CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-151

Evaluation of Faults in the Mohawk Valley Area
Plumas and Sierra Counties, California

by

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INTRODUCTION

Jennings (1975) indicates that historic fault rupture may have occurred along two faults in the Mohawk Valley area during the 1875 earthquake (Figure 1). Therefore, faults in this area are being evaluated as part of a state-wide effort to identify recently active faults and zone those faults determined to be sufficiently active and well defined (see Hart, 1980).

This investigation is primarily directed at examining the evidence concerning recent (Holocene or historic) faulting in the Mohawk Valley area. No attempt was made to evaluate all of the faults mapped in the area. In the sections that follow, the little information available on Quaternary faulting in the area is described and analyzed.

This evaluation included a review of the available published and unpublished geologic literature and interpretation of available aerial photographs. Field reconnaissance was limited to the area near Clio, and took about one-half day.

REGIONAL GEOLOGY

The study area lies in the northern Sierra Nevada near the junction of three geomorphic provinces (the Sierra Nevada, Modoc Plateau, and Great Basin geomorphic provinces). The Sierra Nevada has been described as a tilted-block structure, bounded on the east by a major normal fault (west side up relatively) along which several thousand feet of displacement has occurred (Diller, 1886).

A review of the literature describing the geology of the region indicates that most geologic studies have been directed at understanding the evolution of the region as a whole and have largely addressed the formation and subsequent deformation of several Paleozoic units. Almost all of this regional mapping effort has been devoted to the area north of Clio and has been conducted under the guidance of Cordell Durrell.

According to Durrell (1966; 1967), Mohawk Valley is one of several northwest-trending valleys aligned along the Plumas Trench. Prior to the Pliocene, this trench was the site of a compressional regime dominated by reverse faulting. During Pliocene time, the tectonic stress field changed, and normal faulting dominated the area. Durrell (1959; 1966) indicates that this fault movement was recurrent during the Tertiary, and that there is evidence for several miles of left-lateral displacement along this zone of faults.

This generalized discussion is typical of the brevity used to describe the tectonic events in the area. Few workers have studied the more recent (Quaternary) deposits. Fewer still have mapped any faults that affect these deposits. Simply put, the recent tectonics of this area are little understood. If, as Durrell has suggested, the stress regime has radically changed in the last few million years, then the pattern of Holocene faulting (if Holocene faults exist) may not relate to the pattern of pre-Pliocene faulting, except locally.

SUMMARY OF AVAILABLE DATA

In the course of mapping the geology of the Downieville 30-minute quadrangle, Turner (1891; 1895-96; 1897) reported finding faulted Pleistocene lake deposits in Mohawk Valley. According to Turner's texts (which conflict with his map as will be explained later), faults offsetting these lake deposits were exposed in two places: (1) on the east side of the Middle Feather River opposite the Wash post office, and (2) on the south bank of the river about 1 mile upstream from the post office.

Turner (1895-96, p. 598) described the first locality as follows:

> "On the east bank of the river, the material of the 4,500 foot terrace [equivalent to about 4,440 feet on the map of the Clio 7.5-minute quadrangle] east of Wash post-office shows two small faults, and the fissures along these faults are now filled with sand, forming veritable little sand dikes."

These faults are not described in any more detail. However, Turner also observed that the lake deposits were essentially flat-lying except where disrupted or distorted by faulting. Note that Turner did not indicate whether the fissures he observed were new or old (that is, 1876 or pre-1876). The second locality was not described further by Turner. In addition to these two localities, he also reported that the lake beds were "...flexed, at one point dipping 22° to the southwest" at a third locality, just east of the springs at Sulphur Spring House.

All three of Turner's works indicate that fissures formed in the vicinity of the fault during an earthquake which occurred about 1876 (Bonilla, 1967, and Toppozada and others, 1981, indicate this earthquake actually occurred in 1875). One of these fissures was located about 1 mile east of the first of Turner's localities described above (Turner 1896-97; 1897). Turner's (1891) paper indicates these fissures were located only about 1/4 mile east of his first locality. According to Turner, in 1889 warm, moist air still issued from this fissure, said to originally have been about 2 feet wide. Two hot springs reportedly were located just east of this fissure.

