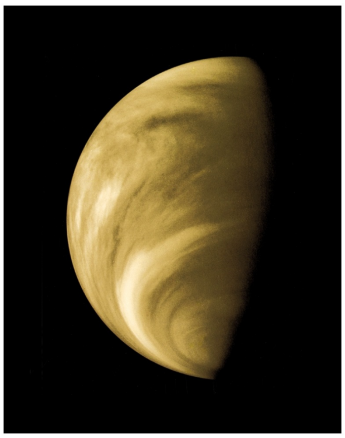
Venus



Earth's Sister?

Question

Is Venus Earth's twin?

(Size, mass, temperature, surface features, atmosphere, history)

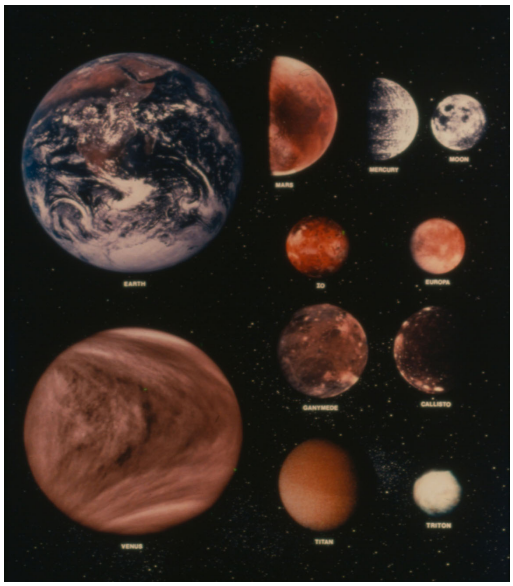
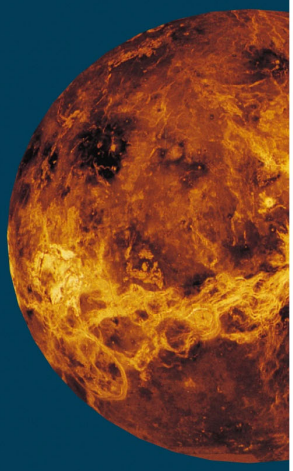


Table 11-1 **Venus Data**

Average distance from Sun:	0.723 AU = 1.082×10^8 km
Maximum distance from Sun:	0.728 AU = 1.089×10^8 km
Minimum distance from Sun:	0.718 AU = 1.075×10^8 km
Eccentricity of orbit:	0.0068
Average orbital speed:	35.0 km/s
Orbital period:	224.70 days
Rotation period:	243.01 days (retrograde)
Inclination of equator to orbit:	177.4°
Inclination of orbit to ecliptic:	3.39°
Diameter (equatorial):	12,104 km = 0.949 Earth diameter
Mass:	4.869×10^{24} kg = 0.815 Earth mass
Average density:	5243 kg/m^3
Escape speed:	10.4 km/s
Surface gravity (Earth = 1):	0.91
Albedo:	0.59
Average surface temperature:	460°C = 860°F = 733 K



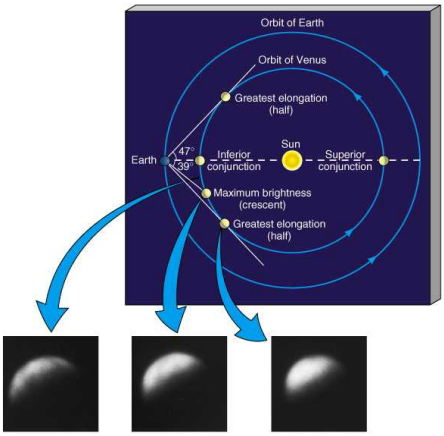
(NASA/JPL)

Appearance

Venus is very bright.

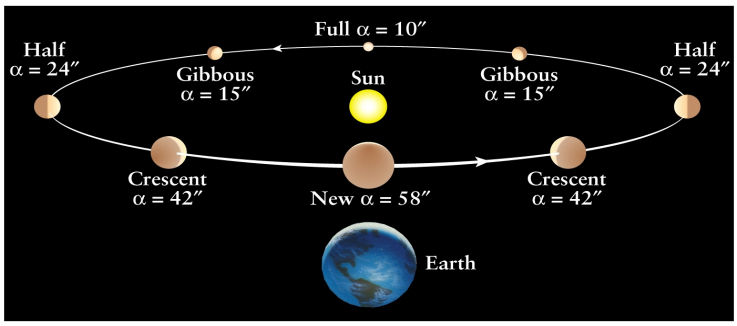
Its greatest brilliance occurs when it is a crescent, with an elongation of about 39°.

This occurs about 36 days before and after inferior conjunction; angular diameter is about 50 arcsec.



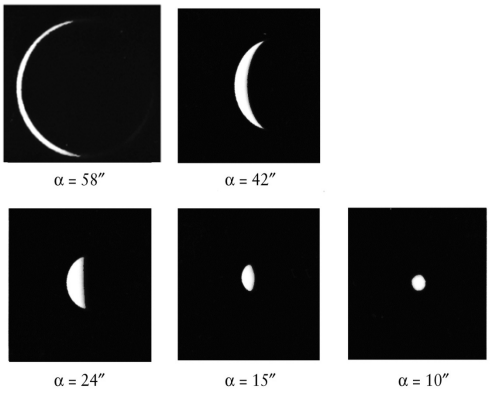
Astronomy Today by Chaisson and McMillan

Phases of Venus



Venus goes through phases, although full cannot be seen.
Angular size varies from 10 to 64 arcsec.

