Title: **Geology of Fort Ross**

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FORT ROSS.

North and south of Fort Ross, the phenomena of displacement are well displayed, both on the open-terraced coastal slope and in the timber. The rupture follows for the most part a single well-defined line in the path of the old Rift, coinciding in many places with ancient scarps and the slopes of low ridges. (See plates 35A and 36D.) The fault-trace is commonly marked by a ridge of heaved sod with diagonal cracks as illustrated in plates 35B and 36B. New scarps occur as shown in plates 36C, and 38A, B, as well as accentuations of old scarps. There are, however, several subparallel cracks. Two of these, having each a length of about 150 feet, lie to the west of the main line at a point 1,250 yards northwest of Doda's ranch-house, one 50 and the other 100 feet distant from the main crack and disposed *en échelon*. Within 300 yards to the southeast of this are two short cracks still closer to the main one, and springing from it, at about 450 yards northwest of Doda's ranch-house, is a parallel crack 440 feet in length and 60 feet from the main line. In this case the scarp appears upon the auxiliary crack, and not upon the main line of rupture. Between the short discontinuous crack and the main line is a swampy depression. On the southeast side of the ravine, southeast of Doda's house, the main crack is paralleled by two subordinate cracks, one on each side. That on the southwest side is about 250 feet long and 50 feet from the main line. It has a low scarp facing northeast, but not so pronounced as that on the main line of rupture. The crack on the northeast side of the main line has a length of about 1,125 feet and converges upon the latter toward the northeast. At its northwest end it is 190 feet from the main crack and at its southeast end only 50 feet distant. It has a low, discontinuous scarp facing northeast.

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The distribution of the line of faulting for a typical stretch of the Rift near Fort Ross, the auxiliary cracks, the disposition of the scarps upon these, and the relation of the whole to the old Rift features, are well shown on map No. 3 by Mr. F. E. Matthes. The horizontal displacement is also indicated on the map, but this needs more detailed statement.

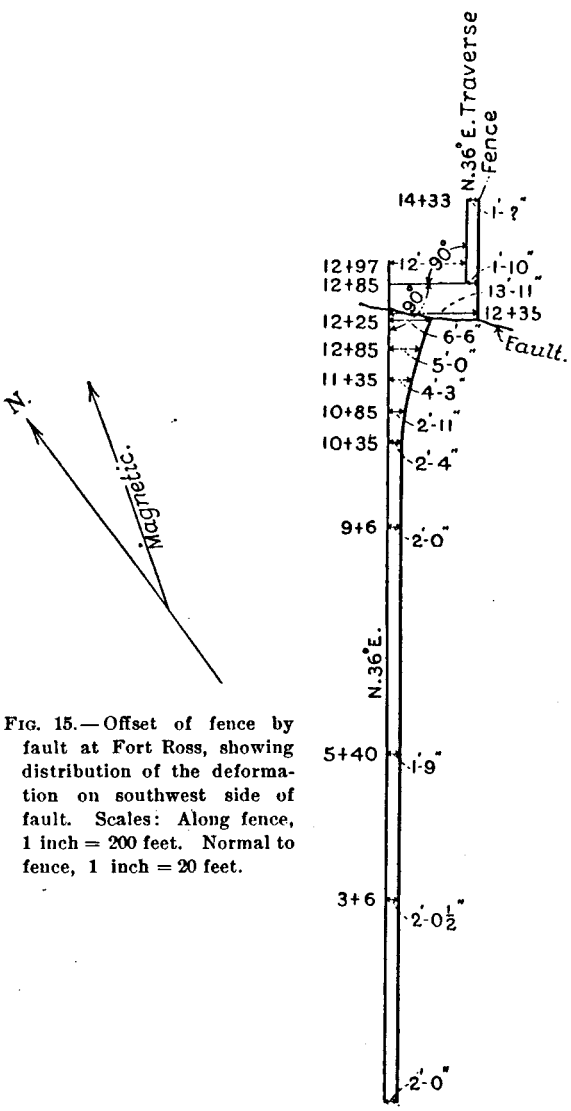


FIG. 15.—Offset of fence by fault at Fort Ross, showing distribution of the deformation on southwest side of fault. Scales: Along fence, 1 inch = 200 feet. Normal to fence, 1 inch = 20 feet.

On the line of the fault, about 300 yards northwest of the road from Sea View to Fort Ross, a steel water-pipe was dislocated by the earth movement, and found to be offset 8 feet, the southwest portion having moved northwesterly. This of course affords only a minimum measure of the relative movement. Where the road just mentioned intersects the fault-trace, both the road and the bordering fences were offset about 7.5 feet, with a slight sag on the northeast side. The zone of shearing here was from 10 to 20 feet wide. A wagon road on the Call ranch, south of the one above referred to, was offset 12 feet 3 inches, the line of dislocation being marked by an open fissure in the soil a few feet deep, and several short diagonal cracks, as shown in plate 36C. Another offset fence is shown in plate 36A, the displacement being here 8 feet at the fault-trace. The effects of the earth movement in the timber to the south of this are well shown in plate 34A. Several large trees standing on the fault line were split or torn asunder. The offset of the south line fence of the Call ranch was carefully surveyed by Mr. E. S. Larsen, and the results of his survey are shown in fig. 15. The bearing of the fence is N. 36° E. He reports that for the first 1,000 feet from the southwest end of the fence the greatest error in alinement was about 1 inch, and that practically there was no deformation in this stretch. In the next 125 feet going northeast there was found a deviation from this alinement of 4 inches to the southeast. In the next 50 feet the deviation in the same direction was 7 inches more. In the next 140 feet the deviation in the same direction was 3 feet 7 inches more. Then came the fault-trace with an abrupt displacement of the fence of 7 feet 5.1 inches. Northeast of the fault-trace the fence retained its line very well. In 100 feet it was out only 1 inch. Beyond this it enters the timber and its course is somewhat influenced by the larger trees, but maintains its line within a few inches. These measurements give a total horizontal displacement of 12 feet distrib-

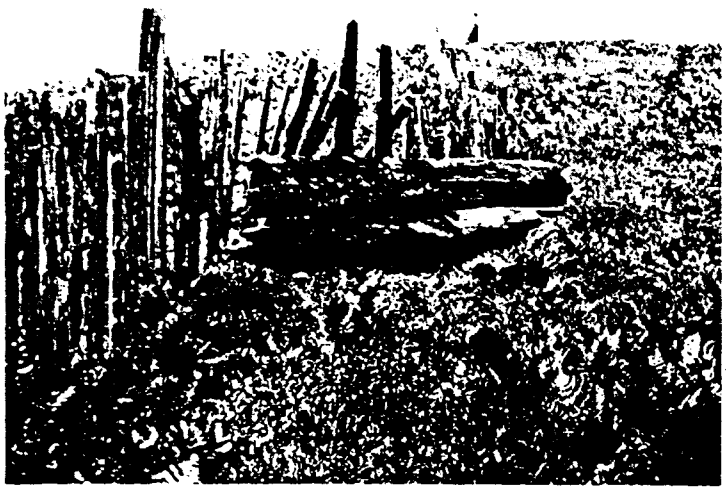
A. Fault-trace in redwood forest near Fort Ross. J. N. L.

B. Dislocation of loam near Fort Ross. J. N. L.

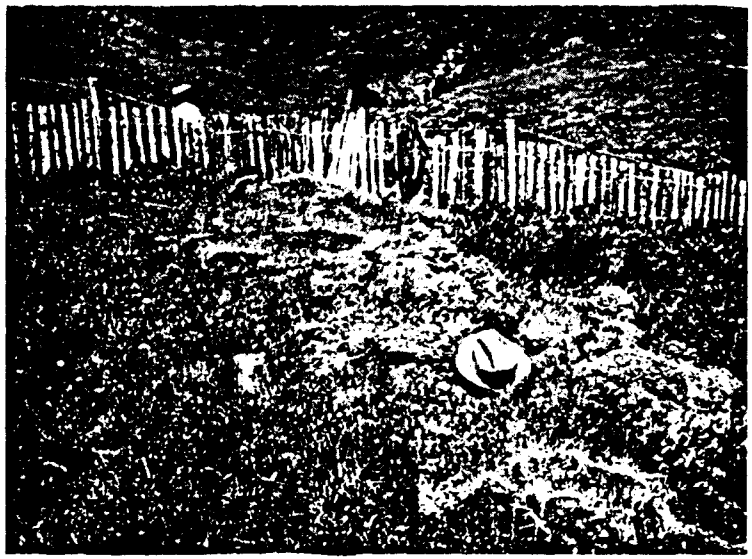
A. Accentuation of old scarp by new fault 1.5 miles north of Fort Ross. J. N. L.

B. Fault-trace on grass-covered slope near Fort Ross. R. L. H.

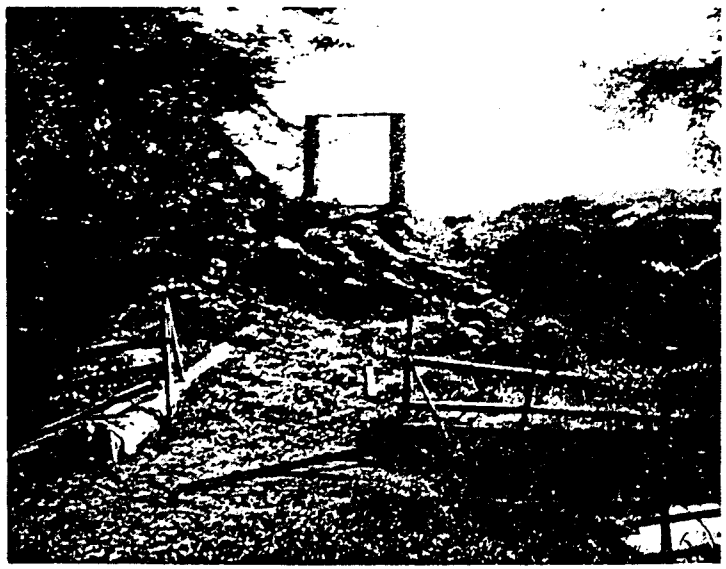
PLATE 36



A. Offset of 8 feet on fence a mile east of Fort Ross. R. S. H.



B. Fault-trace and dislocated fence near Fort Ross. R. S. H.



C. Roadway offset 12 feet. New fault-scarp 3 feet high, facing northeast. Above Fort Ross. F. E. M.

D. Accentuation of old fault-scarp by new fault. Near Fort Ross. F. E. M.

A. Offset of stream trench by the fault and ponding of water by the fault-scarp. Doda's ranch, a mile southeast of Fort Ross. A. C. L.

