

The background of the slide features three large, overlapping celestial bodies against a dark, star-filled space. On the left is Earth, showing blue oceans and white clouds. In the center is Venus, appearing as a pale yellowish-white sphere. On the right is Mars, a reddish-brown sphere with visible surface features. The text is overlaid on these images.

The Ancient History of Venus is Recorded in the Tesserae

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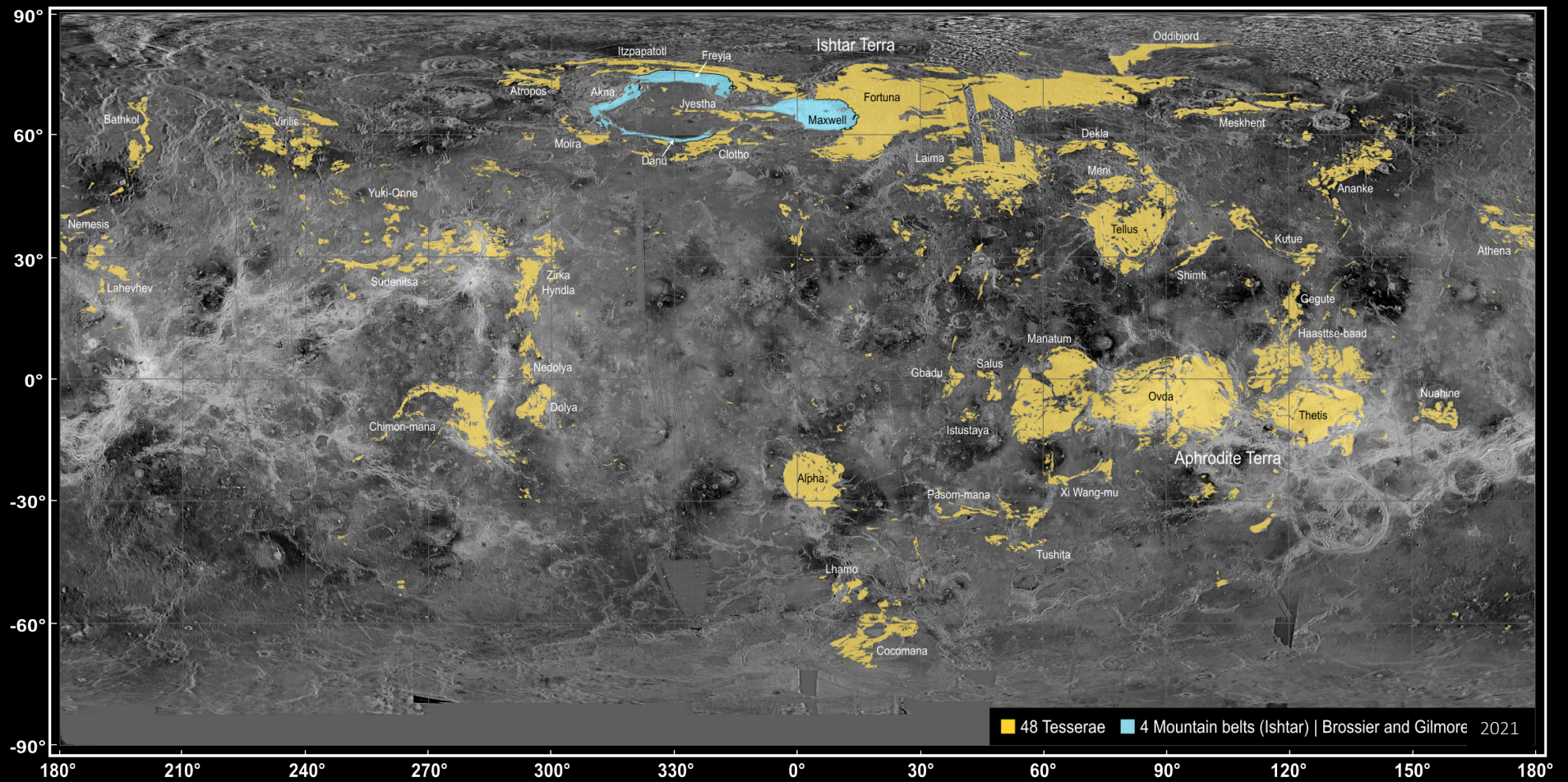
wesleyan.edu/planetary

Planetary Science Decadal Survey: Venus Panel

March 24, 2021

Credit: NASA GSFC

Tesserae and Mountains



3/24/21

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M. Ivanov map of tessera

2

Tesserae are:

(Ivanov and Head, 1996 and references therein)

- Characterized by complex deformation of ≥ 2 sets of intersecting structures.
- Large ($>10^3$ km across) plateaus 1-4 km above MPR and small (~ 100 km outcrops amongst the plains.
- Stratigraphically older than the plains; crater age 1.4x the plains (Ivanov and Basilevsky, 1993).
- ADC indicate thickened crust, not currently dynamically supported (e.g. Smrekar & Phillips, 1991; Simons et al., 1997). Record higher strain rate than today (Brown and Grimm, 1997; Resor et al., 2021)

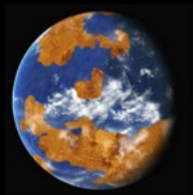
Tesserae are relicts of an extinct era on Venus:

Witness to pre-plains time and plains emplacement.

The oldest rocks on the Venus surface.

20 km

Our neighborhood 4 billion years ago 3 habitable planets?



