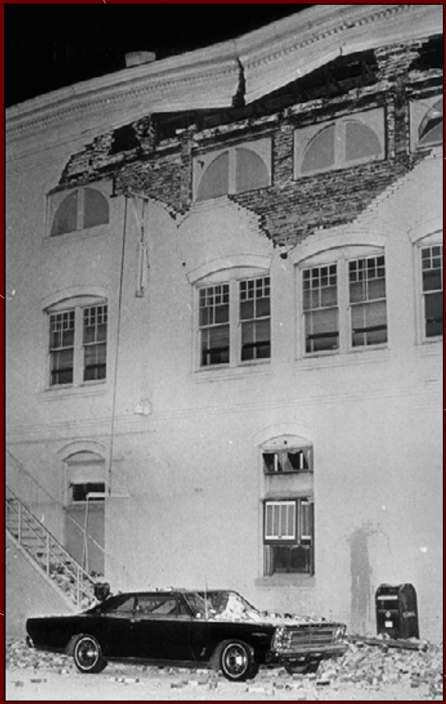
Santa Rosa's Past and Future Earthquakes

Santa Rosa is no stranger to earthquakes. This northern California city was damaged several times in the late 19th and early 20th centuries by shaking from earthquakes, culminating in the devastating earthquake of 1906, whose rupture passed 20 miles to the west of the city on the San Andreas Fault. Then in 1969, Santa Rosa was again strongly shaken and buildings were damaged by a pair of nearby, moderate-sized earthquakes on the Rodgers Creek Fault. Since then, scientists have learned how the underlying geology increases shaking damage in Santa Rosa, have mapped where the Rodgers Creek Fault runs beneath the city, and have discovered that this fault is capable of much larger earthquakes. Following the 1969 earthquakes, Santa Rosa rose to the challenge of improving seismic safety; however, continued progress is needed to increase seismic resilience and reduce the impact of future earthquakes.

"Biggest Quake Since '06 Rocks Santa Rosa"

So proclaimed a newspaper headline, referring to the "twin" earthquakes that struck this city 50 miles north of San Francisco on the night of October 1, 1969. The two earthquakes occurred below the north end of the city at 9:56 and 11:19 p.m. and had magnitudes of 5.6 and 5.7, respectively. Though moderate in magnitude, the shaking generated in Santa Rosa had a significant impact. Many old commercial buildings downtown and dwellings in several residential neighborhoods, plus a few modern, engineered buildings, were significantly damaged by the intense shaking. At least 74 buildings in the central business district were damaged and about a third of those were beyond repair, although none collapsed. Total damage, including to building contents, exceeded $7 million ($50 million in 2019 dollars). The shaking toppled brick chimneys and broke windows over a wide area and locally ruptured water mains and buckled sidewalks and curbs. Fortunately, no one died in the earthquakes, owing in part to the late hour and quiet downtown nightlife.

Santa Rosa had fared far worse six decades earlier in the magnitude 7.9 San Francisco earthquake of 1906, which destroyed much of downtown Santa Rosa and killed at least 85 people in a town of approximately 7,000. Even though the earthquake was on the San Andreas Fault 20 miles away, Santa Rosa suffered more damage in proportion to its size than any other city except San Francisco.



Photos of earthquake damage in Santa Rosa from the 1906 and 1969 earthquakes. Clockwise from upper left: collapsed Sonoma County Courthouse, 1906; partial collapse of brick facade onto car below in Old Courthouse Square, 1969; toppled brick chimney, 1969; and a two-story wood-frame house shaken off its foundation, 1969. Photos courtesy of NISEE-PEER, University of California Berkeley; photos of 1969 damage are from the Karl V. Steinbrugge collection.

