*Aftermath of Mexican earthquake.*

# Earthquake war is GO

**Theories, manpower and money have come together to produce new optimism in the search for ways of predicting dangerous quakes before they strike.**

by Jonathan Eberhart

Whenever a major earthquake has brought tragedy to some part of the world—Alaska, Nicaragua, California—the talk of predicting future upheavals has become louder, only to recede again before the mysteries surrounding the churnings of our active planet. The recent Mexican quake, however, which caused more than 700 deaths and thousands of injuries, has come in a year that may also be seeing the beginnings of the counter-assault.

- A new theory is attempting to relate most of the known warning signals of earthquakes to a single proposed mechanism for almost all destructive tremors. Some success at prediction has been shown.
- The Federal Government is gathering its forces, uniting scattered quake researchers into one masssive task force.
- Additional funding has been provided for the big push, and still more has been proposed.
- Bills in both houses of Congress seek to further focus the effort, coordinating research and seeing to it that new information becomes readily available.
- A program at the U.S. Geological Survey, in charge of the anti-earthquake army, specifically calls for identifying quake hazards around the country, developing and implementing prediction techniques, and, somewhere in the future, possibly even trying to control the quakes themselves.

Knowing the enemy is a key factor in any battle. In the earthquake war, with the foe hidden deep within the earth until he strikes, knowledge has come slowly. Ironically, a chief ally of the death-dealing villain is also the source of life: water.

Almost 30 years ago, when a scientist documented some 600 local tremors that had appeared in the decade following the formation of the Lake Mead reservoir in Arizona and Nevada, it was suggested that the mere weight of added water might be to blame.

A correlation between earthquakes and waste fluid injections into a well at the Army's Rocky Mountain Arsenal was attributed in 1966 to a somewhat more complicated cause: the lubricating effect of the fluid, allowing the subterranean rocks to slide into less stable positions. Since then, however, research has shown the role of fluid pressure to be quite different, and still more complex.

In spontaneous quakes, with no well or reservoir to blame them on, the energy of the tremors comes not from water but from the earth itself. The recent theory of plate tectonics seems to show how. Vast sections of the earth's crust, called plates, move slowly across the globe, grinding together, climbing over one another or wrenching apart at their common borders. Even then water has a role to play, and a clear understanding of this role is vital if man is ever to be able to spot earthquakes before they happen.

Geophysicists studying quakes in New York, California, the Soviet Union and Japan have noted that before a tremor hits, seismic waves traveling through the rock in the area slow down, then speed up again. It is this discovery, and related evidence, that led three seismologists from Columbia University's Lamont-Doherty Geological Observatory to report in April: "Earthquake prediction, an old and elusive goal of seismologists and astrologers alike, appears to be on the verge of practical reality." New evidence since then has further increased their optimism.

The favored explanation for what they think happens is called dilatancy. In the dilatancy model, pressure on the subterranean rocks builds up, forcing the tiny cracks in the rocks to expand. Water trapped in the rocks is no longer sufficient to fill the expanded cracks. This means that the overall density of the area is reduced, which in turn causes seismic waves passing through to slow down. Then water from pores in the surrounding rocks begins to diffuse into the new fissures, filling them up so that the still-increasing pressure can again compress the rocks. At the same time the seismic waves speed up again. Only when the water has saturated the fissures, allowing the rock pressure to build up to its former level, does the earthquake take place.

The hope for earthquake prediction stems from the discovery that the drop and subsequent restoration of pressure in the rock seem to follow a pattern that can be related to the time, strength and physical size of the ensuing tremors. The pressure cycle can range from a few days for a small quake to years for a whopper. So predictable is the pattern, according to the team from Lamont-Doherty, that the length of the zone affected by the quake should be approximately equal to the square root of the number of days in the pressure cycle.

Last month, in both a test and a display of confidence, seismologist Yash P. Aggarwal of Lamont-Doherty predicted a small quake near New York's Blue Mountain Lake two days ahead of time. The tremor, size and all, fulfilled expectations. Studies of several past quakes, says Lamont-Doherty's Christopher H. Scholz, show that they too were preceded by pressure-wave changes consistent with the model.

