The offset in this row of trees is due to horizontal tectonic movement in the Tangshan earthquake in northern China on July 27, 1976. The magnitude 7.8 earthquake, the largest in Chinese history to hit a populated area, exhibited fault movements of up to three meters. This picture, and all the others in this article, were given to members of the National Academy of Science's Earthquake Engineering Delegation by Chinese seismologists and engineers.

The Real China Syndrome

Earthquake Prediction and Engineering in the People's Republic

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China, the world's most populous country, is also among the most earthquake prone. According to historical records, at least 345 earthquakes greater than magnitude 6 have rumbled beneath the land over the past 2,500 years, wreaking terrible death and destruction. Until recently, however, international politics have made it difficult, if not impossible, for the outside world to study Chinese earthquakes. But since the beginning of the thaw in relations between the United States and the People's Republic of China, visiting American scientists have been able to glean more and more useful information about the fascinating scientific puzzle of the tremors that vibrate along the spiderweb of faults beneath China.

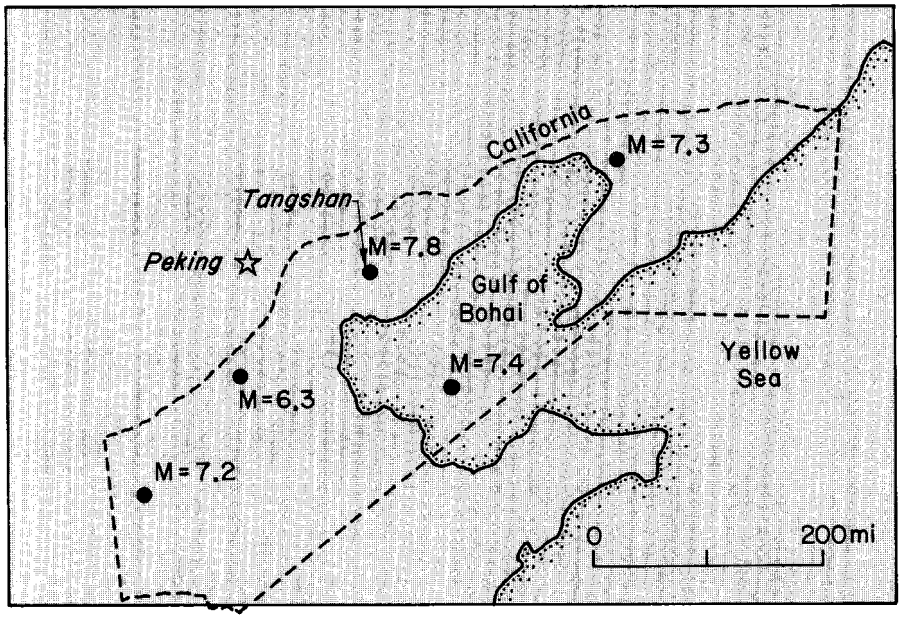
Just as fascinating, they have been able to observe the phenomenon of China's massive program of earthquake prediction. It's an amalgam of science, politics, public relations, and mythic folklore as revealing of Chinese society as it is of the country's geology.

Prominent among the observers of China's prodigious earthquake prediction effort have been seismologists and earthquake engineers at Caltech. Professor of Geology and Geophysics Clarence Allen, who visited China in 1974 with a group of seismologists, has embarked on another trip this fall. And George W. Housner, the Carl F Braun Professor of Engineering, led a delegation of earthquake engineers to China in the summer of 1978 — the National Academy of Sciences (NAS) Earthquake Engineering Delegation — which also included Professor of Civil Engineering Paul Jennings. The NAS will publish a report of the findings of the group in November.

