

# Plume-like Features on Venus: Implications for understanding plume-like features on Earth

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# Outline

- What we know about Venus
- Forms of plume-like features on Venus (hotspots, coronae, flood volcanisms) and comparison w/terrestrial features
- Venusian features as primary, secondary, and tertiary plumes
- Leading theories for why Venus is so different from Earth and implications for plume-like features
  - 1) no low viscosity zone, 2) stagnant lid regime, 3) no-plate tectonics- no plumes

## What We Know/Don't Know

Radar images, topography, and gravity data are used to interpret the geologic history and interior structure.

Without seismology, heat flow, age dating, or petrologic/geochemical data, it is impossible to state definitively whether or not plumes exist on Venus.

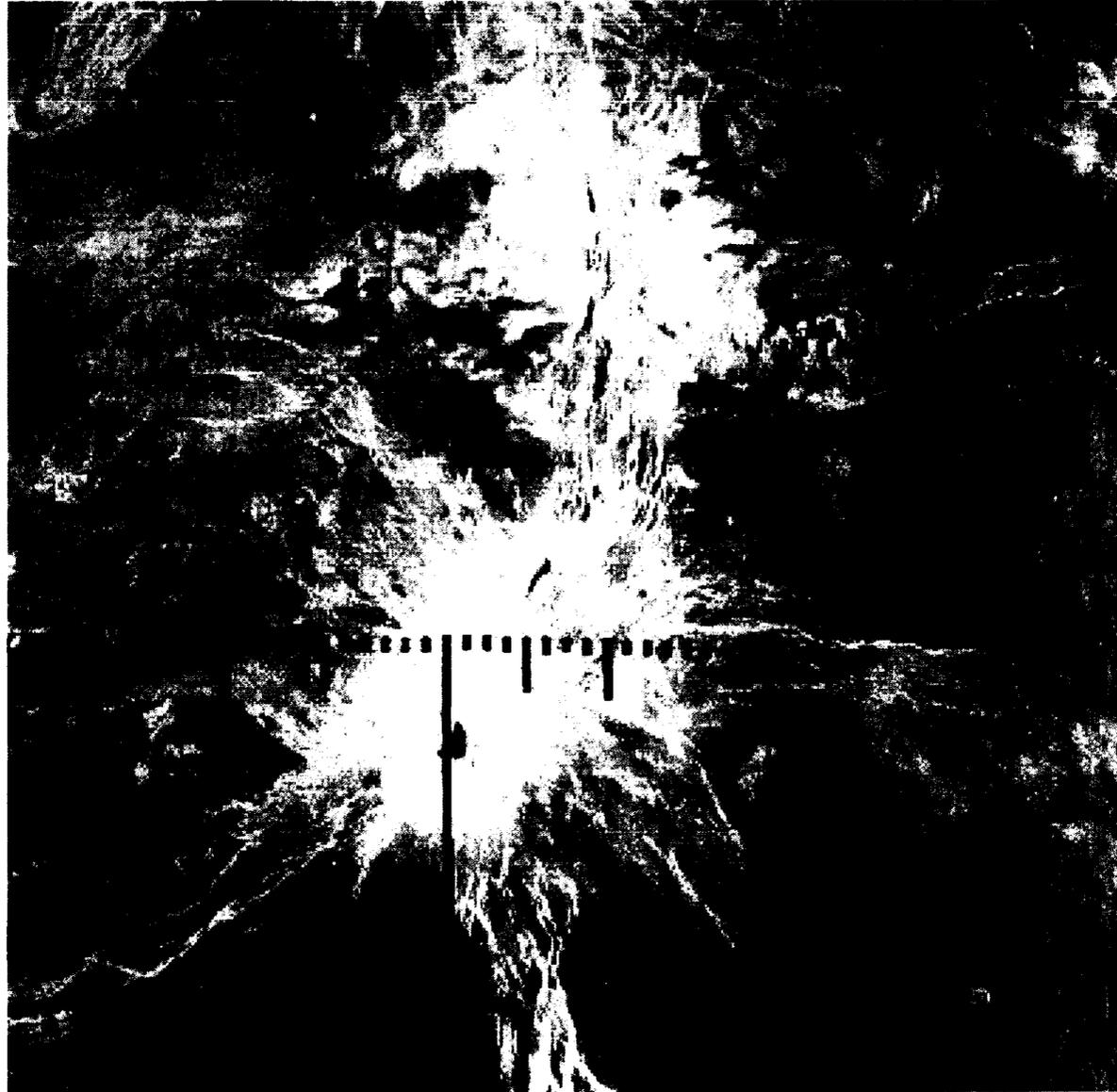
## Why will the study of Venus add to the debate?