The Lamont theory applies to most, and perhaps all, shallow earthquakes—those originating no more than 40 kilometers below the earth's crust. Such shallow quakes says Scholz, include almost all of the destructive ones. However, the evidence so far is only circumstantial. "It remains to be proved," says Jerry Eaton of the U.S. Geological Survey's National Center for Earth-



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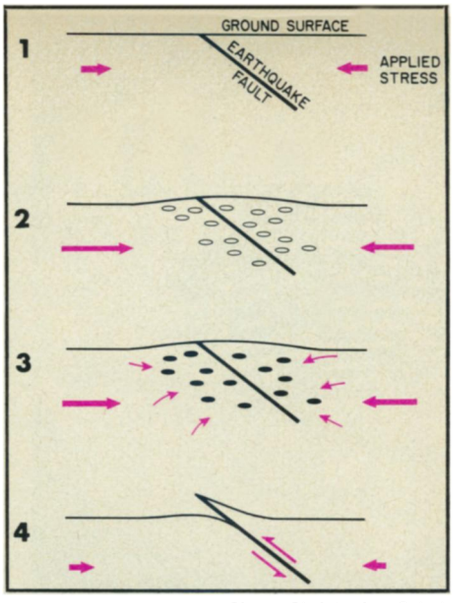



*Dilantancy model: Stress builds (1), opening fissures (2) which relieve stress until they fill with water (3), "hardening" the region and triggering the quake (4).*

Chart: Christopher Scholz

quake Research in Menlo Park, Calif., "that the model is correct. It needs to be proved in a greater number of places and on a larger physical scale."

Don Anderson and others at the California Institute of Technology are trying to see how the theory holds up for quakes originating deeper in the crust. Another question is whether the same pressure cycle holds true not only for strike-slip faults, in which the faces of the fault zone are sliding horizontally against each other, but also for thrust faults, where one side is trying to move up and over the other. Evidence from Soviet quakes is promising.

Even for shallow strike-slip faults, however, reliable prediction is likely to be several years in the future. The only earthquake ever officially predicted by the Government, a medium-small tremor foreseen last March to take place near Hollister, Calif., this summer (SN: 3/31/73, p. 207), has so far failed to occur. Eaton says the stress that might have caused it has apparently faded gradually away. "There were two possibilities," he says. Either there would be an earthquake of about magnitude 4.5 in the succeeding few months, or the material along the fault would allow the two faces to slide past each other rather than rupture. There has been no rupture, and "we think the displacement has taken place."

There are more signs of an impending quake than just pressure-wave changes. The electrical resistance of the rock decreases, as has been reported from the 1969 quake at Garm in the Soviet Union; the dilatancy theory attributes this to the water filling in the newly opened fissures. Another precursor is the increased flow of the water, detectable (as in the case of the 1966 Tashkent earthquake) by increased emission of short-lived isotopes such as radon.

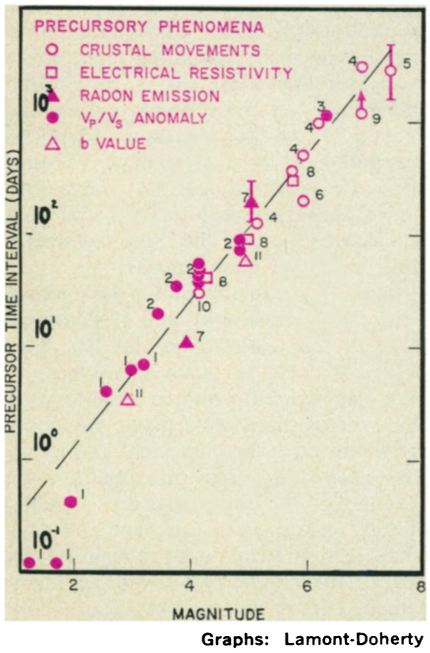
The general level of small-scale seismic activity is also affected in an area due for a quake, dropping off until the end of the pressure-wave cycle and shooting up again just before the main shock. A related phenomenon is a change in the relation between the size and number of these small tremors.

The most commonly reported long-term precursor is the vertical movement of the crust. In the case of the vicious Niigata quake (magnitude 7.5) in Japan in 1964, slow, steady vertical movements had been occurring in the area since 1898, but in 1958 and 1959 the upper crust rose almost five centimeters, centering on the area that later turned out to be the epicenter of the quake, followed by five years of little movement.

Perhaps the most difficult change to measure is in the magnetic field of the area, possibly related to the effects of the water redistribution on the rock's electrical resistivity, or to a piezomagnetic effect of the pressure changes on the rock. Unfortunately the magnetic field changes are so small and weak, they are hard to distinguish from the much larger ordinary daily fluctuations of the field. The phenomenon has been known for about 10 years, but, says Eaton, "only in the last year have results been less enigmatic."