B. The fault-trace a mile northwest of Bolinas Lagoon, looking southwest. Illustrates the ridge phase. G. K. G.

uted over a zone 415 feet in width. Another fence farther southeast on Doda's ranch, having a bearing of N. 36° E., was offset on the fault-line 15 feet; the southwest side, as usual, having moved relatively to the northwest. This fence is shown in plate 34B. One of the most interesting effects of the displacement due to the fault is that seen where the latter intersects a small stream at Doda's ranch-house. The stream flows transversely to the line of the fault, and has a trench across the terrace about 5 feet deep. On the lower or southwest side of the fault, the stream trench has been moved northwesterly about 12 feet, so as to bring a fault-scarp across the entire width of the upper part of the trench and impound its waters in the form of a pool. The result is shown in plate 37A and also on Mr. Matthes' map of the Rift at this place (map No. 3). The impounding of the waters on the line of the fault is interesting evidence of the absence of any open crack.

BODEGA HEAD TO TOMALES BAY.

The location of the fault across the neck of land which connects Bodega Head with the mainland was determined by Prof. J. N. LeConte. He reports that on the south side of this neck the main earthquake fissure was found passing about 50 yards west of a house occupied by Mr. Johnson. It could be traced as a multitude of small cracks in the swampy land from the bay to the road, then as a well-defined fissure up the small depression west of the house for 200 yards to where it disappeared in the sand dunes. No trace of it could be detected in the sand dunes, which reach from this point entirely across the peninsula. Only one fence crosses the fissure and this had been repaired so that no measurement of the displacement was possible. The movement was evidently northward on the west side, as was shown by the direction in which the bushes were bent. The vertical movement was about 18 inches, the uplift being on the west side. The sand spit which closes the bay on the south was examined for evidence of movement, but nothing could be detected in the drifting sand.

At the mouth of Tomales Bay there are two points projecting westward from the east shore, and both of these, according to the observations of Prof .R. S. Holway, are crost by the fault-trace. The first is a long, flat sand-spit extending well across the mouth of the Bay just south of Dillon's. The line of the fault was still visible in the sand on June 11, 1906, in spite of the obliterating action of the wind and the recent rains. The line lies near the base of the spit and has a northwest-southeast course. On each side of the crack are crater-like depressions, some of them being double or overlapping. Mr. Keegan, the owner of Dillon's Beach, reported that these craterlets were numerous and distinct. In some instances a great deal of sand and water had been ejected. Others are reported on the southwest side of the fault-trace, from which the belt containing them extends some 70 feet. The craterlets vary in size up to 6 feet in diameter and it is reported that on the day after the earthquake the water which stood in them could not be bottomed by a fishing pole.

About 1.5 miles southeast of this spit is a promontory about 100 feet high projecting into the bay. Some 400 yards from the end of this promontory on top of the ridge is a line of depression with two or three small ponds. The main fault fissure here divides into two cracks, one each side of this depression, which is about 150 feet in width. Standing on this ridge, the line of the fault can be traced at low tide for nearly 1.5 miles across the bottom of the bay to the sand-spit to the northwest, its course in general being parallel to the axis of Tomales Bay. (See plate 38c.) The horizontal displacement where the fault crosses the promontory is about 8 feet, as determined by the line of tall grass at the edge of the little ponds, the westerly side having shifted to the northwest.

been badly strained by the shock. The ranch stands on the east edge of the ridge, west of the Gualala River, and the fault runs along the mountain side several hundred feet below it. The slope is a steep one, densely timbered except for its upper portion. Landslides were found over a large part of its surface, but only in a few isolated spots had they resulted in the complete removal of the original surface and the forest growing thereon; so that a view from across the river revealed no appreciable changes in the landscape. The slopes east of the river were similarly affected and the fallen timber produced a tangle not unlike that of extensive windfalls. In at least two places the river was temporarily dammed up by slides from both slopes meeting in the stream bed, but none of these dams was of noteworthy size.

On the ridge east of the Gualala Valley, the ranches of A. and Chas. Lancaster were examined and found to have suffered less damage than Casey's. Chimneys were broken, furniture was damaged, and a small slaughter-house collapsed, tho that structure was known to be a weak one to begin with.

Between the two ranches a fissure was found very similar to, tho smaller than, those characteristic of the fault-zone. Its trend was N. 75° E. No marked vertical movement was in evidence, and while the twisted sods and clods along its line clearly indicated a small horizontal movement, this could not be ascertained for lack of definite objects to measure it on.

Plantation House, Sonoma County. — Most of the houses in this place stood the shock well. One cottage which was crost by one of the strongest fault fissures suffered the partial collapse of its underpinning. Had the displacement of the fault not been distributed over a zone 270 feet wide in this locality, the destruction would probably have been much greater. As it was, broken chimneys and windows and slight damage to underpinning were the principal destructive effects within the zone.

Timber Cove, Sonoma County. — Altho this town is fully 1.5 miles west of the fault, the intensity was apparently but little less than at places much closer to it. The underpinning of one dwelling collapsed, all brick and tile chimneys broke off, and household articles and furniture were thrown down with violence.

In the bluffs along the coast and in the numerous rock cuts along the wagon road, the rocks appeared loosened up, many old fissures having opened and left the rock masses in more or less unstable positions. Landslides, in rocky as well as in loose material, have occurred in a great number of places, tho none were at all extensive.

Fort Ross, Sonoma County. — At Fort Ross, 0.75 mile from the fault, the intensity of the shock was probably greater than the actual damage would indicate. The old Russian Church and several other buildings suffered thru collapse of their underpinning, but all in a fair state of repair stood the shock, as did the more recently built dwellings.

The dwelling of Mr. G. W. Call, proprietor of the place, was violently shaken. The table was moved across the floor to the south and furniture generally was thrown to the ground. There was much broken crockery and glassware. The contents of a pantry, consisting of jars of preserved fruit, were nearly all thrown from the shelves. In cleaning up the wreck after the shock, 6 wheelbarrow loads of broken objects were picked up off the floors of the rooms. In Mr. Call's room a high case was thrown across the bed in which he was sleeping.

Mr. Call stated that in his neighborhood hanging lamps were caused to swing in a circle corresponding with the apparent movement of the sun. There were several shocks, quickly following each other; the first was not the strongest. They seemed to increase in force up to the third or fourth and to come from different directions. He judged that there was a strong vertical impulse. Chimney tops were thrown off, some chimneys being shattered to the bottom. Many redwood and pine trees were broken off, some at the ground, being uprooted; but generally broken about halfway up. All loose furni-

ture was turned over, and a few frame buildings set upon unbraced posts were shaken down. The tendency along the fault seemed to be to crowd the two sides together, as a water-pipe in one place had sprung up in a curve out of the ground. The fact that he found no trees broken at a distance of more than a mile from the fault indicates to Mr. Call that the shock was much stronger near the fault than elsewhere.

Mr. Call resided for some years on the South American coast and had experienced the disastrous effects of sea waves consequent upon earthquakes in that region. The moment, therefore, that he felt the shock he turned his attention to the sea, which is in full view of his house. He reports that it was perfectly still during the shock and afterwards.

South of Fort Ross, at Doda's ranch, a large barn about 150 feet west of the fault was found leaning to one side on the verge of collapse. Several of the dwellings and other smaller houses had slipt from their underpinning. All the chimneys had been broken off or destroyed; household articles and furniture had been thrown down, but no window glass had been shattered or even cracked.

Mr. Doda's daughter stated that she was standing in the kitchen at the time of the shock, and was lifted vertically from the floor more than once, in each case alighting on her feet. A ranch hand who was out-of-doors at the time stated that he saw the water-tank thrown vertically upward about 5 feet and then fall in ruins.

In the forest between Plantation House and Fort Ross innumerable trees, many of them redwoods (*Sequoia sempervirens*) of considerable size, had broken off some distance from the ground (plate 69A, B), or had split lengthwise from the roots up. Some were uprooted altogether, as if by a hurricane. No particular preponderance in direction of throw was noted. Trees on the line of the fault were as a rule split vertically and more or less twisted. In some cases the butts had actually been sheared. A fine instance of this may be seen on the stage road 150 feet east of Plantation House.

At Seaview, a post-office on the summit of the ridge overlooking Fort Ross and probably 1.5 miles from the fault, the shock is described by Mr. Morgan, the occupant of the only house there, as very violent. In a room with two beds, one moved across the room to the south, the other was lifted from the floor. The chimney was thrown to the north.

On the wagon road from Seaview to Cazadero, the steep bank of the road-cuts, generally of disintegrated sandstone, had in numerous places slid down upon the road.

At Cazadero the shock was severe and chimneys were generally thrown, but no buildings were wrecked, all the structures being of wood. Mr. H. L. Conley, of this place, stated that according to his observation the shock was from north to south, chimneys falling south. In a store the chief walls of which trend north and south, hardly any damage was caused. Some pictures hanging against walls were turned around so as to face the walls. There seemed to be two maxima, the second being the strongest.

