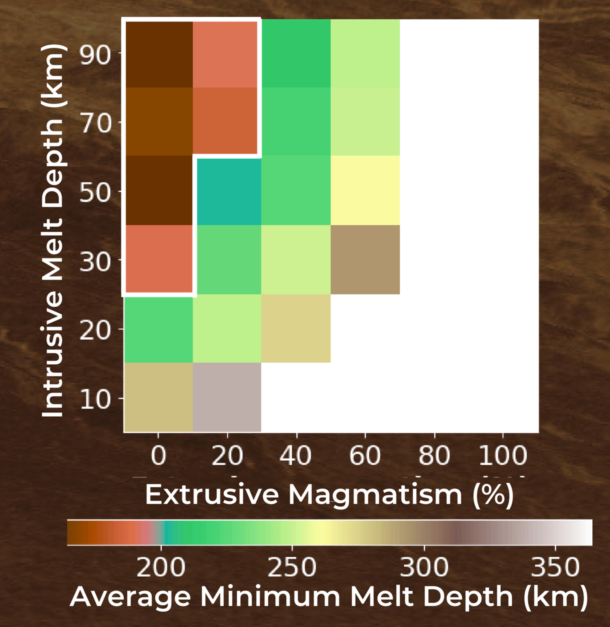


Models in which the extrusive magmatism is higher than 60% cannot explain high local thermal gradients as suggested by studies of elastic lithosphere thickness [5,6,7].

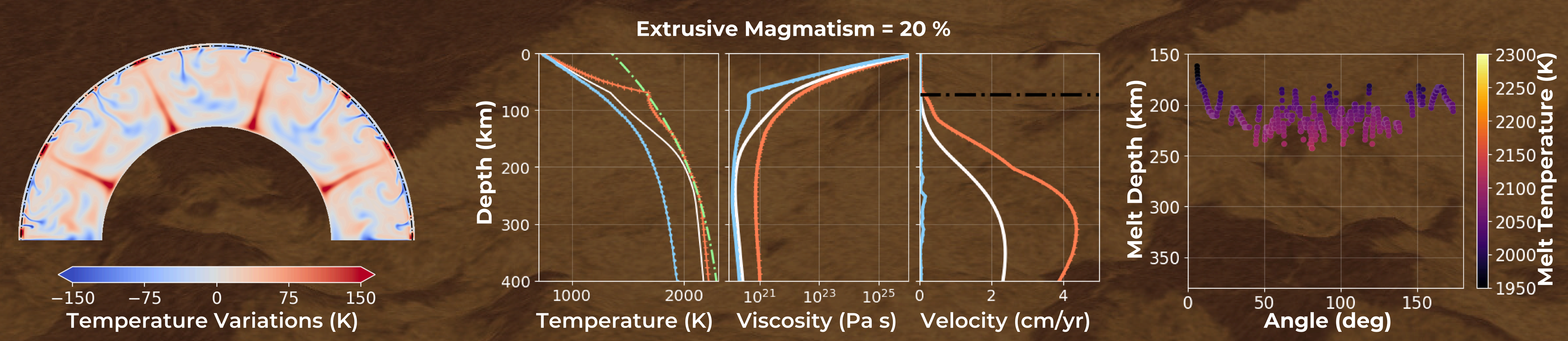
A low viscosity layer (LVL) in the shallow Venusian mantle has been suggested to be related to the presence of partial melt [7]. The LVL starts beneath the lithosphere at depths shallower than 200 km. This places constraints on the depth of melting.

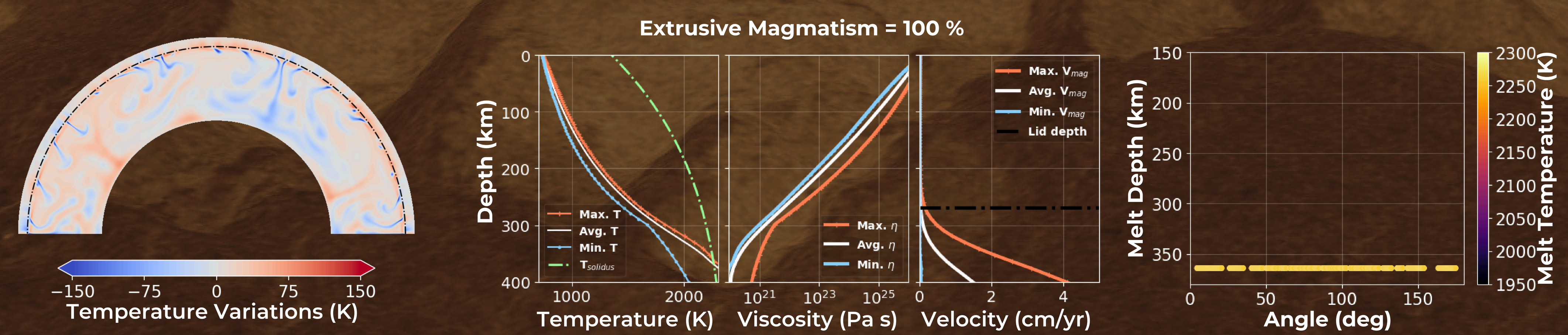


Models that are compatible with partial melting starting at a depth of 200 km or less beneath the surface require less than 40% extrusive magmatism and an intrusive melt depth strictly deeper than 20 km.



