

EARTHQUAKE PREDICTION IN JAPAN AND THE UNITED STATES

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Major earthquakes were predicted on both sides of the Pacific in Shizuoka Prefecture, Japan, and the state of California, the United States, at roughly the same time. These predictions differ from those made previously in that (1) the location, scale, and likelihood in a given timeframe have been specified; (2) the predictions for both regions have been taken seriously by the governments; and (3) there has been an unprecedented increase in earthquake concern among the area's residents.

In the present study, the American and Japanese reactions to these earthquake predictions are compared in terms of earthquake policy and the impact on residents' lifestyles.

Conclusions are that (1) there is a major difference in the time, money, and energy spent on earthquake policy, Shizuoka being far better prepared than California; (2) Tokai earthquake policy is premised on the assumption of short-term predictability, but California policy is not; and (3) Shizuoka residents are ahead of Californians in earthquake preparedness, but public earthquake awareness is growing steadily in California, and should be considerably enhanced in the near future.

Earthquake Prediction in Japan and the United States

The Tokai region in Japan and the state of California share a long history of major earthquakes causing considerable loss of life and property. The Tokai region, for example, has been

hit by at least 46 catastrophic earthquakes, from November 29, 684, Nankai-Seikaido Earthquake with an estimated magnitude of 8.4 on the Richter scale to January 14, 1978, Izu Oshima Kinkai Earthquake. Of the 46, 26 had their epicenter in the Tokai region, and three were magnitude 8 or greater.

California is equally earthquake-prone, and there have been fourteen earthquakes of magnitude 6 or greater since the nineteenth century. Seven of these have topped magnitude 7, and three magnitude 8 (Committee on Earthquake Engineering Research, 1983). Two of the strongest earthquakes occurred along the San Andreas Fault: the Fort Tejon Earthquake of 1957 along the southern side of the fault and the San Francisco Earthquake of 1906 on the fault's northern side. Now 130 years since the Fort Tejon Earthquake, experts believe that the region is due for a recurrence soon (California Department of Conservation, 1982).

Earthquake prediction involves the use of scientific tools to predict when, where, and how severe an earthquake is likely to occur so as to enable individuals and society to prepare for the event and thus minimize their losses. Seismologists, for example, classify earthquake predictions by stage, and the Tokai and southern California earthquakes are ranked as long-term predictions on this scale.

The History of Earthquake Prediction

Scientific earthquake prediction is a recent undertaking, with only a twenty year history in either Japan or the United States. In Japan, the need for earthquake prediction was impressed upon the government by the extensive damage resulting from the 1964 Niigata Earthquake and the 1968 Tokachi Oki Earthquake (Aki, 1978).

In the United States, seismologists recognized the need for serious study of earthquake prediction after the 1964 Alaska Earthquake. The spectacular damage resulting from this earthquake prompted federal government support for earthquake prediction technology (Wesson and Filson, 1981). This awareness was reinforced by the extensive casualties caused by the 1971 San Fernando Earthquake which convinced everyone of the importance of prediction in mitigating earthquake damage.

As part of this earthquake prediction effort in the United States, the Federal Disaster Assistance Administration has estimated that a magnitude 8.3 earthquake (the same magnitude as the Fort Tejon Earthquake) occurring in southern California at 4:30 in the afternoon would leave 14,000 people dead and another 55,000 seriously injured (Federal Emergency Management Agency, 1980).

Tokai Earthquake Predictions

The Tokai Earthquake Assessment Committee was established in April, 1977 to study emergency communication systems and what disaster-prevention agencies, government agencies, private businesses, and local residents should do in the event of an imminent earthquake warning in the Tokai region. The Committee's recommendations were then incorporated into the Large-Scale Earthquake Countermeasures Act enacted in June 1978 to go into force that December (National Land Agency, 1983). Today, the Tokai region has an unparalleled concentration of observation and detection equipment set to alert the area of an impending large-scale earthquake.

To provide financing for these measures, the National Diet enacted the Law for Special Measures to Cope with a Major Earthquake. This law, passed in May 1980 to be effective through March 31, 1985 authorizes government funding for all or partial costs of establishing evacuation routes and also establishing the renovation of public elementary and junior high schools to serve as refugee shelters in the 170 cities, towns, and villages designated as the Earthquake-prone Disaster Potential Region. During the five years of the Law's authorization (fiscal 1980 through fiscal 1984) the Japanese government disbursed ¥417.4 billion for such projects (National Land Agency, 1983), considerably more than spent on earthquake countermeasures by the state of California.

