Earthquake of April 24, 1984, in central California (variously named Mt. Hamilton, Halls Valley, or Morgan Hill).

The following descriptions have been selected from input from Bruce A. Bolt (U.C. Berkeley), Bob Bruce (Degenkolb), Charles Scawthorn and Gilles Bureau (Dames and Moore), R. Gordon Dean (Degenkolb) and A. Gerald Brady (USGS). To these, and to those they have acknowledged, our thanks.

SEISMOLOGICAL ASPECTS

On April 24, 1984, slip along about 28 km of the Calaveras fault (see Figure 1) between Halls Valley and Anderson Lake produced a large earthquake of Richter magnitude $M_L = 6.2$ (Berkeley station). The shaking was felt widely in central California, from Fresno to Sacramento, and strongly in some parts of the San Francisco Bay Area, with damage in the melsosismal area. It was the fourth earthquake with $M > 6.0$ to have occurred in the region since the great 1906 earthquake on the San Andreas fault.

The origin-time of the main shock was 1:15 p.m. local time (211510.02 UTC) and its epicenter was $37^\circ 39.23' W$ and $121^\circ 41.86' W$ with focal depth about 8 km. The recorded strong ground motion in the earthquake is of key importance in studies of near-field motions. The higher accelerations were recorded south of the epicentral area, consistent with the damage to modern wood-frame houses in the vicinity of Anderson Lake and the city of Morgan Hill. Generally, however, modern timber-frame houses were not damaged in the earthquake and the maximum Modified Mercalli intensity probably did not exceed VIII. The nearest accelerometer in Halls Valley, about 5 km from the epicenter, showed a peak horizontal acceleration of 0.31g.

A Richter magnitude 5.2 for the principal earthquake was assessed from a torsion seismograph of Wood-Anderson type operated at the University of California at Berkeley.

The Calaveras fault is right-lateral strike-slip, with a dip of a few degrees to the east and a strike of N 26° W in this region. The rupture was a dislocation moving from the focus to the west of Mount Hamilton southwards to Anderson Lake, or perhaps beyond, a total distance of about 25 km.

The mainshock was widely felt in central California and caused alarm at distances as far as Berkeley (50 km) and San Francisco (50 km from the focus). Most of the damage reported occurred to the south of the mainshock towards Morgan Hill. In the city of San Jose, only 5 km from the seismic source on the Calaveras fault, little damage was reported. The maximum Modified Mercalli intensity assessed in the vicinity of the Jackson Oaks new housing tract, where some walls with cripple studs collapsed in timber-frame houses, might be placed at Modified Mercalli VIII. No lives were lost in the earthquake.

There is an indication in this earthquake that the southward movement of the fault dislocation had an effect on the intensity of the seismic waves, producing higher intensity to the south than to the north. Such a focusing is predicted by the theory of the directivity of a moving wave source in a similar, but not quite identical way, to the Doppler effect in acoustics. The peak horizontal acceleration measured in Halls Valley of 0.31g near the epicenter of the mainshock is higher than the peak horizontal acceleration of 0.25g recorded near the epicenter of the Coyote Lake earthquake in 1979. The largest acceleration recorded in the earthquake appears to be that at Coyote Dam about 30 km to the south of the epicenter where peak horizontal motion of 1.3g was recorded on one horizontal component. The Gilroy array, which traversed the Calaveras fault zone in a region where surface faulting was noticed in the 1979 earthquake, produced accelerations of about 0.3g horizontal. To the north of the epicenter, accelerometers generally showed much lower ground accelerations in San Jose. In Hayward, the motions had a maxima of about 0.05g. A study of the overall set of strong ground motions from this moderate earthquake is likely to throw light on the near-field shaking from moderate seismic sources and answer questions on the importance of directivity, focusing, and the attenuation of motion of various frequencies near to the source.
STRONG-MOTION RECORDS

The permanent networks of both the U.S. Geological Survey and the California Division of Mines and Geology provided an important set of strong-motion accelerograms. Preliminary scaling, digitizing and processing indicate a peak value of 1.3g horizontal at the abutment of the Coyote Reservoir Dam (CDMG), 0.40g horizontal at the downstream site at Anderson Dam (USGS), 0.31g horizontal near the epicenter at Hall's Valley (CDMG), and a range of 0.1 to 0.37g across the Gilroy Array (CDMG and USGS). Vertical accelerations to the south, the direction of rupture on the Calaveras fault, have frequently higher amplitudes than the horizontals.

Figure 3.
Anderson Dam downstream (USGS); components 340, Up, 250; 0.4g peak; R=15 km.

Figure 4.
5% Response Spectrum for 3 components of Anderson Dam downstream.

ANDERSON DAM DOWNSTREAM
RESPONSE SPECTRA, 5% damped

Distorted railings on Dunne Avenue Bridge, looking east.
TWO SERIOUSLY DAMAGED HOUSES

The Jackson Oaks area of the city of Morgan Hill is located in the foothills at the southwest shore of Lake Anderson. This area was the closest part of Morgan Hill to the epicenter of the April 24 earthquake. Two houses in the Jackson Oaks area suffered severe damage due to the failure of the sheathing on their cripple walls.