Turner believed that the fault through the Mohawk Valley area was a northern extension of the Sierra Nevada frontal fault system. He devoted a considerable amount of his written works to discussing the similarities between the general geomorphology of the area with that found near Mono Lake. Based largely on these ideas and the faulted lake deposits, he concluded that the faults traversing the area were probably active during fairly recent times.

A detailed examination of Turner's descriptions and geologic map reveals several important facts. First, the northwesterly trending fault depicted by Turner in Mohawk Valley does not cross the Middle Feather River; thus, it does not coincide with the faults observed at two localities he described. Turner's map clearly shows the fault as passing southwest of the Wash post office, and not east of the post office as indicated in his description of his first fissure locality. Neither does the fault coincide with the fissures reported at Sulphur Springs House and east of his first fissure locality. Considering Turner's notion that the fault in Mohawk Valley was an extension of the Sierra Nevada frontal fault, it makes sense that he would depict the fault as being southwest of the axis of Mohawk Valley. By doing so, Mohawk Valley was an explainable feature, a half-graben in the Basin and Range province. The faults Turner observed in the field were cited as probably related to this larger, master fault.

Second, Turner did not specifically indicate that the fissures observed in 1876 were fault ruptures. He also failed to indicate that <u>any</u> faults coincided with the fissures observed in 1876. This did not prevent other geologists from citing the 1876 (1875) fissures as evidence of historic surface fault rupture. For example, Gianella (1957) quoted Turner's description of his (Turner's) first locality following it with the description of the fissures Turner reported as located about a mile east. To Turner's description, Gianella added:

> "The easternmost fissure was 2 feet wide and followed an old fault along which sulphur springs issued. The new fissure was probably due to recurrent movement on the old fault."

Bonilla (1967, p. 9) expressed a different opinion on the possibility that historic fault rupture had occurred in Mohawk Valley:

> "Whether surface faulting or landsliding occurred during (the 1875) earthquake is uncertain.... E.H. Pampeyan and I

examined a locality which is probably the one described by Turner... [as 1 mile east of Turner's first locality] on the south bank of the Middle Fork of the Feather River. The rock there has numerous short fissures as much as 8 inches wide generally trending upslope; the hummocky ground uphill from the fissures is bounded by a steep arcuate scarp that is probably the head of a landslide. Thus the rock containing the fissures may be in the toe area of a landslide and the fissures produced in 1875 may have been of landslide origin rather than of tectonic origin."

Durrell (1959, p. 181-183) primarily consists of a summary of the stratigraphy of the Blairsden 15-minute quadrangle. Based on stratigraphic relationships, Durrell states that recurrent fault movement occurred during the Tertiary, but that post-faulting planation resulted in a surface of unconformity in which no significant relief can be detected (suggesting no further fault movement has occurred). Of the former Mohawk Lake, Durrell states that "The surface of the lake was between 5,000 and 5,050 feet. The shore line can be followed nearly continuously about the basin, and has been neither tilted nor faulted." Durrell (1959) contains maps of only small isolated areas north of Clio; these published maps do not appear pertinent to this evaluation.

Ford and Swanson (1961) compiled a geologic map of the Mohawk Valley area. Their map shows only two symbols for faults: (1) a solid line for "definite faults" and (2) a dashed line for "inferred faults" (note that in the area shown on Figure 2 of this report, Ford and Swanson only show inferred faults). They do not distinguish between faults which are concealed beneath any particular geologic unit and faults that cut a given unit. Therefore, their map is of limited value. Ford and Swanson's discussion of the geology of the area appears largely to be a summary of Durrell (1959), supplemented by some additional opinions which may be their own or may have been obtained from Durrell as personal communication [except for the list of references, Ford and Swanson lacks any indication of the origin of specific data]. They state that the Mohawk Valley fault is obscured by late Pleistocene morainal deposits in the area evaluated herein. They do not discuss the relationship between other faults they map and stratigraphic units. They describe the northeastern side of the valley as being bounded by a zone of faults along which an indeterminate amount of displacement has occurred. Furthermore, they state "An earthquake occurred along this east side fault zone in 1876. It was reported that during a shock a fissure two feet wide opened up southeast of Clio and that warm, moist, sulfurous air was expelled" (Ford and Swanson, 1961, p. 25).