Scientific Predictions of a Southern California Earthquake

In the United States, steady progress has been made on organizing for scientific earthquake prediction. The Panel on the Public Policy Implications of Earthquake Prediction established by the federal government in April, 1974 published its report the following year. Still, the general public showed little interest in the possibility of a major earthquake occurring. The next year, (February 4, 1976), an earthquake rocked Guatemala killing more than 20,000 people and leaving another 200,000 homeless. Media coverage of this disaster aroused southern California's interest in earthquakes as nothing before had (Turner, Nigg, Paz and Young, 1980). The people of California awoke to the fact that they lived atop a major nest of earthquake activity.

A study of seismic activity at the San Andreas Fault--considered most likely to cause a major earthquake in southern California--found that there have been at least twelve major earthquakes there over the past 2,000 years. These earthquakes have occurred at 100-200 year intervals with the

average interval between earthquakes 140 years (California Department of Conservation, 1982).

The National Security Council has told the President that (1) there is a strong likelihood of a magnitude 8.3 earthquake's occurring in southern California between now and the end of the century, with the probability for any given year at two to five percent; (2) there is a greater than 50 percent probability of a major earthquake's occurring within the next 30 years; and (3) the heaviest casualties are likely to be in the Los Angeles-San Bernardino conurbation only twenty miles from the expected epicenter.

It should be noted here that there are two earthquake prediction agencies in California: the California Earthquake Prediction Evaluation Council--reporting to the Director of the state's Office of Emergency Services--and the National Earthquake Prediction Evaluation Council--reporting to the Director of the United States Geological Survey. These two agencies are, of course, in constant communication, but they put out their earthquake predictions as completely independent organizations (Seismic Safety Commission, 1982; Davis and Somerville, 1982). If the two arrived at conflicting conclusions, it would be up to the disaster-prevention authorities to decide which one to believe. This situation is compounded by the fact that the Governor of California and the local authorities are all given discretionary authority over what to do about earthquake warnings. Thus, there is a much greater danger of confusion in California than there is in Japan where the national, prefectural, and local governments are integrated into a single line of command.

Earthquake Policy

Earthquake Policy in Shizuoka Prefecture

Shizuoka Prefecture has made the Tokai earthquake damage estimates public (Miyagawa, 1981). Admitting that the damage from the Tokai earthquake would extend far beyond Shizuoka's prefectural boundaries, the official estimates are for 10,900 dead, 16,700 seriously injured, and 98,300 slightly injured in the prefecture. The actual figures would probably be much higher, because it excludes the traffic casualties from highways and "the Shinkansen (the bullet train)" in the prefecture for the reason that they are unpredictable.

To acquire the preliminary data needed to formulate earthquake policy, Shizuoka Prefecture has done geological surveys, tested buildings ability to withstand earthquakes, studied traffic

patterns, mapped dangerous concentrations of inflammable and toxic materials, and made surveys of human behavior during earthquakes. The Prefecture found that five percent of its public buildings needed to be rebuilt, twenty percent required immediate repair and reinforcement, and 40 percent should have repairs as quickly as possible.

Shizuoka Prefecture has divided its earthquake policy into "hardware" aspects (earthquake-proofing buildings and other facilities and creating an earthquake-safe environment) and "software" aspects (establishing advanced warning communication systems, promoting disaster-prevention organizations, and heightening public awareness of what to do in case of disaster) with the immediate emphasis on the "software" aspects. One of the first things the Prefecture did was to beef up the radio communications by including radio links with outlying prefectural agencies as well as with cities, towns, and villages to speed the dissemination of short-term predictions and emergency warnings and to facilitate information feedback.

The second step was to organize Jishubou groups (the neighborhood disaster-prevention organization) of 300 households (1,000 people) for fire-fighting, rescue, and evacuation work in the event of an earthquake. The prefectural and local governments provide support to these groups in the form of disaster-relief training and financing for emergency food stockpiling and so on.

