AN IMMEDIATE FIELD SURVEY OF THE SAN FERNANDO, LOS ANGELES, EARTHQUAKE, FEBRUARY 9,1971

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Abstract.

The San Fernando earthquake occurred in the San Gabriel Mountains, about 25 miles to the north of central Los Angeles. Its magnitude, about 6 1/2, was not exceptionally large, and such earthquakes are not uncommon in California. Not since the Long Beach earthquake of 1933 (magnitude 6.3), however, has a significant shock occurred near a densely built-up area. The greatest damage appears to be associated with a zone of overthrusting, where the San Gabriel Mountains meet the San Fernando Valley to the south of the epicentre. In some places this overthrusting caused conspicuous ground deformation through built-up areas of San Fernando and Sylmar.

Domestic wooden-frame houses in general withstood the earthquake well, but large hospital buildings at the Olive View Medical Center and Veterans' Administration Hospital at Sylmar failed badly. Conspicuous damage was also caused to freeway overpasses, the Sylmar Converter Station, and to the Van Norman Reservoir complex. Total damage is estimated as high as U.S. $1,000,000,000. Ground accelerations of about 1g were recorded in the abutment of the Pacoima Dam, to the north of San Fernando.

Introduction.

The earthquake originated shortly after 6.00 a.m., Pacific Standard Time, on Tuesday, February 9, 1971 (14h 00m 41s U.T.). Preliminary epicentres were placed in the San Gabriel Mountains, about 10 miles to the east of Newhall. Positions given by the U.S. Geological Survey, Menlo Park, and the Seismological Laboratory, Pasadena, were 34°24' N, 118°22' W, and 34°26' N, 118°20' W, respectively. A general map of the area is shown in Fig. 1, which also shows the trace of the San Gabriel Fault.

Once the Berkeley seismologists had made their recordings, and established the earthquake's magnitude as about 6 1/2, there was little else we could do from a distance of 330 miles, so Professor Bruce Bolt and I flew to the area to see what we could of the immediate effects of the shock. We arrived at the Hollywood-Burbank airport on a scheduled commercial flight about 10.30 a.m., some four and a half hours after the earthquake occurred.

The airport is about 12 miles to the south of the epicentre in the San Fernando Valley, which to the north and east of us stretched to meet the northwest trending mountains. Between us and the mountains were the small independent city of San Fernando and the Sylmar district of Los Angeles. Newhall is to the northwest through a 1700-ft high pass, and to the west of Sylmar are the two Van Norman Reservoirs. When we arrived, radio reports told us that Newhall was cut off by freeway damage, that San Fernando and Sylmar were badly damaged, and gave us the first news of the collapse of the Veterans' Administration Hospital and the extensive damage to the Olive View Medical Center at Sylmar. We also learned of the damage to the main Van Norman Reservoir and the plans for the evacuation of 36 square miles below the Dam.

Professor Bolt and I spent two days in the area. Apart from a brief visit to Newhall on the second day, we spent our time entirely in the San Fernando and Sylmar areas, and along the join of the foothills and valley to the east of San Fernando.

Areas of Ground Deformation.

Fig. 2 shows in more detail the built-up areas at Sylmar and San Fernando, and marks the three areas of ground deformation that we found. By noon on February 9, within six hours of the earthquake, we had discovered the broad zone in the built-up areas, about 30 to 50 yards wide, over which there was considerable ground deformation, extending eastwards from near the junction of Eighth and Fernmont Streets to Interstate Freeway 210 near Maclay Avenue. We later followed this zone westwards to the corner of Hubbard Street and Glenoaks Boulevard, establishing its existence over a length of at least a mile.

In this zone, streets were broken and curbs buckled, and in some places the roadway had slumped, damaging water and gas mains. The most conspicuous deformation effect was an offset of about five feet in a left-lateral sense that was observed over a distance of about 30 to 50 yards in streets running NW-SE, such as Knox Street, Eighth Street, Cometa Avenue, Bromont Avenue, and Foothills Boulevard (Fig. 3). In streets running NE-SW, such as Orange Grove Avenue, Fernmont Street and Harding Street, shortening of several feet was obvious, with roadways, curbs and sidewalks overthrust or buckled upwards (Fig. 4). In places, vertical steps of up to a foot were found in these streets, with the northeastern side raised. On lawns and open ground, there was also much evidence of ground compression, with the ground broken and cracked in many en echelon scarplets throughout the entire zone of deformation. There was bad cracking on the surface of Interstate Freeway 210, where the

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zone of deformation crossed it near its termination at Maclay Avenue.

The ground deformation throughout this region was consistent with an overthrusting of several feet of the block to the north of the zone over that to the south. This would have produced the compressional effects and most of the left-lateral offset.

About one mile to the southeast of the junction of Maclay Avenue and Interstate 210, where Lopez Canyon emerges from the mountains, a reinforced concrete channel carrying Lopez Canyon stream was severely compressed and telescoped by several feet (Fig. 5). In the fields to the east of this point, a clear zone of thrusting, again about 20 yards wide, was found where the hills appeared to have moved out over the valley. Here we found many fresh scarplets which ran along the base of the hills. This zone crossed a dirt road above Pierce Street in five distinct breaks. At the most prominent, shown in Fig. 6, the vertical rise of the northern block appeared to be about one foot. We found obvious thrusting in Little Tujunga Canyon, two miles to the east of Lopez Canyon, where a scarp about a foot high ran across an orange grove, the road, and then the stream bed of the canyon.

