

PRELIMINARY REPORT ON SEPTEMBER 28, 2004 PARKFIELD EARTHQUAKE

By

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A strong earthquake of magnitude 6.0 (M_w) struck the Central Coast of California at 10:15:24 AM PST (17:15:24 UTC) on Tuesday, September 28, 2004. The epicenter (Figure 1) was 11 km (7 mile) SSE of Parkfield, at a depth of approximately 8 km (5 mile). The main shock was followed by a strong aftershock of magnitude 5.0 roughly four minutes later. As expected, numerous smaller aftershocks continue to strike to epicentral region. At the time of this report, no injuries have been reported and the damage is light, mostly limited to nonstructural damage. This preliminary report presents basic information on the epicenter location, intensity of shaking, and performance of structures in the epicentral region.

Epicenter Location and Shaking Intensity

The epicenter of the earthquake was 11 km (7 mile) SSE of Parkfield. Early analysis by the USGS and UC Berkeley indicate that the event had a strike-slip mechanism and most likely occurred on the San Andreas Fault. The fault appears to have ruptured primarily in the north-west direction as evident from the pattern of aftershocks (Figure 2). Strong shaking during this event lasted for about 10 seconds in the epicentral region. This earthquake is the seventh in a series of repeating earthquakes on this stretch of the fault. The previous events were in 1857, 1881, 1901, 1922, 1934, and 1966. The previous two earthquakes ruptured the opposite direction from NW to SE along this section¹.

Figure 3 shows the instrumental shaking intensity map for the 2004 Parkfield earthquake. The instrumental intensity was about VI in the epicentral region, which corresponds to strongly-felt shaking but light damage. The instrumental intensity in the Paso Robles, Templeton, Atascadero region was about V. Note that this region experienced significant structural and nonstructural damage during the magnitude 6.5 San Simeon earthquake that struck the Central California on December 23, 2003. Figure 4 shows the contours of peak ground accelerations (PGA) made available at the CISN² site shortly after the earthquake. As more information on recorded motions becomes available, it is expected that the information in Figures 3 and 4 will be updated.

¹ Source: <http://www.cisn.org/special/evt.04.09.28/>

² <http://www.cisn.org/shakemap/nc/shake/51147892/pga.html>

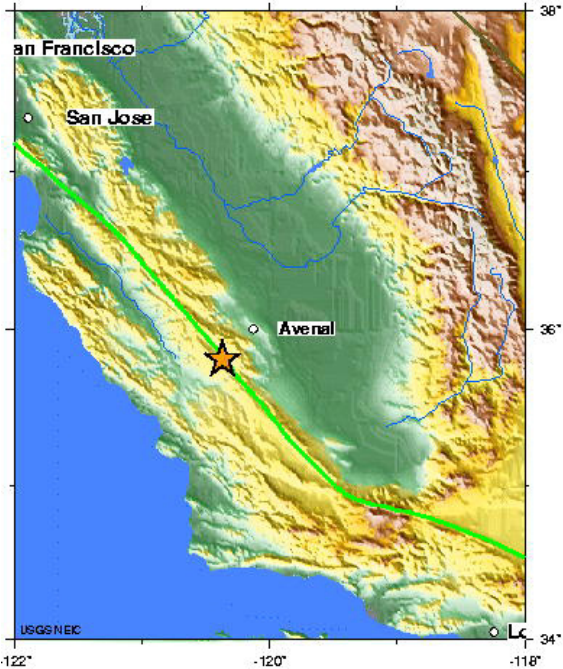


Figure 1. Epicentral location of the September 28, 2004 Parkfield earthquake³.