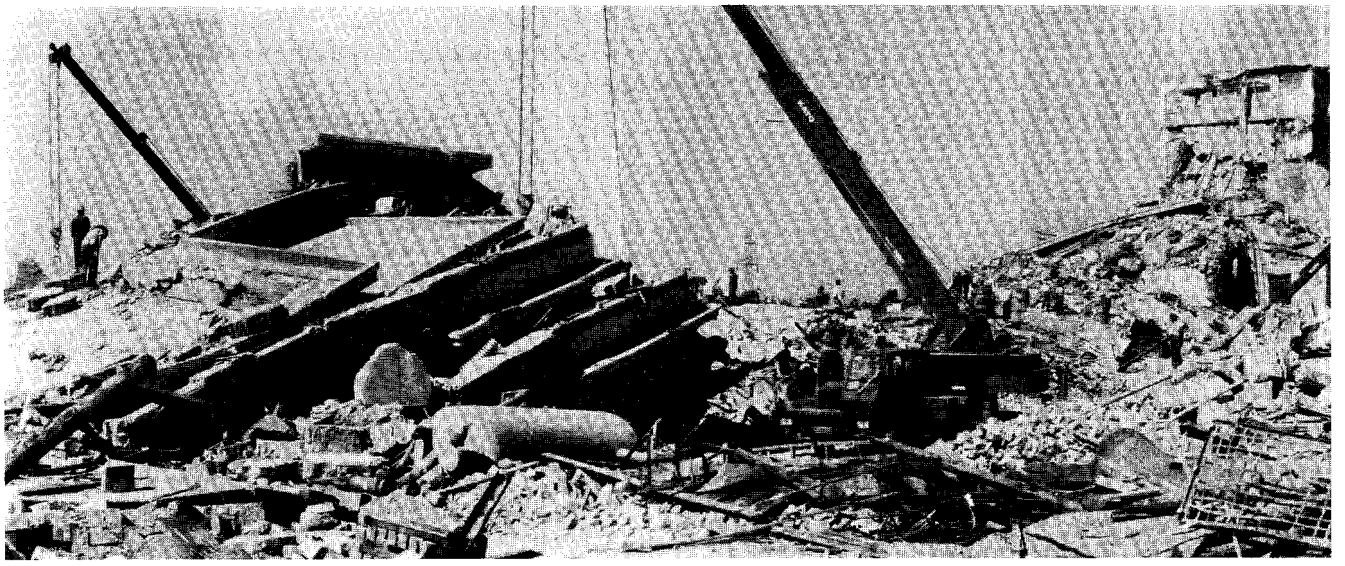
According to the NAS report, earthquake prediction in China is very much a "people's science," involving about 10,000 workers in the provincial seismological bureaus, of which about half are technically educated. However, many times this number of amateur seismologists throughout China gather the masses of data used in prediction studies. These amateurs work with the provincial seismological bureaus and brigades, carrying out their earthquake activities in addition to their regular work as farmers, tradesmen, students, and the like. They work in over 10,000 mass observation posts, gathering an incredible range of data on every natural phenomenon that could possibly pertain to earthquakes. Some of the measurements made by the provincial seismological bureaus are the same as those made by U.S. seismologists. For example, records are kept of seismic activity, velocity of seismic waves through the earth, magnetic fields and electric currents in the earth, groundwater levels, and changes in the amount of radon in groundwater.

Other phenomena carefully monitored by the Chinese have received little attention from American seismologists. According to the NAS report, among the records kept by the Chinese in the case of one earthquake prediction were:

- Lights and outgassing seen prior to the earthquake, in the form of columns, fans, balls, and sheets of fire. For



This map of the Bohai region of northern China gives the epicenters and magnitudes of major earthquakes that have taken place in that area since 1966. The dotted outline of the state of California is superimposed to show that within less than 15 years four earthquakes of magnitude greater than 7 and one of more than 6 took place in a region approximately the same size as California.



This building of the Kailuan Coal Mine General Hospital in Tangshan collapsed in the earthquake. Because of a failure to anticipate the possibility of such a large quake, few buildings in the city were designed to be sufficiently resistant to shaking. Thus, 85 percent of the 916 large buildings in Tangshan collapsed or were severely damaged, and only one percent escaped damage.

example, before one earthquake, the head of the provincial seismological bureau described seeing a fireball 75 kilometers from the epicenter. The fireball reportedly originated at the ground surface 100 meters from where he stood, shot upward and began shrinking, and then curved over, falling to earth. The light dimmed and brightened, and small wisps of white smoke swirled around it. A slight crackling sound was heard, and an odor of garlic or sulfur was detected.

- Earthquake sounds, which in China are called "sounds of the mountains." Experience with these sounds, commonly low rumblings coming in short bursts, is so extensive that people often leave their houses upon hearing them.