The most westerly zone of deformation shown in Fig. 2 is indicated by a dotted line near the Upper Van Norman Reservoir and Sylmar Converter Station. Evidence for ground deformation here was not so clear, but there appeared to be left-lateral offset of about a foot in the NW-SE trending culvert between the Converter Station and Interstate Freeway 5, consistent with that found in similarly trending streets in other areas. (Professor H. B. Seed reports conspicuous cracking and sand fountaining in this area.)

At the time of writing, the movement on these zones of overthrusting (previously mapped uncertainly as the Mission Hills Thrust) is the only known ground breakage or large-scale deformation associated with the earthquake. No movement has been observed on the San Gabriel Fault, which runs between the preliminary epicentre and the observed overthrusting. Movement on the San Gabriel Fault in the geologic past has been transcurrent, in a right-lateral sense. The aftershocks appear to be located to the south of the epicentre, mainly between it and the zone of overthrusting. Preliminary first-motion studies suggest a possible solution of overthrusting on a plane striking approximately east-west, and dipping about 60° to the north. The depth of the main shock cannot be determined precisely, but it is thought to be about 10 km. Depths of aftershocks will be established more precisely, and it should be possible to determine whether tney lie on a surface passing through the observed surface breakage.

Damage to Structures

The greatest structural damage to houses occurred in the zone of ground deformation in Sylmar and San Fernando. Here, largely as a result of the ground movement, many wooden-frame houses were damaged beyond repair, although we observed none that had collapsed completely. Stone and brick veneers often fell off (Fig. 7), some houses were thrown off foundations (Fig. 8) and interiors were often badly damaged. The few brick houses in the neighbourhood fared worse, with partial collapse (Fig. 9). Car ports and verandahs were destroyed in many instances and most chimneys were broken. The interior of the houses was completely chaotic, with broken furniture and contents from cupboards strewn over the floor. In this area there were many breaks in the underground service mains, and I would rate the overall intensity in this central zone as about MM IX, but falling off within a hundred yards or so to MM VIII. Outside this high intensity zone, isolated instances of collapse of masonry buildings were found. The Mission Hotel in the San Fernando Mall had lost its outer brick walls, leaving the roof supported on internal walls (Fig. 10). Also in central San Fernando, in First Street, a two-storey brick building had collapsed completely, killing a boy, one of the few occupants. These buildings, however, and others that failed as far away as central Los Angeles (25 miles from the epicentre) were isolated instances of poor construction in areas that otherwise suffered only moderate to minor damage.

Olive View Hospital

One section of the old Sanatorium building of this complex in Sylmar had collapsed completely (Fig. 11). The building appeared to be of unreinforced concrete blocks, with a heavy tile roof. The walls had failed completely, and the mortar appeared to have little cohesion. The main buildings of the Olive View Medical Centre had been dedicated only in the latter part of 1970, after being built at a cost of nearly $25,000,000. The buildings are now totally beyond repair. The structure was built in four main wings, arranged around a central court, each with a tower block of recreation rooms and stairs at one end. Three of these towers had toppled completely and the fourth, although still standing, was leaning outwards at an angle of about 10°. Where the towers had broken away, the ends of the main block were completely clean, showing that no attempt at all had been made to tie the structure together (Fig. 12). The main blocks themselves, of reinforced concrete construction, suffered distortion of the first floor, and X-cracking of the columns at second floor level. The corner pillars at ground and first floor level had failed particularly badly, with concrete falling away to expose distorted reinforcing. The ground floor of the psychiatric wing, originally a two-storey structure separate from the main building, had failed completely with its ceiling slab now being only a foot or so above the ground. Similarly, the supports had failed under the large slab under which the hospital's ambulances were parked, causing their total destruction. It is remarkable that of the 400 to 500 people in the hospital at the time of the earthquake, only one was killed. Had the shock occurred during the day, when the recreation towers were occupied, the toll would have been much higher.

Veterans' Administration Hospital

While we were in the area, rescue work was still proceeding at this hospital, which was strictly out of bounds to all except rescue workers and reporters. The collapse of these

buildings caused the greatest single concentration of deaths in the earthquake, with more than 40 people being killed.

Schools

There were 5,893 school buildings in the Los Angeles School District at the time of the earthquake, of which 578 did not meet the requirements of the Field Act of 1933. It is comforting to note that of these only 11, all built before the Field Act was passed, will have to be demolished. It is possible that one building built since the Field Act may have to be demolished. With this one possible exception, no schools built since the Field Act was passed would have caused injuries to children had the earthquake occurred during school hours.

Sylmar Converter Station

This large D.C. to A.C. Converter Station is about two miles to the west of the areas already mentioned in Sylmar, between Interstate Freeway 5, near its junction with Interstate 210, and the Upper Van Norman Reservoir. In the curbing and culverts beside the station we found evidence for a foot or so of left-lateral offset, consistent with the general pattern of overthrusting from the north, and suggestive that an expression of the main thrust fault ran through this area. The transformer and switching gear of this station were almost completely destroyed (Fig. 13). Transformers were moved up to several feet bodily from their beds. Some had toppled over completely, and other equipment had sunk up to a foot into the gravelly surface of the ground. An engineer on duty at the time of the shock told us that a computer had shut down the station in a few milliseconds, preventing serious electrical damage.

