



# CALIFORNIA GEOLOGY

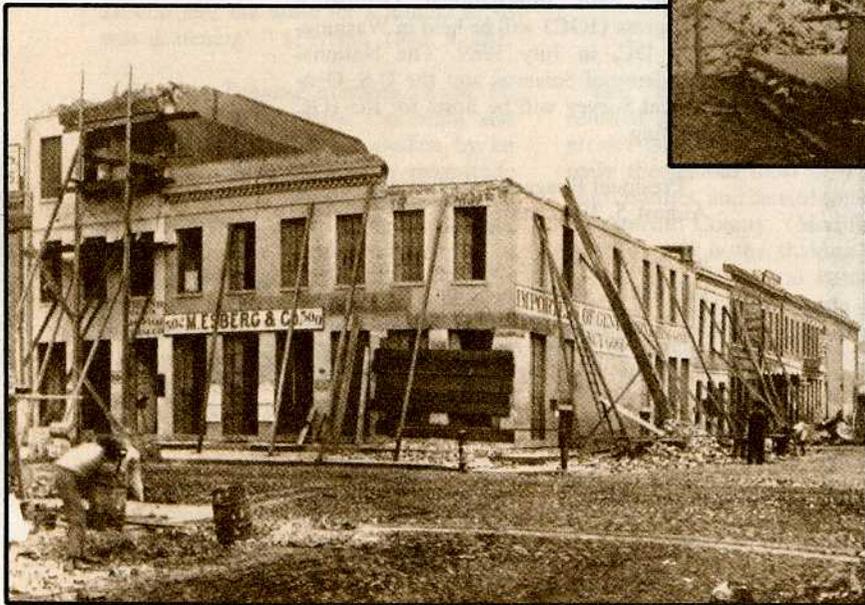
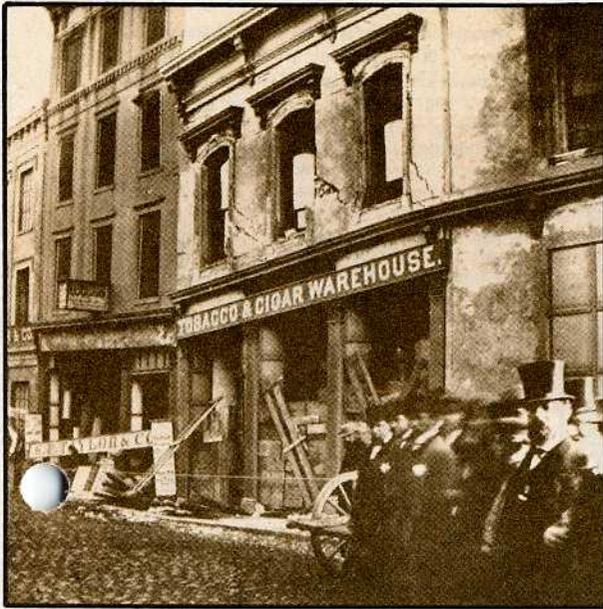
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## EARTHQUAKE DAMAGE

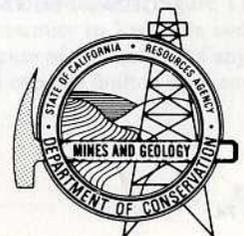


*LATE 1800s*

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# Vacaville-Winters Earthquakes...1892

Solano and Yolo Counties

By

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## INTRODUCTION

This article is based on research of newspaper and other accounts of pre-1900 earthquakes in California. The purpose of the research was to define the source area of the 1892 Vacaville-Winters earthquake sequence and to identify the most probable causative fault or faults....*editor.*

Vacaville's night watchman, S.N. Bettis, was walking down Main Street at 2:50 a.m., lantern in hand, when "his attention was attracted by a rumbling sound coming from the hills west of town. The noise resembled distant thunder or the roaring of water which had suddenly been let loose by the bursting of huge dam gates. Bettis stood still and listened a few seconds, while the noise increased to a roar and the ground beneath his feet seemed to heave up... 'I felt as if I was on the deck of a vessel during a heavy storm, and I put my hands to the ground to prevent myself from falling on my face... After that brick walls and chimneys began to fall all around and the noise for a minute or so was deafening' " (Perrine, 1893, p. 20).

On that Tuesday morning, April 19, 1892, most of northern California and west-central Nevada was shaken by an earthquake of about Richter magnitude (M) 6½. Major damage was concentrated in the communities of Vacaville and Dixon in Solano County, and Winters in Yolo County and surrounding rural areas along the western margin of the lower Sacramento Valley. Two days later at 9:43 a.m. on Thursday, April 21, a second severe earthquake in the M 6 range shook the area again, causing further damage. The largest of numerous aftershocks, approximately a M 5½ event, occurred several days later (April 29). This sequence of destructive earthquakes is noteworthy because along with the 1952 Kern County and 1983 Coalinga earthquakes, it is one of the most significant seismic episodes to directly affect California's Central Valley in historical times.



Clarke's Restaurant on Main Street, Winters; rear view of building, April 1892.

The larger April 19, 1892 event resulted in damage of intensity VII or greater on the Modified Mercalli (MM) scale throughout most of Yolo and Solano counties, and caused some damage in Sacramento County. (Modified Mercalli intensity VII is the shaking intensity at which some structural damage occurs, such as slight-to-moderate damage in well-built ordinary buildings, cracked chimneys and walls, and numerous broken windows.)

Intensity VIII and greater effects were felt as far north as the communities of Esparto and Capay in Yolo County and also at Vacaville and Fairfield in Solano County to the south. (Intensity VIII effects may be envisioned by recalling the damage in Coalinga in 1983.) Recurrence of an event of similar magnitude in the Vacaville-Winters area today could be a

threat to a vastly increased population and attendant facilities in the west Central Valley and San Joaquin Delta areas. The 1892 Vacaville-Winters earthquakes were comparable in destructive potential to the 1983 Coalinga earthquake (M 6.4) or the 1971 San Fernando earthquake (M 6.4). Total damage in the relatively sparsely populated Coalinga area was \$31 million; in the densely populated San Fernando area damage was over \$500 million.