BETWEEN THE COAST AND THE UPPER RUSSIAN RIVER.

For the territory between the coast and the upper Russian River Valley, we have the following notes by Dr. H. W. Fairbanks:

At Geyserville the shock was much less severe than at Santa Rosa. Chimneys and portions of brick walls were thrown down. The shock at Skaggs Springs, 8 miles west of Geyserville, was not severe. Chimneys were knocked down, but no other damage was done. On the summit of the ridge, 6 miles west of Skaggs Springs, chimneys and crockery were broken, the shock apparently being fully as severe as at Skaggs. There are no other dwellers along the Stewart's Point road until within 2 miles of the Rift, where the shock was of course severe.

Another section is that across the country from Point Arena to Cloverdale. At Booneville, in Anderson Valley, there is quite a settlement. About half the chimneys were down, and Dr. Diddle, apparently the best-informed man in the town, thinks that the shock was

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17 September, 1992

Ms Caerleon Safford
Fort Ross State Historical Park
19005 Coast Highway 1
Jenner, CA 95450

Dear Caerleon:

Thank you for your comments during my stop off at Fort Ross a few weeks ago. I am enclosing some materials relating to the effects of the 1906 earthquake at Fort Ross which may be of interest to you. The photocopied articles is from the report of the California State Earthquake Investigation commission (1908). which is probably the most complete study of the surface effects. The map with fault lines and indicators of offset is from the California Division of Mines and Geology Preliminary Report 16 (1972) on "Geology for planning on the Sonoma Coast between the Russian and Gualala Rivers". The third item is a fragment of the US Geological Survey 1:24,000 map of Fort Ross. I have penciled in the approximate fault break of the 1906 event. The two arrows are the two fence offsets mentioned in the CDMG and CSEI reports. If a fence is preserved, my guess is that it would be the one above Fort Ross Creek (south side of Call Ranch). -Fence B

The positions marked on the maps (mine or the CDMG report) are likely to be accurate only to 200 feet (there is a discrepancy of about 100' between the CDMG report and the map in the CSEI report near Doda Ranch). I would certainly be interested in knowing if this fence is still present as well as any other earthquake related geomorphology.

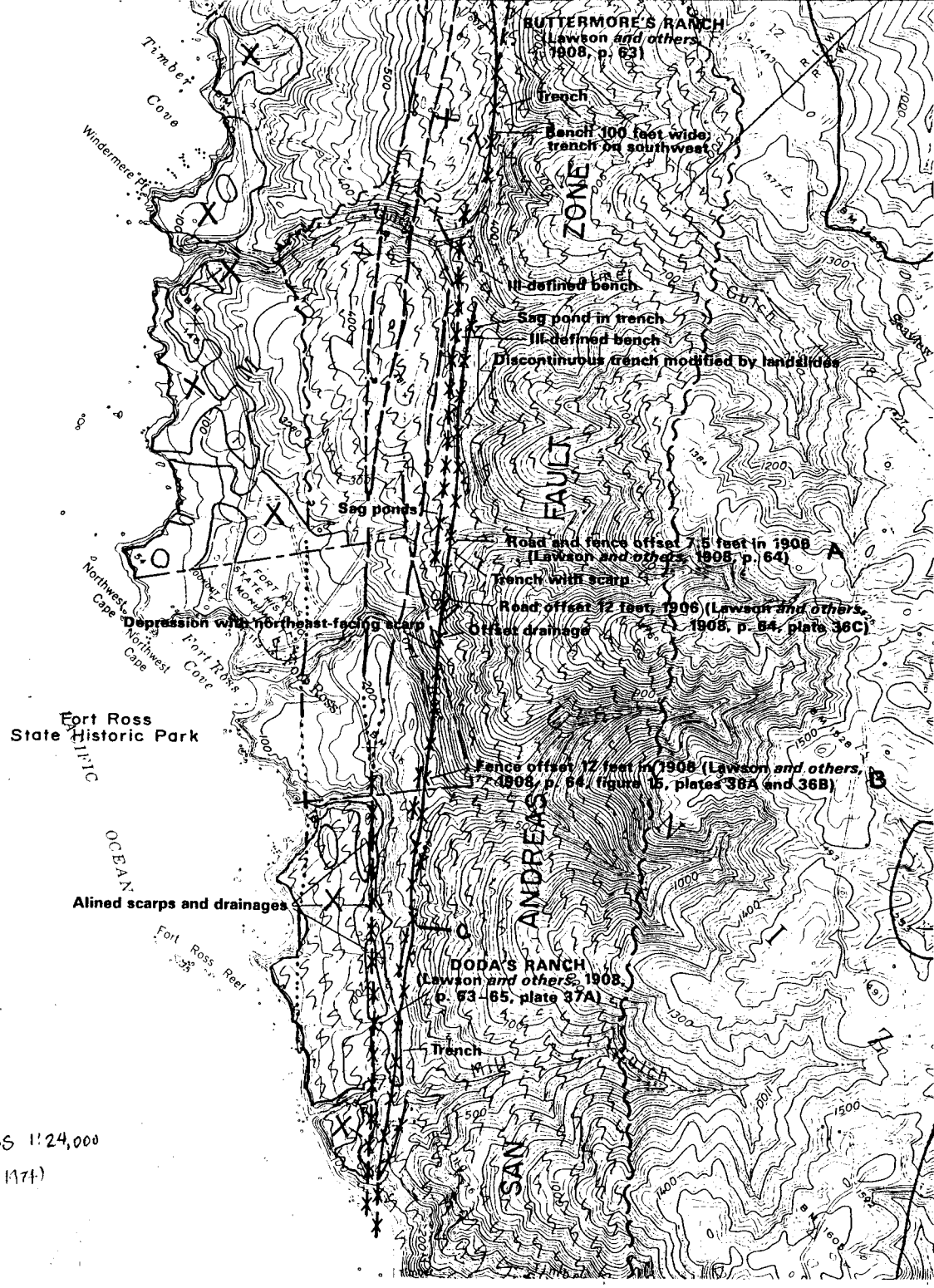
Please let me know what you discover or if I can try to find you some additional information.

Sincerely,

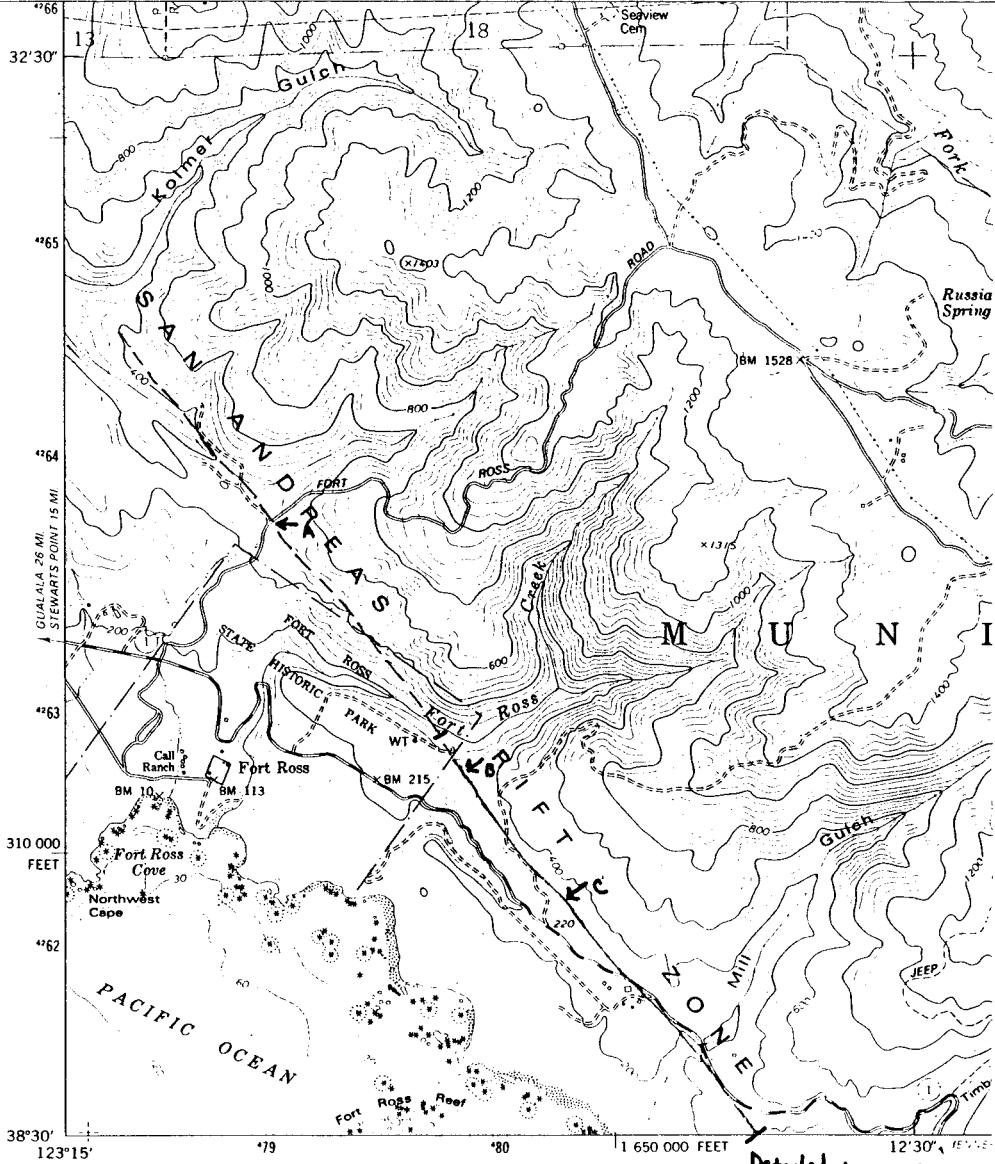
Kazuya Fujita

Kazuya Fujita
Professor
(517)-355-0142
e-mail: kaz@siberia.glg.msu.edu

> I just talked to someone who thinks its the other fence, fence "C" on map 3. He said he was there in the mid 1980's and is just off the dirt road.



