CALIFORNIA DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

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FAULT EVALUATION REPORT FER-225
SAN ANDREAS FAULT AND RIDGETOP-SPREADING FISSURES ASSOCIATED WITH THE OCTOBER 17, 1989 LOMA PRIETA EARTHQUAKE
SANTA CLARA AND SANTA CRUZ COUNTIES, CALIFORNIA

by

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April 2, 1991

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INTRODUCTION

The M_s 7.1 Loma Prieta earthquake (37°02.33'N; 121°52.76'W) occurred in the Santa Cruz Mountains on October 17, 1989. Investigations by DMG and the U.S. Geological Survey indicated that significant primary surface fault rupture did not occur along the San Andreas fault (Hart and others, 1990; USGS, 1990; Lisowski and others, 1990). However, significant surface deformation in the form of ridgetop fissures and fractures ("off-fault surface fractures" as termed by Ponti, 1990) were concentrated in an approximately 8km by 2km zone in the Summit Road/Skyland Ridge area of the Santa Cruz Mountains (Figure 1). Although many of these features formed within Special Studies Zones of the Los Gatos and Laurel quadrangles, several formed outside the SSZs.

Potentially active faults in the Summit Road/Skyland Ridge study area of northern Santa Cruz and southern Santa Clara counties that are evaluated in this Fault Evaluation Report (FER) include traces of the San Andreas and Butano faults (Figure 1). Both the San Andreas fault and selected traces of the Butano fault were zoned for Special Studies in 1976 in the Los Gatos and Laurel 7.5 minute quadrangles (CDMG, 1976a and 1976b; Figures 2a and 2b). Also, the many ridgetop-spreading fissures formed during the Loma Prieta earthquake and associated geomorphic evidence of prior ridgetop spreading are evaluated.

Faults and ridgetop-spreading features in the Summit Road/Skyland Ridge study area are evaluated as part of a statewide effort to evaluate faults for recency of activity. Those faults determined to be sufficiently active (Holocene) and well-defined are zoned by the State Geologist as directed by the Alquist-Priolo Special Studies Zones Act of 1972 (Hart, 1990).

SUMMARY OF AVAILABLE DATA

The Summit Road/Skyland Ridge study area is located in the Coast Ranges geomorphic province. The study area is characterized by right-lateral strike-slip faulting of the San Andreas fault system. A significant compressional component of offset has resulted in relatively recent uplift of the Santa Cruz Mountains.

Topography in the study area is typical of the Santa Cruz Mountains and consists of moderately to extremely rugged relief. Elevations in the study area range from 205 meters to 640 meters and most slopes are covered by dense vegetation and thick forest cover. Development in the study area is moderate, principally consisting of single family homes and two elementary schools.

The San Andreas fault has juxtaposed vastly different basement rocks. Cretaceous and Cenozoic sedimentary and volcanic rocks northeast of the fault overlie basement rocks of the Franciscan Complex. Southeast of the fault Salinian block crystalline basement rocks are overlain by Cenozoic sedimentary rocks (Dibblee and Brabb, 1978; Brabb and others, in press; Clark and others, 1989). Much of the southwestern side of the San Andreas fault consists of relatively weak marine sedimentary rocks that have been recently uplifted, resulting in rapid downcutting and rugged relief. This vigorous erosion through weak bedrock units has resulted in massive and pervasive landslide complexes and landslide deposits. Significant Quaternary deposits in the study area are limited to landslide deposits, isolated terrace deposits, and locally thick colluvial deposits (Dibblee and Brabb, 1978; Clark and others, 1989; Brabb and others, in press).

Aerial photographic interpretation by this writer of faults and ridgetop-spreading features in the Summit Road/Skyland Ridge study area was accomplished using aerial photographs from U.S. Soil Conservation Service (CIV, 1939) and U.S. Geological Survey (WRD, 1966; GSLPEQ, 1989). The main emphasis of aerial photographic interpretation in this FER is to document geomorphic evidence of previous ridgetop-spreading features. Previously mapped traces of the San Andreas fault were photo-checked only, rather than complete an independent photo interpretation. Interpretation of fault-related geomorphic features in the study area is extremely difficult due to the dense forest canopy that covers and obscures most traces of the San Andreas fault. Further complicating the interpretation are pervasive, massive landslide complexes along much of the San Andreas fault.

