# RECONNAISSANCE REPORT

**GREENVILLE (DIABLO/LIVERMORE), CALIFORNIA EARTHQUAKE SEQUENCE**

**JANUARY 1980**

James L. Stratta, Earthquake Investigation Coordinator

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On January 24, 1980, the Livermore area was first shaken by a series of earthquakes. Mr. John Blume, President of EERI, requested that I make a brief reconnaissance review of the damage and issue a report. Since many members of EERI were on the scene, asked each to contribute in part by selecting a particular area of his interests and send me a brief report.

This is a consolidation of all of the data that was gathered relative to these earthquakes. While some may say it appears to be a lot to do about nothing, several noteworthy items of interest arose related to:

1. Seismology - several low level shocks occurring within seconds of each other to create a relatively long period of shaking.
2. Structural Damage - two concrete buildings were damaged at the Lawrence Livermore Laboratory.
3. Tanks - wine tanks and water tanks underwent some amazing buckling problems. Some tanks sheared anchor bolts.
4. Architectural Damage - Lawrence Livermore Laboratory had considerable damage in some areas, lights and ceilings falling.
5. Contents and Mechanical Equipment - All anchored contents and equipment remained in place with no damage. Some unanchored equipment shifted causing problems.
6. Trailer Anchorage - Many trailers in the area fell from unbraced supports creating severe housing problems.
EER members contributing to this report who were on the scene are:

Messers

1. Bruce Bolt
2. Gordon Dean
3. Henry J. Degenkolb
4. Frank McClure
5. Robert Olsen
6. Cris Poland
7. Loring Wylie
8. Peter Yanev

would like to especially acknowledge the cooperation of Wente Bros.
Winery, Inte Semiconductor Facilities, Sunrise Trailer Park and the Lawrence
Livermore Laboratory for allowing EER members to visit and tour their
facilities in EER’s continuing effort in their program of "Learning from
Earthquakes".

Respectfully Submitted,

James L. Stratta
THE GREENVILLE, CALIFORNIA EARTHQUAKE SEQUENCE OF JANUARY 1980

by

B.A. Bolt, T.V. McEvilly, and R.A. Uhrhammer
Seismographic Station, University of California, Berkeley

(abstract)

At 19h00m09.46s GMT, on January 24, 1980, a moderate earthquake caused a surprising amount of damage ($M_L = 5.5$) occurred north of Livermore Valley about 12 km to the southeast of Mount Diablo, and was associated with surface rupture along the Greenville fault. There was a foreshock ($M_L = 2.7$) a minute and a half earlier and a sequence of 59 events ($M_L \geq 2.5$) in the ensuing six days. On January 27, at 02h33m35.96s, a larger magnitude earthquake occurred in the sequence ($M_L = 5.8$). This second principal shock was located 14 km to the south of the first principal earthquake towards the southern end of the Greenville fault. Preliminary estimates of the seismic moments of the two principal shocks are $6 \times 10^{24}$ and $2 \times 10^{24}$ dyne-cm respectively.

Field investigations after the first principal shock indicated surface rupture along the Greenville fault zone for at least 6 km, with both right-lateral strike-slip and some dip-slip motion with the northeast side up. Variable offsets on surface cracks suggested displacements of a few cms (with evidence of increases in some places after the second principal shock). There were 11 earthquakes with $M_L \geq 4.0$ in the sequence up to February 5, 1980. No foreshocks near the Greenville fault ($M_L \geq 2$) were observed by the U.C. Seismographic Stations in the prior three months.

Rapid deployment of field seismographs by a number of seismological organizations permitted precise locations and fault-plane solutions. Some results on seismicity are:

1. The rupture propagated over 15 km to the southeast along the Marsh Creek-Greenville faults on January 24 and stopped in
vicinity of Highway 580. This southern progression may have had some causal connection with the relatively high intensities reported near the southwest end of the Greenville fault.

2. The two principal shocks of the sequence have slight but significant differences in the fault-plane solutions; both are predominantly right-lateral strike-slip, but the strike of the northern one is N 13° W, whereas the strike of the southern one is N 39° W. This change in strike is not evident in the mapped strikes of the Marsh Creek and the Greenville faults.

3. In contrast to the second principal earthquake, the first principal shock was followed by two others ($M_L > 4.0$) in rapid succession, one 53 secs and the other 97 secs after. This repetition gave a relatively long duration to the shaking on January 24, and was commented on in felt reports. It may explain the greater intensity reported in many localities on January 24 compared to January 27.

4. The $b$ value (0.60 ± 0.09) for the sequence is somewhat lower than the $b = 0.70 ± 0.17$ for the recent Coyote Lake earthquake sequence on the Calaveras fault on August 6, 1979. There are fewer earthquakes than normal in the range $3.0 < M_L < 4.0$ in the Greenville sequence.
### Selected Earthquakes* of the Greenville Sequence, January, 1980

<table>
<thead>
<tr>
<th>Jan</th>
<th>Time</th>
<th>Lat $^\circ+$</th>
<th>Long $^{121\circ+}$</th>
<th>Depth (km)</th>
<th>S.E.O.</th>
<th>$M_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>24</td>
<td>185842.14</td>
<td>51.51' ±.18(sec)</td>
<td>49.29' ±.74(km)</td>
<td>11.2</td>
<td>.097</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>190009.47 ±.17</td>
<td>51.29 ±.73</td>
<td>48.96</td>
<td>11.8</td>
</tr>
<tr>
<td>3.</td>
<td>190102.25</td>
<td>50.22 ±.27</td>
<td>48.14 ±1.12</td>
<td>11.3</td>
<td>.202</td>
<td>5.2</td>
</tr>
<tr>
<td>4.</td>
<td>190146.47</td>
<td>50.39 ±.40</td>
<td>48.25 ±3.98</td>
<td>11.3</td>
<td>.365</td>
<td>4</td>
</tr>
<tr>
<td>5.</td>
<td>190320.00</td>
<td>50.19 ±.16</td>
<td>50.94 ±1.07</td>
<td>18.0</td>
<td>.101</td>
<td>4.8</td>
</tr>
<tr>
<td>6.</td>
<td>25</td>
<td>051243.18</td>
<td>51.95 ±.21</td>
<td>48.87 ±1.91</td>
<td>12.0</td>
<td>.162</td>
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<tr>
<td>7.</td>
<td>052436.48</td>
<td>53.03 ±.16</td>
<td>49.97 ±.64</td>
<td>8.1</td>
<td>.053</td>
<td>4.6</td>
</tr>
<tr>
<td>8.</td>
<td>052945.23</td>
<td>52.13 ±.15</td>
<td>49.97 ±.62</td>
<td>9.5</td>
<td>.038</td>
<td>4.0</td>
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<tr>
<td>9.</td>
<td>133902.27</td>
<td>51.60 ±.18</td>
<td>47.69 ±.65</td>
<td>5.3</td>
<td>.063</td>
<td>4.2</td>
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<tr>
<td>10.</td>
<td>140327.75</td>
<td>51.14 ±.19</td>
<td>48.27 ±.77</td>
<td>10.2</td>
<td>.113</td>
<td>4.0</td>
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<tr>
<td>11.</td>
<td>27</td>
<td>023335.96</td>
<td>44.24 ±.11</td>
<td>44.38 ±.45</td>
<td>14.5</td>
<td>.143</td>
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<tr>
<td>12.</td>
<td>105801.30</td>
<td>51.33 ±.23</td>
<td>48.42 ±.96</td>
<td>11.9</td>
<td>.171</td>
<td>4.1</td>
</tr>
<tr>
<td>13.</td>
<td>223316.80</td>
<td>51.32 ±.14</td>
<td>49.46 ±.60</td>
<td>13.5</td>
<td>.171</td>
<td>3.2</td>
</tr>
</tbody>
</table>