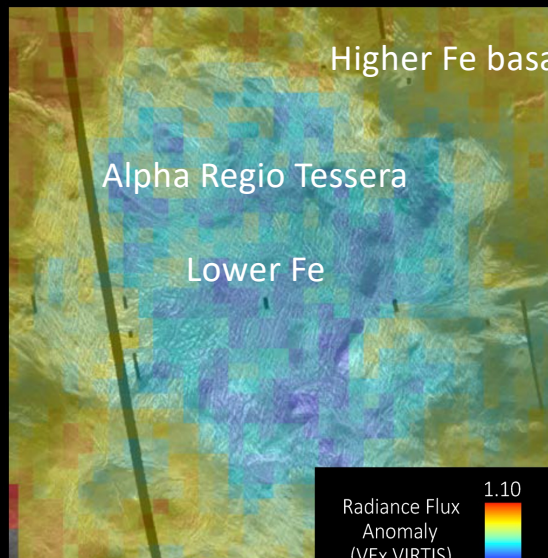
Venus



Earth

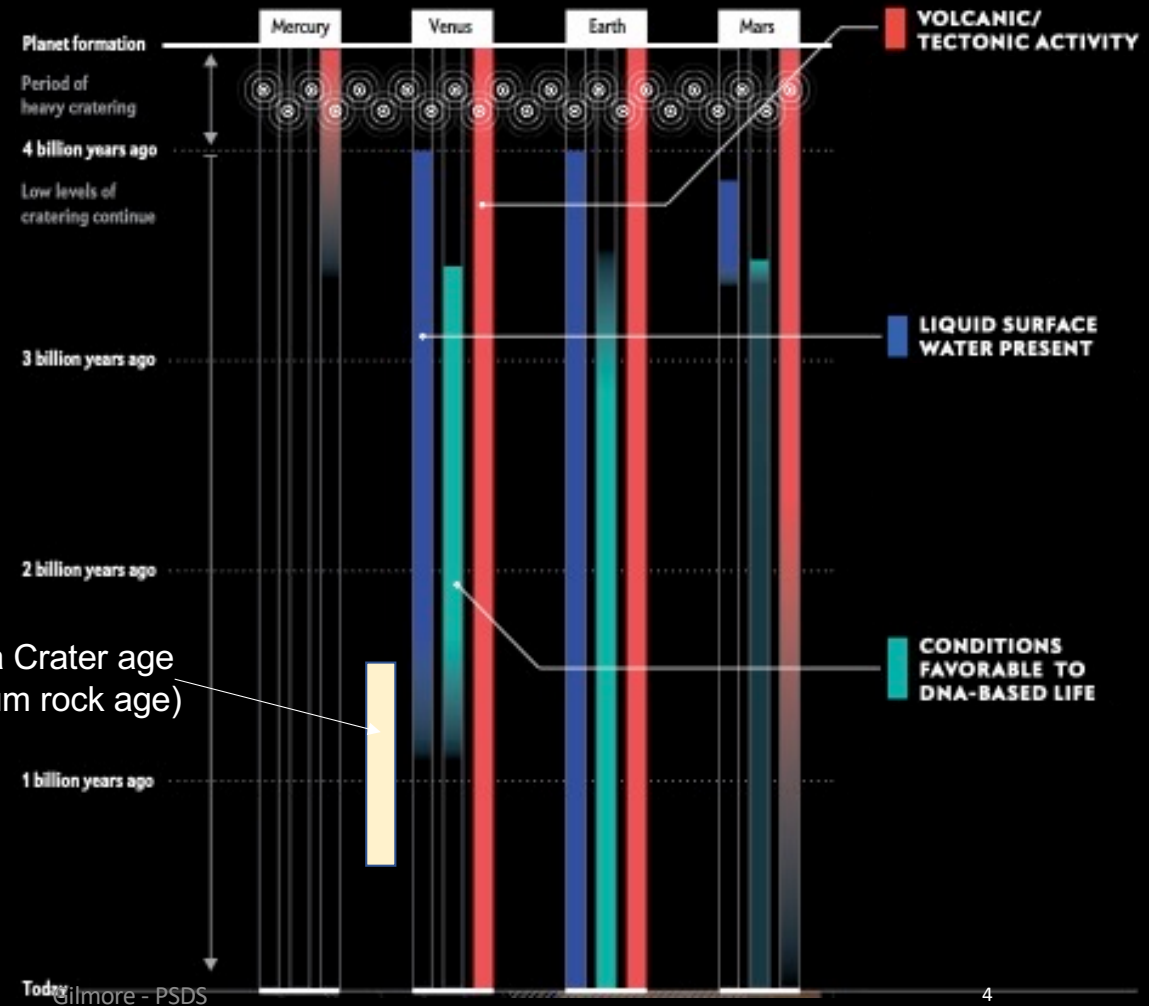


Mars



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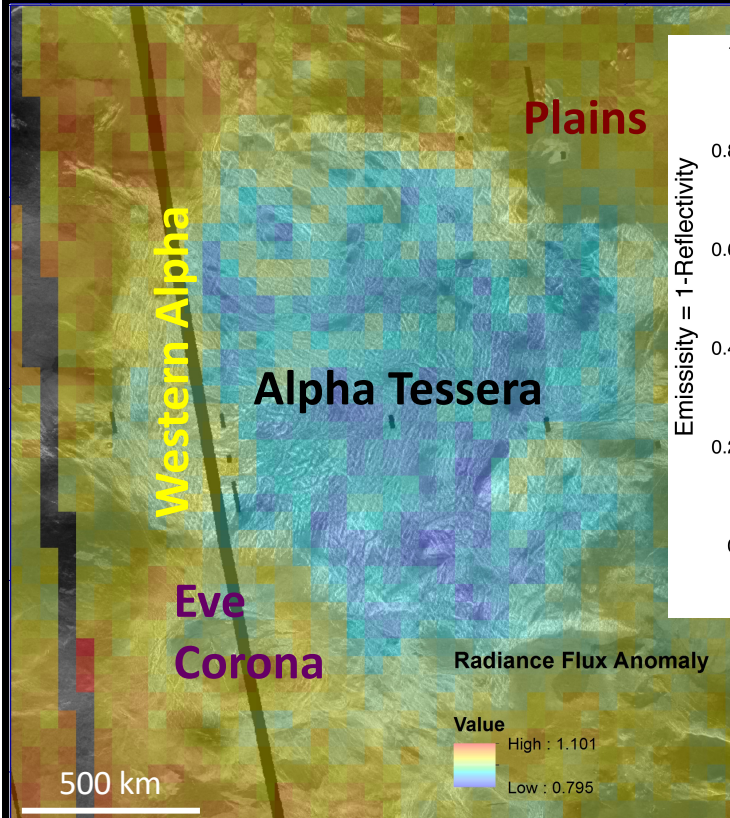
Gilmore et al., 2015