- Abnormal growth or withering of plants. Before this earthquake, fruit trees bloomed twice in one season and bamboo withered, the latter apparently because of a drop in groundwater.

- Nausea and shock before the earthquake. Scientists suspect this phenomenon, if true, may be due to an increased level of microseismal activity.

- Unusual animal behavior before an earthquake. Also studied in the U.S., this has been a part of the Chinese folk wisdom for so long that most of the Chinese scientific community seems to accept it as a fact. The Chinese have even constructed tables that purport to list the period of time before an earthquake during which, for example, dogs, fish, or snakes exhibit strange behavior. Examples of strange behavior include an unusual number of rats on telephone or power lines, or rabbits climbing thatched roofs to escape the ground.

Although much of the reported animal behavior does have some conceivable scientific explanation, other instances are far less obvious.

"It was reported to us that the tiger in the Tientsin zoo became lethargic a few hours before an earthquake in 1969," says Clarence Allen, "— so lethargic that the zookeeper finally called the local earthquake prediction brigade and warned them of an impending earthquake, which subsequently occurred.

"In general, though, we came away from our tour with the impression that, even if perhaps 95 percent of the work going on in China may not ever yield useful results, the other 5 percent represents a far more massive effort than is going on in all the rest of the world combined."

But why such a huge grass-roots effort?

"First of all," Allen says, "earthquakes are a very real problem in China — much more so than in this country. They have had major disasters for thousands of years.

"Furthermore, earthquake prediction in China can save lives. The great numbers of Chinese killed in earthquakes have been killed in their own homes — particularly in the

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Steel rails on the railway bridge across the Ji Canal buckled during the earthquake. Soil spreading caused inward movement of both bridge abutments, shortening the distance between them by 2.1 meters and causing the distortion of the rails.

countryside where the homes are built of tamped earth. In this country, for the most part, family dwellings are among the safest places one can be. Consequently, there is not the benefit associated with prediction that there might be in China."

And finally, Allen points out that the social system in China permits leaders to take strong action with less worry about the consequences of public reaction.

"If the chairman of the local committee says evacuate the village — by God, they evacuate. If Mayor Bradley were to order evacuation of parts of Los Angeles, I don't know what would happen."

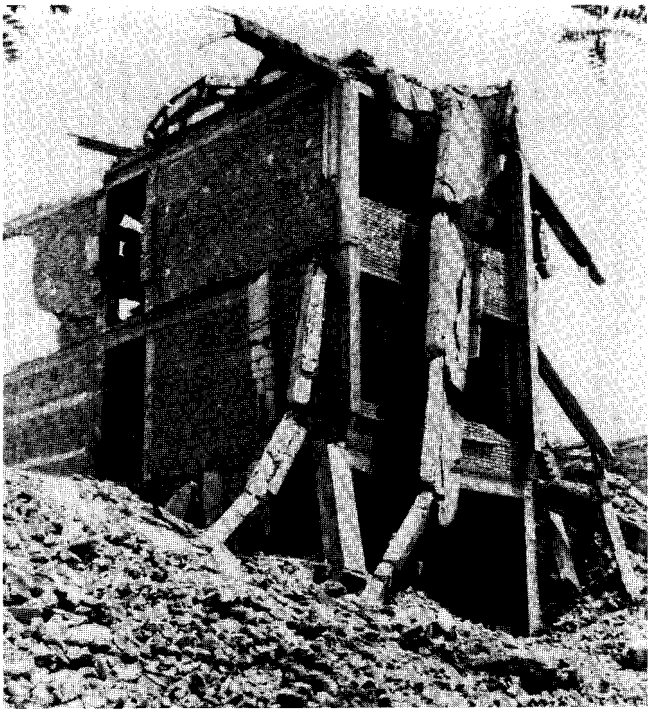
George Housner notes a strong public relations element in the Chinese effort.

"Some of this enormous public effort is also aimed at taking the heat off the government," he observes, "— to show that they are doing something about the very real threat of earthquakes."

