# TRACKING THE RESTLESS CRUST

## One of astronomy's newest techniques, very long baseline interferometry, is being used to track motions of the earth's crust

Earthquake prediction is an ancient dream—or nightmare—that may soon come true. Theories are in print and in the air, and a few predictions have already been made with varying success (SN: 4/20/74, p. 252). To test out some of the theories and possibly to bring the day of accurate earthquake prediction somewhat closer, the Jet Propulsion Laboratory at Pasadena, Calif., is about to begin a program of observations called ARIES (for Astronomical Radio Interferometric Earth Surveying).

One of the latest practical applications of astronomical discoveries and techniques, ARIES will use the extragalactic radio sources (quasars, Seyfert galaxies) and the technique of very long baseline interferometry (VLBI) to chart motions of the earth's crust.

Most geophysicists would probably agree that one of the major causes of earthquakes is the grinding, crunching and general abrasion that takes place at the boundaries between the earth's crustal plates as plates moving in different directions rub against each other. California's San Andreas Fault runs along one such boundary, the one between the North American and Pacific plates. ARIES's first job will be to measure local motions in three dimensions across the San Andreas. Later, plans are to plug it into the worldwide Deep Space Network, NASA's large telescopes that track space probes, to study large-scale plate motions and possibly to find direct evidence that continental drift is really going on right now. In addition to testing present theories, ARIES observers are prepared to study and model any new geophysical phenomena they may find.

To keep track of motions of this kind a very accurate means of measuring distances and a stable and fixed set of reference points against which to measure them are necessary. This is where both VLBI and the extragalactic radio sources come in. The extragalactic sources are ideal for the purpose, says Peter F. MacDoran, the Project ARIES team leader, because they form a frame of reference that does not vary with time.

For example, the Seyfert galaxy 3C84 is 200 million light years away. When the energy now reaching earth left 3C84, the continental plates had not yet separated; the total terrestrial landmass was clumped together in the primordial continent that earth scientists call Pangaea. If one uses a quasar 10 billion light-years away, there was no earth when it emitted the signals we are now receiving. These radio sources at the edge of the known universe thus stand as a reference frame for aeons and aeons.

In principle using these sources to track movements of crustal plates is similar to the navigator's use of the stars as a reference frame to track the movements of ships at sea or of caravans on the desert. But the stars cannot be used for the plate motions because their own proper motions, which change their positions in the sky, are too fast to provide a reference frame stable enough for the accuracy needed, centimeters in hundreds of kilometers. Neither ship nor camel needs that kind of accuracy.

In VLBI the key word is interference. When a wave front emanating from a quasar strikes the earth it will arrive at telescopes in different locations at different times. Thus the signals received at different telescopes will be generally out of phase with each other. If the two signals are mixed together they will produce a "fringe pattern" of reinforcements or cancellations according to how their phases relate to each other. (The term comes from the optical analogue where actual dark and light stripes are seen.)

From the fringe pattern it is possible to calculate the delay between the arrival of the wave at one station and at the other. MacDoran says the ARIES system will be able to do this to an accuracy of a tenth of a nanosecond (one ten-billionth of a second). Then the (three-dimensional) distance between the two stations can be found to a precision of three to five centimeters in a hundred kilometers or more. This is the converse of what astronomers do: They use the *known* distance between two stations to deduce the location, size or structure of the extragalactic source from the fringe pattern.

Until a few years ago interferometry could be done only if the two telescopes were linked by a cable or microwave channel. Now the development of highly accurate atomic clocks makes it possible to record the two (or more) signals on tape and combine them later in a computer. The suppression of the physical link means not only that the telescopes can be far apart; it also means that they can be mobile. One does not necessarily have to have long distances between stations, though MacDoran says many people take the notion that that is so from the name VLBI. "Perhaps it would have been more apt to term the method independent station interferometry, so as not to imply that only very long baselines were allowed," he suggests.

The first stage of ARIES will use a fixed antenna and a movable one. The fixed antenna is the 64-meter dish antenna used for deep-space tracking at Goldstone, Calif. Goldstone happens to be on the east side of the San Andreas Fault zone. A nine-meter antenna will be set up at various locations on the west side of the fault to establish a grid of surveys.

