DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

A CONTRIBUTION OF THE NATIONAL CENTER
FOR EARTHQUAKE RESEARCH

MISCELLANEOUS GEOLOGIC INVESTIGATIONS
MAP I–574 SHEET 1 OF 2

A

B

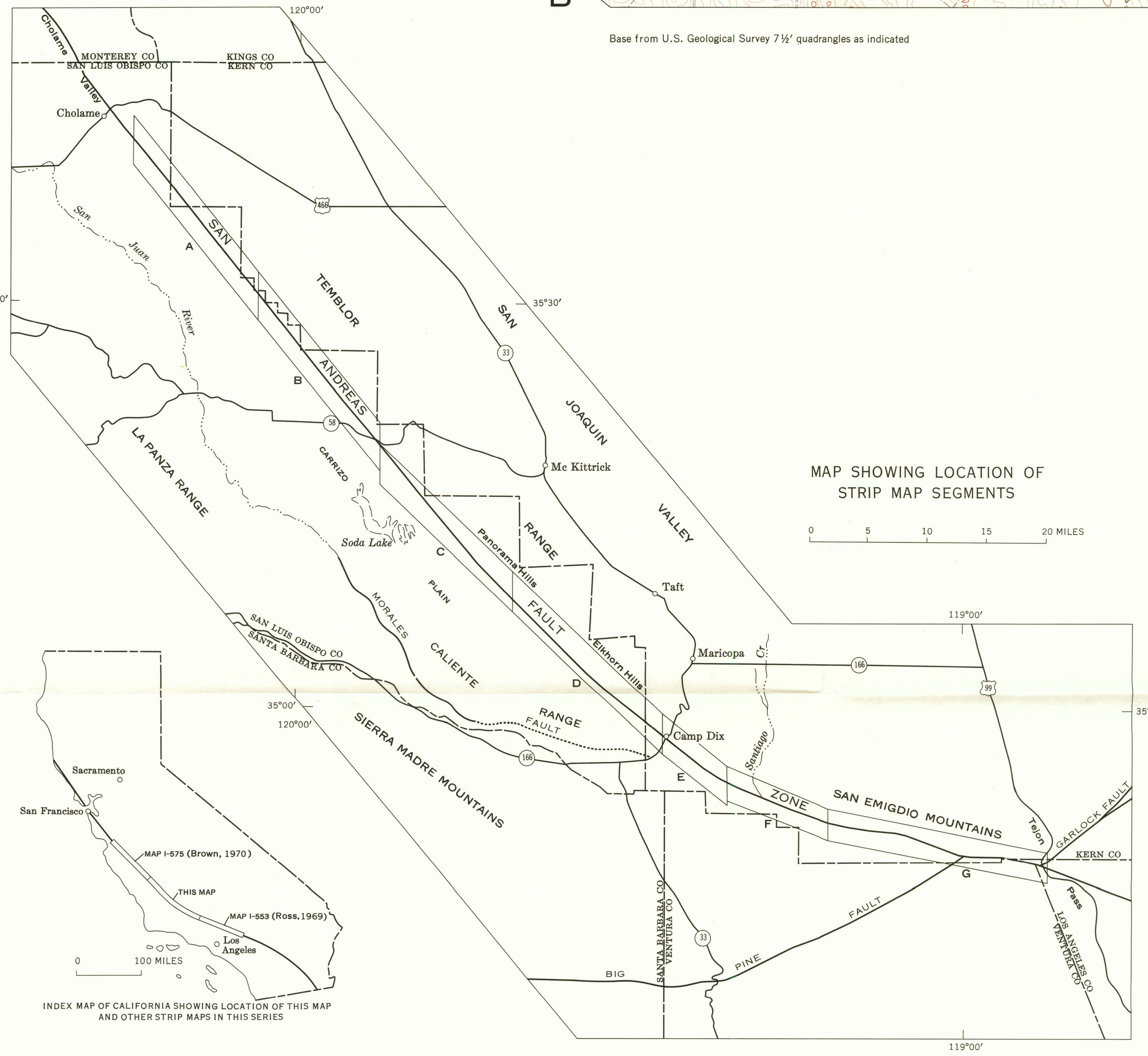
Base from U.S. Geological Survey 7½' quadrangles as indicated

Geology mapped in 1968

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1970

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET EXCEPT FOR SIMMLER AND LAS YEGUAS (40 FEET)
DATUM IS MEAN SEA LEVEL



PURPOSE OF THIS STRIP MAP

This map is one of a set that shows the lines of inferred most recent movements on the San Andreas fault. The character and location of these lines are important to scientists and engineers who study faulting and earthquakes and should be helpful to those concerned with land use and development on or near the fault. The mapped lines mark suspected displacements of the ground surface by rupture or creep along the fault. Map users should keep in mind that these lines are primarily guides for locating fault traces on the ground and are not necessarily located with the precision needed for every engineering or land-use project.