Three days were spent in the field by this writer and other DMG staff (E. Hart, C. Wills, J. Treiman) in October 1989 in search of fault rupture following the October 17, 1989 Loma Prieta. Nine days were spent in the Skyland Ridge area by this writer in November 1989 in order to map landslides associated with the Loma Prieta earthquake (Treiman mapped for about 2 weeks in this area) (Spittler and Harp, 1990). Two days were spent in the Summit Road/Skyland Ridge area in January 1990 by Bryant and Hart. Selected geomorphic features were field checked and subtle features not observable on the aerial photographs were mapped. Results of aerial photographic interpretation and field observations by this writer are summarized on Figures 2a, 2b, 3a, and 3b.

SAN ANDREAS FAULT

Literature Review

The San Andreas fault system is a major right-lateral strike-slip fault that forms the boundary between the Pacific and North American plates. The average rate of lateral movement between these plates is about 48 mm/yr (DeMets and others, 1987). Minster and Jordan (1987) reported that movement along the San Andreas fault only accounts for about 13 mm/yr in the Santa Cruz Mountains due to distribution of movement along other faults of the San Andreas fault system. A significant component of compressional displacement of about 9 mm/yr occurs in the Santa Cruz Mountains (Minister and Jordan, 1987).

Surface fault rupture associated with the 1906 earthquake was not adequately documented in the FER study area (Schwartz and Prentice, 1990; Ponti and others, 1990). Approximately 1.4 m of right lateral displacement was reported in the South Pacific Coast Railroad Company near Wrights Station (at depth) (locality A, Figure 2a), but there was no surface rupture in the vicinity of the offset reported in the tunnel.

Traces of the San Andreas fault in the Los Gatos quadrangle were zoned for special studies in 1974 and revised in 1976 (CDMG, 1976a), based on mapping by Dibblee (p.c, 1973), Rogers (1971), Clark (1970), and Hall and others (1974) (Figure 2a). Mapping since the 1976 SSZ map was issued includes Sarna-Wojcicki and others (1975), Dibblee and Brabb (1978), Schwartz (p.c., 1991), and Brabb and others (in press) (Figures 2a, 3a). Mapping by Hall and others (1974) was at a relatively small scale (1:62,500) and largely was superseded by Sarna-Wojcicki and others (1975). Therefore, Hall and others will not be evaluated further in this FER. Sarna-Wojcicki and others (1975) mapped recently active traces of the San Andreas fault by identifying fault-produced geomorphic features, based on air photo interpretation and field mapping. Mapping by Dibblee and Brabb (1978) and Brabb and others (in press) portrayed the bedrock geology in the Los Gatos quadrangle without necessarily emphasizing the identification of recently active traces of the San Andreas fault. Schwartz (p.c. 1991) mapped principal active traces of the San Andreas fault, based on aerial photographic interpretation and field checking.

The San Andreas fault shown in the Los Gatos quadrangle forms a broad zone up to 730 meters wide (Figure 2a). Rogers (1971) identified the principal active trace (shown as a solid line on Figure 2a) and speculated that it may have ruptured in 1906. There is relatively good agreement with respect to fault location for about 1.2 km at the southern boundary of the Los Gatos quadrangle between mapping by Rogers (1971), Clark (1970), Sarna-Wojcicki and others (1975), Brabb and others (in press), and Schwartz (p.c.) (locality B, Figures 2a, 3a). The northwestern extent of the fault in the Los Gatos quadrangle is characterized by moderate agreement between the mapping of Schwartz, Clark (1970), Rogers, and Dibblee and Brabb. Between locality C and locality B, traces mapped by others vary by as much as 300 meters. Fault traces in this region are obscured by massive landslides, and the dense forest cover prevents accurate evaluation of the location and extent of recently active traces.

A southwestern branch of the fault mapped by Schwartz and Brabb and others was not verified by investigations of Cotton and Associates (1976a - AP-540; 1976b - AP-543) (Figure 2a). A northeastern branch of the San Andreas fault zoned for special studies in 1976 was mapped by Clark (1970), Dibblee (p.c., 1973), and Rogers (1971) (Figure 2a). This branch forms a major lithologic boundary between Cretaceous bedrock on the northeast and Tertiary bedrock on the southwest. McLaughlin (1990) stated that the major lithologic or bedrock San Andreas fault is consistently northeast of geomorphically youthful traces of the San Andreas fault in the study area.