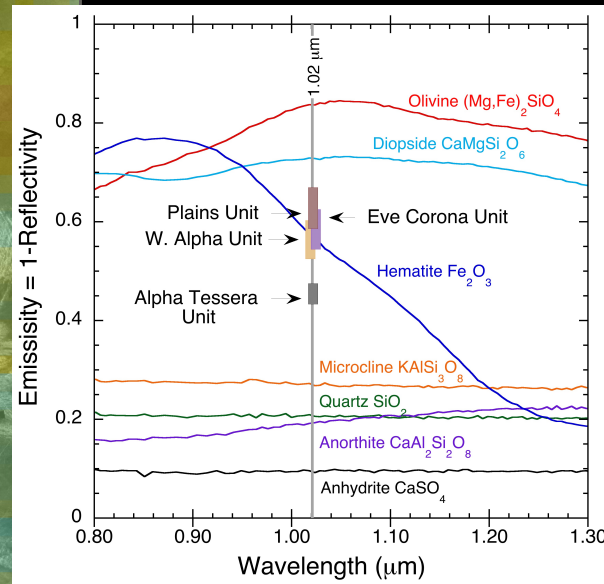
Graphic by Tiffany Farrant-Gonzalez, Dyar et al. Sci. Am. Feb 2019

VIRTIS 1 μm Emissivity of Alpha Regio

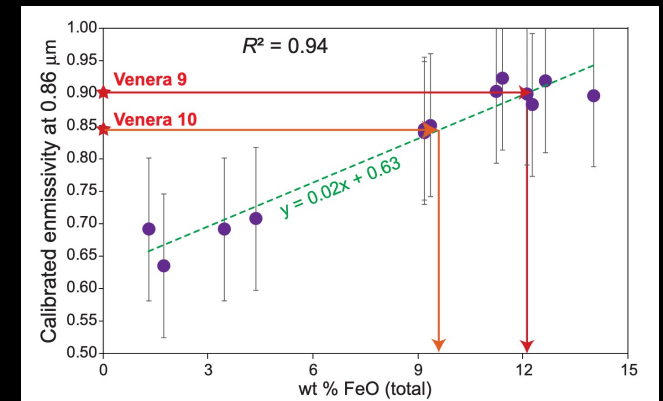
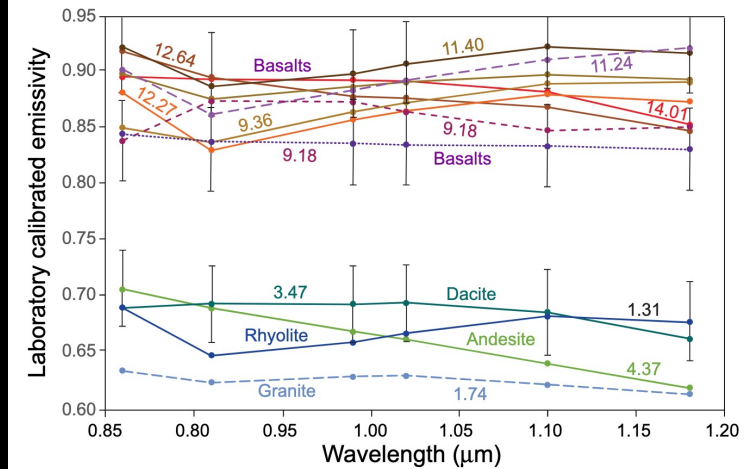
Derived Emissivity, room T



