KOBE EARTHQUAKE

Faculty Picks Up the Pieces of Shattered Research Projects

KOBE, JAPAN—When the earthquake struck this port city of 1.5 million on the morning of 17 January, the granite under Kobe University protected most of its buildings from the massive damage sustained by structures built on softer alluvial material in the center of town. But the quake exacted a heavy human toll on the 46-year-old institution, claiming 39 students and two faculty members among the 5500 fatalities. It also destroyed some $35 million worth of research equipment, which scientists hope the government will replace quickly so they can get on with their work. Yet, even as the earthquake was a tragic reminder that some things are beyond human control, it has spurred new lines of scientific inquiry, from engineering studies of buildings in the region to behavioral studies of survivors.

For Kobe University's researchers, the main preoccupation over the past 5 months has been to resume research projects disrupted by shattered equipment, lost cell cultures and animals, and damaged laboratory buildings. Some were up and running within days, but others—particularly big physics projects—are still idled by broken instruments. Takashi Tonegawa, dean of the faculty of science, says that a sympathetic Ministry of Education, Science, and Culture (Monbusho) has promised to replace equipment lost in the quake. "It will come," he says, "but when, I'm not sure." A Monbusho official confirms plans to restore all labs at least to their prequake conditions, and last month the Japanese Diet approved $36 million for the university—including $33 million for lab equipment—as part of a supplemental budget bill to stimulate the economy.

Classes, suspended after the quake, resumed with the new academic year in April, and many aspects of university life have returned to normal. But reminders of the earthquake aren't hard to find. The medical school, at a separate campus down the mountain, suffered considerably more damage than the main campus. Cracks forming giant X's are clearly visible in the concrete walls of a seven-story building housing research labs. "The engineers say it's repairable," says Takashi Yamadori, dean of the medical school. Although all medical school and hospital buildings are in use, some elevators remain out of order, and Yamadori has to climb three flights of steps to get to his office.

Immediately after the quake, efforts were concentrated on securing food and shelter. Hideo Ohkawa, professor of biological and environmental science, got to his lab about 1 p.m., some 7 hours after the earthquake hit, and found half a dozen of his students there. "They had lost their apartments; some had lost all their notes and textbooks," he says. Scores of students with no place to go camped out in university offices and

PHOTOS BY KOBE UNIVERSITY

Shattered science. Many labs at Kobe University are still trying to recover from January's earthquake.

labs, while a thousand people left homeless by the quake took refuge in university gyms and conference rooms. Ohkawa, whose home on the far side of the mountain was undamaged, brought pails of boiled rice from home for his students.

But science was never far from the minds of faculty members. A bit of luck and quick thinking managed to save years of work for Katsumi Isono, a professor of genetics who lives just a 5-minute walk from the school. Rushing to the campus to check on thousands of samples of ordered clones from the genomes of *Escherichia coli* and *Saccharomyces cerevisiae* stored in freezers at –80°C, Isono found that electricity had been restored to an administration building, but that most lab buildings were in the dark because of fear that an electrical spark could cause fires or explosions. "One of the [maintenance] engineers told me he would turn on the electricity if I could guarantee there were no gas leaks," Isono recalls. Isono and a couple of colleagues raced through the building and, finding no leaks, told the worker to proceed. They held their breath and flipped the breakers—and the building was fine. With electricity restored, the bulk of his samples was safe.

Unfortunately, in the excitement Isono had forgotten about other samples stored in freezers in a graduate lab in another building. Isono estimates that between 2000 and 3000 samples were lost. Luckily, it is not as big a setback as it would have been a few years ago: Isono says he has all the sequencing data to reconstruct what's needed.

Other biology-related groups were less fortunate. Researchers at the medical school had to euthanize their entire population of 4000 rats and mice after half the animals escaped from their cages and, upon recapture, could not be identified, and the remainder were infected with a murine virus that might have been carried into the labs during the cleanup. The $55,000 cost of the lost animals doesn't include rats with special hereditary traits that are not commercially available, says Hak Hotta, professor of microbiology. Although Hotta says that his own research on anti-viral agents was set back only a matter of months and is "almost back to normal," other researchers are still struggling to resume experiments and recover months of lost work.

Most affected by the quake were those dependent on large, expensive devices. Physics Professor Takao Nanba, who works on semiconductor materials, ticks off a list of equipment his department lost: tunneling electron microscopes, lasers, light wave devices, and microwave oscillators. About a year ago he reserved a time slot for this summer on the synchrotron radiation facility at the National Laboratory for High-Energy Physics in Tsukuba, but with so much of his own equipment out of whack he has been unable to prepare his samples. "I'm hoping I can switch that time to the fall," he says.

