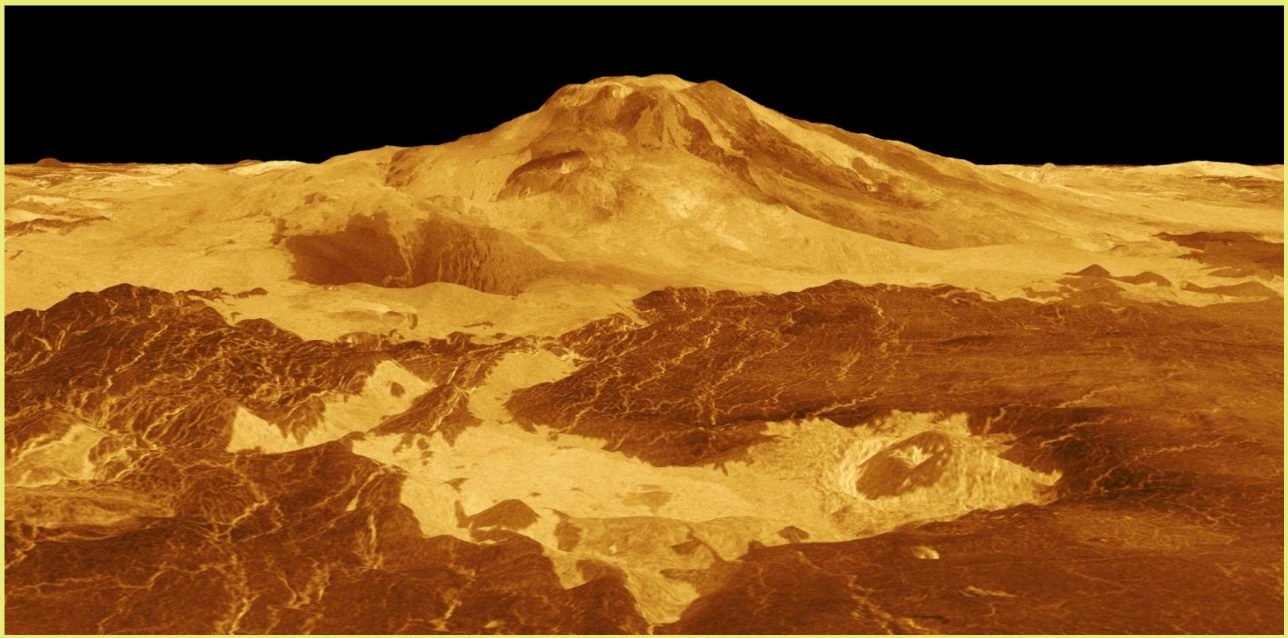
Major Constraints on the Geodynamic State of Venus and Compatible Internal Conditions