Van Norman Reservoir

A complete section of the crest of the main earth dam slipped upstream into the reservoir, taking with it the concrete facing and crest roadway. Water level at the time of the earthquake was 15 feet below a recently imposed upper limit. After the slip only three feet of freeboard remained at some places, with the water being retained by a strip of cracked earth only six feet wide. A seismoscope on the fallen crest was later recovered and indicated acceleration of about 0.5g, transverse to the axis of the dam. Until the level could be lowered to a point at which failure of the dam, possibly during an aftershock, would cause no great water spill, a 36-square mile area of Mission Hills, below the reservoir, was evacuated.

The Upper Van Norman Dam suffered damage to its spillway, but remained unbroken. A small rolled-earth dam containing a reservoir off the main Van Norman Reservoir was undamaged although asphalt roading on it was cracked.

Freeways

The freeway interchange at the junction of Interstate 5 and Route 14, still under construction, was completely wrecked. Apparently, strong columns failed in shear, transferring the entire weight of the structure to vertical reinforcing rods, which then failed. One high two-span overpass collapsed when one span came off its supporting abutment, fell, pulled over the 150-foot high centre column, which in turn pulled down the remaining span. Further serious damage to overpasses occurred at the junction of Interstate 5 and Interstate 210, near the Sylmar Converter Station.

Strong Motion Records

It is believed that more than 200 records of strong-motion acceleration have been obtained during this earthquake. Some instruments were close to the epicentre and high intensity regions, others were in less strongly shaken areas, and some at various levels in high-rise buildings in central Los Angeles. Mr. W. K. Cloud of the Seismological Field Survey of NOAA reports an acceleration of more than 1g recorded in the abutment of Pacoima Dam in the San Gabriel Mountains, about 5 miles from the epicentre and about one mile to the east of the Veterans' Administration Hospital. Here, accelerations of between 0.5 and 0.75g lasted approximately 7 seconds. This is the highest acceleration ever recorded and considerably higher than that thought possible by some earthquake engineers. This record is reproduced in Fig. 14.

Social Effects of the Earthquake

Throughout the emergency, local authorities appeared to act in an exemplary manner. Constant news broadcasts gave all needed information and, where possible, services were quickly restored. Water, power and sanitation services failed for varying lengths of time, in some parts of San Fernando at least into the second day after the earthquake. Water trucks were dispensing water to householders, and portable lavatories of the type used on construction sites were set up at street corners. Guards kept people away from broken gas mains and patrolled areas of broken shop windows. The largest civil defence effort during the emergency was the evacuation of some 80,000 people from the 36 square miles below the Van Norman Dam. Many families moved to the homes of friends or relatives and others were billeted in surrounding schools and neighbouring motels, but even so, the removal of so large a number of people in a few hours is no small task.

People in the high intensity areas were still shocked and numbed when we first met them, about five hours after the quake. They tended to be gathered on the lawns surrounding their homes, or sitting gazing at the chaotic state of the interiors. Far from showing resentment towards our enquiring about the effects of the earthquake, all seemed eager to tell of their experiences and to show us the damage to their houses and property. Having been used to New Zealand's all-embracing earthquake insurance, it was sobering to realize that many of these people had lost their house and most possessions in the earthquake.

A further point of comparison, in which New Zealand does not emerge so favourably, was the weather. People here were fortunate in the still, clear, warm weather, which enabled them to live outside for a day or so after the shake with relatively little discomfort, compared with that which would follow a

New Zealand shock that occurred during a spell of wet, windy and cold weather.

Aftershocks were not as noticeable as they were after the larger Inangahua earthquake, and on the first night after the shake, it was possible to sleep at Burbank, 10 miles from the high intensity zone, with only a few mild awakenings due to aftershocks. At Westport, a similar distance from the Inangahua earthquake, sleep on the first night after the main shock was well nigh impossible.

Summary

Full study of this earthquake will undoubtedly reveal much useful knowledge to earthquake engineers. It is sobering to realize that an earthquake of such modest magnitude can produce such high accelerations. The only large buildings to fail badly appear to have been part of the Veterans' Administration Hospital and the Olive View Medical Center in Sylmar. In general, wooden-frame houses withstood the earthquake well, even in the zone of gross earth deformation, where casualties were minimal. Throughout the Los Angeles area, some poorly constructed masonry buildings have failed, some with loss of life. Undoubedly, the low death toll (about 65) can be attributed to the time of the earthquake. Had it occurred when more people were in the streets, in the working areas of the hospitals, or travelling on the highways, much more serious loss of life would have occurred.

Acknowledgements

I wish to thank Professor Bruce Bolt, my companion during this study, and also Professors H. B. Seed, J. Penzien and V. V. Bertero of the Engineering Faculty of the University of California, Berkeley, for clarification of some of the engineering aspects of the damage during a seminar at Berkeley on February 24. I also thank Mr. W. C. Marion and Mr. Stuart Haynes for help in reprdducing the photographs.