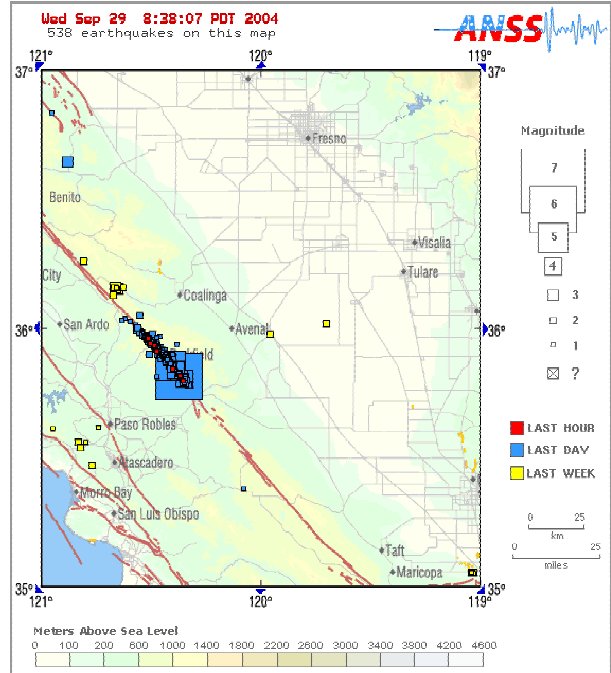


Figure 2. Epicenters of main shock and aftershocks for the September 28, 2004 Parkfield earthquake⁴.

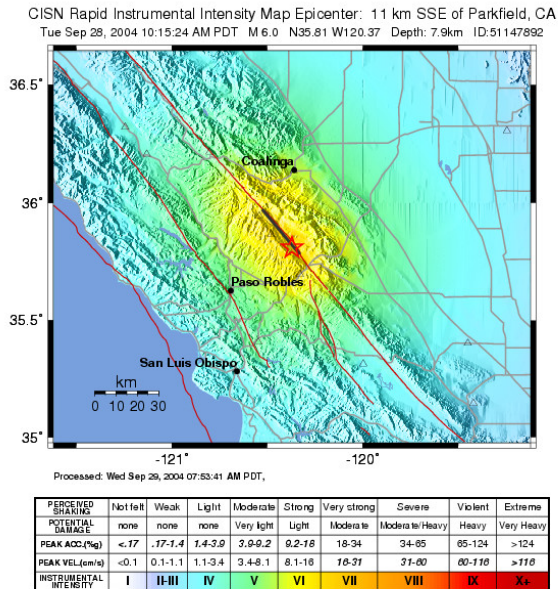


Figure 3. Intensity map (CISN).

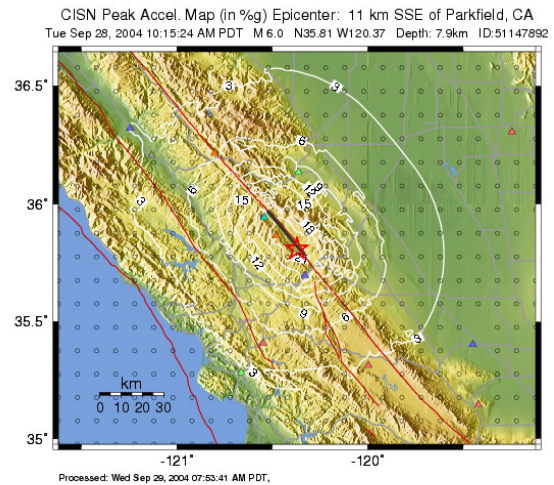


Figure 4. Peak ground acceleration map (CISN).

³ Adapted from USGS NEIC website: http://neic.usgs.gov/neis/bulletin/neic_nybg.html

⁴ Adapted from ANSS website: <http://quake.wr.usgs.gov/recenteqs/FaultMaps/120-36.htm>

Recorded Motions

Due to active seismic history of the epicentral region, the Parkfield area is heavily instrumented by both the California Strong Motion Program (CSMIP) and the United States Geological Survey (USGS). However, very few recording stations in this area possess modern digital technology with automated communication capability. The CSMIP is trying to recover data from analogue recording instruments and has made the recorded ground acceleration traces available online⁵. A list of the recording stations close to the epicenter available at the time of this report is shown in Table 1. Note that the data from these stations, with the exception of Parkfield – Cholame 5W, was available in analogue form – traces of the accelerations histories in the east-west, vertical, and north-south directions – at the time of this report.