USGS 1:24,000
(pre 1971)



Mapped, edited, and published by the Geological Survey

Control by USGS and NOS/NOAA

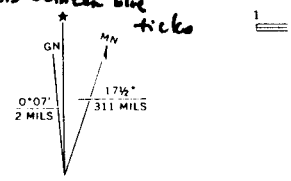
Topography by photogrammetric methods from aerial photographs taken 1971. Field checked 1976
Map edited 1978. Supersedes map dated 1943

Selected hydrographic data compiled from NOS/NOAA chart 5097 (1930). This information is not intended for navigational purposes

Projection and 10,000-foot grid ticks: California coordinate system, zone 2 (Lambert conformal conic)
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue. 1927 North American datum

To place on the predicted North American Datum 1983 move the projection lines 17 meters north and 96 meters east as shown by dashed corner ticks

Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked



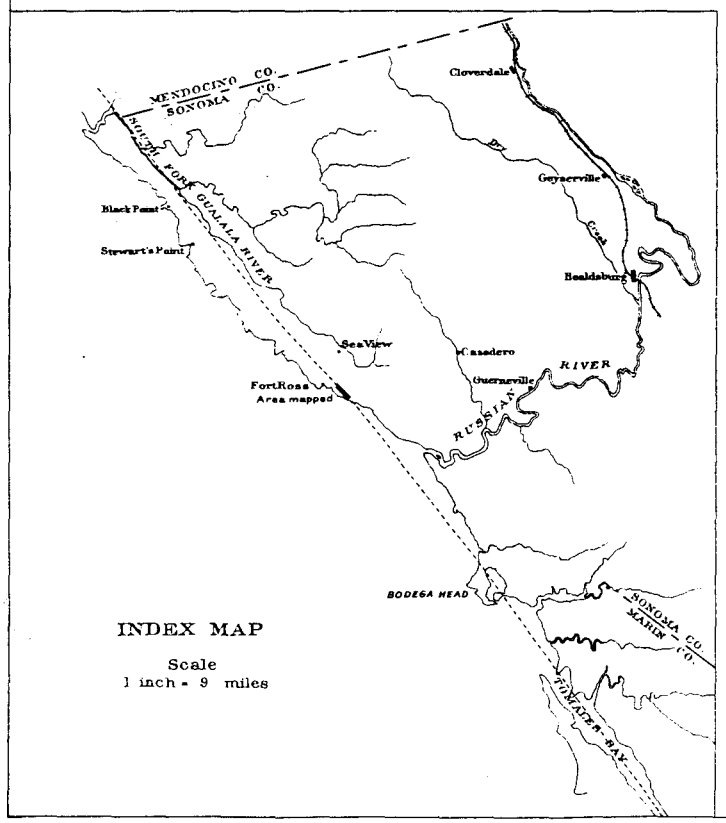
UTM GRID AND 1978 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

FOR

Detailed map no. 3 covers between blue ticks

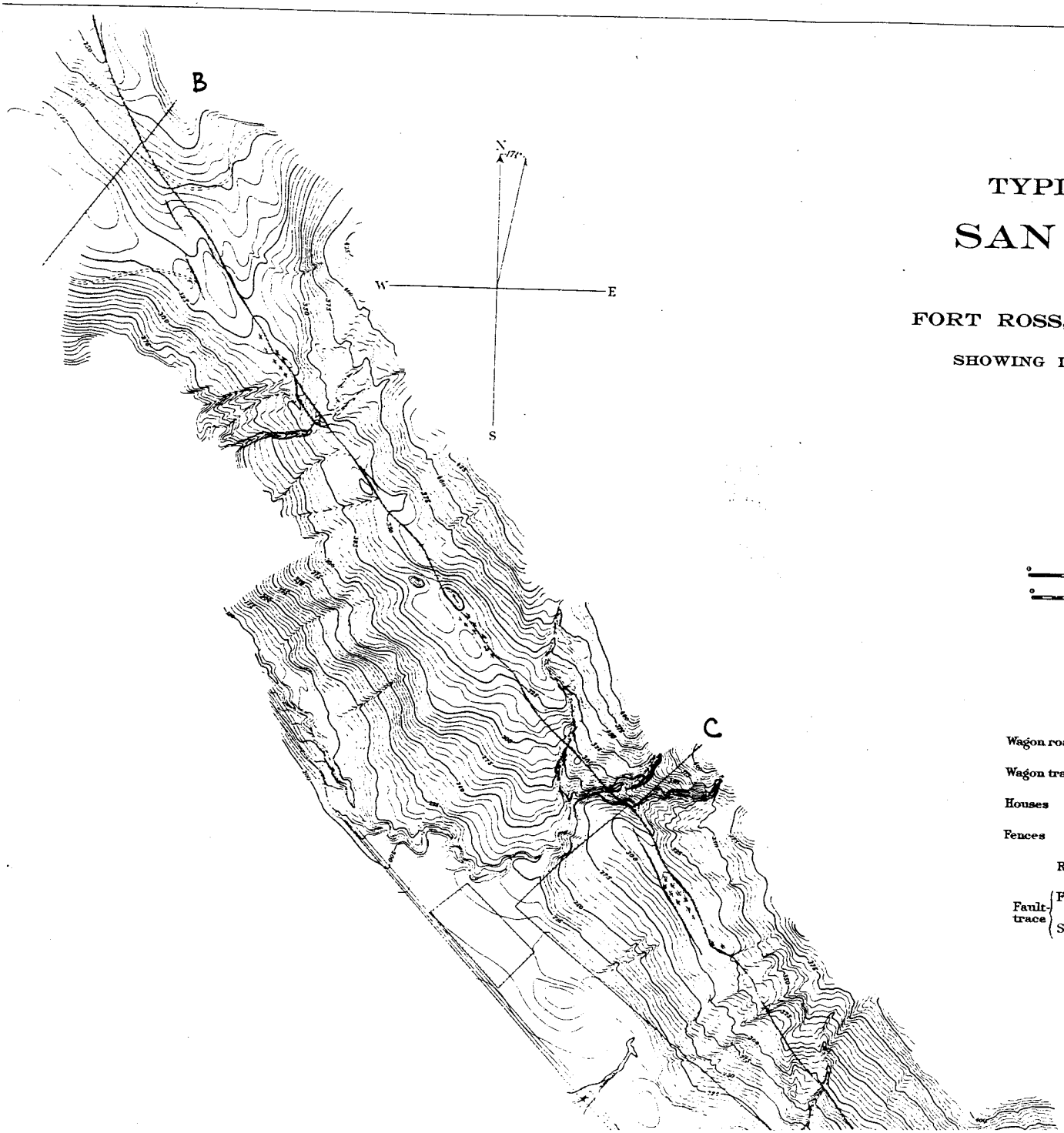
↙ fences offset in 1906

CA. Division of Mines & Geology. Preliminary Report 16 (1972) "Geology for Planning on the Sonoma Coast Between the Russian and Gualala Rivers"



INDEX MAP

Scale
1 inch = 9 miles



DETAIL MAP

OF A

TYPICAL PORTION OF THE

SAN ANDREAS RIFT

NEAR

FORT ROSS, SONOMA COUNTY, CALIFORNIA

SHOWING ITS GEOMORPHIC FEATURES AND THE

TRACE OF THE FAULT

BY

FRANCOIS E. MATTHES

Scale $\frac{1}{3960}$

0 500 1000 Ft.

0 100 200 300 M.

Contour interval 5 feet

Datum is mean sea level at Fort Ross (approx.)

LEGEND

Wagon roads

Wagon trails

Houses

Fences

Ponds

Perennial streams

Intermittent streams

Marshes

Relief (contouring)

Fault-trace: Furrow or crack

Fault-trace: Scarps along fault

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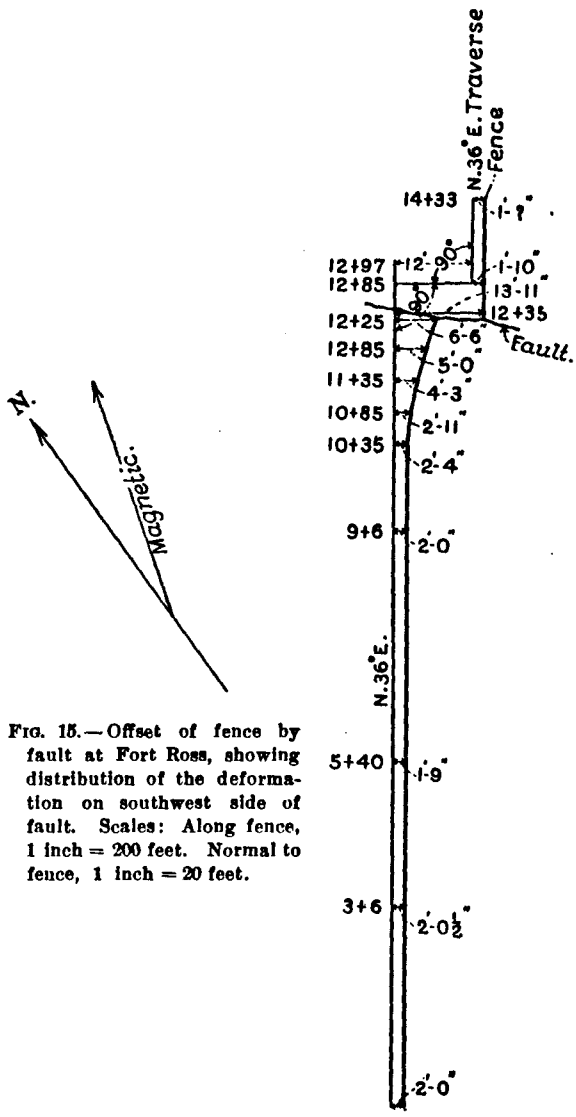

FIG. 15.—Offset of fence by fault at Fort Ross, showing distribution of the deformation on southwest side of fault. Scales: Along fence, 1 inch = 200 feet. Normal to fence, 1 inch = 20 feet.

