Preparing for the Unexpected

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Living in California means living with earthquakes. During the last decade alone we have experienced several damaging earthquakes, some of which have come as big surprises. We were surprised by earthquakes without surface break, surface break without much seismic radiation, and a south-dipping fault in an area of primarily north-dipping structures. Why were we taken by surprise? We were surprised primarily because the duration of our data base is so short compared with the time scale of earthquake recurrence that our knowledge is very limited.

Since the time is very limited today, let me focus our attention on Los Angeles.

Thanks to the recent advances in geophysics, geology and seismology, we now have a much better understanding of the tectonic framework of California than decades ago. As we heard in this morning's presentations, it is fair to say that the existence of the tectonic structure characterized by the Transverse Ranges suggests that it is likely that large earthquakes will occur near Los Angeles in the future. Although the probability that such an event will occur soon is probably small, if such an event occurred, its consequence can be very serious because of its proximity to a large metropolitan area, Los Angeles. A similar situation exits for other cities of the world, such as San Francisco, Seattle, Tokyo, Teheran, Mexico City and Wellington. Unfortunately, despite the advances in science it would be naive to think that we will be able to predict such an event reliably and accurately on a time scale of days, months, and even years. The occurrence of earthquakes is controlled by many factors, and it would be impossible to understand every one of them and to make a deterministic prediction.

One might say that since the probability of such a large earthquake is so low that we can simply ignore it. This might be an acceptable strategy in a hazard reduction program which deals with events with a moderate consequence. However, if the consequence of the event is extremely grave, I feel it prudent to give serious thought to a low-probability event.

Since we are talking about a very rare event, we do not have much data with which we can accurately predict what will really happen. If we cannot make predictions on the basis of existing data, what can we do? Then we must resort to a "deductive" approach in which we use some theories or inferences drawn from something familiar. In science, we take this approach frequently, often with a good success. In engineering practice, however, people seem to be reluctant to take such an approach, probably because of conservatism and difficulty in convincing their clients of the validity of such a deductive approach. This is understandable; such conservatism may be inevitable in dealing with the real world rather than academia. Under these circumstances, an empirical approach is more common in practice. However, if we are to worry about a low-probability event with a potentially serious consequence, I feel that a deductive approach is important.

Going back to the topic of large earthquakes in Los Angeles, we have not experienced such a large earthquake in the history of Los Angeles. What do we know about it? Of course we know very little about it, because it has not happened yet. However, we do know how earthquakes occur. As we heard this morning, a fault would slip a few meters in a few seconds and would radiate large seismic waves in phase causing a large strain pulse. This strain pulse could have very significant effects on large structures. Should this earthquake occur, would the rupture come to the surface? We do not know, but since the recent Northridge earthquake did not break the surface, one may think that a large earthquake in Los Angeles may never come to the surface. Damaging earthquakes without surface break are no longer a surprise in some parts of California. However, it is also true that there are many instances elsewhere in the world where fault rupture went through the surface sediments when the event was large enough. Thus it is not unlikely that the large Los Angeles earthquake we are talking about may break the surface sediments, exciting significantly larger surface waves than the Northridge earthquake. We should be open minded about this, and we should not be too surprised if such an event were to break, or not break, the surface. We must live with this kind of uncertainty.

Of course, all of these matters need further studies, but with the development of modern instrumentation, seismographic network, telemetry, GPS, etc., I believe that we will be able to prepare ourselves much better in many different ways. For example, by developing a reliable real-time information system and better engineering practice; we will be able to make rapid progress through the studies of not only southern California but also other parts of the world in a broader geophysical context. With this approach we will have fewer surprises in the future and will be able to be better prepared for the inevitable earthquake hazard in Los Angeles.

In summary, seismology is a young science, and the data base is very limited. I do not think it wise to prepare for future seismic hazards in California by relying entirely on an empirical approach with a meager data base. Our approach should not be limited to a very narrow geographical region; we should investigate the process in a broader geophysical context. We should fully utilize the knowledge we gained from the studies of large earthquakes elsewhere and from time-tested, good theories to estimate what will happen in the future and to communicate the results to engineers. Needless to say, engineering has more direct relevance to seismic hazard reduction practice than seismology, but seismologists can provide critical information to engineers regarding what to prepare for.

The most effective way to transfer knowledge from seismologists to engineers is through close interaction and extensive discussion. Today is certainly a very memorable occasion where seismologists, geophysicists, geologists, academic engineers and practicing engineers have gathered together to talk about these important issues that must be addressed to develop comprehensive hazard reduction measures for Los Angeles.