Robert Herrick

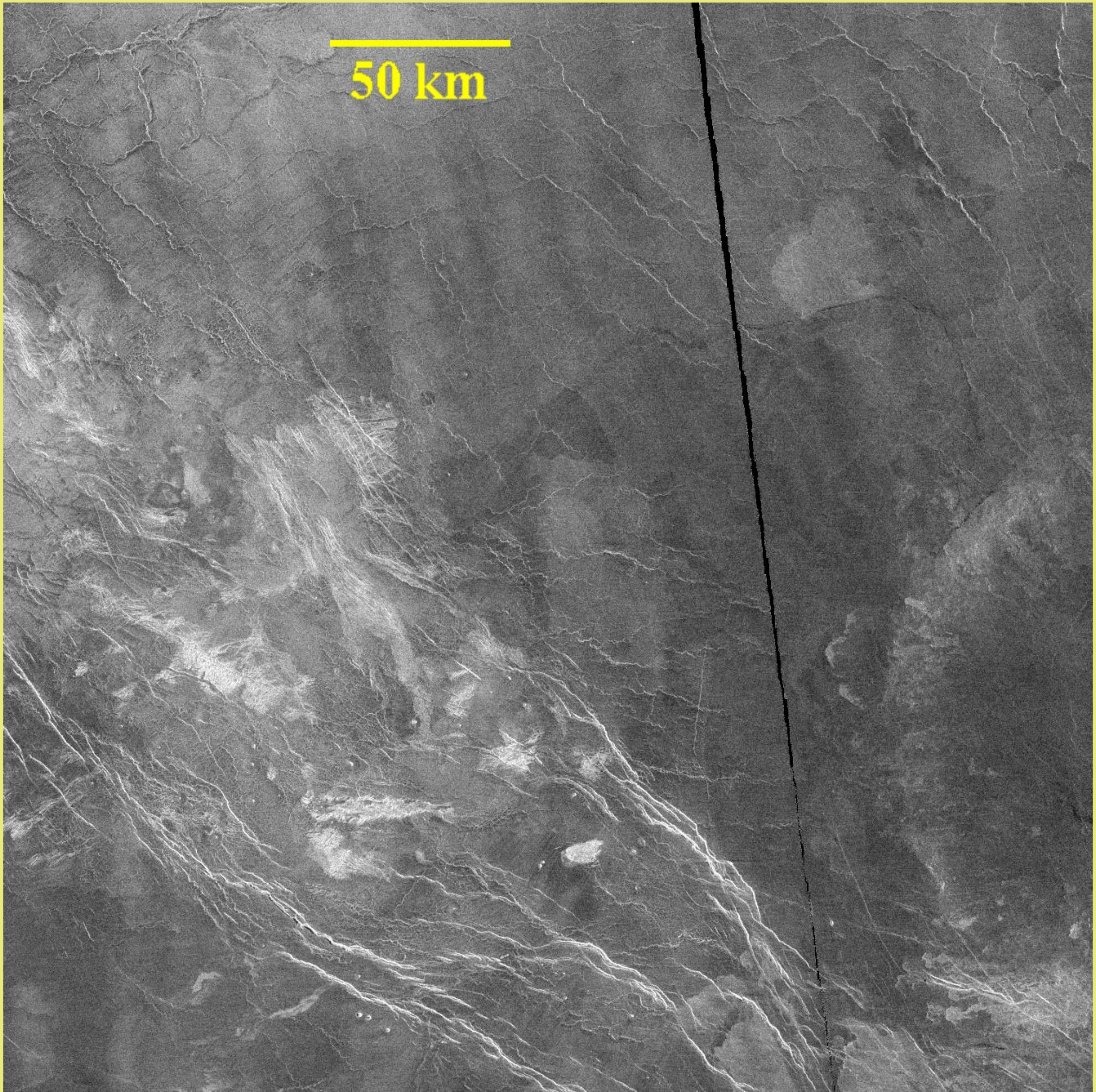
Geophysical Institute

University of Alaska Fairbanks

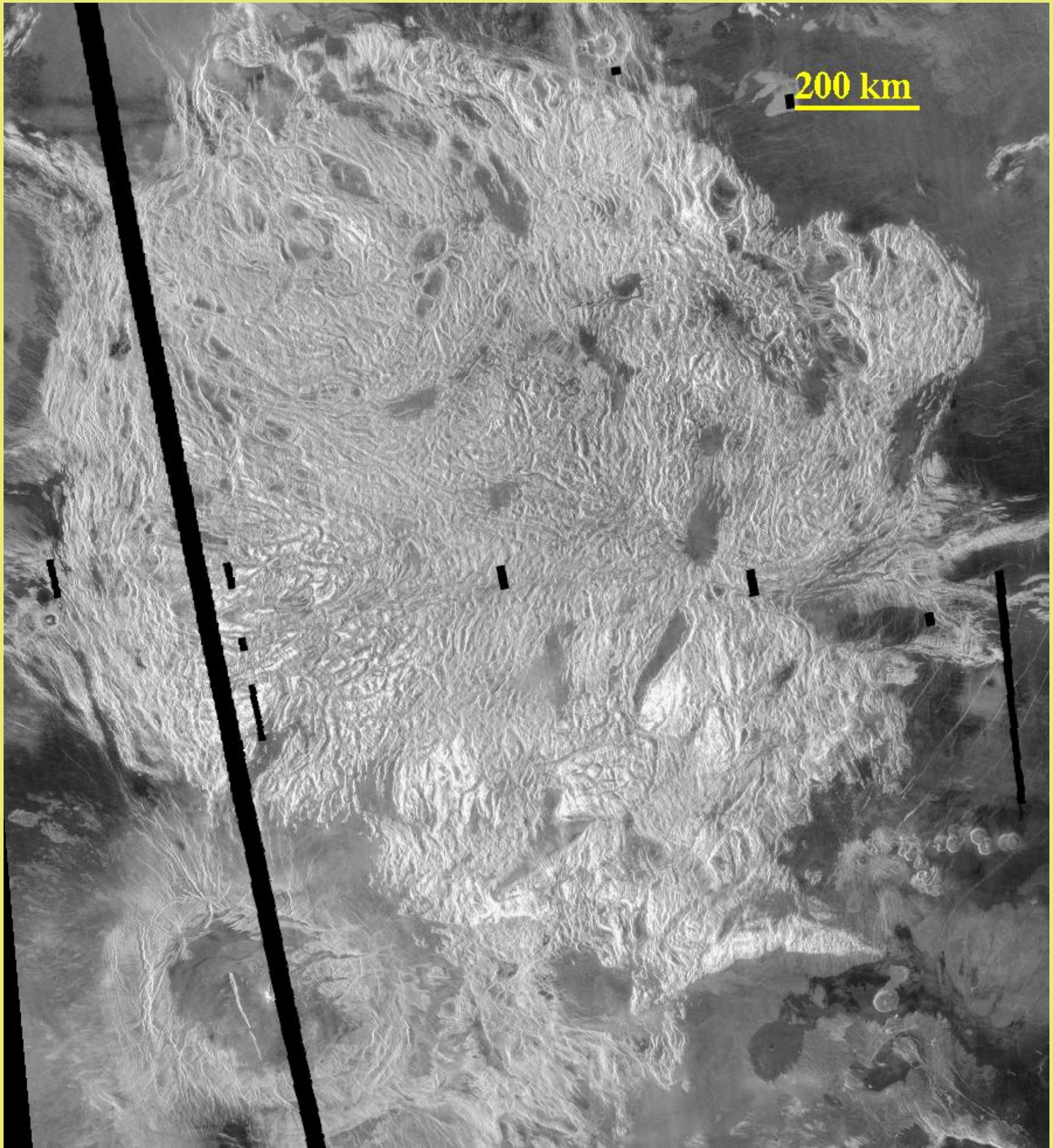
Introduction

- Initial post-Magellan analyses discussed "catastrophic" versus "random resurfacing."
- These initial ideas have matured to an "evolutionary" versus "steady-state" view of the geologic history.
- I will summarize the primary constraints on the geologic history and argue that existing data cannot fully rule out the competing world views, and discuss the implications for internal thermal state.

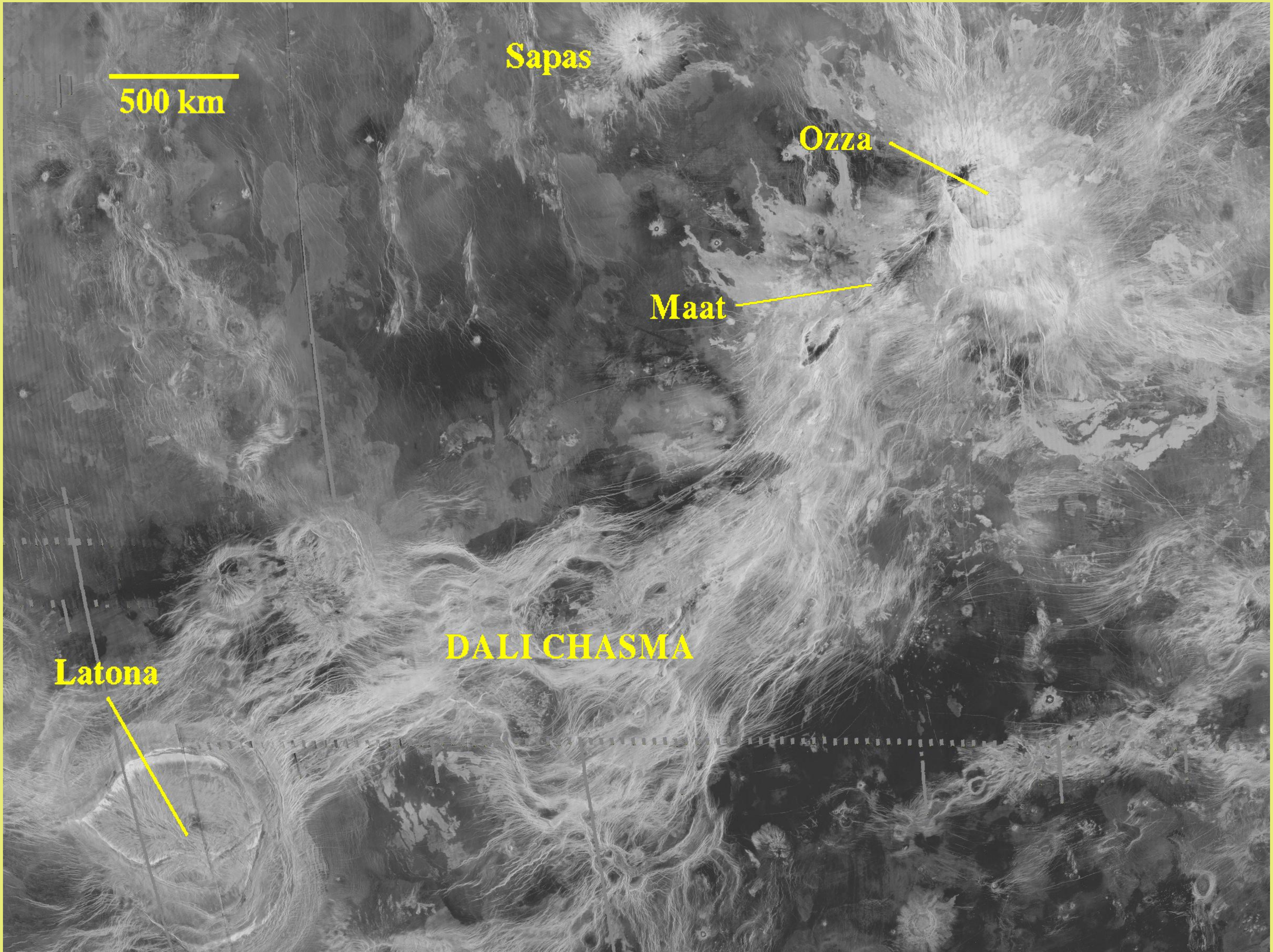
Plains: ~80% of the planet within 1 km of mean elevation



Tessera: <10% of the planet as elevated, deformed plateaus



Rifts, volcanoes, coronae: 10% of the planet



Global stratigraphic sequence, as developed by Basilevsky, Ivanov, Head, et al.