## PREVIOUS WORK

No causative fault has been identified as the source of the 1892 earthquake sequence. Past speculation generally focused on the Midland fault (Figure 1) because of its proximity to Vacaville and Winters and because of the absence of any other recognized capable fault in the general area.

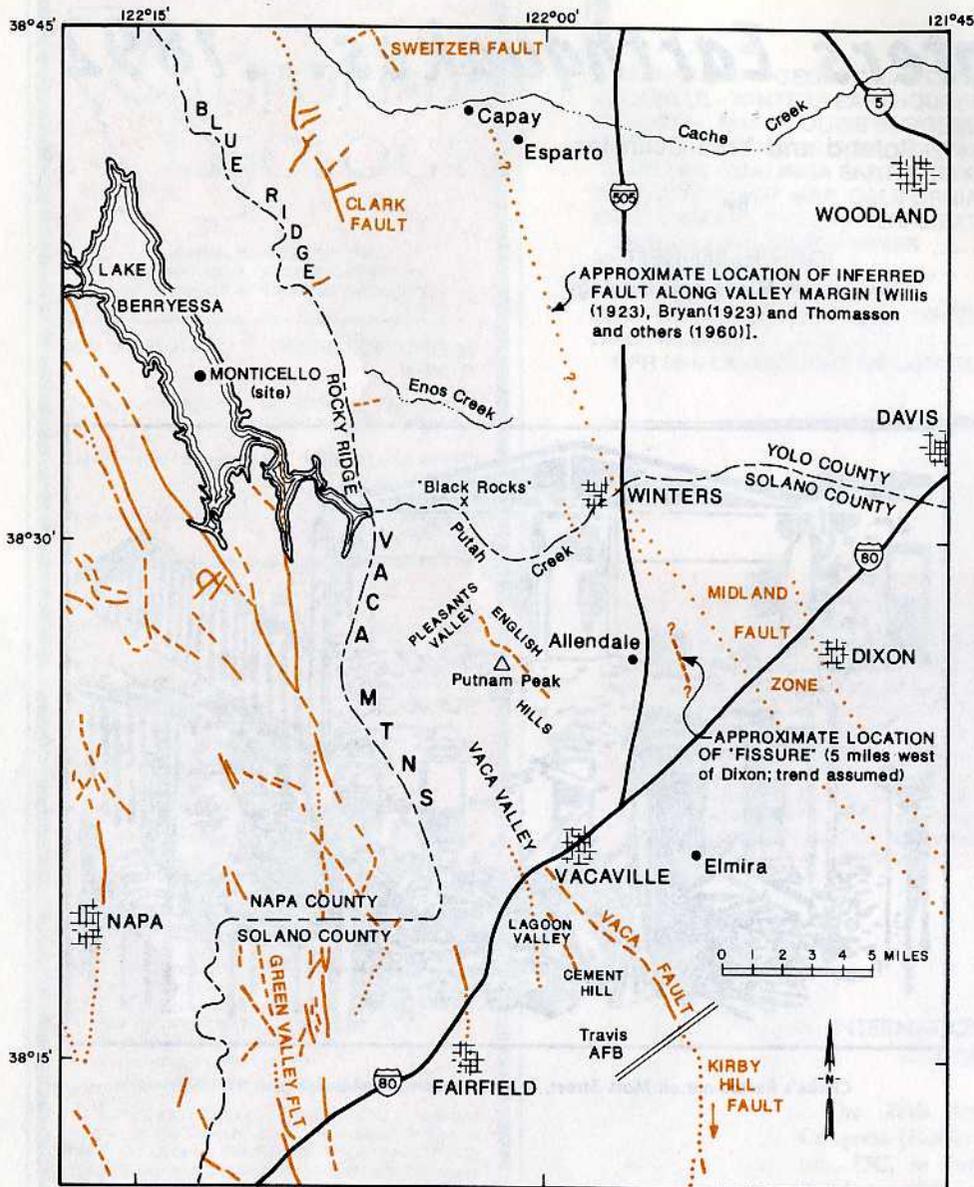


Figure 1. Faults in the Vacaville-Winters region. After Wagner and others, 1981, and Wagner and Bortugno, 1982, except as noted on map.

Newspaper accounts of the 1892 earthquakes were compiled from some 40 periodicals and other reports "with particular emphasis on establishing the location of the epicenters" (Dale, 1977). From this study it was concluded that "the epicentral region for the major events of the April 19-29, 1892, series of seismic events...was not in the Central Valley, as had been previously assumed, but rather in the hills bordering the valley west of Vacaville and Winters" (Dale, 1977).

An exhaustive search of reports of all pre-1900 California earthquakes, including the examination of nearly 12,000

newspaper issues, mission records, diaries, and other accounts was completed in 1981 (Toppozada and others). From these data, isoseismal maps were developed for all significant pre-1900 events and, whenever possible, magnitudes and epicentral locations were estimated. The resulting isoseismal map for the larger event of the April 1892 Vacaville-Winters sequence (Figure 2) was developed from intensity data derived from a search of some 65 newspapers published throughout northern California and western Nevada. The following conclusions were determined from these data (Toppozada and others, 1981).

#### Earthquake of April 19, 1892 - Estimated M 6.4

Extensive damage (VIII MM) occurred at Dixon and Vacaville, Solano County and at Winters, Yolo County. The highest intensity (IX MM) was assigned to Allendale, between Vacaville and Winters. A number of buildings in the vicinity of Allendale collapsed, were shifted off their foundations, or were wrenched apart. Fissures extending about a mile were opened in the ground near Allendale, which suggests possible faulting (*The Dixon Tribune*, 29 April 1892, p. 2). The area shaken at intensity VIII MM or greater was about 1,100 km<sup>2</sup>.

#### Earthquake of April 21, 1892 - Estimated M 6.2

Considerable damage was done to weakened structures in those communities damaged by the 19 April event. The area shaken at intensity VIII MM or greater was about 890 km<sup>2</sup>, but this area was probably larger than normal due to the weakening of structures during the earthquake on the 19th.

#### Earthquake of April 29, 1892 - Estimated M 5.5

This was an aftershock of the 19 April earthquake. The highest assigned intensity (VI MM) was at Davisville (Davis), Yolo County where a few loose bricks fell and at Sacramento where many people ran out.