On the line of the fault, about 300 yards northwest of the road from Sea View to Fort Ross, a steel water-pipe was dislocated by the earth movement, and found to be offset 8 feet, the southwest portion having moved northwesterly. This of course affords only a minimum measure of the relative movement. Where the road just mentioned intersects the fault-trace, both the road and the bordering fences were offset about 7.5 feet, with a slight sag on the northeast side. The zone of shearing here was from 10 to 20 feet wide. A wagon road on the Call ranch, south of the one above referred to, was offset 12 feet 3 inches, the line of dislocation being marked by an open fissure in the soil a few feet deep, and several short diagonal cracks, as shown in plate 36c. Another offset fence is shown in plate 36A, the displacement being here 8 feet at the fault-trace. The effects of the earth movement in the timber to the south of this are well shown in plate 34A. Several large trees standing on the fault line were split or torn asunder. The offset of the south line fence of the Call ranch was carefully surveyed by Mr. E. S. Larsen, and the results of his survey are shown in fig. 15. The bearing of the fence is N. 36° E. He reports that for the first 1,000 feet from the southwest end of the fence the greatest error in alinement was about 1 inch, and that practically there was no deformation in this stretch. In the next 125 feet going northeast there was found a deviation from this alinement of 4 inches to the southeast. In the next 50 feet the deviation in the same direction was 7 inches more. In the next 140 feet the deviation in the same direction was 3 feet 7 inches more. Then came the fault-trace with an abrupt displacement of the fence of 7 feet 5.1 inches. Northeast of the fault-trace the fence retained its line very well. In 100 feet it was out only 1 inch. Beyond this it enters the timber and its course is somewhat influenced by the larger trees, but maintains its line within a few inches. These measurements give a total horizontal displacement of 12 feet distrib-

PLATE 34

A. Fault-trace in redwood forest near Fort Ross. J. N. L.

B. Dislocation of fence near Fort Ross. J. N. L.

THE NORTHERN SAN ANDREAS FAULT: RUSSIAN RIVER TO POINT ARENA

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INTRODUCTION

The segment of the San Andreas fault, between the mouth of the Russian River and Point Arena, last broke at the time of the great San Francisco earthquake in 1906. It was part of a much longer rupture segment from near San Juan Bautista, south of San Francisco, to the vicinity of Cape Mendocino (about 430 km). Since then, this segment of the fault has been locked and essentially aseismic (Bolt and Miller, 1975; Prescott et al, 1981). Although this segment has not been studied as extensively as segments farther south, two references are invaluable to those wishing to become familiar with the fault zone in this area: Lawson (1908), and Brown and Wolfe (1972). U.S.G.S. 7.5' quadrangle maps covering this area are also listed at the end of the paper. Another very useful map is the Automobile Club Association of America's North Bay Counties map.

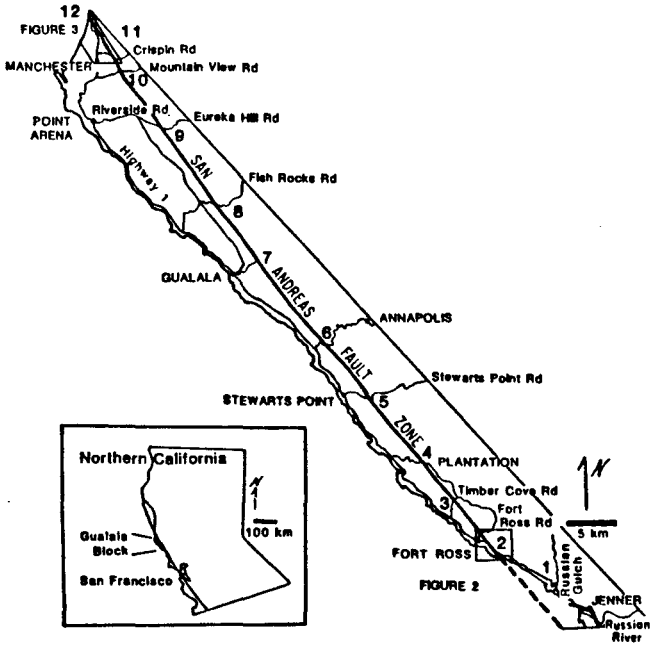

FIGURE 25 Map of the Gualala Block with Roads that Access the San Andreas Fault. Numbers refer to areas mentioned in text. Locations of figures 26 and 27 are indicated.

The region west of the San Andreas fault between Fort Ross and Point Arena is known as the Gualala block (FIG. 25). The San Andreas fault juxtaposes rocks of very different origin along most of its length, and in the area of the Gualala block, rocks of the Franciscan Complex on the east are faulted against a >10,000 m thick sequence of Upper Cretaceous through Tertiary sedimentary and minor volcanic rocks that contain no Franciscan-derived clasts. These rocks were studied by Wentworth (1967). Many interesting geologic problems are associated with the bedrock of the Gualala block, including paleomagnetic interpretations of several thousands of kilometers of displacement since Cretaceous time (Kanter and Debiche, 1985), the origin of the granitic clasts in the Gualala Formation (Wentworth, 1967; James et al, 1986), and the nature of the Gualala basement. This paper only summarizes the Quaternary history and geomorphology associated with the San Andreas fault in this region.

PALEOSEISMIC AND SLIP-RATE RESEARCH

Excavations in a small, late Holocene alluvial fan near Point Arena exposed evidence of five or six seismic events. Because the stratigraphic sequence consists primarily of very coarse fluvial gravel, and deposition of younger deposits clearly involved erosion of underlying units, a minimum number of earthquakes is recorded at this site. Radiocarbon dating of charcoal collected from a layer that has been faulted by all of the events indicates that the layer is less than about 2000 yr old, indicating a maximum average recurrence interval of about 400 yr. The most recent earthquake at this site prior to 1906 occurred after AD 1524 and probably after AD 1635. A buried channel was located on both sides of the fault; a small branch in the gravel that fills the channel yielded a radiocarbon age of 2350-2710 yr.b.p. The maximum offset of this channel is 64 ± 2 m, giving a maximum slip rate of 25.5 ± 2.5 mm/yr. At this rate, the fault would take a minimum of about 200 ± 20 yr to accumulate the five meters of slip that occurred here in 1906. If this segment of the fault is characterized by five-meter slip events, then a great earthquake may not occur here for at least another one hundred years. These data suggest that a long average recurrence interval (from about 200 to 400 yr) characterizes this segment of the fault, leading to the tentative conclusion that a repeat of the 1906 earthquake is not likely to occur within the next century. Results of further radiocarbon analyses will better determine the dates of the individual paleoearthquakes.

Several Pleistocene marine terrace risers have been offset across the San Andreas fault near Point Arena. Preliminary correlation and age estimates of these terraces suggest an average slip rate since the late Pleistocene of about 18-20 mm/yr.

The Pliocene Ohlson Ranch Formation is a shallow marine formation that caps flat, to gently rolling surfaces on ridge tops east of the San Andreas fault near and south of Annapolis (Higgins, 1960). As pointed out by Higgins, no Pliocene marine strata are found on the surfaces preserved on the coastal ridge of the Gualala block west of the San Andreas fault. The Pliocene sea must have had an inlet; deposits near Point Arena that carry mollusks tentatively identified as Pliocene (Peck, in Boyle, 1967) may represent the offset inlet of the Ohlson Ranch Formation sea. Foraminifera collected from strata in both areas allow, but do not prove, this correlation. Zircons collected from an ash in the Ohlson Ranch Formation have a fission track age of 3.3 ±.8 Ma (Naeser, personal communication, 1988). If the correlation and proposed offset (50 km) are correct, then the average slip rate across the San Andreas fault since the retreat of the Pliocene sea is at least 12-20 mm/yr.

These tentative slip rates, if correct, imply three important conclusions about this segment of the San Andreas fault: 1) the slip rate has remained fairly constant over the past several million years; 2) a significant part of the Pacific-North American plate motion must be accommodated on other structures in this region; and, 3) a repeat of the 1906 earthquake is unlikely during the next 100 years.

GEOMORPHOLOGY AND CULTURAL FEATURES

Geomorphic and cultural features associated with the San Andreas fault lie along Highway 1 between Jenner and Point Arena. Some of the features are accessible only through private or state lands, and so permission from the owners is required for entry. These features, from south to north, are keyed to the maps of figures 26 and 27 by numbers and letters.

1. Uplifted Pleistocene marine terraces are found along most of the California coastline, and the highway north of Jenner crosses such a terrace. However, just north of Russian Gulch, the highway climbs through a set of switchbacks well above the terrace surface. The next several miles of highway, known to local residents as the Jenner Grade, is spectacular because the cliffs drop precipitously, with no intervening marine terraces, into the ocean from a height of about 200 m. Part of the reason for this conspicuous lack of terraces is that right-lateral displacement along the San Andreas fault has offset the terraces and has juxtaposed an area of land that was inland at the time of terrace formation next to the modern shore. The fault lies under the ocean less than 2.5 km west of the highway here; northwestward up the coast, marine terraces lie west of the San Andreas fault where it intersects the coastline south of Fort Ross. Note the deformation of the terraces near the fault zone in this region.