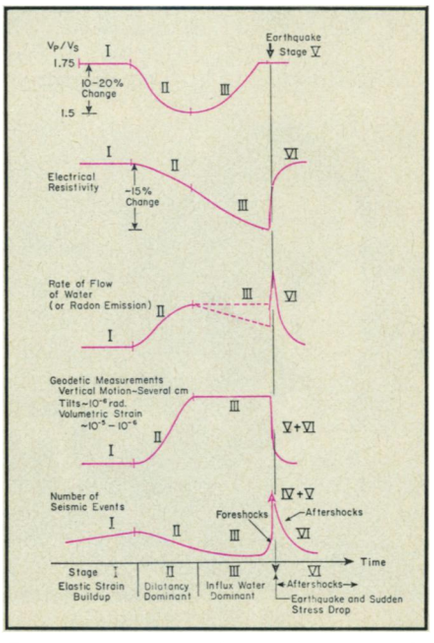
Nevertheless, the Lamont-Doherty theory of Scholz and his colleagues has a place for all of these precursors. The precursors seem to fall obligingly into place on graphs comparing their variation patterns with the size or strength of the ensuing quakes. "We suggest," the scientists reported recently in SCIENCE, "that the dilatancy mechanism is an instability from which there is apparently no return to stage I [before the dilatancy cracking begins] without the occurrance of an earthquake. . . . This encourages us to be-

*continued on page 204*




Graphs: Lamont-Doherty

*Precursors follow distinct patterns.*




*Precursor time tells quake strength.*

glyphs. We've created an apparatus to write these hieroglyphs. But to read them we're going to need help."

American interest in radiation photography was triggered three years ago by the appearance of the book *"Psychic Discoveries Behind the Iron Curtain"* by Sheila Ostrander and Lynn Schroeder. Several American scientists (among them Tiller; Moss; lawyer and inventor Kendall L. Johnson; psychiatrist Montague Ullman, director of the Maimonidies Mental Health Center in Brooklyn; and psychiatrist Stanley Krippner, director of the Maimonidies Dream Laboratory) found the accounts of Russian psychic research interesting enough to visit the Soviet Union and observe at firsthand what was going on. While there, they were given schematic diagrams of the Kirlian apparatus but were not allowed to actually see one in operation. Upon their return to the United States, several such devices were built.

Also leading to the interest in radiation photography is the current sympathy in some quarters toward subjects outside the areas of traditional science. The discovery of the apparent validity of ancient practices such as meditation and acupuncture has opened many minds to new ideas and broadened the perspectives of scientific research. But as to the exact nature of the phenomenon taking place in Kirlian photography there is little agreement among scientists.

Some ardent proponents of Kirlian photography feel that the emanations are none other than what ancient theosophical teachings call the "astral body," "energy body" or "aura" that surrounds the physical body.

A Russian physicist and investigator of Kirlian photography, Viktor Inyushin, explains the phenomenon in vitalistic terms. He believes the photographs reveal the "bioplasma body" of an organism—a previously overlooked state of matter made up of electrons and other subatomic particles that surround and intepenetrate living organisms. He states that it has specific spatial organization, is polarized and determines the form of the organism it penetrates. He associates bioplasmic energy with psychokinesis, acupuncture and similar phenomena still unexplained.

Jane H. Hu, electrophysiologist and director of research and education at the Acupuncture Institute and Research Center in Washington, says she is "very interested" in Kirlian photography. "It is direct evidence that shows the energy circulation in the body that coincides with the theories behind acupuncture and meridians. Whether or not this is an electrical or nonelectrical energy we do not know."

Other investigators are attempting to explain the phenomenon from the viewpoint of traditional Western science.

Tiller says there is a "specific physical explanation called the streamer phenomenon of corona discharge that can account for all the observations made to date."

Electrons, emitted from the object, move to the positively charged plate. By collison, they ionize the air molecules. When the density of positive ions is great enough, they attract the electrons back to the positive ion cloud, producing recombination events that lead to the emitting of radiation. Nitrogen recombination gives rise to the emission of light in the blue and ultraviolet range. The light patterns thus produced, vary with the distribution of the electrical field which is in turn influenced by the physiological state of the person being photographed. The physiological state is governed by the emotional state. But he adds that although there is a physical explanation this does not mean that some unknown type of energy may not be intimately involved.