#### INTENSITY DATA

The following general observations are based on the intensity data:

(a) The intensity pattern is asymmetrical with contrasting very high and relatively low intensities occurring on opposite sides of a line near and parallel to the Napa-Solano county line (Figure 2). There are, in fact, no intensities greater than VI (MM) at any of numerous locations within Napa County, including Napa, Rutherford, St. Helena, and Calistoga in Napa Valley; Pope Valley, midway between the upper Napa Valley and Lake Berryessa; nor at the former community of Monticello in Berryessa Valley (now inundated by Lake Berryessa) where damage was "nominal." Consistent with these low intensities in Napa County are the reported effects from Mare Island and Cordelia in Solano County (V-VI MM). The intensity data indicate that the source area was east of the crest of the Vaca Mountains.

(b) Various newspaper reports of the April 19 event indicated that "Vacaville seemed to be the center of the disturbance" (*Western Watchman*, April 23, 1892, published in San Francisco). These reports were probably based upon the fact that there was more, but not necessarily

more severe, structural damage at Vacaville. As pointed out by Dale (1977), the extent of damage in Vacaville may have been due more to unfavorable foundation conditions than proximity to the epicenter. An article in the *Sacramento Bee*, dated April 20, 1892, noted that, "Eulatis Creek runs through the town of Vacaville. It was noticed that most of the damage was on the south side. This was mainly because nearly all the buildings are in that direction, but it is stated that the shock was not as severe on the north side of the creek...The difference in the violence of the shock is explained by the character of the soil, which is not so deep on the north side of the creek, affording a solid foundation." Most of the downtown area south and west of the creek is on alluvium, while sandstone is common to the north and east.

(c) Accounts of the April 19 event in the Winters-Pleasants Valley area describe numerous cracks and fissures, sounds of escaping gas, water thrown from creeks and rockslides. Similar reports of manifestations of high-intensity shaking are generally lacking elsewhere.

(d) The analysis of the intensity data for the April 19 event resulted in assigning *maximum* intensity (IX MM) to the area near Allendale, about midway between Vacaville and Winters (Topozada and others, 1981).

(e) The April 21 event is reported as follows: "It is quite clear that the focus of today's disturbance has been shifted to the northwest and has been located near Winters. Elmira and Vacaville got off lightly. The direction of the shocks has also perceptibly changed" (*Morning Call*, April 22, 1892, published in San Francisco).

Earthquakes of this magnitude could involve fault rupture exceeding the 20 km distance between Vacaville and Winters and generally equivalent damage at these locations is reasonable assuming rupture along some intermediate fault. The various damage accounts, taken collectively, suggest that the source of both events was located somewhere between these two communities. There is no compelling evidence to conclude that the two events were widely separated spatially, though various reports indicate that the April 21 event was the more northerly of the two.

#### HISTORICAL SEISMICITY

Historical seismicity is nominal and provides no insight to seismically active

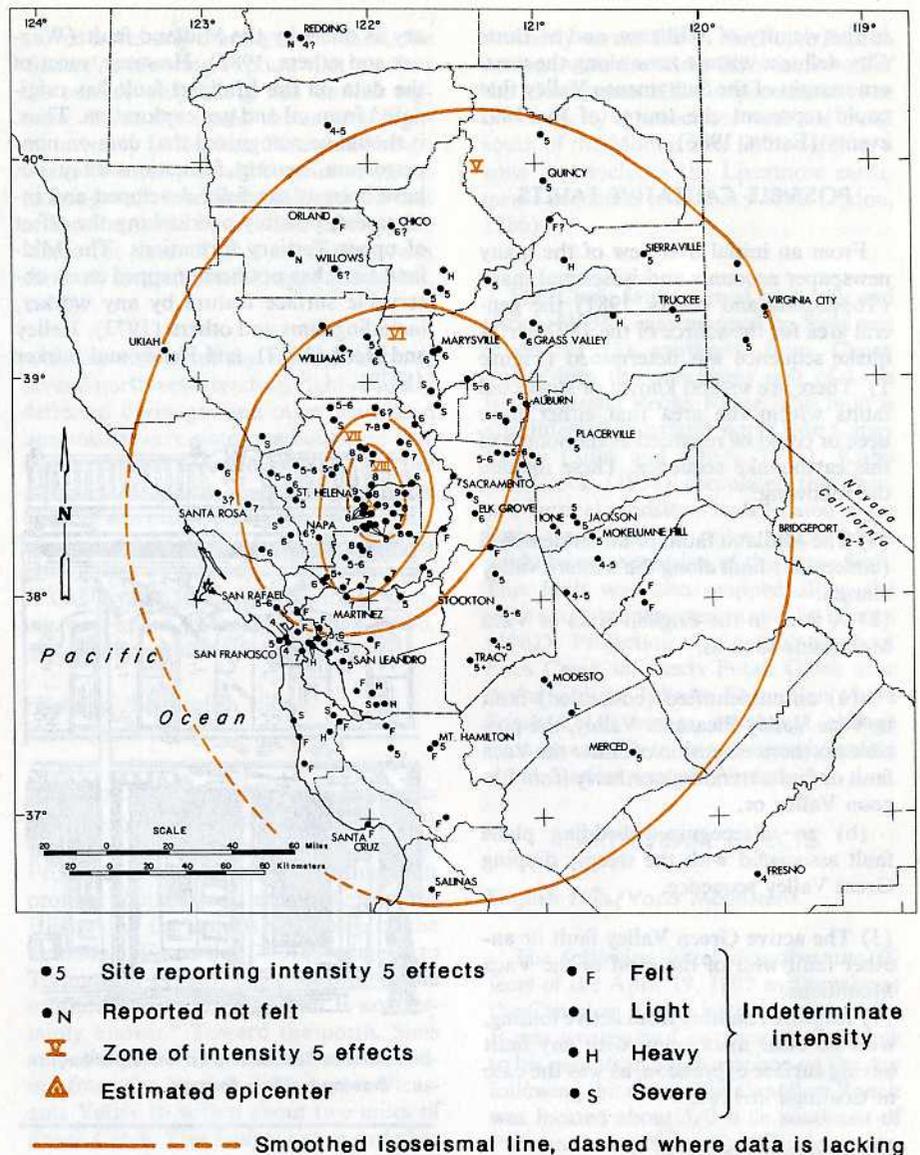


Figure 2. Modified Mercalli isoseismal map of the April 19, 1892 Vacaville-Winters earthquake, (10:50 GMT). Modified from Topozada and others, 1981.

areas within the study area. Other than the 1892 earthquake sequence, the only known  $M \geq 5$  earthquake to occur in the area was an event of about  $M 5\frac{1}{2}$  on May 19, 1902. From the available intensity data, this event was located in the Fairfield-Vacaville (Solano County) area (Topozada and others, 1981).

