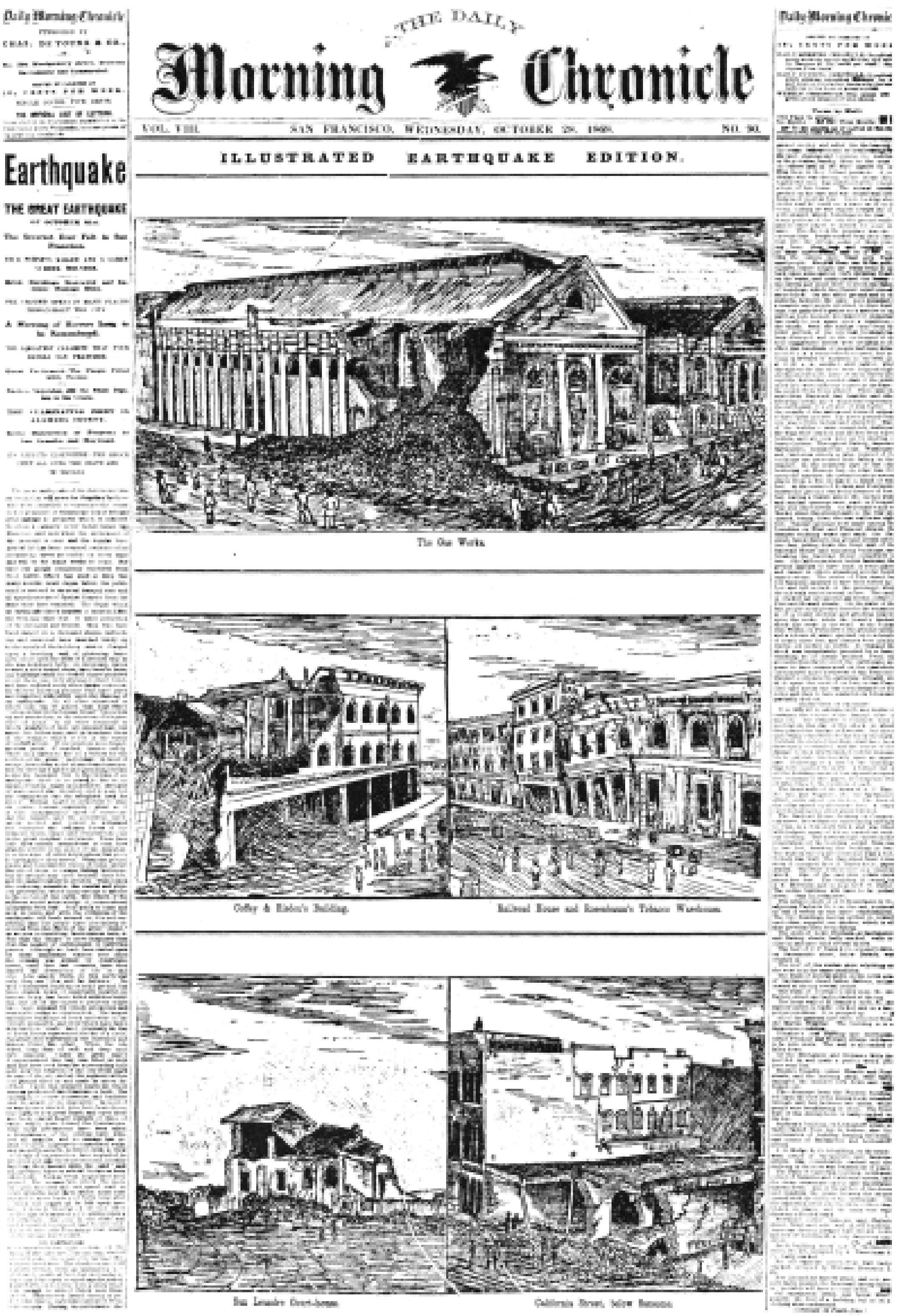
USGS Open House 2000 Field Trip – Hayward fault zone, Hayward

Introduction

In 1868, a length of the Hayward fault zone stretching from Oakland to Fremont broke, and the rocks west of the fault suddenly jumped several feet to the northwest with respect to those east of the fault. The energy released by this sudden motion produced a major earthquake, causing destruction throughout the San Francisco Bay region (Figure 2-1). Until 1906, the Hayward fault zone quake was known as the Great San Francisco Earthquake. Although the effects of this earthquake were well studied at the time, the work was for the most part lost, thought to have been suppressed by local government officials concerned that scientific studies of earthquakes could dampen growth and development in the region!