Finally, Shizuoka Prefecture has made a considerable effort to heighten popular awareness of the danger of the Tokai earthquake. Working primarily through the media and the Jishubou disaster-relief groups, the prefecture has distributed extensive information about earthquakes and their impact. Yet even though Shizuoka has made considerable progress in earthquake policy "software," there is still much to be done on the "hardware" side.

Earthquake Policy in California

Legal framework for earthquake policy. California has drawn upon Shizuoka's example in many areas of its earthquake policy. Numerous earthquake policy study groups have come to Japan to see what is being done in Tokyo, Shizuoka, and other areas. They have met with Japanese earthquake policy officials, seismologists, and disaster researchers to learn about Japanese efforts to anticipate and mitigate the damage from the Tokai earthquake. Before going into a detailed comparison of earthquake policy in California and Shizuoka, it would be well to explain the legal framework for California policy.

In the wake of the 1933 Long Beach Earthquake, which

destroyed many of the district's schools, the state legislature passed the Field Act requiring that all public elementary and secondary schools in the state be earthquake-proof. The Field Act has proved highly effective in reducing the amount of earthquake damage suffered by California public schools. In 1970, the California Emergency Services Act was passed requiring the state to protect its citizens' lives and property from ravages of war, natural disasters, and pollution. It is this Act which provides the legal basis for California's earthquake policy.

The 1971 San Fernando Earthquake destroyed the Veteran's Hospital and badly damaged the newly built Olive View Hospital. The next year, 1972, the California legislature passed the Hospital Seismic Safety Act requiring all new hospitals to be sufficiently earthquake-proof that they remain functional even after an earthquake. New hospitals are checked in the design stage before construction permits are issued, and the state may mandate earthquake-proofing repairs on older hospitals as necessary.

In addition to this state legislation, there are federal laws designed to help state and local governments respond to an earthquake. The 1974 Disaster Relief Act provides financial assistance to state and local municipalities in the case of disaster. Likewise, the 1977 Earthquake Hazard Reduction Act empowers the Federal Emergency Management Agency to draw up and implement a National Earthquake Hazard Reduction Program to minimize the danger to life and property in the event of an earthquake.

One of the main differences between Shizuoka and California is that the California state government is authorized to issue earthquake predictions and earthquake warnings. It is entirely up to the governor to decide whether or not an earthquake prediction warrants issuing an official warning or declaring a state of emergency. Local governments within the state also have considerable discretionary latitude.

By contrast, the national, prefectural, and local governments' responses to a Tokai earthquake prediction are integrated into a single chain of command under Japan's Large-scale Earthquake Countermeasure Act. An earthquake warning from the Tokai Earthquake Assessment Committee would quickly become an official warning from the Prime Minister, setting into motion predetermined policy programs at the national, prefectural, and local level. There is little or no provision for local discretion.

California earthquake policy administration structure. California has two organizations for implementing earthquake policy--federal and state. At the state level are the Governor's Office, the California Earthquake Prediction Evaluation Council, the Office of Emergency Services, the California Division of

Mines and Geology, the Seismic Safety Commission, and the California Emergency Council. At the federal level are the United States Geological Survey and the Federal Emergency Management Agency. The USGS was established in 1879 to study and predict geological disasters and to work out effective countermeasures. Today, earthquake data is carefully reviewed at the USGS monthly and survey data and research results are gone over by the informal Southern California Review Group every six months. The USGS director is authorized to issue earthquake warnings and other directives as necessary, provided he reports to the director of the Federal Emergency Management Agency first.

Established 100 years later in 1979, the Federal Emergency Management Agency (FEMA) is charged with coordinating the federal policy response to an emergency. In case of an earthquake, the FEMA is responsible for managing federal earthquake policy, drafting and implementing emergency relief programs, providing financial and technical assistance for state and local governments, and promoting disaster research. In addition, the FEMA is the center for disseminating information, issuing reports, coordinating relief activities, and otherwise crisis-managing national, state, and local disaster-relief efforts.

Earthquake policy spending in California. California spent rather little on earthquake policy in the five years from fiscal 1977 through fiscal 1981, but the fiscal 1982 start of the five-year plan for improving earthquake preparedness marked a sudden increase bringing the earthquake policy budget to an average of U.S.\$144 million per year. This is an approximately tenfold increase over the average for the preceding five years (U.S.\$15 million per annum) and is indicative of the growing importance placed by the state on earthquake policy.

