



U3A

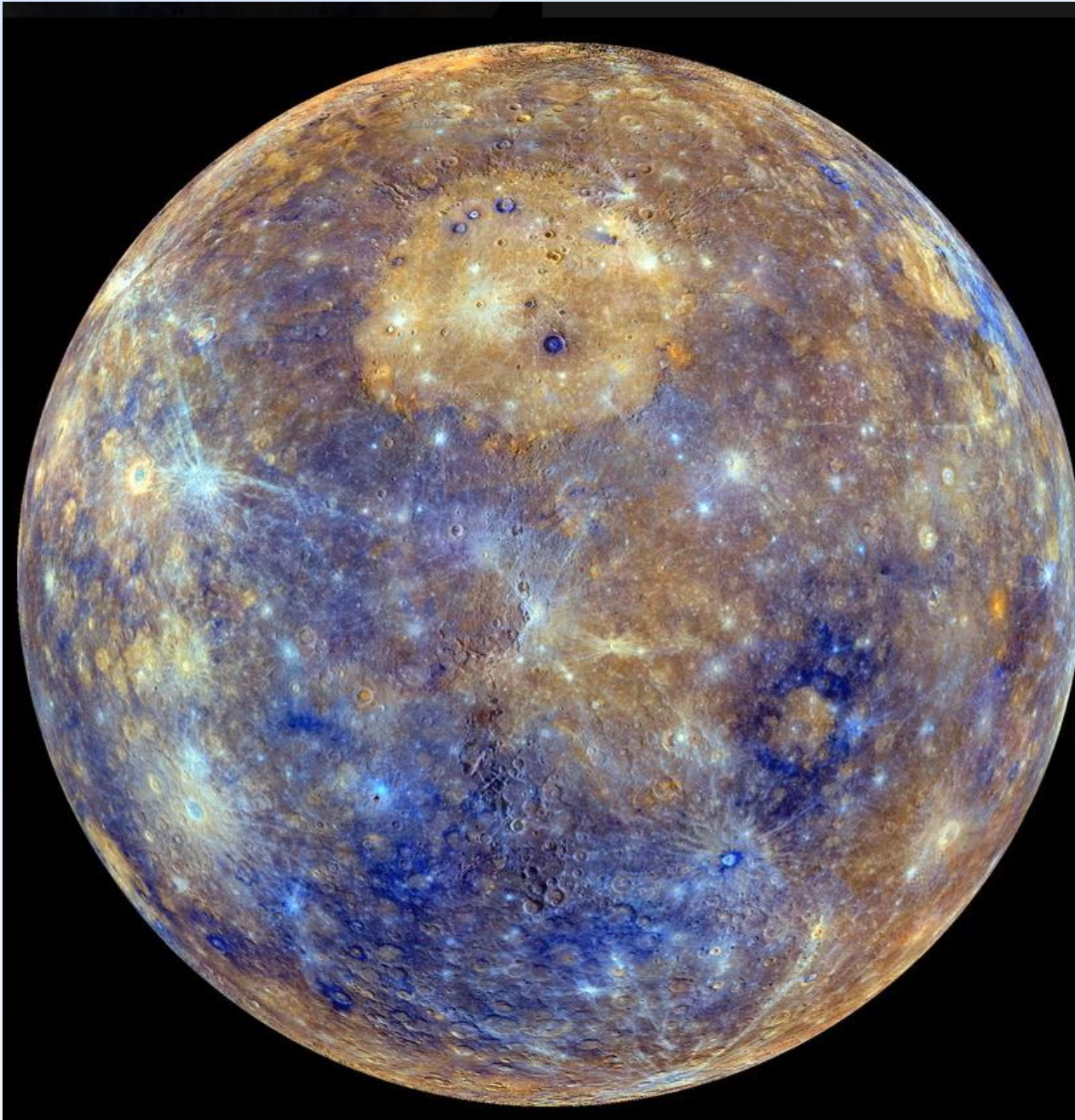
Planetary Geology

Mercury & Venus

Mercury fundamentals

- Mercury is the smallest of the terrestrial planets and closest to the sun
- slow rotation (1 rotation = 59 Earth days)
- high orbital speed → shortest year of any planet (88 Earth days)
- trivial axial tilt → ~perpendicular to ecliptic plane → no seasons
- strong dipolar magnetic field → closely aligned with rotational axis
- surface exposed to the Sun, hot enough to melt Sn, Pb and Zn
- surface temperature plummets during Mercury night*

NASA colour enhanced image of Mercury



Physical properties of Mercury

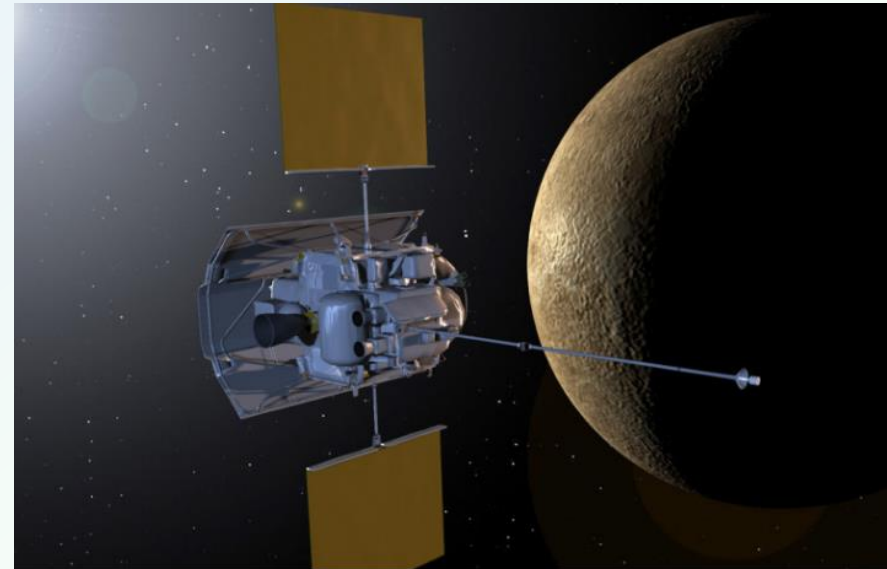
Mean radius:	2,440km
Bulk density:	5427kg m ³
Period of rotation:	59 Earth days
Period of orbit:	88 Earth days
Surface pressure:	10 ⁻¹² bars
Surface temperature:	-180 to 460°C

Planetary characteristics of Mercury

- Second densest planet in solar system (after Earth) → Fe core comprises 42% of its volume c.f. 16% for Earth
- planet mostly Fe core enclosed by thin silicate mantle*
- Mercury thought to have partial liquid core
- thin atmosphere (exosphere) → minor H, He, O, Na, K, Ca and water vapour
- astronomers believe the atmosphere was once similar to Earth, due to weak gravity → atmosphere stripped by solar winds
- water ice may reside in deep craters near poles in permanently shaded regions (due to trivial axial tilt)

Imaging the surface of Mercury

- Mariner 10 → first spacecraft to photograph Mercury close up in 1975 → photographed half of the surface
- MESSENGER (MErcury Surface Space ENvironment GEochemistry and Ranging) spacecraft flew past Mercury 3 times in 2008-9 mapping surface in colour
- MESSENGER entered orbit around Mercury in 2011 → completed mapping of surface, studied atmosphere, detected ice water at poles
- ran out of fuel → crashed onto surface of Mercury in April 2015



Surface features of Mercury

- Heavily-cratered terrains (equiv. lunar highlands)
- surface superficially similar to the Earth's moon → large multi-ringed basins, ubiquitous craters, young ray craters
- long cliffs (rupes) up to 3 km high and 500km in length → younger than most craters, shrinkage of planet interior (?)
- smooth volcanic plains → sparsely cratered, filled old craters and impact basins → cover 40% of surface (equiv. lunar maria)*
- very similar geological history implied to that of the Moon

Geological features on Mercury

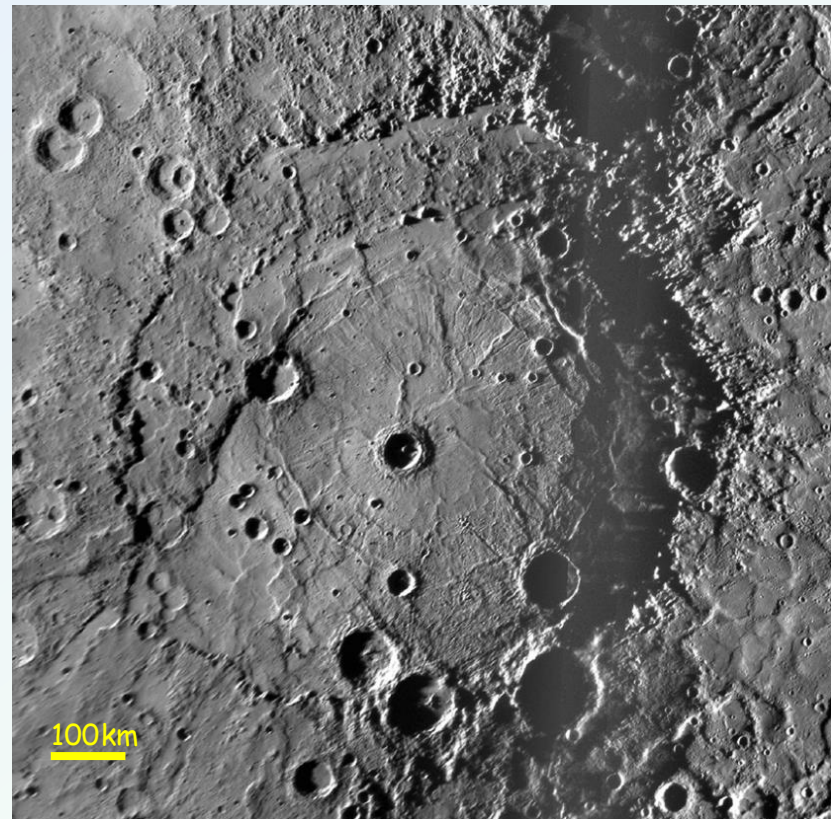
- (1) Craters and impact basins
- (2) volcanic features
- (3) plains
- (4) rupes
- (5) the "Great Valley"
- (6) hollows
- (7) spider troughs

Impact structures on Mercury

- Mercury has highlands pockmarked by impact basins (~1000km across) and impact craters (~100km across)
- impact craters closely resemble lunar counterparts
- gravity on Mercury >twice that of the Moon → ejecta thrown half as far → craters shallower → gravity flattens crater walls
- heavily cratered terrain contains regions of gently, rolling hills
- smooth dark coloured plains much younger*
- timing of cratering consistent with early intense cratering episode that affected the whole solar system