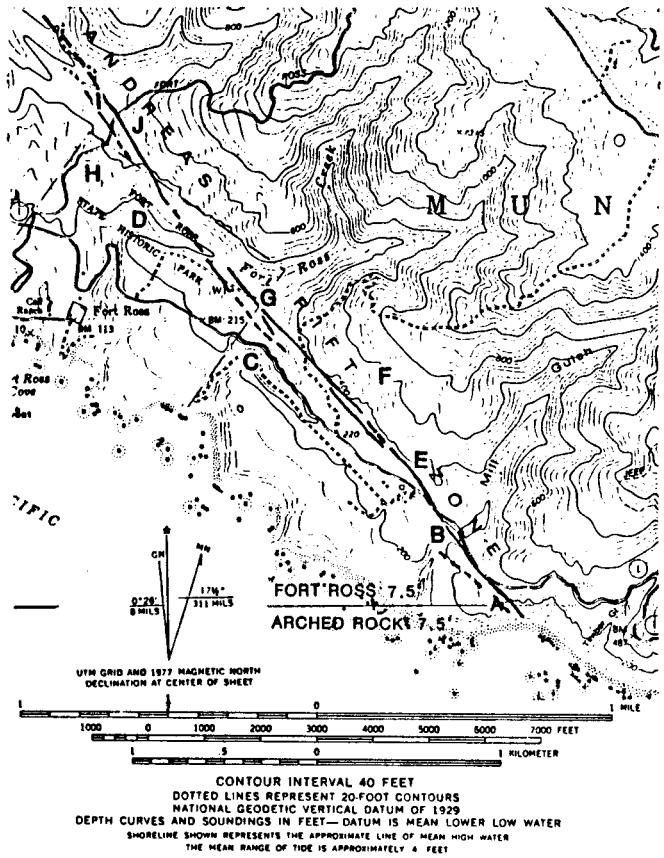

FIGURE 26 Topographic Map of the Fort Ross Area. Letters refer to features discussed in text.

2. The San Andreas fault intersects the coastline about 2.5 km southeast of Fort Ross (FIG. 26). Several small shutterridges (A) can be seen within a few tens of meters west of the highway as it descends from the Jenner Grade onto the terrace. Between here and the ranch houses north of Mill Gulch, the highway is immediately east of and adjacent to the fault zone; it crosses the fault within about 100 m of the ranch buildings and remains on the west side of the fault zone to a point about 10 km north of the town of Point Arena. Several drainages are beheaded or offset within a few tens of meters of the highway in this area (B, C, D). A small stream that was offset and ponded after the 1906 earthquake is a few meters east of the highway (E) (see Lawson, 1908, plate 37, p. 65, and map 3; this is the old Doda ranch referred to in his text). The offset here in 1906 was reported to be about 3.7 m; the stream is actually offset considerably more than this, so the 1906 offset was only the most recent movement to affect this channel. Within 200 m east of the highway in this area the fault traverses a large landslide (F); part of the toe of this slide has been offset nearly 2 km (H, FIG. 26).

A fence that was offset in 1906 and carefully surveyed (see p. 64 of the Lawson report) can still be seen (FIG. 26, G). Although many of the fenceposts

c fallen, the original offset is still very clear. A resurvey of this fence in 1987 suggests that less than 0.5 m of afterslip has occurred since the original survey in 1906. Approximately 25 m south of the fence, the old Russian road that led to Fort Ross (in the 1800s) was also offset in 1906, although because the road crosses the fault at such a low angle, the offset is more obscure. The low, fresh, northeast-facing scarp in this area is probably the result of movement in 1906. The offset fence and road are on state land behind a locked gate; contact the ranger at Fort Ross for access.

Turning east on Fort Ross Road will lead to the fault again in about 0.6 to 0.8 km (FIG. 26). The road traverses a large landslide deposit 0 to 600 m southwest of the fault (H); the source of this deposit is probably the landslide headscarp east of the fault mentioned above. A charcoal sample collected from the base of this deposit was older than the range of radiocarbon dating (i.e. older than 43,700 yr), indicating that the average slip rate of the fault over this time period is less than 39 mm/year. The fault is expressed especially well geomorphically to the northwest (I) and southeast (J) of the point where it crosses Fort Ross Road: there are several sag ponds, linear troughs and ridges, and small scarps. This is also state land, so contact the Fort Ross rangers for access.

3-10. Between Fort Ross and Point Arena the fault is up to several kilometers inland from the Coast Highway, and access is limited to the roads indicated on figure 25. Heavy vegetation along much of this section conceals fault features. Of the available fault crossings, the best expressions of the fault are where the roads to Plantation, Stewart's Point and Annapolis cross the fault zone (4,5,6).

11. About one-half km north of Manchester, turn east on Crispin Road (FIG. 27). A linear trough is evident where the fault crosses this road, and a modified sag pond lies a few hundred meters southeast of the road (K).

Well-developed fault geomorphology (sag ponds, scarps, and shutterridges) exists on the Skaramella ranch (FIG. 27) (this is private land, permission must be secured before visiting the area). In addition, a row of cypress trees that was offset in 1906 is still present less than 100 m northwest of the ranch house (L). An excavation site, where data documenting prehistoric earthquakes and the Holocene slip rate were collected, is about 500 m northwest of the ranch house (M).

12. The fault crosses Highway 1 again under the bridge across Alder Creek (FIG. 27). Within a few hundred meters southwest of Alder Creek, about 200 m northeast of the highway, is a series of sag ponds and scarps (N). The unnamed, paved side road leading northwest from the highway, about one-half km south of Alder Creek, (at mile marker 22.48), leads to the mouth of the creek. This is the site of the old bridge that was destroyed by fault rupture in 1906 (O) (see Lawson, p. 59 and plate 32). The bridge was later rebuilt and the cement abutments of this later structure still stand. In the stream bed within a few meters of the

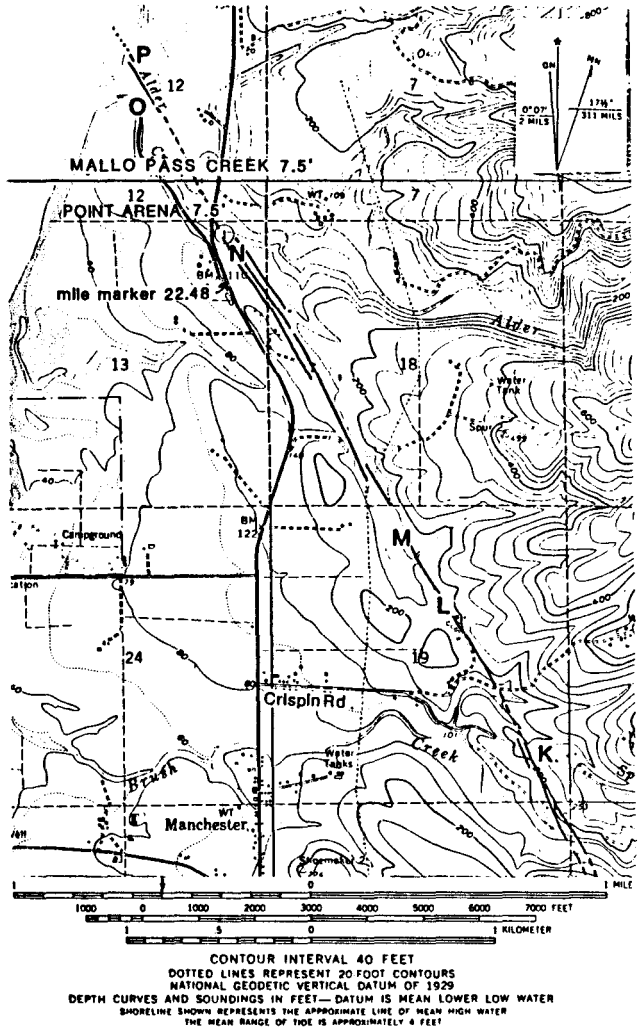

FIGURE 27 Topographic Map of the Point Arena Area. Letters refer to features discussed in text.

western bank, (a few tens of meters northwest of the bridge site), an exposure of fault gouge can be seen when the tide and stream flow are low. A sag pond is present between the stream valley and the modern sea cliff above the northern bank of the stream (P). The cliffs along the beach for several hundred meters north of the stream mouth give an idea of how wide and highly sheared the bedrock fault zone is, but the 1906 trace is obscured by slumping and other erosional processes. Franciscan bedrock is exposed *west* of the 1906 fault trace here, but whether this represents basement west of the fault or merely material caught up in the fault zone is not clear.

U.S.G.S. 7.5' QUADRANGLE MAPS

Arched Rock	Annapolis	Saunders Reef
Fort Ross	Stewart's Point	Point Arena
Plantation	Gualala	Mallo Pass Creek

Acknowledgments

This work was funded by U.S. Geological Survey contracts 14-08-0001-61370, 14-08-0001-61098, and 14-08-0001-22011, a Grant-in-Aid of Research from Sigma Xi, The Scientific Research Society, and the Geological Society of America. Field accommodations were generously provided by Mendocino College at its Point Arena Marine Institute.

OFFICIAL OEVE FIELDTRIP GUIDE

San Andreas Fault
Fort Ross, California

Thomas L. Holzer
U.S. Geological Survey
Menlo Park, California

Branch Chiefs' Retreat
Bodega Bay
September 1989

INTRODUCTION

The San Andreas fault is the locale of some of the most dazzling research in the Earth Sciences (Bakun and Lindh, 1985; Holzer and others, 1988; Prescott and Yu, 1986; Shedlock and others, 1988; Wesson and Nicholson, 1987). Some of this research may have been motivated by the devastating 1906 San Francisco earthquake, M=7.7, which produced effects that were almost as spectacular as this research. These effects included a 430-km-long surface rupture, which extended from San Juan Bautista to the vicinity of Cape Mendocino. Strike-slip offsets as great as 4.9 m were measured at Manchester near Point Arena. The commonly reported maximum dislocation of 6.1 m of a road near the head of Tomales Bay was considered by G.K. Gilbert to be affected by nontectonic lateral spreading and thus suspect (Lawson and others, 1908, p. 71). During our field inspection today in the Fort Ross Area (Fig. 1), we will visit two well preserved man-made features that were offset by the 1906 rupture and view classic examples of active fault geomorphology.