Between 1900 and 1974, only three events (in the  $M 4$  range) were located within the study area (Real and others, 1978). These were located in the hills east of Blue Ridge between Putah and Cache creeks. The accuracy of these epicentral locations is uncertain. More recently a  $M 4.2$  earthquake occurred near Madison in Yolo County (September 8, 1978).

Precisely located hypocenters and focal mechanisms in the eastern San Francisco Bay region for the period 1969-1980 were examined (Ellsworth and others, 1982). These data reveal a broad north-south trending zone of seismicity along the western margin of the Montezuma Hills north of Pittsburg (Contra Costa County). Focal depths are unusually deep, plunging north to a depth of 25 km. Focal mechanisms are consistent with right-lateral strike slip motion parallel to the seismicity. The area involved is located astride the Vaca-Kirby Hill fault (Wagner and others, 1981) (Figure 1). More recently the regional seismicity was summarized and it was noted that recent earthquake clusters north of Antioch, and

in the vicinity of Williams, and at Butte City define a seismic zone along the western margin of the Sacramento Valley that could represent the source of the 1892 events (Eaton, 1986).

### POSSIBLE CAUSATIVE FAULTS

From an initial overview of the many newspaper accounts and isoseismal maps (Topozada and others, 1981) the general area for the source of the 1892 earthquake sequence was determined (Figure 1). There are several known or suspected faults within the area that either have been or could be regarded as the source of this earthquake sequence. These include the following:

(1) The Midland fault, or an unidentified (concealed) fault along the western valley margin.

(2) A fault in the English Hills or Vaca Mountains such as,

(a) an unidentified (concealed) fault in Vaca Valley-Pleasant Valley, the possible northern extension of either the Vaca fault or faults trending northerly from Lagoon Valley or,

(b) an unrecognized bedding plane fault associated with the steeply dipping Great Valley sequence.

(3) The active Green Valley fault or another fault west of the crest of the Vaca Mountains.

(4) Rupture resulting from active folding, with no clear association with any fault having surface expression, as was the case in Coalinga in 1983.

#### The Midland Fault

The Midland fault was evaluated in connection with the Alquist-Priolo fault-zoning program, as follows (Bryant, 1982):

The Midland fault zone is thought to be a north-northwest trending, steeply west-dipping normal fault. The fault zone depicted by Jennings (1975) connects with the Sweitzer fault, an east-dipping reverse fault exposed in the Rumsey Hills (Kirby, 1943) (Figure 1). However, Wagner and others (1981) did not find evidence supporting the connection of the Midland fault with the Sweitzer fault. Indeed, evidence supporting the existence of the Midland fault north of Winters was not found (Wagner, personal communication, 1982).

No observed evidence of displacement on the Midland fault younger than early Oligocene time was reported by Reynolds and Reynolds (1963). Another study did not show beds younger than early Terti-

ary as offset by the Midland fault (Wagner and others, 1981). However, most of the data on the Midland fault has originated from oil and gas exploration. Thus, it should be recognized that data on non-petroleum bearing formations may not have been as carefully developed and interpreted, possibly overlooking the offset of upper Tertiary formations. The Midland fault has not been mapped as an observable surface feature by any worker, including Sims and others (1973), Helley and Herd (1977), and Helley and Barker (1979).



Masonic Temple on First Street, Dixon, showing building damage.

#### Fault Along the Valley Margin

A major fault along the valley margin was postulated by Thomasson and others (1960, p. 40):

North of Winters, the east margin of the foothills is remarkably straight and abrupt. The dip of one exposed gravel bed steepens at the margin of the hills, and the dips of the underlying fine-grained strata appear to steepen also. This marginal steepening becomes accentuated going north, indicating either a monocline whose degree of flexure increases to the north, or a hinge fault whose displacement increases northward, or possibly both. Bryan (1923) has, in fact, postulated a fault along the margin of the hills between Putah and Cache creeks.

An authoritative description of this fault was presented in a geologic report of the Sacramento Valley as follows (Bryan, 1923, p. 79-80):

Another fault...starts at Esparto and skirting the mountains, brings up the alluvium along the foothills to a point opposite Allendale, where the fault disappears." and (on p. 224), "...a...fault, with uplift on the west side. It begins near Esparto, skirts the mountains along the low bench already referred to, crosses Putah Creek east of Winters, and dies out near Allentown (Allendale).

A fault in this same location was depicted by Willis (1923) as lying between Esparto-Capay and Winters.

Several newspaper accounts describe effects of the 1892 earthquake that could be interpreted as expressions of surface rupture associated with a fault along the valley margin:

(1) At the northern extremity of this postulated fault near Esparto-Capay the *San Francisco Examiner* (April 20, 1892) reported, "The earth opened in several places between here (Esparto) and Capay."

(2) In the immediate vicinity of Winters there are several reports of ground failure. Whereas all of these are probably related to secondary failures along Putah Creek, some could be interpreted as manifestations of surface rupture.

(a) It must have been a fearful shock. The sand bars in Putah Creek (to the west and south of Winters) opened, and from the fissures the water spurted high upon the banks...In some places the creek became dry, in others it changed to a torrent. The banks caved-in in some places and almost dammed the stream (*San Francisco Examiner*, April 22, 1892).

(b) Near the town the bank of Putah Creek, ten feet wide, caved in, and along the bottom of the creek for a great distance rents were made by the shocks (*San Francisco Chronicle*, April 20, 1892).

