CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-100

August 22, 1980

1. Name of fault
   Calaveras (Las Trampas Ridge quadrangle).

2. Location
   Las Trampas Ridge 7.5 minute quadrangle, Contra Costa County.

3. Reason for evaluating
   Part of 10-year program (Hart, 1980) and Quaternary fault map of Herd (1978).

4. References

Dibblee, T.W., Jr., 1980a, Preliminary geologic map of the Las Trampas Ridge quadrangle, Alameda and Contra Costa Counties, California: U.S. Geological Survey Open-file Report 80-545, 1:24,000 scale.

Dibblee, T.W., Jr., 1980b, Preliminary geologic map of the Walnut Creek quadrangle, Contra Costa County, California: U.S. Geological Survey Open-file Report 80-351, 1:24,000 scale.

Ham, C.K., 1952, Geology of Las Trampas Ridge, Berkeley Hills, California: California Division of Mines and Geology, Special Report 22, 26 p., map (scale 1:31,680).

Hart, E.W., 1980, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42, 25 p.

Herd, Darrell, 1978, Map of Quaternary faulting along the northern Calaveras fault zone, Las Trampas Ridge, Diablo Dublin, Niles and La Costa 7.5' quads, California: U.S. Geological Survey Open-file Report 78-307, 5 maps (no text), 1:24,000 scale.

Lawson, A.C., 1914, Aerial geology, Concord quadrangle in Geologic Atlas of the United States, San Francisco Folio; California: U.S. Geological Survey, 24 p., maps (1:62,000 scale).

Real, C.R., Parke, D.L., and Toppozada, T.R., 1978, Magnetic tape catalog of California earthquakes, 1900-1974: California Division of Mines and Geology.

Saul, R.B., 1973, Geology and slope stability of the SW 1/2 Walnut Creek quadrangle, Contra Costa County, California: California Division of Mines and Geology Map Sheet 16 (map scale 1:12,000).

Nason, R.D., 1971, Investigation of fault creep slippage in northern and central California; Unpublished PhD thesis, University of California at San Diego, 231 p.

Trask, J.B., 1864, Earthquakes in California from 1800-1864: Proceedings of the California Academy of Sciences, v. 3, p. 130-153.

U.S. Department of Agriculture, 1939, aerial photos, black and white, vertical, scale 1:20,000, BUU-281-289 to 295. Available from National Archives, Washington, D.C.

U.S. Department of Agriculture, 1940, black and white aerial photographs, vertical, scale 1:20,000 (approx.), BUU-281-289 to 295, BUU-337-32 to 37, BUU-344-7 to 15. Available from National Archives, Washington, D.C.

U.S. Department of Agriculture, 1950, black and white, vertical aerial photographs, scale 1:20,000 (approx.), BUT-5G-62 to 68, 5G-122 to 131, 5G-170 to 173, and 7G-124 to 131.

U.S. Geological Survey, 1973, Low-sun angle, color, vertical photos, scale approx. 1:20,000 1-17 to 1-22; flown 9-21-73. (Obtained from Rapidcolor, Burbank, CA.)

Wagner, J.R., 1978, Late Cenozoic history of the Coast Ranges east of San Francisco Bay: Unpublished Ph.D. thesis, University of California at Berkeley, 161 p., 12 maps (1:24,000 scale).

Whitney, J.D., 1865, Geology of California, Vol. I, Part I, Geology of the Coast Ranges: Geological Survey of California, p. 1-97.

Woodward-Clyde Consultants, 1976, Assessment of geologic and seismic hazards for Neighborhood Five, Rossmoor Leisure World, Walnut Creek, California: Unpublished consultant's report, 32 p., app. figs. (Copy filed with CDMG as C-448).

Woodward-Clyde Consultants, 1977, Final report, ground crack monitoring program, Neighborhoods Two and Four, Rossmoor Leisure World, Walnut Creek, California: Unpublished consultant's report dated June 1, 1977, 10 p., 2 app.

Woodward-Clyde Consultants, 1978, Fault study, proposed Clubhouse No. 5, Neighborhood Nine, Rossmoor Leisure World, Walnut Creek, California Unpublished consultant's report dated Oct. 13, 1978, 18 p., 8 figs. (Copy designated C-445a on file in SF District, CDMG.)

Woodward-Clyde Consultants, 1979a, Fault study, Saklan Indian Drive extension, Neighborhood Nine, Rossmoor Leisure World, Walnut Creek, California: Unpublished consultant's report dated January 25, 1979, 25 p., app., 9 figs. and supplemental trench logs. (Copy designated C-445b on file in SF District, CDMG.)

