DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

MISCELLANEOUS FIELD STUDIES
MAP MF-533

DISCUSSION

The U.S. Geological Survey, in cooperation with other federal, state, and local agencies, is studying active and potentially active faults in the counties surrounding San Francisco Bay as part of a program to define and clarify geologic hazards in the region. Much more detailed information about known faults has been collected; in addition, poorly known or previously unknown zones of demonstrable or suspected active faulting have been delineated. Documentation of these zones is of immediate importance because of both their scientific and social impacts.

The purpose of this map is to outline the diverse points of geologic and geophysical evidence that strongly suggest historic tectonic movements on a previously unrecognized fault in the vicinity of Antioch, Calif. Although the weight of evidence for recent fault activity is large, it is emphasized that each point of evidence is by itself inconclusive--there remains a remote possibility that the fault is no longer active and that the apparent evidence for recent movement is only a chance alinement of features that are not fault produced.

The fault with suspected recent movements is exposed in the hills southeast of Antioch where it cuts Tertiary rocks. Fault offsets are particularly clear where the Miocene Neroly and Cierbo Sandstones are drag folded, brecciated, and secondarily cemented with calcite. These relatively resistant, well-exposed formations are stratigraphically offset about 1,000 feet along the fault; offsets on other formations are not as obvious owing to very poor exposures and lack of distinctive marker beds, but the alinement of erosional valleys and ridge saddles in the poorly exposed rocks along the projected trace of the fault indicate that strata as young as Blancan (early Pleistocene) have been offset. Projection of the well-exposed part of the fault along its strike to the south-southeast would connect it with the Davis fault (Brabb and others, 1971) in the vicinity of Lone Tree Valley. A projection north-northwestward through Antioch is remarkably coincident with the linear ridge of Frazier Shoal in the San Joaquin River and with the linear western edge of the Montezuma Hills north of the river. Movement on a single, straight fault with a strike of about N. 25° W. is most likely responsible for both the stratigraphic offsets south of Antioch and these linear features to the north.

Fractures with right-lateral offsets and compressional buckles in walks and curbs in Antioch are coincident with the projected trace of the fault and supply the most compelling evidence for recent movements on the fault. However, because these features are small and are distributed through a zone about 200 feet wide, they are not obvious in the numerous fractured and buckled walks and curbs that occur throughout the city. Much of Antioch has been constructed on a discontinuous veneer of loose, permeable, wind-blown sand that overlies a relatively impermeable hardpan developed on alluvial deposits. Larger and more obvious disturbances in walks and curbs throughout the city result from instability of the sand veneer and the pressure of tree roots that are kept shallow by the underlying hardpan.

Offset fractures shown on the map on east-west streets are considered anomalous because they are not caused by tree roots, they are preponderantly right-lateral in sense of offset, and they cut across structural units in walks and curbs rather than along expansion joints or other pre-existing lines of weakness. Likewise, the compressional buckles shown in the zone on north-south streets are anomalous because they are not caused by tree roots and the amount of shortening caused by compression is not compensated by nearby extension. This zone of anomalous features is most readily explained as resulting from recent small tectonic movements (or "creep") on a fault that appears to be alined with the zone.

Under ideal circumstances, offset fractures and buckles should occur along a narrow trace on all walks and curbs above a creeping active fault, and offset fractures should affect entire walk and curb complexes on both sides of streets that cross a fault. Furthermore, the oldest walks and curbs should display the greatest amount of disturbance, and there should be a general positive correlation between the amount of disturbance on structures and their age. The situation in Antioch is far from ideal in a number of respects: 1) The offsets and buckles that are presumed to result from fault creep are spread over a broad zone instead of a narrow trace. However, creep on multiple fault strands or diffusion of strain in the loose sand veneer could produce this distribution. 2) The zone of offset fractures and buckles is not evident on every street that crosses the presumed trace of the fault. However, fault displacements in some parts of the zone could occur entirely on expansion joints and thus be completely lost amid the nontectonic disturbances. Also, only walks and curbs built before the mid-1960's appear to be affected; structures dated as 1966 and younger do not display the anomalous features that are presumed to result from fault creep. 3) Similar disturbances on both sides of streets are uncommon; many streets that cross the presumed trace of the fault are seemingly disturbed on only one side. However, in all cases this could have been caused either by movement entirely on expansion joints or by replacement of disturbed walks and curbs during 1966 and younger patchwork repairs. 4) There is no obvious correlation between the age of a fractured walk or curb in the presumed zone of creep and the net lateral offset on the fractures. However, data are sparse because few walks or curbs are dated, and much unmeasured offset may occur on joints.