* Complete for $M_L > 4.0$. Numbers 1 and 13 added because of special interest.
Figure 1. Location of the earthquake sequence along the Mt. Diablo (later revised and named Marsh Creek fault) and Greenville faults north of the Livermore Valley in central California. The two principal earthquakes January 24 ($M_L = 5.5$) and January 27 ($M_L = 5.8$) are shown as open circles.
Figure 2. A plot of epicenters of earthquakes in the UCB historical file in a circle of radius 25 km around the seismic source. Only earthquakes with $M_L \geq 4$ are plotted. Earthquake centers estimated from intensity information in the last century are shown with the Modified Mercalli Roman numeral against them.
Figure 3. The map showing the epicenters of 13 of the larger earthquakes in the sequence. The numbers refer to the numbers in Table 1. Faulting was observed in the field from the vicinity of the overpass of Highway 580 near Greenville road northward along the Greenville fault for a distance of about 6 km. No surface rupture was reported from the Marsh Creek fault.
February 1, 1980

Mr. David J. Leeds
Engineering Seismologist
11972 Chalon Road
Los Angeles, Ca 90049

Dear Dave:

I thought you would be interested in a brief report of Woodward-Clyde's activities and evaluations to date of the earthquakes near Livermore January 24 and 26, 1980.

As part of our continuing interest in understanding fault behavior and earthquakes, WCC geologists were in the field immediately after the magnitude 5.5 earthquake at 11:00 AM on January 24. Surface fault rupture was discovered and cracks in pavement were painted so that afterslip could be monitored. Field investigations continued January 25 and 26. Following the magnitude 5.2 aftershock on Saturday evening, January 26, investigations on Sunday revealed the southward propagation of the fault rupture and associated crack zone and the widening of many previously measured cracks.

Interestingly, the geologic and seismic evidence of the earthquakes indicates that the Greenville fault is the causative fault. This fault had not been considered as posing a serious earthquake hazard as it was classified as "inactive" (greater than 2 million years old) by the California Division of Mines and Geology. We understand that the Greenville fault was slated for reclassification to "potentially active" (between 2 million and 11,000 years old) in light of recent study, but was not considered an "active" fault (less than 11,000 years old).

Based on our recent field observations and investigations, there is ample geologic evidence for Holocene activity on the Greenville fault. In our judgment, this geologic evidence would have been found had adequate field investigations been made.

Sincerely,

Lloyd S. Cluff
Chief Engineering Geologist
and Vice President

LSC:ms

Enclosure
Earthquake Parameters

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Epicenter Location</th>
<th>Richter Magnitude</th>
<th>Depth (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/24/80</td>
<td>11:00 AM</td>
<td>37°49.45'/121°47.56'</td>
<td>M_L 5.5</td>
<td>8.6</td>
</tr>
<tr>
<td>01/24/80</td>
<td>11:01 AM</td>
<td>(unavailable)</td>
<td>M_L 5.2</td>
<td>(unavailable)</td>
</tr>
<tr>
<td>01/26/80</td>
<td>6:33 PM</td>
<td>37°44.47'/121°42.84'</td>
<td>M_L 5.2</td>
<td>9.7</td>
</tr>
</tbody>
</table>

These parameters were reported by the U.S. Geological Survey on January 31, 1980. Location error is estimated to be no more than 1 km and depth error, 2 km. Preliminary locations by the U.C. Berkeley Seismographic Station were 4 km northeast of these locations, in the vicinity of Round Valley. Controversy still surrounds the magnitude of the January 26 earthquake (UCB reports M_L 5.6) and whether it is an "aftershock" or another "main" shock in an earthquake sequence. Regardless, hundreds of shocks have occurred since the main event, five of which were of magnitude 4 or larger.

Preliminary fault plane solutions have been prepared by the U.S.G.S. for the January 24 earthquake. They show a right-slip mechanism on a nearly vertical northwest-striking fault.

Causative Fault

Documented field investigations by Woodward-Clyde Consultants geologists David Schwartz, Kevin Coppersmith, and Al Ridley indicate that the source of the earthquakes is the Greenville fault and, most likely, its northern continuation, the Marsh Creek fault (Figure 1). The Greenville fault appears to be one of the active right-slip faults comprising the central San Andreas fault system. The mapped surface rupture, epicenter locations, and aftershock zone relative to mapped faults are shown on Figure 2.
Early reports of the earthquake's association with the Antioch fault were clearly misleading. Likewise, lack of geologic evidence of surface deformation has discounted claims that the earthquake occurred on an unmapped fault in the vicinity of Round Valley. The Las Positas fault also does not appear to have experienced any displacement associated with these earthquakes.

**Surface Fault Rupture**

Field mapping, which Woodward-Clyde began hours after the mainshock, showed well-defined, nearly continuous surface rupture along a 1.4 km-long zone. Locally, the rupture zone is as wide as 25 m. Cracks in road pavement extended south from the continuous rupture nearly to Interstate 580; the zone of observable surface deformation is at least 6.2 km long. At one site, at least 7 cm of right slip was observed across the fault zone; however, local slope failure may have complicated surface rupture patterns. Right slip of about 1 cm on individual cracks was observed at several other locations. Vertical displacements were locally quite variable in both sense and amount.