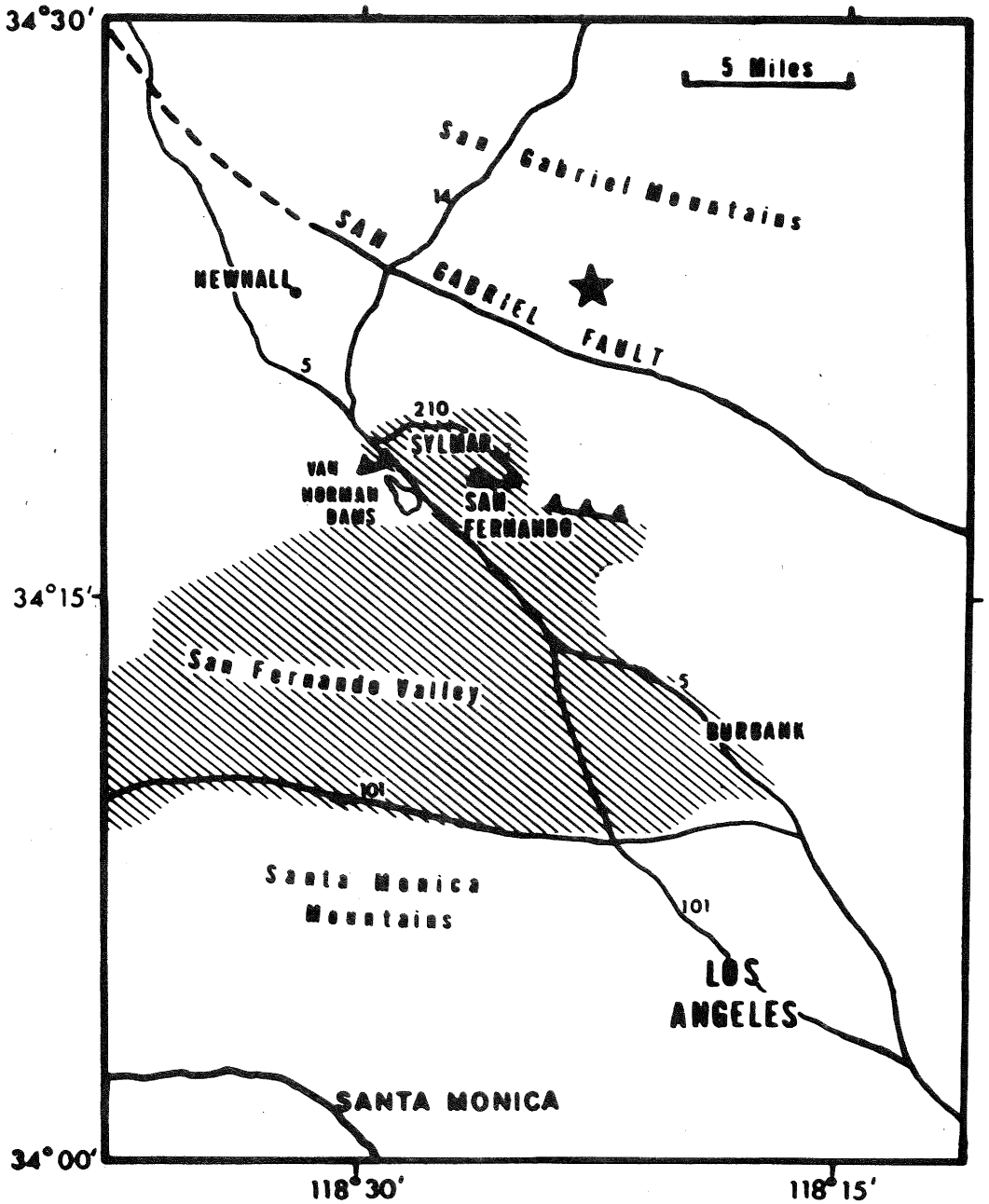

Fig.1. Area of San Fernando earthquake. Star shows epicentre of main shock. Heavy serrated lines show zones of overthrusting in Sylmar and San Fernando. Light lines with numbers are main highways. Shaded area indicates approximate limits of San Fernando Valley.

