Apart from — or perhaps because of — the volcanoes, Io's surface still poses problems for researchers trying to understand its composition from earth-based and spacecraft spectra, where unusual infrared features have prompted a variety of exotic explanations. At the AGU meeting, Douglas B. Nash and Robert M. Nelson of Jet Propulsion Laboratory suggested a particularly complex candidate: grains of sublimated salts such as sodium sulfide, potassium sulfide and sodium hydrosulfide, with quantities of such (presumably volcanic) gases as sulfur dioxide and hydrogen sulfide adsorbed on their surfaces, and with the result then bombarded by protons trapped by Jupiter's magnetic field. Another possibility may be SO_2 frost.

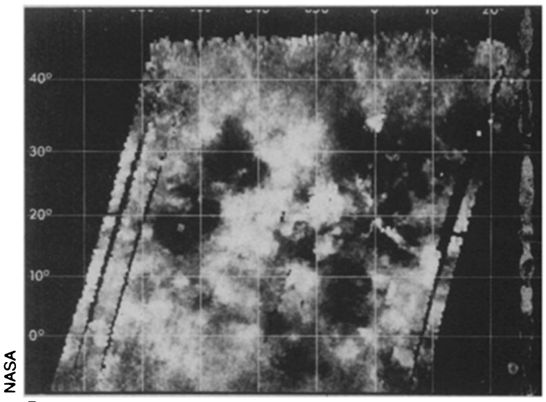
As for what's coming out of the volcanoes, SO_2 gas has been detected by Voyager's sensors, and there are probably other components. Conspicuously missing, however, is water, suggesting that Io has been active (and spewing its water away) for much of its history. Once the gases are in the open, there are signs that they may condense in part and fall back to the surface. Ultraviolet data indicate fine-grained solid particles, possibly less than a micron across, and some bright blue spots on color photos of Io have been tentatively identified by some researchers as "blue snow," in sharp contrast to the satellite's red and yellow surface.

Another Io-related feature is a torus of ionized sulfur that surrounds Jupiter along Io's orbit. Pre-Voyager, earth-based observations had identified singly ionized sulfur in the torus, and the hotter, doubly ionized form turned up in Voyager's data. Now the torus appears more energetic still, with a report from refined Voyager measurements that there are significant amounts of *triply* ionized sulfur.

But Io was not the whole show. Ganymede, another Jovian moon studied by Voyager, was described at the meeting as having a surface covered with fist-sized rubble—except for the significant fraction that is criss-crossed by fault-like features hundreds of meters deep and several kilometers wide. Callisto, which has several large, multi-ringed basins, has yet to reveal topography above several hundred meters.

There was more about the moons, and about Jupiter itself. Data on the famous Great Red Spot indicate that its vorticity is strongest at depth, and that its turbulent winds move more slowly at higher levels. (One researcher raised the possibility of a correlation between solar-cycle activity and the "darkness" of the spot's color.) Norman Ness of the NASA Goddard Space Flight Center described the planet's huge magnetic tail, with a diameter 300 to 400 times Jupiter's radius, and noted the odd eccentricity of the planet's auroral zones, which are centered on neither the magnetic nor rotational axes.

It was a heady dose of Jovobilia — and Voyager 2 will add more in July. □



NASA

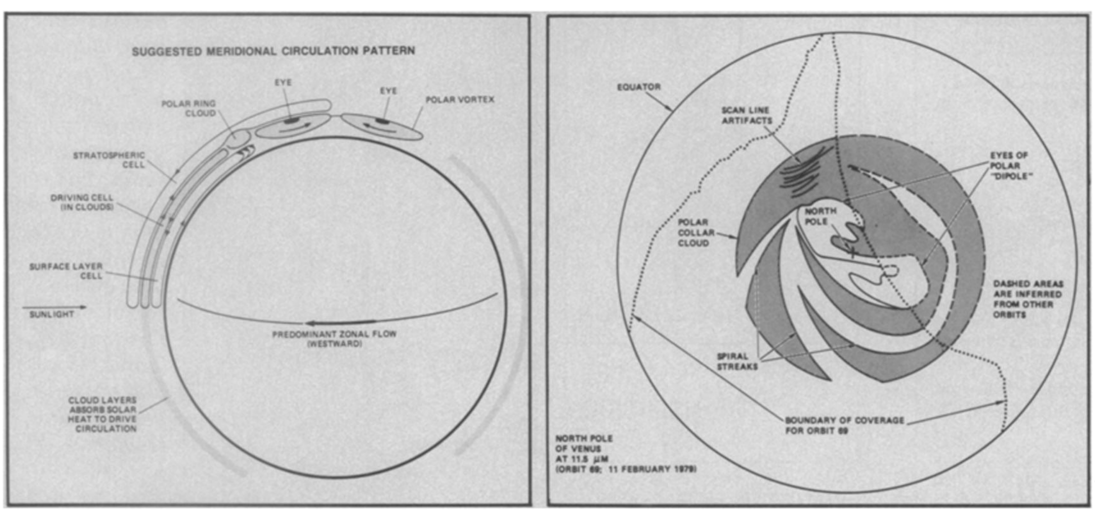
Radar image shows ancient impact craters, with central peaks, in Venus's lowlands.

