Advances in Earthquake Prediction

By Tsuneo Asai

The Japanese archipelago rests on an extremely complicated section of the earth's crust. The Pacific tectonic plate thrusts itself beneath the Eurasian plate, and the Philippine Sea plate wedges into the whole. The result is one of the most earthquake-prone countries on the planet. Given the great damage earthquakes cause in such a small insular country, it is no wonder that Japan leads the world in earthquake research.

There are accurate records of earthquakes in Japan dating back to the 7th century. According to these documents, the country has experienced more than 400 earthquakes of a magnitude exceeding 6 on the Richter scale. Almost every day earthquakes which can be physically felt by people occur somewhere in Japan. In Matsushiro, Nagano Prefecture, an amazing 63,600 tremors were recorded in just four years. Still fresh in memory are the destructive earthquakes which occurred off Miyagi Prefecture in 1978, off Urakawa in Hokkaido in 1982 and along the Japan Sea coast of central Japan in 1983.

The 1983 earthquake on the Japan Sea coast was particularly violent, registering 7.7 on the Richter scale, and caused tsunami (tidal waves). But of all Japan's earthquakes, the Great Earthquake of 1923 left the strongest mark in Japanese history. This 7.9 magnitude quake killed some 100,000 people in and around Tokyo. An additional 44,000 were listed as missing. As many as 250,000 houses collapsed and another 450,000 burned down in the conflagration that swept the city in the wake of the tremor. Six-meter-high tidal waves battered the Pacific coast of the Kanto District. Areas along the Sagami Bay and places around the Boso Peninsula rose or sank, causing extensive damage. In order to preserve the lessons of the devastating Great Kanto Earthquake, September 1 has been designated "Disaster Prevention Day" in Japan and earthquake disaster drills are conducted every year on this date throughout the country.

It goes without saying that many scholars have sought to find out why Japan is visited by so many earthquakes, and whether they can be predicted beforehand to minimize damage. After World War II, a series of typhoons and earthquakes claimed more lives than the casualties incurred on the home front during World War II. Big earthquakes alone in the 7–8 magnitude range included the Nankai earthquake of 1946, the Fukui earthquake of 1948 and the earthquake off Tokachi, Hokkaido, in 1952 and 1968. On the advice of the Geodesy Council under the Minister of Education, the government began emphasizing earthquake research in 1949, and a five-year study on earthquake prediction was launched. In 1961 the Disaster Countermeasures Standards Law was enacted, under which the Central Disaster Prevention Council was formed to draw up measures for earthquake damage prevention.

Resources mobilized for prediction

Today a concerted effort is under way to predict a major quake which scientists think may rock the Tokai District near Tokyo on Japan's Pacific coast in the near future. Scholars and experts have been mobilized from universities and national and public research institutes as well as from the private sector to research the formation and movement of the earth's crust and seismic activities. Numerous seismometers, both large and small, have been installed throughout the country to establish a nationwide earthquake observation network. In each of the past ten years, the Japanese government has appropriated ¥5–7 billion (about $28–39 million at the rate of $1/¥180) for earthquake prediction studies. As a result, it is now almost possible to predict trench-type quakes before the fact in the area off the Tokai District, centering around Shizuoka Prefecture where the three plates mentioned earlier converge.

In 1976, the government established the Headquarters for Earthquake Prediction Promotion and integrated various research activities. Earthquake data were accumulated in this headquarters and a data evaluation system established. In 1978, the Large-Scale Earthquake Countermeasures Act was promulgated. The next year, arrangements were made to report information on regionally predicted earthquakes to the Earthquake Assessment Committee for Areas under Intensified Measures against Earthquake Disaster (hereafter referred to as the Earthquake Assessment Committee) so the council could issue earthquake warnings. Seismic sources are located all over Japan, and it is impossible to predict all the quakes that might occur. At present, prediction capability is limited to forecasting a trench-type earthquake that might hit the Tokai District and the

Tsuneo Asai is a special editor in the Science & Technology News Division of the Nihon Keizai Shimbun.

southern part of the Kanto District. Nonetheless, the establishment of a round-the-clock system to monitor signs of an impending major tremor is unprecedented anywhere in the world.

