Venus: Radar Maps Show Evidence of Tectonic Activity

Venus is so near and so similar in size to the earth that it has always been an interesting planet, but its dense atmosphere has prevented every sort of observation of the surface, except by radar. Previous radar maps have shown only a few bright spots, but new high-resolution maps from two different radio telescopes show the surface of the planet with enough detail that a study of its geology can begin. The newly observed features include a long linear valley that may have been produced by tectonic movement, a very large dome that appears similar to the Olympus Mons volcano on Mars, other mountainlike features, and impact craters of varying sizes. While the new data only cover a small portion of the planet, and their interpretation has already sparked considerable controversy, the effect has been to convince many researchers that Venus is at least as tectonically active as Mars, and possibly as active as the earth.

The highest-resolution images have been obtained from the Goldstone tracking station of the Jet Propulsion Laboratory in Pasadena, California, in a series of eight maps of small regions near the equator of Venus. The data were taken with the 64-m steerable radio dish at Goldstone by Richard Goldstein, head of the station, along with Richard Green and Howard Rumsey. The most striking image shows a 1500-km-long linear trough that lies near the equator. The trough has been compared to large rift systems such as the East African rift system on the earth. It is "strong evidence of extensional tectonic activity" on Venus, according to Michael Malin of the Jet Propulsion Laboratory.

Another feature in the Goldstone maps is a long arc-shaped mountain range, which is crossed and appears to be slightly bowed by another linear feature. This could be evidence for a fault movement, Malin thinks. The feature that is probably a large volcano is 300 by 400 km in size and about 1 km high, with a depression 80 km in diameter in its center. Another type of vulcanism also appears on Venus, according to Malin, and some mountainous features could be caused by compressive tectonic forces, although other explanations are possible.

Circular features ranging from 30 km to thousands of kilometers in size have also been identified in radar maps of Venus, and several scientists have interpreted them as impact craters. Gerry Schaber, at the U.S. Geological Survey in Flagstaff, Arizona, thinks that the impact basins on Venus may be as large as Imbrium on the moon and Hellas on Mars.

Cratered terrain and tectonically molded features seem to represent the two well-defined views of the topography of Venus at present. A high-resolution image obtained recently at the Arecibo Observatory, in Puerto Rico, does not fit into either interpretation exactly, according to Gordon Pettengill of the Massachusetts Institute of Technology, but it does show a very large feature that could be a basin. The Arecibo picture shows a large portion of the northern hemisphere of Venus, and the basinlike feature is about 1000 km across, with a bright sharp rim. The radar contrast is similar to that from large basins on the moon, but "the shape is wrong" for an impact basin, according to Don Campbell at Arecibo.

The best time for making radar maps is, of course, when the earth and Venus are close together, so the Goldstone maps were made during the January 1974 conjunction and the Arecibo maps during the August 1975 conjunction. Even at closest approach, considerable radar power is needed to produce a clear picture before Venus moves out of view, and the time for a radar echo to make the round trip is 5 minutes. Goldstone broadcast into space 400 kilowatts of 12.6-cm radiation, drawing the requisite energy from the local (Southern California Edison) power grid. The Arecibo radar broadcast an equally powerful beam from its 330-m dish, which is anchored in a natural bowl among the mountains of eastern Puerto Rico, drawing the power from a 1.5-megawatt turbogenerator at the site. The technique was to broadcast for 5 minutes, then stop as the first signals returned and receive for 5 minutes, repeating the process as long as Venus was in view (about 2 hours for the fixed Arecibo dish and 8 hours for the steerable Goldstone dish).

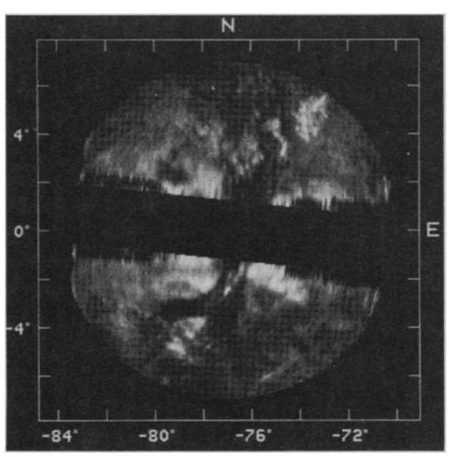

Fig. 1. Radar image of a region of the surface of Venus 1700 km in diameter. A long, riftlike valley is clearly defined, except in the dark "runway," where intrinsic ambiguities in the radar echoes preclude reconstruction of the image. The trough is about 1500 km long, 150 km wide, and 2 km deep, running northeast to southwest. [Source: Jet Propulsion Laboratory]

The radar images were built up by analyzing the power, time delay, and frequency shift of the radar echoes. The most prompt echo comes from the nearest or subradar point, and successively later echoes come from collarlike rings concentric with that point. Frequency changes of the time-delayed echoes, produced by the doppler shifts that arise from the planetary rotation, provide a second spatial coordinate.

The radar pictures are thus tableaus of time-doppler cells. But unfortunately there is an ambiguity, because for each cell in the northern half of the picture, there will be another in the southern half with the same values of time delay and doppler shift. This ambiguity was resolved by using a second, smaller receiving dish to form an interferometer and measure the phase of the reflected signals (the northern and southern cells have opposite phases). Along the radar equator, however, not even interferometric techniques can unscramble the data (time and doppler coordinates run parallel to each other in that region), so the data in the middle of the picture are blacked out.

The Goldstone radar achieved a resolution of 10 km per cell, and heights of features were separately extracted with 400-m contour intervals (a contour map of the feature in Fig. 1 shows that it is indeed a depression). The resolution of the Arecibo image was 20 km, and no topographic information could be extracted, for reasons related to the limited observing time.