One of the things the observations will look for is an uplift of the ground surface previous to an earthquake that is predicted by the dilatancy theory. The dilatancy theory holds that an earthquake is preceded by dilation of cracks and interstices in the rock and the flow of water into the cracks. The water supplies lubrication that triggers a slippage. One of the consequences of dilatancy is a 10-to-100-centimeter uplift over a substantial area, possibly several hundred square kilometers.

MacDoran says conventional methods of geodetic surveying would miss an uplift over such a large area because their baselines are not long enough. Furthermore conventional geodesy depends on clear lines of sight, and in the Los Angeles basin these are often smogged out. ARIES is an all-weather system. Another contrast is that ARIES is independent of the effects of gravity.

One of the planned locations for ARIES's travelling antenna will be Riverside, Calif. On seismological data J. H. Whitcomb of the Caltech Seismological Laboratory predicted an earthquake at Riverside with Richter magnitude 5.5. On Jan. 31 a Richter 4.5 earthquake occurred there. This could be a precursor to a bigger one. MacDoran



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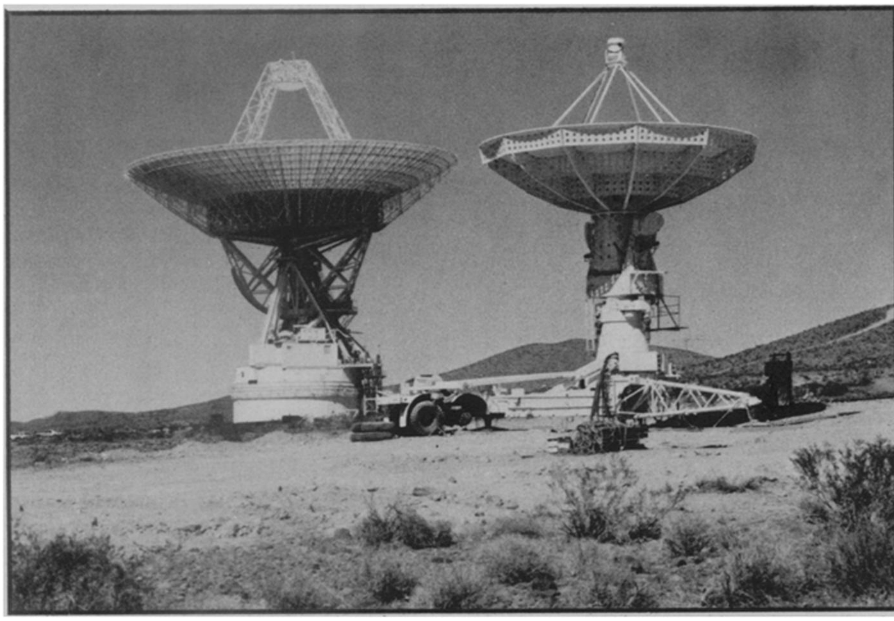
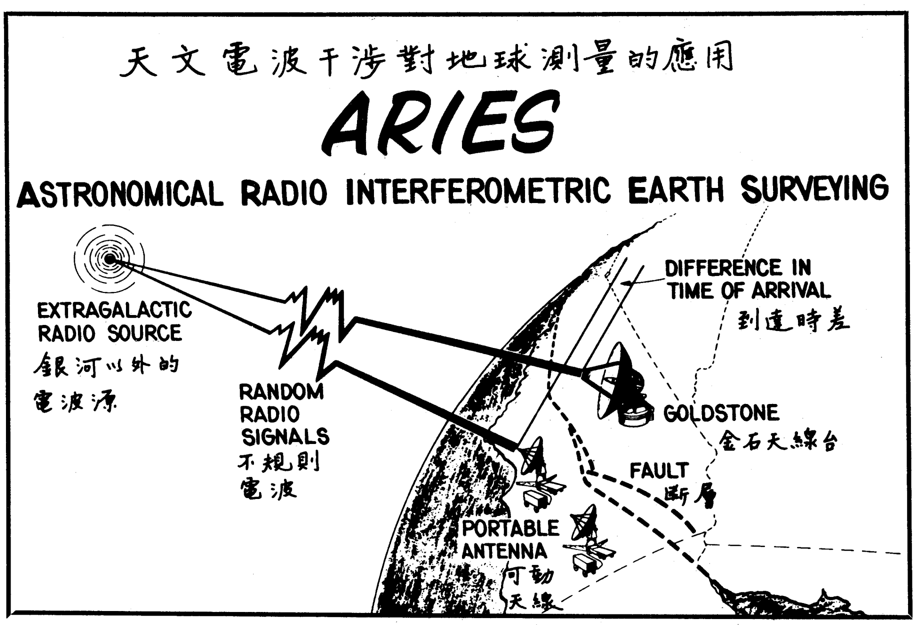
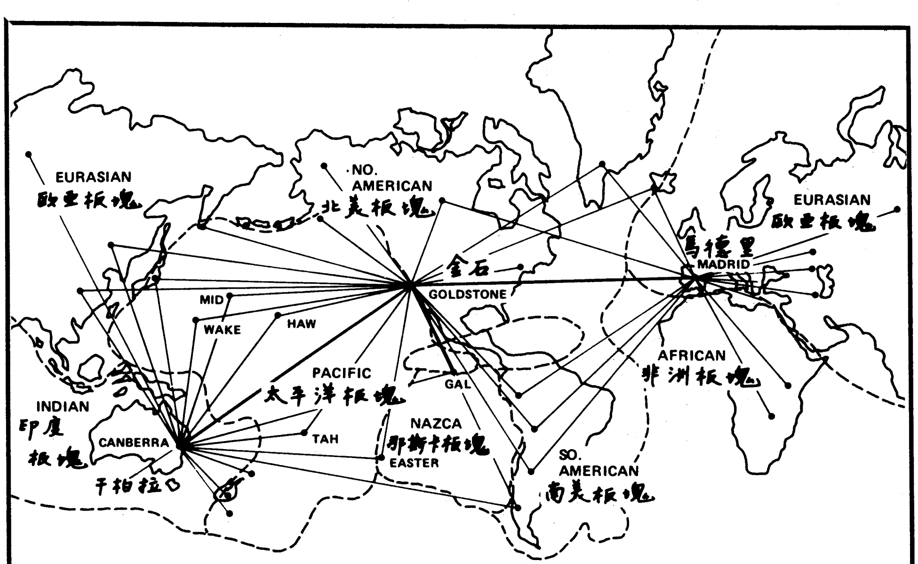