Phases of Venus



The importance of Galileo's discovery of the full set of phases showed Venus did not orbit around the Earth but about the Sun.

Studying Venus

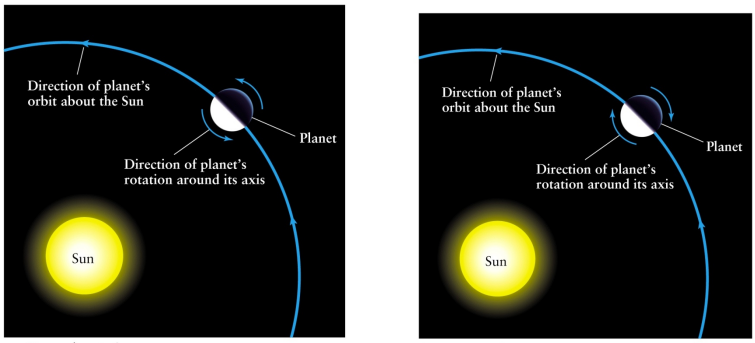
The surface is not visible because it is shrouded by dense clouds. Its albedo is about 60%.

Ultraviolet photography from space-craft sees cloud features, but radar is required to penetrate to the surface.

Radio and radar observations can reveal temperature information and rotation rate.

Rotation

Period was determined by radar in the early 1960's. Showed Venus rotates from east to west – retrograde. Rotation rate is 243.08 days.



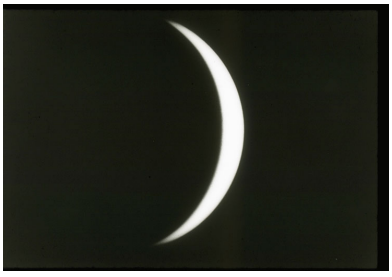
a Prograde rotation b Retrograde rotation

Universe by Freedman, Geller, and Kaufmann

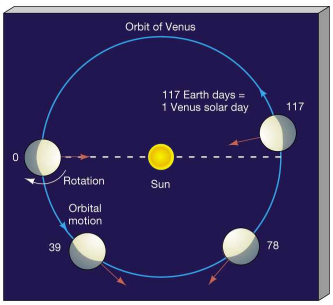
Why?

Rotation

The interval between inferior conjunctions of Venus is 243.16 days, which is very close to the rotation period of 243.08 days. This means that very nearly the same face of Venus is toward the Earth at each inferior conjunction.



Noon to Noon



Astronomy Today by Chaisson and McMillan

The time between successive noons is 115.67 Earth days.

The Venerian day (with respect to the stars) is 19 Earth days longer than the Venerian year (= 224.70 days).

Radar Mappers

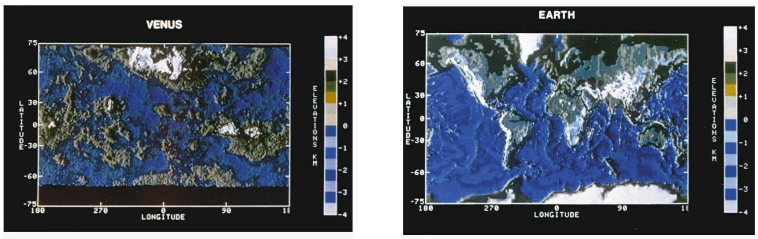
Surface mapping with radar was by the Soviets and the US (Pioneer Venus [1978-1992]). Probes also measured atmospheric quantities.

The most recent US mission [1990-1994] was an orbital radar mapper called Magellan. It was designed to map the entire planet with a resolution of about 200 m.

[*animation*]

Universe by Freedman, Geller, and Kaufmann

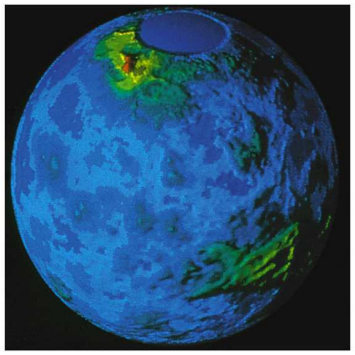
Large Scale Topography



Astronomy Today by Chaisson and McMillan

On Earth about 45% of the crust is continental. Venus, in contrast, consists mostly of low, relatively flat terrain. Only about 10% of the surface is highlands, which might (or might not) be similar to the terrestrial continents.

