A New Scenario Earthquake for Southern California Based on the January 17, 1994, Northridge Earthquake

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SYNOPSIS: Prior to the M 6.8 Northridge, California, earthquake, the two principal scenarios for Southern California were based on a recurrence of a great earthquake (M 8.25) on the San Andreas fault system and a moderate earthquake (M 6.5) on the Newport-Inglewood fault zone. Like the January 17, 1994, Northridge earthquake, the new scenario event--a blind thrust fault beneath Los Angeles--is expected to generate very high levels of ground shaking (acceleration, velocity, displacement, spectral response) in the epicentral region, trigger ground failure over a wide area; cause extensive damage to the built environment; and test all aspects of the earthquake risk management systems in place in Southern California.

BACKGROUND

Until 1994, earthquake scenarios for the greater Los Angeles area (Figure 1) focused mainly on two fault zones:
1. The San Andreas fault, located more than 50 km (30 miles) northeast of downtown Los Angeles, which generated the M 8.25 Fort Tejon earthquake in 1857, and
2. The northern segment of the Newport-Inglewood fault zone west of the city which generated the 6.5 Long Beach earthquake in 1933.

Three earthquakes: the M 6.5 San Fernando earthquake of February 9, 1971 which occurred on the Sierra Madre thrust fault, the M 5.9 Whittier-Narrows earthquake which occurred on October 1, 1987 on a shallowly north-dipping blind thrust fault just east of downtown Los Angeles, and more recently the M 6.8 Northridge earthquake located 28 km (18 miles) from downtown Los Angeles have focused attention on structures known since 1976 as blind thrust faults. They are called "blind" because they are almost invisible at the earth's surface. These blind thrust fault systems are now the basis for a third earthquake scenario--a M 7.0 earthquake on a blind thrust fault beneath Los Angeles. Although such an earthquake would occur much less frequently than the M 8.25 scenario on the San Andreas or the M 6.5 earthquake on the Newport-Inglewood fault system, it would be more damaging because of its location beneath the city.

Fig. 1. Photograph showing elements at risk in the Los Angeles area.

TECTONICS AND OUR KNOWLEDGE OF WHAT HAPPENED IN THE NORTHRIDGE EARTHQUAKE

The geologic dilemma is locating these blind thrust faults and characterizing their seismic activity. Because the faults do not reach the surface, geologists have to search for other clues using geophysical and geodetic techniques to locate them. They are the result of millions of years of north-south compression caused by the big bend in the San Andreas fault which marks the boundary of the southward moving North American and northward moving Pacific tectonic plates (Figure 2). The Transverse Ranges, a web of thrust faults, many which are buried beneath the surface, and a series of buried folded sedimentary rock are results of these continuing compressional forces.

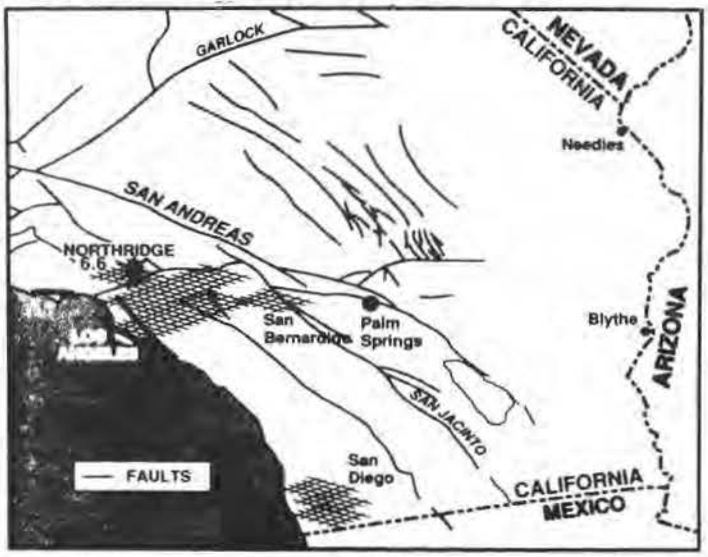

Fig. 2. Location of Northridge Earthquake of January 17, 1994 and major fault systems exposed at the surface. The area is under north-south compression. Los Angeles is underlain by a complex web of blind thrust faults.

