SEISMOLOGY

Research Gets Big Boost One Year After Kobe Earthquake

TOKYO—One year after the Great Hanshin Earthquake rocked Kobe and surrounding communities, the region has made great progress in recovering from the disaster. But the 6.9-magnitude quake, which caused more than 5500 deaths and $100 billion in damage, has heightened Japan's already acute sense of its geological vulnerability atop the intersection of four colliding tectonic plates. Responding to that anxiety, the government last month announced a 47% increase in public spending on earthquake-related research, along with a promise to make more accessible the data gathered by such efforts.

The new $159 million pot has even generated its own seismic motion—a subtle but significant shift away from the idea that scientists should, above all else, try to predict the next big quake and toward a belief in the need to understand better the underlying forces that cause them. "Formerly, there was just observation tied to prediction," says Yoshio Fukao, a seismologist who heads the University of Tokyo's Earthquake Research Institute. "Now there is a possibility of doing more basic and adventurous research."

Not all researchers agree that the government has changed course. Seismologist Robert Geller of the University of Tokyo, an outspoken critic of earthquake prediction, says "the funding increase is almost all bad." He views the growth in existing programs as reinforcing the country's bias toward prediction, and he says some of the items in a new program, called Frontier Earthquake Research, are "even more off-the-wall."

Japanese officials dispute his assessment, and most seismologists say that they don't know enough about the Frontier program to form an opinion. However, they admit to being troubled by the fact that, despite the growing use of peer review in Japanese science, most of the new activities are government initiatives that lacked input from the community. "The budget increase is a good thing," says Mizuho Ishida, current president of the Seismological Society of Japan. "The only problem is we don't know how the money will be used exactly."

The bulk of the new funds will go to the Science and Technology Agency (STA) (*Science*, 5 January, p. 22). Its new Earthquake Research Promotion Office, created last summer, is supposed to oversee the activities of the six ministries that carry out earthquake-related research. It is also the agency's responsibility to plot an overall strategy and to avoid duplication.

The new funds will cover programs ranging from how to make structures more quake-resistant to using new satellite-based radar techniques to map faults. One of its highest priorities is to boost the scope and nature of seismological observations, as well as to conduct field investigations of faults throughout the country. Yuichi Inoue, deputy director of STA's new office, says that the nation's current seismic observation network is overly concentrated around Tokyo and the Tokai area 120 kilometers west of the city, which is believed overdue for a magnitude 8 earthquake. To redress this imbalance, STA is going to place the first of a targeted 500 new seismic instruments on land and beneath the sea in areas outside current networks.

STA also plans to set up 35 observation stations to catch signals from the Global Positioning Satellite (GPS) system. Use of the GPS system, which permits great accuracy in identifying the position and elevation of any spot on Earth, will allow researchers to watch the buildup of distortions in the Earth's crust that precede an earthquake or, conversely, note where blocks of the Earth's crust are smoothly slipping past each other. "What is currently least understood and most interesting in seismology is not what happens after an earthquake rupture begins but the process leading up to the rupture," says the University of Tokyo's Fukao.

JAPAN'S EXPANDING EARTHQUAKE PROGRAM
(selected programs)

Activity	1996 (in millions)	1995 (in millions)
Science and Technology Agency (STA)	$85.6	$45.6
Major STA programs include:		
Land and sea-floor observation stations	23.0	0
Frontier Earthquake Research	11.0	0
Electromagnetic and other phenomena	(3.1)	
Remote sensing research	(2.8)	
Earth Structure Research, land-based	(2.0)	
Earth Structure Research, ocean-based	(3.0)	
Grants for local investigations	10.0	0
Regional disaster mitigation	10.0	0
Oversight office	8.1	0
New or expanding programs at other agencies:		
Seismic, crustal observation stations	3.3	0
Observations for prediction	2.0	0
Earthquake potential of active faults	4.0	0.8
Communications research laboratory	2.0	0.8
Total*	**$158.6**	**$108.0**

* Includes programs at six ministries
SOURCE: GOVERNMENT MINISTRIES

The detail of the observations depends on the density of the GPS station network. There could eventually be more than 1000 GPS stations in place in Japan, counting STA and other agency plans. "If that could be accomplished, it would mark a new era, allowing near-real-time monitoring of the changing condition of the Earth's crust," Fukao says. "I think it's a very important program."