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Santa Rosa Takes Action

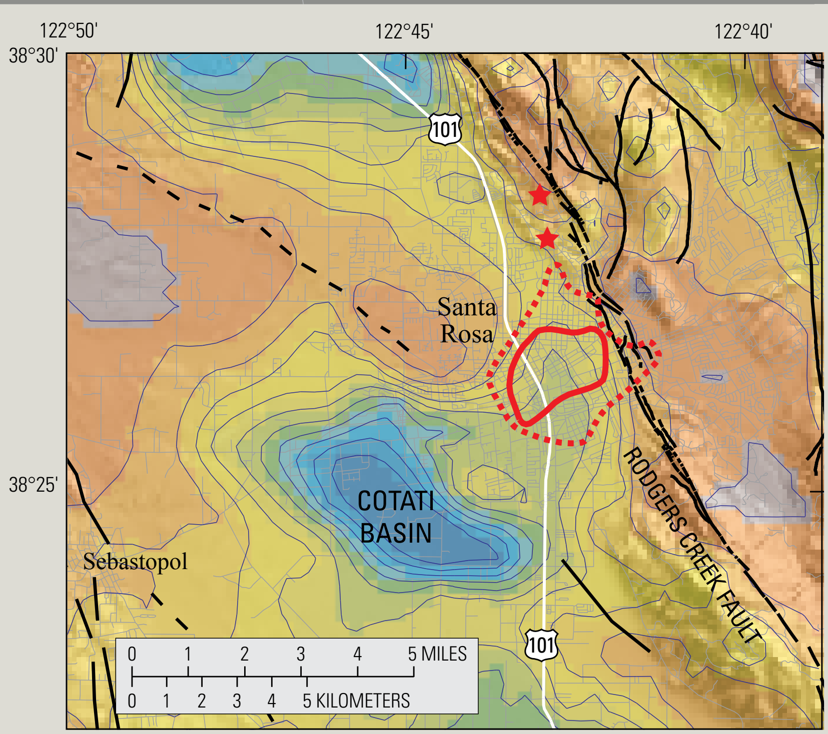
In the wake of the 1969 earthquakes, Santa Rosa established what were at the time some of the strongest policies in the United States to address the problem of seismically vulnerable buildings. Through its sustained efforts to reduce earthquake risk, the city became a model for effective action. The damage to many of Santa Rosa's unreinforced masonry buildings (built mostly in the early 1900s, after the 1906 earthquake) was greater than would be expected for earthquakes of moderate magnitude. This revealed a vulnerability that was addressed using two approaches: (1) by expanding the area of an existing Federal urban renewal project to include the heavily damaged central business district, and (2) by creating inspection and abatement requirements to fix structural hazards elsewhere in the city. Redevelopment involved construction of a regional shopping center on acquired and cleared land, and though the process was delayed by legal challenges and generated controversy, it revitalized the downtown area and lessened the community's vulnerability to earthquakes by removing potentially unsafe buildings.

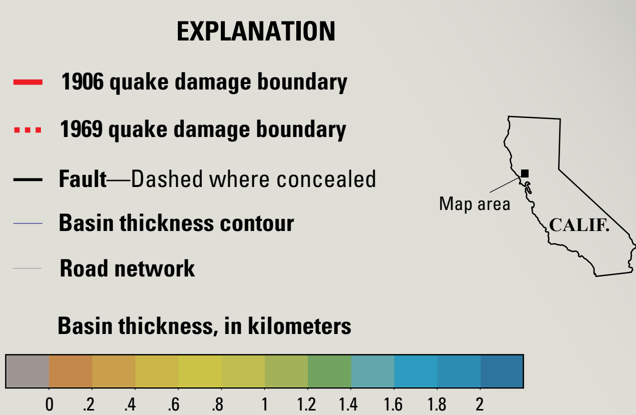
The requirements to rehabilitate older buildings in Santa Rosa evolved as city staff and the City Council worked with local structural engineers and engaged stakeholders to clarify problems and develop workable, economically viable solutions, while at the same time achieving a reasonable measure of seismic safety. In particular, conformance standards were made flexible in order to limit the financial burden on property owners and to encourage rehabilitation rather than demolition of buildings that were undamaged or only slightly damaged in the 1969 earthquakes. The city's commitment to mitigating structural hazards was remarkable in light of the moderate size of the 1969 earthquakes and the absence of building collapses or fatalities.

Google Earth satellite image of downtown Santa Rosa (dated October 19, 2018) showing approximate boundaries of the urban renewal project. Area outlined in orange was included in the original project, which began in 1961; area outlined in red was added following the 1969 earthquakes. The shopping center (large white-roofed complex within the red line) was the cornerstone of the project's second phase.

Why Does Santa Rosa Shake so Hard?