Based on Turner (1897), Gianella (1957), and Bonilla (1967), Jennings (1975) concluded that fault rupture may have occurred in the Mohawk Valley area in 1875. On his map, Jennings depicted two northwesterly trending faults as possibly being the site of historic fault rupture, based primarily on Turner's description of the location of the fissures. However, the actual faults shown by Jennings (1975) were derived from Ford and Swanson (1961).

Also in Jenning's files are several unpublished maps of the area by Durrell (1972; 1976). The 1976 maps are marked as "confidential." Neither of these sets of maps indicates that any faults cut any Quaternary units. This contrasts with Turner (1891; 1895-96; 1897), as already noted, who reported finding faulted lake deposits in Mohawk Valley. Turner and Durrell also differ on the age and extent of the Mohawk Lake Beds. Based on some lithologic differences he observed within these deposits, as well as some local angular unconformities, Turner believed that the valley was flooded during two different time periods, once during the Mio-Pliocene and once during the Pleistocene. He clearly indicated that the faults he saw at his first fissure locality cut the younger (Pleistocene) lake deposits. However, Durrell's limited investigations led him to conclude that there had been only one lake in Mohawk Valley. He suggested that Turner's older lake deposits predated the formation of the valley and were actually part of the Bonta Formation (upper Miocene in age). To the younger lake deposits, Durrell applied the name "Mohawk Lake Beds" (Durrell, 1967). However, despite these differences of opinion, Durrell (1972) shows the deposits at elevations of about 4,440 as Mohawk Lake Beds. Thus, if the deposits of the terrace identified by Turner are truly faulted, then the faulting must be post-Mohawk Lake Beds.

The only estimate of displacement along the Mohawk Valley fault zone was made by Durrell. Durrell suggested that two fossil localities in the Bonta Formation (one located in Mohawk Valley and one located near Gold Lake, about six miles southwest of Clio) were equivalent. Based on this assumption, noting the two sites differed in elevation by 2000 feet, concluding they must once have been at the same elevation, and assuming that the Mohawk Lake Beds were 2000 feet thick, Durrell inferred displacement on the Mohawk Valley fault could amount to 4000 feet or more (Durrell, 1967, p. 43-44). However, he states that none of the moraines appear faulted.

> "There is no evidence that the shoreline of Mohawk Lake has been either tilted or offset by faulting. One may conclude that this segment of the Sierran Front has not been active for some time. There are small faults in the Mohawk Lake Beds, visable (sic) in the road cuts along highway 70 east of Blairsden, but they could have been the result of compaction of the soft sediment rather than a deep seated disturbance" (Durrell, 1967, p. 54).

New technology which permits the dating of various units has been developed in recent years. As a result, ash deposits present in the Mohawk Lake Beds have been dated. These dates cast doubt on some of the interpretations and conclusions of Durrell and Turner. Mathieson (1981) summarized the evidence for the existence of Mohawk Lake during two different time periods. The older of two lakes began filling at least 450 kA BP as a result of the damming of the valley by flows of the Warner Basalt (upper Pliocene). The 450 kA date is based on an ash deposit which has been correlated by trace element analysis with an ash found in the type section of the Merced Formation. This lake remained until approximately 120-140 kA based on the relationships of the lake deposits to several pre-Sangamon lateral moraines. This older Mohawk Lake flooded the valley to an elevation of 5,050 feet, and reached depths of 400 to 800 feet in Mohawk Valley and 10 to 250 feet in Humbug Valley. The beds near Sulphur Spring House, earlier cited as dipping 22° SW, are deposits of this early lake. Mathieson attributes the 22° dip to "Holocene faulting" without discussing his reasons for attributing the dip to faulting, let alone a Holocene fault (p. 214-221).