A second part of this effort is investigating known faults. Researchers can construct a history of a fault's activity and make inferences about future activity by digging a trench across the fault and analyzing successive offsets of soil strata. Public spending on investigations of known faults will skyrocket, from less than $1 million to $13 million, with the work being split between the Geological Survey of Japan and local governments. STA will support the work carried out by local governments. Keisuke Saito, deputy director of research administration for the Agency of Industrial Science and Technology, the arm of the Ministry of International Trade and Industry that oversees the Geological Survey, says the goal is to clarify the seismic risks of 1700 different faults scattered throughout the country.

One initiative that has drawn criticism is the Frontier program. It's intended to support new and risky approaches to the study of earthquakes, including an analysis of electromagnetic phenomena and a search for new ways to monitor sea-floor seismic activity. To Geller, the program embodies the central problem of Japan's earthquake-related research: the lack of a rigorous review process. What particularly incenses Geller is that he believes that parts of the research community and government have garnered support for increased spending by hinting—if not exactly promising—that larger budgets for earthquake research will lead to reliable earthquake predictions.

Geller is extreme in his skepticism about prediction. But even Fukao, who says he believes prediction may someday be possible, thinks the STA program may have been adopted without sufficient discussion. "It was something pushed not by the research community but by politicians," he says. "Researchers didn't hear about it at the time."

STA's Inoue admits that the research agenda was cobbled together quickly in response to public concern over the

Hanshin earthquake. "We only got this office up and running last July," he says. The Frontier research themes and the general priorities were set by STA staffers, he admits, after informal inquiries into potentially promising areas of research. In the future, he said, the office will draw on advice from two committees, one concerned with broad policy and another focusing on issues related to the observation networks. Inoue says a more rigorous review process will be used for future research, particularly work within the Frontier themes.

In addition to seeking outside advice, STA is opening up the program in another way: It plans to make all relevant observational data more accessible. At least 16 universities and agencies now operate observation networks, says Inoue, noting that "walls between the different agencies" have prevented data from being used outside the institution that collects it. Masayuki Kikuchi, a professor of physics at Yokohama City University who uses instrument data to study earthquake sources and mechanisms, says that it was quicker and simpler in the days after the Hanshin earthquake to get data from U.S. agencies, via the Internet, than from any source in Japan.

Even if he had succeeded in getting Japanese data, he might not have been able to use it because of the different methods of recording and digitizing the data. The result, Kikuchi says, is that "a lot of data are collected during an earthquake, but very little is ever used." A single database would allow Kikuchi and others to examine earthquake source mechanisms with greater precision and detail. "Instead of relying on global data, it would be better to get more detailed data from observation points close to the source," he says.

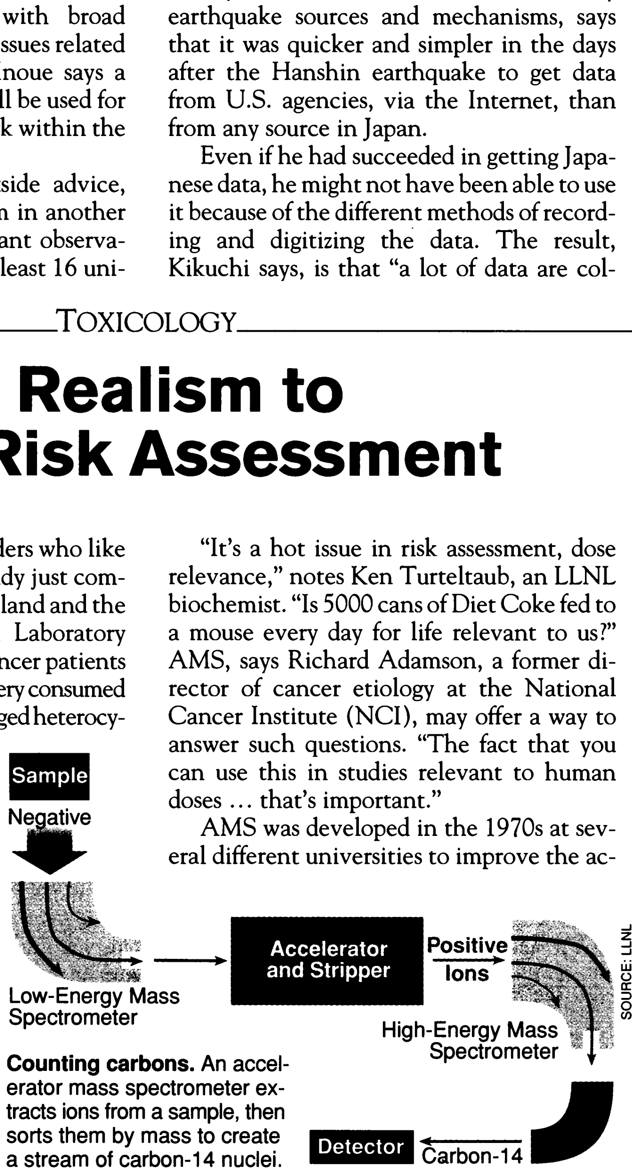
Given the level of seismic activity in Japan, opening up the databases is likely to provide him and other Japanese seismologists with plenty of useful information. And once these data are shared with researchers overseas, the entire world may be able to benefit from the lingering impact of the Great Hanshin Earthquake.

