DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

RECONNAISSANCE REPORT ON GROUND FAILURES AND GROUND CRACKS RESULTING FROM THE COYOTE LAKE, CALIFORNIA, EARTHQUAKE OF AUGUST 6, 1979

By

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ABSTRACT

This report describes ground failures observed during a reconnaissance of the epicentral region of the Coyote Lake, California, earthquake of August 6, 1979. The most abundant ground failures were rock falls*, rotational slumps*, and cracking of highway shoulders and turnout areas. Rock falls occurred in roadcuts in closely jointed or brecciated rocks. Rotational slumps, most of which occurred in pre-existing landslide deposits, moved only a few millimeters as a result of the earthquake. Slumps and cracking of highway shoulders and turnouts occurred only at sites within 1 km of the Calaveras fault. Rock falls with volumes of more than 2 m^3 occurred only at sites within 6 km of the fault; smaller rock falls occurred at distances up to 18 km from the fault. During the reconnaissance, ground cracks caused directly by fault movement were also observed at one locality.

INTRODUCTION

On August 6, 1979, at 10:05 a.m. (PDT), one of the strongest earthquakes to strike central California since 1906 occurred on the Calaveras fault near Coyote Lake; the epicenter was about 100 km southeast of San Francisco and 10 km northeast of Gilroy. The main shock, which was felt throughout much of central California, had a local magnitude of 5.7 (USGS network) or 5.9 (Berkeley Seismographic Station). Strong motion instruments in the epicentral area recorded peak accelerations as high as 0.44g with a duration of strong shaking of 3 to 12 seconds (Porcella and others, 1979). Epicentral coordinates, focal depth, origin time, and magnitude determinations of the main shock are given in Table 1.

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*Ground failure terms are adopted from the landslide classification of Varnes (1978). In rock falls, rock fragments descend slopes by free fall, bounding, leaping, and rolling. In rotational slumps, coherent blocks of material move downslope along distinct failure surfaces, and the movement involves a component of backward rotation.

TABLE I: TIME, LOCATION, AND MAGNITUDE OF MAIN SHOCK

TIME[1]: August 6, 1979 10:05:22.7 local time (PDT)

17:05:22.7 GMT

EPICENTER LOCATION[1]:

Latitude: 37°06.1' N ±0.1'

Longitude: 121°31.3' W ±0.1'

DEPTH OF FOCUS[3]: 9.6 km ±2 km

MAGNITUDE: m_b 5.3[2]

M_s 5.4[2]

M_l (Berkeley Seismographic Station) 5.9[1]

M_l (USGS network) 5.7 ±0.2[3]

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[1] Reference: R. Miller, Univ. of California, Berkeley, Seismographic Station, oral comm., August 10, 1979.

[2] Reference: J. Minsch, U. S. Geological Survey, Golden Colo., oral comm., August 10, 1979.

[3] Reference: Porcella and others, 1979.

On the afternoon of August 6, we conducted a reconnaissance along major roads in the epicentral area to determine the nature and distribution of ground failures—landslides and related effects—caused by this earthquake.

This report describes our observations of ground failures; it also describes shaking damage in one community and ground cracks caused by fault movement at one locality. A few sites that yielded negative results (i.e. no ground failures or ground cracks) are also described briefly because we judged it important to record that those sites were inspected. Plate I shows the itinerary of the reconnaissance, locations of the epicenter and the Calaveras fault, locations of observed ground failures, and locations of the sites described in the text.

OBSERVATIONS

Site I—Steel bridge across Pacheco Creek at Santa Clara-San Benito county line: We found no evidence of ground failure in the bed or along the banks of this dry creek. The bridge appeared to be undamaged. Several empty beer cans perched on girders under the bridge deck were not dislodged, indicating that the seismic shaking at this site was relatively weak.

Site 2—Dunneville: At the Dunneville general store, merchandise was knocked off shelves, a glass case was broken by bottles that toppled, an acoustical tile was dislodged from the ceiling, and a clay tile was dislodged from the roof outside. In the proprietor's house, next door to the store, items were knocked off shelves and tables, but no windows were broken, according to the proprietor's wife. A clerk, describing damage at her 2-story home 1.6 km west of the store, said that items were knocked off shelves and religious statuettes were toppled. Elsewhere in Dunneville, we observed two chimneys broken at roof lines on wooden houses, but we observed no other signs of external damage to either wood or stucco houses. From these descriptions and observations, we estimated that the shaking intensity in the Dunneville area was MMI VI–VII.