Mathieson also presents evidence for a second lake, which apparently originated as a result of two massive landslides which dammed the Mohawk Valley. The water level in this second lake reached an elevation of about 4600 feet. Although he lacked information concerning just when this second lake originated, he inferred that the lake was drained prior to the formation of the alluvial fan of Frazier Creek since these fan deposits overlie the younger lake deposits. He assummed that this second lake originated during Sangamon Interglacial time and, based largely on this assumption, inferred that Frazier Creek fan formed sometime about 26 to 62 kA (Matheison, 1981, p. 219-224). Thus, the younger lake deposits are inferred to be latest Pleistocene in age.

Since the study of the Mohawk Lakes was peripheral to Mathieson's thesis, he did not map the lake deposits in detail. Thus, one cannot establish solely from the literature whether the faults Turner observed at localities (1) and (2) cut older or younger lake deposits. Turner describes them as cutting younger lake deposits, however his older lake deposits apparently are really part of the Bonta Formation. Based on a combination of Turner's (1897) data and that of Mathieson (1981), it appears certain that some fault movement has occurred in the area during late Pleistocene time. However, based on Durrell's limited observations, it appears that slip along this apparent fault has not exceeded a few tens of feet.

More recently, Alt and others (1977, section 3, p. 40-42) identified a "linear scarp" which "...appears to be a fault scarp and is probably related to the 1876 earthquake described by Turner(1898)." Alt and others indicate they based their conclusions on Jennings (1975) and that they did no field work in the Mohawk Valley area. Subsequently, the U.S. Bureau of Reclamation located this feature and attempted to obtain permission to trench the scarp. However, they were denied access to the property across which the scarp runs (Fred Hawkins, oral communication, December 1983).

INTERPRETATION OF AERIAL PHOTOGRAPHS

U.S. Department of Agriculture (1972) aerial photographs were interpreted using an Old Delft stereoscope in order to detect features indicative of recent fault rupture. Unfortunately, these photographs do not cover the area north of Clio (Turner's second reported fault locality).

No features indicative of recent fault rupture were noted along the fault shown by Turner (1897) except possibly near Mohawk Valley Ranch (Section 6, T. 21 N., R. 13 E.) where tonal lineaments were evident in dissected terrain.

These lineaments are permissive, but certainly not conclusive, of recent faulting. However, in light of the difference between Turner's map and text (described in detail in the preceeding section of this FER), a strong correlation between the aerial photos and Turner's map should not be expected.

More significantly, a northeast-facing scarp is evident in the NW/4 of Section 31, T. 22 N., R. 13 E. This scarp, which was originally identified by Alt and others (1977), partly coincides with a tonal lineament which can be traced northwestward from the scarp (on trend). Immediately northwest of and on trend with these features is Sulphur Creek. This investigator believes that, if a recently active fault is present in the valley, then such a fault is most likely to coincide with these features, especially given Turner's descriptions of a fault exposed in the bank of the Middle Feather River. However, it should also be noted that Durrell (1972) indicates that the contact between the Mohawk Lake Beds and Holocene alluvium coincides with this feature.

RESULTS OF FIELD RECONNAISSANCE

On October 20, 1983, I attempted to observe the faults reported by Turner (1897) along the east bank of the Feather River opposite the site of the Wash post office. Both banks along the river and along Sulphur Creek are covered by brush; no exposures were evident. No attempt was made to create any exposures due to the density of the brush, the lack of time available for the reconnaissance, the lack of data concerning the precise location of the exposures observed by Turner, and the fact that this stretch of the Middle Feather River is now a National Wild and Scenic River.