Large impact basins on Mercury

- Formation of impact basins → important process in early evolution of Mercury
- 46 probable impact basins are present on the planet
- the largest impact basin is the Caloris basin that is 1,300km across



Rembrandt impact basin

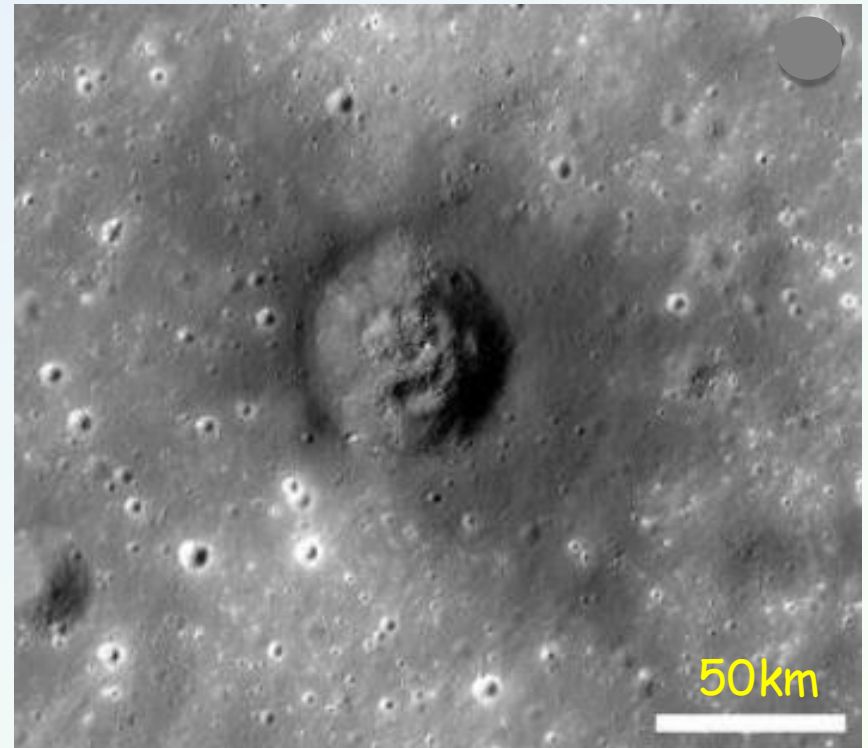
Caloris basin



Impact craters on Mercury

- Some craters have dark rims or dark haloes surrounding them
 - excavated, sub-surface dark layer (?)
 - heat of impact partially melted surface (?)
- surface not as heavily cratered as the Moon

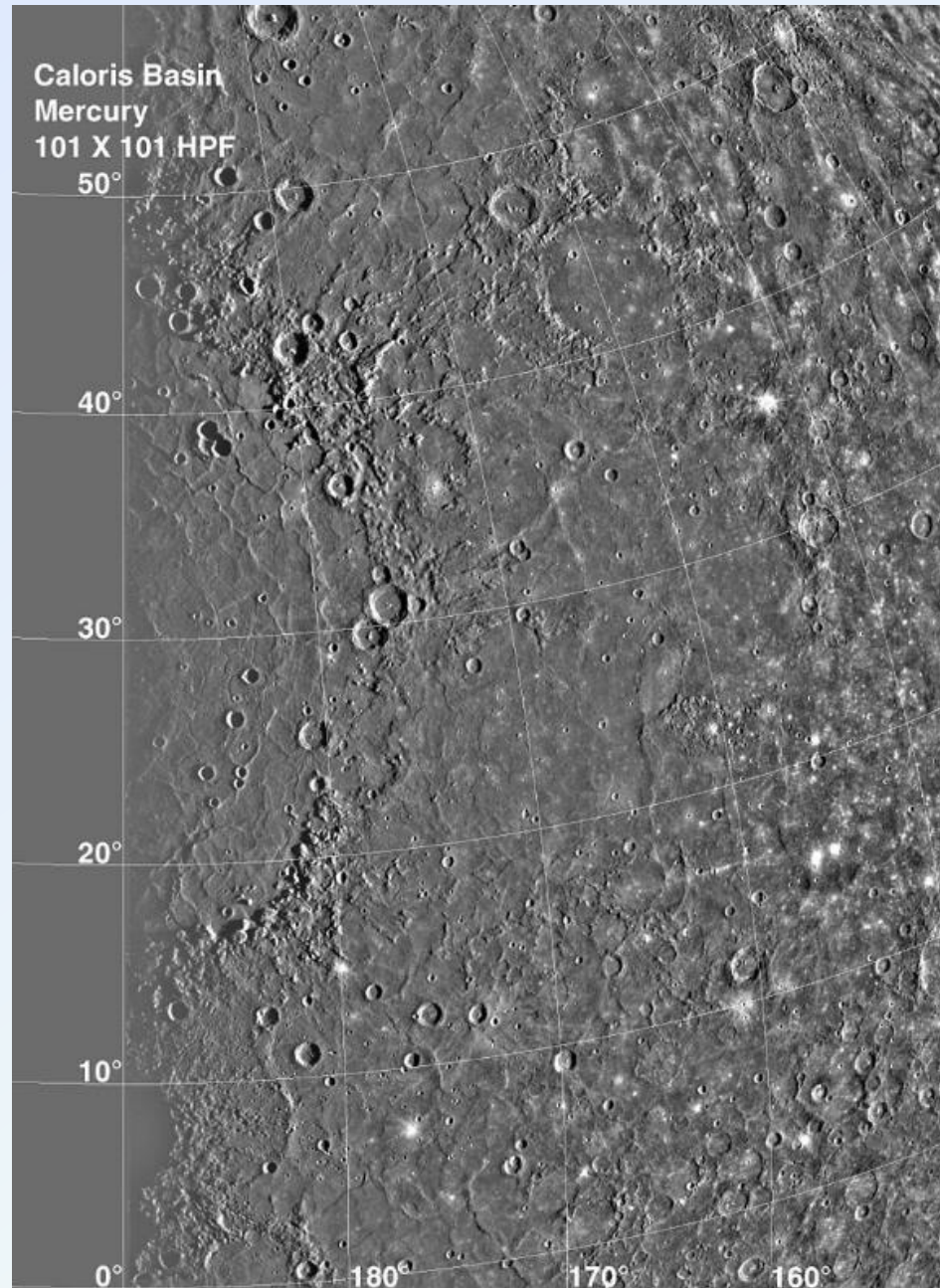
Dark halo around impact crater on Mercury



Old intercrater plains

- Heavily cratered highland terrain not as heavily cratered as lunar highlands → includes large regions of gently rolling intercrater plains
- these plains obliterate or partially fill older craters
- interpretation → lava flows created intercrater plains during late heavy bombardment ~3.9Bya
- origin of intercrater plains is unclear
 - probable widespread volcanic resurfacing (?)

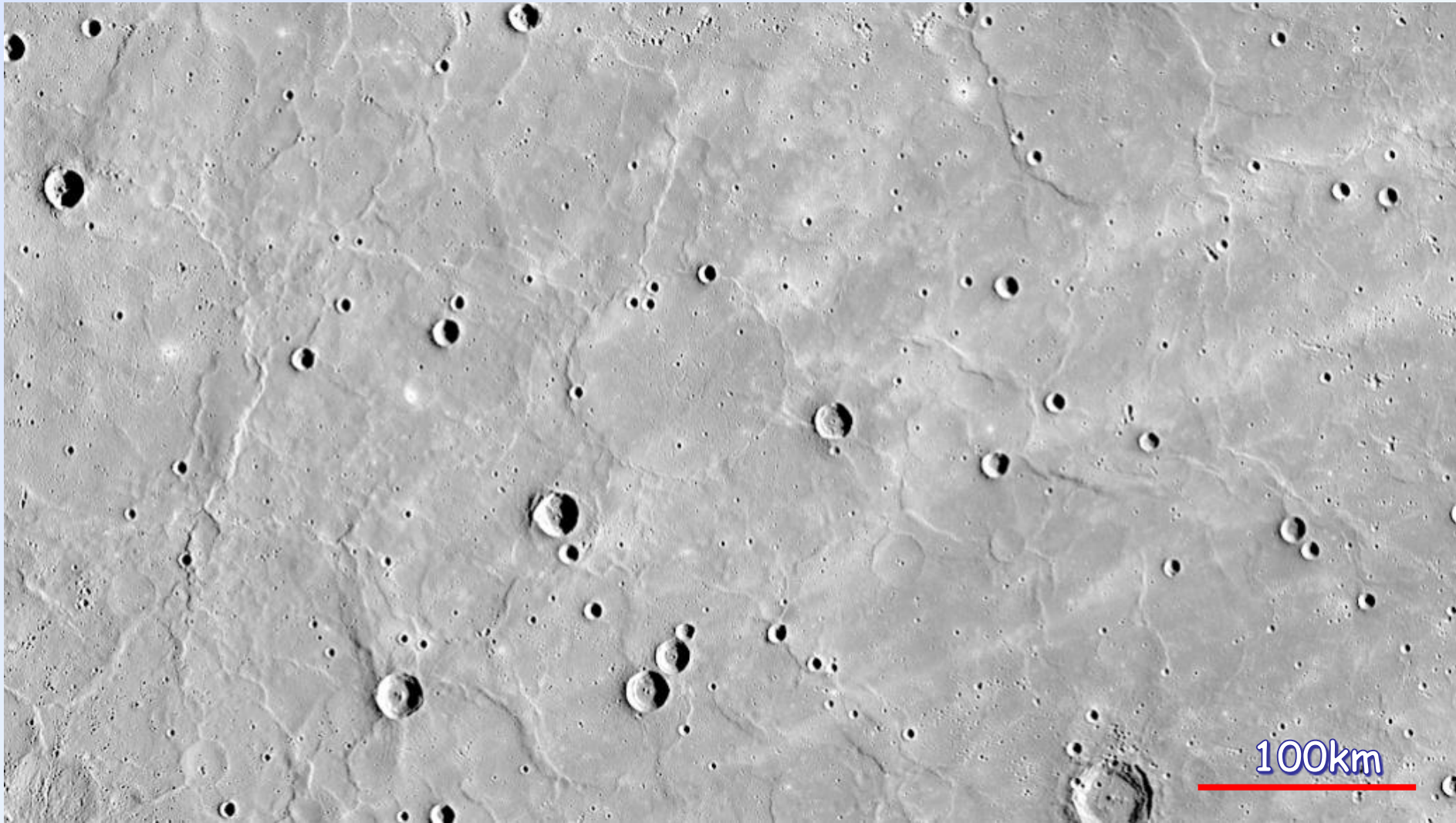
Smooth and old intercrater plains



Smooth lowland plains

- Widespread areas of Mercury → covered by relatively flat, sparsely cratered terrain → smooth lowland plains → flood lavas that formed shortly after the Caloris impact
- cover ~40% of the surface of Mercury
- they are younger than intercrater highland plains and 2km lower
- plains have same brightness as intercrater plains → unlike dark maria on the Moon
- non-circular irregular shaped depressions → interpreted as volcanic vents