The earthquake on January 26 was associated with a further lengthening by about 500 meters of the continuous ground rupture zone. Elsewhere, this earthquake caused additional fracturing and widening of the crack zones observed following the initial shock. Stripes have been painted across fractures in paved surfaces and periodic monitoring will document afterslip and patterns of deformation.

**Previous Studies of Fault Activity**

The most recent investigation of the Greenville fault was by Herd (1977) for the portion of the fault along the northeastern side of the Livermore Valley. North of its intersection with the Las Positas fault, the Greenville fault has evidence for Pleistocene displacement, although Herd (1977) believes Holocene deposits have not been displaced. Herd (1977) states that south of the intersection, the Greenville fault has not experienced displacement in the past four million years. Prior to this earthquake,
the Greenville fault was classified by the California Division of Mines and Geology as "inactive" (greater than 2 million years old) but was slated for reclassification to "potentially active" (between 2 million and 11,000 years old) in light of Herd's data.

Conclusion

The earthquakes released as a result of slip along the Greenville fault demonstrate the need to have more accurate and reliable geologic information regarding fault activity. Our preliminary investigations have revealed geologic evidence suggesting Holocene activity on this fault. In our judgment, the Greenville fault that caused the January earthquakes would have been recognized as posing a potential hazard if appropriate detailed geologic and earthquake evaluations aimed at evaluating the degree of fault activity had been conducted.

REFERENCES


FIGURE 1  GENERALIZED MAP OF MAJOR FAULTS OF THE CENTRAL SAN ANDREAS FAULT SYSTEM
STATE OF CALIFORNIA
STRONG MOTION INSTRUMENTATION PROGRAM
PARTIAL FILM RECORDS AND FILE DATA FROM THE
LIVERMORE VALLEY, CALIFORNIA EARTHQUAKE OF
24 JANUARY 1980

PRELIMINARY DATA

Introduction

On 24 January 1980 a moderate magnitude earthquake (M_L=5.5) occurred approximately 15 km north of Livermore, California. The earthquake, originating at 1900 (GMT), is located at latitude 37.83°N and longitude 121.79°W (USGS).

The information from our files and a copy of the film record for the stations recording significant strong-motion are included in this report.*

These stations are as follows:

- Antioch, Freefield
- Fremont, Mission San Jose
- Hayward, Apeel-3E
- Hayward, Cal State University
- Oakland, Cal Russ Bldg.
- Pleasant Hill, Citizens Savings Bldg.
- San Jose, Great Western Bldg.
- San Jose, Town Park Towers
- San Ramon, Eastman Kodak Bldg.
- So. San Francisco, Kaiser Hospital
- Tracy, Water Tntment Plant, Freefield
- Walnut Creek, Fidelity Savings Bldg.

Stations that recorded low level motion for which the records have been processed but are not included:

- El Cerrito, Capwells Bldg.
- Oakland, Caldecott Tunnel

* Editor's Note:

"Preliminary Data, Partial Film Records and File Data, Livermore Valley Earthquake of 24 January 1980", 35 pages, not included in NEWSLETTER. "Preliminary Information" through 26 January with peak amplitudes are on page following. Complete processed data will be published by CDMG.
## Preliminary Information

<table>
<thead>
<tr>
<th>Station</th>
<th>Channels</th>
<th>24 Jan 1980</th>
<th>26 Jan 1980</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range (km)</td>
<td>Peak Ampl (g)</td>
<td>Range (km)</td>
</tr>
<tr>
<td>1. Antioch</td>
<td>3</td>
<td>21 grnd 0.04</td>
<td>30 grnd 0.11</td>
</tr>
<tr>
<td>2. Briones Dam - Left Abutment</td>
<td>3</td>
<td>40 0.02</td>
<td>49 0.04</td>
</tr>
<tr>
<td>Left Crest</td>
<td>3</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Center Crest</td>
<td>3</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>3. Capitola Fire Station</td>
<td>3</td>
<td>95 grnd&lt;0.02</td>
<td>89 grnd&lt;0.02</td>
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<td>4. El Cerrito, Capwells</td>
<td>6</td>
<td>45 grnd&lt;0.02</td>
<td>54 grnd&lt;0.02</td>
</tr>
<tr>
<td>5. Fremont, Mission San Jose</td>
<td>3</td>
<td>36 grnd 0.06</td>
<td>33 grnd 0.06</td>
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<td>6. Halls Valley</td>
<td>3</td>
<td>55 grnd 0.04</td>
<td>45 grnd 0.03</td>
</tr>
<tr>
<td>7. Hayward, APEEL 3E</td>
<td>3</td>
<td>30 grnd 0.08</td>
<td>31 grnd 0.08</td>
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<td>8. Hayward, California State University</td>
<td>3</td>
<td>30 grnd 0.04</td>
<td>31 grnd 0.06</td>
</tr>
<tr>
<td>9. Lexington Dam - Abutment</td>
<td>3</td>
<td>73 &lt;0.02</td>
<td>66 &lt;0.02</td>
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<tr>
<td>Left Crest</td>
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<td>&lt;0.02</td>
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<td>Right Crest</td>
<td>3</td>
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<td>&lt;0.02</td>
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<td>8</td>
<td>33 grnd&lt;0.02</td>
<td>37 grnd&lt;0.02</td>
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<td>11. Oakland, Title and Trust Bldg.</td>
<td>6</td>
<td>48 not oper.</td>
<td>55 grnd 0.03</td>
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<td>12. Pleasant Hill, Citizens Savings</td>
<td>12</td>
<td>29 grnd 0.03</td>
<td>39 grnd 0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td>roof 0.10</td>
<td>roof 0.12</td>
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<td>6</td>
<td>61 grnd&lt;0.02</td>
<td>60 grnd&lt;0.02</td>
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<td></td>
<td></td>
<td>roof 0.02</td>
<td>roof 0.02</td>
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<tr>
<td>14. San Jose, Great Western Savings</td>
<td>13</td>
<td>55 grnd&lt;0.02</td>
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<td>San Jose Town Park Towers</td>
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<td>15. San Ramon, Eastman Kodak</td>
<td>6</td>
<td>16 grnd 0.15</td>
<td>21 grnd 0.28</td>
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<td></td>
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<td>roof 0.02</td>
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<td>18. So. San Francisco, Kaiser Hospital</td>
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<td>59 grnd&lt;0.02</td>
<td>63 grnd&lt;0.02</td>
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<td></td>
<td></td>
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<td>roof 0.11</td>
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<td>19. Tracy</td>
<td>3</td>
<td>33 grnd 0.09</td>
<td>26 not oper.</td>
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<td>20. Walnut Creek, Fidelity Savings</td>
<td>3</td>
<td>26 grnd 0.03</td>
<td>36 grnd 0.05</td>
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<td></td>
<td>13</td>
<td>grnd 0.03</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>roof 0.17</td>
<td>roof 0.21</td>
</tr>
</tbody>
</table>