Since 1868, however, the Hayward fault zone has been relatively quiet, and has not generated a large earthquake. The forces that lead to earthquakes have not stopped, though. The rocks underlying San Francisco Bay continue to move northwest with respect to those east of the Hayward fault zone, but most of the fault zone itself is stuck, and pressure is slowly building up in the rocks near the fault zone. Eventually the pressure will overcome the friction and other forces that are causing the fault zone to stick, and the accumulated energy will be released in another big earthquake.

While almost all of the fault zone is stuck, in some places conditions within the rock allow the portion of the fault at the surface to slowly slide along in response to the pressure building up on the stuck fault. This slow sliding is called fault creep. Although the motion of creep is very slow (on the Hayward fault zone, the maximum creep rate is 9 mm/yr, or about 1/1000 mm/hr!), over the years the effects of the offset can be seen, especially in manmade structures (Figure 2-2). It is important to note that while creep does allow that part of the fault near the surface to slide along without pressure building up, most of the fault at depth is still stuck, so creep doesn't do much to help reduce the next big earthquake. However, creep does help us find some of the parts of the fault zone where pressure is building up.


THE DAILY
Morning Chronicle
VOL. VIII. SAN FRANCISCO, WEDNESDAY, OCTOBER 28, 1868. NO. 30.
ILLUSTRATED EARTHQUAKE EDITION.

Earthquake

THE GREAT EARTHQUAKE

The Gas Works.

Coffey & Risdon's Building.

Railroad House and Rosenbaum's Tobacco Warehouse.

San Leandro Court-house.

California Street, below Sansome.

Figure 2-1 The front page of the San Francisco Chronicle following the 1868 earthquake on the Hayward fault zone.

Figure 2-2. Concrete curb in downtown Hayward offset by fault creep. It took several years to accumulate this much creep.

How to get there

One of the best places to see the effects of the creeping part of the Hayward Fault Zone is in downtown Hayward, between Mission Boulevard and Main Street.

From I-880
Take the A Street Exit
Go East (towards the hills) on A Street
Pass the BART tracks overhead
Turn right on Mission Boulevard
Park between A Street and D Street

From I-580 Westbound
Take the Redwood Boulevard Exit
Go South on Redwood Boulevard
Redwood Boulevard becomes A Street
Pass the major intersection at Foothill Boulevard
Turn left on Mission Boulevard
Park between A Street and D Street