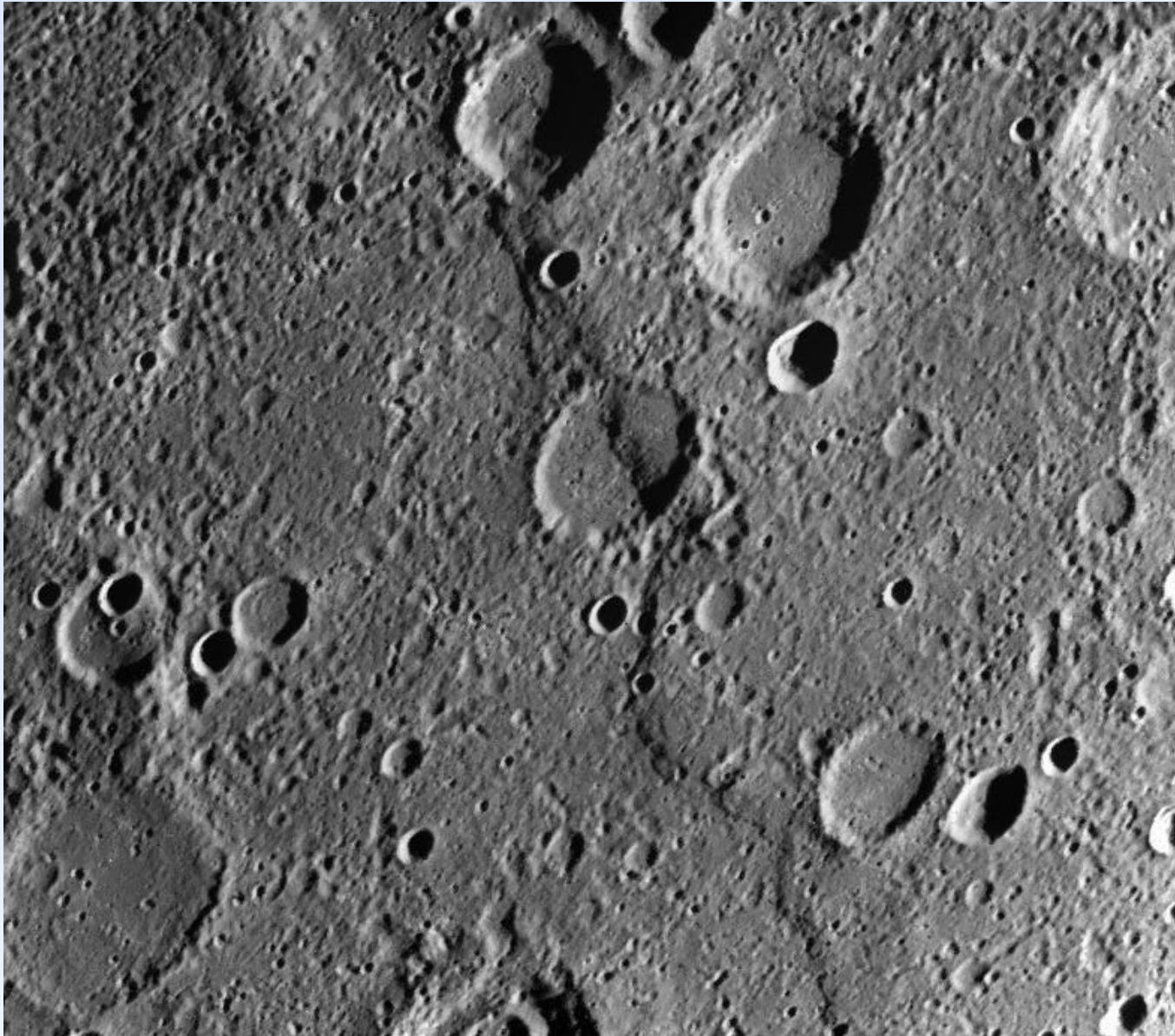
Smooth plains



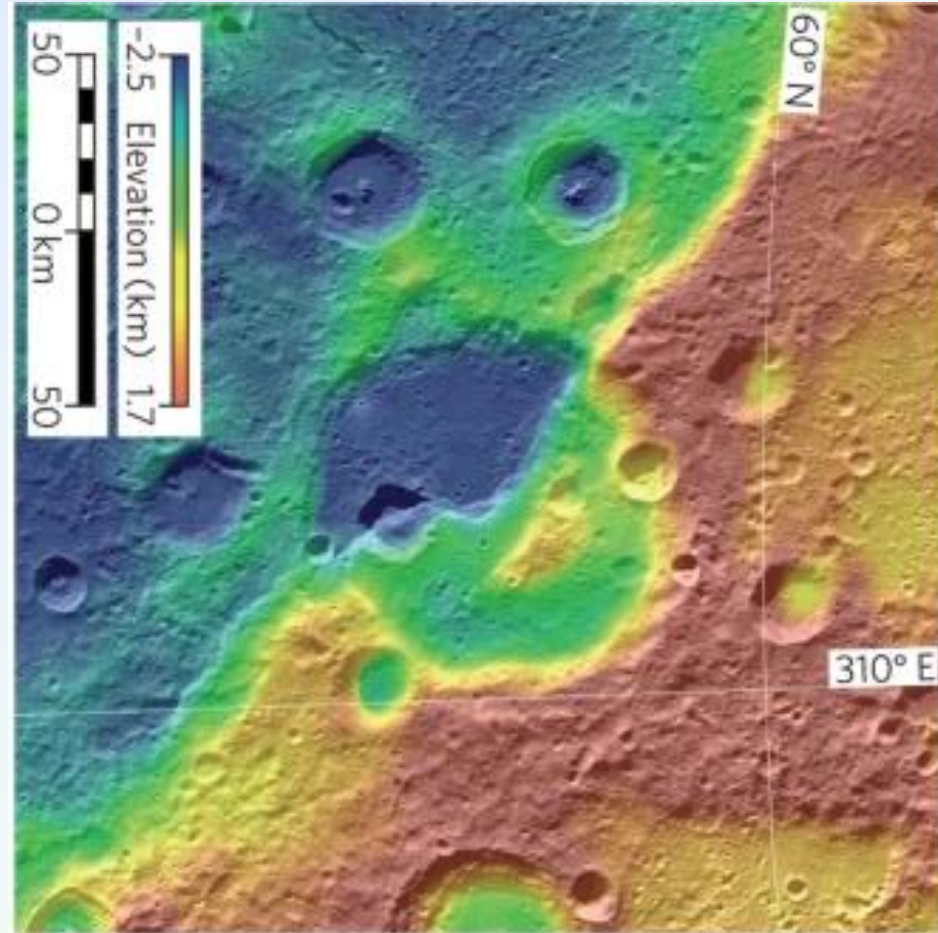
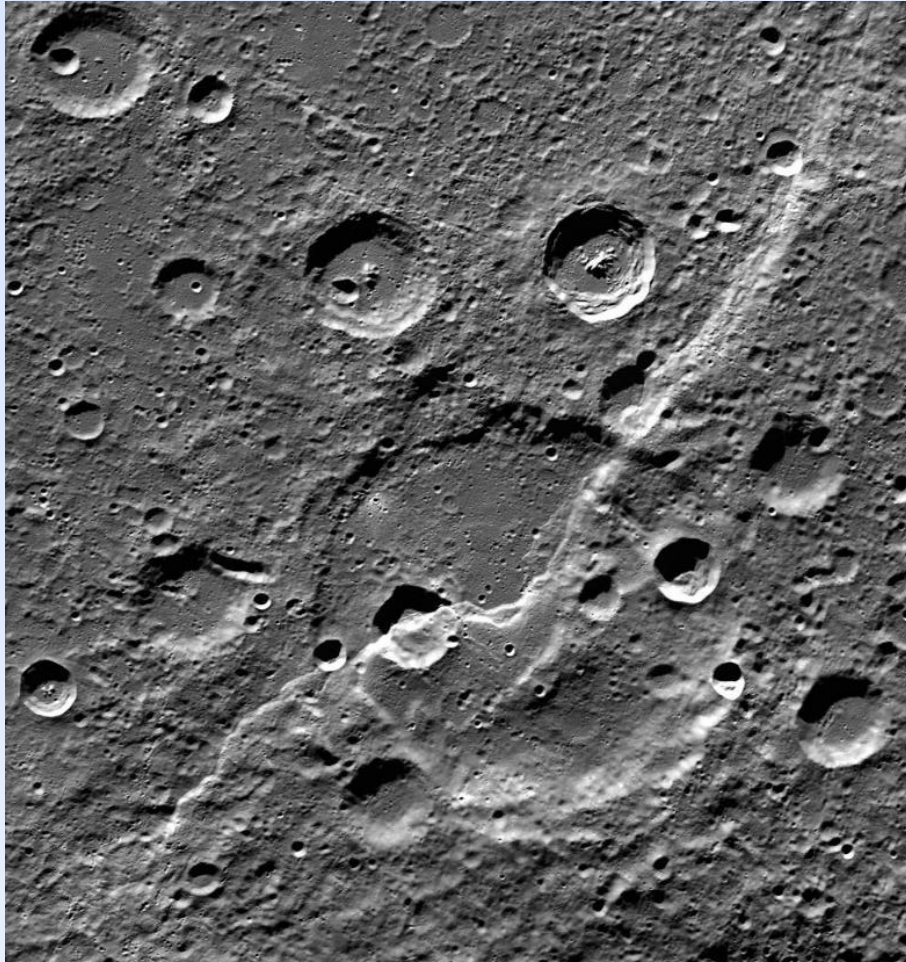
Rupes

- Surface of Mercury features long winding scarps → **rupes**
- individual scarps → 20km to 500km in length with heights between 300m and 3km
- scarps cut across craters with few craters superimposed on them → formed relatively late on early Mercury surface
- rupes attributed to shrinking of the planet as the larger Fe inner core cooled
- no evidence of shrinkage on Moon because of smaller Fe core

