Japan Holds Firm to Shaky Science

Most countries have reduced funding for earthquake prediction following a string of disappointing research results, but in Japan it remains a national priority. Scientific criticism is growing, however

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Fault lines. Kiyoo Mogi *(left)* rejects Robert Geller's criticism that Japan's earthquake prediction program is misguided.

TOKYO—Carrying a pager that hasn't beeped in 15 years might seem like a waste of time to most people. But not to Japanese seismologist Kiyoo Mogi. The 65-year-old Mogi views the silent pager as a proud reminder of his country's ambitious attempt to predict an expected magnitude-8 earthquake with sufficient accuracy to alert a heavily populated region to the west of Tokyo.

Mogi's pager is a key link in this effort, the only major earthquake-warning system in the world. More than 150 instruments buried on land and under water in the Tokai region (see map) measure seismic activity, rock strain, crustal tilt, and tide and ground-water levels. The data are telemetered to headquarters in Tokyo and monitored around the clock. Any anomalies will trigger Mogi's beeper, summoning him and five other eminent earth scientists to a meeting to decide whether the data are precursors to a major earthquake. If the answer is yes, the prime minister will be advised to issue a warning that will stop trains, close stores and schools, reroute traffic, and evacuate people living in areas prone to tsunami and landslides.

The system has never been activated, because there have been no hints of earthquakes in the Tokai region since the network was established. But Japan's commitment to earthquake prediction—the government is spending more than $100 million a year on a variety of prediction programs, including the Tokai network—remains unshakeable. That's not surprising, given its location in one of the world's most seismically active areas and its history of killer quakes. However, that faith is now being questioned—in some cases publicly—by researchers who argue that the program has insulated itself from outside scrutiny, that it consumes more than its fair share of scarce research funding, and that it gives the public a false sense of confidence in the government's ability to warn them of an imminent earthquake. A meeting later this month in Tokyo is expected to provide opponents with their best-ever opportunity to argue their case before the scientific establishment.

Begun in 1965, Japan's earthquake prediction program is based partly on scientific aspirations and partly on the conviction that the government must do everything possible to protect the population from the next major earthquake. "There is a possibility of prediction," says Mogi, professor emeritus of the University of Tokyo, former director of the university's Earthquake Research Institute, and chairman of the six-member Earthquake Assessment Committee. "And prediction would minimize the disaster."

The leading critic of that philosophy is Robert Geller, associate professor in the Department of Earth and Planetary Physics at the University of Tokyo. Noting that research efforts around the world have failed to come up with reliable ways to spot incipient quakes, Geller says "prediction is impossible," adding that the claims of prediction supporters are "irresponsible" and the program's premises and procedures are "specious." Masayuki Kikuchi, professor of physics at Yokohama City University, who analyzes seismograms to study the rupture mechanism of large earthquakes, offers this flat assessment: "At this moment, the majority of seismologists in Japan believe earthquake forecasting is either impossible or very difficult."

At the ready

The impetus for the intensive monitoring of the Tokai area was the discovery by Japanese seismologists that a major quake was apparently overdue in the region—a section of an earthquake-prone fault along the Suruga Trough, where the Philippine Sea Plate is diving beneath the Eurasian Plate. This section last ruptured in 1854. A rupture along this entire section is expected to cause an earthquake of magnitude 8. That prospect generated support for the 1978 Large-Scale Earthquake Countermeasures Act, which established procedures for issuing a warning of the anticipated Tokai earthquake as well as setting up hazard mitigation and emergency response programs.

Supporters of prediction are betting that the next Tokai quake will be preceded by patterns of rapid crustal uplift similar to what occurred shortly before earthquakes along adjacent sections of the Suruga and Nankai troughs in 1944 and 1946. Prediction critics maintain, however, that such "precursors" are identified after the fact, making them "postcursors" in Geller's words, and that any successful warning based on data gathered by the monitoring network would be serendipity.

Geller and other critics of Japan's program base their skepticism on the inability of numerous programs to find reliable ways to distinguish precursors from random geophysical events (see box). In most countries, those problems have led governments to reduce support for prediction research. But not in Japan. "In the United States, if we cannot make a cogent argument, and if we cannot produce some promising results quickly, we simply cannot do the research," says California Institute of Technology seismologist Hiroo Kanamori. "But in Japan it is such a socially important problem that they have to continue prediction-related work even if they cannot make a cogent argument."