- Venus has the nearly same size, mass, and abundance of U, Th, K as the Earth.
- Venus has an abundance of volcanic features and apparently plume-related features, some of which are analogous to terrestrial features.
- Coronae (interpreted as small scale upwellings) are unique to Venus.
- The surface age was reset 0.3-1.0 g.a.
- There is no evidence of plate tectonics.
- Ultimately we must understand why Venus has followed a different path than that of the Earth if we are to understand planetary evolution and the key factors that make Earth unique.
- (Earthlike / Not Earthlike)

# Characteristics of Large Volcanic Rises, or “Hotspots”

- Identified on Venus based on a 1) large topographic rise, 2) a large gravity anomaly, and 3) large amounts of associated volcanism
- Characteristics: Venus/Earth
- Number: 11/ 0-40
- Diameter range: 1000-2700 km/900-1500 km
- Height range: 0.5-2.5 km/0.4-2.1 km
- Assoc. shield volcanoes (or coronae): 1-4/1-2?
- Estimated volumes of associated volcanoes:
  - $33-515 \times 10^3 \text{ km}^3$  /  $3-350 \times 10^3 \text{ km}^3$
- Geoid/topography ratios: 19-33 m/km / 0-5 m/km

# Example Large Volcanic Rise (Hotspot): Beta Regio



# Characteristics of Coronae

- Coronae are nearly quasi-circular volcano-tectonic features unique to Venus
- Definition based on a 1) an annulus of tectonic fractures and 2) a range of topographic morphologies
- Characteristics:
- Number: 513
- Diameter range: 50-1080 km; mean
- Height range: 0.5-2.5 km/0.4-2.1 km
- Topographic morphology includes: domes, plateaus, and depressions, with and w/o rims or outer troughs; roughly half are raised and half depressions
- Gravity signature:
  - occur on the full range of elastic (0-80 km) and crustal (thicknesses found on Venus
  - some variation amongst morphologic types; none associated w/geologic setting
- Two types defined on annulus completeness:
  - Type 1 - 50% or more of annulus complete (#406)
  - Type 2 - < 50% of annulus complete (#107)