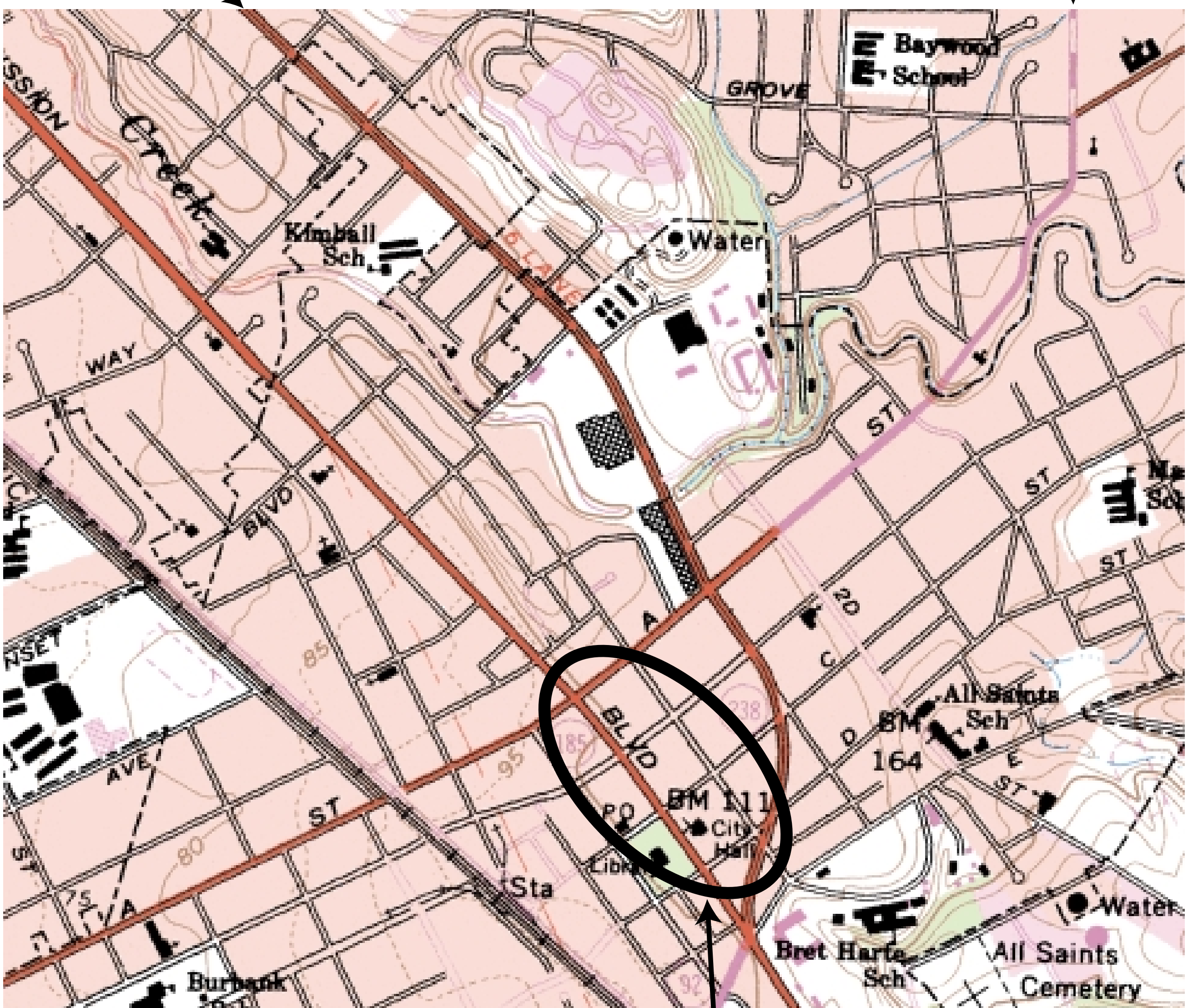
From I-580 Eastbound
Take the Hayward exit
Go onto Foothill Boulevard south
Turn right onto A Street
Turn left on Mission Boulevard
Park between A Street and D Street

What to see

Look for evidence of fault creep (like that shown in Figure 2-2) in the pavement, curbs, and buildings along B, C, and D Streets. The parking lot between A and B Streets is a particularly good place.

Things to think about

Can you tell which way the fault zone is moving?
The streets go up a short section of steeper slope here. Does that say anything about the way the fault zone is moving?
Does the creeping part of the fault pass through any buildings? Do you think the creep affects those buildings? What do you think would happen to those buildings if the fault moved in an earthquake?


Redwood Road from I-580 westbound
Foothill Boulevard from I-580 eastbound
A Street from I-880
Field trip area
Baywood School
GROVE
Creek
Kimball Sch
Water
WAY
BLVD
ST
A
2D
C
D
E
All Saints Sch
BM 164
BM 111
City Hall
PO
Library
Sta
Bret Harte Sch
All Saints Cemetery
Water
Burbank Sch
AVE
85
95
80

More About It

What is a fault zone?

Major fault zones, like the Hayward fault zone, are formed when very large blocks of the Earth's crust slide along, over, or under other blocks. The force that drives the motion of these blocks is provided by the continual formation, motion, and destruction of huge pieces of crust called plates (actually, plates are pieces of lithosphere, but for our purposes crust is roughly equivalent). The collective motion of the plates (Figure 2-3), called plate tectonics, is the driving force for most of the earthquakes, volcanoes, and mountain uplift in the world. Where plates interact by sliding past one another, like they do in California, the crust near the plate boundary is broken into large blocks that are divided from each other by fault zones, like the Hayward fault zone. Driven by the northwest motion of the Pacific Plate with respect to the North American Plate, the blocks in the San Francisco Bay region move, each one moving northwest with respect to the one east of it.

Although most people, including many geologists, tend to think of a fault as a single crack in the Earth's crust, the major fault zones are actually very complex collections of faults (Figure 2-4), not all of which are moving at the same time.