THE SAN ANDREAS FAULT AND FAULT ZONE

The San Andreas fault zone is a major structural break in the earth's crust that can be traced at the surface for more than 600 miles from near the Mexican border northwestward through western California. It crosses the shoreline near Point Arena and is believed to extend northward offshore at least as far as Cape Mendocino. Movement within the fault zone has been distributed along many parallel or subparallel faults that differ in age and in amount of relative displacement. This complex zone of movement ranges in width from a few hundred feet to several miles and presumably has had tens or scores of miles of cumulative horizontal offset during late Cenozoic time (25 ± million years). This zone or band of interrelated faults is termed the *San Andreas fault zone* (*or rift zone*) in contrast to the *San Andreas fault*, which is the surface trace of most recent, or historic, movement (Noble, 1926, p. 416–417). The *San Andreas fault system* is a much broader term (Crowell, 1962, p. 4) that incorporates subparallel major fault zones, similar to the San Andreas fault zone, that form a belt more than 150 miles wide in southern California.

LOCATION OF FAULT BREAKS

The faults shown on this map were located both by on-the-ground investigation and by interpretation of vertical aerial photographs. Most of the segment from Cholame Valley to Camp Dix was examined on the ground by Wallace, and the segment from the southeastern part of the Panorama Hills to a point 4 miles southeast of Camp Dix was mapped independently by Vedder. From this point to Highway 99 through Tejon Pass, the fault breaks were located primarily by photo interpretation by Vedder, but were corroborated in part by spot checks on the ground and by airplane overflights. Several sets of aerial photos were used, including U.S. Department of Agriculture, Commodity Stabilization Service, 1954, 1956, 1957, scale 1:20,000; U.S. Department of the Interior, Geological Survey, 1966, 1967, scale 1:6,000 and 1:12,000; and National Aeronautics and Space Administration, 1965, scale 1:24,000.

A combination of visual inspection and projection was used to transfer lines from the photographs to the topographic base maps; at places the fault traces were plotted directly on the base maps in the field with the aid of stereoscopic pairs of photos. Features large enough to show at the scale of this map are generally accurate to within 50 feet along the main trace, but may be as much as 150 feet off in areas of low relief where map contours are far apart and do not delineate small-scale fault features. Geologists and engineers who make specific use of these maps should confirm the location of lines by surveying from control points on the ground and should determine whether the mapped features are truly fault controlled.

FIELD RECOGNITION OF MOST RECENT FAULTING

Recently active fault breaks can generally be recognized on the basis of topographic features or contrasts in vegetation that reflect varying ground water depths or soil differences across the fault. The most common features are scarps, trenches or troughs, notches, parallel ridges, offset drainage channels, sag ponds, ponded alluvium, undrained depressions, and shutter ridges. These features have been developed by repeated movements and by erosion and deposition along the fault. Horizontal shifting and vertical displacements amounting to a few inches or a few feet result from successive shifts accompanied by earthquakes, from intervals of slow tectonic creep between earthquakes, or from a combination of both. Regardless of their origin, the displacements produce scarps and other topographic features that delineate the fault lines shown on the map. The annotations along the fault traces indicate selected examples of these features that are not limited to the designated places; similar features are present to some degree along all the mapped fault lines. As opposing fault blocks slide laterally, some blocks are relatively depressed to form sags or sag ponds, or elongate graben may form between parallel breaks. Other slivers are raised, tilted, or slid diagonally to produce elongate ridges and shutter ridges. Notches and trenches or troughs along the fault may reflect increased erosion of the crushed and broken rocks in the fault zone, or they may be primary fault features.