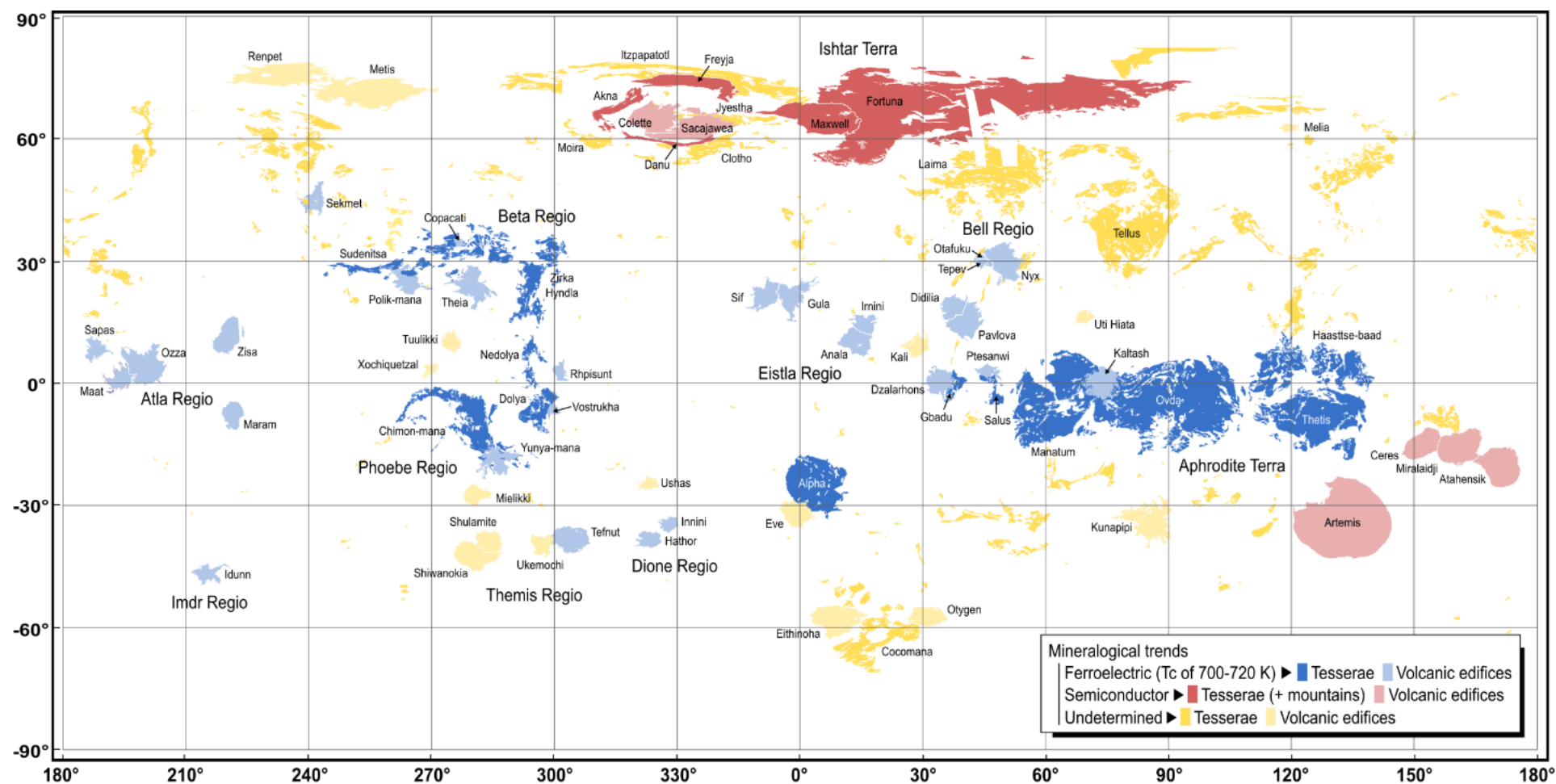
Gilmore et al., (2015)



Emissivity at Venus T
Helbert et al., 2021



GENERALIZED EMISSIVITY CLASSIFICATION FOR ALL VENUS HIGHLANDS



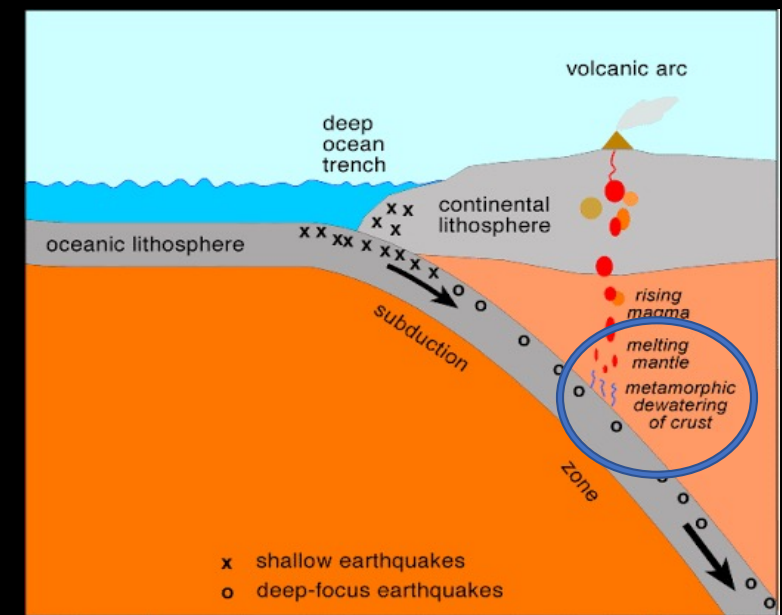
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Brossier et al., 2020; Brossier and Gilmore, 2021

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Interpretation 1: the Tesserae are granitoids formed the common way

- Most Earth granitoids formed via melting of continental crust, sediments and/or peridotitic mantle in the presence of H₂O [e.g., Campbell and Taylor, 1983; Brown, 2013]. Settings:
 - Fractionation of hydrous mantle above subducting plate
 - Remelt older continental crust or sed by basaltic underplating or collision (e.g., Hubbert and Sparks, 1988, Thompson and Connolly, 1985)
 - Archean TTGs partial melting of hydrated basalts/eclogites (e.g., Martin et al., 2005)
 - Rare ($\sim 10^4 \text{ km}^3$) felsic eruptions on Earth associated with continental breakup (plumes) - such volumes requires the partial melting of hydrous lower continental crust materials [e.g., Bryan et al., 2002].
- To get continents' worth of granitic magma – need **water** and **recycling**. Recycling invoked in Venus's past (Parmentier and Hess, 1992; Turcotte et al, 1999) and present (Elkins-Tanton et al., 2007). Therefore, likely limited to lifetime of water on Venus.