Woodward-Clyde Consultants, 1979b, Fault study, Subdivision 5239, Mutual 50, Subdivision 5240, Mutual 51, Neighborhood Four, Rossmoor, Walnut Creek, California: Unpublished consultant's report dated August 21, 1979, 11 p., 6 figs. (Copy designated C-446 on file in SF District, CDMG.)

5. Review of available data.

The Calaveras fault is one of the major right-lateral strike-slip faults in California. It has been mapped from Hollister on the southeast to San Ramon on the northwest, a distance of about 115 km. Being recently active (historic creep*, seismicity, well-defined fault-produced topography), the fault was zoned under the Alquist-Priolo Special Studies Zones Act (Figure 1). The Calaveras fault can be followed only with difficulty northwest of San Ramon to the vicinity of the western margin of the Diablo quadrangle. To the northwest, in the adjoining Las Trampas Ridge (LTR) quadrangle, the fault's position is largely obscured by massive landslides and complexly folded and faulted strata (Lawson, 1918; Ham, 1952; Wagner, 1978; Herd, 1978; Dibblee, 1980a & b; Woodward-Clyde, 1978; 1979a; 1979b). It appears that the Calaveras fault north of San Ramon lacks the recent linear fault features so characteristic to the south. Previous workers seem to disagree as to the location, significance, and nomenclature of what may comprise the northwest extension of the Calaveras fault. The principal faults mapped are shown on Figure 2.

Lawson (1918) designated the Calaveras fault as the Franklin fault, which he conceived as a major northeast-dipping thrust. He showed this fault to be truncated on the south by the southwest-dipping Las Trampas Ridge fault.

Ham (1952) showed these faults to be nearly vertical and partly relocated the traces. He considered the Franklin fault to be the northwest projection of Sunol fault (another name for the Calaveras fault), which he located along the western margin of San Ramon Valley. He considered the Sunol fault to underlie the alluvium of the valley, but speculated that it may have been responsible for uplifting the Pleistocene terraces

* The nearest creep reported along the Calaveras fault is 27 km to the southeast, in Sunol Valley (Nason, 1971).

Figure 1. Location map of Las Trampas Ridge quadrangle, showing Calaveras and other faults zoned for Special Studies (after Hart, 1980).