Santa Maria rupes

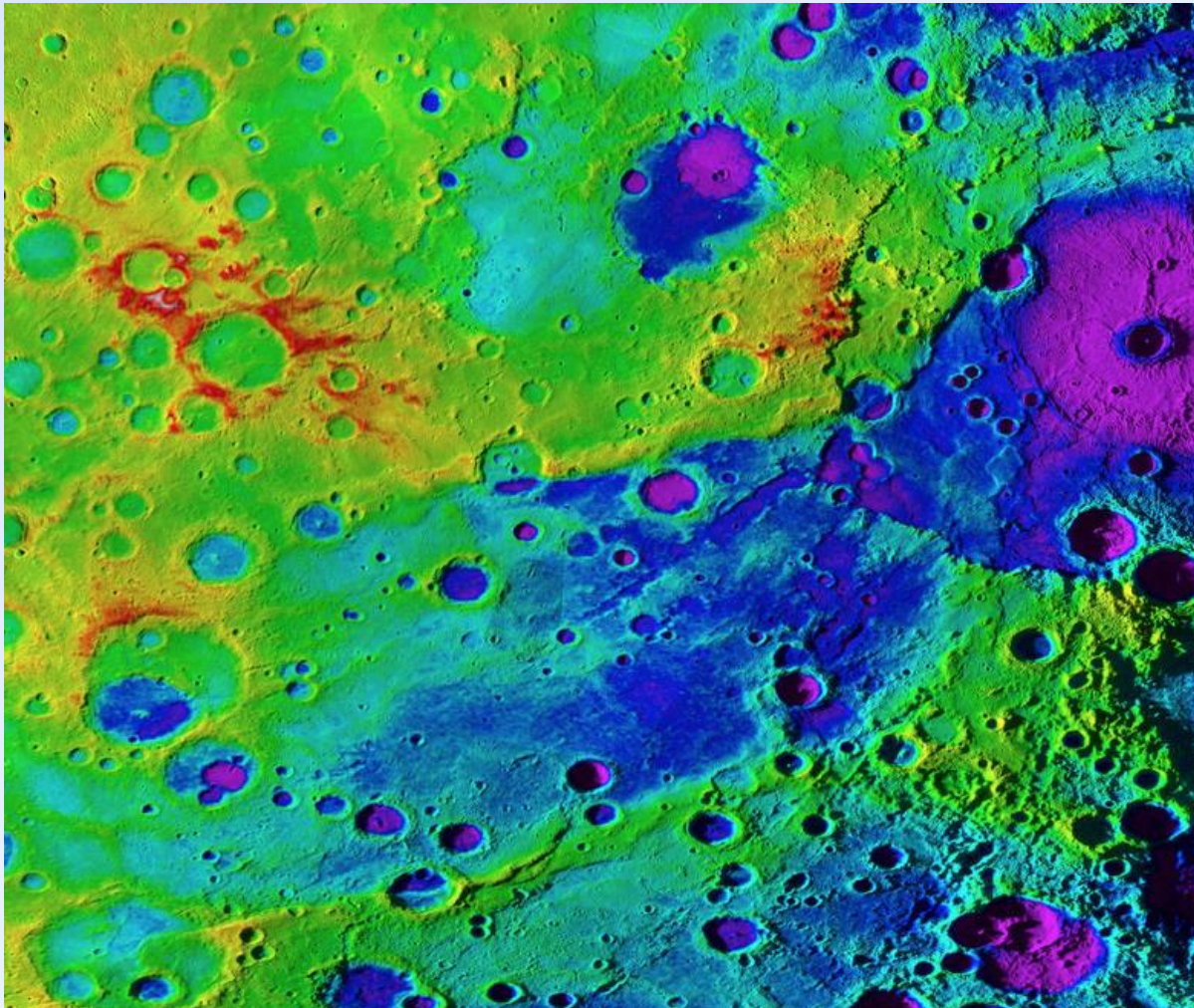


Carnegie rupes

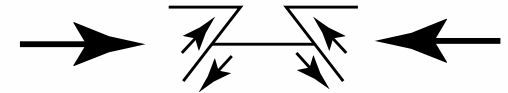


The "Great Valley"

A broad valley, >1000km long, 400km wide, 3.2km deep and bound by thrust fault scarps, extends into the Rembrandt impact crater



Extension



Compression

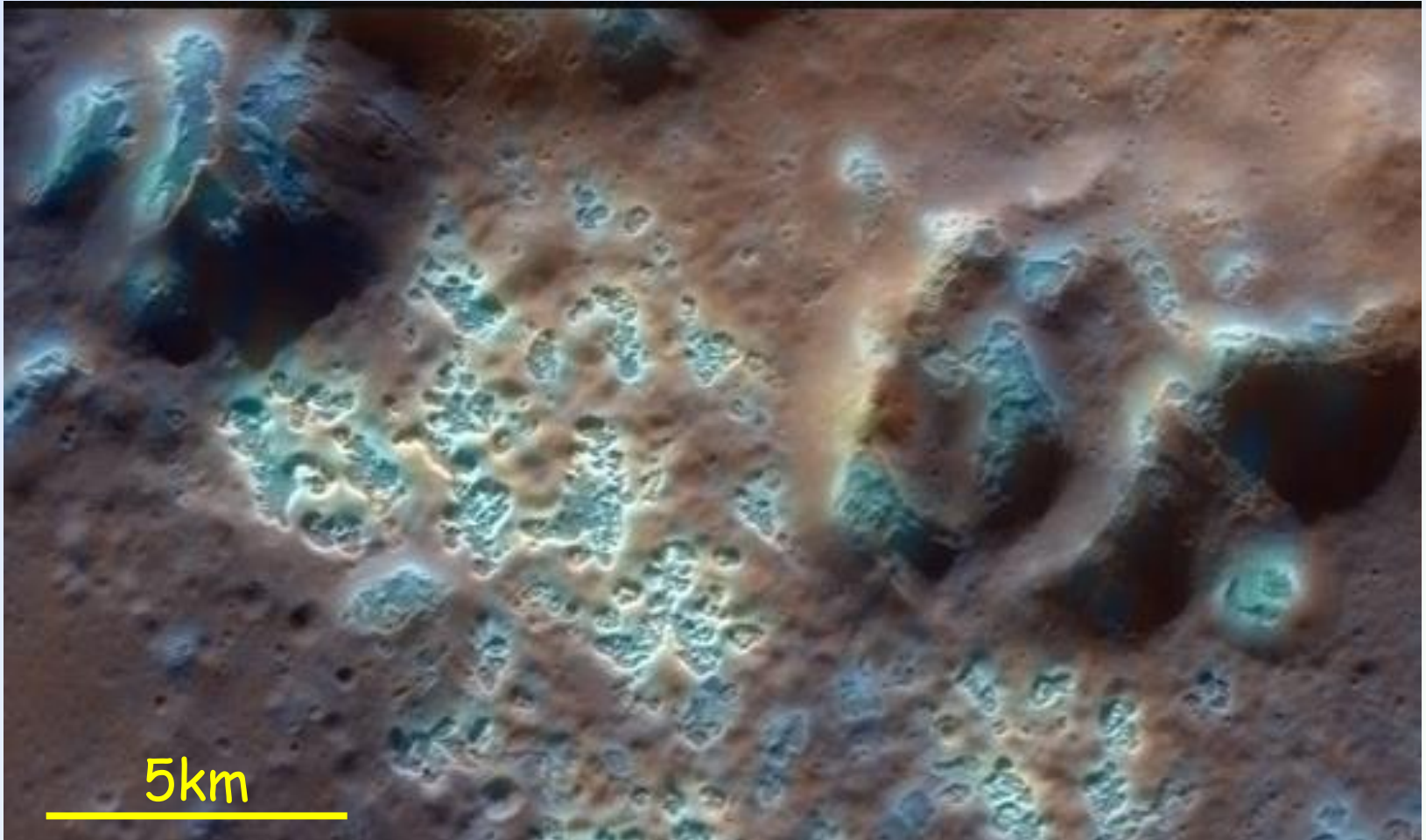
The "Great Valley"

- Bounded by two large reverse fault scarps
- crustal shrinkage caused compression and sagging in crust
- sagging valley floor lowered part of the rim of Rembrandt basin also
- there are rare examples of this type of valley formation on Earth as well

Hollows

- Areas of Mercury are covered with pits not evident elsewhere in the solar system → hollows
- hollows appear as bright clusters of shallow, rimless, irregular-shaped pits
- hollows are between tens of metres to a few km across, 30-40m deep
- possibly formed by release of trapped volatile volcanic gases (?) resulting from micrometeorite impacts