Temporary stations installed after 24 January 1980:

1. Conta Loma 3 27 grnd 0.03
2. Fagundes Ranch 3 6 grnd 0.25
3. Morgan Territory Park 3 9 grnd 0.27

8.11.80
Livermore, California Earthquake of January 24, 1980

General Observations

by

R. Gordon Dean

At 11:00 a.m., on January 24, 1980, an earthquake of Richter Magnitude 5.5 centered on the Greenville Fault was felt throughout much of Northern California. The following day, January 25, the following members of the office of H.J. Degenkolb & Associates were in Livermore and vicinity to observe the extent of earthquake damage: R. Gordon Dean, Bruce Doig and Joseph Ungerer. In addition, Henry Degenkolb and Chris Poland examined damage at the Sandia Corporation facilities at the same time. On Tuesday the following week, Loring Wyllie was able to observe conditions within the Lawrence Livermore Laboratory facilities.

The epicenter of the main shock on January 24, was located ten miles north of the main business center of Livermore on the Greenville Fault which runs approximately south 30 degrees east along a line passing about two miles east of the Lawrence Livermore Laboratory and crosses Interstate Highway 580 near the Greenville Overpass. Surface rupture was observed extending several miles north of Interstate 580 crossing Vasco Road at several locations about five miles north of the Vasco Road Overpass.

In general, the damage to structures in the vicinity was very light. At an area of relatively new homes to the northeast of Livermore, extending north of Interstate 580 just east of Vasco Road, there were indications of stronger shaking than occurred in the older portions of Livermore. This area is within 1-1/2 miles of observed surface rupture.

Here, a few chimneys were cracked and several unreinforced brick serpentine walls were toppled. These walls were 6 feet high and consisted of a single wythe of brick laid at the edge of a sidewalk on Dalton Avenue.

Serpentine walls rely on tangential stresses acting around their undulating curved line for stability. The walls at this location appeared to have failed in tension along vertical lines at points of maximum curvature. It was apparent that the quality of mortar was poor. After the failed walls had been removed, it was obvious that there was virtually no bond between the mortar and the sidewalk surface.

Greenville Road Overpass -

At the Greenville Road Overpass on Interstate 580, the backfill against the west abutment dropped about 6 to 10 inches, interrupting traffic on the highway for several hours until temporary repairs were made by ramping up the surface with asphaltic concrete. Minor cracks were noted in the concrete structure but these were relatively insignificant. The surface settlement was probably the result of lack of compaction of the backfill. But, it should be noted that the southern extension of the Greenville Fault passes almost directly under this location.
St. Michael's Church -

The Livermore City Building Department indicated that the St. Michael's Church located at 4th and Church Streets had reported damage. We examined the building and found that the only evidence of distress was some spalling of plaster from the soffit of concrete arches spanning over the chapel. It appeared that there was some flexing of the arches near mid-span indicating that there may have been out-of-phase movement of the high side walls.

Livermore City Hall

The Livermore City Hall is a fairly new reinforced concrete building of modernistic architectural design located southeast of the main business center on Livermore Avenue. The building had no visible structural damage. However, there was extensive damage to the suspended T-bar ceiling around the perimeter of the rooms where the ceiling was attached to walls and partitions.

Elsewhere in Livermore, there was very little damage to structures except for occasional broken glass and minor plaster cracking, etc.

K-Mart in Dublin -

One highly publicized case of ceiling damage was the K-Mart in Dublin located near Interstate 580. This building is a large one-story commercial building with concrete exterior walls and a roof framed with long span glu-lam beams on steel pipe columns and a panelized plywood roof diaphragm. The ceiling is a light T-bar suspended ceiling with lay-in ceiling panels. The lights were attached to the ceiling T-bar straps without any independent support. During the main shock of January 24th, several of the lights fell to the floor and ceiling panels in the areas of the ceiling up to 10 feet by 50 feet also fell out.

The ceiling was supported by wire hangers at a level about 8 feet below the roof diaphragm. There was no lateral bracing of the ceiling. The damage was concentrated around the perimeter of the building where the ceiling contacted the exterior walls.

After the damage on January 24th, the store was closed to the public by the local building department until diagonal bracing wires were installed. By Saturday, January 26, the installation of bracing wires was completed and the store reopened. No compression struts were installed and no separate support of the lights were provided.

At 6:33 p.m. Saturday evening the strong aftershock again damaged the ceiling, with additional lights falling. It was reported that one customer was injured by falling lights.

Pleasanton

The writer also visited the town of Pleasanton to examine reported damage at the Pleasanton Wells Fargo Bank at the request of a client. Here, no damage was found. A check with the Pleasanton Building Department indicated that no significant damage had been reported.

In general, the overall impression was that very little significant damage to structures occurred with the specific exceptions previously mentioned.
Memorandum

To: ALL COMMISSIONERS

From: Robert A. Olson
Peter A. Stromberg


Observed Damage

On Friday, January 25, the morning after the Ml5.5 and 5.2, Seismic Safety Commission staff were in the Livermore area to conduct a reconnaissance of the area. Concentrating in the eastern portion of the valley where most damage was reported, damage was noted principally in the Sunrise Mobile Home Park. A high percentage of the mobile homes appeared to have fallen from their stands and sustained some damage. It was noted that some single wide mobile homes were still in the upright position, having not been shaken from their piers. Damage appeared extensive to metal porches and stairs as well as skirting and brick facias which serve to cover the piers underneath the coaches. No fires were reported in the mobile home park. Power was lost immediately and the main gas line which serves the entire mobile home park was closed as an emergency precaution, just in case gas lines at the coaches may have broken or separated. Almost a week after the earthquake it was reported that the mobile home residents were still waiting for the power and gas to be turned on.

A survey of conventional housing located adjacent (within tens of feet) to the Sunrise Mobile Home Park turned up virtually no external damage, although internal non-structural damages may have occurred.

In the northeastern area of Livermore, where homes have been recently constructed, damage to a block-long brick wall was noted. The wall is built in modules of about twenty feet long and six feet high which curve in and out in crescents along the sidewalk. Constructed of unreinforced brick, one unit wide, and located between the backyards of homes and streets for noise attenuation, several modules of the wall collapsed because of earth shaking.