Venus: The unveiling continues

The portrait of Venus that is emerging from the spacecraft of the Pioneer Venus project is a strange one, combining similarities to earth with dramatic differences. Some of the involved scientists are still working to understand the initial burst of data from the mission's cluster of atmosphere probes, while other researchers wait impatiently for the slowly precessing orbiter (whose orbital low point shifts only 1.5° per day) to complete its trip around the planet. But the portrait, as presented at last week's AGU meeting and in recent journal articles, is definitely taking shape.

The atmosphere's all-concealing cloud structure is now described as five-layered: a high, thin haze from 70 to 90 kilometers up, a broken cloud deck below that, a "continuous, planetwide" cloud layer beneath that one, another broken layer still farther down and finally another hazy region, decending from about 48 km down to a surprisingly abrupt cutoff some 32 km above the surface. The 1974 Mariner 10 spacecraft's ultraviolet photographs revealed complex circulation patterns in the atmosphere, but half a decade later, with far more data to go on, the Pioneer Venus researchers are still unsure of what atmospheric components are absorbing the sun's UV light to render the patterns visible. One candidate is sulfur dioxide, shown by the orbiter's UV spectrometer to exhibit planetwide variations that correlate with the dark markings photographed at longer UV wavelengths. But SO_2 is not enough, according to the University of Colorado's L. W. Esposito, and some additional, "broad-band" absorber is likely. Without them, Venus by UV would look as bland as it does by visible light.

One of the most prominent cloud features resembles a huge letter "Y" lying on its side with its stem wrapping around the equator. When the "Y" was first identified in Mariner 10's photos, some researchers believed that it was a permanent feature, circling the planet every four days (far faster than Venus itself). Hundreds of Pioneer Venus photos, however, have shown the "Y" to be much more quixotic, circling sometimes in five days, sometimes in three. Sometimes the stem of the "Y" wraps three-quarters of the way around Venus, sometimes it simply disappears, leaving the whole planet girdled by the concentric arcs of the "Y's" throat.



NASA

Poleward heat transport on Venus (far left) consists of stacked circulation cells, driven — unlike earth's system — from the middle cell, where cloud particles trap the heat. North-polar view (left) shows cool, high cloud "collar," containing hotspot "eyes."

Science Service, Inc. is collaborating with JSTOR to digitize, preserve, and extend access to *Science News*. www.jstor.org

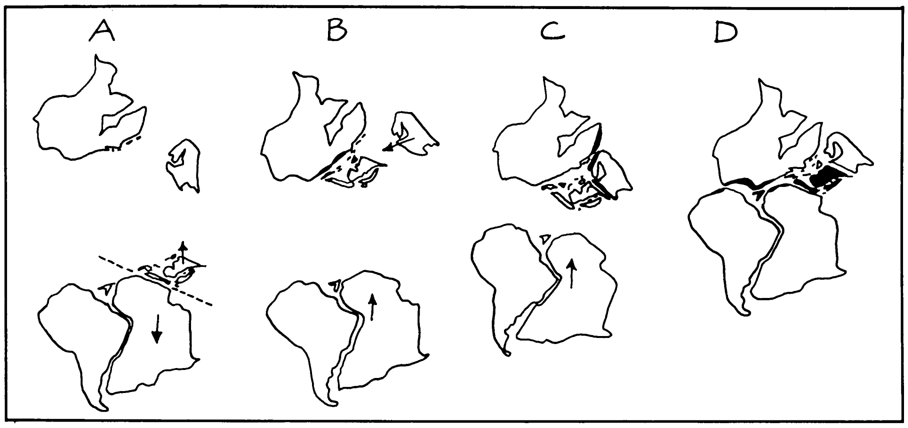
Nor does it seem to be locked to the planet's sub-solar point, where the sun's incoming heat is greatest. The warmest part of the atmosphere visible to the orbiter's infrared heat sensor, in fact, is not the sub-solar point at all, but the north polar region. Surrounding the pole is a "collar" of high, cool atmosphere at whose center are a pair of hotspots, dubbed "the eyes" by project scientists. Although the dominant winds go from east to west, Jet Propulsion Laboratory's Fred W. Taylor suggests that poleward heat transport pours enough rapidly descending atmosphere into the collar (believed to be a vortex) to "clear away" the clouds and reveal the lower-altitude hotspots.

This poleward movement is a key element in the evolving conception of Venus's circulation system, now believed to involve a three-tiered stack of circulation "cells" that carry energy from the equatorial regions to the high latitudes. The earth's atmosphere has a similar structure, with the cell circulation driven primarily from the bottom, where land and water absorb and re-emit the sun's heat. On Venus, however, says Alvin Seiff of the NASA Ames Research Center, the stack of cells is driven by the middle cell, where cloud particles and droplets are the dominant heat absorber.