Does the whole zone move in an earthquake?

Through the long history of a fault zone (the Hayward fault zone is probably about 12 million years old), the sliding motion between the moving blocks is sometimes focused in one area, later in another area. The creeping part of the Hayward fault zone has probably only moved about 5 km, about 1/16 of the total offset of the Hayward fault zone as a whole.

So, only one fault in the whole zone is a problem?

Just as the long history of the fault zone is complex, the active part of the fault zone is more complex than a single crack. In the area near our stop, at least three different faults have evidence of recent activity. Geologists look for evidence of recent fault motion because we believe those parts of a fault zone that have moved last are most likely to move again. Remember that although the moving parts of the fault zone have changed, those changes took place over millions of years.

How can you tell which parts are active?

Recent fault activity leaves a collection of unique landscape features (Figure 2-5) that can be used to locate active parts of a fault zone. In the Hayward area linear ridges, linear valleys, fault scarps, and offset streams all mark the active parts of the Hayward fault zone (Figure 2-6). It is important to note that not all active parts of the fault zone are creeping, although creeping parts are all active.

It is important to know which parts of the fault zone are active because one of the hazards during an earthquake is fault rupture (Figure 2-7). Any structure built across a fault that suddenly moves with offsets up to several feet will suffer extreme damage. The U.S. Geological Survey cooperates with the California Division of Mines and Geology to make special maps showing all faults known to be active, and special geologic studies are required before any structure can be built within 50 feet of one of the active faults. Because of the regulatory nature of the maps, though, only those faults **known** to be active are shown. In Hayward, only the creeping part of the Hayward fault is shown. The other two faults that have features related to recent movement are not shown because their activity is not proven (though proof for one has recently been discovered, so it will probably be added to the next version of the maps).

So I only have to worry if I'm right on top of an active part of the fault zone, right?

Even more important than the fault rupture hazard is the hazard from earthquake shaking and related effects (the 1989 Loma Prieta earthquake occurred deep in the crust, there was no fault rupture damage, all the damage was caused by shaking and related effects). Shaking occurs in response to waves of energy that are released by and move away from the moving fault. In general, the intensity of the energy waves decreases as they move away from the fault, so the farther from the fault rupture, the less shaking is felt. However, shaking can be magnified by the geologic or man-made material under the surface. Loose materials like artificial fill, bay mud, and sand dunes tend to magnify shaking the most, whereas bedrock tends not to magnify shaking at all. In addition, loose materials saturated with water can be converted to "quicksand" by shaking, a process called liquefaction. Shaking can also trigger landslides, especially if there has also been heavy rainfall. Although these hazards have long been recognized (the danger of artificial fill was noted after the 1868 earthquake!), maps of these hazards have only recently begun to be produced. U.S. Geological Survey is currently cooperating with the California Division of Mines and Geology to produce maps showing areas of liquefaction and earthquake induced landslide hazard. Regional maps showing predicted shaking intensity for large earthquakes on several faults in the San Francisco Bay region are available from the Association of Bay Area Governments (their informative earthquake website is http://www.abag.ca.gov/bayarea/eqmaps/eqmaps.html).

So when is the next "Big One"?

The Holy Grail of earthquake study is of course earthquake prediction. Accurate prediction of earthquakes is at present impossible, because irregularities in the fault surface, differences in properties of the rocks cut by the fault, and the interplay of pressure build-up and release on every fault in the region, all affect the exact amount of pressure that needs to build up to overcome the resisting friction on any given part of a fault. Perhaps one day geologists will be able to measure tiny changes in some property of the fault zone (electrical, magnetic, acoustic, production of various gasses, who knows) to give an early warning of an earthquake. For now, scientists at U.S. Geological Survey and elsewhere are using more general techniques to try to determine where and when an earthquake is **likely** to occur. Information about when the last major earthquake was, how fast pressure is building up, and how large an earthquake to expect are combined to give a probability of an earthquake on active faults over a 30 year time period.

A new idea

It may be interesting to note that the idea of plate tectonics that all our understanding of earthquakes and major faults is now based on is a very new idea. The first observations that would lead to the modern ideas of plate tectonics were made after World War II, and the theory was only fully accepted by the scientific community in the late 1960's.