As identified on the aerial photographs interpreted (see previous section), a northeast facing scarp, locally 1 meter high, was evident in Section 31, adjacent to State Highway 89. This scarp trends N 30° W, and commonly slopes 35 to 65 degrees eastward. The area east of the scarp appears to be essentially a level plain. Based on limited exposures just east of the scarp, the area to the east is underlain by reasonably well-sorted sands and silts; no gravel lenses were observed east of the escarpment. Neither the soil nor the sands and silts of this alluvial unit appeared reddened, suggesting they are quite young. West of the scarp, the surface is also fairly level to slightly rolling. However, unlike the area east of the scarp, to the west fist-size cobbles commonly litter the surface. Based on the topography and slightly reddened soil, this western surface may be latest Pleistocene in age. The apparent differences in near-surface strata are reflected in the vegetation. West of the scarp, bunch grasses are common; east of the scarp, the vegetation primarily consists of clover and low grasses. Undoubtedly it is these differences in vegetation which produced the tonal lineament observed on the aerial photographs interpreted.

The scarp, although well defined and only slightly dissected, is only about 600 meters long. However, based on its steepness and linearity, it is clearly a Holocene feature and suggests a Holocene fault may be present. North of State Highway 89, the scarp is not a well-defined feature. The vegetation contrast north of the highway is also not as apparent. No evidence was observed in the field to suggest that the scarp and/or vegetation contrasts continue southeastward of that indicated on Figure 2.

SEISMICITY

As indicated earlier, Turner (1897) reported that a major earthquake occurred in the Mohawk Valley area about 1876. Bonilla (1967) indicates that this earthquake occurred in 1875. However, based on newspaper reports, Toppozada and others (1981) concluded that the 1875 event actually was centered in Honey Lake Valley rather than Mohawk Valley.

Despite this discrepancy, it is fairly clear that the study area is seismically active. Toppozada and others (1981) and Real and others (1978) have documented at least 13 earthquakes larger than M 5.0 that appear to have occurred within 50 km of the faults studied (Table 1) and some may be associated with a NW-SE trending fault in or adjacent to Mohawk Valley. In recent years, more instruments have yielded more precise information concerning smaller earthquake events. For example, summary maps of earthquakes larger than M 1.5 for 1980, 1981, and part of 1982 all show a fairly narrow, northwest-trending zone of epicenters through the study area (Figure 3). During 1980 and 1981, this zone extended from the northern tip of Lake Tahoe to the vicinity of Lake Almanor (Cockerham, 1982). The 1982 data appears to show a bit wider zone that extends farther northwestward to the Mount Shasta area (Cockerham, 1983).

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TABLE 1. Summary of seismic events larger than M 5.0 having epicenters within 50 km of Mohawk Valley. Magnitudes and locations of pre-1900 events are estimated based on newspaper accounts (Toppozada and others, 1981). Post-1900 events are based on seismograph records (Real and others, 1978). These source documents do not indicate quality of data.

DATE	MAGNITUDE	LATITUDE	LONGITUDE
Mar 25, 1855	5.5	39.5	120.3
Sep 03, 1857	6.0	39.3	120.0
May 30, 1868	5.8	39.3	119.7
Apr 29, 1888	5.9	39.7	120.7
Feb 18, 1914	5.0	39.500	119.800
Apr 24, 1914	6.4	39.500	119.800
Mar 30, 1943	5.3	39.430	120.400
Dec 29, 1948	6.0	39.550	120.080
May 09, 1952	5.1	39.420	119.780
Sep 26, 1953	5.3	39.530	119.980
Apr 01, 1959	5.6	39.720	120.200
Sep 12, 1966	6.0	39.420	120.150
Sep 12, 1966	5.3	39.420	120.150

CONCLUSIONS

As indicated earlier in this FER, Turner (1891; 1896-97; 1897) reported that fissures formed in three locations in the Mohawk Valley area during an earthquake which occurred about 1875. However, Turner apparently did not observe these fissures until several years after the earthquake. Turner (1897) depicted only one fault on his map, but none of the fissure localities he described are along the fault he depicted. Indeed, even the localities of the features he describes as being faults clearly do not lie along the fault he depicted. This suggests that Turner's map presents an idealized and highly generalized version of the geology of the area, and that his map should not be used to establish a Special Studies Zone.