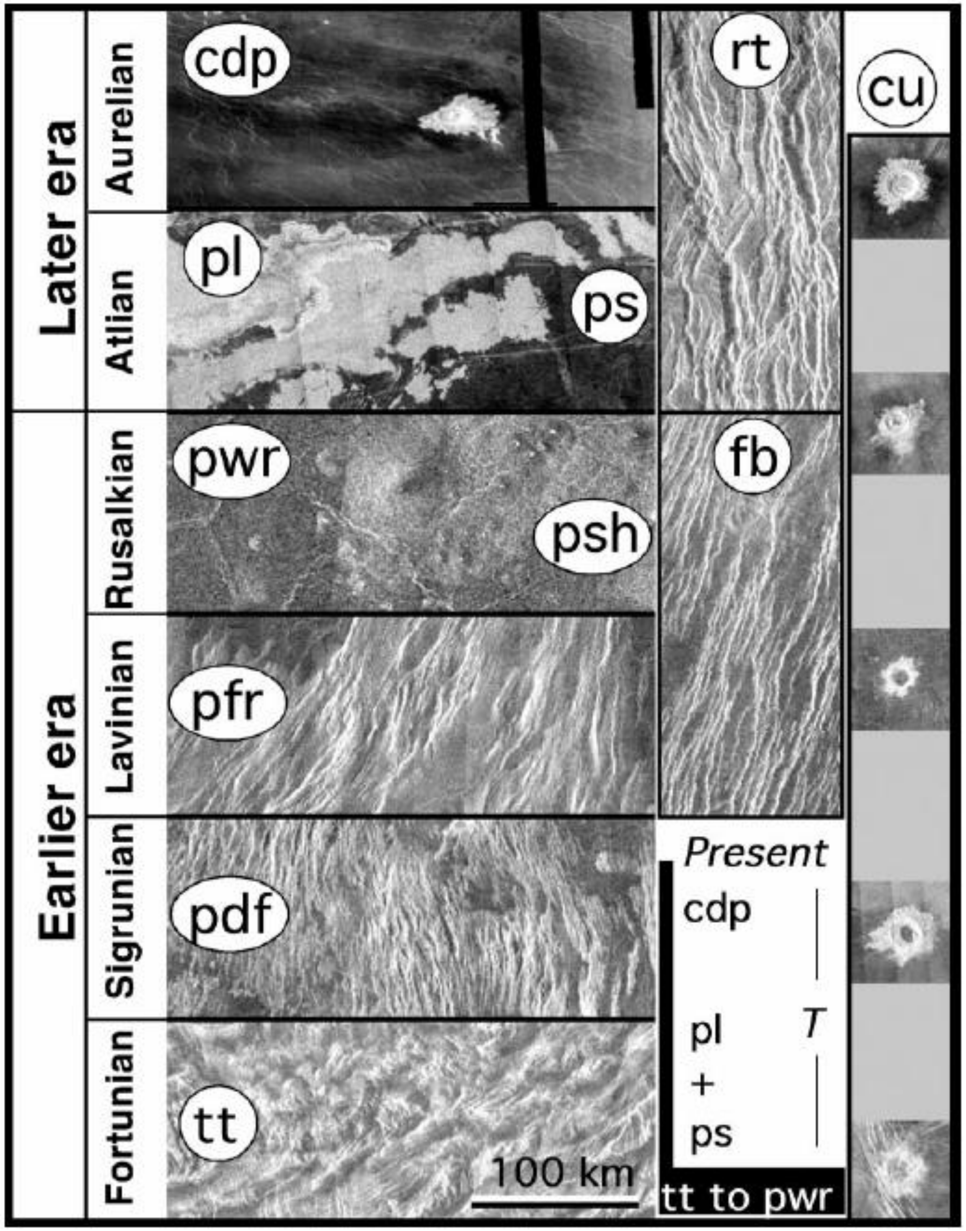


Figure 1. Magellan radar images of geologic units and structures on Venus arranged in order of global stratigraphic model of history of Venus (see text for description and references). Letters designate units and structures: cdp—dark parabolas; pl—lobate plains; ps—smooth plains; pwr—plains with wrinkle ridges; psh—shield plains; pfr—fractured and ridged plains; pdf—densely fractured plains; tt—tessera terrain; rt—rifted terrain; fb—fracture belts; cu—undivided crater materials. Names show time-stratigraphic and geologic time units. Inset shows approximate duration of periods in reference to *T*, mean age of regional plains. These time durations and implied rates show that Venus was very active during short earlier era and much less active in following longer era. Unit cu, undivided craters (right column), was forming throughout both eras.