Critics do not argue with the need for a substantial earthquake research effort, but they charge that Japan's program is too heavily weighted toward applied efforts like the Tokai network. The program, they contend, suffers from institutional inertia and the absence of critical reviews of individual research projects. "[Researchers] have gotten the same amount of money year after year, so there is a reluctance to cut one [institution's] budget to increase another's," says Yoshio Fukao, head of the Earthquake Research Institute at the University of Tokyo.

Critics cite several research activities they believe have yielded questionable scientific results. One research group in Tsukuba, for example, monitors a 340-meter-long tunnel where changes in tunnel length are correlated with regional seismic activity. There are continuing studies of concentrations of radon gas in the region, and one government agency flies a blimp over the Tokai region to spot geomagnetic anomalies.

There is consensus that the observation networks, which form the backbone of the

Hopes Fade for Earthquake Prediction

Japanese seismologists are not alone in looking for warning signs of the next Big One. Researchers around the world have seen signs of imminent temblors in everything from the behavior of animals to cloud patterns. In the United States, optimism over quake prediction peaked in the 1960s and 1970s as researchers developed new detection equipment designed to measure everything from changes in the shape of the land to electric signals in the ground. But so far, none of the signals has proved reliable. Nevertheless, small-scale efforts continue to monitor the following signals for hints of upcoming quakes.

Foreshocks: In 1975, Chinese researchers accurately predicted the devastating Haicheng quake based on an increasing tide of small quakes in the region. The forewarning allowed them to evacuate much of the region before the 7.3-magnitude quake, saving thousands if not tens of thousands of lives. But such crescendos are more the exception than the rule, says Max Wyss, a seismologist at the University of Alaska in Fairbanks. "Some earthquakes have foreshocks and others do not," he says, making pattern detection an unreliable gauge at best.

Bulges and creeps: In addition to measuring motion, researchers also look for changes in the shape of the ground's surface and slow slipping along known faults. In 1966, such creeping along the San Andreas fault was noticed just before a magnitude 6 quake in Parkfield, California, which has a record of earthquakes every couple of decades. And anecdotal accounts from Japan report changes in the shape of the ground prior to the 8.1 Tonankai earthquake in 1944. The problem with measuring shape changes, however, is that rainfall, drying, and natural slumping continually change the shape of the landscape, says John Langbein, chief scientist at the U.S. Geological Survey's (USGS's) Parkfield Earthquake Prediction Experiment.

Electric resistivity: Geologists have long known that ground water, with an abundance of dissolved ions, is a good electrical conductor. They've also known that tectonic stress and strain can move water within rock and change its conductive properties. Researchers measure this changing behavior by simply burying two electrodes in the ground, applying a voltage, and measuring the resistivity—how much resistance the intervening earth puts up to the flow of current. Chinese researchers claim that changes in resistivity have preceded several quakes, including the 7.8-magnitude quake in Tangshen, China, in 1976. "But there are also non-tectonic factors that can affect resistivity," such as changes in rainfall and water pumping patterns, says Leonardo Seeber of Columbia University's Lamont-Doherty Earth Observatory in Palisades, New York.

Magnetic fields: Underground water could also give rise to magnetic signals in advance of quakes. Since rock tends to absorb electrons from water, water often has a slight positive charge relative to surrounding rock. When fracturing and straining pump water through the rock, the slight charge imbalance between them may create an electric current. The current, in turn, could generate a corresponding magnetic signal, which could be measured at the surface using magnetometers. Magnetic fields can also change when magnetic minerals in the rock are squeezed prior to a large quake. While such magnetic signals have shown up clearly during earthquakes such as the 1992 Landers quake in California's Mojave Desert, "what we haven't seen is the precursory [signal]," says Malcolm Johnston, a USGS geophysicist in Menlo Park, California.