The federal government has also spent heavily on earthquake policy--but still not nearly as much as the Japanese government has spent getting ready for the Tokai earthquake. The September 2, 1984 New York Times quotes California Seismic Safety Commission Director Richard Andrews as saying that combined federal and state spending on earthquake preparedness in California has averaged U.S.\$65 million a year. This contrast with U.S.\$1.7 billion spent by the Japanese government on the Tokai earthquake alone.

Social Impact of a Large-Scale Earthquake Prediction

Initial Predictions

The first prediction of a Tokai earthquake was made in August,

1976 and this was later confirmed that October in testimony before the Diet's Standing Committee on the Budget. When this prediction was announced, it was widely assumed that the threat of impending disaster would have major social, economic, political, and other repercussions--both tangible and intangible--in the 170 cities, towns, and villages in the area (Shizuoka and neighboring prefectures) designated as the Earthquake-prone Disaster Potential Region.

Yet several years after the predictions were announced, a conference of scholars, media people, government officials, and businessmen was held to discuss the socioeconomic impact of the Tokai earthquake prediction, but failed to discern any clear-cut pattern. Lacking concrete data, conference participants (this author included) were reduced to subjective arguments based on gut feelings.

What of California? Haas and Miletic (1976) state that any viable prediction of a major earthquake's occurring in a few months or years is certain to create considerable confusion in the affected region. Such dire predictions, however, are based for the most part on unconfirmed assumptions. Any attempt to scientifically analyze the social impact of earthquake prediction must be preceded by an effort to gather as much objective information as possible and to define the relevant indices. It is in realization of this need that there must be continuing studies of the social impact of earthquake predictions in the Tokai and southern California areas.

Impact on Residents' Lifestyles

The Tokai and southern California earthquakes are both still at the long-term prediction stage, and the people's earthquake-consciousness and response patterns are not the same as they would be for a short-term prediction. As the probability of an imminent earthquake increases, residents may be expected to be more earthquake-conscious and to respond differently. Nevertheless, anything which can be learned about residents' reactions at this stage is meaningful not only because of what it tells us about a long-term prediction's impact on the community, but also because it may be possible to extrapolate the probable reaction to a short-term prediction from these data.

The author conducted a four-wave panel survey of local residents in the Shizuoka region (asking basically the same population the same questions on four different occasions to track their earthquake-consciousness and -preparedness). The survey population was randomly selected from adults listed on the town registers.

The first survey of 1,300 people in August 1980 had 1,018 respondents, of whom 668 answered the second survey in February 1981. The third survey in October 1981 drew replies from 827 of the first wave's 1,018 respondents, and the fourth wave in August 1983 drew 684 respondents. All told, 474 persons responded to all four waves. Table 1 gives the number of people responding to each of the four waves and the six response patterns discerned.

As may be seen from Table 2, 56 percent of the respondents referred to earthquakes in one form or another when asked what the three most important problems facing residents of their area were. Of course, this question could indicate earthquakes several times, but the overwhelming concern with earthquakes is nonetheless remarkable.

Turner's group (1979) conducted a similar survey of southern California residents. Of the 1,450 respondents, 1,409 referred to more than one concern, but only two percent referred to an earthquake. From these data, it would appear that the possibility of an earthquake is very much on the minds of Shizuoka residents but is a very minor concern in southern California.

Another question in the four-wave panel survey asked, "Compared to other sections of Japan, do you consider this area a more or less hazardous place to live in?" Responses were fairly equally divided among the three possible answers of "more hazardous," "about the same," "less hazardous." In California, the respondents to a similar question in Turner's survey were twenty percent more hazardous, 42 percent about the same, and 30 percent less hazardous than the rest of the United States. A comparison of the two surveys shows that, while the percentage

Table 1: Response Pattern for Four-Wave Panel Survey.

	Wave Number				Number of Respondents
	One	Two	Three	Four	
	X				99
	X	X			92
	X		X		77
	X	X	X		102
	X		X	X	174
	X	X	X	X	474
Number of Respondents	1,018	668	827	648	

responding "less hazardous" was about the same in the two areas, more Shizuoka residents replied "more hazardous" (and fewer "about the same") than in California. In other words more Shizuoka residents than southern California residents believed that they live in an especially hazardous area.