–Dennis Normile

TOXICOLOGY

AMS Adds Realism to Chemical Risk Assessment

Here's an alarming tale for readers who like their burgers well-done. In a study just completed at York University in England and the Lawrence Livermore National Laboratory (LLNL) in California, several cancer patients who were scheduled for colon surgery consumed trace amounts of radioactively tagged heterocyclic amines—compounds that form in cooked meat. After their surgery, the LLNL researchers analyzed the colon tissue, and so far the results show that even at these minute doses the substances bind to DNA in the tissue. The finding supports other evidence that well-done meat poses a cancer risk. And it's a striking demonstration of a new technique for testing potential carcinogens and other compounds, known as accelerator mass spectrometry (AMS).



Counting carbons. An accelerator mass spectrometer extracts ions from a sample, then sorts them by mass to create a stream of carbon-14 nuclei.

The technique's proponents at LLNL and elsewhere say AMS has the potential to do away with the time-honored tradition of administering massive doses of chemicals to rats and hoping for a response that has some relevance to human beings. Instead, AMS traces the fate of minute quantities of a compound tagged with radioactive carbon-14 (C^{14}) in tissues, cells, or even compartments within cells—generally in an experimental animal rather than a human subject. By literally counting C^{14} nuclei, the apparatus can follow just micrograms of a pesticide, a compound in food, or a potential drug through the body. And it may offer an answer to growing concerns about whether high-dose tests have any real usefulness in predicting human health hazards.

"It's a hot issue in risk assessment, dose relevance," notes Ken Turteltaub, an LLNL biochemist. "Is 5000 cans of Diet Coke fed to a mouse every day for life relevant to us?" AMS, says Richard Adamson, a former director of cancer etiology at the National Cancer Institute (NCI), may offer a way to answer such questions. "The fact that you can use this in studies relevant to human doses ... that's important."

AMS was developed in the 1970s at several different universities to improve the accuracy of radiocarbon dating in archaeology and allow the use of smaller samples. Archaeologists traditionally measured the amount of C^{14} in an artifact—an indicator of age—by monitoring the radioactive decay of the isotope, an approach that requires several grams of sample material. AMS, in contrast, counts the C^{14} nuclei directly, allowing the use of as little as a milligram of material.

To perform this feat, the machine first extracts carbon atoms from the sample and ionizes them by adding an extra electron. The beam of negatively charged ions passes through a bending magnet, where ions of lighter carbon isotopes—carbon-12 and -13—bend more sharply than the heavier C^{14} and can be culled from the beam. An accelerator then propels the beam through a thin foil that removes the electrons and breaks up the remaining molecules before they pass through a second bending magnet. This step further purifies the beam before it reaches a final sorting bin, where the C^{14} nuclei can be detected individually.

The same apparatus can also detect other isotopes with much the same sensitivity—down to one part per quadrillion. As a result, AMS quickly spread beyond archaeology to other fields, including earth science and nuclear physics. The LLNL Center for Accelerator Mass Spectrometry (CAMS), for example, was originally designed to diagnose the fission products of U.S. atomic tests and monitor the spread of nuclear weapons to other countries by detecting telltale radioisotopes in samples of air, water, and soil. But those applications have been swamped by the more than 15,000 measurements a year performed at CAMS by the international research community.

A growing fraction of those outside users are biomedical researchers, who hope to study the biological activity of potential carcinogens and toxins at everyday levels. That's unprecedented, says Bruce Ames, director of the University of California, Berkeley's, environmental health sciences center and a leading critic of current animal studies. "Today, we find the level that will kill an animal, back off a little bit, then feed it that level for a lifetime. ... That's crazy." Ames has long argued that the toxic effects of such high doses spur rapid cell division, which in turn boosts the risk of cancer—whether or not the compound itself is carcinogenic at ordinary doses.

Not every biochemist shares Ames's views about existing tests, but they do agree on the need for a more sensitive test for suspect compounds. The first step is to label a compound with C^{14} and feed it to a laboratory animal. Then different bits of tissue—