The San Andreas fault in the Laurel quadrangle (CDMG, 1976b) was zoned for special studies in 1974 and revised in 1976 based on the work of Hall and others (1974) (Figure 2b). The San Andreas fault has been mapped by Sarna-Wojcicki and others (1975), Clark and others (1989), and Schwartz (p.c., 1991) since the Laurel SSZ map was issued.

Sarna-Wojcicki and others (1975) depict a very broad zone of short, left-stepping fault strands in the Laurel quadrangle (Figure 3b). This zone is up to 2 km wide and generally consists of inferred faults based on vegetation or other tonal lineaments. Mapping by Clark and others (1989) and Schwartz (p.c., 1991), shown on Figure 2b, agrees well with respect to location northwest of Soquel Creek. Sarna-

Wojcicki and others and Clark and others mapped a broad zone of faults, mostly in massive landslide deposits, southeast of Soquel Creek (Figure 2b, locality D). Although Sarna-Wojcicki and others (1975) mapped a very broad zone of generally discontinuous, left-stepping fault strands, they did map a principal active trace that generally coincides with mapping by Clark and others and Schwartz through most of the Laurel quadrangle (Figures 2b, 3b).

Three fault rupture investigations reported evidence for recent faulting along the principal active trace of the San Andreas fault in the Laurel quadrangle. Myers (1980) reported that the fault offset "top soil" against sandstone in trench T-1 (locality E, Figure 2b). A 20 cm-wide soil-filled fissure was located within the fault zone. This soil-filled fissure extended to within about 1.2 m of the surface. The fault was reported just to the northwest in trench T-5. The reported faulting coincides with the location of the San Andreas fault, based on a bench interpreted from air photos by this writer (Figure 3b). Levish (1974) reported faults in trenches along the main active trace of the San Andreas fault mapped by Sarna-Wojcicki and others (1975), Clark and others, and Schwartz (p.c., 1991) (locality F, Figure 2b). Rogers E. Johnson (1974) excavated one trench near a trace mapped by Schwartz, Clark and others, and Sarna-Wojcicki and others (1975) (locality G). No evidence of faulting was reported, although a buried swale or stream channel deposit (clayey fine sand) could be interpreted as faulting.

Air Photo Interpretation

The San Andreas fault in the Los Gatos quadrangle is moderately to locally well-defined at the western end of the quadrangle near Alma College (Figure 2a). Geomorphic features indicative of Holocene right-lateral strike-slip displacement include a linear drainage and linear ridge (shutter ridge), closed depression (artificial?), and right-laterally deflected drainages (locality C, Figure 2a). Mapping by Schwartz (p.c., 1991), Dibblee and Brabb (1978), and Brabb and others (in press) agrees reasonably well with respect to location. The southwestern trace in the Alma College area mapped by Schwartz and Brabb and others is not well-defined and was not verified (Figure 2a).

The San Andreas fault southeast of Highway 17 is poorly defined and is largely obscured by massive landslides and dense forest canopy. The location of the fault locally can be inferred by such features as right-laterally deflected drainages and benches (localities H,I, and J, Figure 2a), but strands are difficult to confidently trace for any significant distance. Schwartz (p.c., 1991) indicated that the principal active trace is delineated by a generally benched area within massive landslides adjacent to Los Gatos Creek, although the precise location of the fault in this area reliably cannot be determined.

The San Andreas fault is moderately well-defined at the southern boundary of the Los Gatos quadrangle (southeast of locality B, Figures 2a and 2b). The fault is delineated by a northeast-facing scarp in landslide deposits, a moderately defined bench, and a saddle or notch.

Eastern traces of the San Andreas fault mapped by Clark (1970), Dibblee (1973), and Rogers (1971) were not verified by this writer with respect to recency, based on air photo interpretation (Figure 2a). The fault, if active, has been modified by lateral stream erosion and is mostly obscured by the dense forest canopy.

Principal active traces of the San Andreas fault in the Laurel quadrangle are moderately defined to moderately well-defined. There is a well-defined linear scarp, moderately defined bench, and a linear drainage within a saddle or notch at the northern boundary of the quadrangle (locality E, Figure 2b). To the southeast, the fault is defined by a linear drainage bounded to the northeast by a linear ridge in bedrock (locality K, Figure 3b). Additional, specific geomorphic evidence of recent faulting is difficult to interpret from air photos due to heavy vegetation.