The first is a split-level house on a sloping site. The house has a wood frame and a concrete perimeter foundation. The house is supported by a cripple wall which varies in height from about 1 foot to 10 feet. This cripple wall is sheathed in particle board of about 3/8-inch thickness. It appears that the earthquake inertial forces on the house caused the particle board on the west end of the cripple wall to fail in shear. This sheathing failure allowed the west end of the house to displace about 18 inches to the north and to drop about 8 inches. The sheathing failure mechanisms included both the brittle failure of the particle board sheathing along approximately vertical lines and the pulling of the sheathing nail heads through the particle board.

The second house is a two-story house on a sloping site. The house has a wood frame and a concrete perimeter foundation. The house is supported by a cripple wall which varies in height from about 3 feet to 8 feet. This cripple wall is sheathed in textured plywood of about 5/8 inch thickness.

It appears that the earthquake inertial forces caused the plywood sheathing on the west cripple wall to fail by nail withdrawal from the framing members. This sheathing failure allowed the west end of the house to displace about two feet to the north. Observation of the west cripple wall revealed that the plywood panels were nailed on three sides with at least 10d nails at about 6 inch spacing. The fourth side was held by a vertical lap joint from the adjacent panel and was not nailed.
DISTRIBUTION AND NATURE OF DAMAGE

Although this earthquake was felt over an area covering most of northern California and strong shaking was reported throughout the Santa Clara Valley, damage to structures was surprisingly light except in a small area near the south end of Anderson Lake about eight miles east of Morgan Hill.

The area of serious structural damage was confined to an area of no more than one square mile adjoining Anderson Lake which included the portion of Jackson Oaks residential development encompassing Oakridge Court, Oakridge Lane, Live Oak Lane, Live Oak Court and the upper end of Jackson Oaks Drive. Within this area, serious damage occurred to about a half dozen houses in addition to two houses that may be a total loss. There were some five water main breaks in this area with visible cracks in streets and driveways that suggest minor lateral shifting of the ground in the area.

At the south end of Anderson Lake the Dunne Avenue Bridge over the end of the lake leading to Henry Coe State Park was seriously damaged. Relative movement of the end abutments of the bridge distorted the bridge superstructure resulting in buckling of the bridge surface and rocking of the supporting reinforced concrete bents. In addition, a large rock slide at the east end of the bridge completely covered the east approach.

Outside the small area of serious damage, no structural damage has been reported to any original structure or building. One old reinforced parapet in Morgan Hill was tipped over, and a few other parapets were cracked. There was scattered damage to unreinforced masonry chimneys.

In about three or four mobile home parks, the usual occurrence of mobile homes shaken off their supports occurred, although at one park it has been reported that there was no damage. The landlord had required his tenants to anchor their trailers. Substantial costs and some injuries have been reported due to furniture and other building contents being tipped over. Furniture, file cabinets and similar items which were not anchored were tipped over and moved around in the upper stories in many of the high-rise buildings in San Jose. Several school children were injured by bookshelves falling over.

Although the earthquake and the resulting damage were of moderate magnitude, the several fires ad fire-related operations related to the earthquake contain significant lessons that will be of paramount importance in a larger earthquake. In the six hours that followed the earthquake, 81 earthquake-related confirmed incidents were reported for the Morgan Hill Fire Department (34), the San Jose Fire Department (29), the California Division of Forestry (4), and Gilroy and the area south of Morgan Hill (14). Of these 81 incidents, 16 involved fire outbreaks, three of which resulted in major structural damage. Other incidents included gas leaks without fire (7), chemical spills, and damage to structures.

The Morgan Hill and San Jose Fire Departments functioned extremely well, smoothly coordinating their efforts and establishing emergency headquarters and procedures.

Phone delays interfered with the ability to alert the San Jose Fire Department. Phone delays are often not differentiated from malfunctions by the users, who do not persist in trying to place their calls. Congestion of the phone lines occurred.

The computer system that controls the dispatching for the San Jose Fire Department "crashed" for several minutes, due to power outage. Emergency services computer outages could become a serious problem in a large earthquake.

Concrete bent supporting Dunne Avenue Bridge.

Photos by Ronald Polivka, James Kasian, and R. Gordon Dean.

IMPORTANT LESSONS LEARNED FROM THE EARTHQUAKE

1. The need for better anchorage for the contents of buildings.

2. The need for better applications of the principles of seismic resistance to nonstructural elements.

3. The need to apply performance requirements of the code rather than using "cookbook" interpretations.

4. With respect to fire: (a) there needs to be redundancy in the fire communication system to facilitate immediate response, and (b) there needs to be an understanding that inspections of chimneys and furnaces must be done before people light them up again.

5. There is no evidence that there is a need to improve structural requirements, but they do need to be applied.