Hansen (2000) – Highlights problems with Basilevsky et al. approach

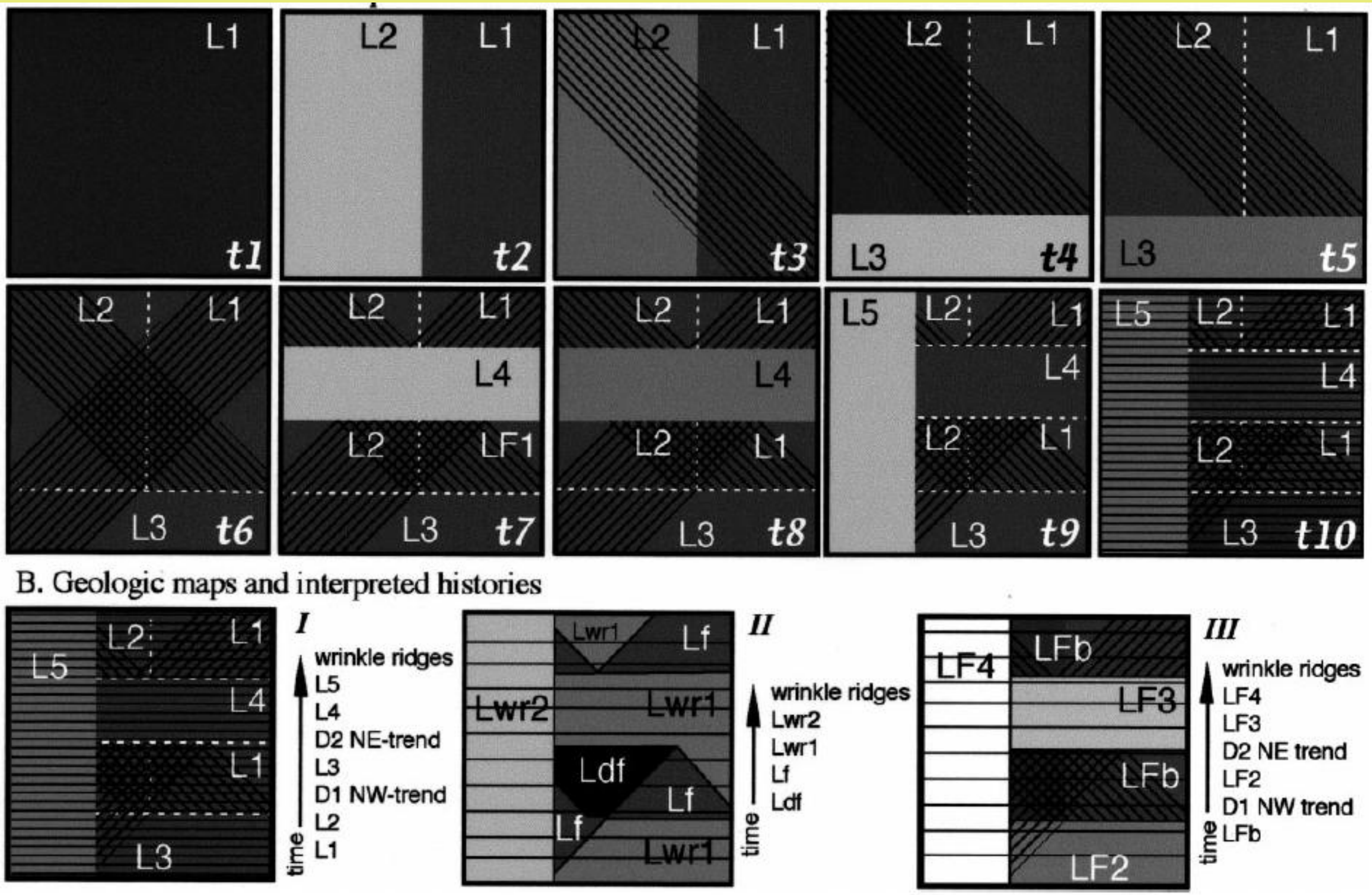


Fig. 1. Geologic history experiment of a simple 10-time-step surface evolution. Sequential flood-lava flows (L1–5) darken with time [19] over three time steps; dotted lines mark flow boundaries; closely spaced black lines indicate suites of secondary structures (fractures, faults, folds); horizontal lines mark wrinkle ridges. B: Geologic maps and resultant histories determined by: (I) experiment; (II) global stratigraphic method (unit definition includes secondary structures: f, fracture; df, densely fractured; wr, wrinkle ridged), and (III) geohistory method.