Site 3—Calaveras fault trace on Shore Road: Two fresh cracks occurred in the road pavement and shoulders a few meters west of the Tequisquita Slough bridge. The cracks both had strikes of N13°W, parallel to the nearest bank of the slough and subparallel to the fault, which strikes N21°W (Plate I). The shorter of the two cracks occurred in the north shoulder of the road, 1 m west of the longer crack. The shorter crack was 3 m long and a few millimeters wide; it showed no vertical or lateral offsets.

The longer crack, which was 10 m long and 10mm wide, contained several left-stepping en echelon segments with north-south strikes (fig. 1). The orientation of these segments relative to the fault trace is consistent with right-lateral shear displacement on the fault (Slemmons, 1977). Maximum vertical offset on the crack was 25 mm, with the east side being displaced relatively downward. The crack showed no lateral offset on August 6. When the site was re-examined on September 25, 1979, however, 5 mm of right-lateral offset was observed on a north-striking subsidiary crack that developed after the earthquake (fig. 2).

The occurrence of these two cracks on and subparallel to the mapped fault trace, their association with a subsidiary crack that subsequently showed right-lateral offset, and the left-stepping en echelon segments in the longer crack indicate that the cracks were surface expressions of the fault.

We found no ground cracks in the field north of the road or any signs of ground failure along the banks or in the bed of the slough. A fresh crack, 1 m long and a few millimeters wide, with a strike perpendicular to the road, was observed in the asphalt of the bridge deck; this crack was probably caused by shaking of the bridge.

Site 4—Calaveras fault trace on California Highway 25: We walked along the road for approximately 300 m on either side of the mapped fault trace, but we found no cracks in the pavement or shoulders.

Sites 5a,b—Calaveras fault trace in Hollister: We found no fresh cracks in the pavement or curbs where either South Street or 6th Street crosses the fault trace.

Site 6—California Highway 152 near San Felipe Village: A rock fall with a volume of 2 m^3 occurred in a roadcut on the north side of the highway. The rock fall was in a closely jointed, moderately cemented, fine-grained sandstone of the Panoche Formation; joint spacings in rock exposed in the roadcut ranged from a few centimeters to a few tens of centimeters.

Site 7—Canada Road at mountain front: We met Earl Hart, a geologist with the California Division of Mines and Geology. He told us that numerous cracks had occurred in the highway shoulder in this area.

Figure I: (Site 3) Crack in pavement on trace of Calaveras fault, a few meters west of Shore Road bridge over Tequisquita Slough. View is northwest. Crack was 10 mm wide. Maximum vertical offset was 25 mm, with the east side down; crack showed no lateral offset. Crack contained several left-stepping, en echelon segments; strike of these segments relative to fault trace was consistent with right-lateral shear. This crack and a shorter crack through the north shoulder of the road had strikes subparallel to the fault. Highway center stripe ended at patch in pavement; the road had been patched before the earthquake, probably because of damage due to fault creep. The two cracks were surface expressions of movement on the fault during the earthquake. Photograph taken 8/6/79.