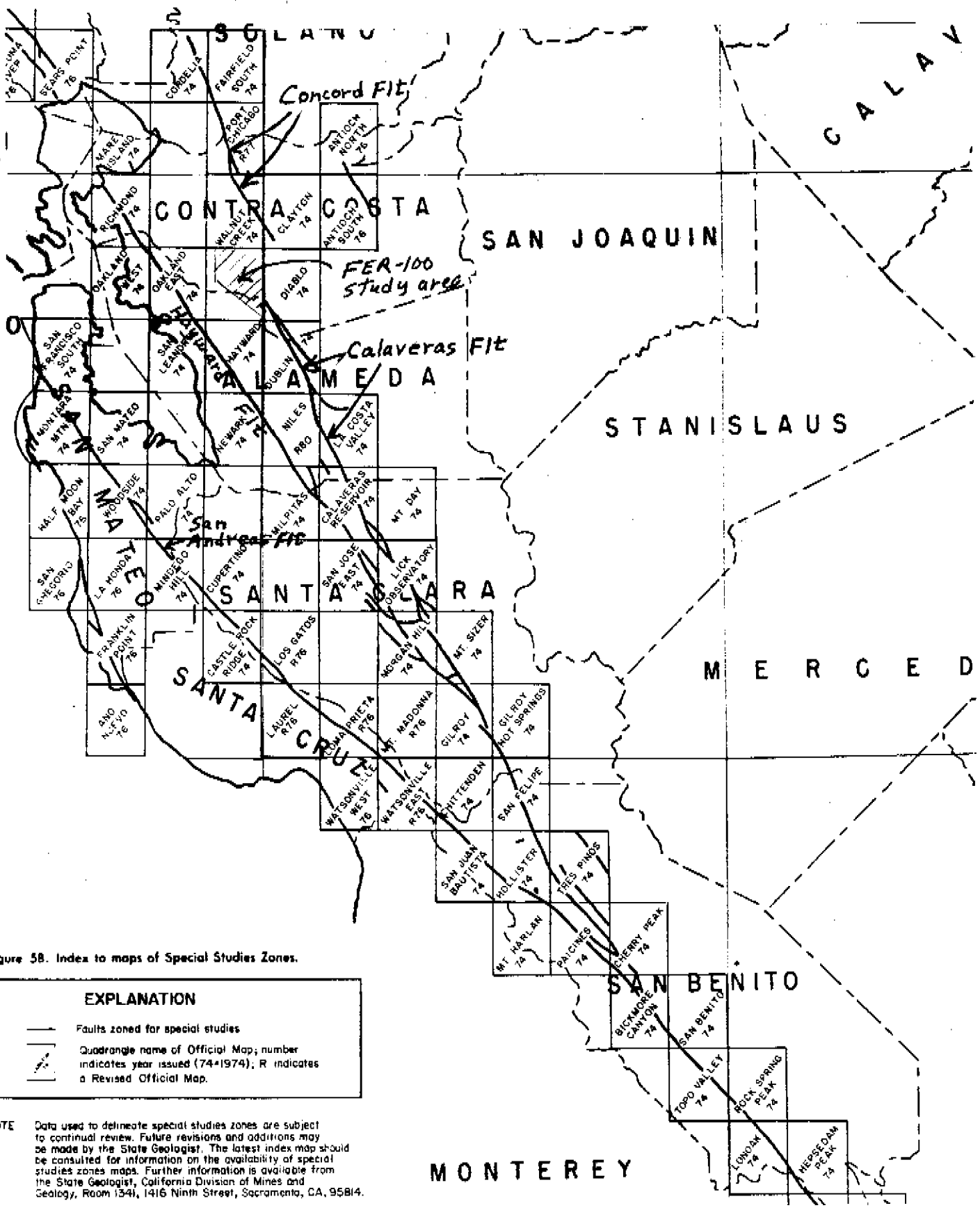


Figure 58. Index to maps of Special Studies Zones.

EXPLANATION

Faults zoned for special studies

Quadrangle name of Official Map; number indicates year issued (74=1974); R indicates a Revised Official Map.

NOTE Data used to delineate special studies zones are subject to continual review. Future revisions and additions may be made by the State Geologist. The latest index map should be consulted for information on the availability of special studies zones maps. Further information is available from the State Geologist, California Division of Mines and Geology, Room 1341, 1416 Ninth Street, Sacramento, CA, 95814.

Scale 1:1,000,000

1 inch equals approximately 16 miles

to the southwest. Ham also shows several transverse faults, which he considered to have caused differential displacement (vertical?) of the Pleistocene terraces. He does not identify terraces on his map. Dashed traces of the Franklin fault and three of the transverse faults are shown on his Plate 1 as bounding or extending into Qal ("Recent alluvium"). Ham does not indicate in his text that the alluvium is faulted and it is assumed that these are drafting errors, as no evidence can be seen on aerial photos of faulted recent alluvium.

J.R. Wagner (1978) mapped part of the LTR quadrangle as part of a regional study (12 7.5-minute quadrangles). His Calaveras fault is similar in location to the Franklin fault of others at Castle Hill, but differs elsewhere. With two exceptions he does not show the fault to offset Qal. West of Rancho Romero School, he shows the fault to bound or truncate alluvium in two tributary valleys. However, this is probably a drafting error* as no linear scarps, offset streams, or tonal features were observed to be coincident with his trace on early aerial photos (U.S. Soil Conservation Service, 1940; 1950). The 1950 photos did indicate a north-trending fault in bedrock between the two drainages. The Las Trampas, Dublin-Pinole, and several other faults are shown by Wagner to branch from or lie close to the Calaveras fault, but none of these are shown to offset alluvium.

The only study directed at the problem of identifying potentially active (Quaternary) faults was conducted by Herd (1978), based primarily on his interpretation of 1940 aerial photos and reconnaissance field checking. Most of the fault features identified by Herd are linear valleys, troughs, saddles, truncated spurs, and scarps in bedrock. Some or all of these features could be due to differential erosion of older faults or

* J.R. Wagner (personal communication, Oct. 13, 1980) verified that this is a drafting error and that he saw no evidence of faulted alluvium.

weak beds. He does identify "prominent NE-facing scarps in alluvium" 2 km northwest of Danville (see Figure 2 herein). Herd (personal communication, 5/19/80) further stated that the scarp offsets an alluvial fan and could not be erosional. Herd believes the offset alluvium could be Holocene in age. However, there is evidence that the alluvium is pre-Holocene (see under Item 6 below).