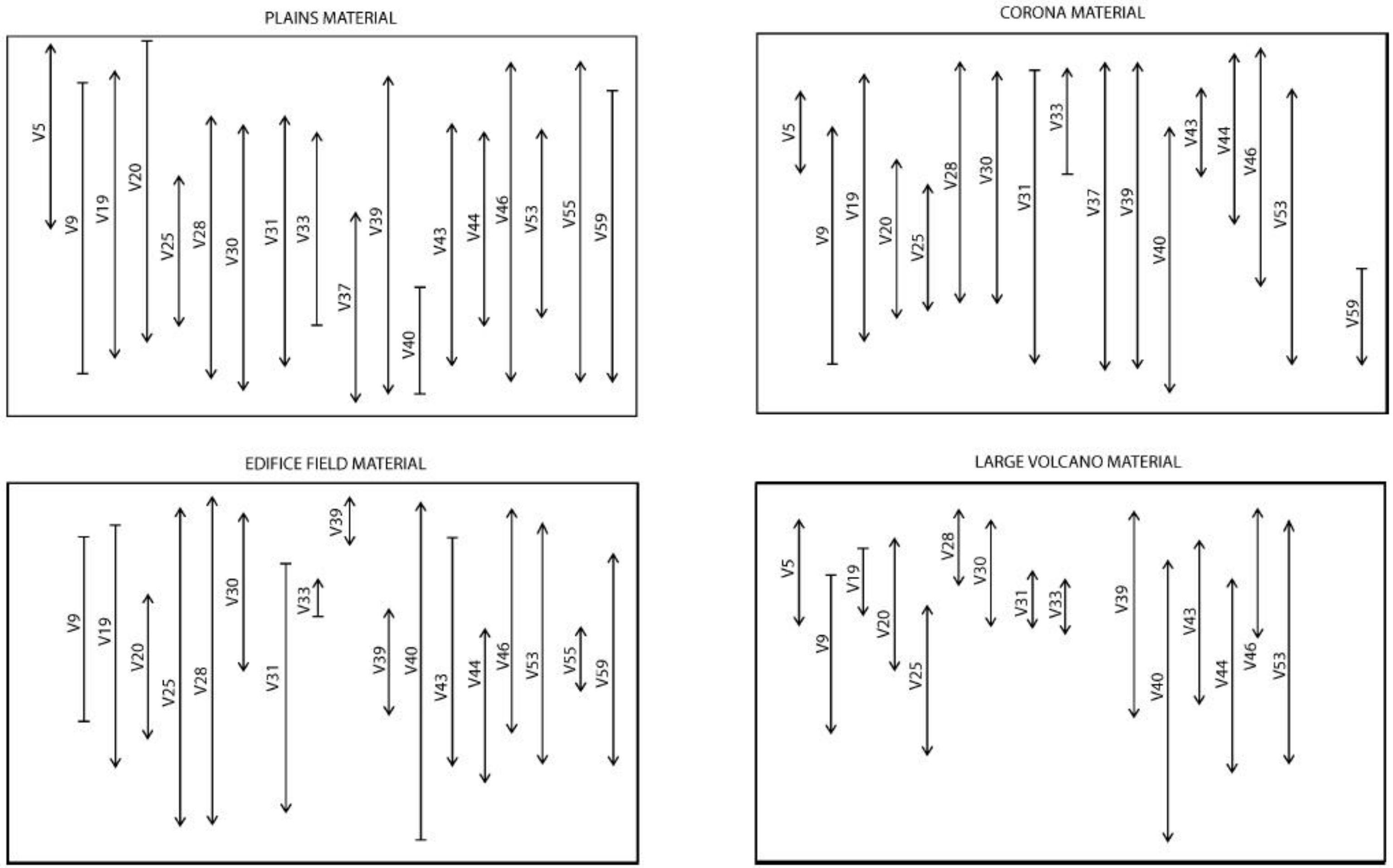
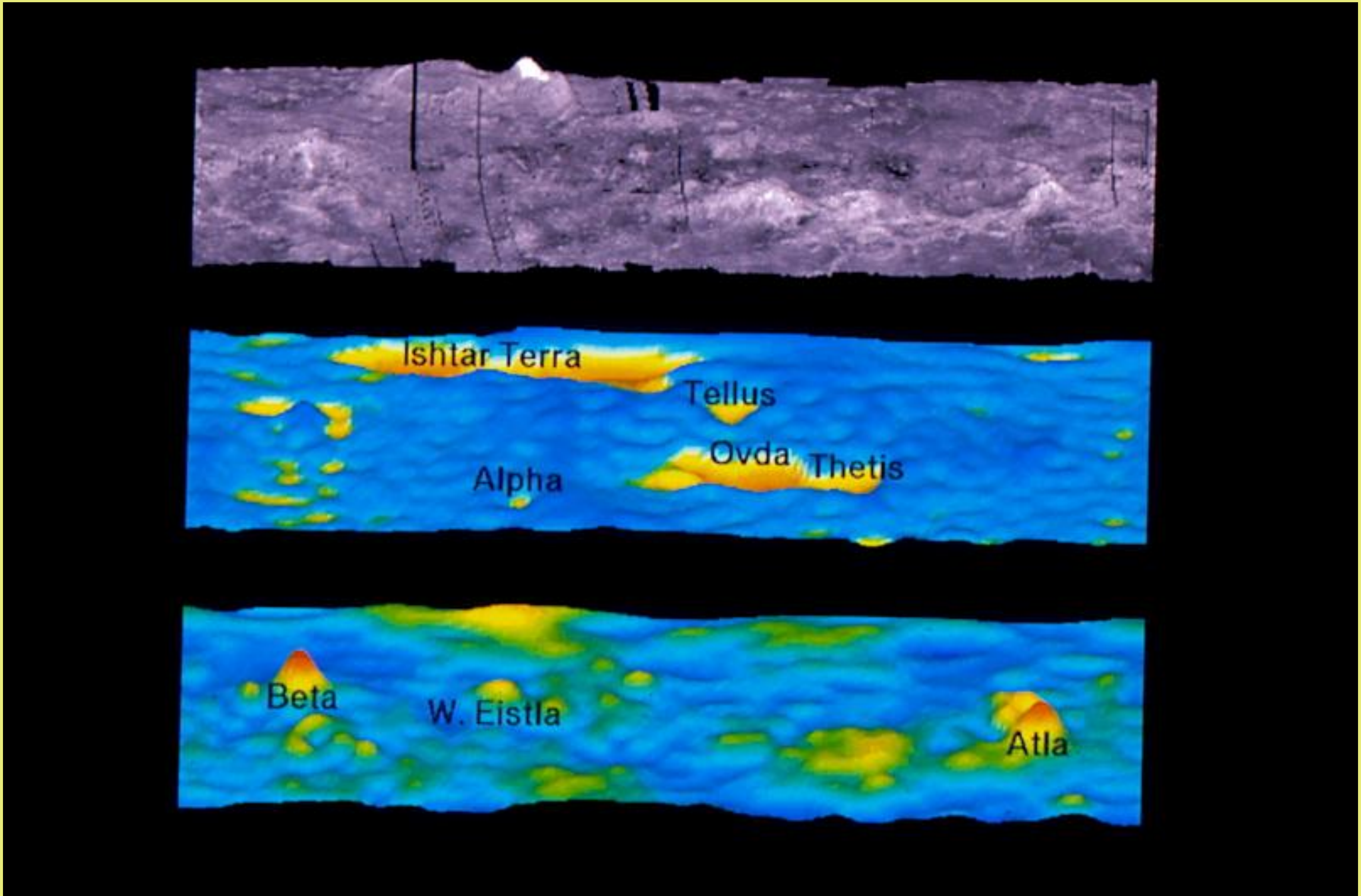
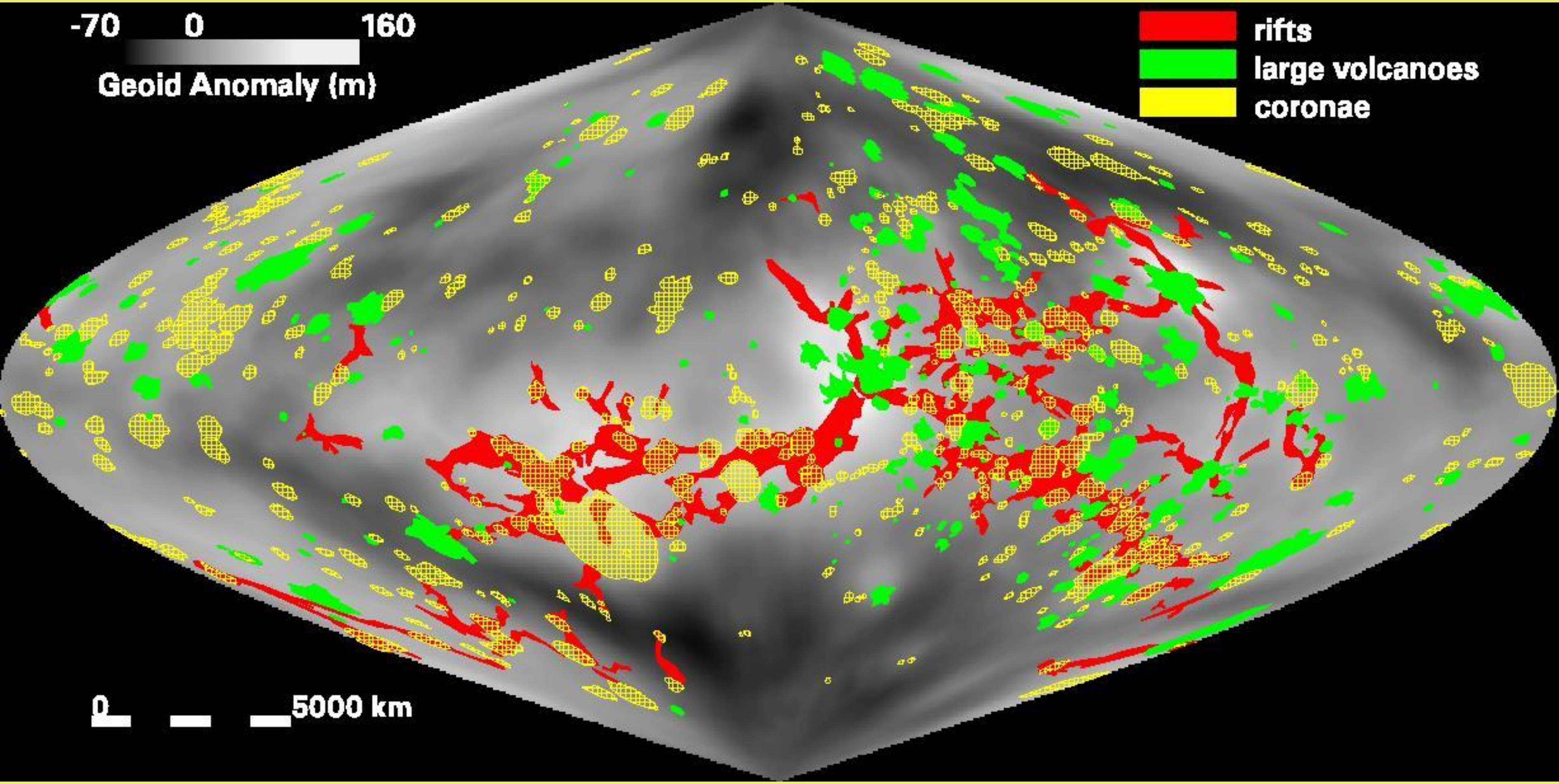