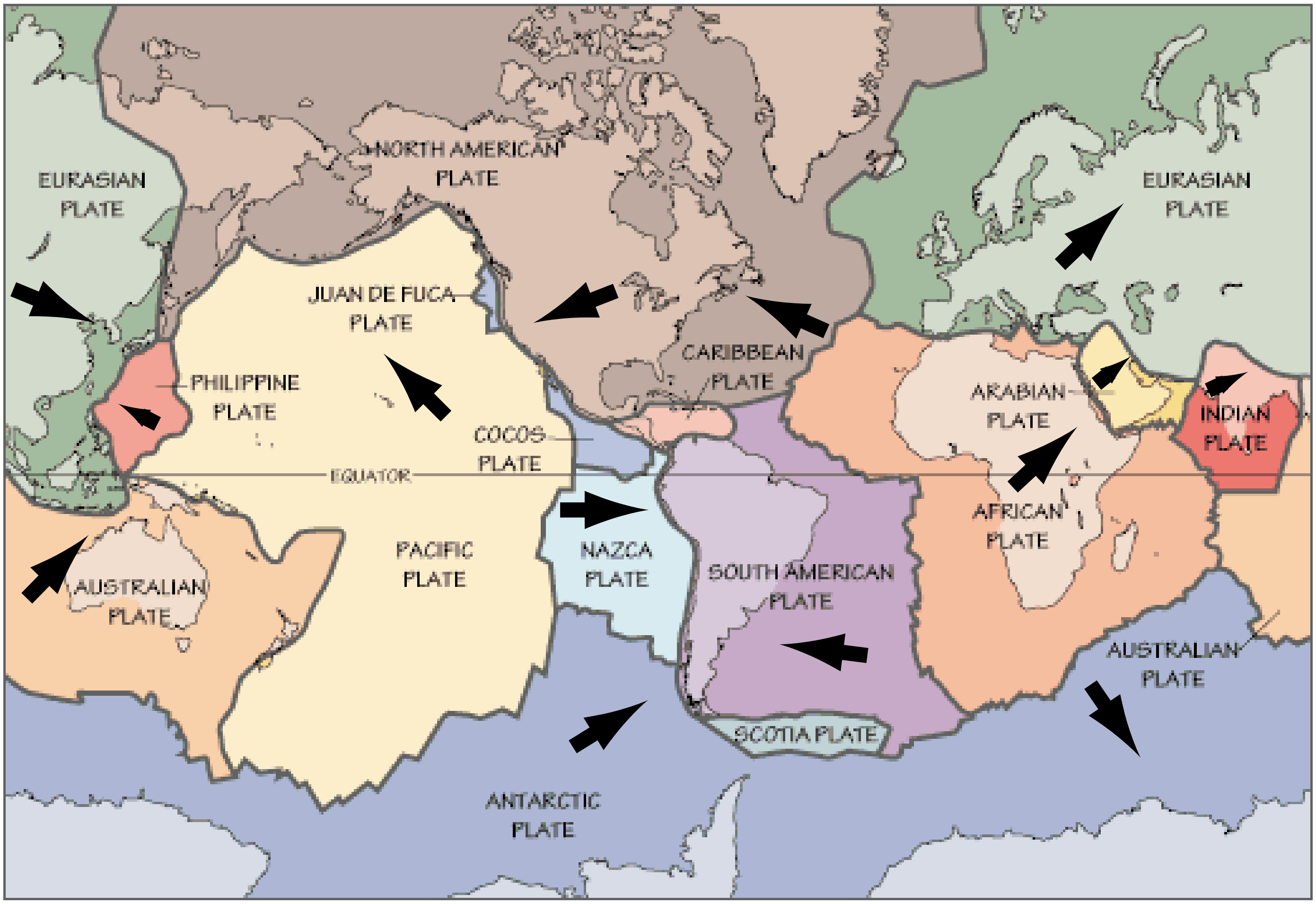


Figure 2-3. Map of the major lithospheric plates, showing the direction of the relative motion of some of the largest. The motion of the Pacific and North American Plates is the driving force for the faults in California, like the Hayward fault. The USGS and the National Park Service have an excellent web-page with more information about plate tectonics and links to detailed descriptions: (http://www2.nature.nps.gov/grd/usgsnps/pltec/pltec1.html)