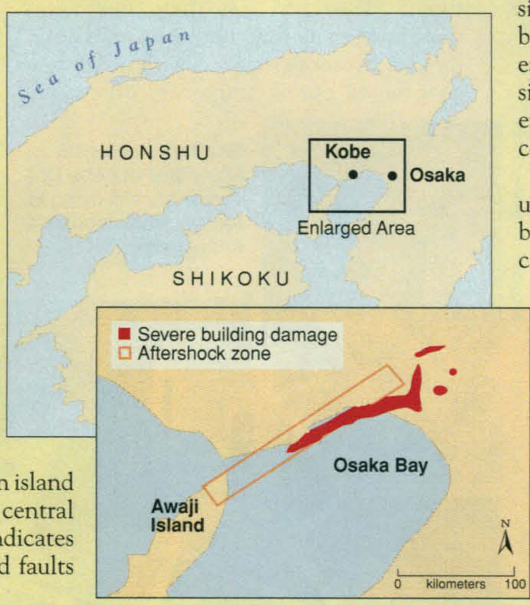
Chemistry professor Hajime Kato's lab suffered a similar setback: $500,000 in damage when a tableful of lenses, mirrors, and lasers crashed to the floor despite an air cushion system designed to isolate the table from vibrations. Kato, who works on new techniques in high-resolution spectroscopy, using combinations of lasers and molecular beams coupled with magnetic or electric fields, has already resumed some experiments using equipment that survived the quake. "We couldn't wait," Kato says. "Other researchers might be working on the same things."

Noboru Nakamura, professor of geochemistry, is in even worse shape. "I haven't done any real research for 3 months," he says. Nakamura had been using two ancient mass spectrometers acquired secondhand from

Deadly Lesson: It Could Happen Anywhere

KOBE, JAPAN—Scientists who have studied the Kobe earthquake have come to an unsettling conclusion: Dozens of cities around the world are ripe for a similar catastrophe. Seismological and engineering studies in the wake of the magnitude 6.9 quake in January have discovered nothing to mark the quake as unique: no previously unknown major faults, unusually strong ground shaking, or unexpected failure of local buildings. Rather, the 5500 fatalities and $100 billion in damage appear to have been caused by a common urban recipe of substandard older structures, built on soft soils and sitting atop a network of active faults. A similar combination appears to have caused more than a thousand deaths in last week's earthquake on Sakhalin Island.

Instead of finding a single major fault, for example, seismologists have traced most of the shaking to a complex system of smaller faults that runs under the city. The rupture began near the northern tip of Awaji Island and rippled through the fault system, eventually extending about 15 km southwest from the epicenter and 25 to 30 km to the northeast—right under downtown Kobe. Surface ruptures were found on Awaji Island southwest of the epicenter and under the Akashi Strait, which separates Awaji Island from the main island of Honshu. No ruptures were found in central Kobe, although the aftershock pattern indicates that one or more previously unrecognized faults runs under the city.



At fault. The age of buildings and soil conditions greatly affected the extent of damage from ground motion along the fault lines.

SOURCES: EARTHQUAKE ENGINEERING RESEARCH INSTITUTE/ARCHITECTURAL INSTITUTE OF JAPAN ILLUSTRATION: C. FABER SMITH

Masayuki Kikuchi, a physicist at Yokohama City University, has tracked the ground motion by analyzing videotapes from a dozen convenience-store security cameras: Videotapes made on opposite sides of the fault, he realized, should show sharp jerks in opposite directions. "It's a very interesting approach," comments Minoru Takeo, a seismologist at the University of Tokyo's Earthquake Research Institute. And it allowed Kikuchi to trace the fault through the devastated heart of the city. His putative fault deviates slightly from a well-defined belt of particularly heavy damage 1 km wide and 20 km long.

Kikuchi says the band is defined by the local topography, as well as proximity to the fault and the propagation of a concentrated pulse of seismic energy that built up ahead of a rupture. A similar pattern of severe damage could result from the faults lying beneath any number of major cities around the world, he says. "One very important thing to recognize about this earthquake is that there was nothing extraordinary about the level of shaking."

As a result, the Kobe quake offers some useful pointers for planners hoping to mitigate such effects elsewhere. Postquake surveys have confirmed initial impressions that newer buildings, built after 1971 and 1981 revisions in the building codes, performed much better than older ones. For example, Obayashi Corp., a large construction company, found that 36% of 223 major buildings it erected before 1971 either collapsed or were unsafe to enter, while only 6% of the buildings completed after 1981 were unsafe, and none had collapsed. "It is quite clear that the upgrading of the code has resulted in safer structures," says Masanobu Shinozuka, professor of civil engineering at Princeton University and head of a Tokyo-based seismic risk consulting firm.