PROPOSED NEW SCENARIO

Four of the dozen or more blind thrust fault systems underlying the greater Los Angeles area have been identified as active and the source of potentially damaging earthquakes. They are:

1. Elysian Park thrust system (EPTS) - a system of shallowly north- and southeast-dipping blind thrust faults that extend from Orange County in the southeast, through downtown Los Angeles, westward beneath the Santa Monica mountains along the Malibu coast.
2. Sierra Madre-Cucamonga fault system (SM-CFS) - this system extends along the southern mountain front of the San Gabriel mountains for 100 km (60 miles) from the San Jacinto fault near Rialto westward to the northern edge of the San Fernando Valley. The western most 19 km (11 miles) of the SM-CFS ruptured during the M 6.5 San Fernando earthquake on February 9, 1971.
3. Compton-Los Alamitos thrust fault (C-FAFS) - this system extends more than 45 km (27 miles) from Los Alamitos in Orange Country north-north westward to the Baldwin Hills area, and possibly further to the southern flank of the Santa Monica mountains.
4. Oak Ridge fault system (ORFS) - this south dipping thrust fault extends for more than 70 km (42 miles) from south of Ventura where it trends offshore to at least the eastern end of the Santa Clarita River valley. The previously unrecognized eastern extension of this fault system ruptured in the Northridge earthquake.

TECHNICAL ISSUES

One of the major technical issues is, "Do these fault systems rupture in sections as a series of moderate-magnitude (M 6.0-6.5) earthquakes, or could the entire thrust fault system rupture at the same time, generating a very large-magnitude earthquake (M 7.0-7.5? The answer is not clear, at present.

Some people are now referring to the web of blind thrust faults beneath Los Angeles as the "Tranverse Ranges Compressional Zone." Fifteen years of geologic and seismological data in the region indicate that California has a "seismic deficit," i.e., only one-third of the earthquake expected on the basis of the strain accumulation due to the movement of the Pacific and North American plates has happened. The question is, "Where are the missing earthquakes?" The region could be due for at least five more Northridge-size earthquakes, or one large earthquake of M 7.5 to 8.0. Only one M 8.0 earthquake would be needed to release the energy of 30 M 7.0 earthquakes.

POTENTIAL IMPACTS

The Northridge earthquake, scaled for distance and magnitude, can be used to estimate the minimum consequences of the new hypothetical scenario earthquake The most costly earthquake disaster in history, the Northridge earthquake:

- impacted 580,000 people
- caused losses estimated at $25 billion with insured losses exceeding $6 billion
- killed 63 and injured at least 10,000
- damaged 1000's of wood frame buildings and 100's of steel frame buildings, the two most earthquake-resilient building materials.
- collapsed freeway interchanges and portions of the road beds of 11 road systems.
- caused nonstructural damaged approximately equal in cost to the aggregaate direct damage to hospitals, schools, and universities
- ruptured pipelines, triggering fires, flooding, and explosions
- disrupted water supply
- knocked out electrical power over the entire area affecting 3.5 million people
- generated strong ground motion accelerations reaching 1.8 g horizontally and vertically and velocities reaching 170 cm/sec in some locations
- produced thousands of aftershocks
- caused permanent vertical uplift of 40 to 50 cm in San Fernando valley and horizontal displacements of 2 to 20 cm
- triggered landslides on unstable slopes
- disrupted commuters and school children for weeks to months
- forced the evacuation of hospitals
- adversely impacted small businesses and the fragile economy of the region

The effects of the hypothetical scenario earthquake would be expected to be worse than those of the Northridge earthquake, depending on location, time of day, and the degree of preparedness in place when it happens. Such an earthquake scenario, however, would be expected much less frequently than either the M 8.25 San Andreas or the M 6.5 Newport-Inglewood scenarios. The possibility of a tsunami also exists. Had the epicenter of the Northridge earthquake been 50 km (30 miles) further to the west, one may have been generated on January 17.

CONCLUSIONS

The Northridge earthquake was a "wake-up call" for Los Angeles. It demonstrated the need to identify and understand the web of seismically active blind thrust faults underlying the greater Los Angeles area and to incorporate knowledge about them and the physical and societal impacts of the Northridge earthquake into a realistic new earthquake preparedness scenario to complement other scenarios.

REFERENCES

Earthquake Engineering Research Institute, 1994, Northridge Earthquake January 17, 1994, Report 94-01, Oakland, CA, 104 p.

United States Geological Survey, 1985,. Evaluating Earthquake Hazards in the Los Angeles Region- An Earth-Science Perspective, Professional Paper 1360, Government Printing Office, Washington, D.C., 505 p.