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## Historical Research in the Loma Prieta Area

The 1906 San Francisco earthquake was the first scientifically studied earthquake in the U.S. The report written about the earthquake by the California State Earthquake Investigation Commission (SEIC), edited by Andrew Lawson (1908), is a landmark scientific document. However, this report was compiled from the observations of many investigators, and some areas were studied more thoroughly than others.

Careful scrutiny of the SEIC Report along with other historical documents (letters, original reports, historical maps, photographs, etc.) shows that the Loma Prieta area was relatively poorly studied after the 1906 earthquake. Most of the observations in this region were made by G.A. Waring. Historical research shows that at the time of the earthquake Waring was a beginning Master's student working under J.C. Branner at Stanford University. Because Waring had little experience, was sent to a difficult area, and had only small-scale maps to work with, he made very few observations along the actual San Andreas Fault. Our research shows that most of the locations where "faulting" was reported are in fact nowhere near the San Andreas fault, and that Waring missed a section of the fault about 20 km long.

There are three localities in the Loma Prieta area where enough information is known from 1906 that detailed comparisons can be made between the ground ruptures produced in the 1989 and 1906 earthquakes: A) The Wrights tunnel, B) Morrell Road, and C) The blacksmith shop near Burrell school. All of these locations are in the Summit Ridge area, where numerous ground ruptures occurred in 1989. These ground ruptures have been the subject of continuing controversy, with some scientists concluding that they are the result of shaking, and others concluding that they are instead the direct result of fault slip.

### A) WRIGHTS TUNNEL

The Wrights tunnel is an abandoned railroad tunnel that crosses the San Andreas fault in the southern Santa Cruz Mountains in the vicinity of the 1989 Loma Prieta earthquake, that was damaged and deformed during the 1906 earthquake.

A plot showing post-earthquake measurements made during reconstruction of the tunnel after the earthquake appears in the SEIC Report. The amount of offset shown on this plot (5 ft) has been used

in several studies as being representative of the amount of fault offset along this segment of the San Andreas fault in 1906. However, historical research shows that different observers reported differing amounts of fault offset in the tunnel (ranging from 3.5 to 5 ft), and that the 5 ft given on the plot is not a surveyed measurement. In addition, the plot of the tunnel has been interpreted in several previous studies as evidence of a broad (about 1 mi) zone of faulting beneath Summit Ridge. However, our analysis shows that this plot does not indicate a broad zone of faulting.

If our idea is correct, we can use these 1906 measurements to determine the total amount of fault offset, which we conclude was about 6 feet (1.8 m). Most of this offset (60 - 85%, depending on whether the 3.5 or 5 feet reported across the fault is correct) occurred across a single fault plane; the remainder was distributed over a zone less than one quarter of a mile wide.

Most of the mapped cracks on Summit Ridge after the 1989 earthquake fall outside of the zone of faulting that occurred in 1906 in the Wrights tunnel. Similar widespread cracks on Summit Ridge occurred in 1906, but our analysis shows they were not associated with deformation of the tunnel below Summit Ridge. This indicates that in 1906 the Summit Ridge fractures were a surficial phenomenon, not a reflection of tectonic faulting. This is most likely the case for the 1989 fractures as well.

## **B) MORRELL ROAD**

One of the most perplexing photographs in the Lawson Report is this one, showing displacement in the opposite sense (left lateral) to the sense of offset across the San Andreas Fault (right lateral). We have examined the glass plate negative of this photograph and have determined that it is printed correctly, therefore, the left-lateral sense of displacement is true. In 1989, left-lateral faulting occurred across Morrell Road, near the crest of Summit Ridge. This occurred in the same location photographed in 1906. The nature of the rupture was very similar in 1906 and 1989. It was both left lateral and extensional.

A map of the Morrell fractures by H.R. Johnson appears in the SEIC Report, but it shows the fracture with right-lateral offset. Letters we have found that were written between the members of the SEIC suggest that Johnson's original map was changed so it would agree with the overall right-lateral faulting seen along the San Andreas.

A map made of the area (made by Sumaryanto and Johnson, in press) after the 1989 earthquake shows that the 1906 and 1989 features were very similar. We superimposed the two maps, using only the stream, the old road and the location of the house to guide the overlay, and found that these fractures are nearly identical, but the 1906 fracture was longer and had more offset.

## **C) BLACKSMITH SHOP**

A photo of ground rupture on Summit Ridge was taken very shortly after the earthquake early in the morning of April 18, 1906. The SEIC Report states that this photograph was taken in front of the blacksmith shop, near Burrell School. The blacksmith shop is gone, but the schoolhouse, now a private residence, is still standing. To understand the nature of this rupture, we needed to locate it precisely to determine its orientation.

Two roads intersect near Burrell Schoolhouse, Loma Prieta Avenue and Summit Road. Both roads are shown on the oldest (1915) topographic map of the area. In addition, older county maps show a third road, Sears Road, intersecting Summit Road and Loma Prieta Avenue near Burrell school. The photograph could have been taken in either direction on any of the three roads; there are no definitive landmarks in the background to distinguish among these six possibilities. However, our analysis indicates that it was most likely taken in the morning, looking northwest on Summit Road.