Richard Miller, a physicist and director of research at the department of paraphysics and parapsychology at the Experimental College in Seattle, is not convinced air ionization is the main process involved in Kirlian photography. He thinks the radiations are related to the normal discharge of gases from living organisms.

With photospectrometry, Miller and his colleagues have looked at the emission lines coming off the human body and have identified them as gases related to the phenomenon of pheromones (gases that contain communication signals, like odors). "Much human emotional interaction could depend on the exchange of pheromones," says Miller. "Of course, this goes on at a subliminal level—below the level of conscious awareness."

"Gas emissions are functions of the emotional state and are potential clues to what goes on inside the head, and may lead to accurate measure of human responses and health state. The Kirlian process gives us a handle to measure these states," concludes Miller.

Both he and Tiller agree that careful experimentation under well-controlled conditions is needed to evaluate the significance of the phenomenon. Says Tiller: "We have not been sufficiently careful experimentally in the past."

Though scientists do not clearly understand the phenomenon taking place in Kirlian photography, many are excited about its applications.

"Whatever it is," Moss says, "I'm interested in it because it reveals enormous differences in energy states in individuals and thus may have practical applications for treating diseases, alcoholics, for psychotherapy and for studying people's interactions." She hails the discovery of Kirlian photography to be "as important as the invention of the X-ray machine. X-rays show what goes on inside the human body, Kirlian photography reveals what goes on outside the body."

Jampolsky is planning to take photographs of fingertips of children to see if he can determine when a child is daydreaming or actually concentrating on his books. He is also planning to do some work with dying patients to find how long emanations continue after death and if the photographs will reveal when a patient makes the unconscious decision to stop living. "Krilian studies of persons in a hypnotic state show that unconscious decisions do affect the aura," he says.

Researchers James Hickman and Larry Amos of Sonoma State College in New Mexico are planning to take photographs of fingertips of normal and abnormal persons at a nearby mental hospital. Preliminary studies with Kirlian photography, Hickman says, indicate that it is possible to detect emotional disturbances.

Says Moss: "At this moment in time, it is impossible to draw any conclusions about this research, except one. Whatever these pictures reveal—corona discharge or bioplasma—the changes which have been observed to occur in organic materials demonstrate that a most interesting, still undeciphered story is being told. And there lies the challenge." □

## . . . earthquakes

lieve that the number of 'false alarms' in predicting earthquakes may well be small."

The elaborate theory may not be precisely accurate, but, says one seismologist, "even if it is wrong it is valuable. It gives us something to measure."

One factor in prediction will certainly be the amount of available instrumentation, particularly if there is to be a practical prediction network covering most of the seismically hazardous areas in the United States, to say nothing of other countries. The only area now instrumented for any appreciable number of precursors, says Scholz, is Garm, which is equipped to monitor pressure-wave velocity, local seismicity, crustal uplifting and electrical resistivity.

Among the most important techniques now being developed to help catch quakes napping, according to Eaton, are ways of directly measuring the general level of stress deep in the rock. One approach, called pressure packing, has already been used at the Rangeley oil field in Colorado. A layer of a plastic material is placed around a hollow sleeve which is then inserted

# physical sciences

## A confirmation of element 104

Many isotopes of elements with atomic numbers greater than 100 have been experimentally manufactured in recent years. The usual means of identifying them has been to use their fission products or their alpha-particle spectra to deduce their atomic number.

The best way to identify an unknown element, according to a group from the Oak Ridge National Laboratory (C. E. Bemis et al), is by its characteristic K- or L-series X-rays, which are directly connected to its atomic number. In the Sept. 3 PHYSICAL REVIEW LETTERS the group reports that they have identified element 104 by a modified X-ray technique which includes measurement of the daughter isotope produced by alpha decay of 104 (element 102) in coincidence with the alpha particles emitted in the decay. They say this is an unequivocal identification of element 104 and confirmation of its earlier reported discovery. The sample was produced by bombarding a target of pure californium 249 with nuclei of carbon 12.

## More on Titan's atmosphere

Saturn's satellite Titan has aroused interest lately because its atmosphere appears to be thick enough to have a possible greenhouse effect. This could lead to a surface temperature much above what would be expected at Titan's distance from the sun, and there has even been a suggestion it might be warm enough for life.