Large Scale Topography

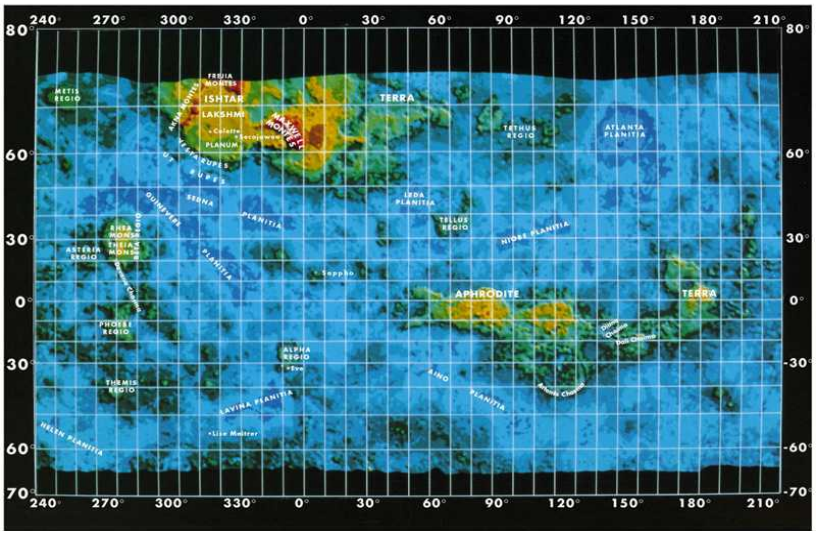


Astronomy Today by Chaisson and McMillan

The largest highland area (Aphrodite) is about the size of Africa. It stretches along the equator nearly halfway around the planet.

Next largest is the northern region called Ishtar, which is about the size of Australia. It contains the highest mountain, Maxwell.

There are no other continent-size highland areas. There are several rises that appear to be either huge individual mountains or ranges.



Astronomy Today by Chaisson and McMillan

Geology

To determine the age of the planet, one should count the number of impact craters. The thick atmosphere prevents smaller meteors from reaching the surface.

Images show that the number of craters on the plains of Venus are generally only 10 to 20% of the lunar maria values, indicating a surface age considerably less than that of either the lunar maria.

Geology

The crater counts suggest the surface is less than a billion years old and *strongly argues for persistent geological activity*.

Thus, although apparently less active than Earth, Venus seems to have retained more of its internal heat than Mars, Mercury, and the Moon.

Plate Tectonics?

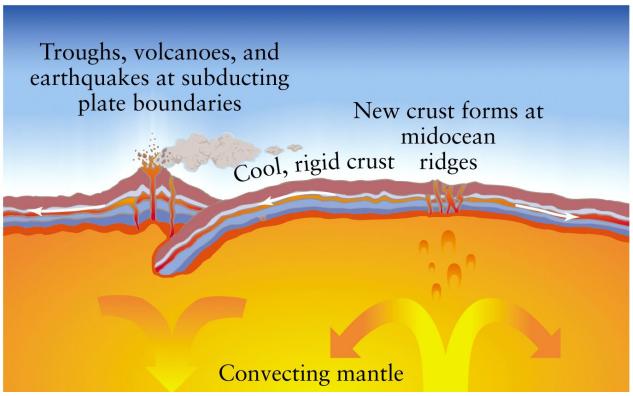
Are there active Plate Tectonic regions on Venus?

Radar data suggest only weak tectonic activity, at best.

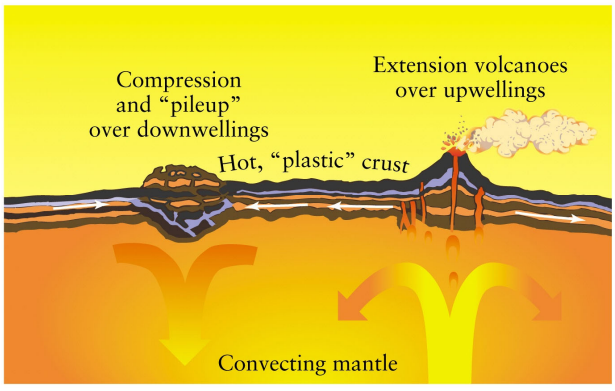
There are suggestions of several rift areas near the equator, and the Maxwell Mountains may be compressional features like the mountains on the Earth.

But there is no equivalent of the young ocean basins on Earth, and any plate motion must be relatively sluggish.

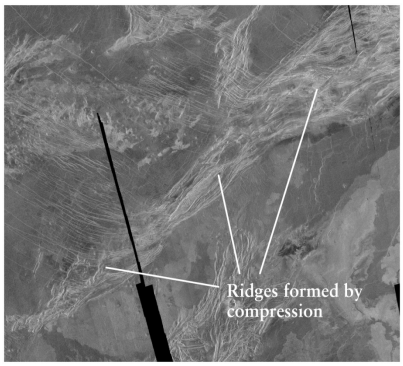
Earth's Crust



Venus' Crust



Compressional Folding



This Magellan radar image shows part of the low-lying Lavinia Planitia.

Compression of the surface has formed a bright belt of ridges that run from the lower left to the upper right.

Aphrodite Terra

A Magellan image of Ovda Regio, which is part of Aphrodite Terra. The intersecting ridges indicate repeated compression and buckling of the surface. The dark areas represent regions that have been flooded by lava upwelling from cracks.

Volcanoes?

There may be some volcanoes, possibly active.

1. Electrical discharges (lightning bolts) have been detected.
2. From 1978 to 1983 there was a decline of SO_2 by a factor of 10.
3. Smooth radar reflectivities indicate recent lava flows.

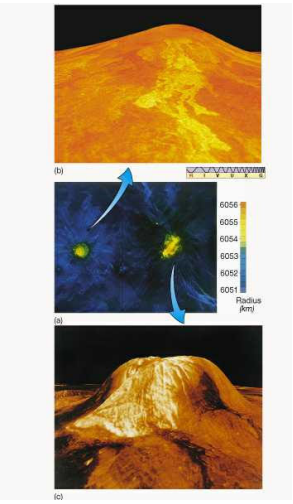
However, all of the above are circumstantial indications for active volcanoes, but there are no direct sightings.