Felsic Rocks:
Need water and lithosphere cycling

Interpretation 2: the Tesserae are granitoids formed via differentiation of large mafic bodies

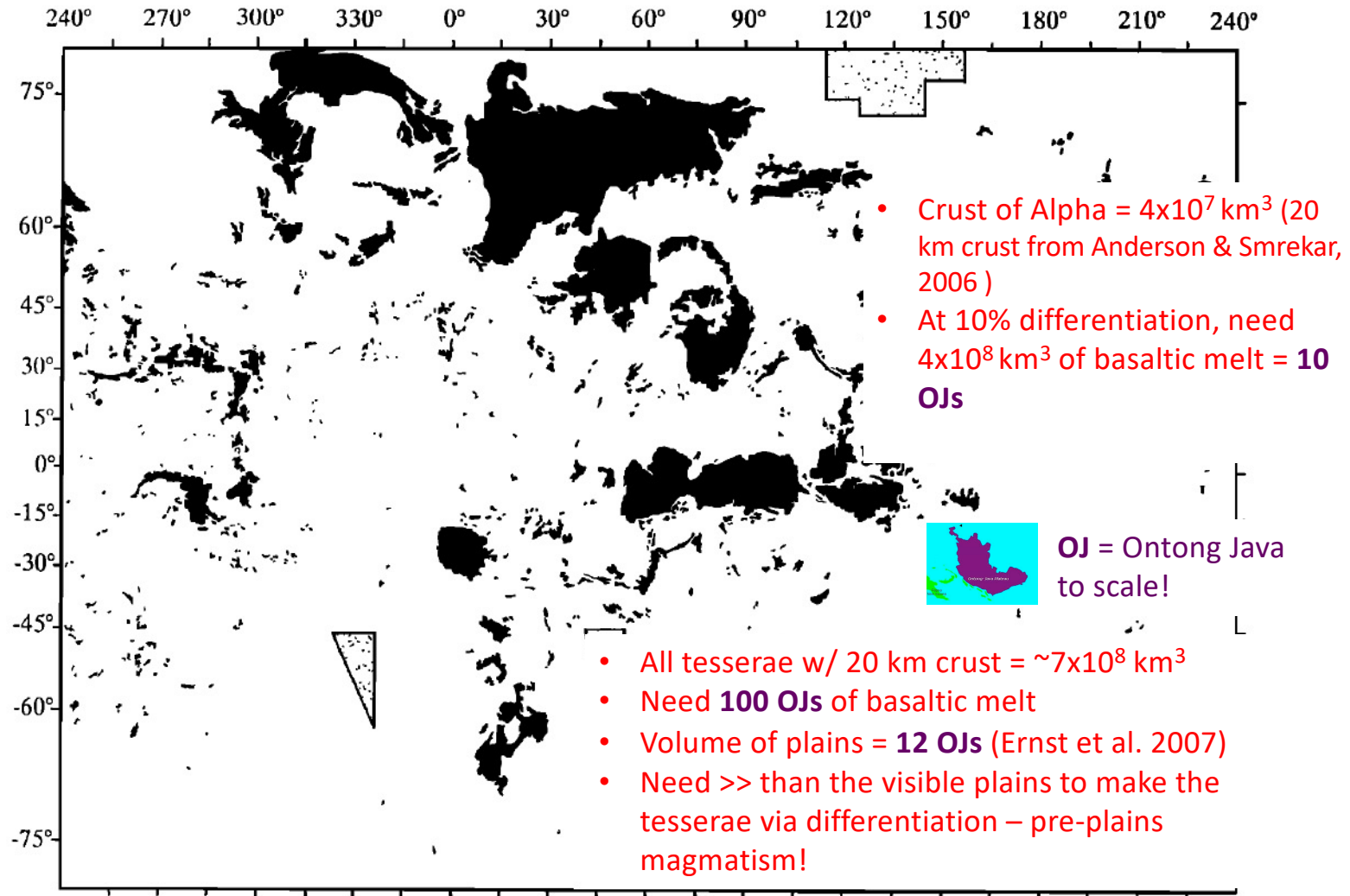
- Process should generate ~10% felsic melt (e.g., Spulber and Rutherford, 1983; Shelnutt, 2013)
- LIPs typically associated with ~5% felsic rocks (Bryan et al. 2002).

SHELLNUTT: FORMATION OF SILICIC ROCKS ON VENUS

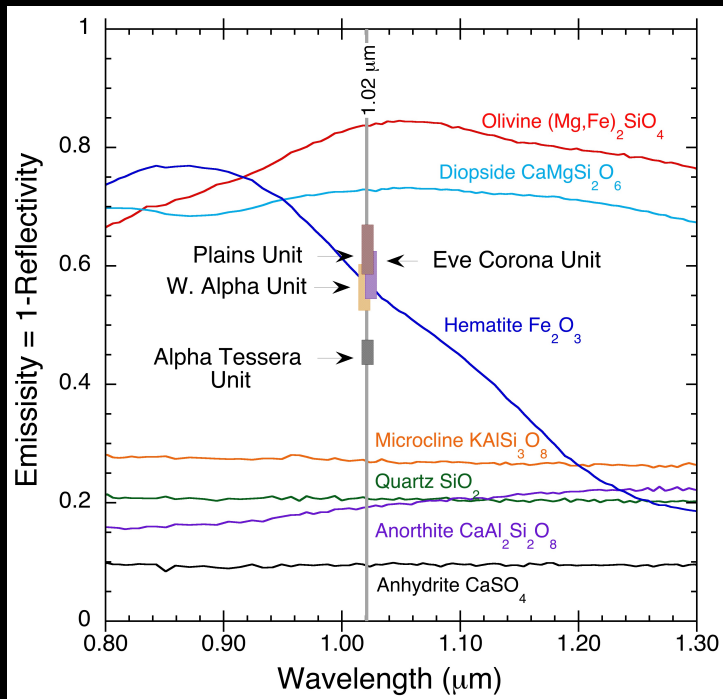
Table 2. Physical Parameters of the Modeled Silicic Liquids^a