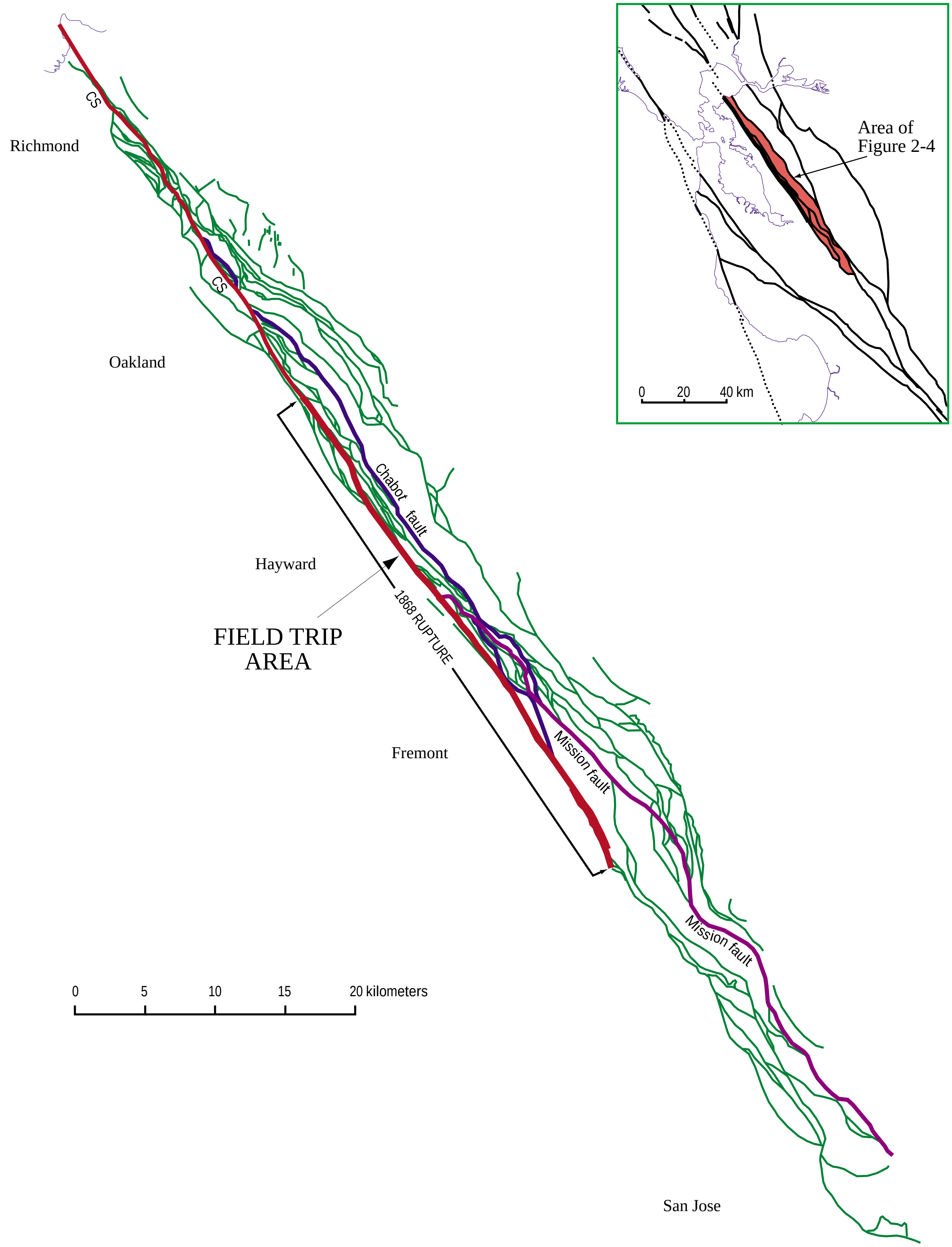


Figure 2-4. Generalized map showing all the faults in the Hayward fault zone. Note that most of the faults are not presently active, but all have played a part in the 12 million year history of the fault zone. The creeping part of the fault zone is shown by the thick line marked CS, and other named faults in the fault zone are labeled. The length of the fault rupture in 1868 is also shown.