Maxwell Mountains

The Maxwell Mountains rise about 11 km (~7 miles) above the average elevation and are about 700 km across. The best radar images show that this range generally consists of long parallel ridges spaced about 20 km apart, similar to many folded mountains on Earth.

Although some suggest Maxwell is a large shield volcano, most feel it is tectonic in origin, having been uplifted and folded by compressional forces.

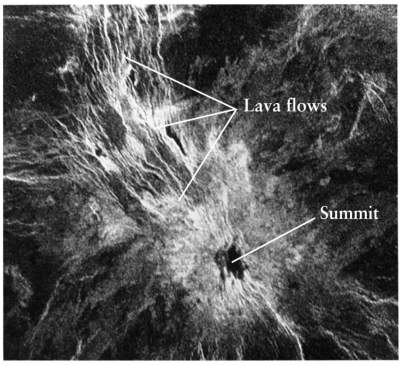
Volcanoes



Two large volcanoes, known as Sif Mons and Gula Mons, appear in the middle Magellan image. Color indicates height above a nominal planetary radius. The two volcanic calderas at the summits are about 100 km across.

[The top and bottom images are computer generated, with the vertical scale having been multiplied by 40X.]

Volcanoes



Theia Mons is centered near the bottom of this Earth-based radar image.

Dark areas are where the surface is smooth and reflects microwaves only weakly, while bright areas have a rough-textured surface that reflects microwaves more strongly.

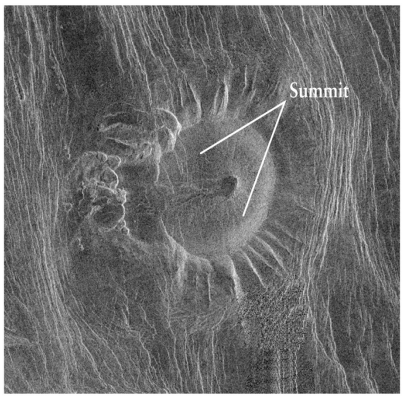
Bright lava flows extend from the volcano's summit toward the upper left of the image. The image area is about 3 times the size of Texas.

Volcanoes

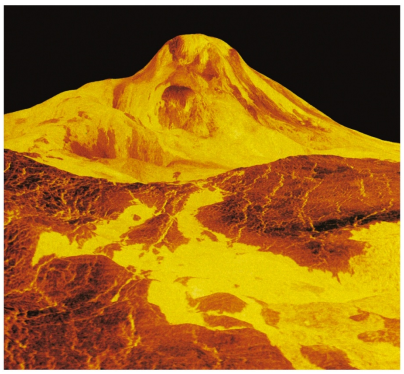
This Magellan image covers an area of about 60 by 50 miles. The smallest details are about 100 m across.

The flat, wide summit of this volcano is surrounded by a number of ridges and valleys.

It is referred to as “The Tick.”



Lava Flows



The tall peak in this computer generated view is Maat Mons, the second tallest volcano on Venus.

The bright lava flows are estimated to be no more than 10 million years old.

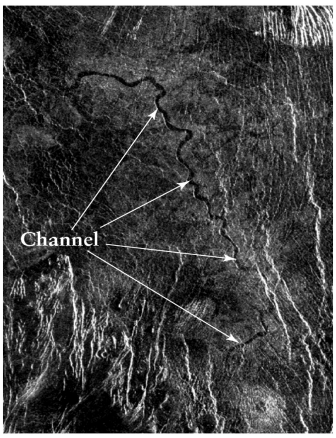
[It has a height of 8 km but a diameter of 395 km. The vertical scale has been multiplied by 22.5 times (equivalent to stretching a house into the shape of the Washington Monument.)]

Lava Channels

This Magellan image shows a part of a long, meandering, 2 km-wide channel. Although it resembles a river on Earth, it could never have held liquid water.

Instead, a moderate increase in Venus' surface temperature could have melted lavas rich in calcium compounds while the rest of the surface remained solid.

The entire channel is 6800 km long (longer than the Nile River).

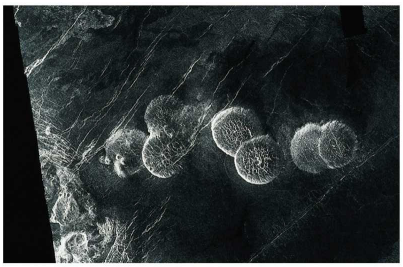


Lava Channels

This lava channel in Venus' south polar region, known as Lada Terra, extends for nearly 200 km.

Its nickname is "Gumby."

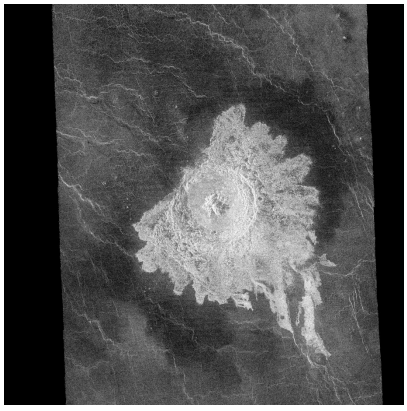
Lava Domes



These domed-shaped structures resulted when viscous molten rock bulged out of the ground and then retreated, leaving behind a thin solid crust that subsequently cracked and subsided.

Referred to as “Pancakes.”