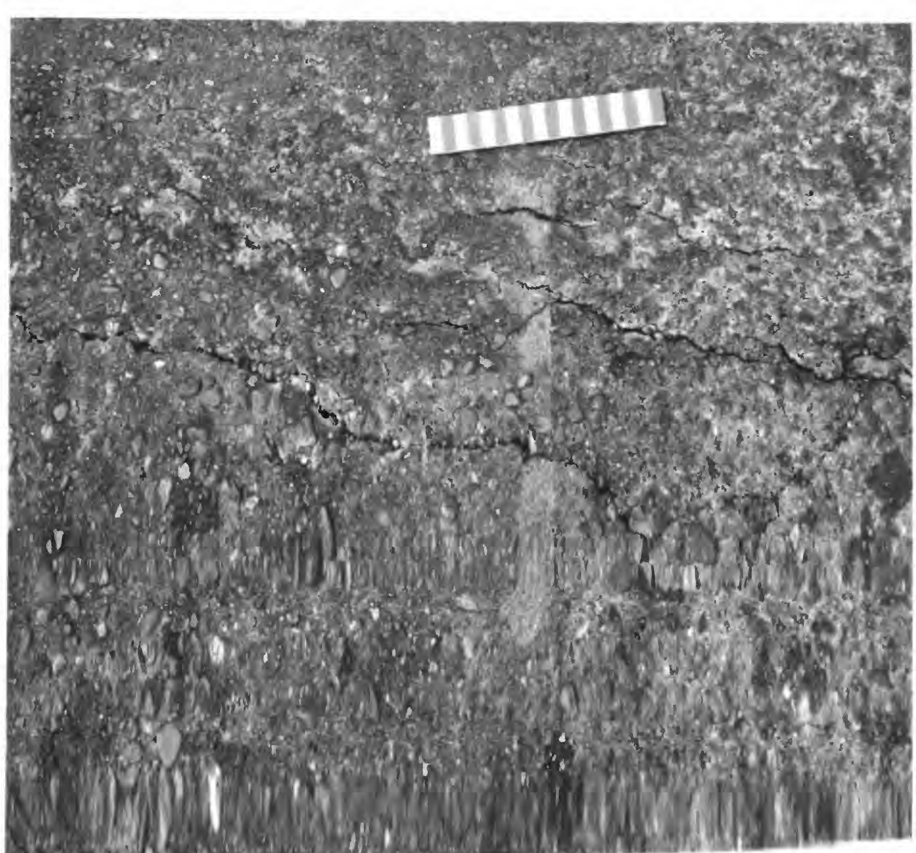

Figure 1: (Site 3) Crack in pavement on trace of Calaveras fault, a few meters west of Shore Road bridge over Tequisquita Slough. View is northwest. Crack was 10 mm wide. Maximum vertical offset was 25 mm, with the east side down; crack showed no lateral offset. Crack contained several left-stepping, en echelon segments; strike of these segments relative to fault trace was consistent with right-lateral shear. This crack and a shorter crack through the north shoulder of the road had strikes subparallel to the fault. Highway center stripe ended at patch in pavement; the road had been patched before the earthquake, probably because of damage due to fault creep. The two cracks were surface expressions of movement on the fault during the earthquake. Photograph taken 8/6/79.

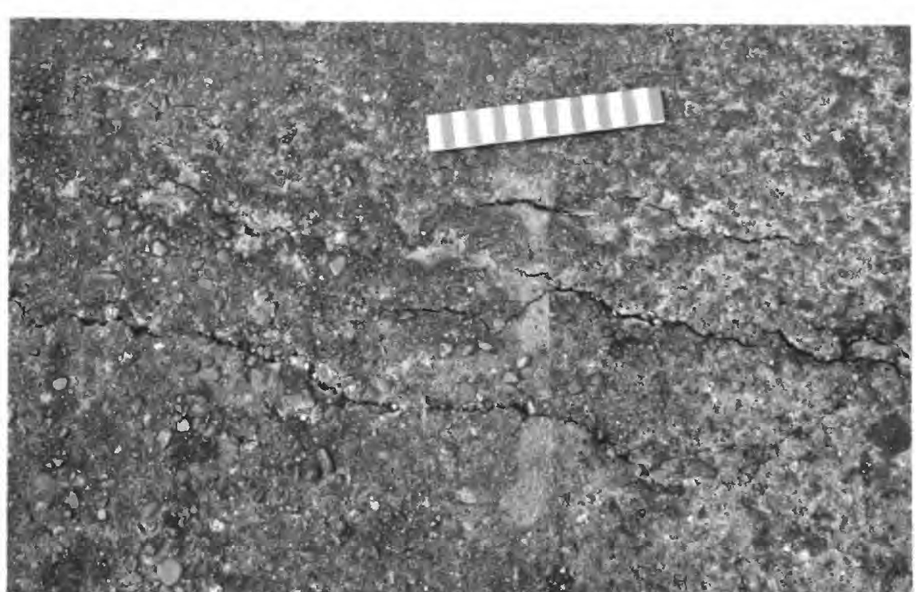

Figure 2: (Site 3) Part of crack shown in figure 1 and subsidiary crack (closest to scale) that developed after our observations on August 6. Scale is marked in 1 cm divisions. Offset of light-colored bar, painted after our visit on August 6, showed that 5 mm of right lateral displacement had occurred on the subsidiary crack. West is toward top. Photograph taken 9/25/79.