The Science and Technology Agency takes the initiative in research on earthquake prediction, while the Earthquake Prediction Promotion Headquarters steers the research to be conducted. Actual research is undertaken by universities mobilized by the Ministry of Education. It is also carried out by the National Research Center for Disaster Prevention of the Science and Technology Agency, the Geological Survey of Japan of the Agency of Industrial Science and Technology within the Ministry of International Trade and Industry, the Geographical Survey Institute of the Construction Ministry and the Radio Research Laboratory of the Ministry of Posts and Telecommunications. The Maritime Safety Agency and the Japan Meteorological Agency operate the observation network for predicting earthquakes. In this manner, research results are quickly translated into action.

Special research funds of more than ¥1 billion ($5.6 million) each were appropriated for two major projects. One, conducted from 1981 to 1985, focused on predicting perpendicular-type earthquakes and on overall disaster prevention systems for the Tokyo area. The other, carried out from 1980 to 1984, analyzed the seismic tectonics of the northern tip of the Philippine Sea plate. Both projects produced significant results.

High-performance observation and measuring instruments were developed for these projects and the composition of the earth's crust and movements in the vicinity of earthquake foci were surveyed in great detail. The multi-channel seismic reflection method was used to trace accurately crust formation on the ocean floor where subsidence is taking place in the Philippine Sea plate. Three observation lines were laid over 300 kilometers of land and sea, and big explosions were used to conduct seismic surveys to track precisely crust formation in the sea off the Izu Peninsula and the Tokai District. A 1:400,000 scale crustal movement map has been compiled showing deformations that have taken place over the past 10,000 years.

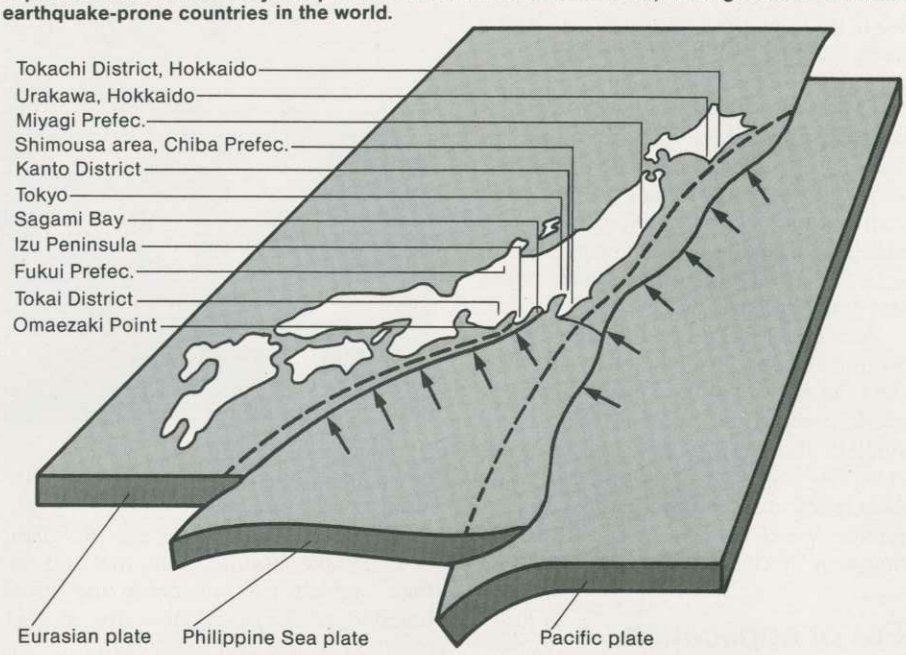
A seabottom seismograph transmitting data to shore via cable was placed in the sea 11 kilometers off Omaezaki Point in Aichi Prefecture, and a continual survey of seabottom earth potential is being conducted using the device's submarine earth contact electrodes to identify changes caused by earthquakes. A new seabottom tiltmeter for measuring crustal movements around earthquake foci has been developed. New ways to predict earthquakes by observing electromagnetic fields or underground water levels are being tried.