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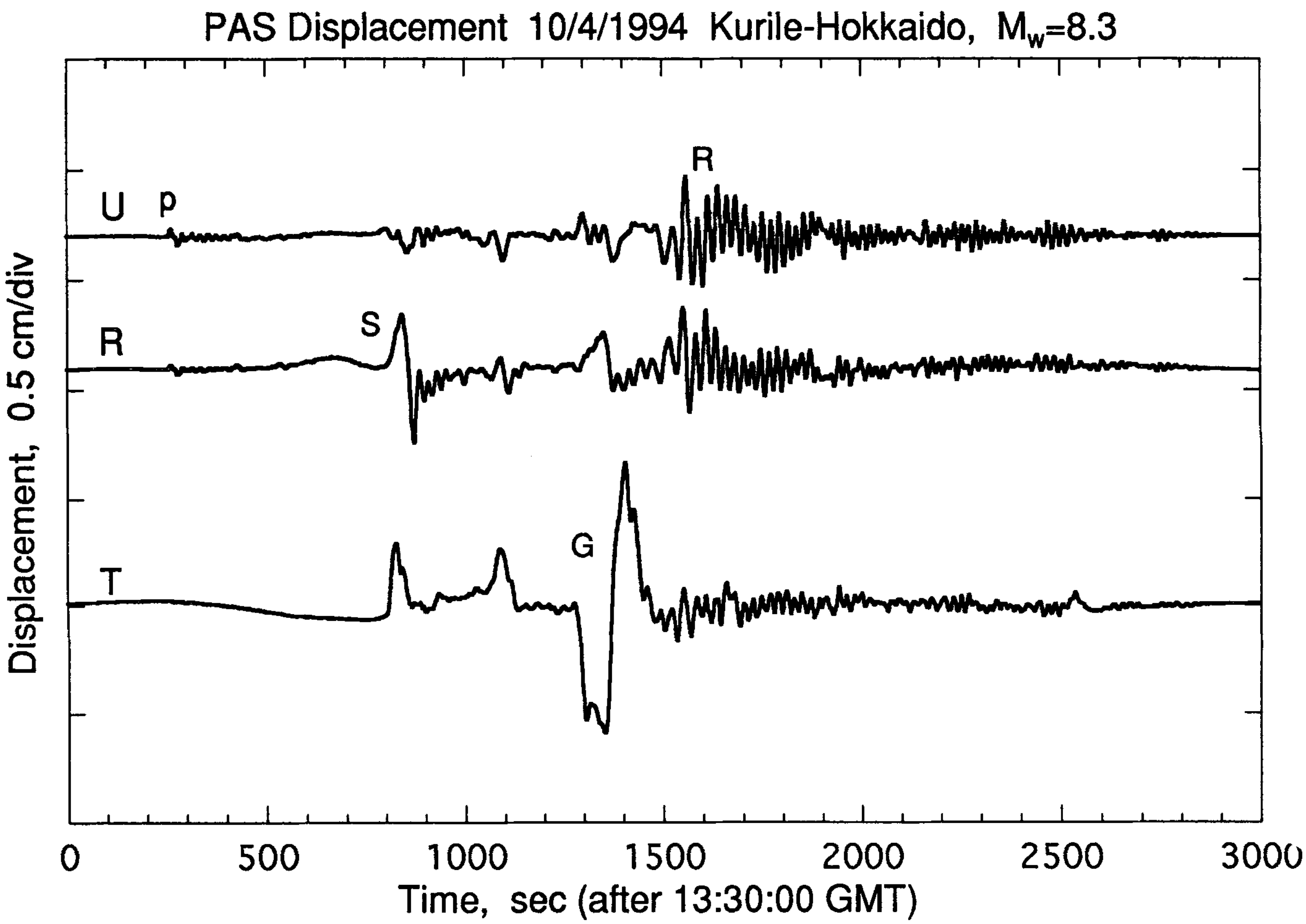

The displacement of $M_w = 8.3$ earthquake in the Kurile Islands (October 4, 1994) recorded at the Pasadena TERRAscope station. The amplitude of the long-period G wave is almost 1 cm. For interplate thrust earthquakes in the Kurile subduction zone, both Love and Rayleigh waves are close to nodal at most stations on the west coast of U.S. The large G wave suggests that, despite the large M_w, this earthquake is not a typical plate boundary earthquake but is an intraplate lithospheric event.

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