In the vicinity of the Burrell Guard station the fault splays into several traces defined by notches, linear drainages, ponded alluvium, a sidehill bench, and linear tonal contrasts (localities L - N, Figure 2b). Knobs and linear drainages in bedrock delineate the fault just northwest of Soquel Creek. Soquel Creek is deflected right-laterally just southeast of the knobs and linear drainage in bedrock (locality D).

The San Andreas fault is poorly defined southeast of this deflected drainage to the eastern boundary of the Laurel quadrangle. Recently active traces of the San Andreas fault are obscured by massive landslides in the Soquel Creek area. The fault apparently changes to a more easterly trend, so it is difficult to project the location of the fault through the landslide complex.

RIDGETOP-SPREADING FISSURES

A large number of fault-like fissures and associated fractures developed in the epicentral region during the October 17, 1989 Loma Prieta earthquake (Wells and others, 1989; Hart and others, 1990; Spittler and Harp, 1990). The largest concentration of fissures occurred in an approximately 8 km by 2 km region in the Summit Road/Skyland Ridge area (Figures 3a and 3b). This region was mapped in detail by Wells and others (1989) to identify those fissures and associated fractures thought to be tectonic in origin (i.e. regional uplift). The identification of tectonic fractures by Wells and others apparently was based on linearity, continuity along trend, relatively large vertical or lateral displacements, and general coincidence with linear topographic features (USGS, 1990). Although extensional displacement was dominant, vertical and left-lateral components of slip suggested flexural-slip (i.e. secondary) faulting. Later work by the USGS (Ponti and others, 1990) considers the origin of these fractures to be due mainly to shaking, although a tectonic origin cannot be ruled out.

Most of the fissures in the Summit Road/Skyland Ridge area have a N50°W to N60°W-trend, which is generally parallel to the regional strike of Tertiary strata (Dibblee and Brabb, 1978; Brabb and others, in press; Clark and others, 1989) as well as the ridgelines. Other fissure zones trend more westerly or northerly and also tend to parallel ridge spurs. Individual fissures tend to be relatively straight and apparently are controlled by bedrock structures (bedding, faults or joints). However, some zones of fissures are curved, sinuous or irregular (localities O - Q, Figures 3a and 3b), as well as complexly branching and anastomosing (localities R and S, Figure 3a). Selected fissure localities, field-checked by this writer and DMG from October 1989 to January 1990, are identified on Figures 3a and 3b (refer to Table of Observations).

Fissure zones are as long as 600 m and individual fissures are open as wide as 0.8 m (locality T, Figure 3a). Although extension dominates the sense of displacement, many fissures have vertical components of displacement to 0.4 m and uphill-facing scarps are common. Left-lateral components of offset were reported for about 67% of the fissures (Ponti and others, 1990) and approached 0.4 m at localities O and T. Right-lateral slip components are less abundant and smaller (Wells and others, 1989). Pure extension accounted for only about 5% of the fissures (Ponti and others, 1990). The depth of the fissures generally could not be determined because thick colluvial soil from the walls would tend to collapse into the fissures. However, depths to four or five meters were observed (Baumann and others, 1990). Presumably, the larger fissures extended even deeper into bedrock. The general linearity of fissures and the fact that they followed existing geomorphic features (linear depressions, ridgelets, and scarps) indicate that they are anchored in bedrock and probably follow bedding planes, faults, and joints. Exposures at localities U, V, and W further verify this relationship. The fracture zone and offset highway pavement at locality U (Figure 3a) was mapped as a bedding-plane fault in both of the 20 m high road cuts of Highway 17 by Cotton and others (1990). The fractures parallel bedding in a shale unit of the Vaqueros Formation and offset a colluvial/soil wedge in the same sense (north side down) as the pavement of Highway 17 and the closely associated fissure zone just west of the highway. The highway pavement was vertically offset 40 cm.

Many fissures are clearly associated with geomorphic features indicative of past extension and vertical displacement, based on air photo interpretation and field observations by this writer (e.g. localities P, W, X, and Y, Figures 3a and 3b). However, individual depressions, swales, and scarps seldom exceed 200 to 300 meters in length and most lack the degree of linearity and continuity normally associated with recent faulting. Recurrence of displacement has been documented in a road cut at Highway 17 (Cotton and others, 1990, locality U, Figure 3a), in trenches at the C.T. English School (Cleary Consultants, 1990) and Loma Prieta School (Rogers E. Johnson and Associates, 1989) (localities V and W), and at a residential site (Nielsen, 1988, locality Z; Coyle, 1978, locality AA). Recurrence also has been documented at Morrill Road (locality T), which was offset left-laterally as much as 0.4 m in 1989 at the same location where 1.1 m of left-lateral offset was recorded in 1906 (Lawson, 1908, plate 64B; USGS, 1990, p. 290).