Site 8—Roadcuts on Gilroy Hot Springs Road near fire station: Angular pebbles and cobbles up to a few centimeters on a side were scattered on the road at the bases of two roadcuts. The roadcuts were in closely jointed sandstones, siltstones, and shales.

Site 9—Gilroy Hot Springs Road northeast of fire station: The greatest concentration of rock falls observed during the reconnaissance was between 4.6 and 5.5 km from the epicenter along a 3-km stretch of the Gilroy Hot Springs Road. Abundant boulders and cobbles from rock falls were strewn on the road (fig. 3). The rock falls originated on roadcuts through narrow spurs composed of moderately-cemented Franciscan graywacke with minor amounts of claystone. The largest boulder observed on the road was approximately 60 cm long, 60 cm wide, and 30 cm thick.

Site 10—East Dunne Avenue 0.8 km west of Cochrane Bridge: Movement of a small rotational slump opened cracks a few millimeters wide in the pavement. In a roadcut a few meters from the slump, a small rock fall ($< 1\ m^3$) occurred in weakly cemented, Quaternary sediments of the Santa Clara Formation.

Site 11—East Dunne Avenue 0.4 km west of Cochrane Bridge: On the south side of the road, a rock fall with a volume of $10\ m^3$, the largest we saw during our reconnaissance, occurred in a roadcut. The rock fall, which partly blocked an unpaved road, was in brecciated, hydrothermally altered serpentine (fig. 4).

On the north side of the road, an unpaved turnout area was disrupted by numerous cracks, and material around the edges of the turnout was shattered into blocks, a few tens of centimeters on a side (figs. 5,6). These blocks slid off the edges of the turnout area; displacements ranged up to 30 cm. The cracked and displaced material was compacted fill consisting of a heterogeneous mixture of rock fragments, sand, silt, and clay. The rock fall and the turnout area were on the nose of a steep, high ridge less than 200 m from the Calaveras fault.

Site 12— East shore of Anderson Reservoir: Numerous cracks occurred in the pavement and shoulders along a 1-km stretch of the highway on the east shore of Anderson Reservoir.

Figure 3: (Site 9) Boulders from rock falls along part of Gilroy Hot Springs Road between fire station and Coyote Creek bridge. Boulders of similar size were common along this north-south trending part of Gilroy Hot Springs Road, which had the largest concentration of rock falls of any area observed during the reconnaissance. View is north. Failures took place in roadcuts in graywacke with moderate amounts of claystone.

Figure 4: (Site 11) Largest rock fall observed during reconnaissance (volume = 10 m^3). View is south. Failure occurred in roadcut in brecciated, hydrothermally altered serpentine.

Figure 5: (Site II) Cracks and displaced blocks of compacted fill in highway turnout area on nose of steep, high ridge. View is north. Lens cap is 55 mm in diameter.

Figure 6: (Site II) Displaced blocks of fill on eastern edge of road turnout. View is north. Portion of signpost visible in picture is approximately 2 m long. Maximum displacement of block was 30 cm.

Reservoir. Most of these cracks were caused by movements of a few millimeters on rotational slumps (figs. 7,8); a few cracks were caused directly by shaking. This site was on the Calaveras fault in an area where the ground had been disrupted by numerous older landslides; the earthquake-induced cracks and slumps took place in old landslide deposits derived from weakly cemented sandstones, mudstones, and shales of the Berryessa and Santa Clara formations.

The most prominent crack in the pavement (fig. 7) was the crown of a complex slump about 20 m long and 50 m wide. Offsets on the crack indicated that the slump had moved up to 25 mm vertically and 18 mm horizontally. Movement was toward the western shoulder of the road where the ground sloped down toward the reservoir at an angle of about 45°.