In the 1971 upgrade, the amount of steel reinforcing required near critical joints in reinforced concrete columns was dramatically increased to give the columns greater strength in transferring horizontal forces from the upper part of a structure into the ground. In 1981, to conform with global changes in design philosophy, the codes were revised again to prepare buildings both for moderate earthquakes that could occur during a building's useful life and the more powerful quakes that strike every few centuries. In moderate quakes, beams and columns are now designed to stretch and bend, then snap back to their original shape. In stronger earthquakes, structural members are designed to absorb the earthquake's energy by twisting permanently but not collapsing.

But although newer buildings stood up well to the shaking at Kobe, older buildings fared poorly. The lesson for cities that want to significantly reduce their earthquake risk is clear, says Shinozuka: "The priority should be [retrofitting] older structures."

Engineers say older concrete buildings can be shored up by adding solid walls for greater lateral strength, although this often requires sacrificing windows. The columns supporting older elevated highways can be wrapped with steel jackets that prevent the concrete from crumbling, and heavier bracing can be added to steel structures. The traditional Japanese houses, which accounted for 90% of the casualties in Kobe, can also be strengthened by replacing the heavy clay tile roofs with lighter roofing and by adding bracing or plywood sheathing to walls.

But even though most newer buildings performed well, many were damaged, developing cracks in the welded connections between beams and columns. The same was true in the January 1994 Northridge, California, earthquake, where more than 100 Northridge-area buildings have been found to have cracked connections and 400 more are under inspection.

The damage has shaken the engineering community's confidence in steel structures, once thought to be inherently earthquake-resistant because of their ability to deform slightly rather than crack. Michael Engelhardt, professor of civil engineering at the University of Texas, Austin, thinks engineers may have been misled by testing the welded connections on smaller, thinner steel beams than the ones typically used in commercial buildings. "There appears to be a scale effect at work that we don't understand," Engelhardt says.

Although Japanese engineers had hoped their slightly different welding would avoid the problem, "we can't say we didn't have that kind of damage," says Masayoshi Nakashima of Kyoto University's Disaster Prevention Research Institute. But Nakashima doesn't advocate ripping every building apart to see if it's structurally sound. "I'm concerned," he says, "but not to the point where I think all these buildings should be opened up and checked tomorrow."

–D.N.

other institutions to study trace elements in meteorites, cosmic dust, and moon rocks, but the earthquake threw the 2-ton instruments against an interior wall, knocking the optics out of alignment and wrecking electrical circuits. Replacement parts for the 20-year-old instruments are unavailable, Nakamura says, and the company that made them doesn't even want to send a technician to assess the damage. What's worse, Nakamura worries that Monbusho won't authorize the $30,000 to $40,000 needed to buy a replacement because the damaged ones weren't new when he acquired them.

If the earthquake has set back some areas of research, it has also created new opportunities. Monbusho has just approved a 3-year, $2.8 million research project involving about 100 researchers from practically every department. Earth scientists will study the region's faults; engineers, the performance of local structures. There will be studies of the social and economic effects of the earthquake, and the Department of Computer and Systems Engineering is planning a digital archive of earthquake data.

The medical school has its own programs. An epidemiological study is focusing on the psychological and mental stress suffered by quake survivors, while another group is trying to understand high rates of renal failure among certain patients injured in building collapses. Kosaku Mizuno, chair of the department of orthopedic surgery, says they have been puzzled by what he calls crush syndrome, in which a person is trapped in wreckage for some length of time but whose vital organs appear undamaged. "It is very difficult to differentiate the patients that succumbed to crush syndrome from patients that recovered," he says.

Regardless of their field, many of the researchers at Kobe feel they now have a proprietary interest in earthquake research. "We're living in Kobe," says Kunio Kataoka, dean of engineering, "so we should be doing this research."

–Dennis Normile

AUSTRALIA

Ocean Anomaly Triggers Record Fish Kill

MELBOURNE—Hundreds of millions of pilchards, small relatives of herrings, have washed ashore during the austral autumn along the entire 5000-kilometer length of Australia's southern coast, leaving scientists scrambling to explain the biggest fish kill in the country's history.