In an attempt to extend knowledge of Titan's atmosphere F. C. Gillett, W. J. Forrest and K. M. Merrill of the University of California at San Diego observed the satellite in the infrared range between 8 and 13 microns using the UCSD-University of Minnesota 60-inch telescope at Mt. Lemmon. They report in the Sept. 1 ASTROPHYSICAL JOURNAL LETTERS that they find evidence of a strong temperature inversion, a region where temperature rises with distance above the satellite's surface instead of falling as it would be generally expected to do.

There is also evidence for a spectroscopically active component in the atmosphere in addition to the molecular hydrogen and methane that have previously been reported. This might be ammonia or ethane depending on its location. Further observations in the same range with better wavelength coverage and higher-resolution observations around 20 microns are suggested.

## A strange new X-ray source

Earlier this year T. H. Markert and collaborators at the Massachusetts Institute of Technology reported the existence of an X-ray source designated GX 339—4. Now, after several months of observation with the MIT experiment on the OSO-7 satellite, they report in the Sept. 1 ASTROPHYSICAL JOURNAL LETTERS that GX 339—4 behaves in a way "unlike that of any previously reported X-ray source."

The intensity of the emissions of GX 339—4 varies by at least a factor of 60 over a time interval of hundreds of days. Yet, unlike a number of other X-ray sources, it shows no evidence of periodic or cyclic behavior. Nor does it show the abrupt intensity changes over time scales between 3 minutes and 13 days that characterize still another group of X-ray sources. GX 339—4 has distinct times when its intensity is high; it has lows during which the spectrum softens and seems to indicate that X-rays are being absorbed by something near the source, and there are off periods when no statistically significant emission is recorded from GX 339—4.

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into a hole drilled in the rock. Fluid is pumped into the sleeve, expanding it and forcing the plastic into the fractures in the surrounding rock. When sleeve and plastic are withdrawn, the plastic retains a "print" of its surroundings, indicating the amount of fracturing and compressing in the area.

Another method involves pumping fluid directly into a hole with enough pressure to open fractures in the hole walls; the pressure is then relaxed, allowing the rock to squeeze the fluid back out. At some point the pressure with which the rock is expelling the fluid will drop off suddenly, representing the "minimum principal stress" at that point. Several such holes will indicate the axis of minimum stress, which can help reveal where, in a seismically active area, a tremor could occur.

To build a united front against damaging earthquakes, the Federal Government is consolidating its troops, moving quake researchers from the National Oceanic and Atmospheric Administration over to join those at the U.S. Geological Survey. Part of the idea is to reduce duplication of effort. Robert Hamilton, who will head the new combine for the Survey, points out that cutting down competition has its disadvantages, but he maintains that the time is certainly right for a concerted effort. "I don't know of any really well-known or prominent seismologist who regards prediction as crazy," he says, "whereas five years ago there were some."

Eaton concurs. "Some of these answers are so long overdue that it strikes me as being criminal to defer," he says. "The inattention to such things, as demonstrated by the San Fernando earthquake, is truly frightening."

On May 27, 70 NOAA seismologists and geologists were transferred to the USGS; in the next month or so, about 100 more will go. In fiscal 1973, the USGS was appropriated an extra $7 million specifically for the earthquake effort; $3 million of that was impounded by President Nixon, but this has since been released and will serve as additional funding for FY 1974.

To go with the mandate of its additional funding, the USGS is also developing a directed program of earthquake hazard reduction.

Additional impetus may come from bills, now in committees of both House and Senate, to delineate plans and appropriate more money for the purpose of carrying them out. The strongest may be that of Rep. Richard Shoup (R–Mont.), who has proposed the creation of a powerful Earthquake Research Board, made up of Presidential appointees recommended by Congress, the National Science Foundation, the National Academy of Sciences, the Interior Department, NOAA, the Defense Department and professional societies. Shoup's bill would give the board an initial budget of $15 million, with an annual allotment of $12 million for five years after that, along with authority to review research, set new goals, "and accept or reject the suitability of proposed research, engineering and development efforts." (This could be an almost unprecedentedly powerful panel, some geologists feel, and an acceptable proposal may have to be a milder one.)

Even without such legislation, however, the war on earthquakes has certainly begun. "New developments have moved us closer to realization of earthquake forecasting," says Shoup, "and the recent quakes in Mexico should be convincing proof of the need for forecast capability." □