Several of Herd's traces to the northwest, in Sections 11 and 14, were investigated by Woodward-Clyde Consultants (1978; 1979a; 1979b), who concluded that the faults did no exist and that the features identified by Herd (1978) were due to differential erosion along bedding. Their trench locations are shown on Figure 2.

Recently released maps by T.W. Dibblee, Jr. (1980a, b) of the Las Trampas Ridge and adjoining Walnut Creek quadrangles provide a comprehensive summary of the stratigraphic units and principal faults and folds. Dibblee's Calaveras fault trace is located close to the fault traces of others in the Castle Hill area, where he shows a major truncation of Tertiary strata. To the south of Alamo, he shows the fault to be concealed under Holocene alluvium and an undifferentiated Pleistocene alluvial/landslide unit (mapped as a landslide by Herd, 1978). His Las Trampas fault is similar in location and sense of offset to faults of others (see Figure 2), except in the southeast segment where he infers it to cut the undifferentiated Pleistocene alluvial/landslide unit. To the northwest, the Las Trampas fault is shown to merge with the Lafayette fault, which is concealed under Holocene alluvium.

There is no evidence for Holocene activity presented for any of these faults. Other faults are mapped by Dibblee (1980a) to the west of the Las Trampas fault, but there is no evidence that they are recent. They are not shown on Figure 2.

Detailed investigations of fault-rupture hazards have been made for Rossmoor Leisure World Walnut Creek by Woodward-Clyde Consultants (1976; 1977; 1978; 1979a; 1979b; 1979c). These investigations included field mapping, aerial photographic interpretations, and exploratory trenching (see Figure 2 for locations). Near Castle Hill (Figure 2), they have mapped and named the Saklan fault (Woodward-Clyde, 1976; 1978; 1979) which is similar to an unnamed branch of the Franklin fault of Wagner (1978). This fault is considered to be an east-dipping thrust in bedrock. The Franklin fault to the east also was trenched and shown to be nearly vertical. Sheared and locally offset soils over these fault features (identified as "Features A and B" in the 1978 report) are attributed to shrink-swell changes in expansive claystone bedrock. The consultant concludes there is no evidence to suggest that either fault has been recently active. However, they did not believe there was evidence to conclusively show that these faults are inactive (i.e. pre-Holocene). Potential for surface faulting was considered to be "very low" although building set-backs were recommended. According to Al Ridley (p.c., Aug. 1980), these recommendations were intended to be conservative.

Trenching investigations of Herd's (1978) Quaternary fault traces near Castle Hill (Fig. 2) led Woodward-Clyde Consultants (1979a) to conclude that: 1) the Franklin fault is not present as previous mapped and the shears in bedrock are due to folding or secondary movement on the Saklan faults; and 2) there is no evidence of Quaternary faulting, as mapped by Herd. However, in the vicinity of Herd's westerly trace (as well as elsewhere), the trench logs clearly show discrete zones of shearing, deformed and disrupted bedrock units, and clay-filled fractures (Woodward-Clyde 1979a, Fig. 7, 8, 9 and supplemental logs). The highly uneven surface

between bedrock and overlying soil and colluvium (Fig. 7) and the shears in older alluvium (Fig. 8) are suggestive of at least minor Quaternary faulting. This may be due to distributive tectonic deformation and/or gravity adjustments of the ridges during seismic shaking. The two easterly traces of Herd were tested only by very shallow trenches. Nonetheless, there is no evidence of systematic offset of the ground surface (i.e. scarps or offset drainages) observable on aerial photos (see Item 6 below).

Other Quaternary faults of Herd (1978) were investigated by Woodward-Clyde (1979b) 1.5 km south of Castle Hill (see C-446 Figure 2). Although certain anomalous features were encountered in thick colluvial soils that were trenched, the consultant concludes that the evidence did not support the existence of Quaternary faults. They (p. 8-9) believe that the topographic features used by Herd to infer recent faulting were caused by "differential erosion along steeply dipping sedimentary beds." Their Figure 4, however, clearly shows sheared and deformed bedrock, but there was no evidence of offset in the overlying colluvium. That same figure reveals evidence of large-scale landsliding.