EFFECTS OF INTRUSIONS ON VENUS PRESENT-DAY STATE

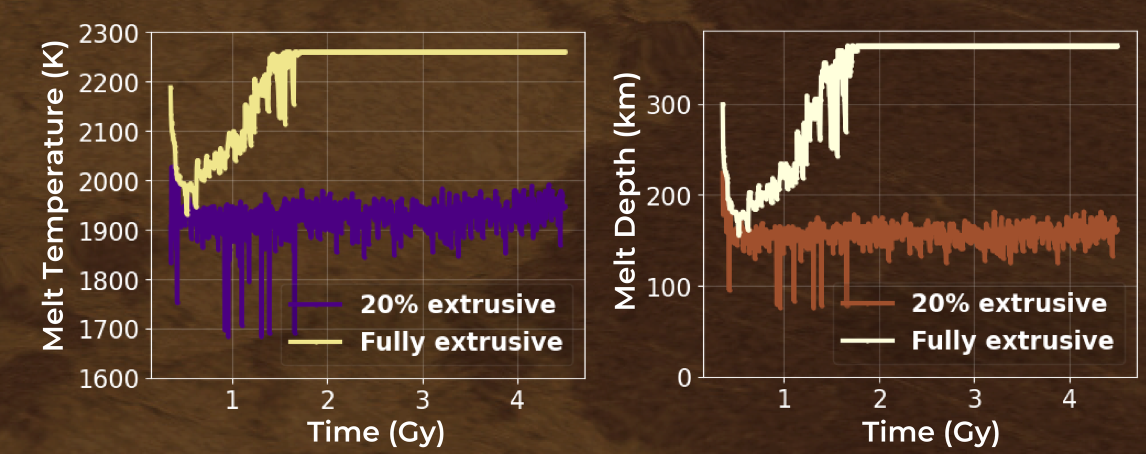




Intrusions affect the temperature, viscosity, and velocity across the mantle. The case with intrusions (placed at 70 km depth) shows more vigorous convection than the fully extrusive one. Moreover, the intrusive melt depth seems to control the lid growth. In general, the more intrusive the magmatism, the thinner the lid is.

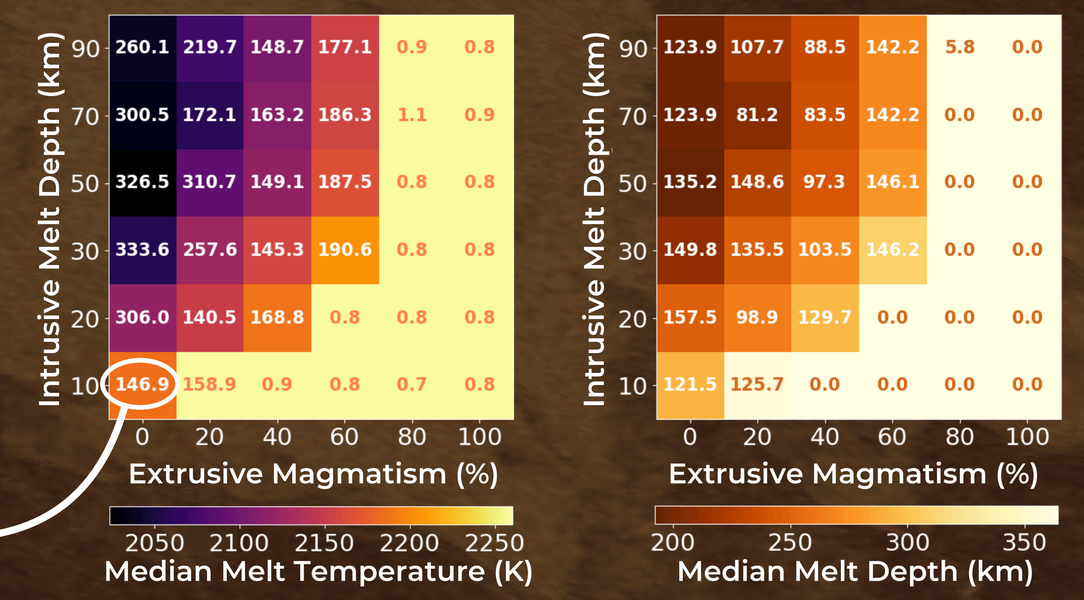
EFFECTS OF INTRUSIONS ON MELT PROPERTIES

The distinction between intrusive and extrusive cases starts very early in the evolution. Cases that have fully extrusive magmatism present hotter melt and melt deeper than the cases with some percentage of intrusions. The fully extrusive cases melt so deep that our models reach the density crossover assumed to be at ~ 11 GPa [9].



At present day, the range of melt temperatures lies between ~2000 and 2250 K, and the depth of melting between ~200 and 360 km.

These estimations serve as a starting point for high-pressure-high-temperature laboratory experiments that will be done at the University of Münster to investigate the mantle compositions of Venus that explain the Venera and Vega data.



These values show the maximum variation of the melt property range.

MAIN FINDINGS

Our analyses indicate that Venus is magmatically active, primarily governed by highly intrusive magmatic processes, compatible with the plutonic-squishy lid regime.

ACKNOWLEDGEMENTS

Authors acknowledge financial support from the Deutsche Forschungs Gemeinschaft (DFG) Grant number 509061759.

REFERENCES

[1] Herrick & Hensley, Science, 2023. [2] Rolf et al., SSR, 2023. [3] Hüttig et al., PEPI, 2013. [4] Fleury et al., Geochem. Geophys., 2024. [5] Borelli et al., JGR, 2021. [6] Maia et al., JGR, 2022 . [7] Smrekar et al., Nat. Geoscience, 2023. [8] Maia et al., GRL, 2023. [9] Ohtani et al., Chem. Geol., 1995.