The early reports indicate that the fault rupture propagated north-east of the epicenter. The conventional wisdom would, therefore, suggest that the ground motions should be stronger north of the epicenter compared to south of the epicenter. However, recorded motions indicate an strong shaking both south and north of the epicenter: 0.84g, 0.82g, 0.61g, and 0.82g acceleration was recorded at Parkfield–Stone Corral 1E (7.8 km south-east), Parkfield-Fault Zone 1 (8.8 km south), Parkfield-Cholame 2W (Sta 2) (12 km south-west), and Parkfield Cholame 3E (12 km south-east), respectively; 1.13g and 1.31g accelerations were recorded at Parkfield-Fault Zone 11 (9.2 km north-east) and Parkfield-Fault Zone 14 (12 km north), respectively. At the time of this report, reasons for this pattern of PGA distribution are being investigated.

At the time of preparing this preliminary report, digital information on the recorded ground motions was available from one ground site: Cholame Station 5W, which is about 13 km from the epicenter. At this station, the recorded PGA value in the east-west, north-south, and vertical direction are 0.25g, 0.23g, and 0.17g, respectively (Figure 5). The horizontal acceleration records contain noticeable pulses that appear to be consistent with past observations on near-fault acceleration recordings. Similar pulses are visible in traces of accelerations at several other recording stations listed in Table 1.

Linear elastic response spectra (5% damping) for the three components of the acceleration at the Cholame 5W station are shown in Figure 6. Also included for comparison is the elastic design spectrum ($R = 1$) for UBC-97 without near-source factors and for a stiff-soil site condition. This figure clearly shows that the response spectrum in the east-west direction, the predominant fault-normal direction, is higher than the response spectrum in the north-south direction, the fault-parallel direction, for periods up to about 0.75 sec. This observation is consistent with the expectation in near-fault zones that fault-normal ground motion is stronger than fault-parallel motion. For this station, the linear elastic response spectra in both horizontal directions are lower than the UBC-97 elastic design spectrum. For other recording stations with more intense ground shaking, however, such a conclusion may not be valid.

In addition to free-field recordings, motions were recorded on a Caltrans bridge. This bridge is located on Highway 46, roughly 11 km south of the epicenter and 150 m west of the San Andreas Fault. The recorded shaking at the abutment was 0.67g, with shaking recorded on the deck near the east abutment of 1.05g. This bridge was immediately operational after the earthquake. The high accelerations at the east abutment appear to be due to pounding between the deck and the abutment.

⁵ http://www.quake.ca.gov/cisn-edc/IQR/Parkfield_28Sep2004/iqr_dist.htm

Table 1. Recording stations and peak ground accelerations within 15 km of the epicenter⁶.