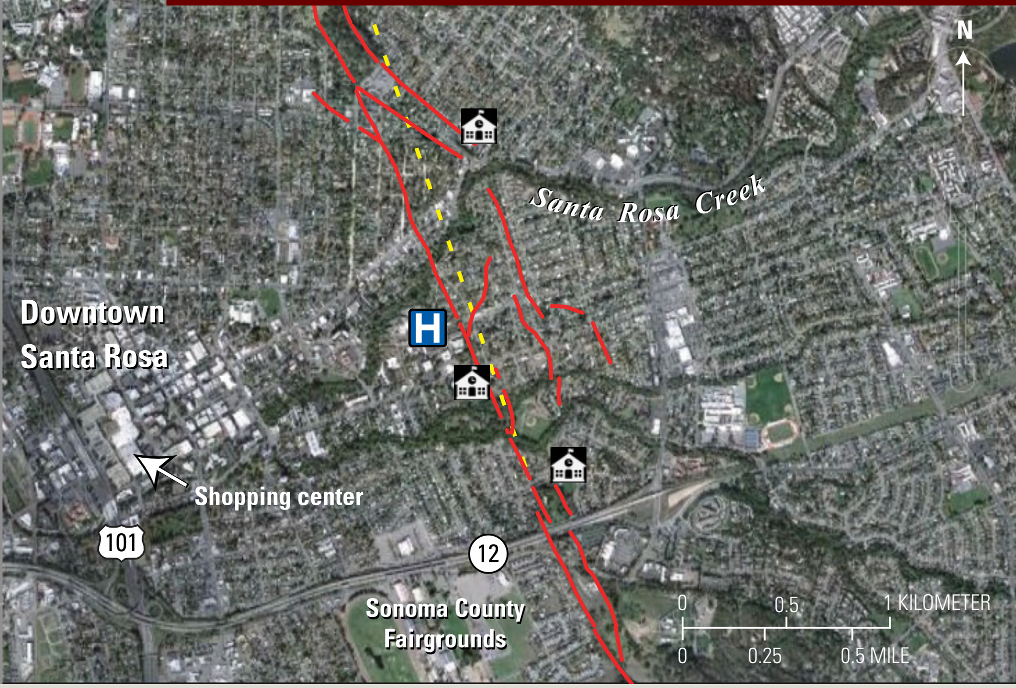
The 1906 and 1969 earthquakes caused major damage that was centered in the downtown area of Santa Rosa. This damage pattern had been attributed to shallow, weak sediments left behind by streams and uncompacted fill placed by early developers of the city. Investigating further, U.S. Geological Survey scientists used gravity measurements to define the distribution of contrasting rock densities beneath the Earth's surface and discovered a sedimentary basin beneath Santa Rosa on the southwest side of the Rodgers Creek Fault. Named the Cotati basin, it is filled with low-density, uncompressed sediments and deepens to more than a mile below the surface southwest of Santa Rosa. This basin likely played a role in focusing shaking damage in 1906 and 1969: when seismic waves enter such a basin, they slow down and increase in amplitude, thereby increasing the shaking at the ground surface. Downtown Santa Rosa is located on the northeast edge of the Cotati basin, suggesting that seismic waves from the 1906 and 1969 earthquakes may have been focused into this area and amplified at the basin's edge. Computer simulations of the effect of the basin on seismic waves from these earthquakes support these conclusions, demonstrating that local basin structure plays a major role in shaping the distribution of damaging shaking in and around Santa Rosa.





Map showing thickness of basin sediments in the vicinity of Santa Rosa (contour interval is 200 m). The Cotati basin's thickness, as well as its embayed shape, may intensify earthquake ground shaking in and around Santa Rosa. Areas of concentrated earthquake damage are indicated by red outlines (solid,1906; dotted, 1969). Approximate epicenters of 1969 earthquakes are shown by red stars.

New Mapping Reveals the Trace of the Rodgers Creek Fault Through Santa Rosa



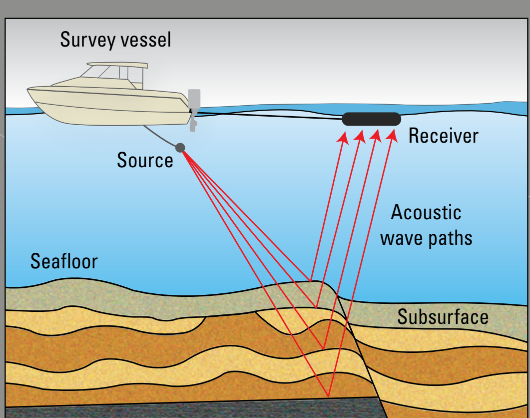
Detailed topographic models made from airborne three-dimensional laser scanning (called "lidar," for "light detection and ranging") have made it possible to identify subtle landforms on the Santa Rosa Creek floodplain that indicate where rupture on the Rodgers Creek Fault in past large earthquakes extended up to, and offset, the ground surface. Prior to the availability of these data, the exact location of the fault through central Santa Rosa had been obscured by urban development, making it difficult to assess the hazard to manmade structures (such as buildings, roads, and pipelines) built across the fault. The new mapping shows that the zone of faulting at the ground surface is wider and more complex than previously thought, exposing a larger area to the possibility of damaging offsets in a large earthquake.