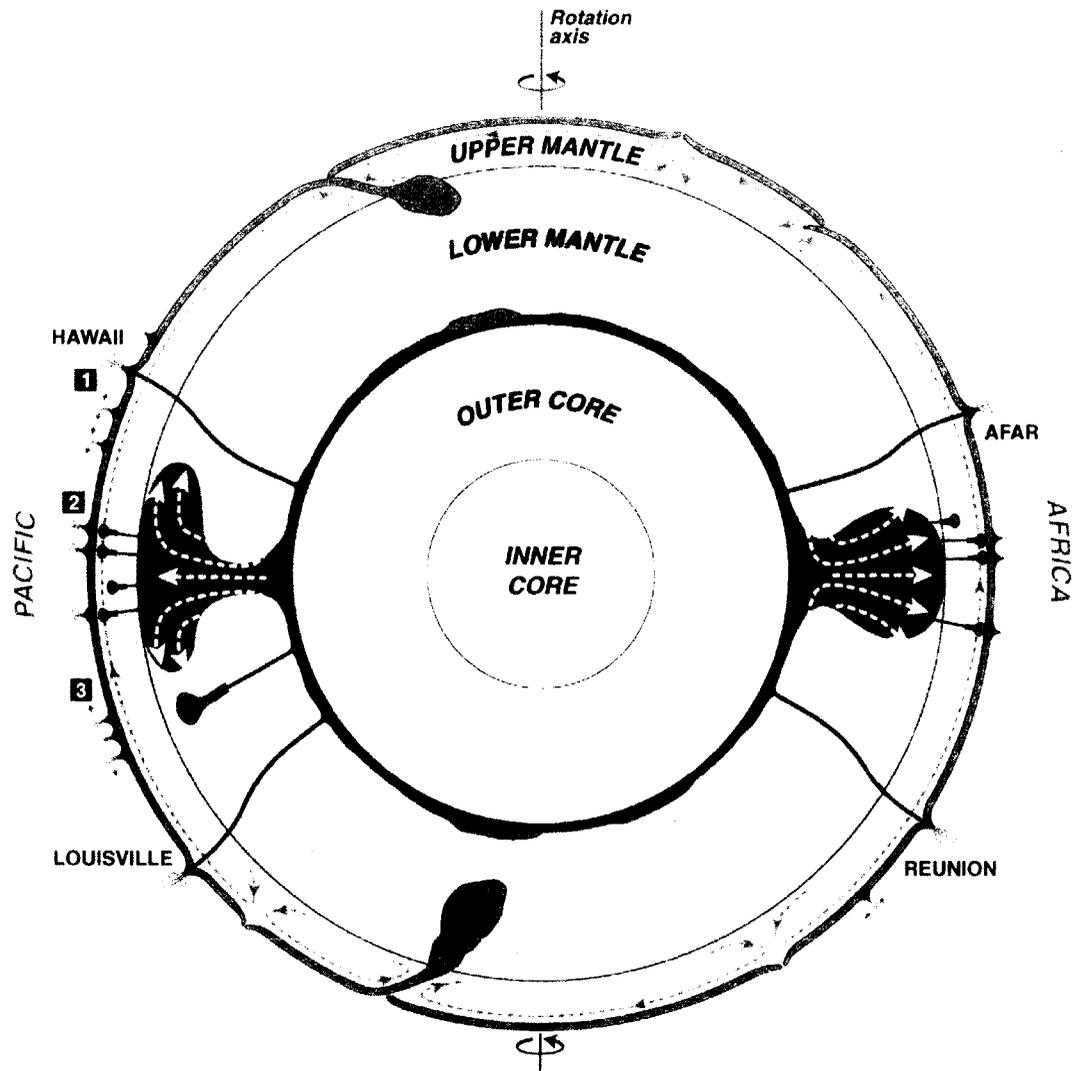
## Example of a Corona



## Example Large Volcanic Province: Mylitta Fluctus



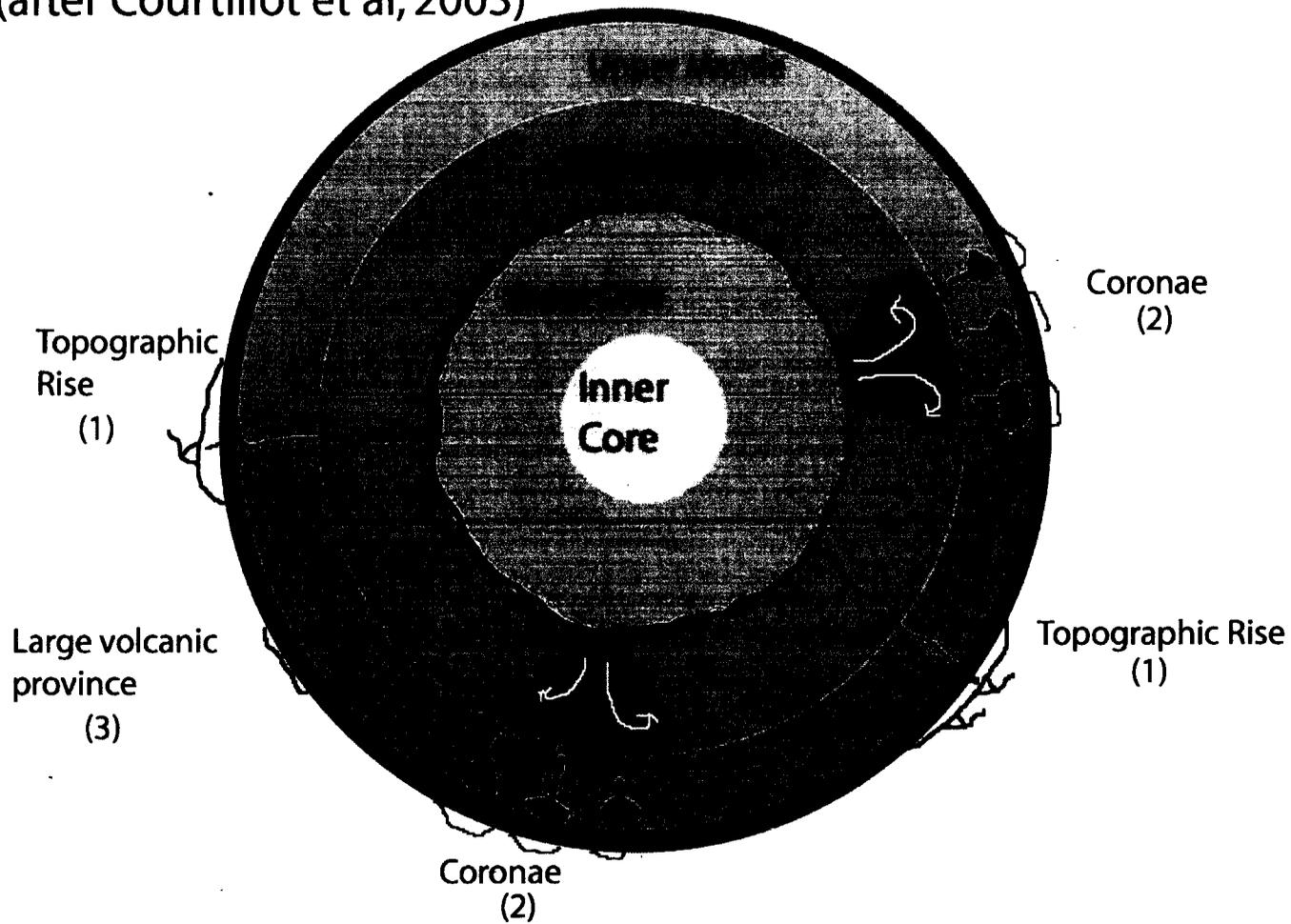
# One Model for Terrestrial Hotspots: Courtilot et al. 2003