Station Name	Station No./ID	Network	Dist. (km)	PGA (g)	
				NS	EW
Parkfield - Gold Hill 1W	36415	CGS	0.5	0.15	0.16
Parkfield - Gold Hill 2W	36416	CGS	1.6	0.28	0.17
Parkfield - Fault Zone 4	36414	CGS	3.0	0.12	0.13
Parkfield - Fault Zone 3	36408	CGS	3.9	0.41	0.38
Parkfield - Gold Hill 2E	36421	CGS	3.9	0.23	0.17
Parkfield - Gold Hill 3W	36420	CGS	4.0	0.45	0.85
Parkfield - Fault Zone 6	36454	CGS	6.4	0.22	0.18
Parkfield - Fault Zone 7	36431	CGS	6.8	0.25	0.24
Parkfield - Fault Zone 8	36449	CGS	7.0	0.51	0.63
Parkfield - Gold Hill 3E	36439	CGS	7.1	0.11	0.21
Parkfield - Gold Hill 4W	36433	CGS	7.1	0.40	0.43
Parkfield - Stone Corral 1E	36419	CGS	7.8	0.84	0.73
Parkfield - Stone Corral 2E	36422	CGS	8.3	0.20	0.19
Parkfield - Fault Zone 1	36407	CGS	8.8	0.82	0.59
Parkfield - Fault Zone 11	36453	CGS	9.2	1.13	0.57
Parkfield - Fault Zone 9	36443	CGS	9.6	0.10	0.16
Parkfield - Stone Corral 3E	36437	CGS	9.6	0.23	0.20
Parkfield - Elementary School	36531	CGS	10	0.29	0.23
Parkfield - Gold Hill 5W	36434	CGS	10	0.19	0.25
Parkfield - Fault Zone 12	36138	CGS	10	0.31	0.27
Parkfield - Cholame 1E	36452	CGS	11	0.37	0.45
Parkfield - Cholame 2W (Sta 2)	36228	CGS	12	0.37	0.61
Parkfield - Cholame 3W	36410	CGS	12	0.58	0.34
Parkfield - Cholame 3E	36450	CGS	12	0.82	0.53
Parkfield - Cholame 4W	36411	CGS	12	0.52	0.58
Parkfield - Cholame 2E	36230	CGS	12	0.51	0.48
Parkfield - Fault Zone 14	36456	CGS	12	0.59	1.31
Parkfield - Cholame 4AW	36412	CGS	13	0.29	0.30
Parkfield - Cholame 5W (Sta 5)	36227	CGS	13	0.23	0.25
Parkfield - Gold Hill 6W	36432	CGS	14	0.10	0.11
Parkfield - Cholame 6W	36451	CGS	14	0.39	0.24
Parkfield - Fault Zone 15	36445	CGS	15	0.23	0.15

⁶ Information for CISN (10/5/04)

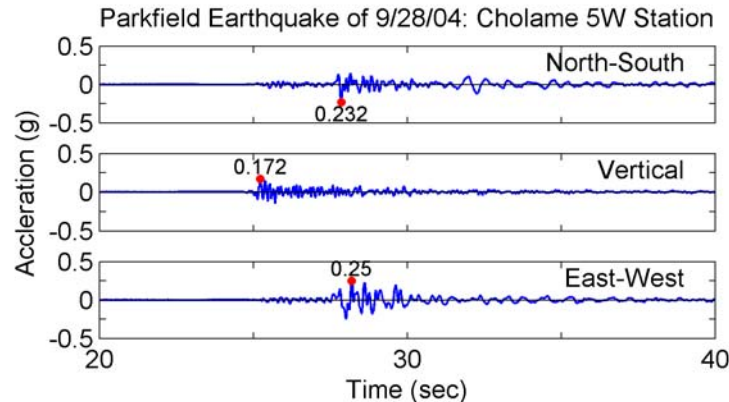


Figure 5. Ground accelerations recorded at the Cholame 5W Station during the Parkfield earthquake of September 28, 2004 (Data from CISEN).