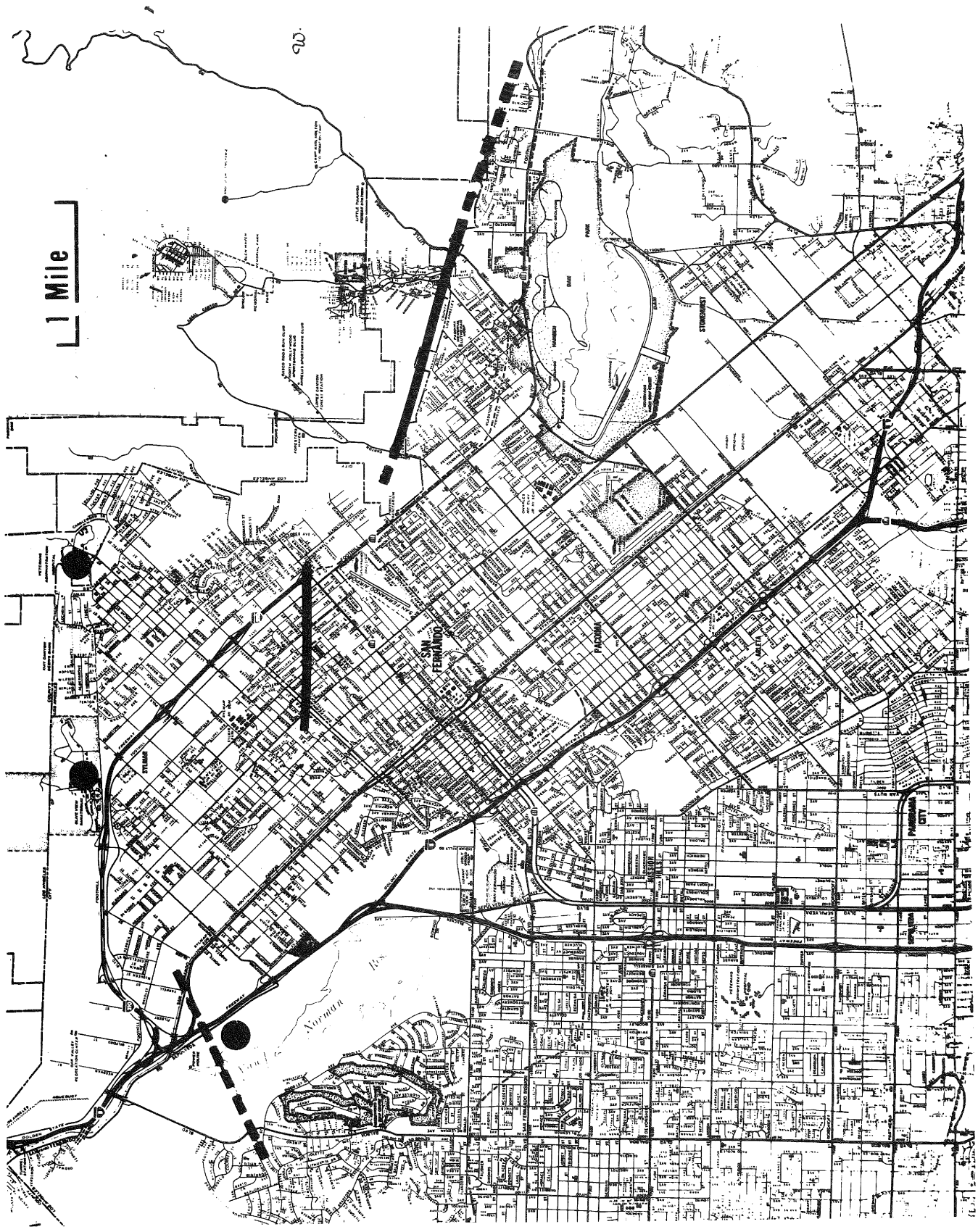

Fig 2. San Fernando and Sylmar areas, with heavy lines showing zones of overthrusting and ground deformation. From left to right, these zones are those near the upper Van Norman Reservoir and Sylmar Converter Station, built-up San Fernando and Sylmar, and from Lopez Canyon to Little Tujunga Canyon. Circles from left to right show positions of Sylmar Converter Station, Olive View Medical Center, and Veterans' Administration Hospital.

Fig 3. Offset curb looking SE along Eighth Street. Camera is on line of curb in distant part of street.

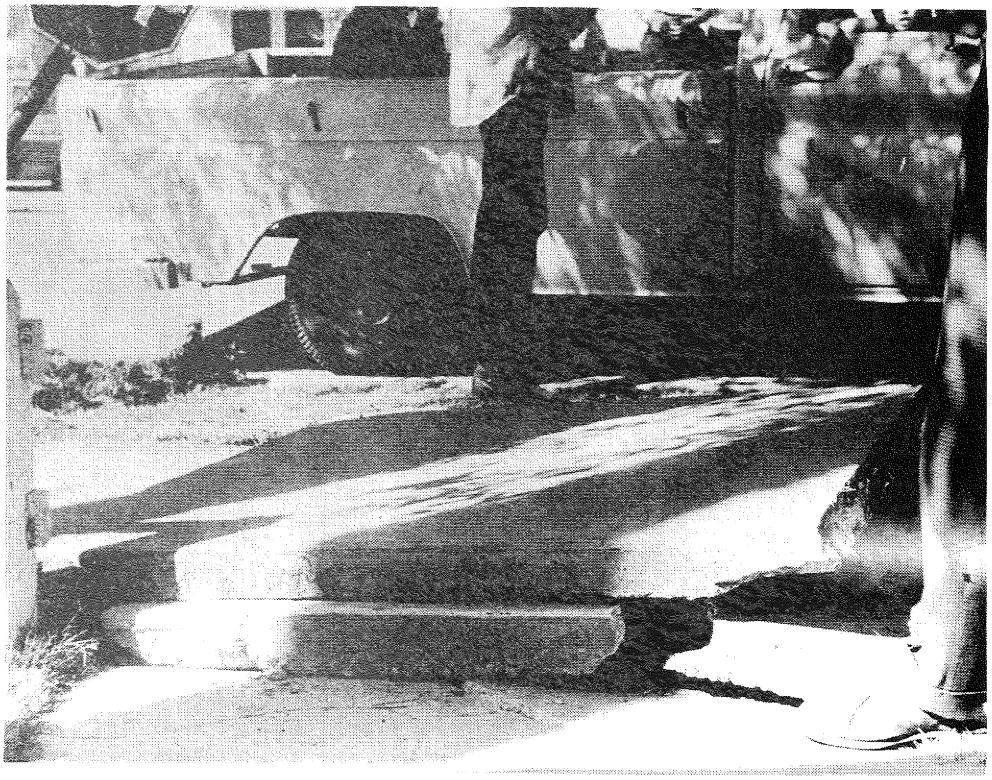

Fig 4. Overthrust sidewalk in Orange Grove Avenue. Compression of ground has forced the upper slab out of the pavement.