Craters



Fewer than 1000 impact craters have been found on Venus. In fact, craters are completely missing from regions as large as 5 million km^2. Most craters are tens of km in diameter, Aurelia (30 km) is surrounded by a thick layer of rough ejected material, which appears bright because it reflects radar well. Many of the craters have flat, smooth floors and seem to be been flooded with lava that may lie close to the surface.

[*animation*]

Magellan Results

1. Found numerous volcanoes, domes, and "pancake" mountains, which are apparently due to a type of lava not found on the Earth.

2. Found multiple lava flows, flood plains, and "canali", which appear to have flowed uphill – the explanation is that the flow was downhill, but uplifting of the area has occurred since then.

3. Did not find any *currently erupting* volcanoes.

4. Found that the highest peaks are all highly reflective.

5. Found that the crust has been very fluid – "gravitational relaxation".

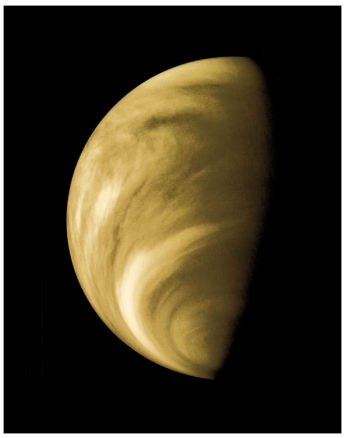
Magellan Results

6. Found very few craters, and the ones that were seen, appear to be similar to terrestrial craters. There are none below 2 km in diameter (due to the thick atmosphere). Dark halos were seen around many of the craters; it is theorized that a shock wave is created in the thick atmosphere that interacts with the ground shortly before the impact occurs.

7. Found that there has been some sort of geologic activity (i.e., re-surfacing) about 500 million years ago. It is unknown whether it was gradual or catastrophic, but it apparently removed most of the craters.

8. Found that plate tectonics probably did not happen. Why? Possibly because the crust was too pliable – responded differently to upwellings. Or maybe oceans are needed in order to have subduction zones. Or the interior was cooler than the Earth's.

Venus



Earth's Sister?

Exploration

Venus was the first planet to be observed by a passing spacecraft. The U.S. spacecraft Mariner 2 passed within 21,600 miles (34,760 km) in 1962. Instruments measured the high temperatures.

Two unmanned Soviet spacecraft "explored" Venus in 1966. Venera 2 passed within 15,000 miles (24,000 km) on February 27, and Venera 3 crashed into Venus on March 1.

In 1967, Venera 4 dropped a capsule of instruments into the atmosphere by parachute, and Mariner 5 passed within 2,480 miles (3,990 km). It did not detect a magnetic field. **Both probes reported large amounts of CO_2.**

On Dec. 15, 1970, Venera 7 landed. On its way to Mercury, Mariner 10 flew near Venus on Feb. 5, 1974. It transmitted the first close-up photos.

Exploration

In 1975, **Venera 9** landed on Venus and provided the first close-up photograph on the surface. Three days later, **Venera 10**, reached Venus. It photographed the surface, measured its atmospheric pressure, and determined the composition of rocks on its surface.

Four spacecraft arrived in December 1978. **Pioneer Venus 1** sent radar images of Venus, produced a map of its surface, and measured temperatures at the top of the clouds. **Pioneer Venus 2** entered the atmosphere and measured its density and chemical composition. Two weeks later, **Venera 12** landed, and four days later so did **Venera 11**. Both sent back data on the lower atmosphere of Venus.

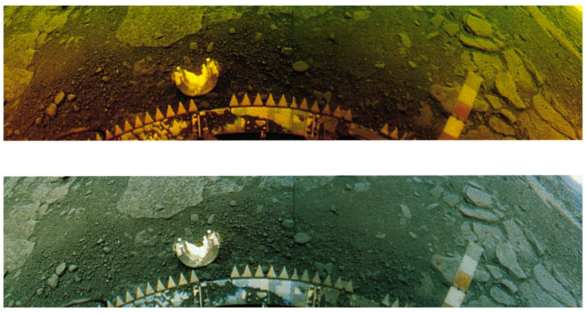
Exploration

Two more Soviet spacecraft landed on Venus in 1982 – **Venera 13** on March 1 and **Venera 14** on March 5. Both probes transmitted pictures of Venus and analyzed soil samples. Beginning in October 1983, two additional Soviet spacecraft mapped some of Venus by radar. **Venera 15** finished its mapping in July 1984; **Venera 16**, in April 1984. The two probes provided clear images of features as small as 0.9 mile (1.5 km).