The Holocene history of earthquakes on the part of the San Andreas that ruptured in 1906 is poorly known. Excavations by Carol Prentice of BESG in a small, late Holocene alluvial fan near Point Arena, about 65 km northwest of Fort Ross, exposed evidence for a minimum of five earthquakes. A layer displaced by all of the events was dated with radiocarbon at 2,000 years, indicating a *maximum* average recurrence interval of 400 years. The most recent pre-1906 earthquake at this site occurred probably after 1635 A.D. A buried channel that was offset 64±2 m was dated at 2,350-2,710 years B.P. which gives a maximum slip rate of 25.5±2.5 mm/yr. On the basis of this rate, the fault would take a minimum of about 200±20 years to accumulate enough strain to repeat the release of the five meters of slip that occurred at Point Arena in 1906. Thus, any way you cut it, six adrenaline-crazed branch chiefs and one peripatetic office chief are unlikely to witness a major seismological event on this trip. As a consequence of this non-event, the road on which they will travel and the restaurant in which they will dine this evening are more apt to remain cliffside.

FIELDTRIP LOG

Beware of poison oak. To make this fieldtrip representative of actual geologic field work California-style, all stops will be agronomistically correct.

From Bodega Bay drive north about 16 km along the California Highway 1 to the Russian River south of the town of Jenner (Fig. 1). You are driving on an uplifted Pleistocene marine terrace with an age ranging from 84 to 120 ka. The San Andreas fault lies beneath the ocean floor about 2.5 km to the west of the highway. The fault enters the ocean north of Bodega Head, about 2 km west of Bodega Coast Inn. The fault trace near Bodega, however, is obscured by a large dune field, prompting our drive to the north.

After you cross the Russian River, be sure to stay on Highway 1. If you bear right on Highway 116, you will be on a champagne tasting trip for which this guidebook, but not its author, will prove useless. Drive north for about 6 km to the Russian Gulch where a series of switchbacks will carry you well above the terrace surface. You might wish to take note of the River's End restaurant on your left as you leave Jenner. Wolfgang and Sybille Gramatzki are

expecting you to join them for a dinner that will quickly make you forget the drive you are about to take.

This section of the highway, known to locals as the Jenner Grade, is spectacular because the cliffs drop precipitously 200 m with no intervening marine terrace into the Pacific Ocean. Part of the reason for this conspicuous lack of terraces is that right-lateral offset along the San Andreas fault has offset the terraces and has juxtaposed an area of land that was inland at the time of terrace formation next to the modern shore.

Proceed north for another 6 km to another switchback at Timber Gulch. The San Andreas fault intersects the coastline just to the west of us. Several small shutterridges can be seen within a few tens of meters west of the highway as it descends from the Jenner Grade onto the terrace. Between here and the ranch houses north of Mill Gulch, the highway is immediately east of and adjacent to the fault zone; it crosses the fault within about 100 m of the ranch buildings and remains on the west side of the fault zone to a point about 10 km north of Point Arena. Several drainages are beheaded or offset within a few tens of meters of the highway in this area. A small stream that was offset and pondered after the 1906 earthquake is a few meters east of the highway (Fig. 2); this is the old Doda ranch referred to in the Lawson report. The offset here in 1906 was reported to be about 3.7 m; the stream is actually offset considerably more than this, so the 1906 offset was only the most recent movement to affect the channel. We will not be stopping here unless time permits at the end of the trip. East of the highway in this area, the fault traverses a large landslide; part of the toe of this slide has been offset nearly 2 km and we will drive over it on the way to our second stop.

To get to **Stop 1** (Fig. 2), drive north for about 1.8 km from the old Doda ranch and turn right on a dirt road. The wooden gate should be unlocked. Proceed to the northeast for about 300 m where the road turns to the right. The fault is obscured in the trees to our left. Continue to the end of the dirt road. The wooden fence in front of you was offset in 1906 and carefully surveyed by E.S. Larsen following the earthquake (Fig. 3). The original 3.7-m offset is still very clear. A resurvey of this fence in 1987 by Carol Prentice suggests that afterslip since 1906 was less than 0.5 m. The low, fresh, northeast-facing scarp is probably the result of movement in 1906. Approximately 25 m south of the fence, the old Russian road that led to Fort Ross (in the 1800's) was also offset in 1906. The offset is more obscure than that of the fence because the road crosses the fault at a low angle.

To get to **Stop 2** (Fig. 2), return to Highway 1 and turn right. Proceed north for about 1.2 km to Fort Ross Road which is across from the entrance to Fort Ross State Park. The rebuilt fort on the left with its Russian Orthodox church was established by the Russians in 1812 as part of their fur trading empire, based principally on sea otters. It was abandoned in 1843 much to the delight of the Mexicans, Gringos, and Brits. Turning east on Fort Ross Road will lead to the fault again in about 0.6 and 0.8 km. We are driving on a large landslide deposit that is probably part of the landslide offset by the fault east of the old Doda ranch. A charcoal sample collected by Carol Prentice from the base of this deposit was older than the range of radiocarbon dating, 43,700 years, indicating that the average slip rate of the fault over this time period is less than 39 mm/yr. Two 1906 traces cross the road here. The westernmost active trace is distinguished by a gorgeous growth of poison oak in a large redwood stump on the north shoulder of the highway.

Park on the left just past this stump and cross the fence on the north side of the road. At this stop, we will inspect the well preserved examples of fault geomorphology including sag ponds, linear troughs, ridges, and small scarps. Right next to the paved road, be sure to note the abandoned wagon trail that was offset by the 1906 fault offset.

By now, our efforts to manage and conduct scientific research undoubtedly have earned us a dinner on the North American Plate. Wolfgang and Sybille await.

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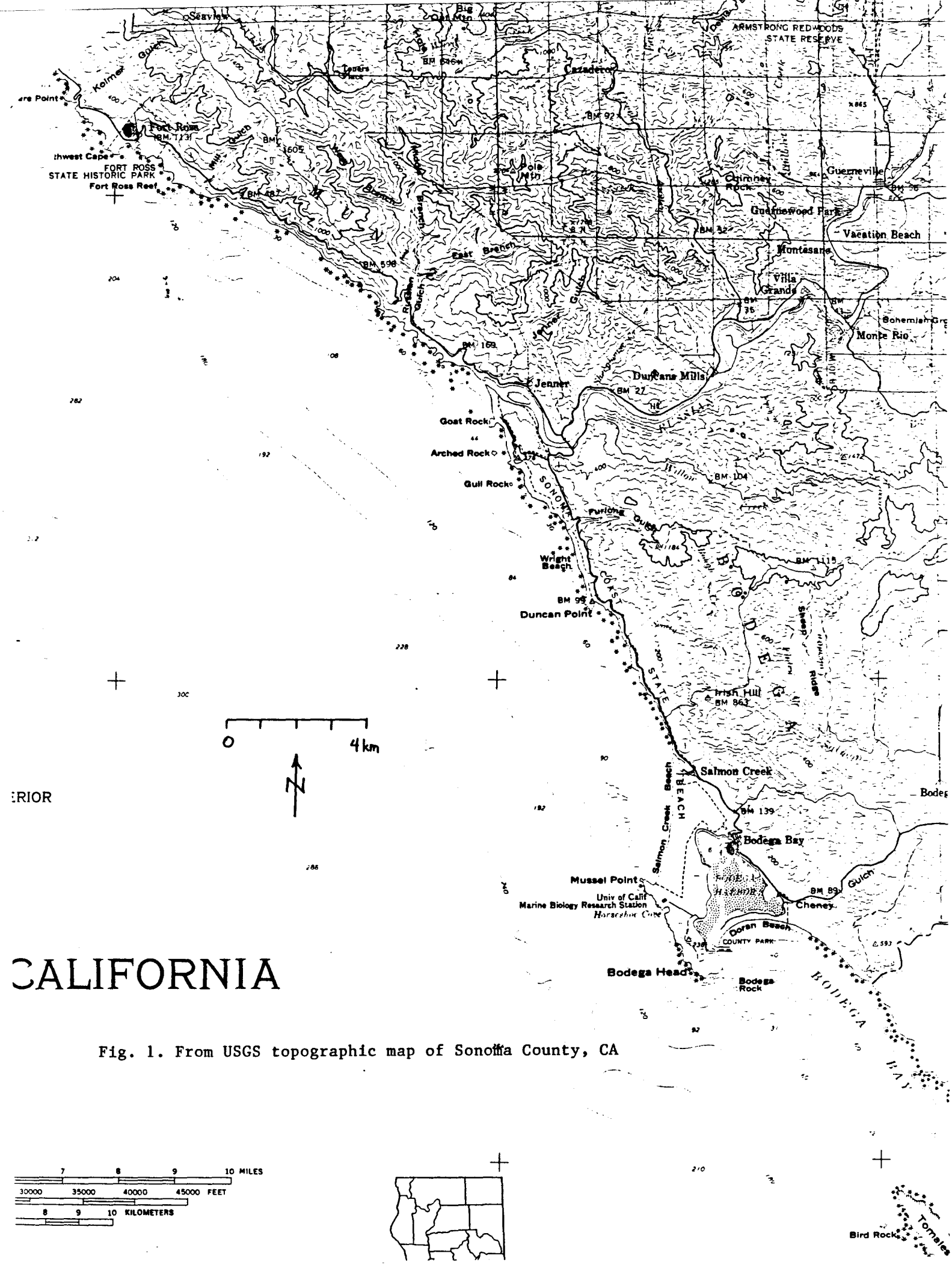