In addition to this evidence in Antioch, suggestions of recent fault creep are displayed by the Contra Costa Canal and by the alluvial fill of a small valley southeast of the city. The canal, which was built in 1940, is free of any significant structural problems except where it crosses the projected trace of the fault. The linings on both sides of the canal at this point are bulged inward and the lining on the south side is fractured and offset. However, this is a low area in the natural topography, and a drain pipe enters the canal where the lining is buckled--the distortions in the canal could result entirely from normal problems associated with swampy, poorly drained foundation conditions. In the small valley south of Lone Tree Valley there is a slight step in the Holocene valley fill along what has previously been recognized as the trace of the Davis fault. Alluvium on the higher, western side of this step is entrenched to the level of the eastern side, suggesting that the step is a fault scarp of recent origin.

Distortions in sidings of the Atchison, Topeka, and Santa Fe Railroad in the northwestern corner of Antioch and structural problems in the cafeteria of the John Fremont School in the center of the city should also be mentioned because they occur within the zone of offset and buckled walks and curbs and may be indirectly related to the effects of fault creep. Two of the three railroad sidings, which are not as rigorously maintained as the main line, are distorted and out of alinement with the main line; the third siding is comparatively straight and parallel to the main line. These distortions may reflect ongoing fault creep and partial maintenance since 1915--the date on the siding track--but the sidings are laid on a base of windblown sand and swamp deposits, and normal instability in these materials could be the entire cause of track distortion. The cafeteria of the John Fremont School has undergone distortion since 1965; northeast-southwest extension and relative downdrop to the northeast is expressed by fractures and buckles in the walls and floor. Other man-made features in the vicinity have been undisturbed since 1965, however, and it is thus unlikely that fault creep is the immediate cause of the structural problems. Differential settling or movement of the underlying alluvium and windblown sand could nonetheless be localized along discontinuities formed in these materials during earlier fault creep.

The seismic record for the Antioch area supports the likelihood of recent fault movements in and near the city and fits well with the observation that anomalous fractures and buckles do not occur on walks and curbs built after 1965. Numerous earthquakes have occurred in historic time in the area, including one in May of 1889 that caused major structural damage in Antioch and the town of Collinsville, on the western edge of the Montezuma Hills. Although they must be interpreted with some caution (see Brabb, 1967, for example), plotted epicenters for earthquakes in the past decade (Bolt and others, 1968; Bolt and Miller, 1971) appear to define a zone that is coincident with the mapped fault and the zone of presumably fault-produced features. A swarm of small earthquakes in Antioch in 1965 (McEvilly and Casaday, 1967) is of particular significance because the swarm is believed to have been generated by right-lateral motion of a fault having a north-northwest strike, and because this last significant seismic activity in the area could have been coeval with the youngest (pre-1966) presumed tectonic movements in the city.

Given the coincidence and correspondence of the different lines of evidence discussed above, it appears extremely likely that a fault having right-lateral strike-slip motion cuts the alluvium beneath Antioch and that movement and associated earthquakes periodically occur along the fault--the last episode of movement having taken place in 1965. Additional detailed studies such as precise microseismic monitoring, triangulation across the zone of presumed fault creep to detect small future increments of strain, and trenching across the zone to search out fault offsets in the alluvium beneath the city would help to resolve any remaining doubt about the existence of the fault and its recent activity. Future study may also demonstrate whether the Davis fault has been recently active north of Lone Tree Valley and may provide information about the rate of creep and periodicity of creep events on these faults.

References Cited

Bolt, B.A., Lomnitz, C., and McEvilly, T.V., 1968, Seismological evidence on the tectonics of central and northern California and the Mendocino escarpment: Bull. Seismol. Soc. America, v. 58, p. 1725-1767.

Bolt, B.A., and Miller, R.D., 1971, Seismicity of northern and central California, 1965-1969: Bull. Seismol. Soc. America, v. 61, p. 1831-1847.

Brabb, E.E., 1967, Chittenden, California, earthquake of September 14, 1963: Calif. Div. Mines and Geol. Spec. Rpt. 91, p. 45-53.

Brabb, E.E., Sonneman, H.S., and Switzer, J.R., 1971, Preliminary geologic map of the Mount Diablo-Byron area, Contra Costa, Alameda, and San Joaquin Counties, California: U.S. Geol. Survey open-file map (scale 1:62,500).