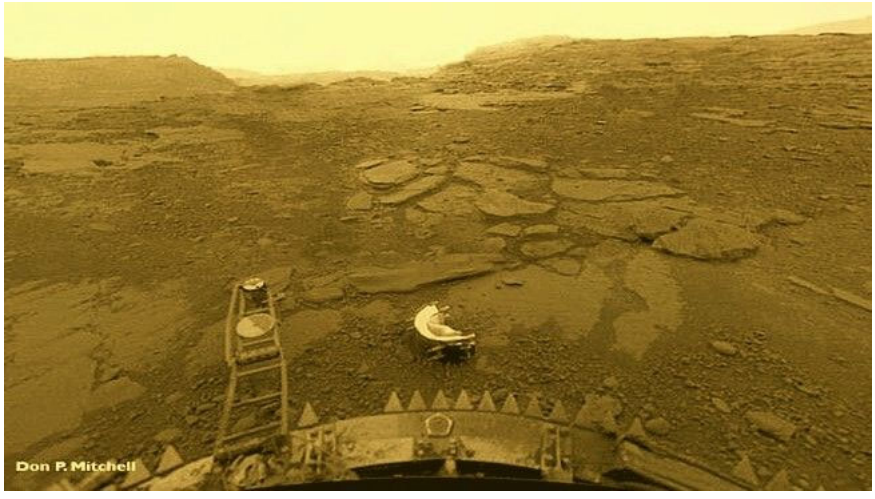
The U.S. spacecraft **Magellan** began orbiting Venus on Aug. 10, 1990. Radar images received from the Magellan show details of features as small as 330 feet (100 m) across. It ceased operating in 1994.

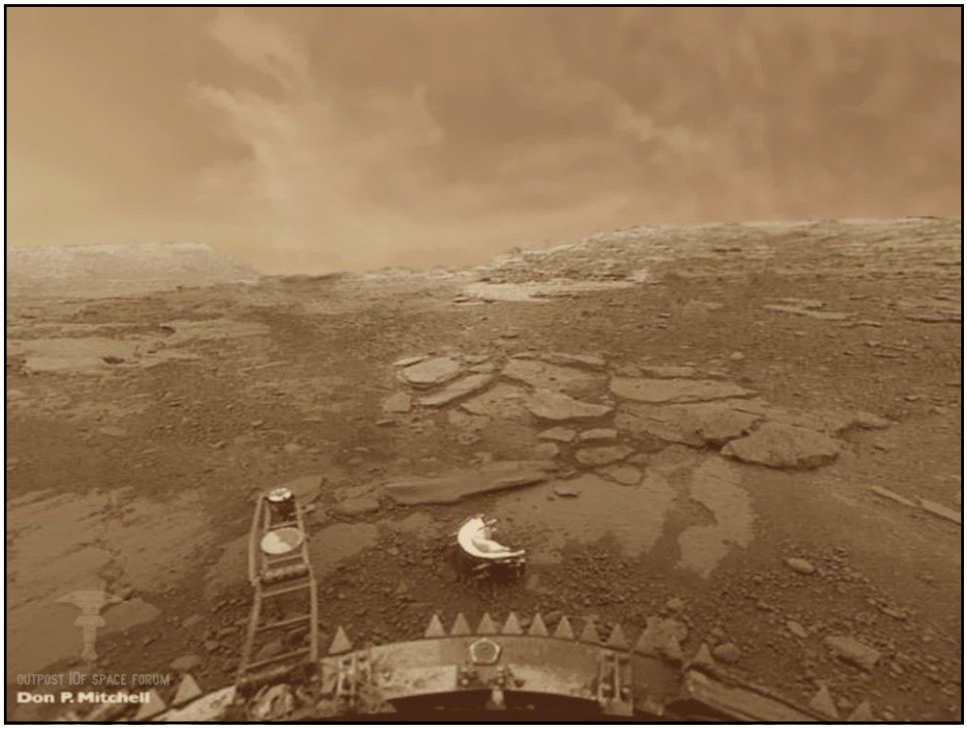
Exploration of Venus

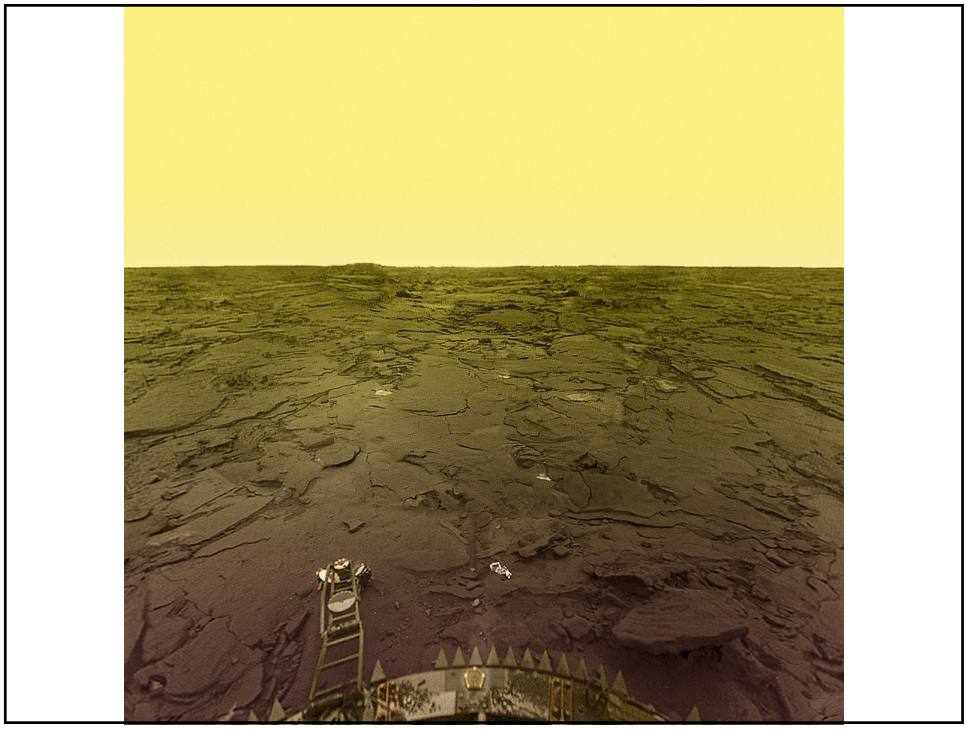
In the 1980s, Russian Venera landers investigated the surface, taking color pictures and performing chemical analyses of the soil. The rocks are probably basalts. Pictures showed a desolate, flat landscape with a variety of rock types, which may be ejecta. Other areas showed flat, layered rock, perhaps exposed lava flows.