The northwest set of left-stepping faults mapped by Hall and others (1974) and Sarna-Wojcicki and others (1975) generally were not verified, especially with respect to the inferred continuity of individual traces (Figures 3a and 3b). What was observed in unforested areas is a rather complex set of short, linear to curved depressions, troughs, swales, scarps, and hummocks that generally parallel the ridgecrest along Summit Road (Figures 3a and 3b). There is no question that these features are youthful. The only question is their origin.

Features observed on Skyland Ridge are less parallel to the ridgetop and associated spurs, being a mosaic of young hummocks, swales, and benches punctuated with round to elongate depressions (Figure 3b). These ridgetop features are clearly gradational with the hummocky and benched landslides of the steep slopes of Skyland Ridge.

Many additional fissures were mapped in the Summit Road/Skyland Ridge area without regard to origin by Spittler and Harp (1990) in cooperation with Santa Cruz County, DMG, USGS, and various consulting geologists. Most of these features appear to be landslide related, but selected linear traces that are parallel to the traces of Wells and others (1989) are shown on Figures 3a and 3b.

BUTANO FAULT

The Butano fault branches from the San Andreas fault just southwest of the Loma Prieta School and has a more westerly trend (Figure 2a). Selected traces of the Butano fault were zoned for special studies in 1976, based on mapping by Hall and others (1974). Dibblee and Brabb (1978) mapped the Butano fault as inferred south of the San Andreas fault in the Los Gatos quadrangle (Figure 2a), where it juxtaposes Oligocene Vaqueros Sandstone on the northeast against Eocene Butano Sandstone on the southwest. It has been suggested that strands of the Butano fault may be associated with the Morrill Road offsets in 1906 and 1989 (locality T, Figure 2a). However, the 1989 fissures have a more northerly trend and cross the trace mapped by Dibblee and Brabb at an acute angle (Figures 2a and 3a). Also, the 1906 and 1989 fissures where extensional and had a significant left-lateral component of displacement, which is not consistent with displacement expected for primary fault rupture (right-lateral) along a northwest-trending fault.

The Butano fault locally coincides with the location of ridgetop-spreading fissures associated with the Loma Prieta earthquake (Figures 2a and 3a). However, geomorphic evidence indicating the location of the ridgetop-spreading fissures does not support the interpretation of a continuous fault (refer to Ridgetop-spreading fissures section for discussion of these features). The Butano fault is poorly defined and lacks geomorphic evidence for a throughgoing right-lateral strike-slip fault.

SEISMICITY

Seismicity in the Summit Road/Skyland Ridge study area was characterized by small and moderate magnitude earthquakes located on and near the San Andreas fault prior to the 17 October 1989 M_s 7.1 Loma Prieta earthquake (CIT, 1985). These epicenters do not clearly correlate with specific fault traces at the surface.

The M_s 7.1 Loma Prieta earthquake was located southwest of the San Andreas fault (Figures 1 and 5). The main shock focal mechanism indicated a 70° southwest-dipping reverse-oblique slip fault at a depth of 17.6 km (McNutt and Toppozada, 1990). Slip at depth along the fault was inferred to be 1.6 ± 0.3 meters of right-lateral strike-slip and 1.2 ± 0.3 meters of reverse slip (up on the southwest) (Plafker and Galloway, 1989). The aftershock zone was 53 km long after the first 4 days and had extended to 66 km by 31 October 1989 (Figure 5).

DISCUSSION AND CONCLUSIONS

SAN ANDREAS FAULT

The San Andreas fault in the Summit Road/Skyland Ridge study area is only locally well-defined (Figures 2a, 2b, 3a, and 3b). Many traces are obscured or modified by massive landslides in most of the Los Gatos quadrangle (Figure 2a) and the southeastern part of the Laurel quadrangle (Figure 2b). Further hindering the evaluation and mapping of recently active traces is the dense forest cover along much of the fault trend. Evidence of significant primary surface fault rupture along the San Andreas fault was not observed following the M_s 7.1 Loma Prieta earthquake (Hart and others, 1990). No through-going surface fault rupture was documented following the 1906 earthquake, although detailed mapping was not undertaken (E.P. Carey, in Lawson, 1908; Ponti and others, 1990; Schwartz and Prentice, 1990).