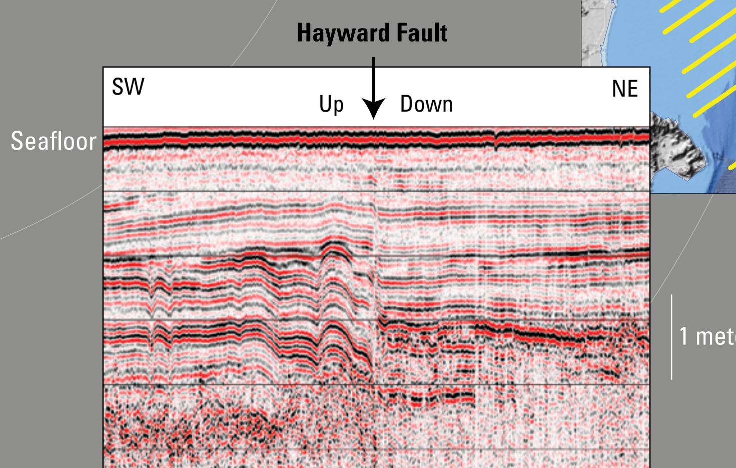
Google Earth satellite image of central Santa Rosa (dated October 25, 2009) showing the surface trace of the Rodgers Creek Fault in red lines. The yellow dashed line shows the previously inferred location of the fault across the Santa Rosa Creek floodplain prior to laser-based mapping. The building symbols mark the locations of schools close to the fault; the H represents a hospital complex. The labeled shopping center lies within the urban renewal project area shown on facing page.

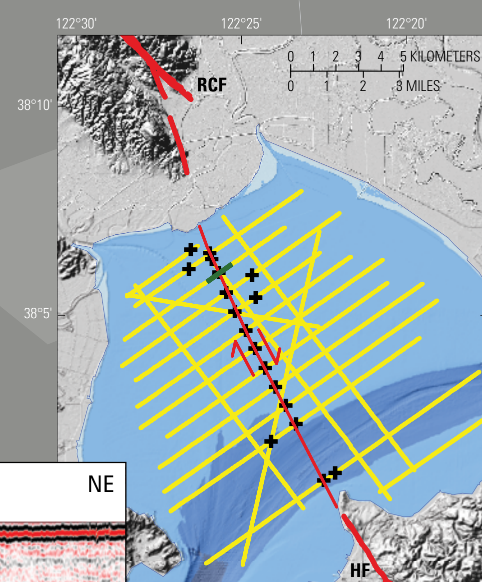
The Rodgers Creek Fault-Hayward Fault Connection: Enabling a Major Earthquake

Using detailed subsurface imaging, USGS scientists have discovered that the Rodgers Creek Fault is connected beneath San Pablo Bay to the infamous Hayward Fault to the south. The Hayward Fault traverses the densely populated "East Bay" communities of the San Francisco Bay region and was responsible for a destructive magnitude 6.8 earthquake in 1868. If the two faults operate as one longer fault, then it's possible to produce a much larger earthquake, estimated as large as magnitude 7.4. Geologic studies show that the most recent ground-rupturing earthquake on the Rodgers Creek Fault occurred sometime in the early to middle 18th century, during approximately the same time period as an earthquake documented on the Hayward Fault. This raises the possibility that the two earthquakes were actually a single larger earthquake.

Regardless of the potential for simultaneous rupture of both faults, the latest 30-year rupture forecast for the San Francisco Bay region gives a 33 percent probability of one or more large earthquakes (magnitude 6.7 or greater) occurring somewhere on the Rodgers Creek or Hayward Faults by the year 2043.