The existence of a zone of discontinuous cracks in soil extending for 4000 feet west of Tice Valley was noted recently by Woodward-Clyde Consultants (1977). These cracks occurred in claystone ("hard fissured clay") near the steeply dipping contact of a sandstone unit. A 1400-foot long segment of the feature (see Fig. 2) was trenched and evaluated by monitoring survey monuments and piezometers to determine if the movement was due to faulting. After about a year of monitoring, it was concluded that the cracks resulted from shrink-swell due to moisture changes in expansive claystone and that downhill creep may also have contributed to the cracking.

Saul (1973) mapped the Calaveras, Franklin and Las Trampas faults in the adjoining area to the north and shows a complex pattern of faults and folds. He indicates that the late Tertiary units have been offset 1-3 km along the Calaveras and Las Trampas faults and shows abrupt lithologic contrasts along the Calaveras-Franklin zone. However, he provided no evidence of Quaternary offset or comments on systematic offset of drainages or the existence of scarps along individual fault strands.*

The above descriptions and Figure 2 indicate that the Calaveras fault zone is rather poorly defined over most of its length and lacks through-going elements in the LTR quadrangle. The detailed trench logs of Woodward-Clyde clearly indicate distributive shearing and other penetrative deformation has occurred over a zone at least a kilometer wide. Some of the elements of the Calaveras fault zone apparently had at least minor Quaternary displacement, but Holocene faulting has not been demonstrated.

6. Interpretation of aerial photographs; field observations.

Large-scale aerial photographs of the U.S. Department of Agriculture (1939, 1940, 1950) and U.S. Geological Survey (1973) were examined carefully to determine if recent fault-related geomorphic features are present in the LTR quadrangle and, if so, if such features indicated systematic displacement. Several localities also were examined in the field.

The Calaveras fault, over much of its length, is well-defined by linear scarps, offset drainages, and other geomorphic features indicative recent right-lateral slip. These features lose their definition about a kilometer northwest of San Ramon (2 km SW of the boundary of the LTR quadrangle), where the fault enters a massive landslide area on the north-

* Saul did report possible creep evidence along the Las Trampas fault about 3 km north of the LTR quadrangle where an aqu duct tunnel showed one-inch of right-lateral offset shortly after it was bored (in bedrock at a depth of 200 feet). This was considered to be due to "rebound" and no evidence of surface movement was observed. According to Burt Marliave (personal communication, 1979), consulting geologist to the East Bay Municipal Water District, no additional slip was observed in the tunnel and the offset was considered to be due to "squeezing".

east side of Las Trampas Ridge (Herd, 1978). The fault can be traced only with difficulty to the vicinity of the quadrangle boundary. Beyond there, the fault location and activity become questionable and it is not possible to confidently identify the trace(s) of an active fault in an active landslide. The crude alignment of aerial photo features identified in the SE part of the LTR quadrangle (figure 2) may be the result of gravity failure along old faults and steeply dipping beds.

Herd does not map a landslide in part of Section 24, yet there is no evidence of systematically displaced drainages along discrete faults mapped by him or others. The fault may have lost its definition (and become distributive) and/or it is less active to the northwest. Another possibility is that much of the section 24 covered by massive landslides (the terrain is somewhat hummocky).

Northeast of the landslide area, the terrain is marked by numerous linear and discontinuous features (e.g. drainages and saddles), but there is no evidence on the aerial photos of systematic strike-slip or dip-slip offset in the topography. It would appear that these linear features are erosional, following older faults or bedding. As indicated above (Item 5) Herd has interpreted Quaternary faults to exist; Woodward-Clyde Consultants conclude that at least some of those faults do not exist or at least are not Quaternary.

Some specific localities worthy of further consideration are discussed below by locality numbers (which are keyed to the map, Figure 2):

1. Interpretation reveals Northeast facing scarps in bedrock flanked by alluvium to the NE that constitute a discontinuous, slightly arcuate feature (aerial photos of USDA, 1939 and 1950). Tributary drainages that cross the feature do not appear to be offset vertically or horizontally and the alluvium of the tributaries is not marked by groundwater barriers. The scarps are generally concave upward at the

base, suggesting uninterrupted deposition of colluvium since the scarps were formed. Also, the alluvium east of the scarps is slightly dissected and apparently not subject to flooding. This suggests a late Pleistocene age for the alluvium. Field observations are limited by recent development and vegetation, but verify photo interpretations. The scarps are due, at least in part, to stream erosion (late Pleistocene)--probably controlled by bedrock faults, joints or bedding. Offset of Holocene alluvium, as reported by D. Herd (p.c. May 1980), could not be verified. Sandstone and mudstone beds exposed in Kirkcrest Lane 100 m SW of the scarp show variable dips and are sheared. Open cracks indicate downhill movement of bedrock unit.

