Research Notes

Controlling the Shakes

About the last thing any of us want to experience is an earthquake right under our feet. But if a joint research project with several petroleum companies materializes, that's exactly what Charles B. Archambeau, professor of geophysics, will be working toward. In fact, he and several other researchers will be hoping for a number of small earthquakes, or microquakes, the study of which will shed light on the possibility of controlling major shocks by inducing strategically placed lesser ones.

Archambeau expects microquakes to result when a group of oil companies try to beef up petroleum output in a Santa Fe Springs oil field by pumping great quantities of water at high pressure down the shafts of oil wells. Called repressurization, the technique has two effects: It forces the oil toward other wells where it is more easily pumped out; and it seems to reduce the "locking pressure" on faults or fractures, permitting the rocks on either side to slide, and resulting in the small earthquakes.

A similar test last year by the U.S. Geological Survey touched off nearly 1,000 microquakes in a Colorado oil field. When Geological Survey personnel reversed the process and drew the water out, the microquake activity turned off.

What Archambeau and the oil companies are doing in Santa Fe Springs needn't worry local residents. The shocks they induce won't even be felt on the surface. The important factor will be what's going on one to two miles beneath the surface, and Archambeau will use several delicate, highly sensitive seismometers to find out. The seismometers will record changes in the microquake pattern before, during, and after repressurization. The records will be transmitted to Caltech's Seismological Laboratory in Pasadena.

Charles Archambeau is testing the theory that inducing strategically placed microquakes might give the data that will make it possible eventually to control major earthquakes.

A computer there will use data on microquake and stress pattern changes and water flow dynamics to produce a model of the process. Archambeau expects to use the model to assess in detail what effects water has in causing or inducing earthquakes.

Ideally, repressurization will set off from 20 to 30 microquakes in the first six months of the year-long test. Archambeau estimates that 10 is a more realistic figure, but maintains that even as few as that should supply enough information to pinpoint the active areas, to learn the orientation of the stress field, and to outline the faults.

He is optimistic that lessons learned at Santa Fe Springs will bring us a step closer to earthquake control, and he theorizes that the ultimate outcome could be to replace the violent snap in the earth's crust that occurs in major earthquakes with slow or creeping movements that produce small harmless earthquakes. He hopes to find out if water can do the trick.

Associated with Archambeau in the experiment are David G. Harkrider, associate professor of geophysics; Donald Helmberger, assistant professor of geophysics; Wolfgang Knauss, associate professor of aeronautics; Ronald F. Scott, professor of civil engineering; and Robert L. Kovach, professor of geophysics at Stanford and now on leave at Caltech.

Mapping a Mystery

For centuries the planet Venus remained veiled, its secrets secure behind dense clouds that stubbornly turned aside the telescopic probings of astronomers.

But, in the last decade, Venus has grudgingly begun to surrender its anonymity to a new breed of astronomers who use radar waves to pierce the thick clouds to "see" the surface below. As a result, the mystery shrouding our next-door interplanetary neighbor is slowly being unraveled, and Richard M. Goldstein, manager of JPL's communication systems research section, and visiting associate professor of planetary science at Caltech, is contributing as much toward this unraveling as anyone in the field.

Venus, which is about 68 million miles from the sun and never closer to earth than 26 million miles, was the subject of Goldstein's doctoral dissertation, written in 1961. The problem then was to map the planet, and his plan was to get the job done by bouncing radar beams off its surface. He devised a technique that enabled him to do this, and while it has been honed considerably since then, it remains the basis of his current research.

Step number one in the operation is to direct radar waves toward Venus from the huge transmitter at the JPL-operated Goldstone Tracking Station in the Mojave Desert. The waves, about 12.5 centimeters long, are launched into space by the 450-kilowatt transmitter in a narrow-angle searchlight beam. By the time the waves reach Venus, they are so dispersed that most pass right on by. The rest are either absorbed by the planet's surface or deflected into space. However, a small but critical fraction return to earth as a barely audible echo, a tiny fraction of a watt. The round trip takes about 4½ minutes. Despite the feeble signal, Goldstone's 64-meter (210-foot) parabolic antenna and receiver provides enough sensitivity to allow Goldstein's team to determine quite a lot about where the signals have been.