Yet the shifting patterns, longitudinal heat flow and latitudinal winds of the atmosphere seem almost simple compared with the ionosphere. With virtually no inherent magnetic field to hold it in place (if there is an inherent field, says Christopher Russell of UCLA, it is less than a ten-thousandth as strong as earth's), the nightside ionosphere in particular is a highly erratic phenomenon, whose outer edge has been detected as far as 3,100 km from the planet and as close in as 180 km.

Emerging more slowly is the picture of the surface from the orbiter's radar mapper, which may need nearly two more years to cover the planet's circumference. An early radar image has revealed a pair of large, apparently ancient impact craters in the planet's lowlands, while similar terrain found on other worlds, says Harold Masursky of the U.S. Geological Survey, has all been in highland regions. Elsewhere on Venus, a huge northern-hemisphere plateau (SN: 4/7/79, p. 231) is described by Gordon Pettengill of the Massachusetts Institute of Technology as "almost inarguable proof of tectonic activity." A deep canyon and high uplifts also mark the surface, but some of these features do not show up as mass-distribution variations in early data on the planet's gravitational field. The range of gravity variations so far (only about a tenth of the planet has been measured) extends from only about +34 to −24 milligals, compared with about 500 for Mars's Olympus Mons and 100 for a typical "mascon" on earth's moon. Perhaps this is the one way in which Venus, planet of extremes, may be considered "mild." □

Continental collisions: Pangea revised



Van der Voo's reconstruction of Pangea: (A) 500 million years ago, newly postulated plate, Armorica (southern England, Wales, northern Germany, Poland, France and Spain), breaks off from Gondwanaland (South America, Africa, India, Antarctica, Australia). (B) Armorica collides with North America to form early Appalachians (shaded area). (C) North America-Armorica bumps eastern Euro-Russia, forming the Caledonians and creating the northern supercontinent. (D) 300 million years ago, Gondwanaland and the northern continent meet, forming Pangea.

Armorica, a previously undescribed continental plate, may have been involved in collisions that helped form the Atlantic-bordering mountain belts, reported Robert Van der Voo of the University of Michigan at the AGU meeting. Van der Voo's hypothesis offers a new model for the formation about 250 million years ago of the supercontinent Pangea, which included all of the earth's landmasses.

Researchers had long believed that Europe and North America welded together about 400 million years ago to form a huge northern continent, which, when the southern continent, Gondwanaland, collided with it, created Pangea. But recent years have exposed problems with that theory, in the form of two mountain belts: the Taconic, which was the predecessor of the Appalachians, and the Caledonians, which are found in northern England and Scotland and eastern Greenland. The Appalachian-Caledonian features had long been ascribed to the closure of the ancient Atlantic and the collision of Europe and North America. The Appalachians, however, apparently peaked about 450 million years ago, while the main phase of Caledonian formation was 395 million years ago. Moreover, the Caledonians have recently been traced from Wales through the North Sea, the Netherlands, northern Germany and into southern Poland, making a nearly 90° angle with the Greenland-Scotland branch. How could the closure of one ocean have managed to create not one but two belts of such different age and shape?

Van der Voo and co-workers believe they have found the answer in paleomagnetic data from southern England and Wales, France and Czechoslovakia. Paleomagnetic dating, because it measures the direction of magnetization that is preserved in a rock when it forms, can give the polar wander path, or the ancient latitude of a landmass relative to the pole. Paleomagnetic data from these regions, compared for the first time, show "striking similarities" in their polar wander paths, Van der Voo says, meaning that they were once part of the same continent. And, up until 500 million years ago, the polar wander path of these regions and of Gondwanaland were the same. Apparently, says Van der Voo, this section of Europe and the United Kingdom was part of Gondwana until 500 million years ago. These areas were previously believed always to have been part of the rest of the Euro-Russian landmass, not meeting Gondwana until the collision 300 million years ago that formed the Hercynian range that runs through central Europe, Spain and France.

Based on these results, Van der Voo proposes the existence of the Armorica plate, named for the Armorica Massif in Brittany from which one of the critical pieces of data came. Armorica, he says, consisted of southern England, Wales, the northern border of Germany, Poland, France and Spain and possibly New England and Newfoundland. He envisions the following scenario:

- The Armorica plate separated from Gondwana about 500 million years ago and collided with North America to produce the early Appalachian features.
- The combined North America-Armorica continent collided with the Baltic Shield and the Russian Platform about 395 million to 345 million years ago, forming the Caledonians and welding together to form the northern supercontinent.
- Gondwana drifted up about 300 million years ago and smacked into the northern landmass, crumpling the Hercynian, Alleghenian and Acadian (in New England, Canadian Maritimes and Newfoundland) mountains and forming Pangea. □