2. Steep northeast-facing scarp in bedrock, partly oversteeped by stream erosion at its base. Scarp ends at massive landslide deposits to south. Sandstone beds exposed in stream at base of scarp dip 0-30 NE and do not appear particularly faulted or sheared. The terrace and gravels from a tributary stream do not appear to be offset along the scarp line. The apparent left-lateral offset in the stream opposite the scarp may have been controlled by massive landsliding on the south.

3. West-trending linear trough and dark tonal lineament shows on USDA 1939 and 1950 aerial photos. A grading cut on the south side of the cul-de-sac of the end of Hemme Way exposed a vertical sheared contact between Neroly Sandstone and older (Pleistocene?) gravels along this trough. A dark clayey-organic unit in the gravels suggests a former ponded environment, which could be indicative of pre-Holocene faulting. Features are believed to be due to differential erosion along a Pleistocene fault. No evidence of Holocene faulting was observed.

4. Alignment of broad linear troughs and saddles in bedrock are shown on aerial photos (USDA, 1939 & 1950; USGS 1973) as indicated by Herd (1978). However, there is no evidence of systematic vertical or horizontal offset (scarps or deflected drainages) along this feature. Origin probably due to differential erosion along weak beds or old fault zone.

5. No tonal or topographic evidence in alluvial flats was observed on USDA (1939 & 1950) photos where Wagner (1978) shows fault. SW-facing scarp of Herd (1978) in bedrock appears to be erosional and does not appear to relate to recent fault features to NW or SE.

6. Well-defined landslide scarp (USDA photos, 1950) between massive landslide deposits and NW-dipping bedrock units (partly landslid); coincides with segment of Las Trampas fault of Dibblee (1980a).

7. Circular cut around water tank exposes steeply SW-dipping to vertical beds of closely fractured sandstone with interbedded conglomerate and mudstone; some minor faults and much internal deformation (shears; boudins). Evidence for recency of faulting not exposed and no significant shear or gouge zone observed. Exposures on trend with Herd (1978) fault trace (Figure 2).

8. Steeply dipping, sheared mudstone and fine sandstone with NW strike exposed in road cut just west of Herd (1978) fault trace (Figure 2). Vertical striations on fractures and slightly open cracks indicate downhill movement and tensional opening. Rock is somewhat expansive; soils very expansive.

9. Road cut just west of the main Calaveras fault trace of Herd (1978), Dibblee (1980) and Wagner (1978)--exposes east-dipping sandstone that is considerably sheared and jointed (vertical to east-dipping). Vertical shears trend north to NW and are partly open and filled with soil from above. Overlying soil (expansive) has developed differentially over shears and weak beds, partly due to burrowing animals; no evidence of offset. Soil-filled cracks probably formed by downhill creep and gravitational spreading of ridges. Road cut to west exposes sandstone and mudstone overlain by highly expansive soil with open cracks to 3 cm.

10. Sharp right-lateral deflection in Tice Creek observed on maps and aerial photos along general northward projection of main Calaveras fault. Tice Valley Blvd. checked for creep-related cracks and offset (none found). Air photos do not indicate systematic offset of drainages to north in Walnut Creek quad.

11. Approx. location of cut on N side of Saklan Indian Drive (E of Terra California Dr.) exposing nearly massive sandstone (u. Miocene) with contorted faint bedding; truncated on W by near vertical clay/sandstone beds. Contact not erosional, so must be faulted. Massive sandstone probably deformed in soft sediment stage.

7. Seismicity

Earthquake epicenters that have been specially studied and that are accurately located (generally within 2-3 km) are classified as "A" quality and plotted by Real and others (1978). Such epicenters in the vicinity of the Las Trampas Ridge quadrangle are shown on Figure 3. Linear zones