Fig 5. Telescoping of reinforced concrete wall of channel leading from Lopez Canyon.

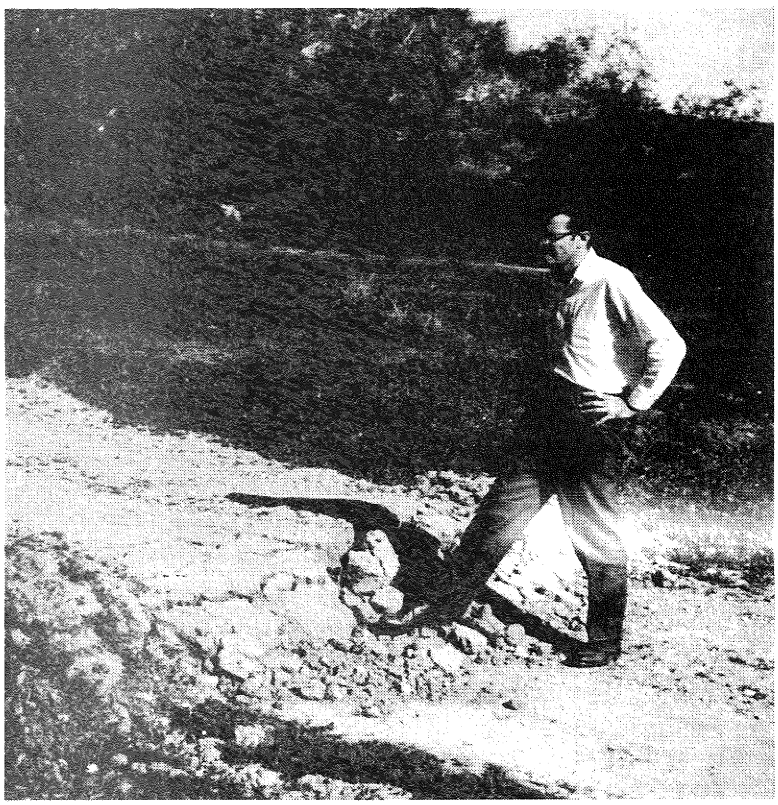

Fig 6. Thrust scarp in fields above end of Pierce Street.

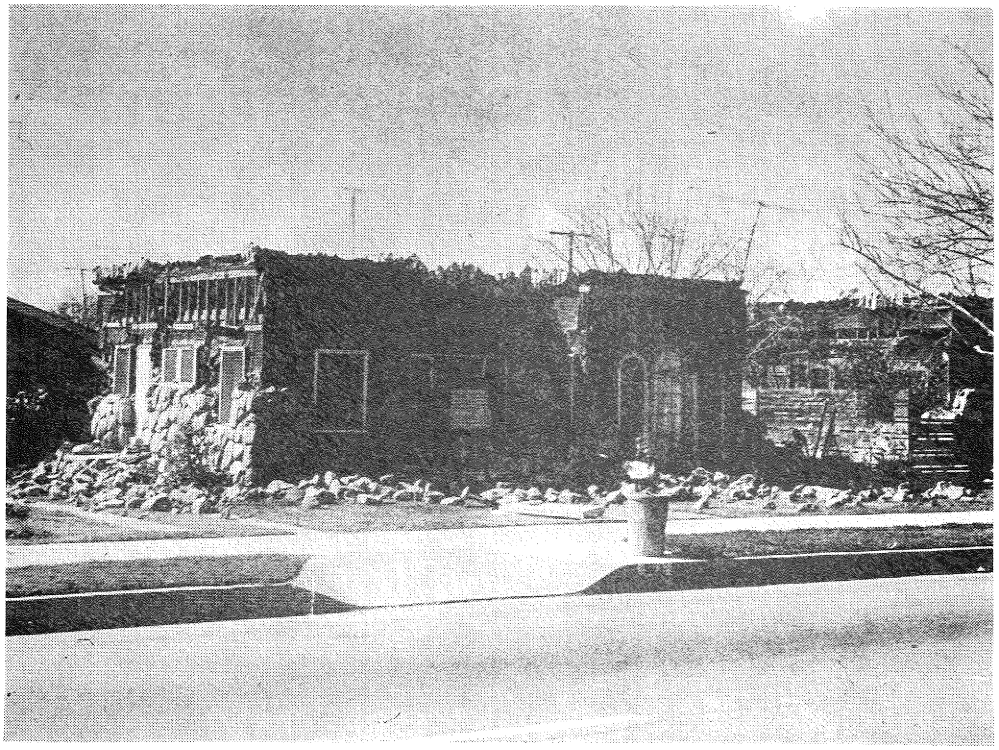

Fig 7. Fall of stone veneer off house in Eighth Street.

Fig 8. House in Orange Grove Avenue, thrown off foundation towards camera. Note door step forced upwards.

Fig 9. Collapse of brick walls of house in Eighth Street.

Fig 10. Mission Hotel, San Fernando Mall. Masonry walls

Fig 11. Collapsed wing of Olive View Sanatorium. Walls were constructed of unreinforced concrete blocks, with poor cement.