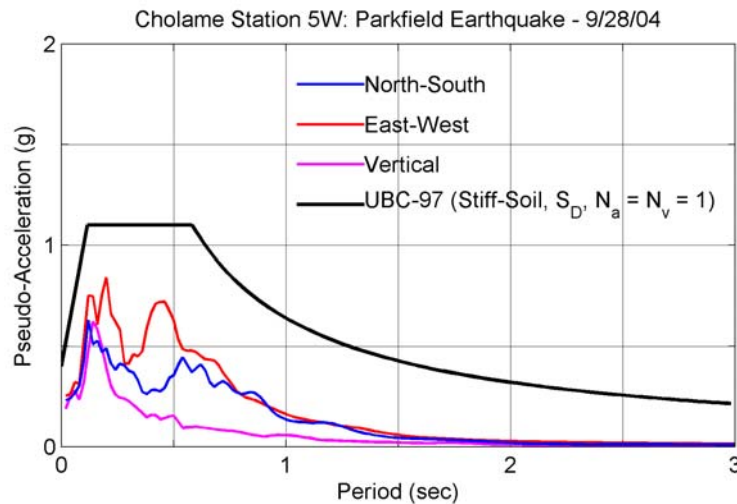


Figure 6. 5%-damped elastic response spectrum for three components of ground accelerations recorded at the Cholame 5W Station during the Parkfield earthquake of September 28, 2004, and the UBC-97 design spectrum for stiff-soil with near-source factors equal to 1 (Data from CISEN).

Structural Performance

Consistent with a moderate-size earthquake in California, the damage, overall, was mostly nonstructural. The area of Parkfield is rural and sparsely populated with approximately 37 local inhabitants (Figure 7). The building stock of Parkfield consists primarily of low rise, single family, timber construction with wood and stucco facades.

Overall, minor nonstructural damage was observed to local residences through drywall cracking, stucco cracking, a collapsed un-reinforced masonry parapet wall, broken windows, and fallen bookcases. There were reports from local residents of two chimneys that suffered moderate damage but these were not confirmed by the investigators at the time of this report.

Local bridges showed minor to no damage and were open with immediate occupancy post event. The bridge located at the intersection of Cholame Road and Parkfield-Coalinga Road (Figure 8) in Parkfield, which crosses the San Andreas Fault, did show approximately 4 cm of separation between the approach slab and abutments that was quickly filled with asphalt by the bridge maintenance crew.



Figure 7. Road-map showing town of Parkfield (Source: www.mapquest.com).

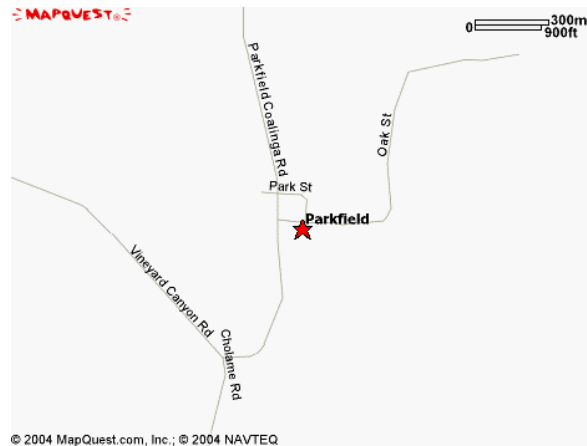


Figure 8. Close-up map of Parkfield (Source: www.mapquest.com).

Typical Building Performance

There was no noted damage to the Parkfield Café and the Parkfield Inn, two major structures in central area of the town. However, there were reports of minor structural and significant nonstructural damage to residential buildings in the area. The damage pattern described next for two residences located on Parkfield Coalinga Road (Figure 8) roughly 7 and 5 km north of Parkfield is typical of what has been reported in the epicentral region.

The first residence is a two-story timber building constructed originally in the late 1800's with a substantial addition constructed in the 1930's. The house is located less than 0.5 km from the San Andreas Fault. The strongest shaking at this location occurred in the fault-normal, east-west direction, as evident by fallen stacks of firewood in the east-west direction (Figure 9). Significant cracking was observed in the plaster (stucco finish) throughout the house but primarily in the east-west direction (Figure 10). As expected, separation also occurred between the older and newer portions of the residence (Figure 11). Although shaking at the site caused significant cracking in the stucco, the masonry chimney of the house did not show any signs of distress (Figure 12). This is due to retrofit of the chimney by strapping it at several levels to the house (Figure 13).

The second home was constructed in the 1950's but had undergone several renovations and upgrades in recent times. This house is located immediately adjacent to the San Andreas Fault that runs through the backyard. The damage in the residence predominately was nonstructural but substantial. The home suffered extensive drywall cracking (Figure 14) and other content damage (Figures 15 and 16). Outside, a timber canopy separated from the house and was dangerously leaning (Figure 17) and a portion of the unreinforced masonry parapet wall collapsed (Figure 18).