McEvilly, T.V., and Casaday, K.B., 1967, The earthquake sequence of September 1965 near Antioch, California: Bull. Seismol. Soc. America, v. 57, p. 113-124.

NOTES TO ACCOMPANY NUMBERED MAP LOCALITIES

Localities with heavy outlines display the best evidence for recent fault creep. Except where otherwise stated, fractures that are mentioned cut across structural units, rather than along pre-existing joints.

1.--Distorted railroad sidings; main-line tracks seemingly undisturbed.

2.--Right-lateral offsets on curbs on both sides of street. Horizontal displacements of 2 mm on north side, 7 mm on south. No walks on street.

3.--No offset fractures on 1970 walks and curbs.

4.--Zone of thoroughly fractured asphalt in street trending N20W. Undisturbed 1973 walk and curb on extension of zone on east side of street.

5.--Fractures but no offsets between joints on old curbs on both sides of street. Newer walks undisturbed.

6.--Dirt road with no walks or curbs.

7.--Right-lateral offsets on old curbs on both sides of street. Horizontal displacement of 4 mm on north side, 2 mm on south. Walks recently replaced and undisturbed.

8.--Right-lateral offset of 2 mm on old curb on north side of street; no disturbance in younger (1966?) walk. Right-lateral offset of 12 mm along joint on old curb on south side alined with 2 mm offset between joints on old walk.

9.--Two fractures with 1 mm of right-lateral offset each on old curb on north side of street; new walk undisturbed. One fracture but no lateral offsets between joints on old curb on south side; new walk undisturbed.

10.--East-west buckle with about 15 cm of relief on west side of road with joint on crest. Old curb and asphalt-covered concrete street are buckled, but new walk undisturbed. Buckle dies out eastward, and east side of street is unaffected.

11.--East-west buckle with about 2 cm relief on east side of street in walk and curb with numerous patchwork repairs; joint on crest. Buckle dies out westward, and west side of street is unaffected.

12.--Broad east-west buckle with about 3 cm of relief on walk and curb on east side of street.

13.--Patchwork repair of curbs with many fractures of inconsistent offset in older portions. No offsets on more uniform younger walks.

14.--Patchwork repair of walks and curbs. No obvious buckles unrelated to tree root growth.

15.--No offset fractures between joints; inconsistent small offsets along joints.

16.--Right-lateral offset of 5 mm and other slight left- and right-lateral offsets on old curb on north side of street. Right-lateral offset of 3 mm on old curb on south side. Numerous left- and right-lateral offsets on walks on both sides of street.

17.--Three offset fractures on 1948 curb on north side of street: 5 mm right lateral with adjacent undisturbed young walk; 1 mm right lateral with adjacent 1948 walk similarly offset 2 mm; 2 mm left-lateral with adjacent 1948 walk undisturbed. Three right-lateral offsets of 1, 2, and 3 mm and two left-lateral offsets of 1 and 3 mm om 1948 walk and curb on south side.

18.--Open cracks as much as 1 cm wide in north and east walls of cafeteria and generally northwest-southeast fractures in floor with extension and relative down-drop to the northeast of about 5 mm.

19.--Right-lateral offset of 7 mm on pre-1965 curb on south side of street adjacent to undisturbed 1966 walk; undisturbed 1966 repair patch in walk and curb on north side.

20.--Numerous fractures with no offsets or with right-lateral offsets of less than 2 mm in 1957 walks and younger (but pre-1965) curbs. Fractures on north side of street occur largely in western part of area; fractures on south side occur largely in eastern part.

21.--Thoroughly disturbed old walks, curbs, and asphalt-covered concrete street with many large trees. No obvious anomalous offsets or buckles.

22.--Fractures with no offsets or with right-lateral offsets of less than 2 mm on old curb on north side of street; undisturbed new curb. Undisturbed new walk and curb on south side.

23.--No obvious distortion of railroad tracks, although much of the original siding has been removed.

24.--Right-lateral offset of 2 mm and left-lateral offset of 1 mm on pre-1960 curb on north side of street; undisturbed 1972 walk. Two right-lateral offsets on south side: 5 mm offset on pre-1960 curb with undisturbed new walk; 2 mm on pre-1960 curb, walk, and low retaining wall.

25.--Largely new, undisturbed construction. Many large trees near remaining older construction; no obvious anomalous offsets or buckles.