(c) At Winters there have been developed a number of fissures in the earth, water has been ejected, gas has escaped, and the bed of the creek has been filled up for a distance of over 70 yards (Perrine, 1893, p. 31).

(d) The greatest damage done by the earthquake outside of that wrought in the town itself is in the wrecking of the country road skirting Putah Creek, on the south side of the town...A new road will have to be cut through adjoining property, as a dangerous cliff fifty feet deep has been formed at the spot where the embankment gave way. A long zigzag fissure six inches wide extends right along the center of the roadway. As in nearly every other case the fissure was north and south... (*Morning Call*, April 22, 1892, p. 2).

(e) On Putah Creek, half a mile west of Winters, a phenomenon was witnessed by a young man named Fred Willis, who was riding past at the time of the big shake. There seemed to be an explosion, and the water was thrown from the creek to a distance of twenty feet on either bank. Then followed a hissing sound as of gas escaping.

At daylight several fissures were found in the bed of the creek and in the roadway and fields adjoining. On each side of the creek where the explosion took place the banks caved in, the landslides being seventy-five feet in length and twelve feet deep (*San Francisco Examiner*, April 21, 1892, p. 1).

(3) Southeast of Winters, near Allendale, two newspaper reports describe a fissure that is not ascribed to secondary ground failure or shaking effects:

(a) The *San Francisco Examiner* (April 23, 1892) reported this fissure as follows:

A FISSURE HALF A MILE LONG—It is also a fact that out by the old Allendale road, five miles west of Dixon, a fissure in the ground can be traced for fully half a mile. It opened at first over an inch wide and closed again as the edges of the crack crumbled inwards. Now all that is left is a ridge of fine dust, like the trail of some huge insect.

(b) *The Dixon Tribune* (April 29, 1892) reported:

The earthquake opened fissures in the earth near Allendale from one to three inches in width and extending about a mile.

The trend and continuity of these cracks were not reported. Ground cracking due to shaking was widespread throughout the area. The *Morning Call* (April 22, 1892) indicated that most of the fissures observed throughout the area had a general north-south trend. The cracks described near Allendale appear to have been extensional rather than a mole track formed by compressional deformation.

One can assume that the fissure near Allendale was noticed because of its proximity to the Allendale Road. If it was surface rupture it may have been of greater length than reported since the feature, as described, was relatively obscure, and may have been intermittent and/or offset along a greater length. Considering these factors and the rural setting, the full extent of a more lengthy surface rupture could have gone unnoticed.

If a fault exists at this location, it could constitute the southerly extension of a fault located along the linear valley margin between Winters and Esparto-Capay (Willis, 1923; Bryan, 1923; and Thomasson and others, 1960).

It could be speculated that the earthquakes resulted from rupture that in-

involved a westerly dipping thrust fault, the 'fissure' evidencing rupture that reached the surface only along this limited segment. Given this model the areas of highest intensity (Allendale, Pleasants Valley, west of Winters) would be situated on the hanging wall, a setting analogous to that at San Fernando in the 1971 earthquake, where the area of greatest damage was similarly located (Steinbrugge and others, 1975).

In the vicinity of the reported rupture several northwest-trending, right-laterally deflected drainages and other associated lineaments were noted, although no systematic magnitude of deflection or other evidence of recent or recurrent surface faulting was evident (Bryant, 1982). During recent trenching of one of the most pronounced lineaments by the University of California, Davis, no evidence of faulting was found (Martha Merriam, 1986, personal communication).

#### Faults in the English Hills/ Vaca Mountains

A fault within the English Hills was mapped by Thomasson and others (1960) and also by Sims and others (1973). From its southern extremity, this fault projects southeasterly across the English Hills along the approximate base of the Tehama Formation. According to Thomasson (1960), "The location of the southeastern end of this fault is not certainly known." Toward the north, Sims and others (1973) show this fault extending from the English Hills across Pleasants Valley to within about two miles of Putah Creek. This fault is not regarded as an active feature by Sims and others (1973).

Two faults, which trend northerly across Cement Hill northeast of Fairfield, possibly merge within Lagoon Valley and extend north to a point about 2 miles west of Vacaville before terminating at the alluvium in Vaca Valley near Alamo Creek, were mapped by Sims and others (1973). Continuation of faulting northwesterly into Vaca Valley is a reasonable extrapolation.

Another fault that may extend into Vaca Valley is the Vaca fault (Wagner and others, 1981). This fault, mapped by Bailey (1931), trends northwest along the northeast flank of the hills just south of Vacaville terminating at the alluvium at the southern end of Vaca Valley just west of Vacaville (Figure 1). Wagner and others (1981) show the Vaca fault extending

southerly across Travis Air Force Base to connect with the Kirby Hills fault west of the Montezuma Hills. A prominent zone of seismicity is associated with the trend south of the Montezuma Hills, defining a zone that includes the Livermore earthquake sequence of January 1980 (Eaton, 1986).

The Clark fault, named by Kirby and Crook (1934), was mapped by Sims and others (1973) southerly from Capay Valley into the mountains east of Lake Berryessa and Rocky Ridge. This fault is also inferred to extend north into Capay Valley (Sims and others, 1973). Kirby and Crook (1934) speculated that massive vertical sandstone beds located along Enos Creek several miles to the south might be an expression of this same fault. This fault was also mapped along the same south-southeasterly trend by Brooks (1962). Projection of this fault south of Enos Creek intersects Putah Creek near the base of the Tehama Formation where Putah Creek makes an abrupt change from an easterly to a southeasterly course about 5 miles west of Winters.

#### EARTHQUAKE EFFECTS

##### English Hills/Vaca Mountains

The following letter describes the effects of the April 19, 1892 earthquake at the Cantelow Ranch in the English Hills. It was written by Lawrence A. Cantelow to his parents in San Francisco on the day following this event. The Cantelow Ranch was located about 1/2 mile southeast of Putnam Peak (Figure 1). (This letter was provided by Herbert P. Cantelow, of Oakland and nephew of the two Cantelow brothers, both of whom resided at the ranch in 1892.)