According to a history book of this area (Payne, 1978) a blacksmith shop was located across the street from Burrell School, and was owned by Jack Smith. A deed of sale on file in the index of deeds at the Santa Clara County Recorder's office indicates that John W. Smith bought a piece of property near the intersection of Loma Prieta Avenue and Summit Road from A. E. Sears for \$10.00 in 1903. The deed description, though lacking in precision, describes the property boundaries with respect to the roads and a small stream. The roads and stream are shown on surveyed maps of the area drawn in 1880, 1892, and 1903. We located the property purchased by Smith on a compilation of these historic maps as precisely as possible given the deed description. Given the location of the blacksmith shop, its appearance on the right side of the 1906 photo, and the orientation of the shadows in the photo, the view in the photo must be either southeast on Sears Road in the afternoon or northwest on Summit Road in the morning.

Several lines of evidence support a northwesterly view on Summit Road. The deed indicates that by 1903 Sears Road was abandoned, yet the road shown in the 1906 photograph does not appear to be an abandoned road. Additionally, if the view is southeast on Sears Road, the small stream shown on old maps and described in the deed should be visible between the road and the blacksmith shop. Additional evidence for a northwesterly view up Summit Road is given by the shadows in the 1906 photograph. The caption accompanying this photograph reads: "Burrell corners on summit 1 1/2 miles above Wrights station. Taken April 18, 1906 1 hr. after the earthquake by F. E. Caton, San Jose." In addition, the caption accompanying Waring's original report, referring to this photograph, reads: "Crack across road at blacksmith shop near Wright. Sulphur fumes rose here for several hours. Taken 6 a.m. April 18, 1906 by G. E. Caton, San Jose." If the photograph was taken at about 6:00 or 6:30 in the morning (the earthquake occurred at about 5:12 AM), the view must be northerly for the sun to cast the shadows in the direction seen in the photos.

We conclude that the two photographs were taken at the intersection of Summit Road and Loma Prieta Avenue, in the morning, looking northwest up Summit Road. Given the location and view direction of this photograph, the fracture must trend nearly north-south. The exact angle that the fracture makes with the road is not known, but it appears from the photographs to be intersecting the road at an angle

of about  $40_i \pm 20_i$ . The old maps show Summit Road trending about N40W near this intersection; therefore, the trend of the fracture is around  $000_i \pm 20_i$ . This is parallel to some of the small fractures produced nearby in 1989, but not parallel to the overall regional trend of the San Andreas fault or most of the nearby fractures produced in 1989

In addition to the large vertical displacement, this fracture had a significant extensional component, as is demonstrated by the gentleman standing in the fissure. Also, it may have had a right-lateral component: the edge of the road on the right side of the photo may show right-lateral offset across the fracture. Unfortunately, this part of the photograph is in shadow, and it is not possible to place much confidence in this observation.

The main trace of the San Andreas fault is located approximately 150 m to the east of this location (see map above), and this fracture could represent surface rupture on a splay of the San Andreas fault. Alternatively, it could be a secondary shaking-related or ridge-top spreading feature similar to those produced in the Summit Road area in 1989, or it could be a landslide scarp. Maps of the active San Andreas fault zone show short fault traces with NW-NNW orientations crossing Summit Road at this location. The linear feature shown on the above map could be due to this rupture. If this is the case, then its linear nature makes it unlikely to be a landslide scarp. However, whether this fracture continued in a linear pattern or had an arcuate shape in 1906 is not discernible from the photographs. Without additional information about the nature of this fracture, it is not possible to be certain which of the three possibilities is correct. No large fractures occurred across Summit Road near the intersection of Loma Prieta Avenue in 1989, nor was any fracture in the immediate vicinity this large (the photographs and reports suggest about 1 m of vertical displacement, and several decimeters of extension in 1906). One possibility is that this fracture is associated with surface rupture along the San Andreas 1906, and did not break in 1989 because the San Andreas did not have surface rupture in 1989. The other fractures along Summit Ridge, such as the Morrell fracture, are due to strong shaking, and so moved during both earthquakes.

There are important similarities and differences between ground ruptures produced in 1906 and 1989. The ground ruptures in the Summit Ridge area were similar in both earthquakes. In at least one case, the Morrell Ranch fractures, the location is virtually identical, and the extensional nature and left-lateral sense of slip are the same. However, the amount of displacement on the larger 1906 fracture was more than two times greater than the displacement on the northeastern 1989 fracture. The descriptions of other off-fault ground ruptures in 1906 indicate that these features were common in the Summit Road area, as they were in 1989, and shared the same characteristics as the fissures produced in 1989: left- and right-lateral slip and large extensional and vertical displacements along north to northwest trending fractures. However the locations of other 1906 fractures in the Summit Road area are not well enough known to make specific comparisons with those produced in 1989. Unlike the 1989 earthquake, the 1906 earthquake appears to have produced similar phenomena well outside the southern Santa Cruz Mountains area.

U.S. Geological Survey, Earthquake Hazards Program

URL [http://quake.wr.usgs.gov/info/1906/historical\\_lp.html](http://quake.wr.usgs.gov/info/1906/historical_lp.html)

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