26.--East-west buckles in early-1960's walks and curbs with about 2 cm of relief

27.--Two left-lateral offsets of less than 1 mm on early-1960's walk and curb on north side of street. Right-lateral offset of 8 mm on similar walk and curb on south side.

28.--On north side, canal lining bulged inward about 4 cm and left-laterally offset about 5 mm. On south side where drain pipe enters canal, lining bulged inward about 5 cm.

29.--Indistinct, east-facing step in alluvium no more than 15 cm high. Stream channel on higher, western side entrenched to level of eastern side.

EXPLANATION

See Brabb and others (1971) for description of Tertiary rock units

QUATERNARY

Holocene

Qys — Unconsolidated younger alluvial and marsh sediments

Pleistocene

Qos — Partly consolidated older alluvial sediments. Includes overlying discontinuous veneer of loose windblown sand on margin of San Joaquin River

TERTIARY

Pliocene

Tt — Tehama Formation (Wolfskill Formation of Brabb and others, 1971)

Miocene

Tne — Neroly Sandstone

Tc — Cierbo Sandstone

Eocene

Tmk — Markley Sandstone

Tnv — Nortonville Shale Member of the Kreyenhagen Formation

Td — Domengine Sandstone

Tme — Meganos Formation

CONTACT

FAULT: Dashed where effect on Quaternary deposits unknown. Letters (U-up; D-down) and arrows show principal directions of fault offsets. Hachure pattern represents zone of calcite-cemented fault breccia. Stipple pattern represents zone of anomalous features in the city of Antioch that seemingly result from recent fault creep

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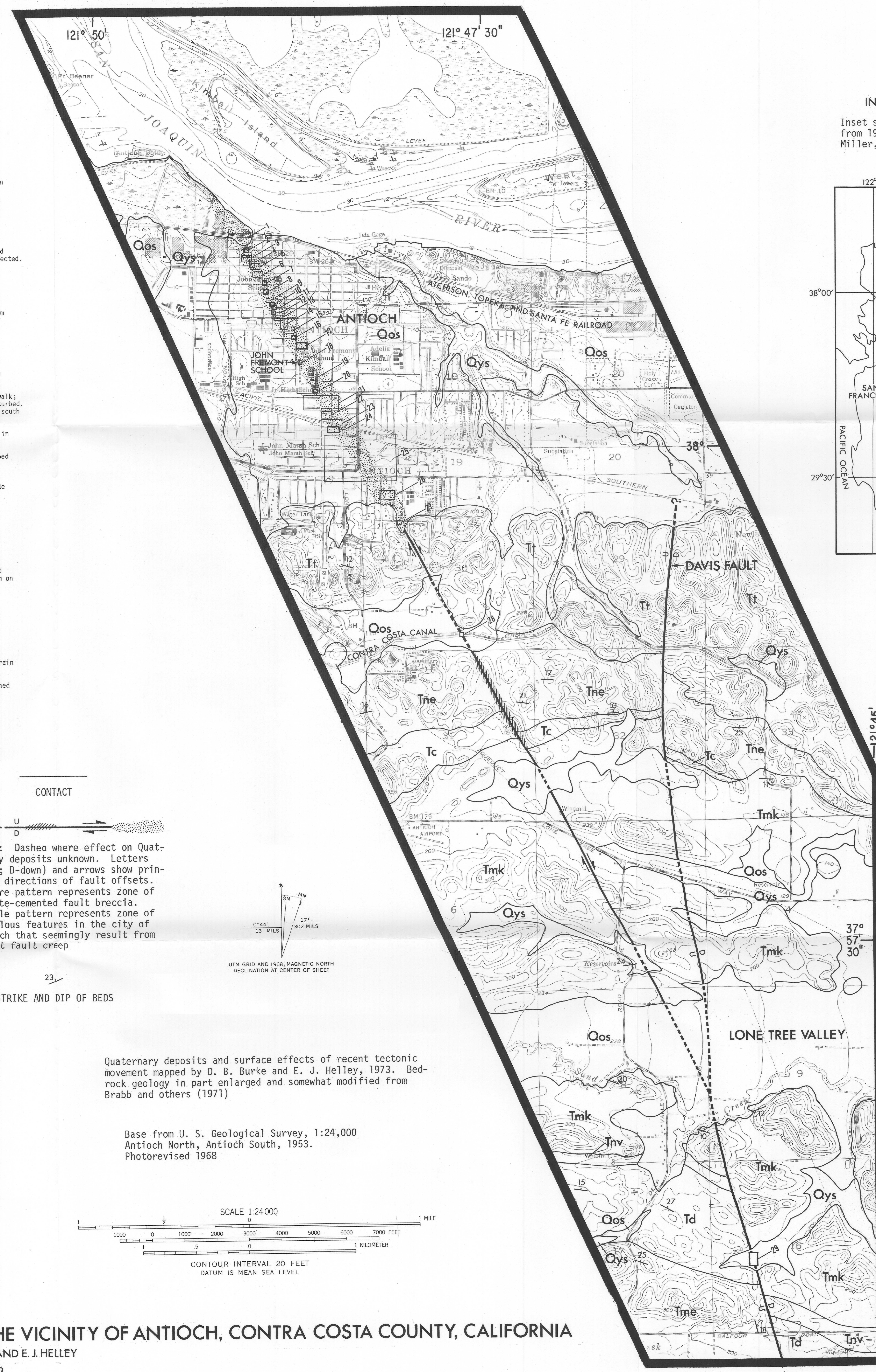
STRIKE AND DIP OF BEDS