Electrical Power

The Las Positas Substation, located near I 580 and about one mile west of the Greenville fault, lost power during the initial shock of January 24th. Seismic Safety Commission staff was told by P G & E personnel at the substation that one of the transformers shut down "very hard" during the earthquake and "got stuck." P G & E rerouted current, had bypassed the
the substation, and on Friday afternoon workers were still trying to get the transformer "unstuck." According to workers at the substation, no structural damage occurred to any of the equipment.

Seismic Safety staff was told that the power was restored to most areas in the Livermore Valley by 6:00 p.m. Thursday, the day of the earthquake.

A Problem of Rumor

One interesting aspect of this earthquake was the problem of rumor. The Lawrence Livermore Laboratory has a number of projects which include working with nuclear materials. Within an hour after the first shock, a rumor spread very quickly throughout parts of the community that a lethal radiation leak had occurred at the Laboratory. During the time that the rumor was rampant, the Livermore Lab decided it would in the best interest of its employees dismiss them so they could go home and check their families and property. Many people, seeing the entire facility being evacuated, assumed the worst (that radiation was actually in the atmosphere). Many residents decided to flee; parents who had children in nearby schools drove as quickly as possible to pick up their children and get out of the valley, or at least away from the Livermore Laboratory.

With approximately 7,000 persons leaving the Lab, and an unknown number of parents driving to pick their children up from school, a major traffic jam occurred. A spokesman from the Livermore Fire Department said that he had never seen such a traffic jam before and attributed its occurrence to the rumor of the radiation leak and persons attempting to get themselves and their families far away from the Laboratory.

Fire

No fires were reported. Immediately following the earthquake a "Condition C" emergency was radioed to all on and off duty emergency personnel to report for duty. In accordance with established procedures, fire equipment was moved outside of its buildings. Fire department personnel did assist in assessing damage and other related functions. Mutual aid was not required.

City employees at the Corporation Yard were alerted by the Emergency Coordinator to be ready to move into the community in case debris, fallen trees, etc., blocked access of emergency vehicles.

Law Enforcement

Except for traffic control, no major law enforcement problems were reported. A large number of police, including many who were off duty, were attending a training session at the time of the earthquake. Their presence facilitated the response by allowing a full force to be dispatched almost immediately.

Injuries

Valley Memorial Hospital, located west of downtown Livermore, treated thirty persons who were injured during the first shock on Thursday morning. Seismic Safety Commission staff was told by the nurse in charge that most of the injuries they treated occurred in mobile homes and were minor in nature. Three
persons were injured seriously enough to be admitted to the hospital; these injuries included a broken hip and acid and tar burns. Other injuries treated were twisted ankles and several suspected heart attacks.

The initial shock knocked out the electrical power at the hospital, but the emergency generator started and power resumed. Phones at the hospital became immediately overloaded and hospital personnel who were off-duty stayed until injured persons stopped coming for treatment.

Radio Communications were set up by three volunteers who came to the hospital without being asked. These volunteer citizen and operators stayed until normal telephone communications resumed.

Damage to the hospital building was minimal. According to the Chief Engineer, no structural damage occurred. The only damage reported was a broken water pipe which was fixed immediately, and some hairline cracks in interior plaster walls.

The third earthquake of this sequence which occurred at 6:33 p.m. on Saturday, January 26th (M = 5.6) resulted in several more injuries. Five persons were treated for minor injuries at the Valley Memorial Hospital. No persons were injured seriously enough to be admitted to the hospital.

Red Cross Activities

The Livermore Chapter of the Red Cross set up an emergency recovery center at the Recreation Hall near the Sunrise Mobile Home Park. The Red Cross Center, which assisted over sixty families, provided shelter and meal arrangements for many of the people living in the mobile home park. Most persons from the mobile home park needing shelter contacted friends and relatives through Red Cross assistance; others were provided rooms and meals at nearby motels.

Emergency Recovery

According to a spokesman from the Livermore Fire Department, the Emergency Operations Center for the City of Livermore was in operation within one hour of the 11:00 a.m. shocks. The most important function carried out by the Emergency Operations Center was to dispatch responsible city personnel to check for obvious building damage within the city. If any damage was suspected, a person from the City Building Department was sent to carry out a more detailed inspection.

The Emergency Operations Center was closed down at approximately 6:00 p.m. on the day of the earthquake.
FIGURE 1
WATER TANK AT WENTE BROS. WINERY

FIGURE 2
ONE OF THE BUCKLED LEGS OF THE WATER TANK AT WENTE BROS. WINERY
DAMAGE AT TWO WINERIES DUE TO THE Mt. DIABLO, CALIFORNIA, 
EARTHQUAKE OF JANUARY 24, 1980

by

Onder Kustu

URS/John A. Blume & Associates, Engineers
San Francisco, California

A reconnaissance by an engineer from URS/John A. Blume & Associates, Engineers, on January 26, 1980, indicated that damage to storage tanks at the Wente Bros. Winery near Livermore, California, from the Mt. Diablo earthquake of January 24, 1980, was of engineering significance. A survey team* was assembled, and this team visited the Concannon and Wente Bros. wineries on January 28, 1980. The team spent the next two days documenting the damage at the Wente Bros. Winery.

The two wineries surveyed are located about three kilometers southeast of Livermore, and are one kilometer apart from each other. Each winery contains, in addition to buildings, one elevated water tank and a variety of cylindrical wine tanks. No damage to any structure was observed at the Concannon Winery. Extensive damage was sustained by the elevated water tank and the wine tanks at the Wente Bros. Winery, even though no damage to the buildings was observed.

The elevated water tank at the Wente Bros. Winery has a capacity of 20,000 gallons. Total height to the top of the tank is about 85 feet. The tank is supported on four L6x6x½ legs, which are connected with 3-inch-angle horizontal members and braced with 1-inch-diameter diagonal turnbuckle rods (Figure 1). The earthquake caused the two northern legs to buckle at the lowest two spans (Figure 2). There was evidence of uplift at the two southern legs: the base plate at the southeastern leg had shifted inward about 0.5 inch. An approximate analysis indicated that a base shear coefficient of 35% would be necessary to cause the observed damage, neglecting the effect of vertical accelerations.

The water tank was drained immediately following the first shock and was empty during the aftershocks. At the time of this report, no estimate of the repair costs was available.