The principal active trace of the San Andreas fault mapped by Sarna-Wojcicki and others (1975) in the Los Gatos and Laurel quadrangles was generally verified by this writer (Figures 2a, 2b, 4a, 4b). However, the many short, left-stepping en echelon traces inferred by Sarna-Wojcicki and others (1975) were generally not verified, especially with respect to the continuity of the features. Selected traces mapped by Rogers (1971) and Dibblee and Brabb (1978) in the Los Gatos quadrangle and Clark and others (1989) were also verified (Figures 2a, 2b, 4a, and 4b). It should be pointed out that well-defined traces of the San Andreas fault in the Los Gatos quadrangle only exist at the northwest and southeast ends of the quadrangle (localities B and C, Figure 2a). Traces between these two localities are obscured by massive landslide complexes and covered by dense forest cover and thus can only be approximated in this area. This also applies to the southeastern traces in the Laurel quadrangle (Figure 2b).

RIDGETOP-SPREADING FISSURES

Many of the fissures in the Summit Road/Skyland Ridge area are considered to be tectonic in origin by some geologists, based on the fault-like characteristics and general linearity (e.g. Cotton and others, 1990; USGS, 1990). Cotton and others concluded that bedding plane faults exposed in the Highway 17 roadcuts are analogous to second-order bending-moment faults related to coseismic, active folding processes described by Yeats (1986).

The evidence for a tectonic origin of other fissures is indirect and is based on the assumed 1.3 ± 0.4 m of uplift and presumed extension across the southwestern block of the San Andreas fault (USGS, 1990). Furthermore, some of the fissures follow linear depressions, scarps and other small-scale geomorphic features often associated with active faulting (Figure 3a and 3b). Some of these same geomorphic features were used by Sarna-Wojcicki and others (1975) to map left-stepping en echelon faults in the Summit Road/Skyland Ridge area (Figures 3a and 3b). Yet, the fissure and fracture zones mapped by Wells and others (1989) only coincide to a limited extent with traces of Sarna-Wojcicki and others (1975) (Figures 3a and 3b). This suggests that the fault traces shown on the 1975 publication are rather interpretive and inadequately predicted the 1989 fissure locations.

Most of the linear, fault-like fissures were concentrated within a relatively small area on or near ridgecrests. Therefore, it seems unlikely that the fissures could be caused by tectonic uplift that extended over a much larger area. Hart and others (1990) and Ponti and others (1990) pointed out that strong ground motion probably accounted for many of the fissures. Hart and others (1990) suggested that the fissures in the Summit Road/Skyland Ridge area were caused by intense shaking that caused the ridges to spread laterally and the tops to settle (Beck, 1968; Tabor, 1971; Mahr, 1977; Varnes, 1978; Radbruch-Hall, 1978; Bovis, 1982; Savage and Varnes, 1987; and Thorsen, 1989). The fact that the fissures tend to parallel the ridgecrests and spurs suggests this is so, and the association of the 1989 fissures and scarps with existing depressions and scarps demonstrates a repetition of events. The gradational relations with landslide fissures developed on the flanks of the ridges (Spittler and Harp, 1990; Hart and others, 1990) further indicate a common cause for both types of fissures. Ponti and others (1990) reported that estimates of cumulative extension across these fissures totalled several meters. Because current geodetic models predict a maximum uplift of only 35-45 cm in the Summit Road area, it is "...unlikely that tectonic extension due to uplift across a broad arch would alone result in such large displacements" (Ponti and others, 1990).

It is concluded that the ridgetop fissures are caused largely by intense shaking, although the uplifted southwestern block of the San Andreas fault probably was associated with some tectonic stretching. Being unable to prove the absence of faulting, it is difficult to recommend against zoning the fissures, particularly when some are clearly related to geomorphic features indicative of repeated events. In addition, these fault-like features are certainly hazardous to structures for human occupancy and are best mitigated by avoidance. It seems prudent to treat the features like faults and to zone them under the APSSZ Act.

BUTANO FAULT

The Butano fault, mapped as inferred by Dibblee and Brabb (1978), offsets Oligocene Vaqueros Formation against Eocene Butano Sandstone (Figure 2a). The fault locally coincides with the location of ridgetop-spreading fissures associated with the Loma Prieta earthquake, including the Morrill Road fissures (locality T, Figures 2a and 3a). However, the fault is poorly defined and lacks geomorphic evidence of a through-going right-lateral strike-slip fault, based on air photo interpretation by this writer.