If the signals bounce back unpolarized —that is, with their electric fields scrambled—they indicate rough terrain. Unscrambled echoes mean smooth surfaces. Goldstein draws other inferences from variations in the time it takes the signals to return—an indication of changes in distance—and from Doppler shifts, which are changes in wave frequency caused by the rotation of the planet.

A computer then processes these inputs to produce a two-dimensional map, composed of 40,000 mapping cells, that forms a visible trace of the planet's surface features. Each cell is one-half degree square and encompasses a 35-square-mile patch on the face of Venus.

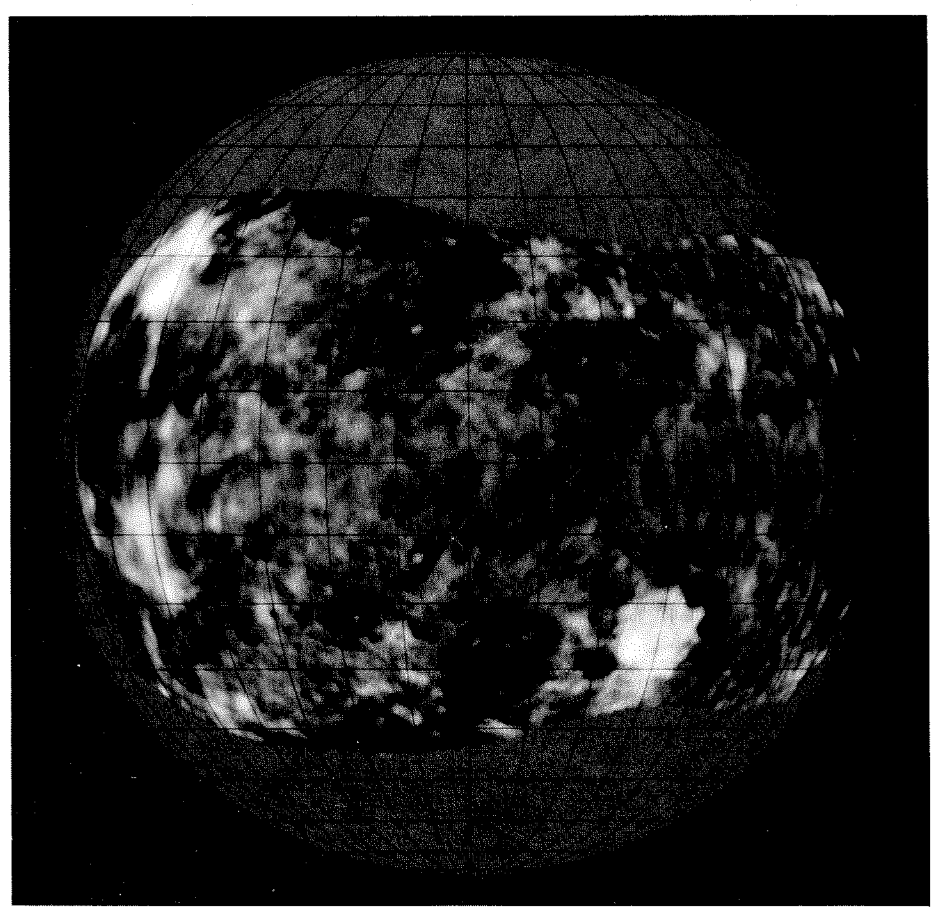
Goldstein has a long wait between mapping observations, because the most productive mapping occurs at 19-month intervals when Venus makes its closest approach to Earth. He has performed a radar experiment at each of the six opportunities since 1961. (*E&S*, November 1967).

Although dramatic increases in radar power and resolution techniques have vastly improved the maps, they are not without defects. One problem that faces Goldstein is his inability to determine the nature of surface features by the way they show up on the map. Radar-bright areas on Venus' surface could be the result of mountains, boulder fields, canyons, lava flows, and craters. He is seeking a way to tell them apart.

Goldstein may have found that way in interferometry, a new technique that he may use in June 1972 when Venus makes its next close pass to Earth. The technique will team Goldstone's 26- and 64-meter dishes to provide simultaneous readings as the basis for calculating the altitudes of surface features. The prospects are exciting, and Goldstein thinks the result may be the most conclusive surface map ever made of Venus.

Goldstein's romance with Venus has endured through his college days at Caltech and at JPL. Much of what he has done has influenced the development of new technology for the Deep Space Network (DSN) that JPL runs for NASA. Residual benefits like new transmitters, receivers, weak-signal processing techniques, and information about the orbits and rotations of the planets have had a strong influence on spaceflight navigation.