Sample	Process	Pressure (GPa)	Temperature (°C)	Viscosity (Pa s)	Density (g/cm ³)	Rock Type	Water State
Venera 13-1	FC	0.01	1060	10 ^{3.8}	2.44	Phonolite	anhydrous
Venera 13-2	FC	0.1	1070	10 ^{3.7}	2.46	Phonolite	anhydrous
Venera 13-3	FC	0.01	1060	10 ^{3.3}	2.43	Phonolite	hydrous
Venera 13-4	FC	0.1	1060	10 ^{3.5}	2.44	Phonolite	hydrous
Venera 14-1	FC	0.01	970	10 ^{5.8}	2.42	Rhyolite	anhydrous
Venera 14-2	FC	0.1	980	10 ^{5.5}	2.44	Rhyolite	anhydrous
Venera 14-3	FC	0.01	960	10 ^{5.0}	2.37	Rhyolite	hydrous
Venera 14-4	FC	0.1	910	10 ^{4.8}	2.32	Rhyolite	hydrous
Venera 14-5	FC	1	900	10 ^{3.8}	2.49	Rhyolite	hydrous
Venera 14-6	PM	0.01	1080	10 ^{2.6}	2.54	Andesite	hydrous
Venera 14-7	PM	0.1	940	10 ^{3.3}	2.27	Andesite	hydrous
Venera 14-8	PM	1	880	10 ^{4.6}	2.49	Rhyolite	hydrous

^aFC = fractional crystallization, PM = partial melting.



Interpretation 3: the Tesserae are mafic.....but weathered differently



Treiman and Schwenzer (2009)
 diopside + atmospheric S $\leftrightarrow$ anhydrite + enstatite
 + quartz



plagioclase + atmospheric S $\leftrightarrow$ anhydrite +
 andalusite + quartz

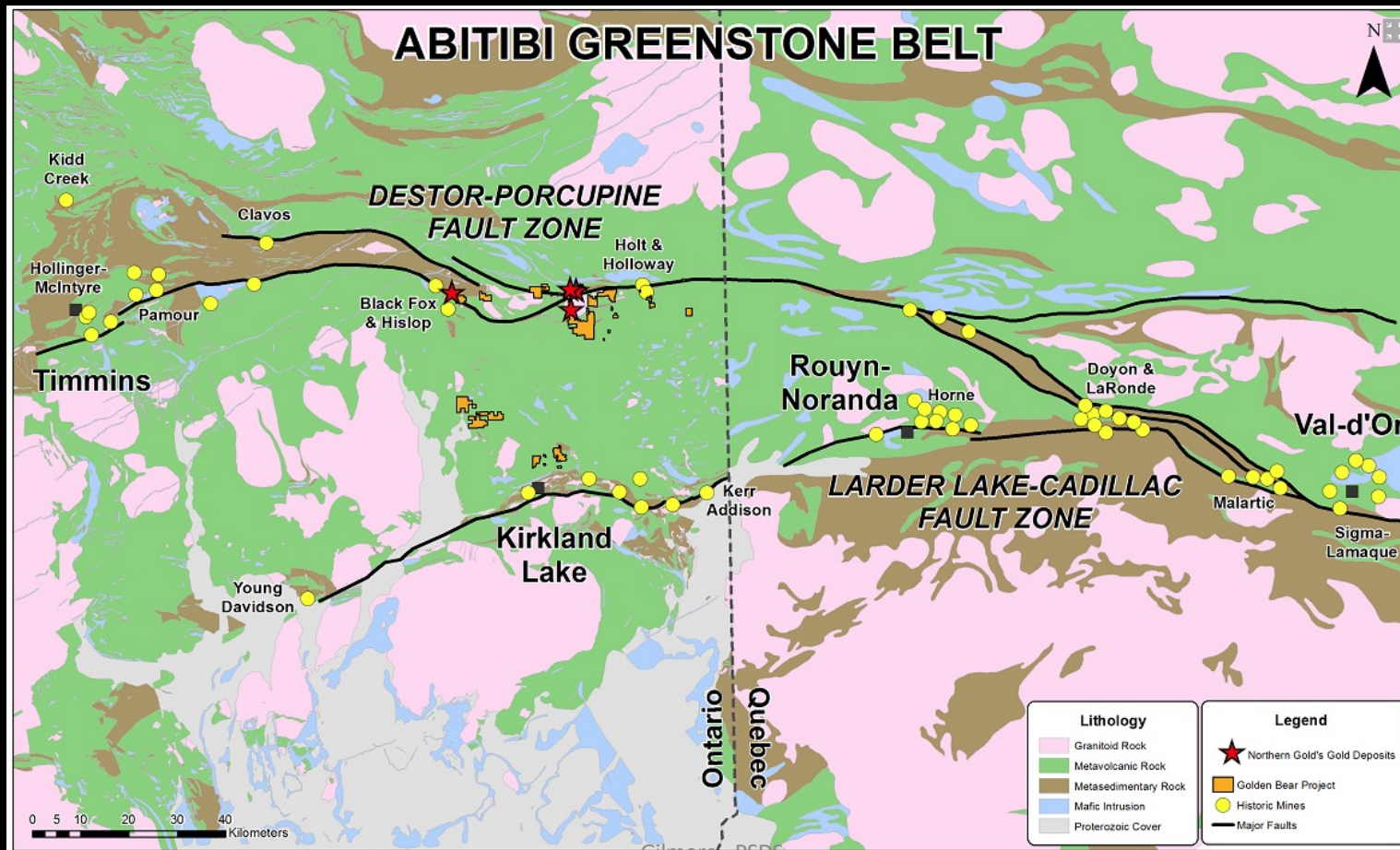


Zolotov (2007)