EARTHQUAKE EPICENTERS 1900-1974: SAN FRANCISCO SHEET

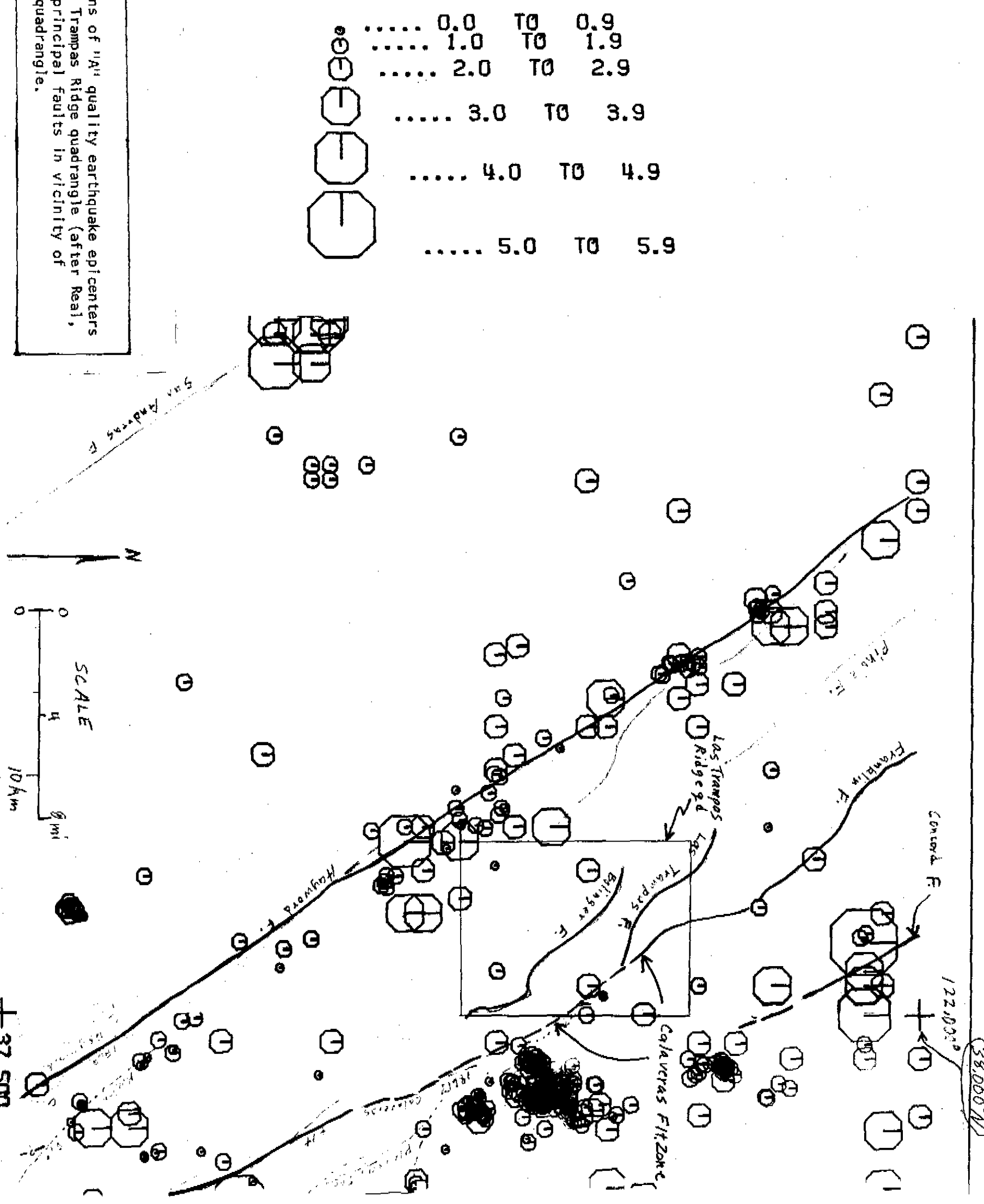
OF A QUALITY ACCORDING TO CATALOG SOURCE

EARTHQUAKE CATALOG EDITION I

CALIFORNIA DIVISION OF MINES AND GEOLOGY

TRANSVERSE MERCATOR PROJECTION

SCALE = 1/250000



FER 100

Figure 3. Locations of "A" quality earthquake epicenters in vicinity of Las Trampas Ridge quadrangle (after Real, et al., 1978) and principal faults in vicinity of Las Trampas Ridge quadrangle.

of epicenters fairly well identify the active Hayward and Concord faults. The dense clusters of epicenters east of the LTR quadrangle are not associated with known surface faults, but suggest that the Concord fault may connect with the Calaveras fault in the subsurface. Several other earthquakes (0.0 to 2.9 M) suggest subsurface activity along the Calaveras or nearby faults in the LTR quadrangle and just north of it.