A total of 208 cylindrical steel tanks were surveyed at the Wente Bros. Winery. Thirty-one of these were small, fiberglass-lined steel tanks supported on individual legs constructed of pipes. The remaining 177 tanks were stainless steel tanks with capacities ranging from 6,000 to 50,000 gallons. Some of these stainless steel tanks had cooling jackets consisting of a belt of a second layer of steel wrapped around the shell with a gap in between through which the coolant is circulated. In addition, a number of wood casks and barrels were surveyed, none of which was found to be damaged by the earthquake.

*URS/Blume survey team members: T. Allan Moore, Gerald W. Kralik, Charles D. Kensler, Peter I. Yanev, and Roger E. Scholl
The typical damage to the small, fiberglass-lined steel tanks was toppling of the tanks due to broken legs at the cast iron joints. However, no rupture of the tanks or loss of their contents was observed. Damage to these tanks did not appear to be significant, and they could be easily repaired and modified to withstand similar ground motion without damage.

The most extensive damage occurred to the stainless steel tanks (Figure 3). These tanks are vertical cylinders made of 12- to 14-gage stainless steel sheets. The diameters vary from 6 to 22 feet with a height-to-diameter ratio (H/D) between 0.8 and 3.0. The tanks are seated on elevated concrete pads 2 to 4 feet above the ground. The tops of the pads are sloped slightly to facilitate drainage of the tanks. Most tanks are anchored to the concrete pads at two points at the high side of the pads, although a few are anchored at six to eight points.

During the earthquake, 47 stainless steel tanks were empty or partially full. Forty of these suffered no damage or only minor damage from the earthquake. Out of the 130 tanks that were completely full at the time of the first shock, 10 suffered no damage and 24 suffered minor damage consisting of minor spalling of concrete, failed anchorage welds, or minor local buckling. Seventy tanks suffered a medium level of damage consisting of concrete spalling at the pads, failed anchorage welds and bolts, and some shell buckling with peak-to-peak buckle amplitudes of less than 2 inches. Twenty-six of the tanks sustained damage considered to be severe. Most of the anchors for these tanks had failed, and the shells were buckled extensively with buckle amplitudes exceeding 2 inches peak to peak. Most of the severely damaged tanks had permanent overall deformations such as uplift at the base by as much as 3 inches and visible tilting from the vertical. Only one tank was reported to have ruptured at the base.

A cursory study of the damage data indicates that the mode of failure or the pattern of damage was a function of the following factors:

1. Fullness or emptiness of tanks: Empty tanks suffered little or no damage.

2. Height-to-diameter ratio (H/D): The tanks with low values of H/D (H/D < 1.5) had predominantly large-amplitude 'elephant foot' buckles all around (Figure 4). The tanks with intermediate values of H/D (1.5 ≤ H/D ≤ 2.0) exhibited varying patterns and combinations of diamond-shaped buckles (Figure 5) and elephant foot buckles. Tanks with high values of H/D (H/D > 2.0) suffered minor or no damage to the shell but had some failed anchorage welds or bolts.

3. Location of the cooling jackets: Where this extra sheet of steel was close to the bottom of the tank, there was no damage to the shell. Where the jacket was located 3 to 4 feet above the base, the major buckling occurred between the cooling jacket and the base.

The other damage at the Wente Bros. Winery consisted of a few buckled, broken or dislocated pipes; some damage to the catwalks around and above the tanks also occurred.

The total dollar value of repairs to the wine tanks is estimated to be between $1 million and $1.5 million, which is considered to be a small loss. A greater loss would have been sustained if tank ruptures and complete loss of contents had occurred.
FIGURE 3 A GENERAL VIEW OF TANK DAMAGE AT WENTE BROS. WINERY

FIGURE 4 TYPICAL 'ELEPHANT'S FOOT' BUCKLING PATTERN
FIGURE 5  TYPICAL DIAMOND-SHAPED BUCKLING PATTERN
Livermore, California Earthquake of January 24, 1980

Lawrence Livermore Laboratory

by

Loring A. Wyllie, Jr.

Lawrence Livermore Laboratory occupies an area of approximately one square mile bounded on the west by Vasco Road, on the south by East Avenue and by Greenville Road on the east. The complex reportedly contains 147 buildings and 961 trailer units representing about 3.5 million square feet of floor area. Approximately 7100 people are employed in the Laboratory.

Lawrence Livermore Laboratory sustained considerable damage in the earthquake of January 24, 1980. Damage to furniture and partitions was extensive in several of the buildings. Twenty-five people were reportedly injured from the falling of building contents and received medical treatment. Access to the Laboratory by the Reconnaissance Team was difficult due to an extensive security system on the site. A tour of portions of the site was arranged for the afternoon of January 29, 1980. No photographs could be taken but Lawrence Livermore Laboratory officials indicated that they would make photographs available to the team.

Building 113 - Physics Building -

Building 113 is a five-story reinforced concrete building 90 feet square in plan. The floor system is a two-way joist or waffle slab with columns typically on a 30 foot grid each direction. Two interior columns are replaced with reinforced concrete core walls which provide the primary lateral force resistance for the building. The building was designed in 1964 reportedly to the 1964 Uniform Building Code's seismic requirements.

The core walls had considerable fine diagonal cracking several feet apart. The walls resisting east-west lateral forces generally had diagonal cracks up to the west only while north-south walls had cracks in both diagonal directions. Horizontal cracks typically occurred at construction joints within the stairwells. Cracks were observed in the floor system of the Fourth and Fifth Floors near the corners of the concrete core which is within 20 feet of the perimeter frame. This cracking was approximately 1/16 to 1/8 inch wide and the core side of the crack was frequently slightly higher. This floor cracking appeared to be the result of vertical shear or interaction of the walls and frame system as the slabs attempted to transfer overturning forces from the walls to the perimeter columns.

The building had extensive cracking of non-structural partitions and several light fixtures fell. One large lens of a fluorescent fixture in front of the elevators was hanging by its hinge creating an obstacle to corridor traffic. Office contents were scattered and dislodged. In one office a security file cabinet which reportedly weighs over 1000 pounds empty, slid nearly two feet on the floor blocking the doorway to the office.
Building 111 - Administration Building

Building 111 is a seven-story reinforced concrete building in the shape of a T. The building has various concrete shear walls although it was impossible to determine their layout and extent during a brief visit. Shear walls generally had fine cracking but not as extensive as in Building 113. In one stairway it was noted that cracks frequently followed grooves in the concrete finish.