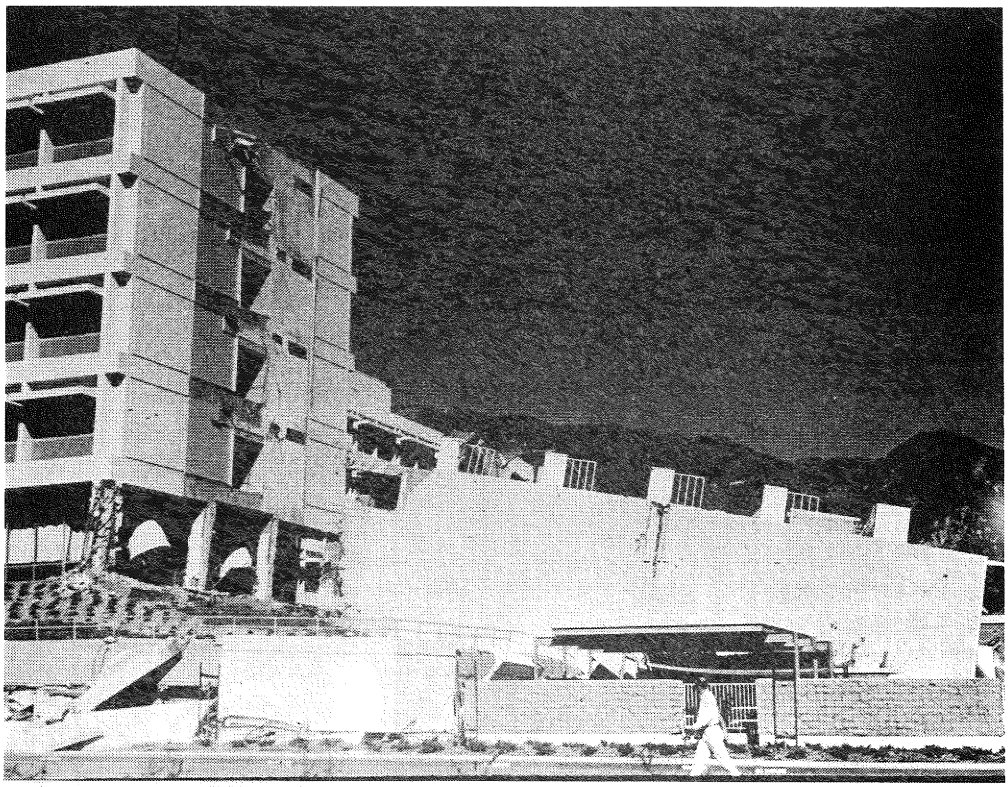

Fig 12. Overturned end tower of Olive View Medical Center, Sylmar. Note complete absence of ties between tower and main building and failed corner column of main building.