Neither the pilchards' natural predators nor seabirds gorging on the dead fish seem to have been affected, suggesting that the culprit is not an algal toxin. The leading suspects are currently a diatom bloom or a virus, but there are hints that the cause may lie deeper, in unusual changes in the temperature profile of the Southern Ocean. However, scientists are puzzled by the fact that juvenile pilchards and other species have not been affected, as well as by the absence of a diatom bloom or temperature change in the waters of Western Australia.

The mysterious killer's handiwork was first spotted in late March. South Australian fishermen reported unusual "black water" ahead of the kill in Spencer Gulf, in the eastern half of the Great Australian Bight; a month later, fishermen in eastern Victoria were complaining of a sticky slime on their nets and lines. The kill spread eastwards at some 60 km a day from Spencer Gulf and then swung north around the coastline, eventually halting at Newcastle, north of Sydney; it also spread south into Tasmanian coastal waters and west across the Bight into Western Australia.

Surface water samples were found to be teeming with cells of the diatom *Thalassiosira*, a specialized marine alga with a lacy silica skeleton. Researchers suspect that the pilchards were suffocated or otherwise incapacitated by floating slime secreted by the algae. Marine biologist David Smith, research director at the Victorian Marine Research Laboratories at Geelong, found that almost all the lamellae on the pilchards' gills had eroded away, destroying their capacity to absorb oxygen.

The killer's modus operandi in the west was more puzzling, however. For one thing, there are no signs of a diatom bloom, and the destruction followed a strange path, spreading westward from the Bight at around 25 km per day. "It's the weirdest thing, because it is spreading against the direction of the Leeuwin Current, which flows eastward into the Bight at around 2 km per hour," says biologist Rick Fletcher of the Western Australian Fisheries Research Laboratories in Perth.

Oceanographers initially thought the culprit was a Kelvin wave, a deep, eastward-propagating pulse of water of varying temperature that breaks through the thermocline, the boundary between warmer water on the surface and a colder, deeper layer. These planetary-scale waves carry a mound of warm, low-density water from the western Pacific to the South American coast during an El Niño, blanketing the nutrient-rich cold waters of the northern Humboldt Current and starving anchovies and other fish.

Gary Meyers of the Commonwealth Scientific and Industrial Research Organization's (CSIRO's) division of oceanography in Hobart says temperature soundings in the eastern Indian Ocean indicate the thermocline had been thinned by a bulge of cold, deep water, and that the collapse of such a mound could have spawned such a wave. In theory, it could have initiated an ecological chain reaction whose fallout proved fatal for pilchards. But the killing front appears to have moved too rapidly to have been caused by a Kelvin wave, Meyers now believes.

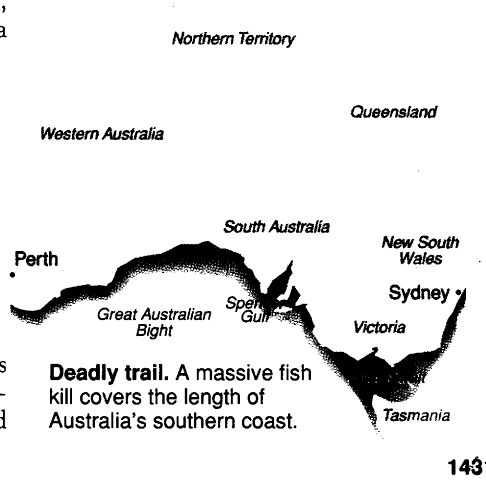
Kelvin wave or not, something extraordinary seems to have stirred the Southern Ocean recently. Sea-surface temperatures between Spencer Gulf and eastern Victoria have been 2 to 4 degrees lower than normal since late December, suggesting a series of major upwellings of cold water. Competitors in the Sydney-Hobart yacht race in late December also reported unusual algal bloom in Bass Strait.

One theory being pursued by fish virologist Mark Crane, of the CSIRO's Australian Animal Health Laboratory at Geelong, is the possibility of a herpesvirus epidemic. Crane has found aggregations of herpeslike virus particles in the pilchards' gill tissues, although he has not yet been able to isolate or culture the virus. He speculates that the virus could have been a harmless passenger that emerged once the pilchards' immune system was weakened by some form of environmental stress—for instance, oxygen deprivation from slime coating the gills.

For Fletcher, the kill is something more than a scientific conundrum. Perth is "the largest pilchard fishery in Australia," he says, with most of its annual catch of 10,000 tons used as bait. Although the kill has ebbed, Smith fears its effects will be felt on other commercial species—including mackerel, Australian salmon, and barracuda—that prey on pilchards.

–Graeme O'Neill

Graeme O'Neill writes about science from Melbourne.



Deadly trail. A massive fish kill covers the length of Australia's southern coast.

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