A freestanding exterior stairway pounded with the main building spalling concrete and damaging expansion covers. Diagonal cracks were noted in one corner building column.

Building 331 - Plant Engineering

Building 331 is a two-story concrete frame building apparently designed in 1965. The exterior columns and roof beams and eyebrow are exposed concrete with a curtain wall system between columns and concealing the Second Floor framing. This results in the interior face of the typical exterior column being in the same plane as the exterior edge of the Second Floor perimeter beam. The building has no shear walls although one short concrete wall was observed adjacent to one stairway in the lower story with considerable cracking. The building had considerable partition damage.

The columns had some cracks below the stiff roof beam, particularly at the corner columns. Some spalling was noted in typical exterior columns at the Second Floor level where the rubber base was loose. At one column where the curtain wall mullion was not tight to the column, vertical cracks in the column were noted for the depth of the floor framing. This building warrants additional study.

Building 391 - Shiva Laser Building

Building 391 is a large building housing the Shiva Laser. The building apparently had no structural damage but the large laser frame had failed its anchorages. The facility was about two years old.

The Shiva Laser consists of two parts, a target area frame and the laser frame. The target area frame appeared to be 50 to 60 feet high and perhaps 40 feet in diameter. The frame is constructed of heavy structural steel tubes welded together at about 3 foot centers resulting in a very rigid frame to maintain optical alignment. The target frame was anchored by 20 - 3/4 inch diameter bolts at a center anchor about 3 feet in diameter. Vertical supports were also provided around the perimeter, but these supports resisted no lateral forces as they permitted thermal growth of the frame. The 20 anchor bolts all failed, some in shear and some apparently in tension. The frame apparently move 1/8 to 1/4 inch and some evidence of rocking had been observed by the technicians. The total weight of the target frame reportedly was about 350,000 pounds and anchorage had apparently been designed for 0.25 its weight. The technicians stated there was no further movement in the January 26 aftershock.
The laser frame appeared to be about 24 feet high, 140 feet long, and perhaps 40 feet wide. It was constructed with steel tubes similar to the target frame. The frame was anchored for thermal control at one corner and it was allowed to expand on one edge on a rail from the fixed anchor and on biaxial rollers elsewhere. The frame reportedly weighed 500,000 pounds. At the fixed anchorage, the bolts loosened and concrete was spalled below the base plate. No bolt failures were reported. Technicians reported that some bolts sheared where restraints to the fixed rail failed. A complete inspection was not complete at the time of the visit but the laser was reportedly in alignment. Raised, unbraced computer floor surrounding the frame had dislodged floor tiles but had been repaired.

Building 381 - Laser Fusion Laboratory

Building 381 is a large laboratory and office complex of fairly recent construction. The laboratory portion of the building is a high bay structure with steel framing and a crane. Exterior precast tilt-up wall panels connected to the steel column with plates and bolts and movement was noted with daylight in several joints. It was reported at one corner that the T-bar ceiling joint was not caught within the joint between precast panels. Portion of the ceiling fell and optics and cameras on test tables shifted.

The office portion of Building 381 is a two-story steel framed building with exposed frames on the perimeter. There was no apparent structural damage. The curtain wall had popped off many covers of the mullions and one mullion anchorage at the roof failed with a 3 inch permanent mullion movement. No glass was broken. Inside this building there was relatively little distress in the lower floor but the upper floor had suffered considerable damage to contents. Partitions were cracked and many portions of the T-bar ceiling were damaged. Numerous light fixtures which clipped into the T-bar system fell. The ceilings and light fixtures appeared unbraced.

Building 332 - Metallurgical Chemistry

Building 332 is a one-story laboratory facility which houses radioactive elements. The original portion of the laboratory was constructed in 1960 and has 10 inch exterior reinforced concrete walls in a large rectangular plan. Interior corridor walls and walls between all laboratory rooms are 9 inch reinforced concrete. A few fine, hairline diagonal cracks were reportedly caused by the earthquake. A newer portion occupied in 1978 appeared to have no damage. Some movement and damage to ceiling tile and floor plate was noted at an expansion joint. Equipment was all anchored and none shifted. Chemicals in a wall hung cabinet apparently shifted but were restrained by closed wire glass cabinet doors. The newer portion reportedly was designed to a spectrum beginning at 0.5 g and the older building apparently had been reanalyzed to that criteria.

An office portion of this building was also constructed in 1960 with walls of stacked bond concrete masonry. The masonry had numerous cracks and one interior partition wall appeared to be leaning slightly. An offset of 3 to 4 inches was observed in one parapet. It was reported that preliminary investigation had revealed that the masonry was both ungrouted and unreinforced. An engineer with the laboratory indicated that the 1960 drawings, prepared in the eastern United States, did not show the masonry to be reinforced.
A loft over the laboratories containing mechanical equipment was framed with structural steel and precast concrete cladding panels. The steel frame was reportedly K-braced several years ago. It was reported that the cladding panels had some spalling at their joints.

**General Observations**

Lawrence Livermore Laboratory reportedly began a program of anchoring laboratory and service equipment several years ago. The program was reportedly about 75% complete. Critical equipment, that related to radioactive materials, was anchored for a spectra with 0.5 g minimum horizontal and vertical but most equipment anchorage was sufficient for 1.0 g horizontal and vertical. Non-critical equipment was anchored to UBC criteria. For convenience, 3/4 inch round bolts were typically used. No equipment anchored to this criteria reportedly moved. Some tanks had minor stretching of anchor bolts. All anchored equipment observed during the tour had performed well. An unanchored chiller in Building 331 had shifted off its spring isolators.

Emergency generators came on after the earthquake when power was lost. The power reportedly came back on very shortly. The only breaks in underground utilities were several transite pipes. Piping apparently performed well although a considerable amount of plastic water pipe in a laboratory was broken.

Gas bottles were generally restrained by chains which restrained the bottles. Unrestrained gas bottles fell over throughout the site, although none exploded. Apparently, only one pane of glass was broken in the entire complex.

Trailer units are used for offices and storage throughout the site. Many trailers had braced supports which apparently performed well. Some unbraced trailers remained on their supports, especially when a large group were ganged together. However, numerous trailers did fall from their unbraced supports and repairs were well underway during the January 29 visit.
Livermore, California Earthquake of January 24, 1980

Sandia Laboratories

by

Chris D. Poland

Located to the south of, and immediately across the street from the Lawrence Livermore Laboratories, Sandia Laboratories is a complex of one and two-story office and laboratory buildings at the foot of the rolling hills in the east Livermore Valley. This complex, located near the Greenville Fault, is constructed of a variety of building types and ages. Reports from personnel at the labs indicate that the shaking lasted for about 15 to 20 seconds and could be classified as VI on the Modified Mercalli Scale. Peak ground acceleration at the site has been estimated in the .2 to .3 g range, though the nearest strong motion record was taken 15 km away. Personnel of H.J. Degenkolb & Associates toured the damaged areas on January 25 and 31.