Fig. 1. From USGS topographic map of Sonoma County, CA

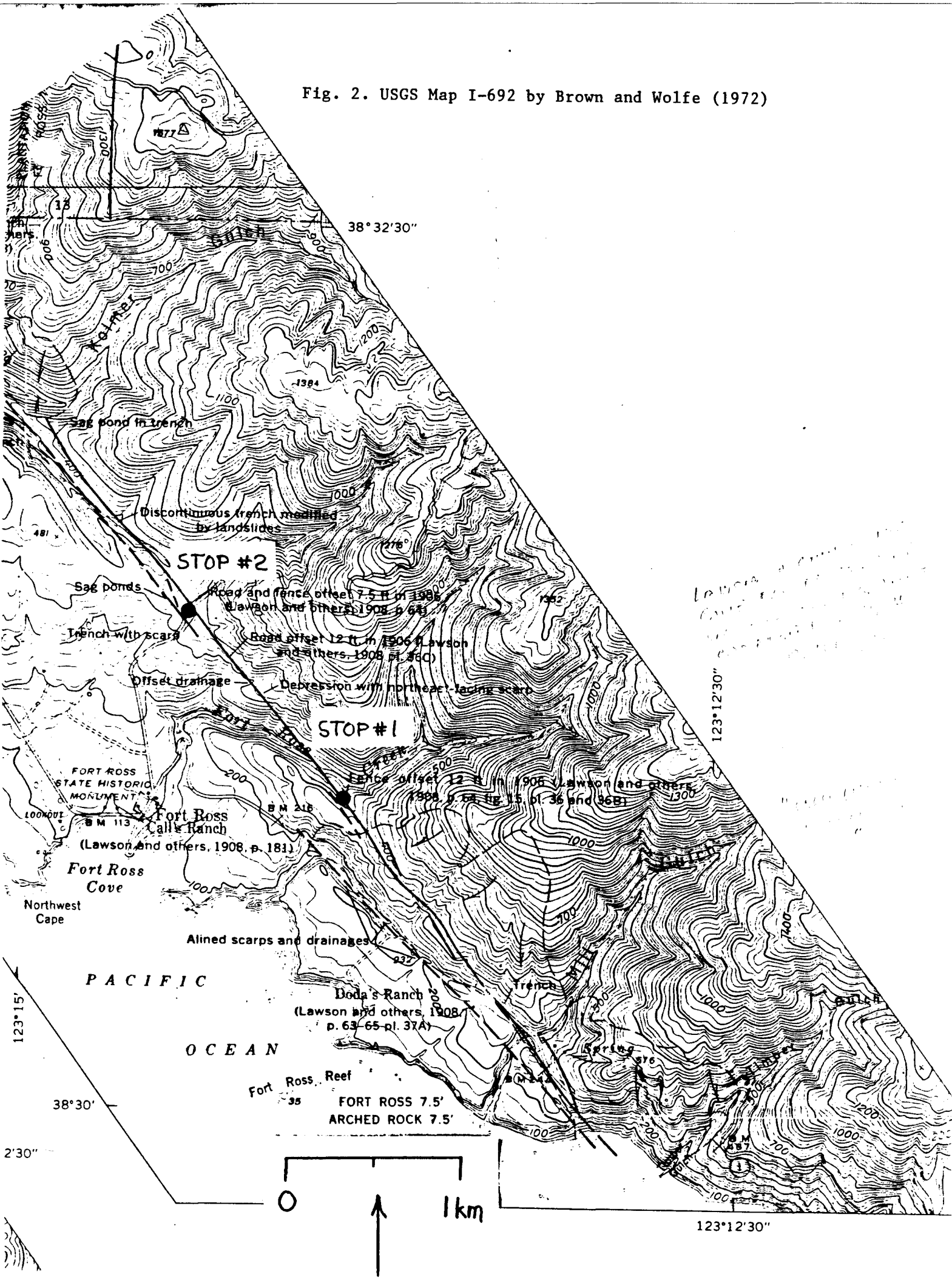
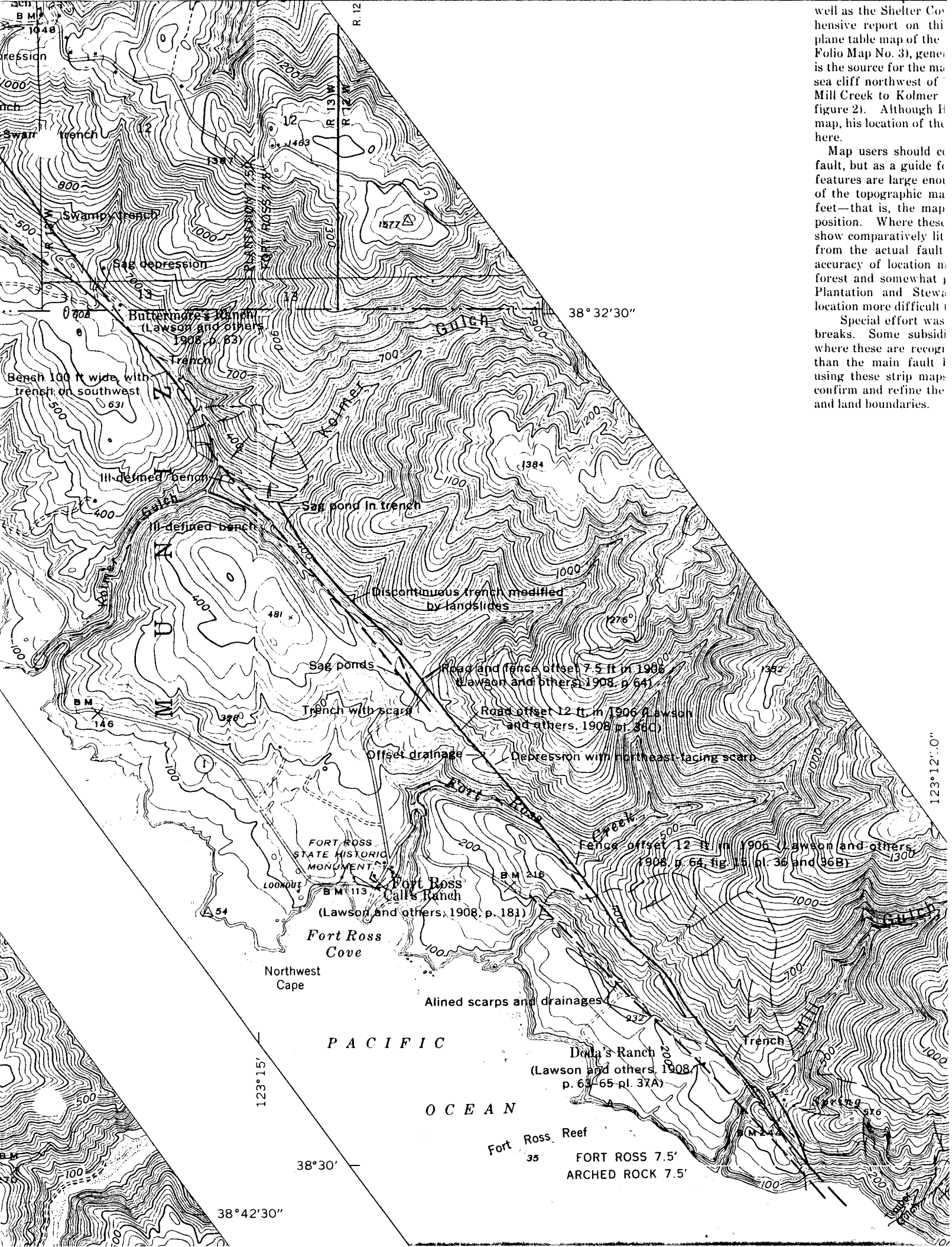


Fig. 2. USGS Map I-692 by Brown and Wolfe (1972)



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than the main fault
using these strip maps
confirm and refine the
and land boundaries.

United States Department of the Interior

GEOLOGICAL SURVEY

Branch of Engineering Seismology and Geology
345 Middlefield Road
Menlo Park, CA 94025
October 3, 1989
(415) 329-5613

William S. Walton, Jr.
California Department of Parks and Recreation
Fort Ross State Historic Park
19005 Coast Highway 1
Jenner, CA 95450

Dear Bill:

Thanks for photographs of the surface effects from the 1906 earthquake. They definitely confirm the saga of the split tree.

I also promised to write to you about the significance of the offset fence east of the fort to help any efforts to preserve it. The fence is the last remaining cultural feature that was offset by the 1906 rupture on the northern segment of the San Andreas fault. All other man-made features have been either repaired or destroyed. The offset fence on the Strain Ranch at Point Reyes is reconstructed. Thus, the fence is unique from this historical perspective. The fact that the fence was carefully surveyed after the earthquake to infer fault offset and ground deformation near the fault makes the fence scientifically significant. The old survey and preservation of the fence will provide an excellent opportunity to test the repeatability of ground displacements during earthquakes. In fact, the fence should be referenced to permanent bench marks that are not susceptible to fire in case the fence is accidentally destroyed.

Although there are other examples in the United States of features offset by faults, the 1906 rupture is special in several respects. It was the first thoroughly documented fault offset in the United States and as such demonstrated conclusively the relation between faults and earthquakes. It is the longest ground rupture, 430 kilometers, that has been observed in the continental United States. And it was produced by the largest instrumentally recorded earthquake in California history.

All of these observations indicate that you have a very special fence at Fort Ross and one that should be protected from accidental destruction. I strongly encourage any efforts in this regard by the Department of Parks and Recreation.

Yours truly,

Tom

Thomas L. Holzer
Branch Chief
Engineering Seismology and Geology