RECOMMENDATIONS

SAN ANDREAS FAULT

Zone for Special Studies recently active traces of the San Andreas fault mapped by Rogers (1971), Sarna-Wojcicki and others (1975), Dibblee and Brabb (1978), and Clark and others (1989) as depicted in Figures 4a and 4b. Zone boundaries should be drawn conservatively in the Los Gatos and Laurel quadrangles where massive landslide complexes obscure fault locations. Principal references cited should be Rogers (1971), Sarna-Wojcicki and others (1975), Dibblee and Brabb (1978), Clark and others (1989), and Bryant (this report).

RIDGETOP-SPREADING FISSURES

Zone for special studies ridgetop-spreading fissures associated with the October 17, 1989 Loma Prieta earthquake and associated fault-like geomorphic features indicative of prior surface rupture mapped by Wells and others (1989), Spittler and Harp (1990), and Bryant (this report) as depicted on Figures 4a and 4b. Principal references cited should be Wells and others (1989), Spittler and others (1990), Hart and others (1990), and Bryant (this report).

BUTANO FAULT

Do not zone for special studies traces of the Butano fault. Traces of the Butano fault are neither sufficiently active nor well-defined.

Report reviewed; recommendations approved. Earl W. Hart CEG 935 4/16/91

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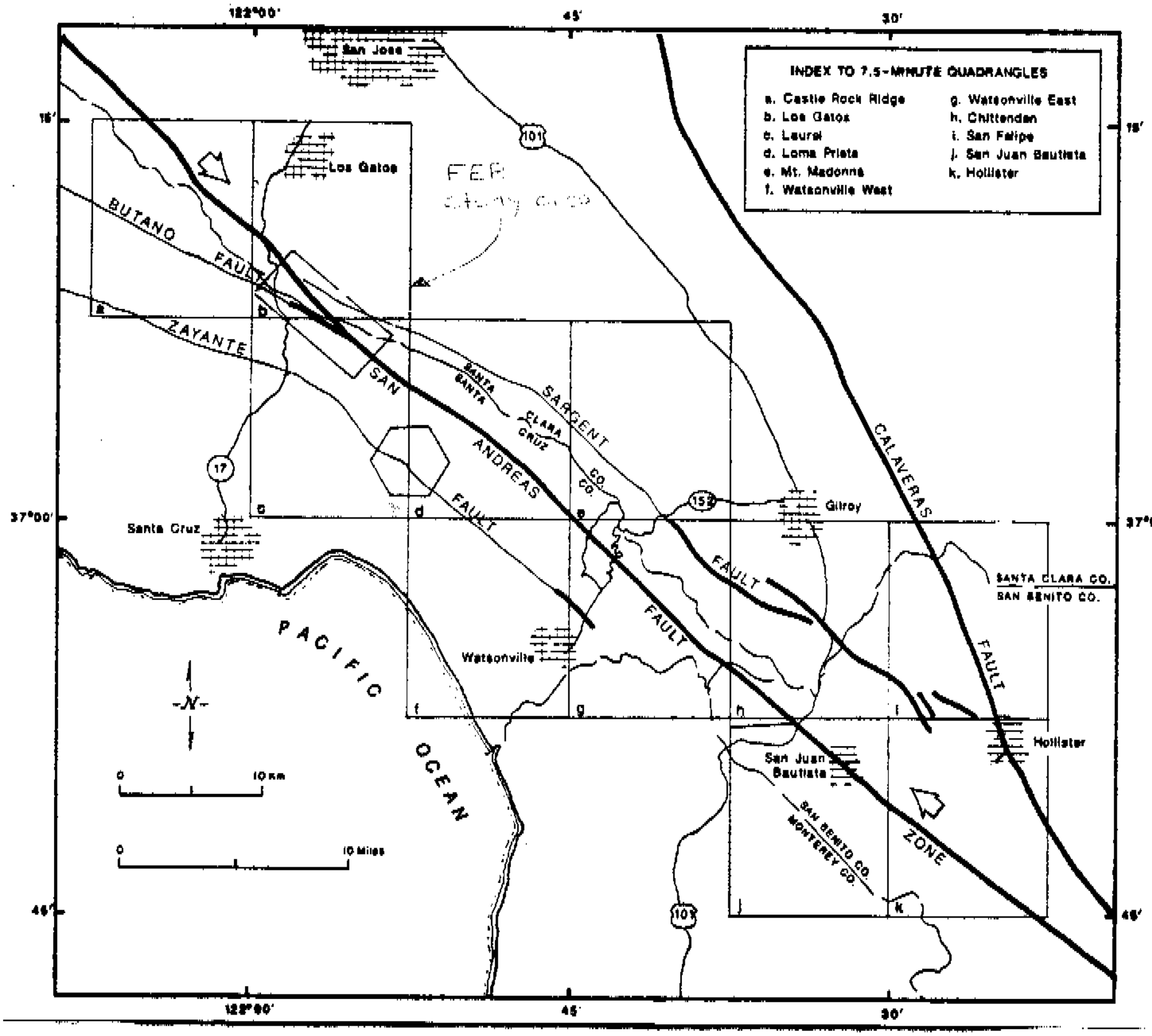