When asked why they felt their area was more hazardous, one-third of Shizuoka residents said they feared an earthquake. In Turner's survey, only seven percent of the residents who said their area was more hazardous said it was so because of the possibility of an earthquake. Again, this indicates less earthquake-awareness in California than in Shizuoka.

Table 2: Concerns of Tokai District Inhabitants. Percent (N=1,018).

Question: We would like to know what, in your opinion, the three most important problems facing residents of this area are today?

	Percent
1. Earthquakes in general	7
2. Earthquake swarms	3
3. Earthquake damage	3
4. Earthquake predictions	1
5. Official earthquake relief measures	3
6. Individual countermeasures to earthquakes	0
7. Highway and rail traffic accidents	17
8. Tourism	12
9. Youth problems	5
10. Renovation and extension of school buildings	7
11. Agriculture and fishing industries	1
12. Commerce	1
13. Public facilities	4
14. Environmental control	24
15. Prices	15
16. Housing problems	3
17. Medical ethics	2
18. Human relations	3
19. Others	3
20. Crime	1

This does not mean, however, that California residents are oblivious to the possibility of an earthquake. In response to the question carried out in 1971, "Which of these possible disasters do you most fear?" earthquakes consistently ranked among the main disasters respondents selected from the list. In both California as a whole and Los Angeles as representative of southern California, the people cited earthquakes third, after air pollution and riots, among the most-feared catastrophes (California Field Poll). There is obviously a latent, and gradually surfacing, fear of earthquakes.

Table 3 shows how Californians' attitudes have changed over the past few years. When asked what they thought the probability was of an earthquake's occurring in their area, more people in southern California--and indeed in all of California--thought that a major earthquake was more imminent in 1983 than in 1979. When asked what precautions they would take if a major earthquake were predicted, the number of California residents responding that they would put in stores of food, drinking water, and other supplies more than doubled in the four-year interval (32 and thirteen percent in 1983 and 1979, respectively), and there was a slight decline in the number saying they would not do anything (eighteen and 27 percent in 1983 and 1979, respectively) (California Field Poll). While its development has been slow, there is a discernable increase in earthquake preparedness in California.

Getting back to Shizuoka, residents were queried in all four waves of the panel survey on the specific steps they were taking to prepare for an earthquake. These results are given in Table 4, which shows the changes in earthquake preparedness among residents. A plus sign (+) or a minus sign (-) is assigned to each category of preparedness which has shown the increase or the

Table 3: Cognition of the Likelihood of Major Earthquake Occurring in Their Town (California Field Poll). Percent.

	Los Angeles/ Orange County		Statewide	
	1983	1979	1983	1979
Extremely or very likely	57	46	55	41
Somewhat likely	27	30	28	32
Not too or not at all likely	9	16	11	22

Table 4: Earthquake Preparedness of Tokai District Inhabitants.

Question: How accurate do you think today's scientists can predict big earthquakes such as the Tokai earthquake?

	First Wave	Second Wave	Third Wave	Fourth Wave
1. Storing dangerous objects in safe and stabilizing furniture	31	41+	42+	44+
2. Keeping an emergency supply kit	31	32+	34+	32-
3. Keeping a supply of fresh water	31	32+	34+	32-
4. Keeping fire extinguishers and other fire equipment	50	49-	57+	60+
5. Storing medical supplies and protective wear	45	46+	51+	54+
6. Keeping an emergency supply of food and drinking water	45	46+	51+	54+
7. Bought or increased earthquake insurance	19	23+	22-	26+
8. Fortified or remodeled roof, walls, fences, etc.	5	5	10+	8-
9. Made plans for where to go and what to do in an emergency	35	44+	48+	52+
10. Made plans for getting in touch with other family members during an emergency	21	26+	33+	33
11. Took part in earthquake emergency drills	34	35+	48+	52+
12. Try to avoid being in dangerous areas	22	19-	22+	22
13. Keep an ample supply of cash on hand	6	7+	8+	10+
14. Others	1	3+	1-	3+
Number of plus signs		11	12	8
Number of minus signs		2	2	4

decrease since the previous survey and their totals are tallied for the table. As can be seen, eleven categories received pluses in the second wave (denoting the increase in eleven categories of preparedness between survey waves one and two), twelve in the third survey, and eight in the fourth survey. The increase in preparedness thus slowed somewhat between the third and fourth waves. In this, the Shizuoka question about what actually had been or was being done differed from the California question about "What would you do if ..." Generally speaking, in people's responding behavior to a questionnaire, the precautions they would take in the future would be more inflated than the preparedness which have been done actually. Nevertheless, a comparison of the responses to the two surveys reveals that Shizuoka residents are far better prepared for an earthquake than Californians are (Hirose and Ishizuka, 1983; Hirose, 1985).