The only record of possible historic ground rupture of the Calaveras fault is associated with the July 4, 1861 earthquake. According to J.B. Trask (1861, p. 150) a severe earthquake was reported in San Francisco and was more severe in the City of San Ramon. Near the house of Mr. Larabie "it opened a large fissure in the earth." Herd (1978) shows this house to be in the Diablo quadrangle, 2 km S of Danville and west of San Ramon Road. The site lies at the base of a massive landslide and close to the general trend of the Calaveras fault zone. Whether the fissure is the result of faulting, landsliding or some other cause is unknown.

Whitney (1865, p. 15) also refers to an earthquake in 1861, but in June. He reported "fissures in the soil along the west side of San Ramon Valley, which were formed during the earthquake of June 1861..." This is probably the same earthquake referred to by Trask. Whitney also refers to a "line of quite recent disturbances of the rocks through the San Ramon and El Hombre Creeks, which line crosses the general line of stratification at an angle of 35°." The relevance of Whitneys' remarks are not clear, although it is unlikely that he would be able to see ground fissures 3 years after the earthquake or that he could perceive the complexities of the Calaveras fault without the availability of good quality basemaps. Nonetheless, a fissure up to 3-4 inches wide and traceable for 8 miles was reported in Murray Township, Alameda County following "recent earthquake" (Mining and

Scientific Press, July 27, 1861). Mining and Scientific Press (July 4, 1961, p. 4) had previously reported an earthquake on July 3 at 4:10 PM in Contra Costa County.

8. Conclusions

Based on the work of Ham (1952), Wagner (1978) and Dibblee (1980a), it is concluded that the Calaveras fault zone is a complexity of strike-slip and reverse faults that comprise a zone of deformation about a kilometer wide in the Las Trampas Ridge quadrangle. Within this zone, the strata are steeply dipping, tightly folded, and internally deformed. The Las Trampas and other west-to northwest-trending faults and folds west of the main Calaveras zone indicated a even wider zone of deformation. Only west of Castle Hill, and possibly at Locality 1 (Figure 2), is there reasonable agreement as to the location of the Calaveras fault. In all probability, many more faults exist than are mapped or inferred (Figure 2) and undoubtedly a large amount of slip has been distributed along bedding planes and weak clayey beds or absorbed by folding. It is concluded that the Calaveras fault is poorly defined, being a zone of complex deformation.

To the north in the Walnut Creek quadrangle, the recent trace(s) of the Calaveras fault is even less well-defined in terms the geomorphic evidence (USDA aerial photos, 1939). That the fault is a complex, but important zone of right-slip and compressive deformation is demonstrated by the field mapping of Saul (1973) and Dibblee (1980b). Neither, however, indicate that late Quaternary alluvial units are faulted in that quadrangle.

There is good evidence that the Calaveras fault and its branches were most active during Pliocene to early Pleistocene time. This is demonstrated by the major offset and deformation of the Pliocene Orinda and Mulholland Formations (and older formations) and the lack of systematic offset of

drainages and alluvial units and surfaces considered to be of late Quaternary age. Nowhere in the LTR quadrangle were features observed that are comparable to the well-defined geomorphic features that mark the most recent trace of the Calaveras fault to the southeast. Investigations of Woodward-Clyde Consultants (1976, 1977, 1978, 1979a & b) indicate there is no evidence of Holocene activity for faults in the Castle Hill/Tice Valley area. However, evidence of shearing and minor offset of older colluvial soil units and clay filled fractures in bedrock are present, suggesting at least minor deformation sometime during late Quaternary time (Woodward-Clyde, 1978, Fig. 4; 1979, Fig. 8). These minor features may be due to various causes, including down-slope movement of rock units and expansive soils. Recent offset of alluvium at Locality 1 is inferred to be Holocene by Herd (p.c. 1980), but this could not be verified by this study.

It is concluded that the evidence for surface Holocene rupture on the Calaveras and related faults is weak or absent in the LTR quadrangle. Moreover, there is evidence that late Quaternary faulting is either minor or very distributive. Some of the strain evident on the Calaveras fault to the southeast may largely shift to the Concord fault, as suggested by the seismicity east of the quadrangle (Figure 3). Even so, minor strain-release along the Calaveras fault is documented by several small earthquakes in the LTR quadrangle.

9. Recommendations

It is recommended that no Special Studies Zones be established for the Calaveras fault Las Trampas fault, or any of their branches as the criteria for zoning are not met. Specifically, no faults were identified

that were "sufficiently active and well-defined" to warrant zoning (Hart, 1980, p. 5-6).

10. Report prepared by Earl W. Hart, August 22, 1980.

Earl W. Hart
RG #462
CEG #935