Subsequently, several workers have concluded that fault rupture occurred in Mohawk Valley in 1875 or 1876 (Gianella, 1957; Jennings, 1975; Ford and Swanson, 1961; Alt and others, 1977). However, none of these workers presents any conclusive evidence that fault rupture actually occurred during that event.

Other attempts to find active faults in the area have been unsuccessful. Bonilla (1967) dismissed one of Turner's fissure localities as probably due to landslide movement. Durrell (1959) concluded there was no evidence that the shoreline of Mohawk Lake (which would be crossed by any of the postulated faults) has been tilted or offset by faulting. Subsequent efforts by the U.S. Bureau of Reclamation and CDMG (this investigation) to determine the origin of this scarp have proven unsuccessful.

Detailed geologic maps of the area — particulary maps which show the relationship between the deposits of the two Mohawk Lakes and any faults — apparently are non-existent. Due to the lack of such maps and the limited funds and manpower available, this investigator relied heavily upon the interpretation of aerial photographs. Based on this air photo interpretation and the working hypothesis that any major, recently active fault should be evident from a distinct set of geomorphic features common to such faults, a limited field reconnaissance was performed. Only one feature was found which might reasonably owe its origin to recent fault rupture along such a fault. However, this feature, a well-defined scarp appears to separate two different Quaternary units and may not be tectonic in origin based on Durrell (1972). In addition, the shortness of the scarp suggests that it probably has not been produced by movement along a major, recently active fault. Diagnostic exposures are lacking along this feature. As a point of information, it should be noted that this scarp does not coincide with any of Turner's fissure localities.

Based on all of this information, it does not appear that a fault which is sufficiently active and well-defined has yet been identified in the Mohawk Valley area. The available seismic information strongly suggests that an active fault may be present in or very near the area studied herein. However, since no features suggestive of a major (that is, a fault having a fairly high rate of slip) recently active fault were identified in the area studied, it is still unclear whether an active fault exists at or near the surface in this region.

RECOMMENDATIONS

Based on the information summarized above, no faults in the Mohawk Valley area should be zoned at this time. Should new evidence concerning the origin of the seismic events become available, a re-evaluation of faults in this area may prove warranted.

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I have reviewed this report and aerial photos of the area and concur with the recommendations.