Road from Anderson Reservoir to Henry W. Coe State Park: We drove about 3 km north and east of Site 12 on the road to Henry W. Coe State Park; the only evidence of ground failure was a few scattered pebbles on the road at the bases of some roadcuts. Mrs. Candy Breckling, who lives at the State Park headquarters, reported that only one small rock fall occurred on the road between Anderson Reservoir and the park. On a horseback tour of the back country in the park, she did not observe any rock falls or other damage to trails caused by ground failures.

Other rock falls: Several other earthquake-induced rock falls with volumes of less than 1 m^3 occurred in roadcuts along the reconnaissance route; localities of these are plotted in Plate 1. One of these rock falls occurred in serpentine; the rest were in closely jointed, weakly to moderately cemented sandstones, mudstones, or shales.

SIGNIFICANT FINDINGS

The most abundant ground failures observed in the epicentral region were, in order of decreasing numbers, rock falls, rotational slumps, and cracking of highway shoulders and turnout areas. Rotational slumps and cracking of shoulders and turnout areas occurred only at sites within 1 km of the Calaveras fault and 12 km of the epicenter. The

Figure 7: (Site 12) Crack in highway pavement was part of crown of complex rotational slump. View is north. Segment of crack in foreground had strike of N87°W; segment in backround had strike of N59°W. Offsets on the crack showed the slump had moved a maximum of 18 mm horizontally and 25 mm vertically.

Figure 8: (Site 12) Crescentic crack in highway pavement was crown of small rotational slump. Location is 300 m north of locality of figure 7. View is southwest. Offsets on cracks showed slump moved a few millimeters during the earthquake.

site where slumps were most abundant (Site 12) was on the fault and 9 km northwest of the epicenter. Small rock falls occurred as far as 18 km from the fault and 23 km from the epicenter; however, rock falls larger than 2 m^3 were restricted to sites within 6 km of the fault and 8 km of the epicenter. This conforms to findings that, in other recent California earthquakes with magnitudes between 5.1 and 5.9, ground failures have occurred only at sites within a few kilometers or tens of kilometers of the causative faults (Bonilla, 1959; Bonilla, 1960; Yerkes and Castle, 1967; Nason and others, 1975; Harp and others, 1980). Ground failures in the Coyote Lake earthquake caused only minor damage, mostly by cracking highway pavement and by partially blocking roads with debris.

Rock falls occurred only on roadcuts; the abundance of roadcut failures and the lack of rock falls on steep natural slopes indicate that cut slopes have higher susceptibilities to seismically-induced rock falls than do natural slopes in the same materials. This finding conforms to observations made after several other recent earthquakes (Keefer and others, 1978; Harp and others, 1980). A cut increases a slope's susceptibility to failure by steepening the slope, by disturbing the rock, and, in some cases, by exposing planes of weakness in the rock.

Rotational slumps were restricted to a small number of sites, and those slumps that were activated moved only a few millimeters. The restricted distribution and short distances of travel are due, in part, to the short duration of significant ground motion and, in part, to the properties of the materials in which the slumps occurred; though most slumps occurred in young landslide deposits, the earthquake occurred near the end of the summer season when little precipitation falls in the Coyote Lake area. The landslide deposits were, therefore, depleted in moisture and relatively resistant to failure.

The most prominent cracking of a highway turnout area (Site 11) occurred on the nose of a steep, high ridge; this suggests that the ground motion was relatively severe in that topographic setting. Similar instances of severe cracking on steep ridges and promontories have been reported in other earthquakes (Bonilla, 1959; Hadley, 1964; Nason, 1971; Harp and others, 1978; Youd and Hoose, 1978; Harp and others, 1980), and theoretical studies have shown that ridges and promontories do amplify ground motion (Wong and Jennings, 1975).

We observed ground cracks caused by fault movement at one site (Site 3) on the Calaveras fault approximately 11 km north of Hollister. We searched for fresh ground cracks at three other sites farther south (Sites 4, 5a, 5b) but found none. We did not search for fault-related cracks north of Site 3; investigations by others, however, indicate that ground cracks occurred at several sites on a 14-km-long section of the fault north of Site 3 (Cotton and others, 1979; Herd and others, 1979).

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