Fig. 4. Summary of correlation charts for the eighteen quadrangles surveyed for plains materials, corona materials, edifice field materials and large volcano materials. The length of the line for each feature type represents the box length for the unit from each quadrangle's correlation chart, with jagged ended boxes (represents minimum duration) identified by an arrow and flat ended boxes (units with determinable duration) represented by a horizontal line. We also grouped all units of that type into a single line; for example, a corona line from a quadrangle may actually combine four or five corona materials units. Not every quadrangle is represented for every feature type, as some quadrangles did not have the unit type (for example, quadrangle V55 did not have any large volcano materials units). The bottom of nearly all the correlation charts, and thus also this chart, is set by the stratigraphic position of tesserae; any uncertainty in merging the charts is dependent on the interpretation of this unit as a globally older unit.

Gravity and topography can be inverted for mass anomalies on two surfaces – top, crustal thickening; bottom, dynamic support.



Looking just at the rift-volcano-corona system, the big volcanoes are on geoid highs, and the remainder of the rift-coronae avoid geoid lows.



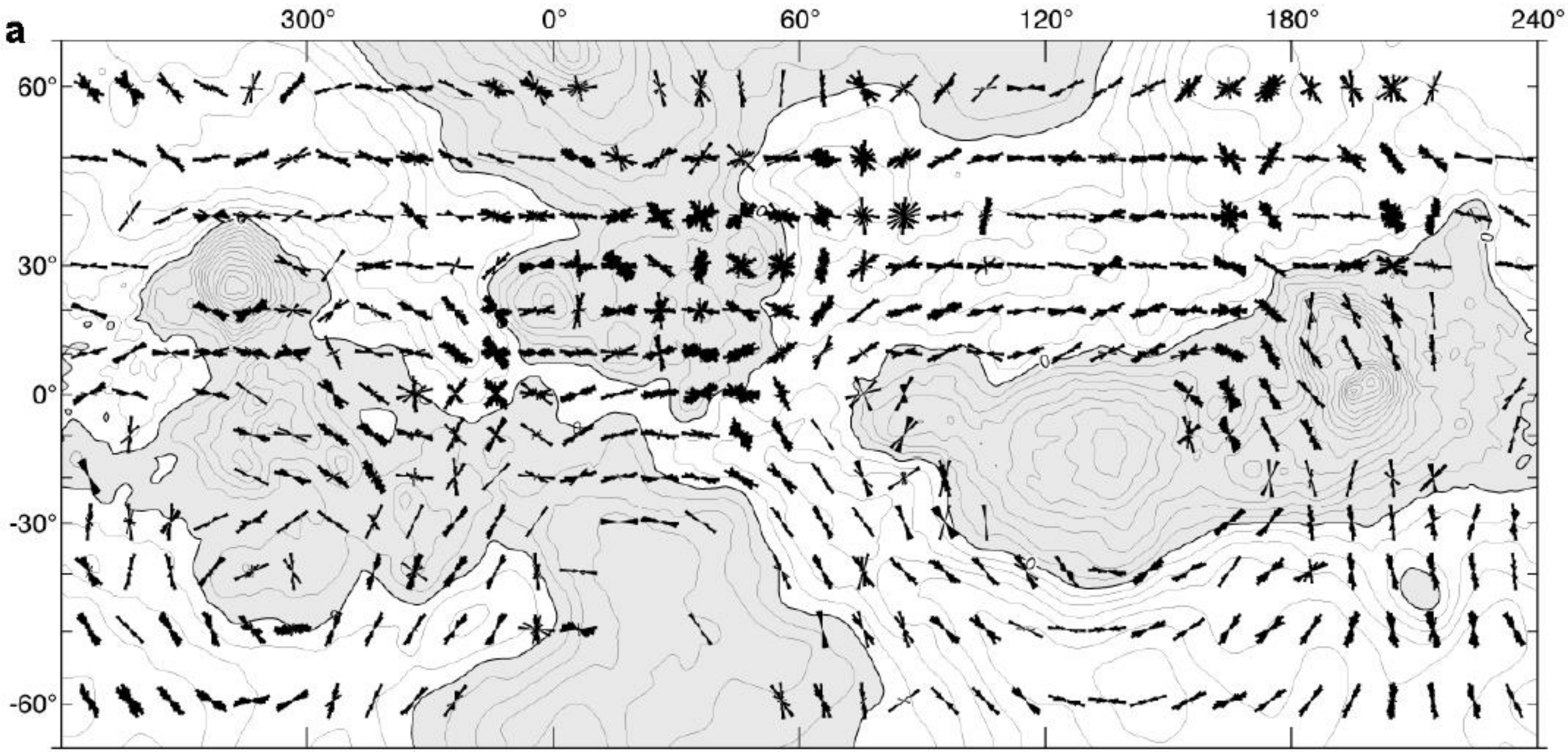
Constraints on Crustal Thickness and Thermal Lithosphere Thickness

- **Crust:** Use gravity and topography to determine compensation depth for crustally supported feature. 10-40 km
- **Elastic lithosphere:** Wavelength-dependent topography and gravity/topography response to loading. 5-30 km
- **Thermal lithosphere:** Assume "dynamic support" of a feature mostly occurs at base of lithosphere. 125-250 km

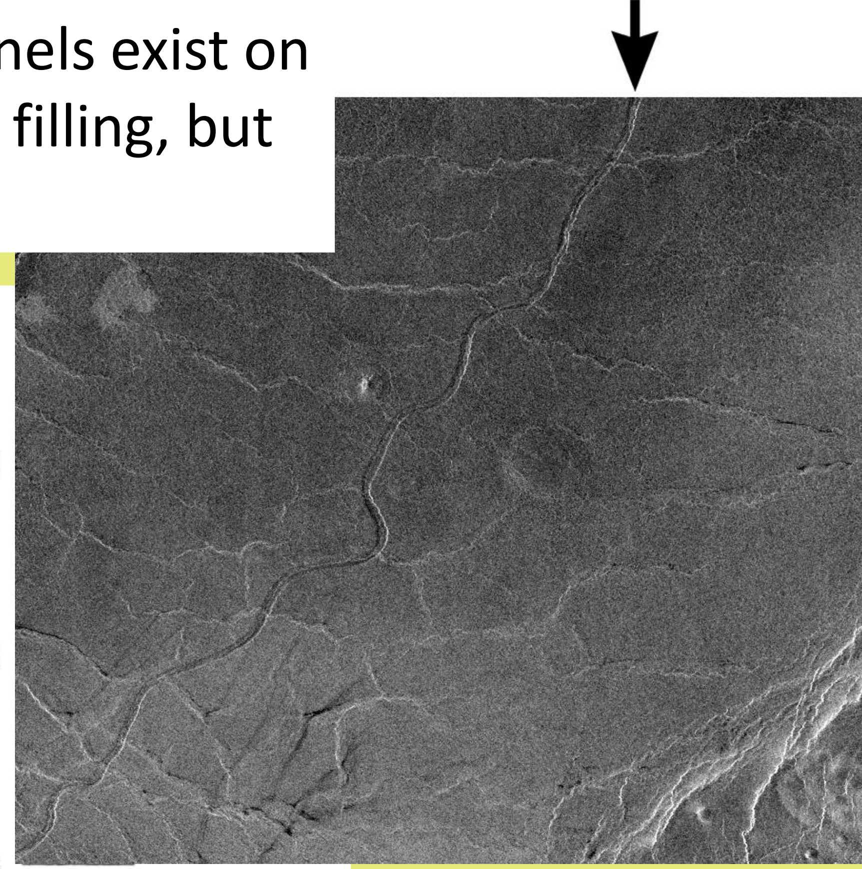
Bottom line – mostly Earthlike, with little precision.