Fe silicates + atmospheric (S, CO₂, H₂O)? ->
 magnetite -> atmospheric (S, CO₂, H₂O)?
 -> hematite

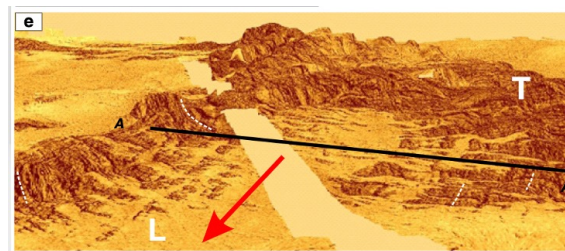
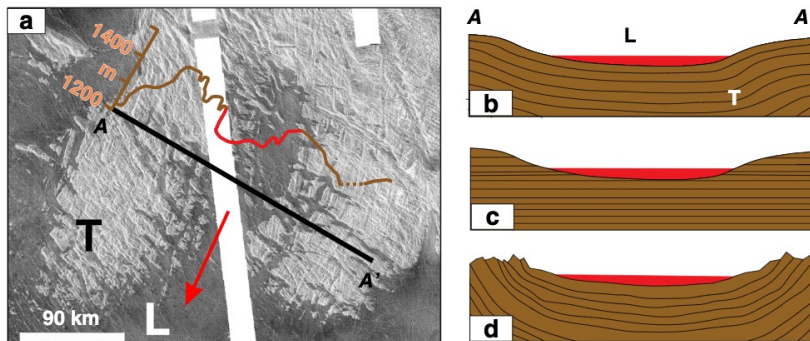
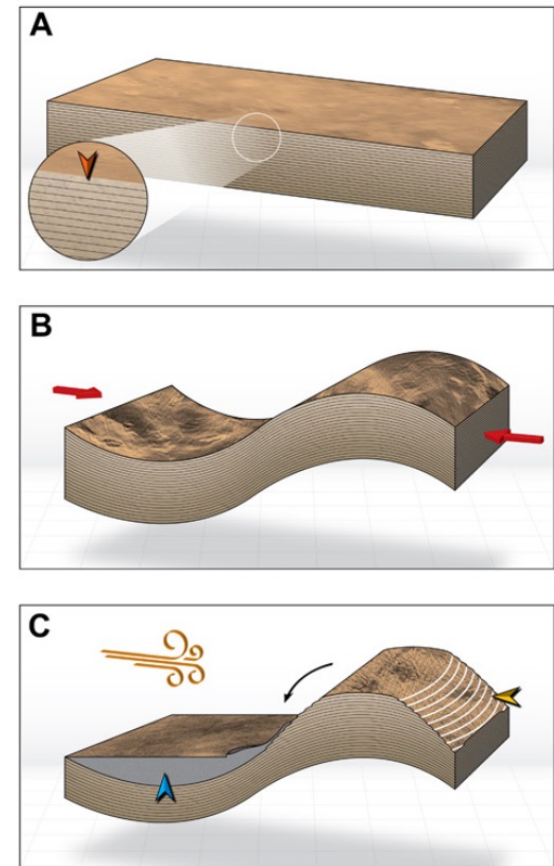
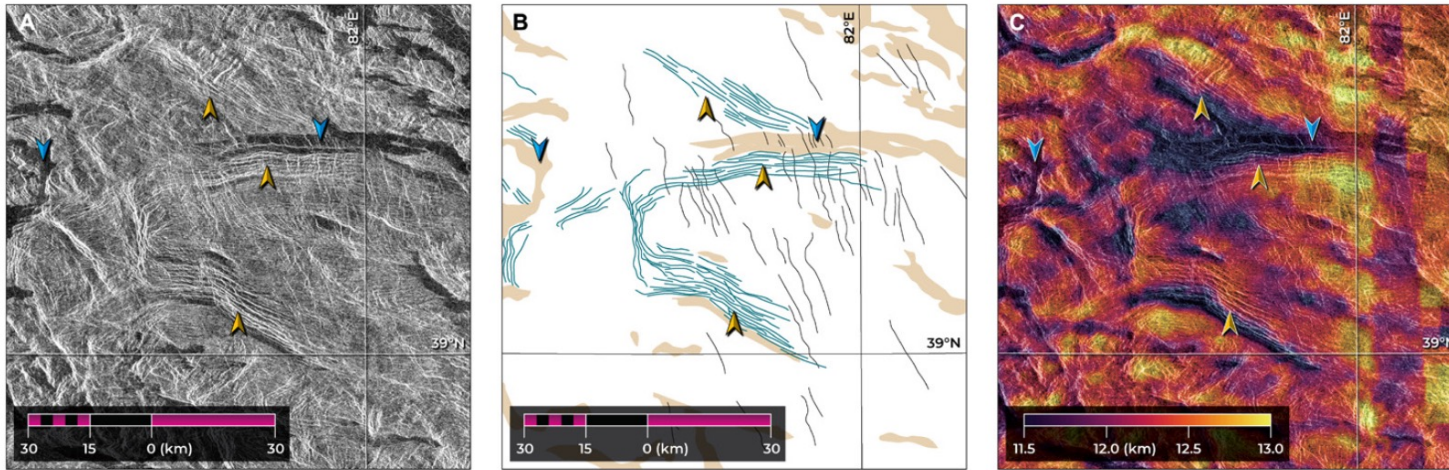
Elevate pH₂O get everything to completion and more
 Weathering during plains emplacement? On ancient Venus?