Hollows

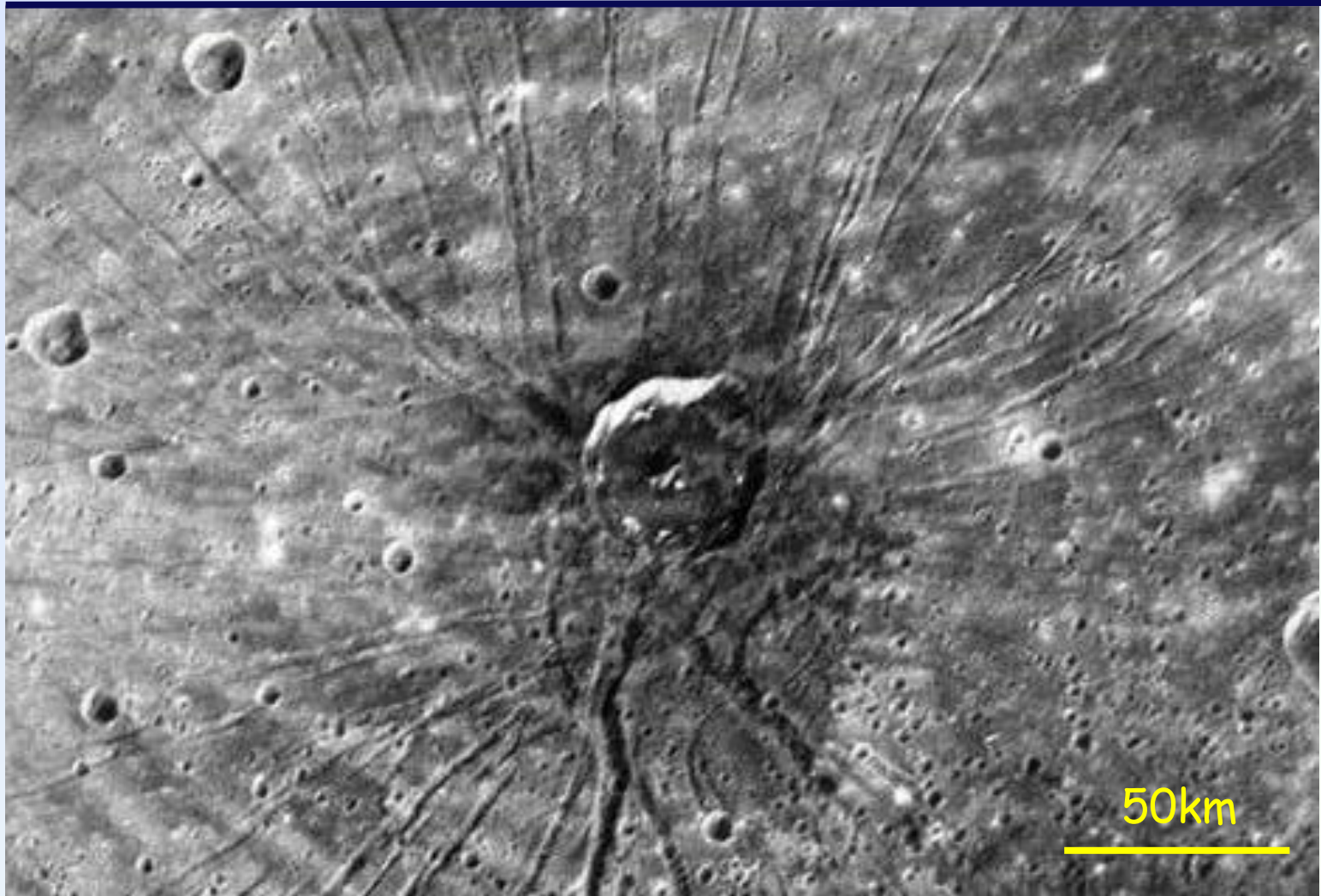


Hollows inside the Raditladi impact basin, Mercury

Spider troughs

- Discovered on surface of Mercury by the Messenger spacecraft
- radiating troughs appear to be extensional grabens formed as a result of crustal expansion
- a 40km wide crater (Apollodorus) sits near centre of the radiating troughs

Spider crater (Apollodorus)



Venus

- Brightest planet in the sky
- nearest planet to Earth
- similar in size and density to Earth
- perpetually shrouded by dense cloud*
- high atmospheric pressure → ~92bars
- surface intensely hot → temperature 380 - 490°C

Venus fundamentals

- No magnetic field on Venus but, the dense atmosphere deflects solar winds
- Venus rotates in a retrograde direction
- ~85% of the surface of Venus is covered by smooth, low-lying volcanic lava flows. The remaining 15% consists of large volcanoes
- vertical motions associated with upwelling hot spots have buckled, crumpled, deformed, fractured and stretched surface of Venus
- the surface of Venus exhibits well-recognised volcanic features as well as the unique features called arachnoids and coronae

Physical properties of Venus

Mean radius:	6052km
Bulk density:	5243kg m ³
Period of rotation:	243 Earth days (retrograde)
Period of orbit:	225 Earth days
Surface pressure:	92bars
Surface temperature:	~460°C
Gravity:	similar to Earth

Venus' atmosphere

- Very dense
- atmosphere dominated by $\text{CO}_2 \rightarrow 96.5\%$
- $300,000 \times \text{CO}_2$ in atmosphere as Earth
- pale yellow clouds are composed of concentrated sulphuric acid droplets, low H_2O concentration
- atmospheric pressure at the surface is 92bars*
- only a small percentage of solar radiation reaches Venus' surface
- greenhouse effect maintains a high surface temperature
- strong winds spiral towards poles $\rightarrow$ whirling polar vortices

Imaging of the surface of Venus

- Surface features indiscernible using telescope
- Magellan spacecraft produced radar images of Venusian surface*
- bright areas indicate roughness of surface
- radar images enable geological interpretation