Wrinkle ridges are superposed on huge expanses of the globe, and with a few exceptions, follow broad geoid/topography contours (Bilotti and Suppe map; Sandwell et al. on driving forces). Are they a single time marker? and the last event to occur?

THE GLOBAL DISTRIBUTION OF WRINKLE RIDGES ON VENUS



Several long, presumably volcanic channels exist on Venus. There is subsequent disruption, filling, but whole sections are not eliminated.



1498 BASILEVSKY AND HEAD: VOLCANIC PLAINS ON VENUS

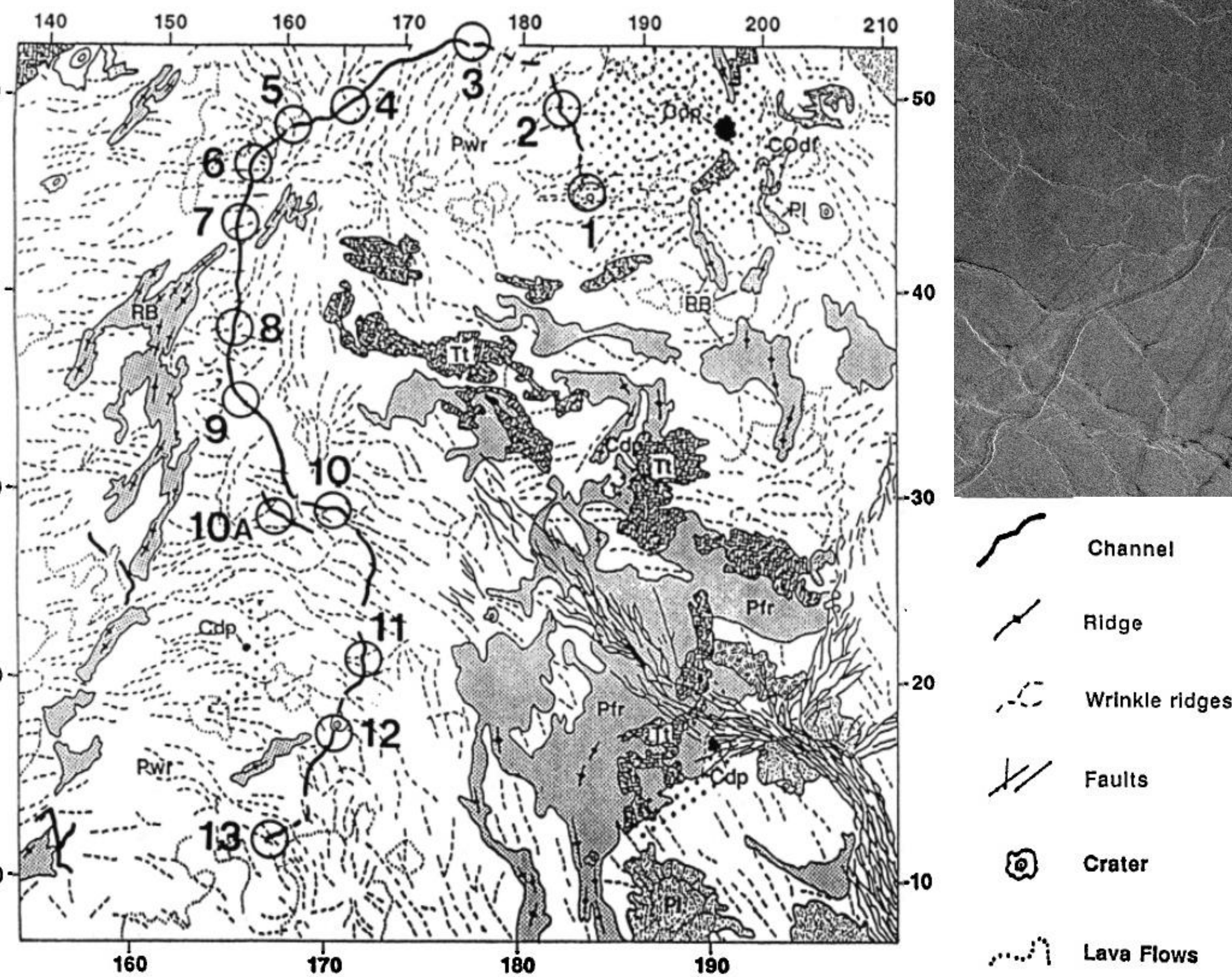
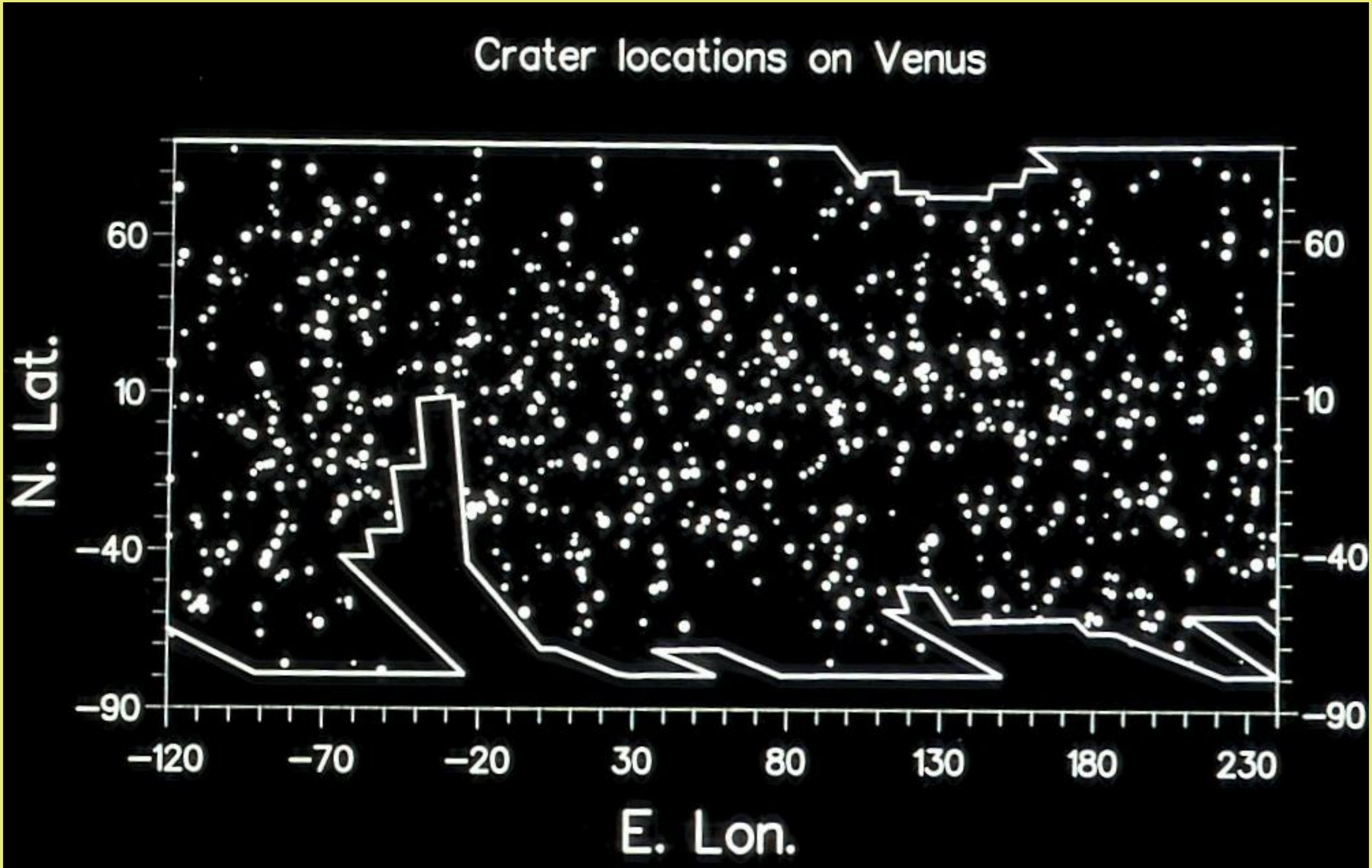
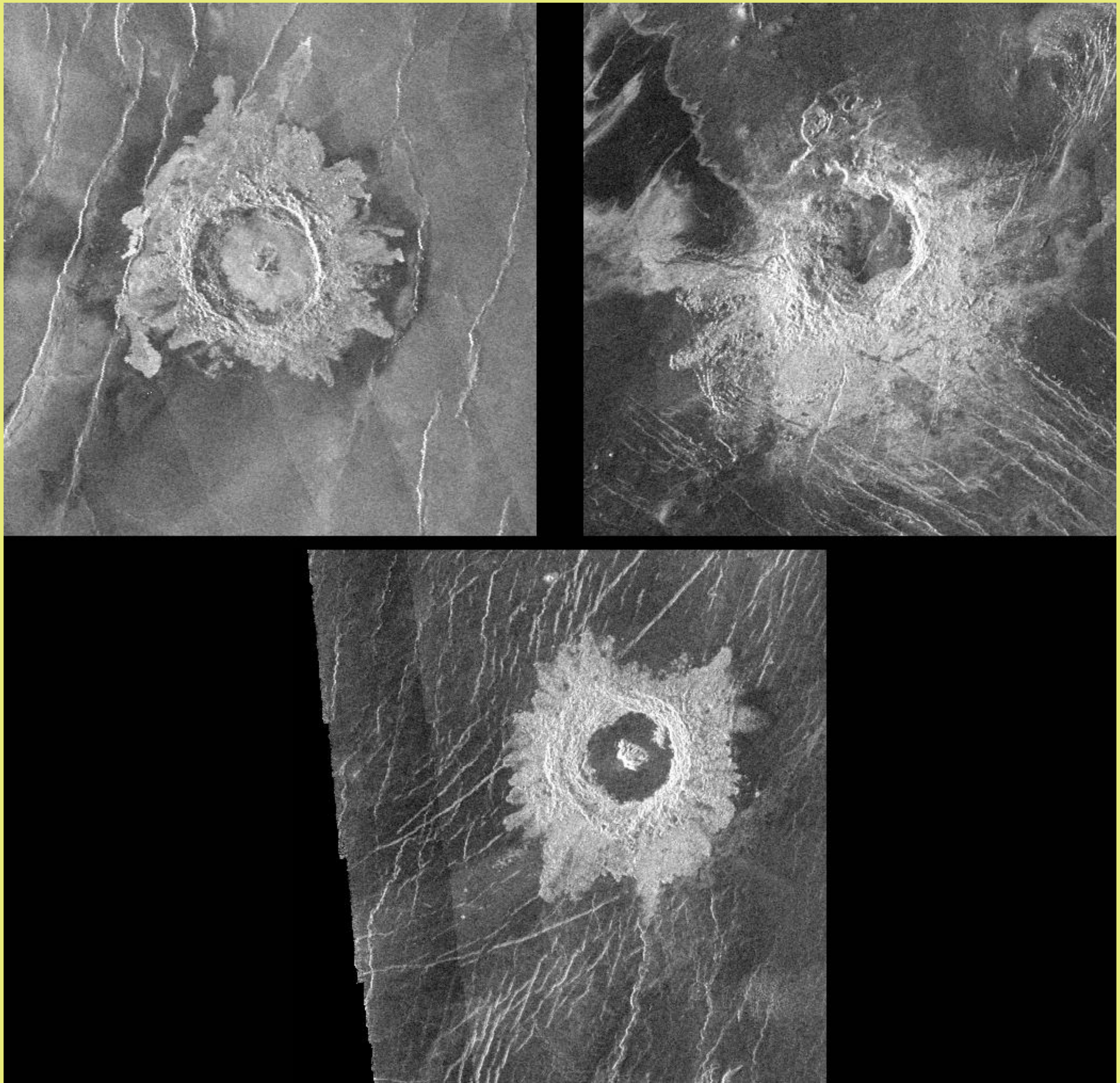


Figure 1. Photogeologic map of the Baltis Vallis study area. Circles with numbers designate geologic observation stations. See further explanations in text.

The locations of craters on Venus look nearly random, but the geology of Venus is not random.



The vast majority of craters look like the bottom crater. The floor is definitely post-impact fill, probably volcanic.



Conclusions

Two end-member scenarios

- Scenario 1 – Evolution (slow) from tessera era to hot-spot era.
  – Either we have estimated thermal lithosphere wrong, Venus has far less interior heating, or we are not in equilibrium and will have another cycle.
- Scenario 2 – Steady-state, with a lot of activity everywhere.
  – Mantle convection pattern changes slowly and/or resurfacing removes remnants of the old pattern.

Summary of Constraints

- Overall stratigraphy – debated, tessera on bottom
- Geoid pattern – matches current geology
- Thermal lithosphere estimates ~Earth-like
- Wrinkle ridge pattern ~matches geoid
- Canali mostly preserved
- Craters well distributed, mostly flooded/embayed