Cantelow Ranch  
April 19, 1892

Dear Folks,

The chimney here broke off at the top of the house, but did not break through the roof. All the back fell out and it is badly cracked around the fireplace. There was about a ton of brick and dirt. In the sitting room the tables and desk were thrown over and pictures turned wrong side to. In the little room where I sleep, the shelves were all torn down and everything generally tumbled over. In Nomia's room the bureau was turned over on its face, pitcher and wash bowl broken, and the bed wheeled across the room. The big clock is a total wreck—the frame is all peeled apart. In the dining room not much damage was done as there was nothing in there.

But in the kitchen! You should have seen the mess—milk, jelly, preserves, coal oil, sugar, flour, tea, in fact everything all in one mess and this held down by four big wheelbarrow loads of dishes and bottles broken into ten thousand pieces. It just naturally smashed everything in the room but the stove. I think at one time the east end of the house was four feet from the ground. The underframing is all knocked galley west and the two parts of the house are split apart so there is a crack in the door big enough for a cat to go through. The cap is knocked off the stovepipe.

...There is a big crack running across the lot and up the hill. I don't know how long, as I did not go to the end of it, but it is so big that the cows were afraid to cross it, and in two places where it crossed the fence, the posts would fall in but for the wire. There are also lots of smaller cracks and the whole side of the mountain slid in west of Pleasants [house]. I could shove my arm in the holes around the posts at the wagon house and cow barn. The cows are nearly scared to death yet. Everything in the house upstairs was turned over, even to the wardrobe which brought down a ceiling joist with it...

There was another quite heavy shake last night at two o'clock, but not enough to knock things down. The telephone will not work between here and Vacaville, so we have no news from there, but I think the rest of the walls must have surely fallen in. I was just talking with Mr. Pleasants, 9 A.M. There were two more small shocks just now. We may be swallowed up yet. There are lots of cracks in the hills.

Other reports from Vaca Valley-Pleasants Valley at the time of the 1892 quakes include the following:

In Pleasant Valley, between here (Vacaville) and Winters, the shock was terrific and it is said not a chimney is standing in the entire valley...W.J. Pleasants' house in Pleasant Valley was wrecked from its foundation (*San Jose Daily Mercury*, April 20, 1892).

Falling boulders in Gate's Canyon Thursday morning barely missed the Alpine schoolhouse, one weighing three tons being among the number (*Vacaville Reporter*, April 21, 1892).

In Vaca Valley...They saw where the trembler had made a small fissure in the creek. *Marysville Weekly Appeal*, April 22, 1892, and near J.S. Pleasants in Pleasants Valley...The creek banks contracted shoving one end of the bridge forward three feet (*Vacaville Reporter*, April 21, 1892).

#### West of Vaca Mountains

The active Green Valley fault extends from the western margin of Suisun Bay northward into Napa County. Associated with this fault and its northwestward extension along the western margin of Lake Berryessa is a prominent zone of continuing earthquake activity (Eaton, 1986). Neither this recognized



Bartolet Building, Winters. All plates are from photographs in *San Francisco Examiner*, April 1892.

Holocene fault or any other fault west of the crest of the Vaca Mountains is regarded as a likely source of the 1892 earthquakes based upon the intensity distribution and contemporary accounts.

The effects of the 1892 earthquakes west of the crest of the Vaca Mountains were described by S.B. Dunton of Winters as follows:

The earthquake was scarcely felt in Berryessa Valley, hence, no damage was done there...Berryessa was not, therefore, the focal center of greatest disturbance. In Lake County the "quake" was scarcely felt and in Mendocino County, it was not felt at all. Notwithstanding this, the shake was very severe along a base line east of the range (Vaca Mountains) for twenty-five miles (*Winters Express*, June 4, 1892).

Mr. Dunton's statement of "no damage" in Berryessa Valley is supported by a report in the *Sacramento Evening Bee*, April 19, 1892, as follows:

Nathan Hagard has just driven in from Monticello and brings news that the damage there was nominal.....

In Pope Valley northwest of Berryessa Valley, the April 19, 1892 event was reported as "no damage done, not even the falling of a chimney," and the April 21, 1892 event only as setting "household things to rattling and dancing" (*St. Helena Star*, April 29, 1892). Thus, it seems apparent that the effects of the earthquakes diminished rapidly along the western boundary of Yolo and Solano counties) and appears to preclude the possibility that a fault west of the Vaca

Mountains within Napa County was the source of the earthquake.

#### West of Winters

The observations by S.B. Dunton of Winters constitute some of the most descriptive material encountered concerning the geological effects of these earthquakes in the area west of Winters. He gives the following description of the effects of the earthquake shock on the cement grade west of Winters. The following account, titled EARTHQUAKE FORCE—Great Boulders Leave Their Beds and Crash Down the Mountains, was published in the *Woodland Mail*, April 26, 1892:

I was on the cement grade when the 15 to 10 shock came [April 21, 1892]... I had just cleared the road of rocks up to the county line, some of which weighed 2,000 lbs., I rolled them with my team and chain. Rocks of 50 tons came down the mountain a distance of 500 or a 1,000 feet, crashed through pines, over the road and into the creek, to join many other like boulders, that had proceeded them many centuries before from like causes. One of those "needle points" south side of canyon above the "Black Rocks" broke off. There are many slides and immense boulders toppled over, and they came into the creek with a tremendous crash. The upper canyons and Berryessa Valley were not shaken so hard. The focal point of greatest force was on the Black Rock line and Vacaville (is) directly in the path of this lava line of fracture and ancient volcanic ebullition.

The "cement grade" corresponds to the present State Highway 128 that traverses Putah Canyon west of Winters and the "Black Rocks" are identified on the map by Kirby and Crook (1934). These

"Black Rocks" refer to several small exposures of basalt located immediately north of the previously mentioned location in Putah Canyon where the Creek makes a bend to the southeast (base of the Tehama Formation). The "Black Rock line" and "lava line of fracture and ancient volcanic ebullition" described by Dunton evidently corresponds to these small remnants of basalt (Putnam Peak Basalt). Use of the word "above" in the phrase... "those 'needle points' south side of canyon above the Black Rocks..." undoubtedly means "farther up" the canyon. Very large boulders and some rock spires exist along one of the two north-south-trending ridges that intersect the canyon about a mile west of the "Black Rocks."

A subsequent article by S.B. Dunton was published in the *Winters Express*, May 7, 1892.