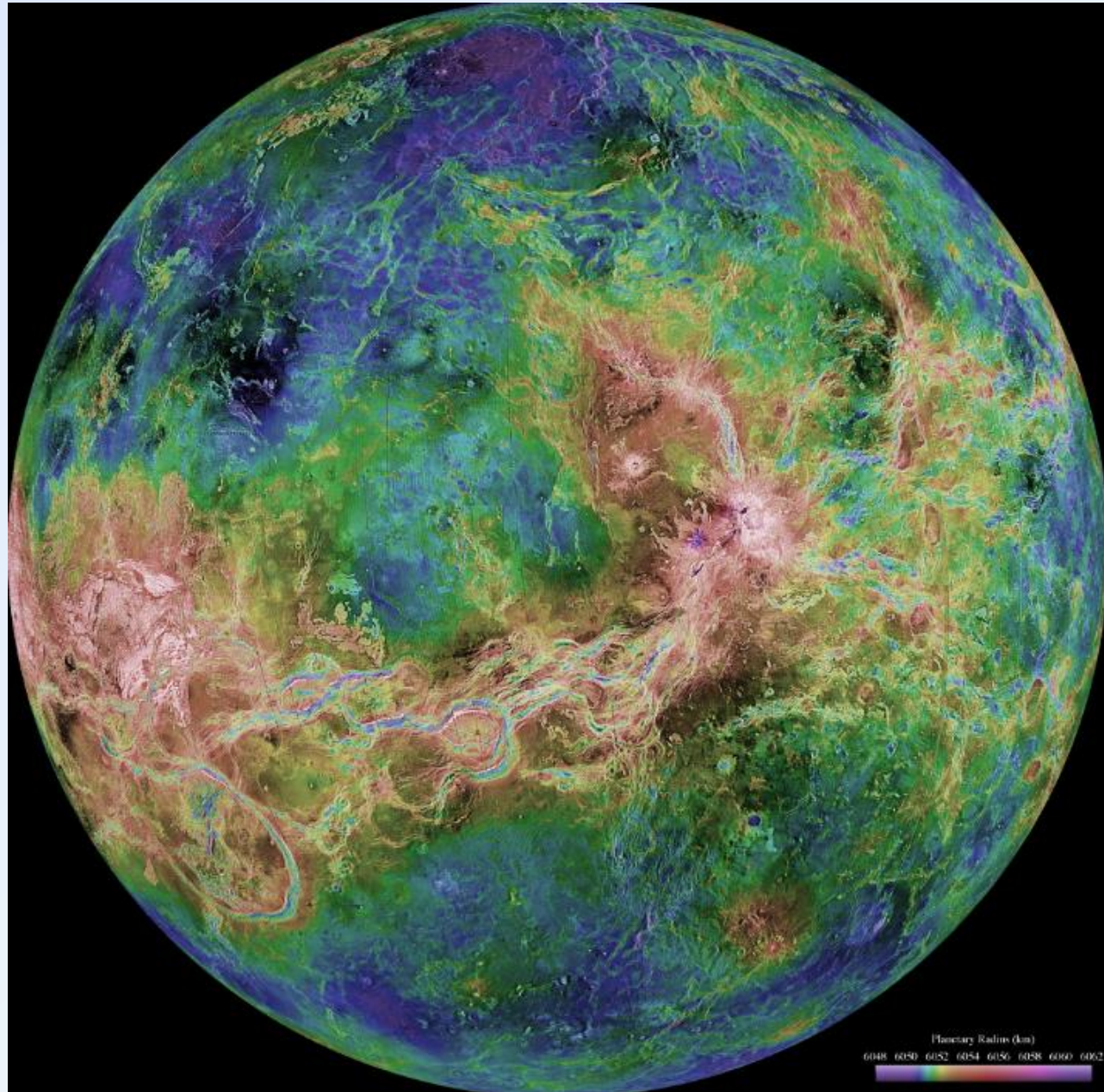


Telescope view of Venus



Radar image of part of the surface of Venus by Magellan spacecraft

False colour image of Venus

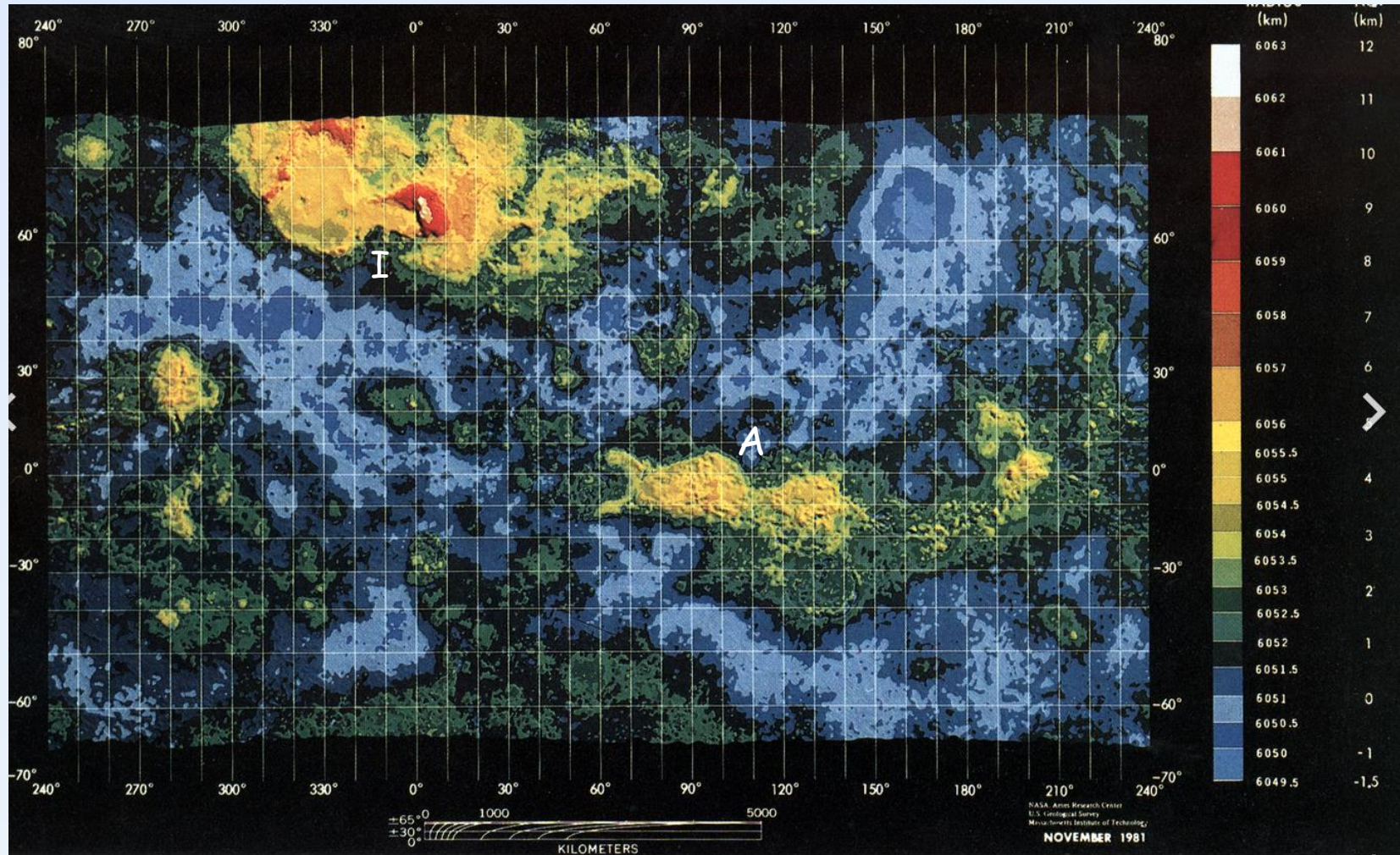


Unveiling the surface of Venus with radar

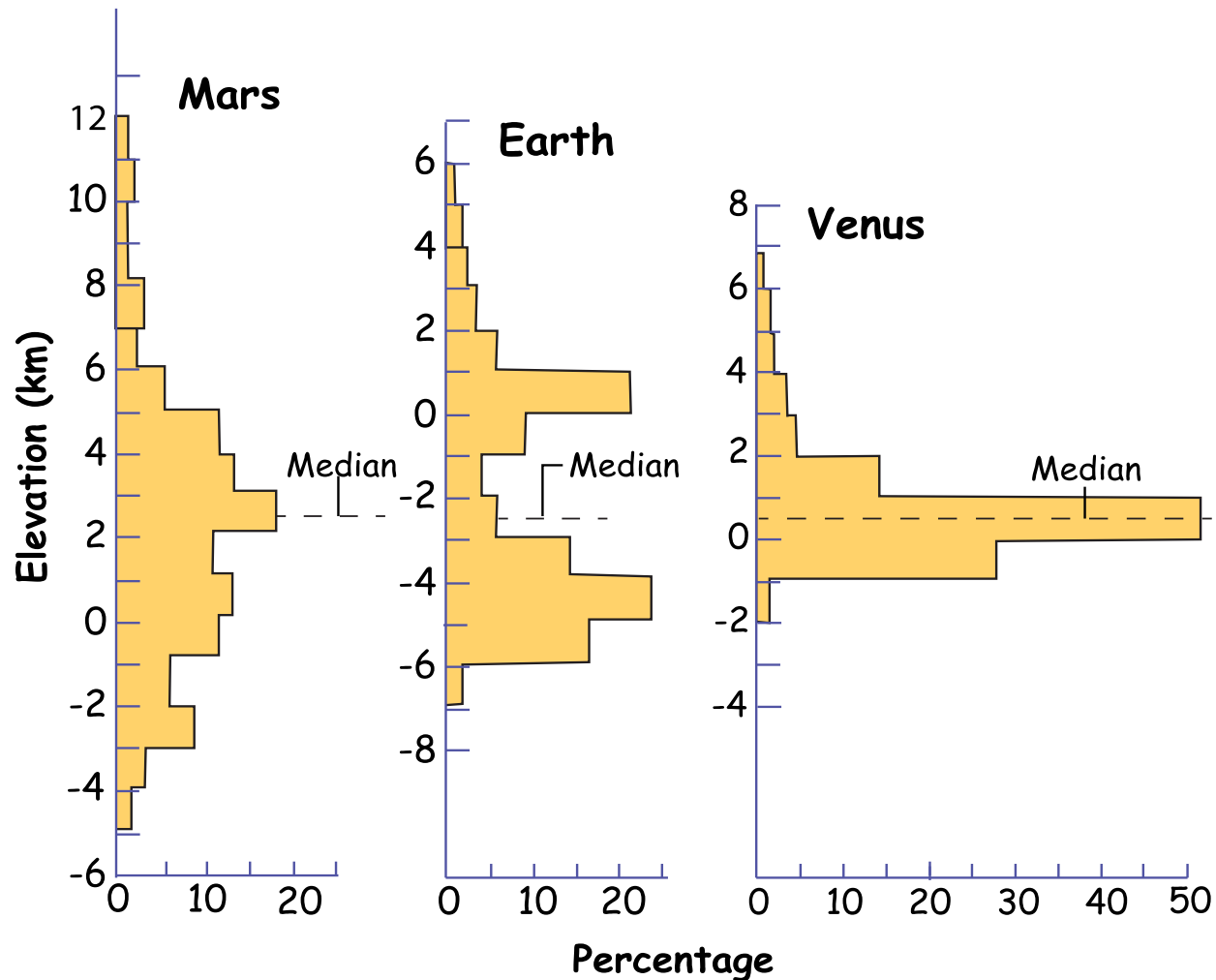
- Magellan's radar image revealed a surface vastly different to Earth
- the surface is shaped by volcanic activity → topography dominated by massive outpourings of lava and numerous shield volcanoes
- sparse impact craters surrounded by outflows and surfaces fractured, stretched and split open by upwelling magma
- surface features are pristine
- there are two large scale elevated regions
 - Aphrodite Terra* - equatorial region
 - Ishtar Terra - in far north

Composite radar image of Venus showing surface elevations

- Wide range of surface elevations
 - large high areas resembling continents (e.g. Aphrodite, Ishtar)
 - broad low elevation regions like ocean basins
 - no evidence for Plate tectonics features



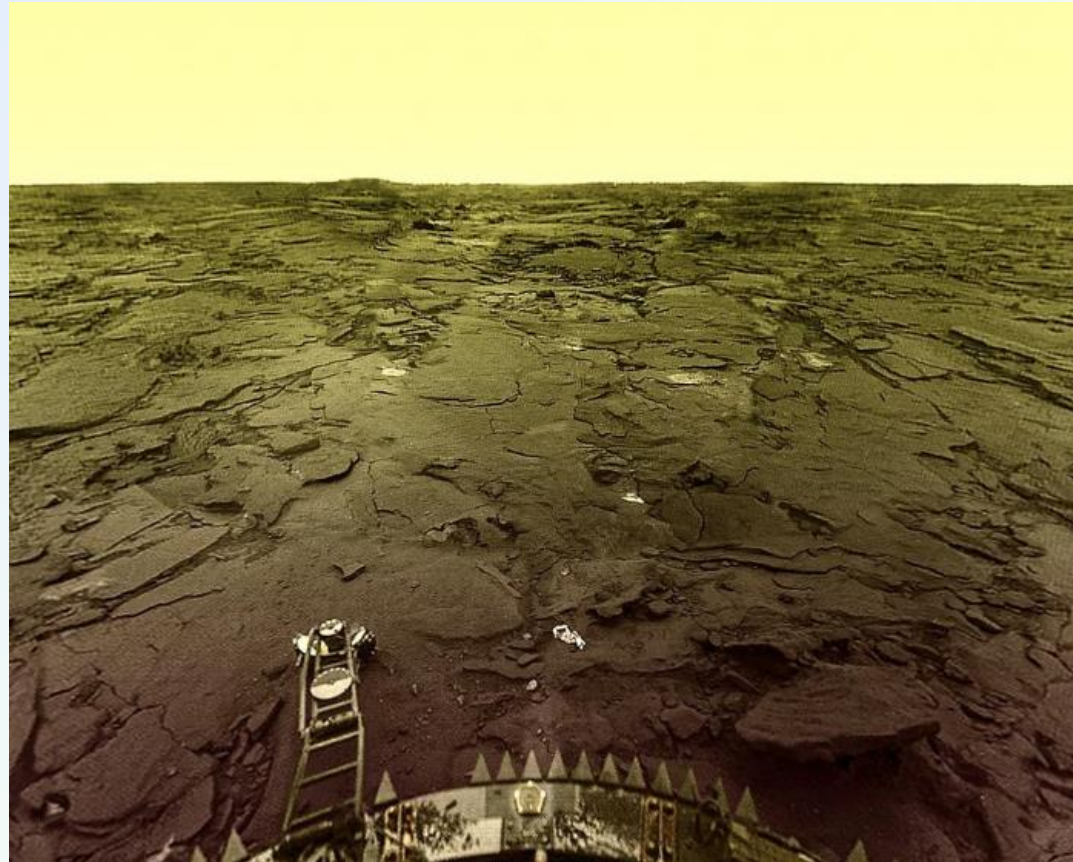
Comparative elevations of Venus, Earth and Mars (Lang 2011)



Surface of Venus

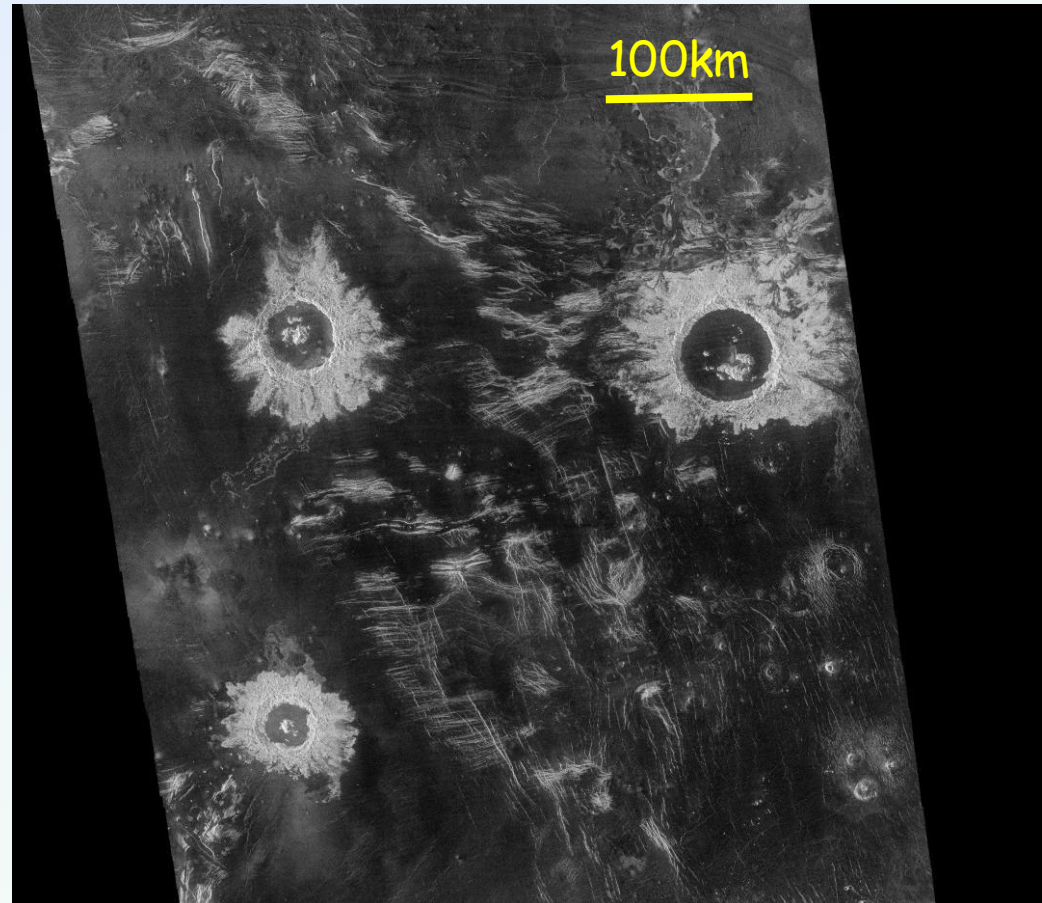
- Surface scarred by sparse, pristine, impact craters
- only Jupiter's moon Io is more volcanically active
- ten Venera Russian probes landed on surface of Venus*
- surface of the planet intensely hot (380 - 490°C)
- some data transmitted back to Earth