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December 28, 1983

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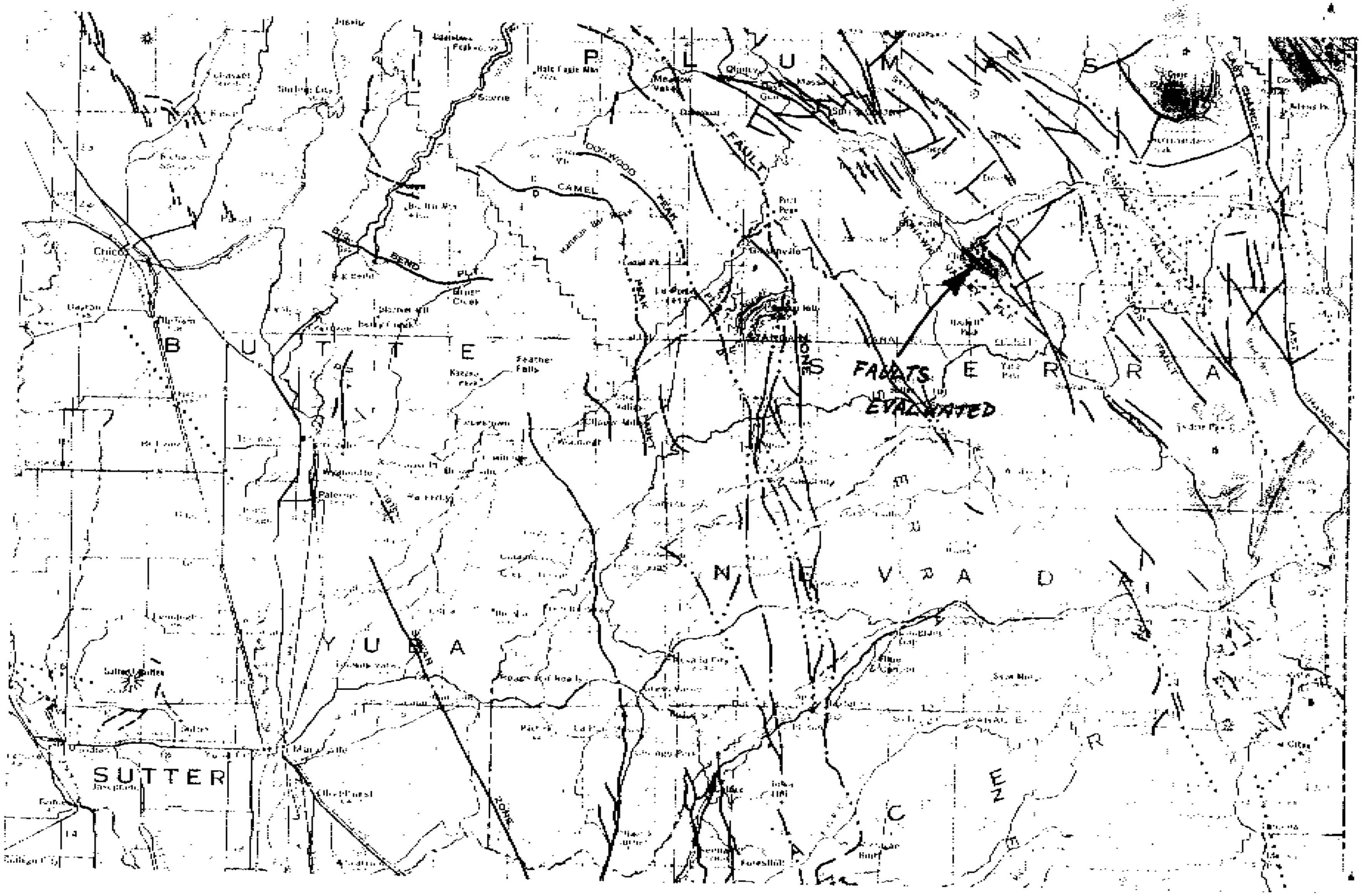
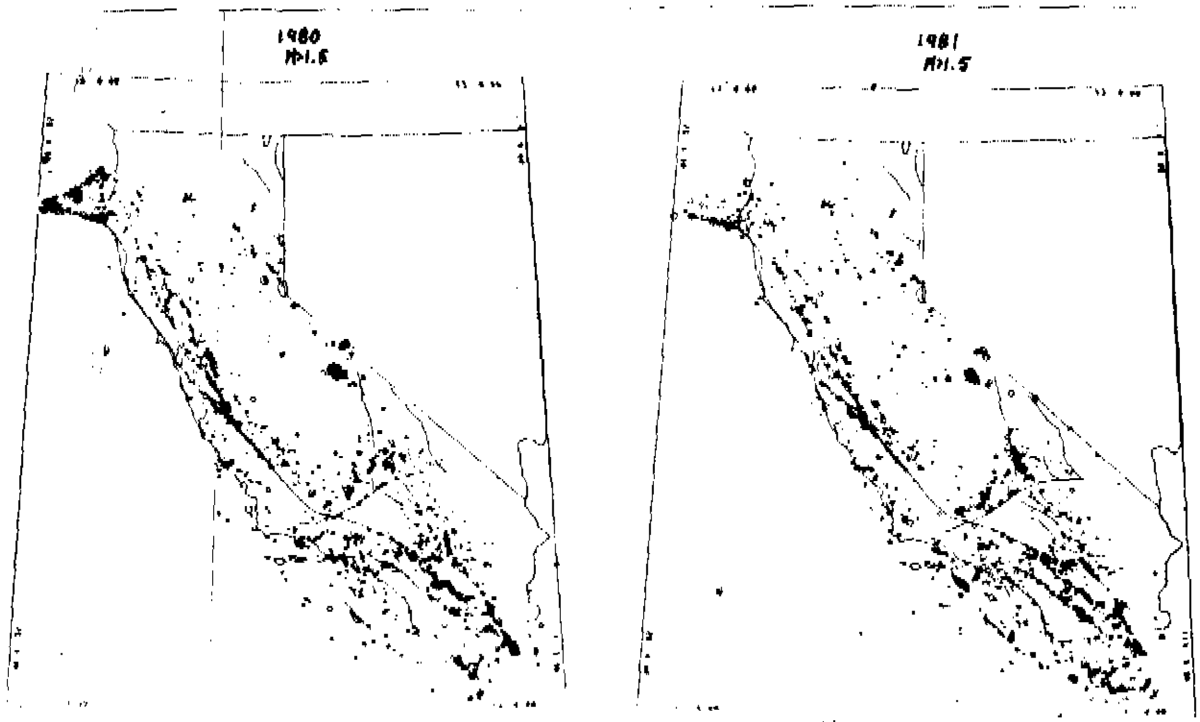
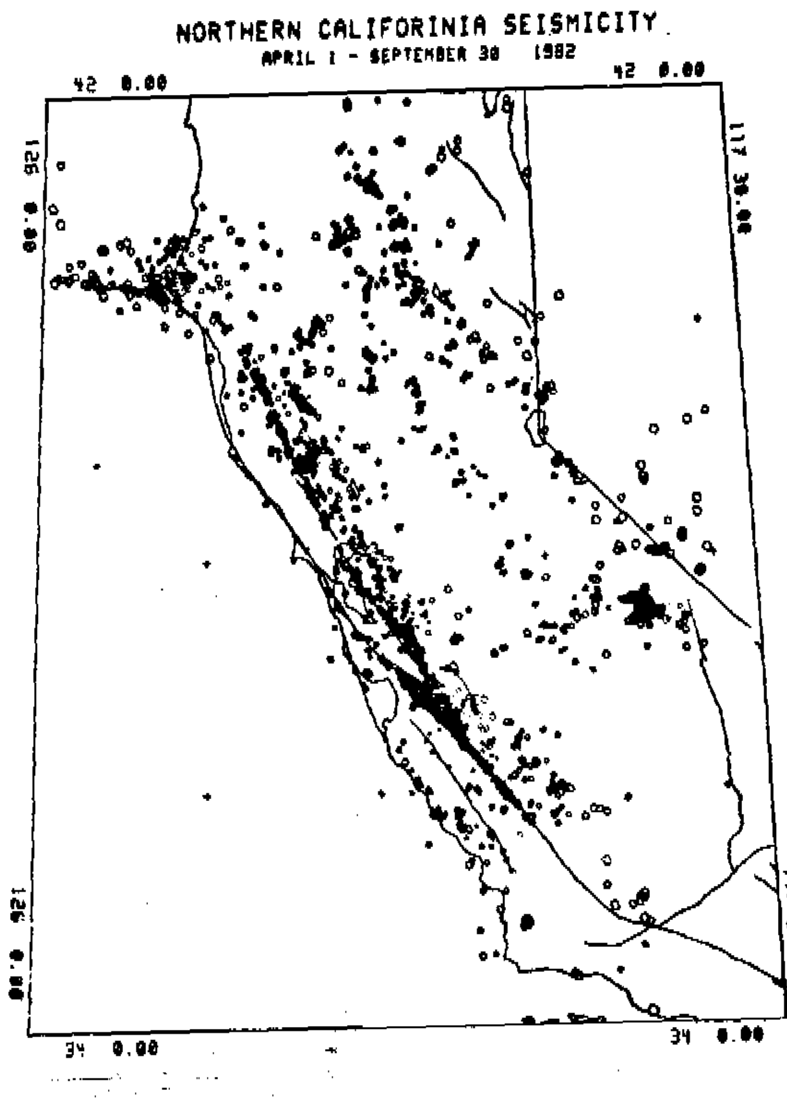


FER-151. Figure 1. Location of faults evaluated (from Jennings, 1975).





FER-151. Figure 3. Summary maps of epicenters in California for the years 1980, 1981, and part of 1982. These maps are reproduced from Cockerham (1982; 1983). The figures in these source documents lack any legends.