# An Analogous Interpretation of Venusian Features

Venus Model

(after Courtillot et al, 2003)



# Plume-Like Features and the Stagnant-Lid Hypothesis

[e.g. Moresi and Solomatov, 1998; Reese et al., 1999; Solomatov and Moresi, 2000]

- In the stagnant lid hypothesis suggests, the key difference between Venus and Earth is that the lithosphere on Venus is so dry and strong that it cannot deform easily enough to allow plate tectonics to develop.
- In this hypothesis, the mantle convection pattern is essentially Earth-like, but heats up with time, possibly allowing for lithospheric overturn.
- If the convection pattern is the same, the prediction for 'plume-like' features is essentially the same.
- Pros:
  - 1) Suggests a mechanism for resurfacing
  - 2) Could coronae result from heating of the mantle?
- Cons:
  - 1) how does lithospheric overturn occur?
  - 3) Would strong lid preclude ongoing surface deformation and volcanism?

# Plume-like Features and the No Low Viscosity Zone Hypothesis

[Smrekar and Phillips, 1991; Kieffer and Hager, 1992]

- In this hypothesis, the key difference between Venus and Earth is that the asthenosphere on Venus is so dry that no plate tectonics occurs, and the surface manifestation of upwellings are very different.
- In this hypothesis, the mantle convection pattern is essentially Earth-like, but heats up with time, possibly allowing for lithospheric overturn.
- If the convection pattern is the same, the prediction for 'plume-like' features is essentially the same.
- Pros;
  - 1) explains the large geoid to topography ratios at large volcanic rises on Venus
  - 2) explains why coronae are present on Venus but not on Earth (on Earth, small upwellings would have a different manifestation)
  - 3) might explain why there is no plate tectonics, if the low-viscosity zone is important
- Cons:
  - 1) Doesn't explain young surface age on Venus

# Plume-like Features and the No Plate Tectonics-No Plume Hypothesis

[Jellinek et al., 2002; Johnson and Richards, 2003 ]

- In this hypothesis the key difference between Venus and Earth is that subduction of cold material controls the temperature contrast at the core-mantle boundary and the formation of large plumes. On Venus, the lack of subduction would preclude the formation of large plumes.
- In this case, both the convection pattern and mantle upwellings are thought to be different. Thus coronae are due to a fundamental difference in the convective pattern.
- Pros:
  - 1) explains why coronae are present on Venus but not on Earth
- Cons:
  - 1) Some large volcanic rises are thought to be active.
  - 2) calls on some other explanation for lack of plate tectonics and for the young surface age for Venus

## Ultimate Questions for Venus

- Why does Venus have no plate tectonics?
- Why has there been less resurfacing in the last ~700 m.y.?
- How do coronae form? Why only on Venus? What is their contribution to heat loss?