Venus surface
image from
Venera 13 probe,
1981



Venus - impact craters

- **Impact craters**
 - circular craters, central peaks prominent, ejecta blankets
 - impact-triggered melting → lava flows
 - there are very few of them (~300, similar number to Earth)
 - constant re-surfacing → obliterated old craters



Impact melts

- Ejecta blankets appear to have field of lava flows → 'bleed'
- reflects temperature of crust → melting point of interior at shallow depth
- impacts generate lavas



Dickinson crater

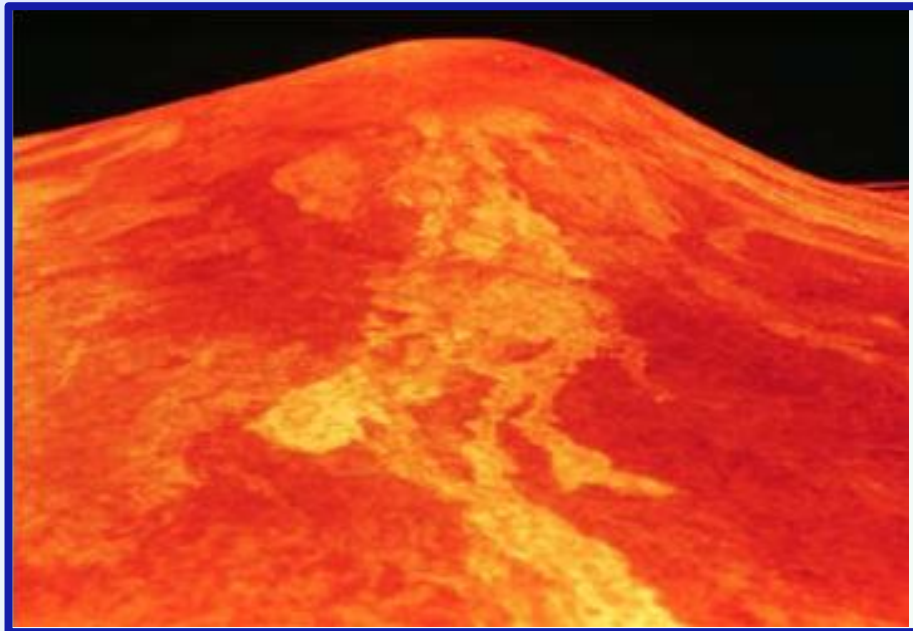
Volcanic features on Venus

- Venus is dominated by volcanic features → tens of thousands of volcanoes pepper the surface some of which are still active today
- Venus shows every volcanic feature observed on Earth plus some that are unique to the planet and more than on any other planet
- >90% of the surface is covered by basalt with most of the planet → volcanic plains
- 10% of the planet are highlands
- Venus must have had a vast volume of hot material in its interior

Venus - volcanic features

Volcanic features

- extensive lava fields → volcanic plains
- large central shield volcanoes e.g. Maat Mons, Sapas Mons
- large 'Corona' and 'Arachnoid' volcanic structures
- small 'pancake' volcanoes



Volcano Sif Mons (2km high
~300km diameter)

Volcanic surface

- Surface → fresh-appearing rock without eroded edges
- smooth surfaces imply formation by flowing lava
- as molten lava spread across the surface and cooled → produced thin, fractured rock layers
- rock analyses (Venera 13 and 14) → similar composition and specific gravity as basalt c.f. typical lunar basalt
→ much lower Ti, Fe, higher Si, Al, Mg

Venusian and Lunar basalt analyses

	Venera 13	Venera 14	Vega 2	Lunar basalt
	wt %	wt %	wt%	wt%
SiO ₂	45.1	48.7	50.8	41.0
TiO ₂	1.6	1.25	0.22	11.3
Al ₂ O ₃	15.8	17.9	17.8	9.5
FeO	9.3	8.8	7.7	18.7
MnO	0.2	0.16	0.16	0.25
MgO	11.4	8.1	12.8	7.3
CaO	7.1	10.3	8.3	11.0
Na ₂ O	-	-	-	0.51
K ₂ O	-	-	-	0.36

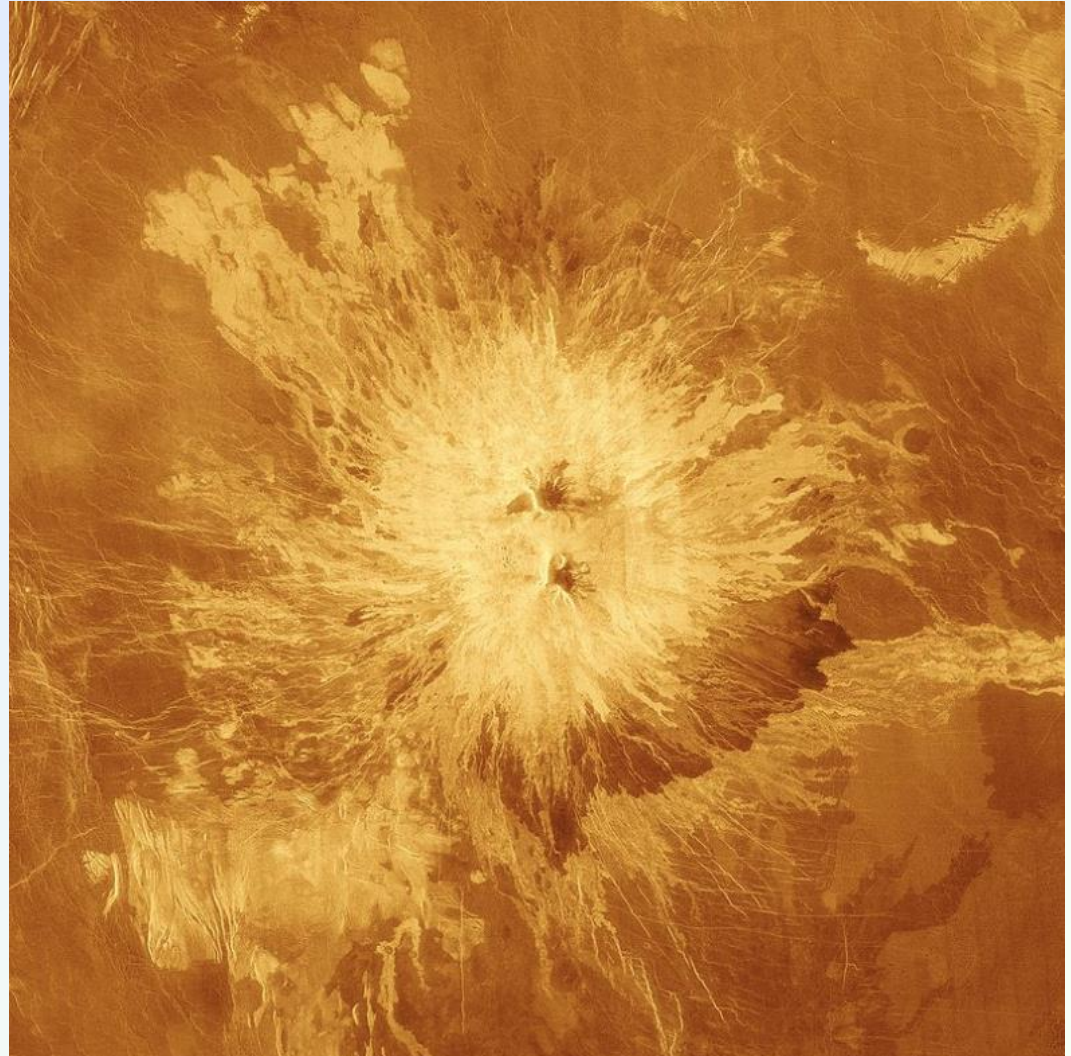
Volcanic plains on Venus

- Radar data → Venus contains large areas of smooth, low-lying plains
- plains contain meteorite impact craters
- craters on Venus are much fewer and more widely spread than on the Moon → much younger surface than Moon
- small craters seen on the Moon are absent on Venus → meteors burn up in thick Venusian atmosphere

Radar image of volcano Sapas Mons

- In addition to volcanic activity associated with meteorite impact → also central conical volcanoes
- Sapas Mons ~1500m high
~400km across
- summit has two craters
- surrounded by network of fractures