Universe by Freedman, Geller, and Kaufmann




OUTPOST OF SPACE FORUM
Don P. Mitchell



On the Surface

Venera probes measured the (1) surface pressure = **90 times sea-level** and
(2) surface temperature = **750 K** (860 F).

The Sun cannot shine directly through the heavy, opaque clouds, but the surface is fairly well lit by diffuse light. The illumination is actually about the same as that on Earth under a very heavy overcast, but with a strong red tint, since the massive atmosphere blocks blue light.

Interior

The mass of Venus is 81.5% that of the Earth.

Its average density is 5.2 g/cm^3.
(Uncompressed is 4.2 g/cm^3 = Earth's.)

Obviously, the surface conditions will never allow seismometers to study the interior.

What about a Magnetic Field?

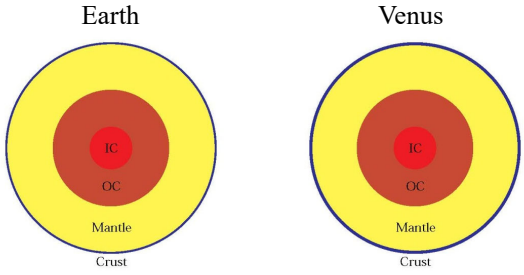
Magnetic Field

No magnetic field has been detected by any of the spacecraft. Having an average density similar to the Earth's, Venus ***probably*** has a similar overall composition and a partially molten iron-rich core.

The lack of any detectable magnetic field is surely the result of the planet's extremely slow rotation and consequent lack of dynamo action.

Having no magnetosphere, Venus has no protection from the solar wind. Its upper atmosphere is continually bombarded by high-energy particles, which keep the topmost layers permanently ionized. However, the great thickness of the atmosphere prevents any of these particles from reaching the surface.

Comparison of Venus

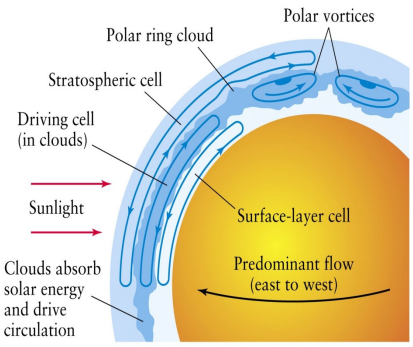


Weather

Venera probes measured the (1) surface pressure = **90 times sea-level** and
(2) surface temperature = **750 K** (860 F).

The weather is unchanging, with a temperature of 750 K and winds of less than 2 m/s. Because of the heavy blanket of clouds and atmosphere, one spot on the surface of Venus is pretty much like any other as far as weather is concerned.

Venus' Atmospheric Circulation

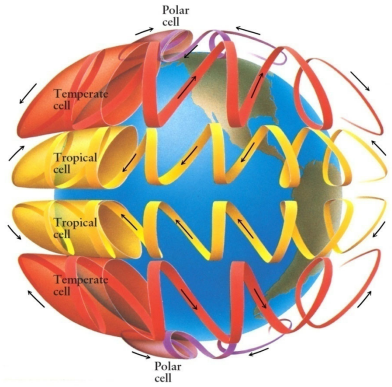


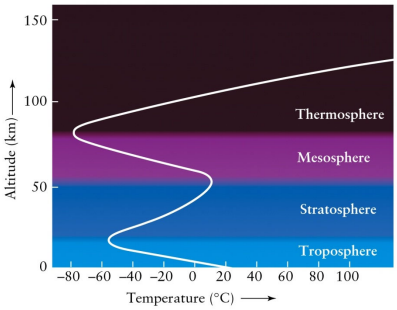
Venus' atmosphere has a huge **troposphere** that extends up to at least **80 km** above the surface.

Within the troposphere, the gas is heated from below and circulates slowly, rising near the equator and descending near the poles.

With no rapid circulation to break up the flow, the atmospheric circulation is highly stable.

Earth's Atmosphere





Composition and Structure

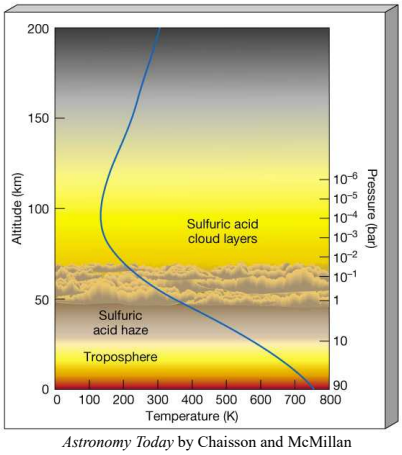
Atmosphere:

CO_2 accounts for 96%;

Next is N_2 at 4%.

Some SO_2 is detectable.

No water.