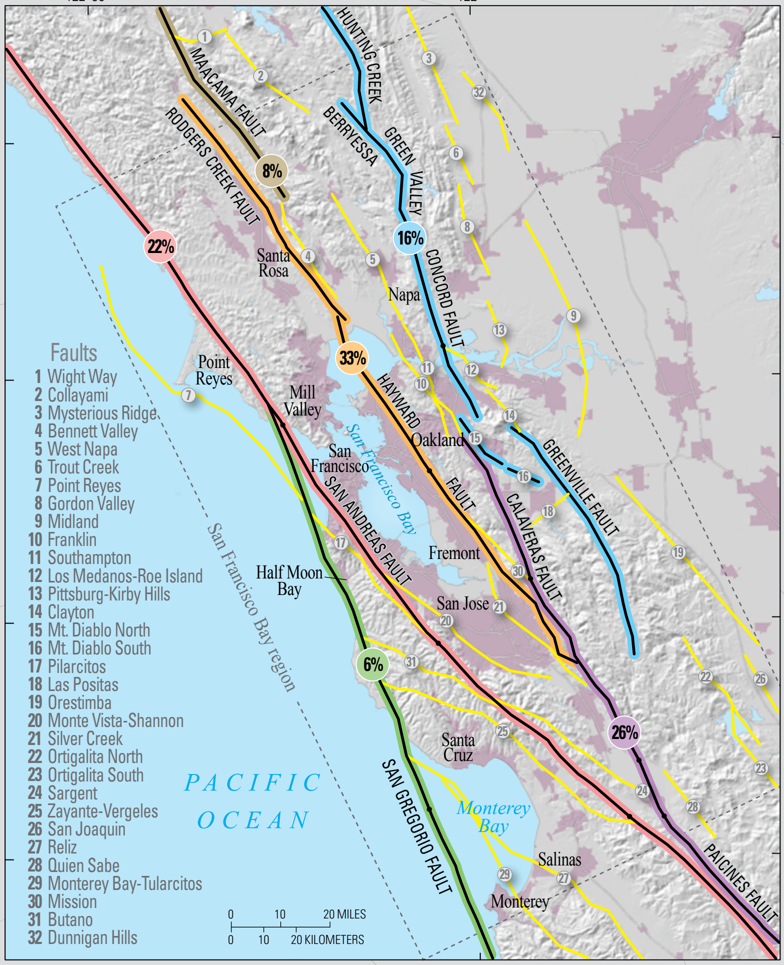
Left: Cartoon illustrating subsurface imaging (seismic-reflection) method. Acoustic waves are emitted from a boat-towed source and the signal reflects off sediment layers that have contrasting acoustic properties. The reflected signal is recorded by a receiver and analyzed. Middle: Seismic-reflection profile across the Hayward Fault at the north end of San Pablo Bay showing where sediment layers beneath the seafloor are offset by faulting. Right: Map of San Pablo Bay showing survey profile lines (yellow) and the location of the profile shown in middle (short green segment). X's mark where faulting has been identified in each of the profiles. RCF and HF are Rodgers Creek Fault and Hayward Fault, respectively.

Facing the Challenge of Future Earthquakes

Since 1969, the only damaging earthquakes to strike the region north of San Francisco Bay have been to the east of Santa Rosa near the towns of Napa and Yountville (8 miles north of Napa). The magnitude 6.0 South Napa earthquake in 2014 was 25 miles away from Santa Rosa, and, although too distant to produce damaging ground shaking, it provided a vivid reminder to Santa Rosans of the danger posed by earthquakes.

A recent test of the community's spirit and resilience in the face of natural disaster was the 2017 Tubbs fire. The firestorm killed at least 22 people, destroyed 5 percent of the homes in Santa Rosa and caused an estimated $1.2 billion in damage. Experience gained from responding to and rebuilding from the Tubbs fire may inform emergency response, preparedness, and policy decisions relevant to mitigating the effects of future disasters, including earthquakes.

Thanks to redevelopment efforts and other policy initiatives begun following the 1969 earthquakes, Santa Rosa and surrounding Sonoma County have made progress in reducing seismic risk. Recent efforts include measures to retrofit the water-supply system, upgrade hospitals, and to address the problem of soft-story construction (multi-story buildings with large open spaces that lack resistance to shaking). However, much remains to be done to strengthen vulnerable buildings, infrastructure, and critical facilities. In the 50 years (and counting) since the 1969 earthquakes, Santa Rosa has more than tripled in population, to more than 175,000, and earthquake science has elucidated the hazards posed by the Rodgers Creek Fault and by geologic conditions beneath the city that enhance ground shaking. Armed with this knowledge and a history of effective public policy, Santa Rosa and nearby communities are positioned to make further progress. Continued, committed action by elected officials and community leaders, as well as by individual citizens in their own homes and workplaces, will be needed to improve seismic safety and prepare Santa Rosa to withstand the next damaging earthquake.



Map showing probability of a magnitude 6.7 or greater earthquake between 2014 and 2043 on major active faults in the San Francisco Bay region. Lesser-known faults are shown in yellow.

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Additional Resources

Outsmart Disaster (California Seismic Safety Commission and California Business, Consumer Services, and Housing Agency statewide campaign website) https://outsmartdisaster.com

Seven Steps to Earthquake Safety (Earthquake Country Alliance website) https://www.earthquakecountry.org/sevensteps/

Putting Down Roots in Earthquake Country, USGS General Information Products 15, 41, and 42, at http://www.earthquakecountry.org/booklets/.

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