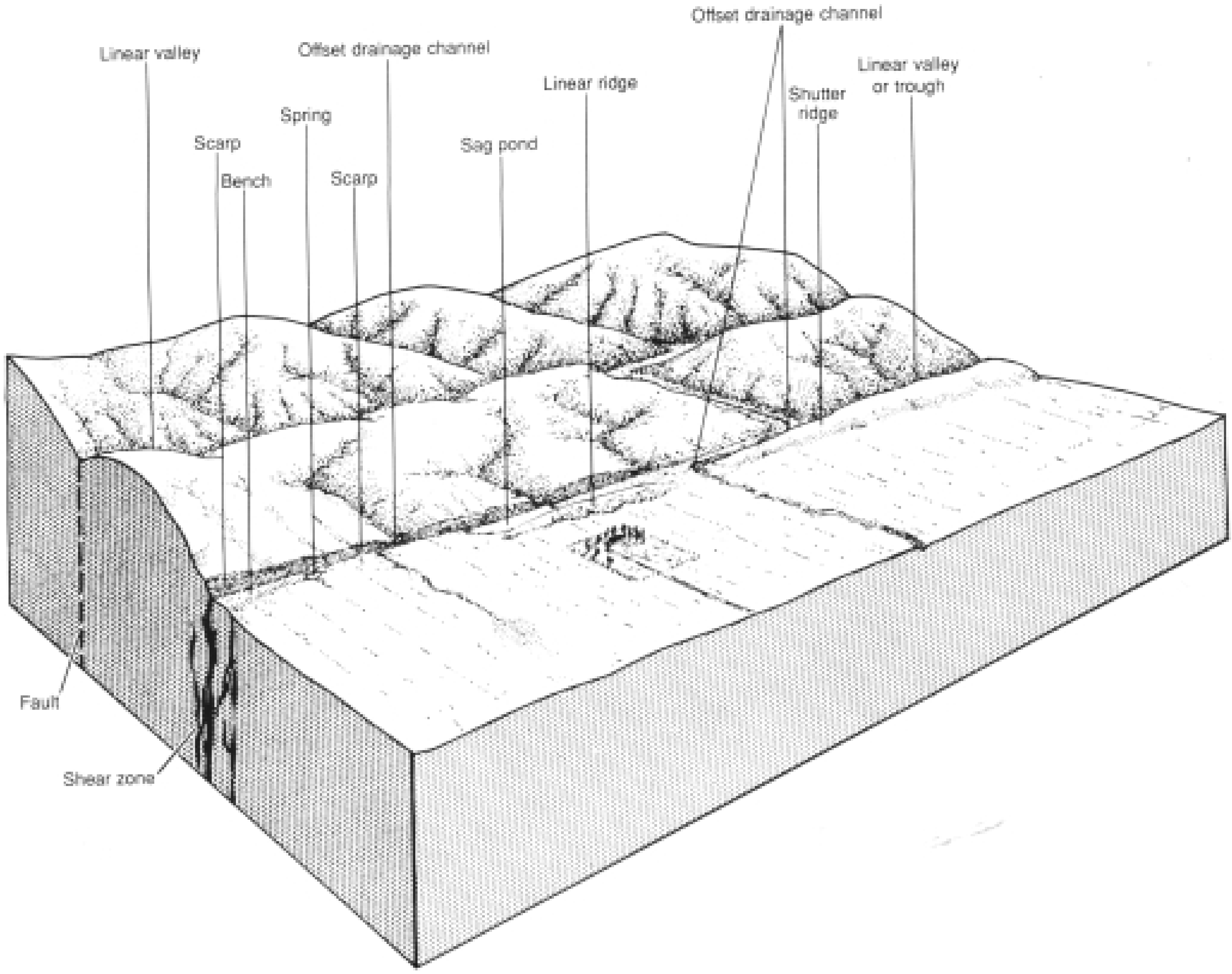


Figure 2-5 A block diagram of part of the upper part of the crust showing the landscape features associated with fault offset. Recognizing the presence of these features can help geologists locate faults that might be active even if they are not creeping. (Diagram from Wallace, R.E., ed., 1990, The San Andreas Fault System, California: U.S. Geological Survey Professional Paper 1515, p. 17.)