...I have been asked to say something in regard to the causes of our recent awful visitation...I see that Professor Davidson thinks that the Berryessa valley is the focal center of our great shocks. The writer is somewhat familiar with the mountain structure west of Winters, and is willing to admit all that Professor Davidson says as to the geological status of Berryessa valley and Putah canyon, still there are other geological factors that stand out with salient clearness to the geological observer. We hear of convergent lines from the focal center of greatest disturbance. There is no focal point of greatest seismic disturbance in this section, so fearfully shaken, still there is a central or base line of greatest violence in our recent quakes. This is the line of black basaltic rocks four miles west of Winters. This line varies in width from a few rods to one fourth of a mile, and follows the general trend of the mountains on the east for a distance of 25 miles that we know of. The black rocks at the Seeley place in the lower Putah canyon are on this line. Putnam's Peak is of basalt. Vacaville is directly on this fracture line of basalt; Capay is very near it, and Esparto is not far away. Dixon is not more than eight miles from it. Basaltic rock is of volcanic origin, as much so as green lava. It is of true igneous formation and origin, composed of augite and feldspar, with magnetic iron and other minerals disseminated through it. When the coast range rose up from the sea, there was of necessity a line of fracture along its eastern base. It was through and along this line that igneous "intrusion rocks" diked up. These were centers of volcanic discharge and volcanic ebullition. This great vent between the mountain forms and the lower forms of the valley is a line of geological weakness, less able to resist great seismic forces than unbroken subforms are...

Professor Davidson's statement to which Mr. Dunton responded was not located. However, his apparent belief that Berryessa Valley was the source of these earthquakes is evident from the following

article (*Woodland Daily Democrat*, April 23, 1892):

Esparto; April 23; the people of Esparto are very uneasy. Agent Coates has a telegram in which it is announced that Professor Davidson has predicted that a severe shock will occur this afternoon, and that Berryessa Valley will be the seat of the disturbance. This telegram has thoroughly alarmed the people and they refuse to stay indoors.

Another article by Dunton was published in the *Winters Express* of June 4, 1892, as follows:

EARTHQUAKES—Editor Express: - Three weeks ago I wrote an article for the Express upon earthquakes. Since then a number of intelligent people have importuned me to write again...in the issue of that journal (*Dixon Tribune*) of May 27, 1892, Reverend Mr. Hemphill, of Dixon, in a very intelligent, deferential and respectful manner, takes exceptions to my ideas of seismic disturbances. The reverend gentleman says that I opposed the ideas of Professor Davidson, of the Lick Observatory. In this he is just a little mistaken. I admitted all which Professor Davidson had said, as to the geological status of Berryessa valley and Putah canyon. I only dissented from the Professor's theory that Berryessa valley was the focal center of greatest seismic disturbance. And now, for the "evidences" along that line:

The writer was one of a party who removed the boulders from the Putah canyon road after each of the two heaviest shocks, and knows whereof he writes. He was in Putah canyon during the second great shock. All of the great boulders, which came crashing down the mountain sides, were in the lower canyon. There were not any rocks in the road at the "Devil's Gate," [present site of Monticello Dam, at Napa, Yolo, Solano County junction] or "middle canyon," and none in the upper part of Putah canyon. The earthquake was scarcely felt in Berryessa valley, hence no damage was done there. I have conversed with many citizens living there, and all tell the same story. Just above the "Seeley Black Rocks" immense rocks, many in number, some of which would weigh from ten to fifty tons, came down from five hundred feet above into the bed of the creek. Hence, Berryessa was not, therefore, the focal center of greatest disturbance. In Lake county the "quake" was scarcely felt, and in Mendocino county it was not felt at all. Notwithstanding this, the shake was very severe along a baseline east of the range for twenty-five miles.

Dunton was obviously observant and his correlation of the "focal point of greatest force" with a geologic formation trending southerly toward Vacaville may be very close to the actual facts. However, it should be noted that in 1892 earthquakes were commonly associated with volcanic processes and, accordingly, the existence of a singular formation of volcanic origin could have prejudiced his conclusions.

Further evidence of violent shaking within the hills west of Winters is indicated by the following accounts:

Many people drove over (to Winters) from Woodland and Dixon. All these say that along the roads are evidence of the earthquake's power. On the Solano and Pleasant Valley roads particularly the highway is covered by great cracks and the earth is banked up in hummocks...It was reported that several boiling springs had burst from the foothills on the north and west and were flowing steadily (*San Francisco Examiner*, April 22, 1892, p. 1)

West of here (Winters) about three miles, an acre of ground slid into the creek. On the county road this side of the cave there are great cracks in the ground (*San Francisco Chronicle*, April 20, 1892).

Up the canyon the road is chocked up with boulders dislodged from the hillsides. In one place an acre of ground slid into the creek, in the creek are many fissures caused by the quake, from some of which gas is hissing forth (*Solano Republican*, April 22, 1892, p. 3)

Up the Berryessa road the passage is blocked by immense boulders, some weighing several tons. They were thrown with mighty force down the hillsides into the road. (It is near this point where the rents in the road were noticed.) From all around came reports of wells filling up with caving earth (*Sacramento Evening Bee*, April 19, 1892, p. 1).

A *Sacramento Evening Bee* reporter in Winters noted that, "...everybody had his version of the shaking. The most commonly accepted statement was that the shock was preceded by a trembling of the earth, which rose in billows off toward the hills. Then came the shock like a terrible twist that tore the stronger walls and dashed down enormous masses of rock from the hillsides" (*Sacramento Bee*, April 22, 1892).