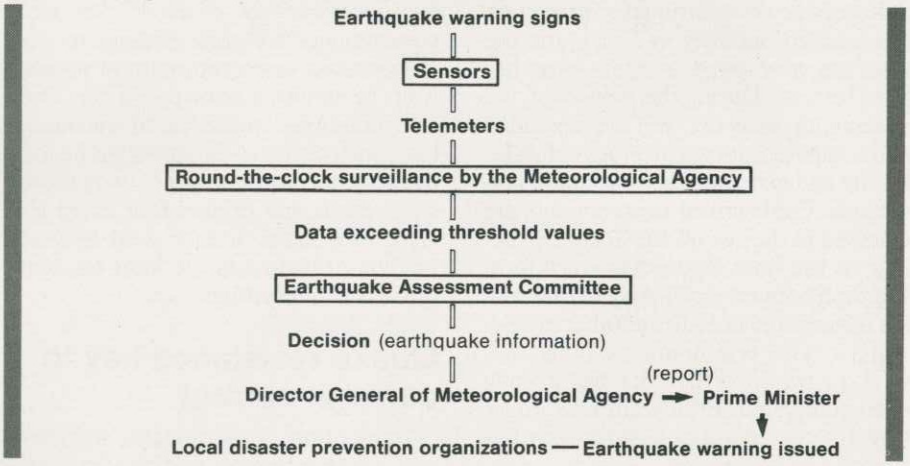
It is still impossible to predict perpendicular-type earthquakes that might occur in the Tokyo metropolitan area. Therefore, it is essential to be able to detect the first sign of a quake and to work out systems for minimizing the scope of the disaster. The southern Kanto District, with its population of 30 million, has been designated along with the Tokai District as an area for intensified earthquake observation. From observations to date, it seems possible that any perpendicular-type earthquake that hit the southern Kanto District would be smaller than a Tokai earthquake. With sufficient warning, damage could be largely contained.

But this is no easy task. Man-made vibrations and noises abound in Tokyo and environs. Moreover, the area is covered with a soft sedimentary layer, rendering accurate seismic observation difficult.

The National Research Center for Disaster Prevention has drilled a 3,510-meter deep-layer observation well in the Iwatsuki area of Saitama Prefecture, a 2,330-meter well in the Shimousa area in Chiba Prefecture and a 2,781-meter well near Tokyo's Fuchu. Precision seismometers in these wells continuously monitor crust movements. The center has also developed a laser observation device to detect horizontal displacement of the crust around Tokyo. By repeatedly measuring the distance between points 1 to 10 kilometers apart with a laser optical distance measuring device, the center can calculate accumulated distortions with a precision of 1/10 millionth (1 mm error per 10 kilometers). The center is confident that by observing distortions in the crust

Japan rests on an extremely complicated section of the earth's crust, making it one of the most earthquake-prone countries in the world.





from shallow as well as deep wells and from its laser observation posts, it can issue an earthquake warning before the seismic waves actually reach Tokyo.

At present, it is said that word of an impending earthquake can be gotten to Tokyo 20 seconds in advance of the first shock. If detection signals are linked to traffic signals, cars could be brought to a safe halt. Similarly, it might be possible to shut the valves on city gas mains before the quake strikes.

Because there are earthquake foci all around Japan, tiltmeters for detecting crust movements have been installed in 140 locations, seismometers large and small in another 150 and microseismometers in about 220. In addition, tide gauges are installed at 112 sites, underground water survey meters at 45 and magnetic sensors at 29.