Sapas Mons



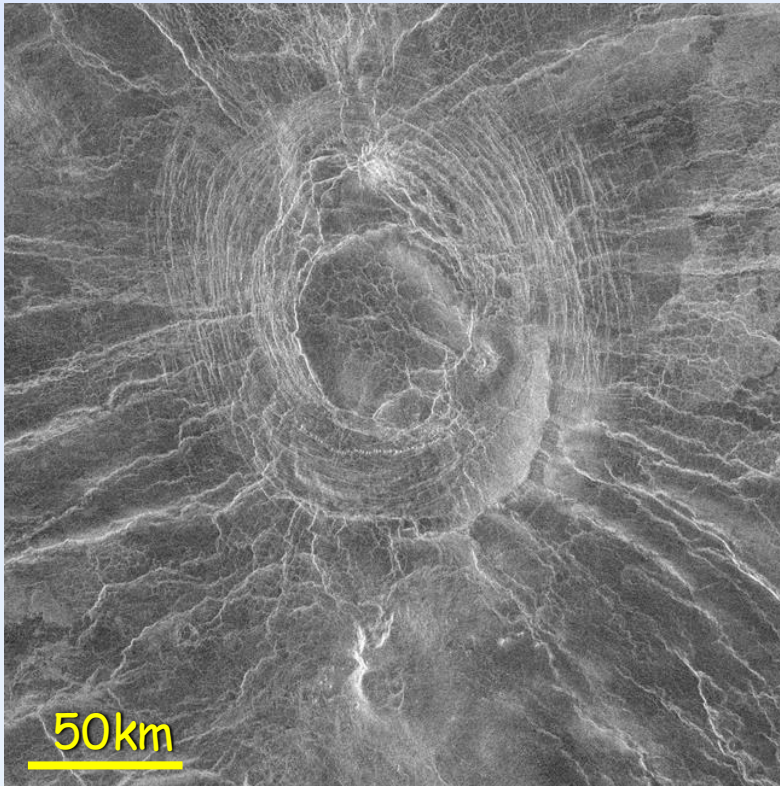
Venus - coronas and arachnoids

- **Coronas**

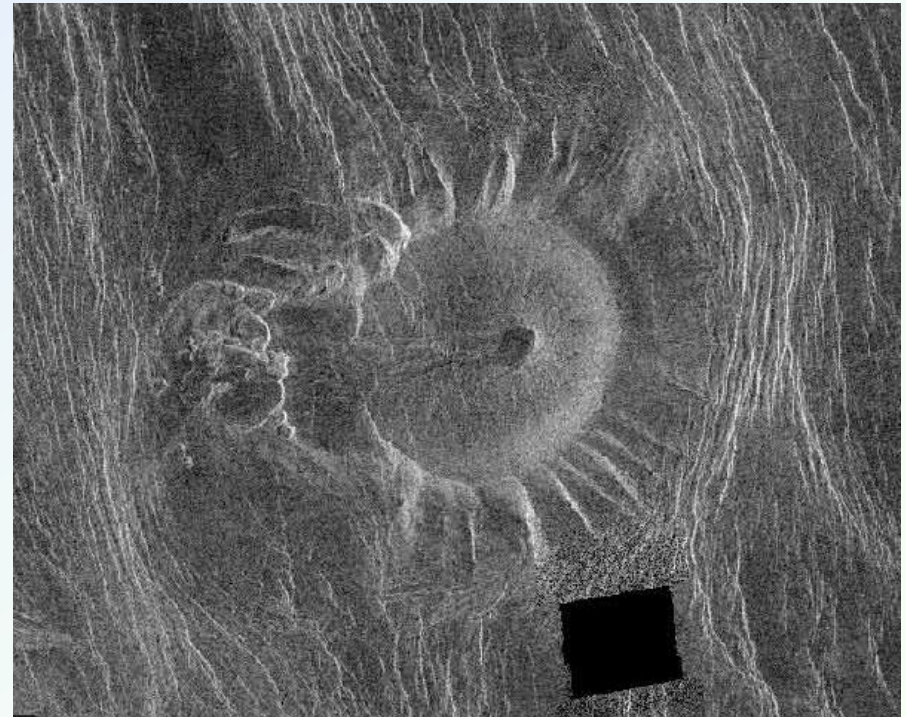
- circular to elliptical features a few hundred km in diameter
- formed by upwelling of mantle

- **Arachnoids**

- smaller than coronas (up to 100km diameter)
- probable similar origin to coronas

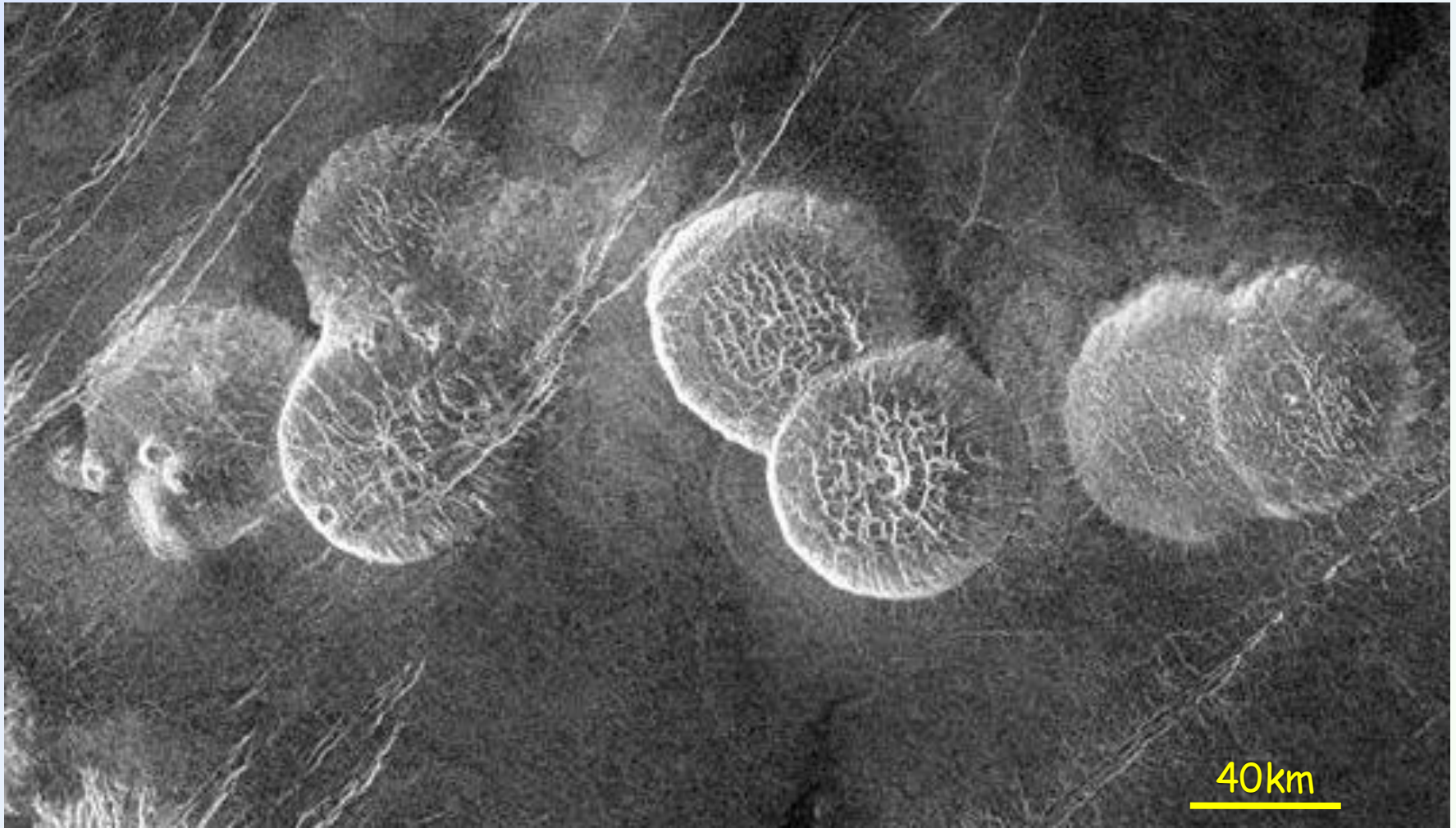


Corona



Arachnoid

Venus -small volcanic domes

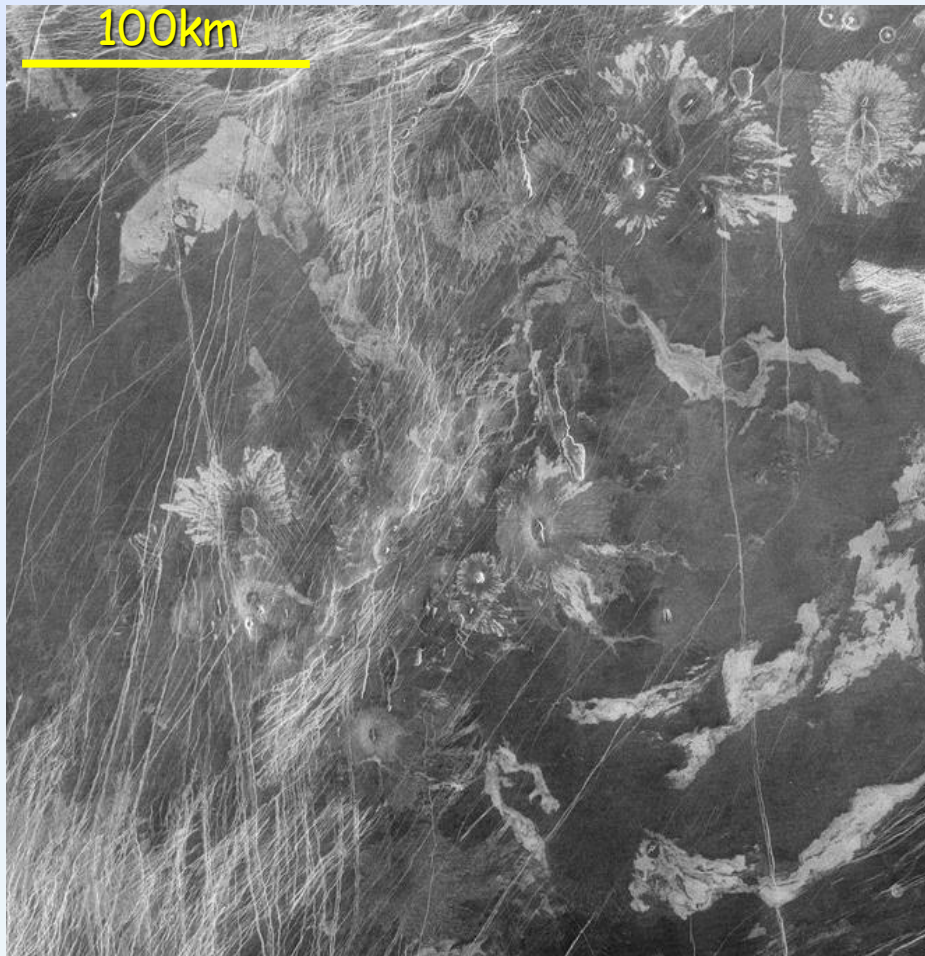


Other features of Venus

- (a) Widespread surface faulting and fracturing
- (b) evidence of past deformation of rocks
- (c) no evidence of erosion by running water
- (d) complex and very active geological history
- (e) no record left of early impact cratering
- (f) still geologically active today

Surface fracturing on Venus

- Surface fracturing ubiquitous on Venus
- fractures not covered by lavas → younger than volcanism



Volcanic features and fracturing, Atla region

Deformation in the Venusian crust

- Magma in the Venusian interior rises to crack and deform the planet's surface
- hot rising magma → buckled, stretched and fractured the Venusian crust
- when bubble of magma rises to just below the crust → causes crust to bulge and crack or is erupted as lava
- circular and radial features → created around edge of rising dome → split crust open → spread apart forming rift valleys

Surface deformation Ovda region

- Evidence of horizontal compression in Ovda region
- series of ridges and broad domes appear to have formed by N-S compression



Deformation in
Ovda region (Aphrodite
Terra)