Finally, a most descriptive and interesting account:

I drove over with Mr. Devilbiss this morning to look at the geological changes effected by the earthquake. To the west and south of the town (Winters) runs Putah Creek, which in the summer is an insignificant stream, but in winter is a raging torrent, covering a bed a quarter of a mile in diameter [width]. It is along the line of this creek and in its bed that the last shock seems to have originated. There are no such ghastrly rents emitting gas and steam as have been described by imaginative and verdant young pencil-sharpeners on the strength of some frightened rustic's statement, but there are undoubtedly a number of cracks rapidly closing up and holes from which volumes of water were ejected at the time of the last quake. The water had evidently gained admission laterally, and been squeezed out as the earth collapsed after the wave passed by. An eyewitness furnished a brief but vivid description of the passage of this wave on Thursday (April 21) morning. He said that he was cultivating a

field a little to the west of the Devilbiss residence (about one mile west of Winters) when he noticed that the cultivator, on which he was riding, plunged violently. At the same moment, there was a loud, roaring noise, and cloud of dust sweeping rapidly along toward the town of Winters. The ground rose and fell like the sea in a storm, and a moment later a tremendous crash announced that it had struck the Devilbiss house. Successive crashes showed when it reached other houses as it passed along, and when it reached the town, the noise was tremendous. Immediately after the shock, the eyewitness saw distinctly that the ground was broken up into reefs and furrows, which closed up even as he was watching them. Large volumes of water spurted up from the dry bed of Putah Creek (*The Morning Call*, April 23, 1892).

Surface waves travel at a velocity of approximately 3 kilometers per second. A singular wave or wave train would, therefore, travel the mile or so from "just west of" the Devilbiss residence to Winters in only about 1 second. Damage at the Devilbiss home and that at Winters would, therefore, occur almost simultaneously. The observer's comments, however, relate to the "noise" from the damage as the wave(s) progressed toward and arrived at Winters. Since sound travels at a velocity of about 300 meters per second, some 7-8 seconds would lapse between the time an observer "just west of" the Devilbiss residence (assume one-quarter mile) would hear the noise from damage at the Devilbiss house and the time he heard noise from damage at Winters.

## CONCLUSIONS

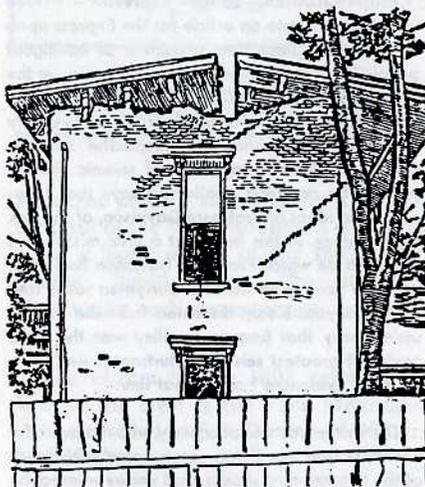
From these various accounts, there appears little doubt that the source area of the April, 1892 events and, presumably, the entire earthquake sequence lies in the hills west of the lower Sacramento Valley. These additional accounts, therefore, affirm the earlier and corresponding conclusion by Dale (1977). In fact, this same general conclusion was stated rather well 95 years ago in the *Morning Call* of April 23, 1892, as follows:

From the same general appearance of things..., there seems to be little doubt that the shock originated in the foothills on the west side and travelled in a wave 20 or 30 miles long directly to the Sacramento River (*Morning Call*, April 23, 1892).

These data suggest further that the source area was located east of the crest of the Vaca Mountains in Solano and Yolo counties. This conclusion is predicated on the absence of any significant damage at Monticello in Berryessa Valley, at Pope Valley, and generally throughout Napa County and on Dunton's observation that

shaking effects in Putah Canyon diminished rapidly westward towards Berryessa Valley. These observations are in marked contrast with the reports of intense shaking at all locations east of the county line.

From the numerous accounts, the most intense shaking occurred in the area generally bounded by Pleasants Valley, Putah Creek, Winters, and Allendale. The northern limits of this area are vague, however, since there was no significant settlement and, hence, no reports originating within the hills north of Putah Creek.



End view of the Dobbin's house, Vacaville, showing split roof.

This study supports the earlier conclusion by Dale (1977) that the source area of this earthquake sequence lies within the hills bordering the valley west of Vacaville and Winters. The evidence further supports a conclusion that the source area lies northerly of Vacaville and east of the crest of the Vaca Mountains, thereby eliminating the known Holocene-active Green Valley fault, or other faults within Napa County. This earthquake sequence appears to have originated within an area of some six to eight miles in width centered on the English Hills, the area extending from near the Sacramento Valley margin to just west of the Vaca Valley-Pleasants Valley trough.

Within this area possible sources of the 1892 earthquake sequence include:

(a) an unrecognized thrust fault or faults related to the development of folds along the western margin of the Great Valley, a source similar to that which produced the 1983 Coalinga earthquake,

(b) a concealed fault within the Vaca Valley-Pleasants Valley trough, possibly the northern extension of the Vaca Fault,

(c) a bedding plane fault within the steeply dipping Great Valley sequence.

The significance of the Vacaville-Winters earthquakes has become more apparent since the 1983 Coalinga earthquake focused attention on the seismic hazard associated with the western margin of the Great Valley. It is highly probable that both of these destructive earthquakes were the result of the same tectonic processes taking place in similar environments. Logic dictates prudent planning for seismic hazards mitigation all along this major boundary and most certainly in the rapidly urbanizing counties east of San Francisco Bay.

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## Memorial

### Mary Louise Burgess

Mary Louise Burgess, formerly with Division of Mines and Geology, died on January 17, 1987 after a short illness. She began working with the Division in 1945 when the Division of Mines and Geology (DMG) was part of the Department of Natural Resources. During her career she was Executive Secretary to seven State Geologists — Olaf P. Jenkins, Gordon B. Oakeshott (interim), Ian Campbell, Wesley G. Bruer, James E. Slosson, Thomas E. Gay, Jr. (interim), and James F. Davis.

When she retired, Mary Louise was Senior Information Clerk at the DMG's Sacramento Information Office, the office that receives more public inquiries than any other Division office. Mary Louise developed many informational packets and



procedures to provide the public with prompt responses to information queries. In May 1984 she received the Department of Conservation certificate of award for Sustained Superior Accomplishment in recognition of her work.

At her retirement dinner, Mary Louise was awarded a Letter of Appreciation from Governor George Deukmejian, a Resolution from the State Legislature (signed by Senator Greene and Assemblyman Isenberg), and a Letter of Appreciation from the Department of Conservation.

Mary Louise retired in November 1984 after 39 years of state service with the Division. She will be remembered for her dedication to her job, her friendly manner, and her thoughtfulness.