Era of application

Research on earthquake prediction has reached maturity in Japan, and the time has now come to apply what has been learned. During this new stage, the observation network will be upgraded and computers utilized to process data instantly and generate highly accurate predictions. Cable-linked seismometers are installed in the sea off the Tokai District and off the Boso Peninsula, which form wings on both sides of Tokyo, so that data are transmitted one after another by telemeters. The telecommunications network to transmit the data has already been completed. Efforts are now under way to upgrade the seismic activities surveillance system.

Research on earthquakes is also making headway in the United States, the Soviet Union, China and Italy. But Japan is probably the only country that has completed a system, including software, for predicting earthquakes with highly advanced technology in specially designated areas.

Say people in charge of earthquake prediction, "We will not miss the coming of any kind of earthquake, but we must also try to minimize false alarms." As earthquake prediction technology advances, and it becomes possible to detect the advent of even minor shakes, the issuing of warnings becomes a serious problem. If an earthquake does not occur after a warning has been issued, the public might not trust the next one that comes along. Faulty warnings could invite confusion rather than helping minimize possible damage. The upshot is that the Earthquake Assessment Committee must exercise extreme prudence in judging whether or not to issue a quake warning.

Data processing system in the National Research Center for Disaster Prevention

There is a popular saying in Japan, "Earthquake, thunderbolt, fire and father," which lists in order the most dreaded of things. People are in part resigned to the eventuality of an earthquake as an "act of God." Yet local governments are now making routine preparations to prevent natural disaster from becoming a human disaster. They are promoting measures to encourage the construction of fire-proof and earthquake-proof buildings and to reinforce cliffs, roads and bridges that could collapse in a major tremor. And they are holding drills to educate local residents in disaster prevention.

Quake resistance key to damage control

In addition to earthquake prediction and disaster prevention systems, research on resistance to earthquakes has also made impressive progress. The world's first large-scale experiment to measure a building's resistance to quakes has even been conducted using an actual building as part of a joint Japan-U.S. research project.

The Building Research Institute in Tsukuba Science City in Ibaraki Prefecture constructed the life-sized building for this life-sized test. The seven-story structure is subjected to earthquake-like shocks created by hydraulic jacks, and measurements taken on displacement, tilting and changes in structural strength. Present earthquake-proof construction standards in Japan are very strict, constricting interior space and raising building costs. The institute's work on methods of constructing strong but economical buildings has attracted attention abroad, and researchers from the University of California, the University of Michigan, the University of Illinois and the Portland Cement Association participated in the building test.

The world's largest and most sophisticated shaking table to test the earthquake resistance of nuclear power plant facilities has been completed on Shikoku Island. The National Research Center for Disaster Prevention already has a 12-meter-square shaking table, and the University of Tokyo's Institute of Industry and Science has a shaking table measuring 10 by 2 meters. But at the Nuclear Power Engineering Test Center, a 1,000-ton structure can be placed on the 15-meter-square shaking table to simulate earthquake motions.

Research is continuing nonstop on remote-sensing technology to predict earthquake destruction of bridges and industrial plants well in advance. There are dozens of other projects as well and the future should see the commercialization of the most promising results.

Although systems have been developed to predict earthquakes accurately, prevent fire, and evacuate residents after the shocks have subsided, it will not be known until a major earthquake actually occurs whether or not they will work as intended.

In the best-selling novel *Nippon Chinbotsu* (Japan Sinks), later made into a movie, other countries give refuge to the entire Japanese population when the nation is destroyed by a gigantic tectonic upheaval. It is just as important for Japan to make available to the rest of the world the results of its own research on earthquakes. The earth is in constant motion, generating massive earthquakes in many parts of the world. Countries bordering on the Pacific Ocean are often hit by major tremors. It is the wish of people everywhere that all countries will cooperate to minimize earthquake damage. They look to Japan to promote international cooperation in earthquake research. ●