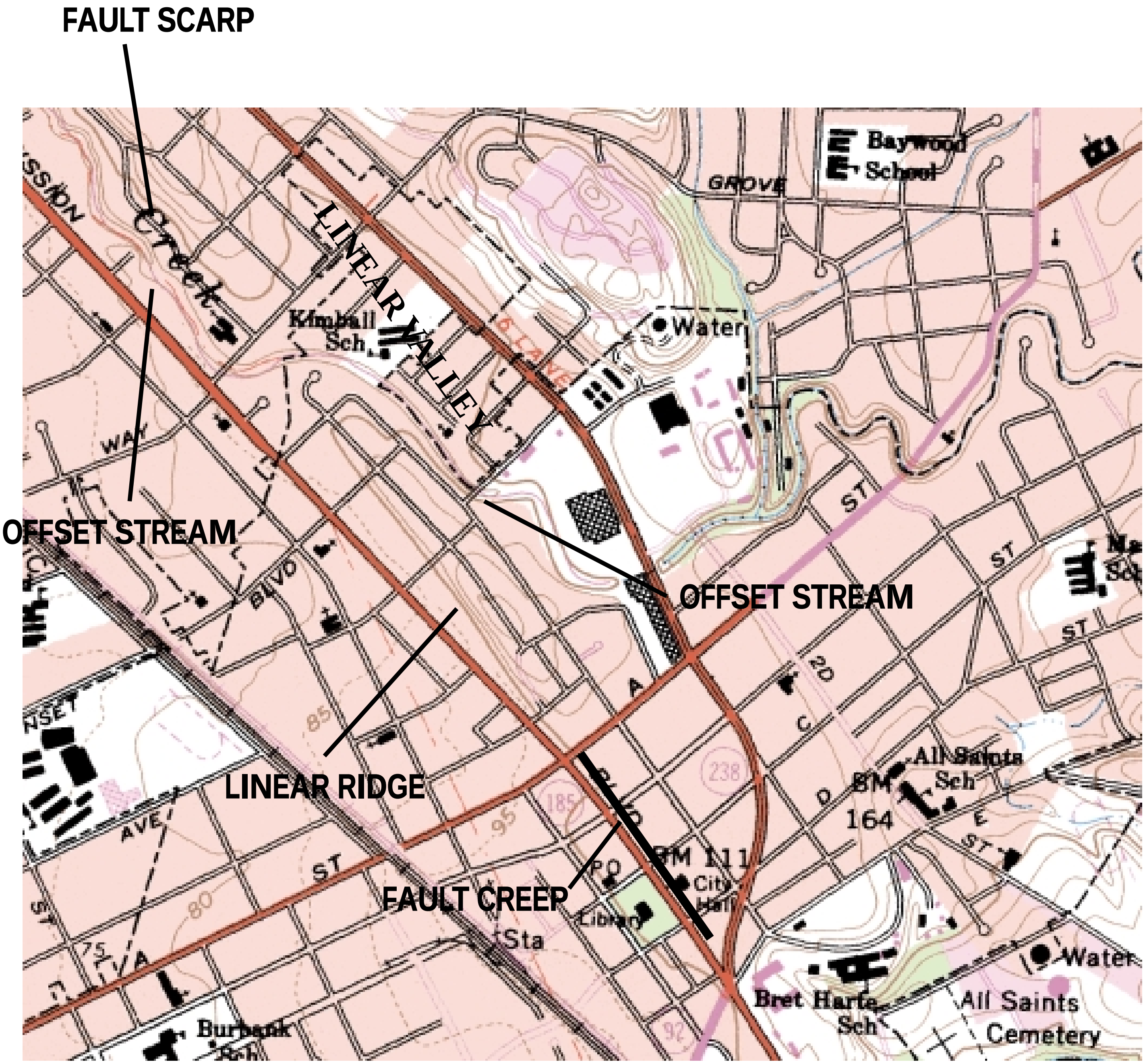


Figure 2-6. Topographic map of northern Hayward showing the landscape features associated with the Hayward fault in the area.

A

B

Figure 2-7. Two photos showing the effects of fault rupture. During an earthquake, the Earth's surface along a fault can be suddenly and permanently offset by many meters. Photo A shows the result of six meters of offset that occurred during the 1940 Imperial Valley earthquake in southern California. Photo B shows the crack left by six meters of offset that occurred near Point Reyes during the 1906 San Francisco earthquake. Imagine what would happen to anything built across the fault. (Photos from Wallace, R.E., ed., 1990, The San Andreas Fault System, California: U.S. Geological Survey Professional Paper 1515, p. 163.)