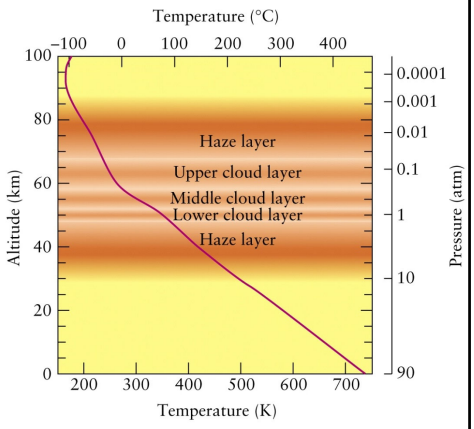


Astronomy Today by Chaisson and McMillan

Composition and Structure

Clouds are composed of sulfuric acid droplets (H_2S, SO_2, H_2SO_4, HF, HCl, HSO_3F).

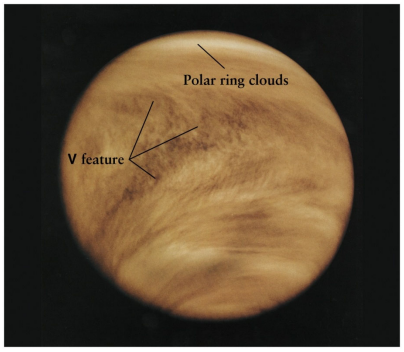
The clouds lie in the upper troposphere, between 30 and 60 km above the surface. Below 30 km, the air is clear. In the middle, the conditions are Earth-like.



Universe by Freedman, Geller, and Kaufmann

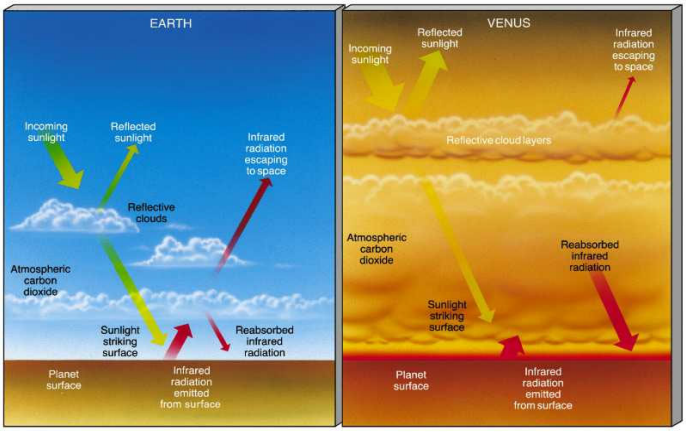
Composition and Structure

At the top of the troposphere, the wind speeds are very high, blowing from east to west at about 100 m/s. At the speeds of the Venerian "jet streams", cloud patterns are carried clear around the planet in just over four days.



Universe by Freedman, Geller, and Kaufmann

Greenhouse Effect

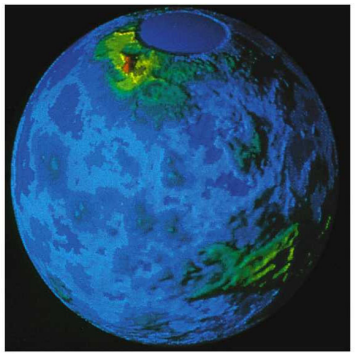


Astronomy Today by Chaisson and McMillan

Runaway Greenhouse Effect

1. Venus has many similar characteristics to that of the Earth. What if it had oceans at a time early in its history?
2. Venus has a higher temperature than the Earth because it is closer to the Sun.
3. More water is in the form of vapor, so the temperature increases.
4. Consequently, more CO_2 is boiled out and the temperature increases more.
5. Solar UV disassociates H_2O into H_2 and O.
6. The H_2 escapes and the O recombines. When the H_2 escapes, water is gone for good.

Ancient Oceans?



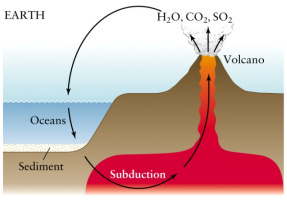
Astronomy Today by Chaisson and McMillan

Could there have been oceans?

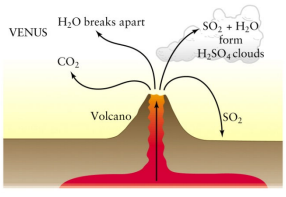
Deuterium (hydrogen with a neutron) abundance is 100 times greater than expected for the given amount of H_2.

Supposition is that there were once oceans that evaporated. Because the deuterium is heavier than H_2, it cannot escape as easily.

Evolutionary Differences



Because the Earth has liquid water, CO_2 and SO_2 dissolve in rainwater and are taken out of the atmosphere.



Because Venus lost its oceans, the CO_2 and SO_2 remain in the atmosphere and contribute to the Greenhouse Effect.

Life in the Clouds of Venus?

In 2020, astronomers said they had detected **phosphine** in the clouds of Venus. On Earth, the toxic gas is often created by microbial life. The astronomers suggested there are microbes living in the clouds of Venus.

"This is very exciting and was really very unexpected."

And that is why the phosphine discovery was met with both excitement and a heavy dose of skepticism. Some wondered whether the detection itself was simply an error. And even the scientists behind the study cautioned that there could be some unknown chemistry that explains away the phosphine, even if it's not fully understood.

Now, a new analysis has come to a completely different conclusion. Another team of astronomers say that the **signal was from SO_2**.