Figure 1 (to FER-225). Location of the San Andreas and related faults in the Summit Road/Skyland Ridge study area and ridgetop-spreading features and fissures associated with the 17 October 1989 Loma Prieta earthquake. Location of the M_s 7.1 epicenter is shown by the hexagon; arrows indicate the approximate extent of the mainshock subsurface rupture zone. (Modified from Hart and others, 1990).

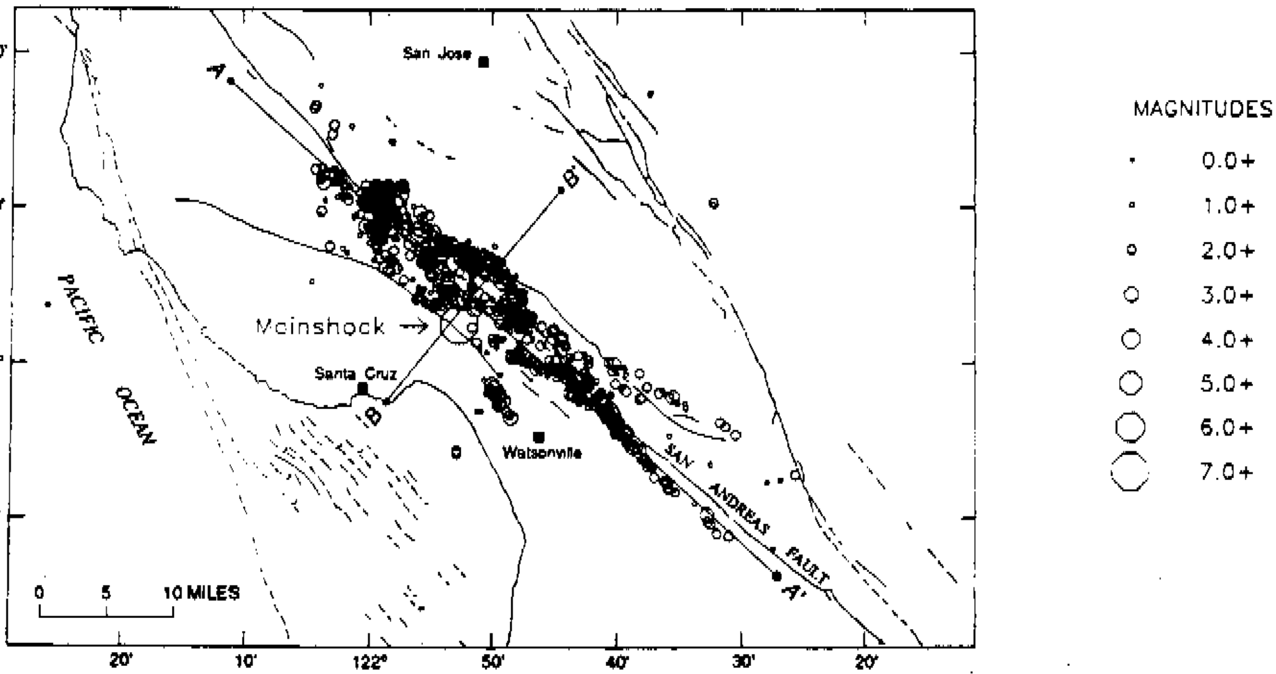

Figure 5 (to FER-225). Spatial distribution of aftershocks of the M_s 7.1 17 October 1989 Loma Prieta earthquake in relation to the San Andreas fault. (From Plafker and Galloway, 1989).