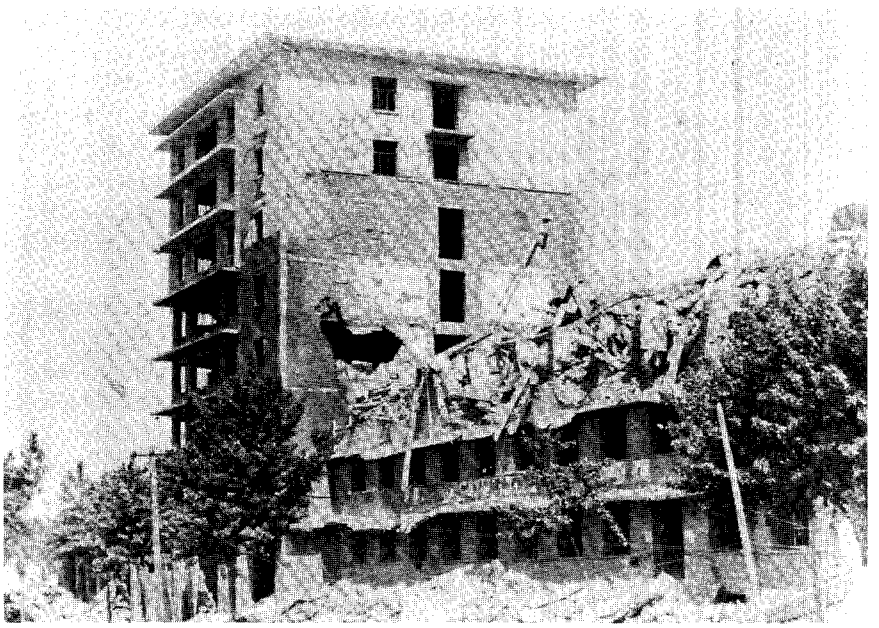
During their visit, Housner's NAS group was briefed on how the Chinese predicted a series of three large earthquakes, around magnitude 7, that occurred in Szechuan Province in August 1976. The briefing revealed how the massive state bureaucracy turns itself to the task of issuing a prediction.

The prediction process began with data from routine field monitoring about six years prior to the earthquake. Seismologists' studies of historical data showed that whenever a moderate or large earthquake occurred in one fracture zone of the area (called the Lungmenshan fracture zone), it was usually followed by a similar event in the Sungpan area of Szechuan. So on February 24, 1970, when a 6.25 earthquake occurred in the Lungmenshan area, an extensive program of seismic monitoring was begun. In November 1975 seismological workers submitted their opinion, based on this work, to the State Seismological Bureau in Beijing, concluding that an earthquake of greater than magnitude 6 might happen during the next six months in the Sungpan-Mouwen region. They had observed changes in the pattern of seismicity, in the velocity of seismic waves through the earth, in the tilt and level of the ground, in the radon gas content of groundwater, and in groundwater levels.

Later, in January 1976, this opinion was confirmed, and even closer monitoring was begun. In June 1976 further



The reception building of the Kailuan Coal Mine also collapsed.



The eight-story Hsin-Hua Hotel was badly damaged at the fifth-story level, but it remained standing. In the foreground is a six-story building that collapsed completely. The behavior of soft soil had an appreciable effect on the damage sustained by structures; that is, buildings located on thin soil, on thin layers of rock, or on thin layers of soil over rock did not exhibit the same degree of severe damage as buildings located on less firm soil.

data led seismologists to submit another report that stated there was a high probability of a greater-than-magnitude-6 earthquake in one to two months.

Following discussion and debate, the State Seismological Bureau gave permission to alert the local government, and the provincial revolutionary committee issued an "urgent announcement" that the earthquake was expected. In the affected regions, anti-earthquake commands were established, and professionals converged on the suspected source region with a variety of instruments. Along the Lungmenshan fracture zone, the number of observation posts manned by the masses increased rapidly from 280 in 1975 to 4800 just prior to the earthquake.

Finally, the accumulation of new data prompted the issuance in early August of earthquake reports stating that around August 13, 17, and 23 there would be earthquakes of greater than magnitude 7 in certain areas. Specific formulas provided the basis for predicting the dates and areas, but the NAS group was not given details. Apparently, though, the formulas were rules based on past experience that related a given precursor, such as radon content changes, fireballs, unusual animal behavior, and the like, to the expected time of the earthquake.