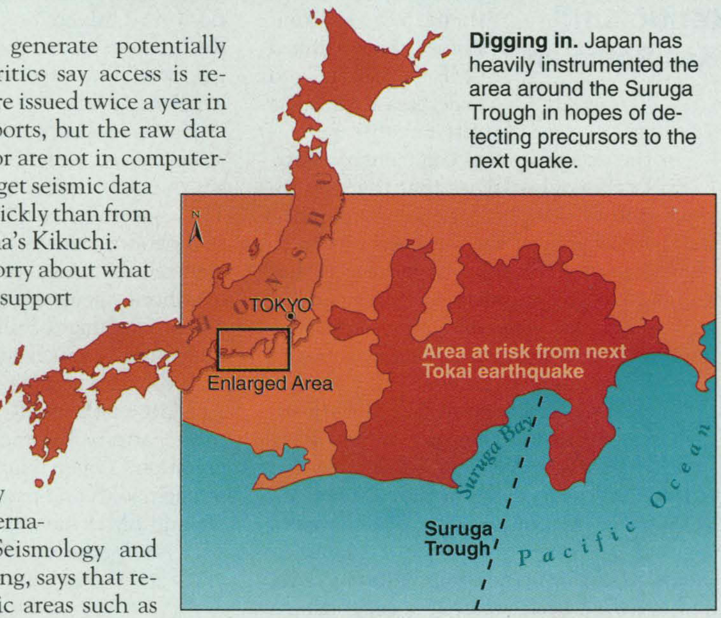
Ultra-low frequency electromagnetic waves (ULFs): A possible connection between these electromagnetic waves and earthquakes was suggested in 1989, when atmospheric scientist Antony Fraser-Smith of Stanford University measured ULFs 300 times stronger than normal 3 hours before the magnitude 7.1 Loma Prieta earthquake near Santa Cruz, California. Fraser-Smith and his colleagues believe ULFs, too, may result from fluid flow and the magnetic fields it may generate. But since Loma Prieta, Fraser-Smith points out, no ULF signals have been detected in advance of other earthquakes.

In the hope of sorting out the different predictors, USGS researchers have placed dozens of instruments near Parkfield to measure these different signals along the San Andreas fault. But because different types or sizes of quakes may be associated with different precursors (if any at all), few researchers expect the Parkfield experiment to point to a single clear warning sign. "If there were an easy way to predict [earthquakes], we would have figured it out long ago," says Langbein.

–Robert F. Service

prediction program, generate potentially valuable data. But critics say access is restricted: Summaries are issued twice a year in phone book–sized reports, but the raw data are often embargoed or are not in computer-usable form. "We can get seismic data from the U.S. more quickly than from Japan," says Yokohama's Kikuchi.

Other scientists worry about what has been sacrificed to support earthquake prediction. Although there are no central records of funding by discipline, Katsuhiko Ishibashi, a seismologist at the Ministry of Construction's International Institute of Seismology and Earthquake Engineering, says that research into more basic areas such as earthquake source physics, crustal dynamics, and seismotectonics is being neglected. "We are talking about projects being funded in terms of millions of yen [tens of thousands of dollars]," says Kikuchi, "while the prediction research projects get hundreds of millions of yen [millions of dollars]."



Digging in. Japan has heavily instrumented the area around the Suruga Trough in hopes of detecting precursors to the next quake.

Increasing public concern

The debate over the scope of the program and its chances of success has so far barely reached the general public. "I'm embarrassed to admit this, but until I took over this position I thought earthquake prediction was much more advanced," says Yukiko Hirakawa, an official with the Ministry of Education, Science and Culture (MESC) who recently moved into a position involving regular contact with the Geodetic Council. The council is an advisory body to MESC, but it drafts prediction research plans that get funded by a number of ministries. For example, few citizens realize that the Tokai area is the only place the government even intends to try issuing a short-term warning, or how tenuous that effort is.

That public ignorance could prove costly to the program. Last year, after a tsunami claimed more than 200 lives following a magnitude 7.8 earthquake off the coast of Hokkaido, experts reluctantly appeared on television to explain that the region had few instruments and, therefore, that no warning was possible. An increasingly critical media has also bolstered Geller's campaign to open the program to greater public and scientific scrutiny; one small victory was the inclusion of scientists not directly involved in prediction research on a review panel reporting to the committee drafting the next 5-year prediction research plan.

Despite their participation, these outside reviewers remain unhappy about their influence on the plan, which went into effect on 1 April. "To a certain extent, I feel our suggestions were reflected in the seventh plan," says Fukao, "but there are areas I am very unsatisfied with." In particular, the new plan does not change how funds are divvied up, nor does it shift any money to new areas of research, especially at universities. Supporters respond that there's no need for major changes. "Basically, most of the research programs we see as being valuable are in the present plan," says Yoshimitsu Okada, a seismologist at the National Institute for Earth Science and Disaster Prevention and a vocal prediction supporter.