Illustrations: JPL

*Fixed and movable antennas. Camera foreshortens, falsifies size difference.*




*Time difference in arrival of signals measures distance between antennas.*




*Three fixed antennas and possible mobile locations for worldwide survey.*

wants to measure how the ground is deforming around Riverside in hopes of getting some information on the role of water in triggering earthquakes. He also wants to set up the mobile antenna at various places including JPL, Table Mountain, and Piñon Flats.

For the more distant future plans are to use one or more movable antennas in conjunction with Goldstone and the other two 64-meter dishes of the Deep Space Network, at Madrid and at Canberra, in a global survey of large-scale crustal motions. VLBI techniques will also be used with the Deep Space Network to study polar wandering and variations in Universal Time. J. L. Fanselow is the team leader for this aspect of the work.

The global survey can be done only if there is international cooperation. So far there is international interest, and that comes from a quarter not previously notorious for a cooperative attitude, the People's Republic of China. During the spring, MacDoran and the other scientists and engineers involved briefed a visiting Chinese delegation on the project. China, of course, has seismically active areas and has suffered severely from earthquakes throughout history. One Chinese tremor alone is estimated to have killed 800,000 people.

If we arrive at the possibility of accurate earthquake prediction, what do we get? Suppose we can say that on July 19, 1980, there will be an earthquake of Richter magnitude 8 centered on the San Andreas fault somewhere in San Mateo county. What then?

Mass panic, say the pessimists. General exodus of population and economic collapse of several important cities. People have a phobic reaction to the possibility of an earthquake that is deeper and stronger than their apprehensions about other kinds of natural disaster.

There are optimists. MacDoran qualifies as one. Peter Briggs in his book *Will California Really Fall into the Sea* points out that realistically facing the danger of earthquakes can lead to useful precautions. He reports that schools and other buildings designed to be earthquake resistant survived the 1971 San Fernando Valley tremor quite satisfactorily, but he faults Californians (and San Franciscans especially) for taking a head-in-the-sand attitude to the danger. Perhaps the advent of hard and fast earthquake prediction will shake them out of their never-never land.

Meanwhile the scientists and engineers are at work. Whether the public reaction be panic or precaution, if earthquake prediction is at all possible, we are likely to get it. It will be for the same reason that Eve bit the apple. □