On August 11, 1976, the seismological bureau submitted an urgent report to the provincial revolutionary committee. Early on the morning of August 12, the committee issued a bulletin ordering an emergency alert and called for limited evacuation of women, children, and older people from their houses. Adult workers remained on their jobs. Four days after the order of the state of alert, on August 16, a magnitude 7.2 earthquake occurred, and on August 22 and 23 two other earthquakes occurred, though none of those were near a city. When asked if recordings had been made of the strong ground shaking, the seismologists said that Szechuan Province had no strong motion seismographs but that the adjoining province had some that had been installed at the boundary between the two provinces about 100 miles from the earthquake epicenter.

The most spectacular failure of the Chinese prediction effort was, no doubt, the failure to predict the massive Tangshan earthquake of July 28, 1976. At 3:24 a.m., the terrified residents of that industrial metropolis in northern China were jolted by the largest earthquake to hit a populated area in Chinese history. The earthquake, totally unanticipated by Chinese seismologists, killed hundreds of thousands — perhaps as many as three-quarters of a million — and transformed the once-populous city into a wasteland bleakly reminiscent of Hiroshima. More than 90 percent of the brick buildings and nearly 80 percent of the industrial constructions were either totally collapsed or seriously damaged. The sudden liquefaction of the soils in the area in the course of the shaking caused heavy damage.

Even more important than the failure to predict the earthquake was the failure to anticipate with stricter build-

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Roads were severely damaged by soil failure. Although all the usual manifestations of soil liquefaction occurred during the Tangshan earthquake, relatively little new information about the phenomenon came out of it, mainly because there were no strong-motion records of ground shaking in the regions where liquefaction took place.

ing code requirements that such an earthquake could occur in the area. Tangshan was zoned for earthquakes measuring no more than Intensity VI (on the Chinese Intensity Scale which, differing from the Richter Scale, measures reactions of people, structures, and so forth to the severity of the shaking), and the Tangshan earthquake was an Intensity XI.

But outside of the obvious failures and the obvious successes, it is difficult to pry from Chinese scientists much specific information on their overall record.

"The nagging question to me is how many failures and false alarms they have had," Clarence Allen says. "If you ask them, they say, 'very many.' The Chinese readily admit to many failures, and although they can rightfully claim a number of successful predictions, they do not yet claim to have a successful program of routine prediction."

Another question is whether the Chinese definition of "prediction" is the same as the U.S. definition.

"We were told that in one place in Szechuan there had been successful predictions of 17 out of 55 earthquakes," George Housner says. "However, the Chinese don't try to predict precisely the time and place of an event. What they do, I would call issuing an earthquake alert for a region."

Politics affect more than just the dissemination of information about their prediction effort. Housner discovered on his delegation's inspection trip of Chinese building sites that construction also suffers.

"An active building program is under way that is utilizing all available materials. The supplies of cement and steel are rather limited, so most buildings are brick. They are using everything they have, even adobe brick for small structures," says Housner. At one site he visited, the masonry was so poor the mortar could be crumbled with the fingers.

"I asked the building foreman why the workmanship was not better. He said that under the Gang of Four manual labor was exalted and respected, while intellectual concepts were demeaned. In construction practice this meant that the worker had increased authority and stature with respect to the engineer or inspector. If the inspector tried to disqualify work or refuse to accept poor materials or workmanship, the worker could disregard him."

Even considering the politicization of science and engineering in China, and the very different social systems between China and the U.S., can the two efforts toward prediction be usefully compared?

"Their earthquake prediction effort is certainly bigger — there's no question about that," says Allen. "But in many ways we feel that our program is more promising. The Chinese effort is terribly pragmatic.

"I think we feel that in this country in the long run the basic understanding of the phenomenon is critical to the development of prediction capability. And, thus, we have a much greater emphasis on instrumentation like seismographic arrays — sophisticated methods of really trying to understand what's going on down there.

"I do emphasize that the differences in the Chinese and U.S. programs to some degree reflect very basic differences in the needs of the two countries — in their social and political philosophies, and in the relative prosperity of the two countries. So, in this context, it would not be really fair to say that one program is necessarily better than the other.

"When we do become able to predict earthquakes on a routine basis, my hunch is that both the Americans and the Chinese will be able to look back and claim a fair share of the credit."

– by Dennis Meredith