The sponsors of this month's symposium, the Science Council of Japan and the Seismological Society of Japan, would like it to lay the groundwork for a new "blueprint" for prediction research. But the most critics are expecting from the 2-day meeting is a public airing of their concerns. They note that already, newspapers and TV programs are giving them the rare opportunity to comment on official positions. Fukao also thinks that the outside reviews carried out at a few universities and research institutions of specific departments will spread eventually to prediction research. "Fundamental changes are coming," he says—a prediction that may be as difficult to pin down as the time and place of the next Tokai earthquake.

–Dennis Normile

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ELECTROMAGNETIC FIELDS

Breast Cancer Link Claimed, Criticized

The 15 June issue of the *Journal of the National Cancer Institute* contains an unusual pair of articles: An epidemiological study purporting to show a link between low-level electromagnetic fields (EMFs) and increased risk of breast cancer, and a commentary explaining why the research findings shouldn't be taken seriously. Welcome to the latest battle in the EMF wars.

The study, conducted by University of North Carolina (UNC) researchers, found that women working as electrical engineers or technicians, or as telephone installers, repairers, or line workers, seemed to have a 38% higher risk of dying of breast cancer than other workers. One of the researchers, David Savitz, calls the conclusion "tenuous" and "awfully tentative," saying it deserves attention only because breast cancer is such a common disease. But Dimitrios Trichopoulos, head of the department of epidemiology at the Harvard University School of Public Health, suggests in the commentary that the UNC data don't support even a tentative conclusion and notes that three other occupational studies have shown no link between EMFs and breast cancer in women.

"The interpretation should be infused with much more skepticism." —Ken Rothman

The UNC researchers, Dana Loomis, Savitz, and Cande Ananth, identified 27,882 deaths from breast cancer in death records from 24 states. They then classified the women by occupation and compared the occupational histories of women who died of breast cancer with those of women who died of other causes. The researchers themselves note that the 38% risk increase they found among electrical workers is small, in epidemiologic terms, and the data it's based on may be unreliable. Only 68 of the breast-cancer deaths occurred among electrical workers. And as Loomis points out, "we only have information about people who are already dead."

Indeed, he says, they might not have considered their results worth publishing if not for the existence of a supporting biological hypothesis—a proposal that EMF exposure reduces production by the pineal gland of the hormone melatonin, which helps control cell growth. Suppressing melatonin, according to the hypothesis, increases the risk of sex hormone–related cancers. Also weighing in favor of publication, Loomis says, is the fact that four studies have linked EMF exposure to male breast cancer, a very rare disease.

In the accompanying commentary, however, Trichopoulos argues that the melatonin hypothesis is a poor rationale for publishing the results, since it is unproven and virtually untested. "The risk," he writes, "is that an unproven hypothesis may be invoked to support results generated from imperfect data, which, in turn, could be cited in support of the guiding hypothesis." He adds that although four studies have linked EMFs to male breast cancer, several dozen more have looked at EMFs and cancers of all types and reported no cases of male breast cancer at all.

More to the point, Trichopoulos writes, "at least six other studies have examined breast cancer in women in relation to EMF, and none has been reported as supporting a causal relation." Three of these, he notes, were occupational studies "of superior design" to the North Carolina study. Loomis and his colleagues, however, question the relevance of those studies because they were undertaken in Sweden and Denmark, where "occupational exposures and background patterns of breast cancer may be different than in the United States."

But Trichopoulos suggests it's more likely that something is amiss in the UNC group's study. Trichopoulos sees several "warning signs" in the results. Perhaps the most obvious shows up when the electrical jobs are classified as managerial and professional or manual. Women in the white-collar electrical jobs, such as electrical engineer, had a considerably higher rate of breast cancer than did women in the manual jobs—almost twice the rate of women in non-electrical occupations. Yet it's the women doing manual jobs like installing telephone lines, says Boston University epidemiologist Ken Rothman, editor of the journal *Epidemiology*, who would be expected to face the highest exposure levels.

Savitz says he "can't argue" with that criticism. Indeed, he and his colleagues point out another apparent contradiction themselves: They saw no excess of breast cancer in seven occupations that "also involved potentially elevated electrical exposures," including telephone operators and computer operators and programmers. Still, says Savitz, "there is probably not much more that can be done with the data to address [these] concerns."

Maybe not, says Rothman, but he thinks these patterns "detract from a causal interpretation." Given that the association is weak to begin with and past studies of breast cancer and EMFs have been negative, he adds, "the interpretation should be infused with much more skepticism."

–Gary Taubes