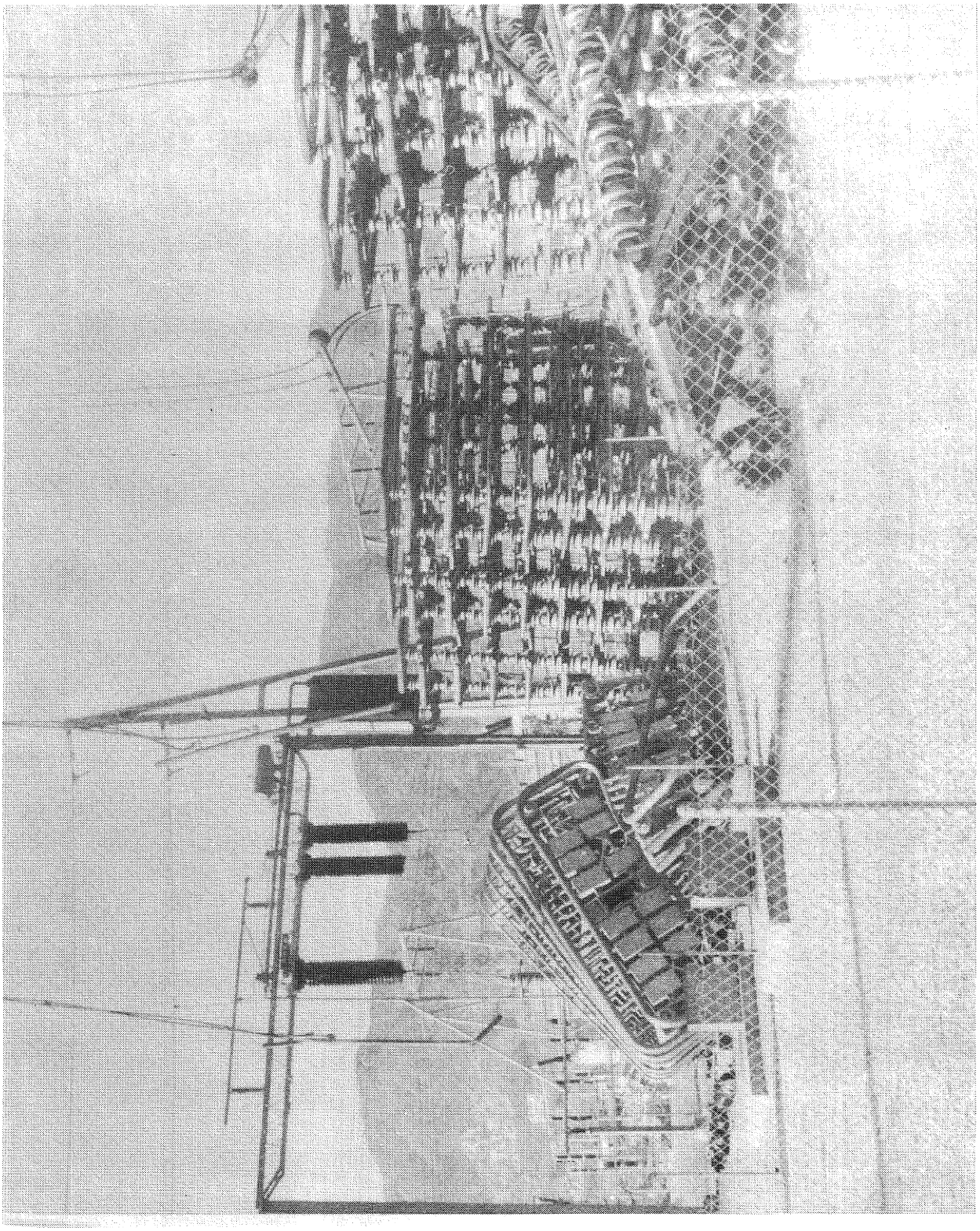

Fig 13. Collapsed outdoor equipment at Sylmar Converter Station.

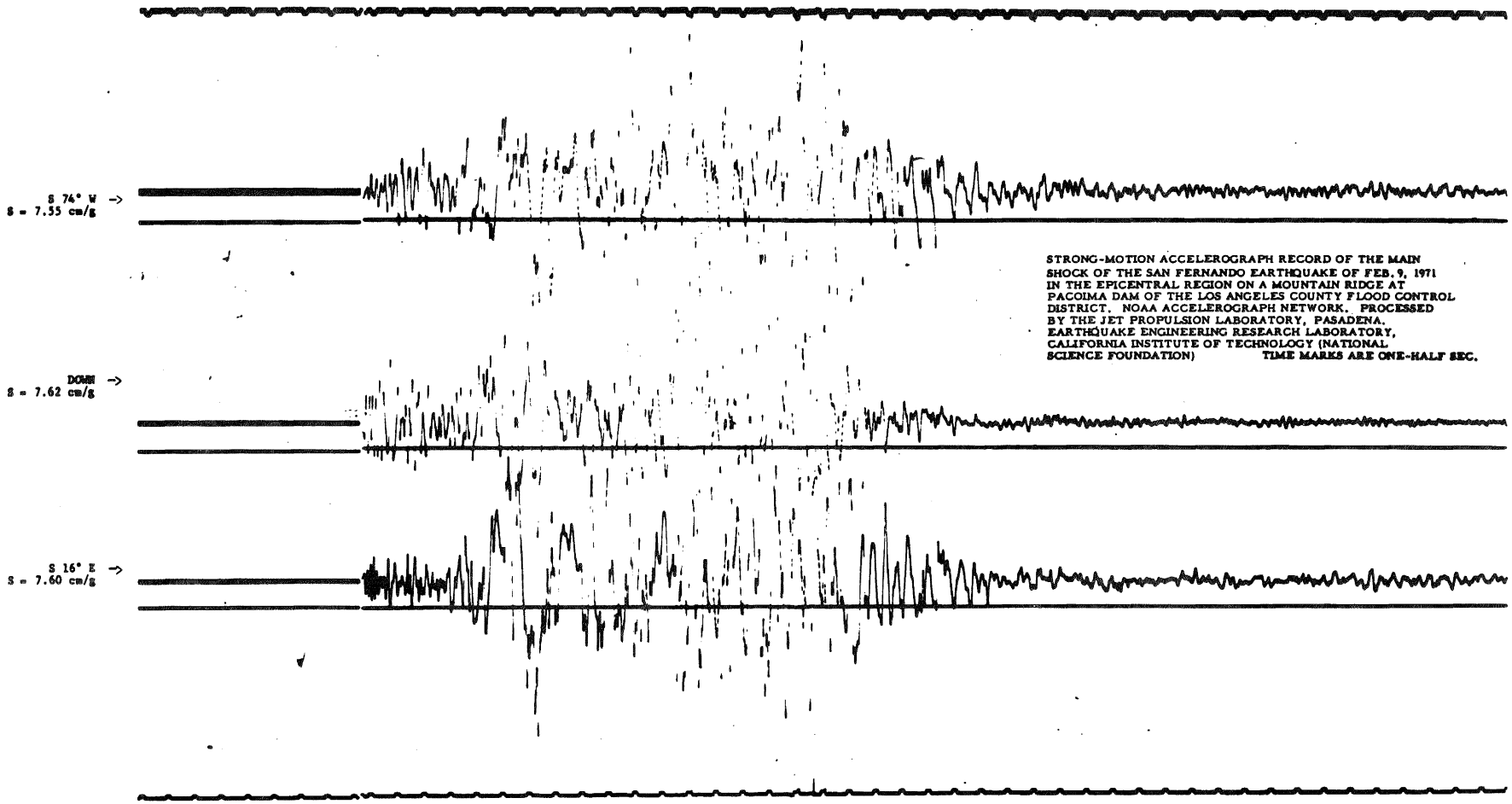

Fig 14. Strong-motion accelerogram recorded at Pacoima Dam. Maximum acceleration greater than 1g. Reproduced by permission of Mr W.K. Cloud, Seismological Field Survey, N.O.A.A.