Interpretation 4: the Tesserae are not igneous



Morphological Evidence for Layering

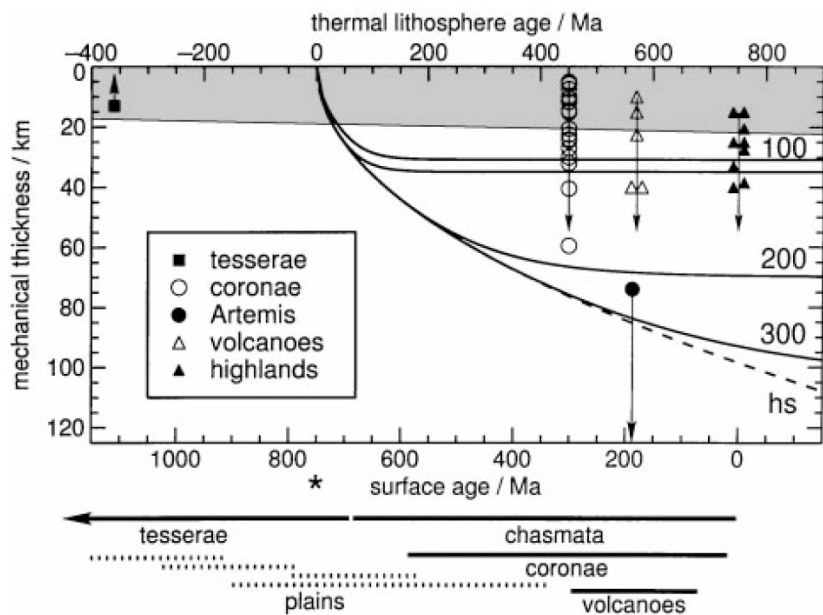
Byrne et al., 2020



Khawja et al., 2020

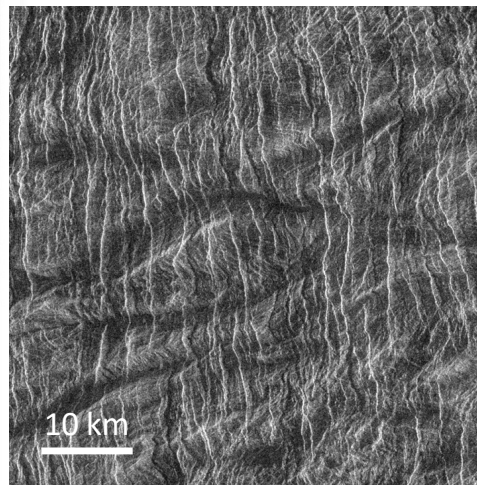
Constraints from Buckling Theory

- Tesserae deformed in a different thermal regime
- Characteristic wavelengths of structures are similar across tesserae and consistent with a lithosphere that is thinner than that estimated today (Brown and Grimm, 1997; 1999).
- Strain rate estimates 1-2 orders of magnitude > today (Grimm, 1994).
- A global process.

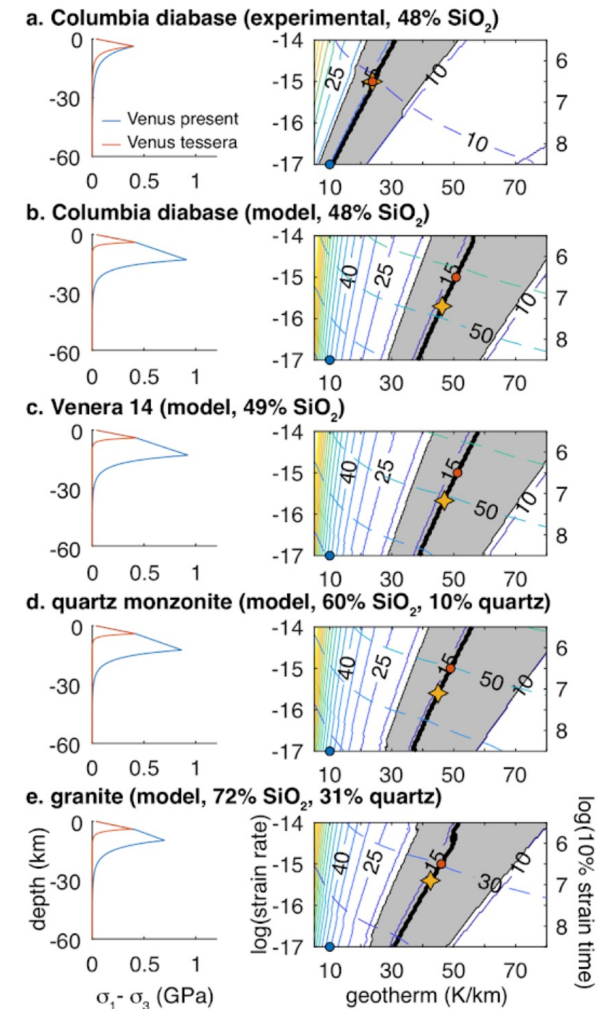


3/24/21

Brown and Grimm, 1999



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Resor, Gilmore et al., JGR, in press

Tesserae are key to understanding Venus geologic evolution, climate and habitability

I encourage the Decadal to Emphasize and Prioritize:

- TESSERA Composition
 - Mineralogy from orbit and probe – VERITAS/DAVINCI+
 - Measure chemistry and mineralogy at tessera landing site – VITaL/Flagship
 - Experimental work on weathering of rocks under Venus conditions
- TESSERA Morphology and History
 - High resolution imaging and topography (CTX, MOC, MOLA at Venus) – VERITAS/DAVINCI+
 - Improved gravity – VERITAS

A Venus Flagship class mission would enable direct measurement of tessera terrain and a comprehensive study of the inventory, movement and fate of the volatiles in the current and ancient Venus system. I urge the Decadal to recommend a Venus Program of missions, research and technology advancement, including a Flagship-class mission in the next decade.