In general, Sandia appears to have fared this earthquake quite well, especially when compared with the damage reports from Lawrence Livermore Labs. Structural damage to buildings was generally limited to hairline cracking of some concrete elements, and working between concrete frame members and infill concrete block walls in two, two-story concrete frame buildings, and diagonal cracking of some of the panels in a tilt-up building.

The two-story frame buildings are generally non-ductile concrete frames with transverse concrete or steel braced shear walls and irregularly placed concrete block infill walls. They were designed under the 1955 Uniform Building Code and because of the window wall layout, include exterior perimeter frames with 5 feet, 6 inch deep beams, concrete block infill and "short" columns. Structural damage to the buildings included hairline shear cracks in the short, exterior columns, hairline cracks due to frame action and varying degrees of diagonal and separation cracks in the infill concrete block walls.

The 100 foot by 400 foot long concrete tilt-up building, which is currently being strengthened with a new roof diaphragm and new diaphragm to tilt-up panel connections, developed diagonal cracks from the roof truss seats at the top of the panels down to the edge of the panel. It is suspected that these new cracks were the result of the existing style of panel to truss connection, and out-of-plane forces.

The mechanical HVAC systems at Sandia were generally unaffected by the shaking even though most of the equipment sat unanchored on rubber isolation pads or on spring isolators. None of the HVAC equipment went off line as a result of the earthquake.

The shaking caused a considerable amount of disruption to the architectural finishes. As is typical, it was in the form of wall cracking, displaced T-bar ceilings and lights, dislodged expansion joint covers, pounding and separation of elements of different stiffness, and the breakage of a small amount of glass.
As is typical of all earthquakes and especially aggravating with small events such as this one, the contents of Sandia's buildings were considerably disrupted. In the library, the bookshelves stood-up well but the books filled the aisles. Office contents were generally scattered, and in the personnel offices, most of the files on the floor-to-ceiling open shelving spilled to the floor. Indicative of the predominate shaking of this event, nearly all the files facing toward the east fell while a similar set, in the same room, facing north remained in place.

In the computer center, located in a separate, wholly underground facility, the only indication of strong shaking was a 2" - 3" movement of the computer main frames, some of the peripheral equipment, and the 10" - 12" sliding of the linked together tape storage racks. In a couple of cases, isolated 6 feet tall by 4 feet by 1 foot tape storage shelves overturned. The computer system went off line immediately after the earthquake because of a loss of electrical power but was soon restored to operating status. The infinite access floor, which was intermittently braced with metal banding as well as bounded by concrete walls was undamaged.

The only significant structural damage observed occurred to Sandia's 170,000 gallon fuel oil storage tank, which was full at the time of the earthquake. The tank is approximately 25 feet in diameter and stands 50 feet tall. The base and first 8 feet of the tank wall is reportedly 5/16" plate steel with the balance of the tank constructed of 1/4" thick plate steel. The tank was anchored to a concrete mat foundation with 20 - 5/8" diameter We-jits, all of which failed. A continuous elephant's foot buckle developed during the shaking and lateral compaction of the soil around one of the supply pipes occurred. The tank did not overturn, rupture, or otherwise spill its contents save a small amount that was forced out of the vent at the top of the tank.

While the Livermore Earthquake was a small enough event to avoid general structural damage to these older buildings, it points out once again the importance of properly anchoring architectural features and office furniture to limit the life safety hazards and cost of damage in a small event.
On Friday morning, January 25, 1980, the day after the earthquake, I visited the Livermore Intel site to assess damage that the earthquake might have caused. It was not an extensive investigation, but I spent about one hour visiting the plant.

No structural damage was noted anywhere, nor was any pointed out by the Intel personnel.

A tour of the basement revealed that all anchored equipment did not move. A fiberglass scrubber at the West wall was noted as not being anchored but no apparent motion was noticeable. A small air handling unit supported vertically by four rod supports at the corners, but not laterally braced, had broken a small plastic line (PVC) supplying it, but no other damage occurred. It was being braced laterally at time of the inspection.

The Fab area was visited, and it was pointed out that several pieces of equipment had shifted slightly - 2" being about the maximum excursion. All of the anchored pieces held fast and did not shift although obvious strain was taken by the rather small anchors. The shelves at the West wall which also were anchored by rather small devices also held fast. The stored material did shift slightly to the front but did not fall out due to the low intensity and short duration of the shock.

Some furnaces had moved slightly and caused a small buckling situation in one of the walls of the furnaces.

One piece of equipment, which did move, had rigid conduit coming up from the floor and obvious strain on this conduit was evident. Another piece which shifted had flexible conduit and no strain was noted.

One of the D.I. storage tanks had pulled out one anchor. It appeared as though it had not properly been set. The D.I. polishing columns were not anchored to the brace designed for their support, but fortunately no movement occurred.

I feel strongly that this small quake served to show that equipment must be secured to prevent business disruption. Even the small but effective anchors used in the Fab area were sufficient to prevent motion.

The facility was located on North Mines Road, off of First Street near HI 580.
The park is located immediately off Highway 580 on the north side and approximately 1.5 miles west of the Greenville overpass on 580. The park had 133 trailers (mobile homes) in its community; and, of this total, 90 fell from their supports during the sequence of Greenville earthquakes. It was related to us that an additional 40 suffered some degree of damage. All of the trailers investigated were supported by steel pyramid-like support with a base approximately 12 by 12 inches and a height of about 2 feet. There was no means of lateral support in any of the fallen trailers.

Some trailers had fallen forward, some sideways, and some to the rear, but all fell in the same direction, N60E. (It was subsequently learned that most motions were said to be in an E-W direction.) At the time of investigation, we had information that the fault break had a direction of approximately N30W. This would have indicated a motion of the ground of 90 degrees to the break.

The type of failure that occurred here was similar to that observed in other California earthquakes. It is basically a very simple mode of failure. Unrestrained trailers on vertical load-carrying devices will topple off of them when subjected to horizontal forces. High winds will also have a similar effect.

Certainly, codes and building officials have sufficient past history with these devices to require horizontal restraints. Retroactive action should also be considered.