Figure 9. Stack of firewood collapsed in due to strong east-west shaking (Photo: Goel).



Figure 10. Typical cracks in the stucco finish (Photo: Chadwell).



Figure 11. Separation between older and newer portions of the house (Photo: Goel).



Figure 12. Undamaged chimney of the house (Photo: Goel).



Figure 13. Undamaged chimney retrofitted by strapping to the house (Photo: Goel).



Figure 14. Dry wall cracking (Photo: Chadwell).



Figure 15. Damage to contents of the entertainment center (Photo: Chadwell).



Figure 16. Damage to office area of the house (Photo: Goel).



Figure 17. Damage to the timber canopy outside the house (Photo: Chadwell).



Figure 18. Collapsed unreinforced masonry boundary wall (Photo: Chadwell).

Bridge Performance

Two bridges were investigated in the reconnaissance. The first bridge, located approximately 8 km south of Parkfield, is typical of many bridges in the area: multi-span, steel riveted viaduct bridge with a concrete steel composite roadway. This bridge showed no signs of distress. There was evidence of ground shaking from surface cracking found surrounding the pile extensions (Figure 19) and some signs of minor distress apparent from fresh peeling of paint at the girder-column joint (Figure 20).

The second bridge investigated is located at the intersection of Cholame Road and Parkfield-Coalinga Road (Figure 8) in Parkfield and crosses the San Andreas Fault (Figure 21). This bridge had apparently undergone a recent retrofit and performed adequately. The minor distress to the bridge included roughly 4 cm separation between the approach slab and the bridge deck, which was filled up quickly by the bridge maintenance crew (Figure 22). Below the deck level, the concrete bent caps had minor shear cracking through the knee joints (Figure 23 and 24) as well as evidence of the flexural cracking at the top of the pile extension (Figure 25). The pile extensions at the ground level also exhibited noticeable movement (Figure 26). In addition, there was evidence of recent motion (approximately 4 cm) in the bridge bearings supporting the superstructure. Angle iron apparently installed in an effort to restrain transverse motion of the superstructure at the bearings was knocked free (Figures 27 and 28).



Figure 19. Surface cracking surrounding the pile extension (Photo: Chadwell).



Figure 20. Signs of distress at girder-column joint (Photo: Goel).



Figure 21. Bridge crossing the San Andreas Fault (Photo: Goel).



Figure 22. Separation between the approach slab and the bridge deck (Photo: Chadwell).



Figure 23. Knee-joint of the bent cap (Photo: Chadwell).



Figure 24. Fresh shear cracks in the knee joint of the bent cap (Photo: Goel).

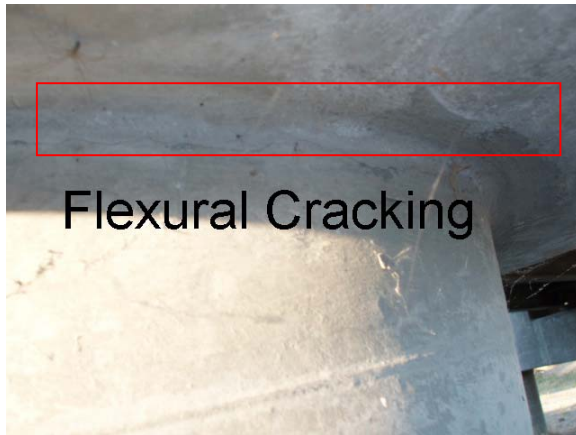


Figure 25. Flexural cracks (digitally enhanced) at the top of pile extension (Photo: Goel).



Figure 26. Movement of the pile extensions at the ground level (Photo: Goel).



Figure 27. Bridge bearing support (Photo: Chadwell).



Figure 28. Movement at the bridge bearing (Photo: Chadwell).