What comes next will depend a great deal on the direction of the space exploration program at JPL. Current priorities have Goldstein looking at Mars and Mercury and then making studies of Jupiter and Saturn. For the time being, however, Goldstein will be keeping at least one "eye" on Venus.



The latest map of Venus is actually a composite of two mappings made a year and a half apart. Then almost nine months of computer processing went into producing this final radar image.

Vanishing Silver and the Fall of Rome

A Caltech geochemist has come up with a new explanation for the fall of Rome. Clair Patterson, research associate in geochemistry, thinks the Roman Empire may well have gone under because it lost its supply of silver.

Dr. Patterson is convinced that the gradual accidental loss of silver stocks played an important part in determining the course of history. Fortunately, vanishing silver supplies do not upset national economies today because of the use of paper money and bank credit.

In ancient times, silver was lost in the form of coins and jewelry that were dropped and covered by soil or ashes, sunk in shipwrecks, buried in graves, or hidden away in undisclosed hoards. When the metal reached the moist earth, it corroded and was irrecoverably dispersed as silver salts.

Patterson's discovery of the high accidental loss rate of coined silver was made during his earlier research on air pollution. He discovered that lead from gasolines had infiltrated the atmosphere at both the north and south poles. In connection with that work, he began looking into lead production in ancient times. This meant he had to study old records of silver production because few records were kept for lead. Lead was obtained as a byproduct of silver—about 400 tons of lead being produced for every ton of silver.

Silver production was roughly inferred from silver stocks, such as the size of a king's treasury. However, silver production could only be accurately determined if the size of the stocks and the rate of the loss of silver were known. Patterson obtained that rate from data about modern silver losses, modified by physical conditions that might affect silver losses in those early times. He found that the loss rate figure in past times was surprisingly high—about 2 percent a year—and was due largely to the accidental loss of silver coins.

The general use of silver coins around 600 B.C. by the northeastern Mediterranean nations and their loss by handling caused silver stocks to begin to decline irrecoverably, with a half life of about 35 years. That is, every 35 years half the silver stocks vanished. Mine production had to equal this loss to maintain a steady level of stocks. The magnitude of the problem is illustrated by a case involving 2,200 tons of silver bullion plundered from Persia by Alexander the Great. The entire stock was put into coins by about 300 B.C., but by 160 B.C. this particular mass of silver had shrunk from handling losses to only 90 tons.

The development of coins after 600 B.C. was a strong impetus to the growth of the Roman Empire. It provided the Romans with the "mobile capital" they needed to evolve from the barter system of economy. With its new-found flexibility Rome was able to extend economic control over a vast empire and to govern the economy of most of the civilized world.

Rome's wealth was founded on the silver deposits of Spain, where slaves were used to boost the world's production rate of the ore nearly eight-fold. But, Rome's financial position began to slip when its production of silver failed to keep pace with the growth of the unexplained losses. Rome finally exhausted all her silver deposits. Within 150 years the Romans were forced to revert to the cumbersome barter system. In short, the Roman economy collapsed. After Rome's demise, the Dark Ages gripped Europe until rich German silver mines were opened about 900 A.D.

The fraction of total silver mined from ores and added to world monetary stocks from 1885 to 1938 was about 210,000 tons, plus 50,000 tons existing in 1885. But the total of world monetary silver stocks at the end of 1938 was only 160,000 tons—indicating a loss of 100,000 tons in 53 years.

The actual loss was even greater when the loss by industry was added to this tonnage. Today there are almost no silver coins in circulation. There are two reasons for this. One is the industrial demand for silver. The other is that, in this country at least, the silver in U. S. coins is worth about twice as much as their face value.

Although only about one millionth of the silver in the earth's crust has already been mined—most of it in the past 60 years—it represents most of the mineable silver. Like many other metal ores, the rich silver deposits were near the earth's surface and thus were easily extracted.

About another millionth of the silver in the earth's outer crust may be obtainable with present mining and smelting technology, but additional amounts beyond that will require new recovery techniques. The quantity of silver that still can be extracted from the earth in the form of very lean ores will depend upon demand—and technology.

Clair Patterson, research associate in geochemistry. His research on air pollution led to studies of silver.