The Arecibo telescope has recently been upgraded for improved radar mapping by replacing the antenna surface and installing new transmitting and receiving equipment. Further shakedown of the new system should improve the resolution of the Venus radar maps to 4 to 5 km, according to Don Campbell. By contrast, the Goldstone facility was not intended for mapping at all, but rather for communications and deep-space tracking. The Venus radar maps were the result of a small program, piggy-backed along by the Goldstone staff in addition to their primary responsibilities.

The high-resolution maps only cover a small fraction of the area of Venus, and they raise as many questions as they answer. But it is already clear that the topography of Venus is abundant, complex, and fascinating, and worth many more observations.—WILLIAM D. METZ

Cell Biology: Cell Surfaces and the Regulation of Mitosis

Cell membranes are now known to be dynamic structures in which the components can and do move about. Learning what causes and controls the movements has become a favorite occupation of many investigators during the past few years. This is not just a sterile exercise designed to determine how many proteins can dance on the surface of a cell.

Normal cells usually divide in culture only when anchored to a surface; they stop dividing, and also moving, when in contact with other cells. Transformed or cancerous cells, on the other hand, may divide even when floating in the culture medium, and they do not necessarily stop when in contact with other cells. Since cells must communicate with each other and with the environment through their membranes, many investigators think that alterations in the spatial arrangements of membrane components may be signals that are involved in the control of cell division, mobility, and interaction. The research on membranes not only has obvious implications for understanding cancer, but also applies to organ formation in the developing embryo, since this requires migration and interaction of cells.

If surface events do participate in the regulation of these activities, then there must be a mechanism for transmitting signals from the membranes to the internal machinery involved in mitosis and the other functions. There is evidence,* although largely circumstantial and thus somewhat controversial, that certain cytoplasmic structures, the microtubules and microfilaments, participate in regulating signal transmission. The evidence includes demonstrations that the movements of some membrane constituents are restricted or nonrandom, and are apparently controlled by microfilaments or microtubules or both. Moreover, for at least one cell type, the lymphocyte, the capacity to divide appears to be influenced by alterations in the mobility of some of its membrane components.

*Some of this evidence was described at the 1976 ICN-UCLA Winter Symposium on Supramolecular Structure: Cell Shape and Surface Architecture. The symposium was held in Squaw Valley, California, on 7 to 12 March.

Two types of experiments have led to the conclusion that microtubules and microfilaments somehow regulate the distribution and mobility of membrane components. One involves studying how the distribution of various membrane constituents changes during phagocytosis. The other makes use of ligands, agents that bind to receptors on the cell surface, in order to label the receptors and permit observation of their movements. (A receptor is any constituent of the cell surface that combines with another chemical entity. The specific combination of certain receptors with agents such as hormones can alter biological functions.)

Phagocytosis is the process by which cells such as macrophages engulf external particles. The cytoplasmic membrane invaginates and envelops the particles. Eventually the portion of the membrane engulfing the particles pinches off from the surface membrane and forms a vesicle inside the cell. In an actively phagocytizing cell as much as 50 percent of the membrane may end up in the intracellular vesicles. According to Richard Berlin, Janet Oliver, and their colleagues, first at Harvard Medical School and more recently at the University of Connecticut Health Center, certain membrane constituents are redistributed during phagocytosis in such a way that none are lost from the external surface.

The transport of a number of nutrients is known to require the activity of specific carriers located in the membrane. The investigators found that the nutrients were transported just as well after phagocytosis as before, even though a large portion of the surface membrane was removed during vesicle formation. Berlin and his colleagues ruled out the possibility that the cells were synthesizing new carriers and inserting them into the membrane. They concluded that there must be a means of separating the carriers from the portions of the membrane that go into vesicles.

In the presence of colchicine, a drug that disrupts the structure of microtubules, phagocytosis did result in a decrease in the transport rate that was proportional to the amount of membrane lost in the vesicles. This result suggests that the microtubules somehow directed the movements of the transport carriers during phagocytosis.

Lymphocytes are frequently used for the ligand-binding studies because they are readily available and relatively well characterized. One class of lymphocytes, the B (for bone marrow–derived) cells, carries immunoglobulins on their outer surfaces. It is possible to make antibodies, which are themselves immunoglobulins, against the surface immunoglobulins.

Several investigators, including Steffano de Petris of the Basel Institute for Immunology, Martin Raff of the Medical Research Council Neuroimmunology Project at University College in London, Emil Unanue and Morris Karnovsky of Harvard Medical School, and Gerald Edelman and Ichiro Yahara of Rockefeller University, have studied what happens when antibodies bind to the surface immunoglobulins. They find that the antibody-receptor complexes first associate to form a number of aggregates or patches. The patches may then coalesce to form a single cap on the cell surface. The formation of caps, but not of patches, requires energy; it will not occur in the presence of inhibitors of cell metabolism.

A number of agents can interfere with patch and cap formation. One of these is concanavalin A (Con A), a plant protein that also binds to cell surface components. Yahara and Edelman found that antibodies against surface immunoglobulins failed to elicit patching and capping on cells that had first been exposed to Con A. This restriction of the movements of the antibody receptors, which Edelman calls anchorage modulation, was reversible. Con A has four sites that can bind to receptors; in order to produce anchorage modulation it must be in its normal multivalent state. The restriction does not occur with Con A that has been chemically altered so that it has only one or two binding sites.

Edelman thinks that Con A does not act directly on the membrane to restrict receptor movements but, rather, that it