UTM GRID AND 1968 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Quaternary deposits and surface effects of recent tectonic movement mapped by D. B. Burke and E. J. Helley, 1973. Bedrock geology in part enlarged and somewhat modified from Brabb and others (1971)

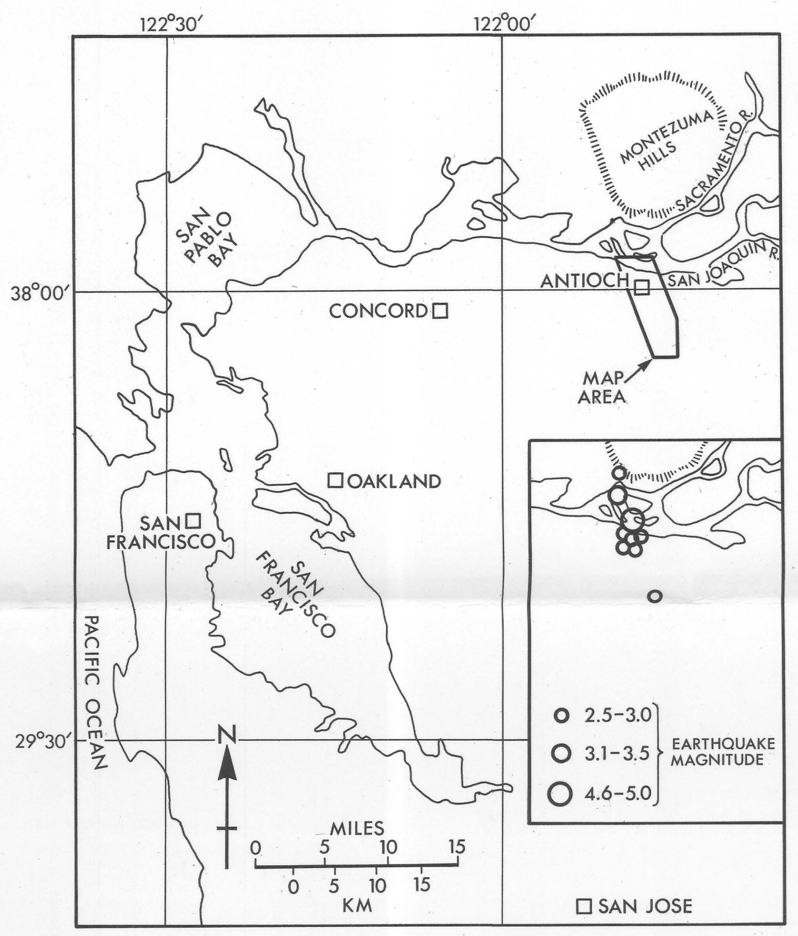
Base from U. S. Geological Survey, 1:24,000 Antioch North, Antioch South, 1953. Photorevised 1968

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

INDEX MAP OF SAN FRANCISCO BAY REGION

Inset shows seismic events in the vicinity of Antioch from 1962 to 1969 (Bolt and others, 1968; Bolt and Miller, 1971).



MAP SHOWING EVIDENCE FOR RECENT FAULT ACTIVITY IN THE VICINITY OF ANTIOCH, CONTRA COSTA COUNTY, CALIFORNIA

BY D.B. BURKE AND E.J. HELLEY

1973

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