At the same time, there has been a slight but definite change in the attitude of Shizuoka residents toward the reliability of scientific earthquake prediction, as seen in Table 5. Asked how accurately they thought today's scientists could predict big earthquakes such as the Tokai earthquake, a majority responded "not very accurately" or "cannot" in the first two waves of the survey. The ratio was reversed, however, by the third and fourth waves indicating a growing faith in the reliability of scientific earthquake prediction.

In summary, Shizuoka residents are several steps ahead of Californians in earthquake preparedness. But public awareness of the danger of an earthquake is growing steadily in southern

Table 5: Accuracy of Tokai Earthquake Prediction. Percent.

Question: How accurately do you think today's scientists can predict big earthquakes such as the Tokai earthquake?

	First Wave	Second Wave	Third Wave	Fourth Wave
Very accurately	2	2	3	4
Somewhat	46	40	50	50
Not very accurately	36	33	33	32
Cannot	14	18	8	12
D.K. N.A.	2	6	6	2
Total	100	100	100	100

California, and their preparedness should be considerably enhanced in the near future. Should the predicted earthquake occur, the damage will be considerably greater in Shizuoka, where large numbers of people live in wooden houses crowded along narrow roads abutting on petrochemical plants. This is, thus, no time for Shizuoka to be complacent, and even more determined efforts are needed to further enhance the level of earthquake-preparedness. Happily, steady success of any earthquake policy depends on how long the residents of the threatened region and government authorities can maintain their heightened awareness and preparedness.

Social Impact of Predictions of an Imminent Major Earthquake

Earthquakes were predicted on both sides of the Pacific, in Shizuoka Prefecture and California, at roughly the same time. The circumstances surrounding these predictions differ somewhat from those made previously in that (1) the location, scale, and likelihood in a given timeframe have been specified; (2) the predictions for both regions have been taken seriously by the governments concerned, and legal framework established for funding earthquake policy heavily; and (3) there has been an unprecedented increase in earthquake-consciousness and concern among the areas' residents. Sharing a common desire to minimize the damage from an earthquake, seismologists, administrative authorities, and local residents are making unprecedented efforts to prepare for one. It is impossible to overestimate the importance of the prediction for both the people and their governments.

As noted above, the American and Japanese reactions to these earthquake predictions differ widely. Most significantly, there is a major difference in the time, money, and energy spent on earthquake policy. The Tokai region is far better prepared for an earthquake than southern California in several respects. Another major difference is in the attitudes of seismologists and earthquake policy administrators toward the question of whether or not an earthquake is predictable. Tokai earthquake policy is premised on the assumption of short-term predictability, but American seismologists question this premise at present.

At the same time, there is relatively little social pressure on seismologists to make accurate earthquake predictions in the United States. Conditions are quite different in Japan, which has six times California's population in roughly the same amount of space. The population density in the Tokai region, in particular,

is considerably greater than in southern California and a major earthquake in this area would be devastating. If short-term prediction is possible, however, much of the damage can perhaps be avoided. The Japanese people are convinced that only short-term prediction can save the Tokai region, and this conviction has spurred Japanese seismologists and disaster-prevention agencies to seek greater precision in their predictions. In California, the emphasis is on what to do after an earthquake; in Japan, it is on what to do before one.

While it is difficult to ascertain the full significance of earthquake prediction, it is clear that scientific prediction is one step on the long path to managing those incredible outpourings of earthquake energy that were once considered "acts of God." The day may come when earthquakes will no longer be able to inflict mortal wounds on society, and it is the people's faith in science--as demonstrated and justified by accurate earthquake prediction--which will help to make this dream come true.

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