Surface features that result from faulting are geologically temporary. Their recognition is limited by the durability of small, easily destroyed geomorphic features whose preservation is largely dependent on climate. In arid regions, such as the Mojave Desert or the Carrizo Plain, these fault features are best preserved and, in some cases, may be older than similar features in more humid regions. They may be obliterated by erosion or vegetation; may be obscured or covered by deposition of alluvium or other sediment; or may be modified or destroyed by works of man. Where slip has been entirely lateral (strike slip), relief may not have been produced and the recently active break may not be identifiable. Only when fault movement is relatively young are fault features as well preserved as those along the San Andreas fault zone.

LAND USE SIGNIFICANCE OF LOCATING RECENT FAULT BREAKS

Sudden movement along the San Andreas fault in 1857 within the area of this strip map, and again in 1906 in central California, duced disastrous earthquakes. In 1857, horizontal displacement across the fault may have been as much as 30 feet at places; in 1906, similar dislocations amounted to as much as 20 feet. In 1940, severe structural damage resulted from horizontal movements of as much as 14 feet along the Imperial fault, part of the San Andreas fault system. Measurable tectonic creep along the San Andreas fault near Hollister is slowly rending a building that straddles an active strand in the fault zone (Tocher, 1960), and similar creep along the Hayward fault zone is dislocating railroad tracks, a culvert, a water tunnel, and a building (Radbruch and others, 1966). A pipeline, sidewalks, walls, and foundations are being offset in the city of Hollister by tectonic creep in the Calaveras fault zone (Rogers and Nason, 1967). Within the area of the adjoining strip map to the north (Brown, 1969), tectonic creep along recently active fault breaks in the San Andreas fault zone is indicated by the deformation of fences and by fractures in paved roads (Brown and Wallace, 1968); and ground breakage during the 1966 Parkfield-Cholame earthquakes closely followed previously mapped fault traces (Brown and Vedder, 1967, p. 4). Geomorphic studies of the fault zone by Wallace (1968) within the Carrizo Plain area of this map show that displacements have recurred many times along the same break during the last 10,000 to 20,000 years.

In summary, all these observations suggest that the line of most recent ground breakage is likely to break again during future major earthquakes. Thus, the most recently active breaks should be recognized as geologically hazardous by builders, planners, engineers, landowners, school boards, civil defense officials, and others; or by anyone concerned with existing man-made structures, land utilization, or planned construction on or near these most recent fault breaks. At present, no one can predict when movement on these faults will recur or which ones will move next, but it is virtually certain that some will move again. It should not be inferred, however, that movement will be confined entirely to these mapped features or that movement will occur on all of them. Surface fracturing may develop anywhere within the fault zone or on branching or otherwise related faults beyond the fault zone. Gaps or discontinuities along the main fault trace do not necessarily represent stable or unfaulted segments; they are merely places where no evidence for recently active faulting was observed.

SPECIAL FEATURES OF THE SEGMENT BETWEEN CHOLAME VALLEY AND TEJON PASS

The most conspicuous feature of this segment of the San Andreas fault is the large bend in the southern part between Santiago Creek and Tejon Pass. Here the fault trace deviates nearly 40° from its relatively consistent trend of N. 40° W. northward through the Carrizo Plain. The cause of this bend is highly conjectural (Hill and Dibblee, 1953; Benioff, 1955); it may be related to crustal warping that has resulted from lateral shifts on the Big Pine and Garlock faults, which intersect the San Andreas fault at about 40° within the bent segment; it may result from buckling due to compression in the Transverse Ranges; or it might simply represent the path of least resistance between relatively rigid crustal blocks.

Some of the widest zones of recently active breaks along the San Andreas fault are shown on this strip map, particularly in the Elkhorn Hills and in a belt about 4 miles long southeast of Highway 33. The widest of these zones is nearly 1½ miles across in the central Elkhorn Hills and southeastern Carrizo Plain. Presumably, the west-trending traces located 2 miles southeast of Camp Dix on Highway 33 are related to the Morales fault, a range-front reverse fault along the southwest side of the Caliente Range. Similar topographic lineaments with a northwest trend are evident in the low hills south of Highway 33, near the San Luis Obispo–Kern County line about 3 miles southwest of Camp Dix, but are not related to any known major fault. Active faulting in this general area about 1900 is reported by Upson and Worts (1951, p. 39).

It is noteworthy that the main trace is a nearly continuous line, or pair of lines, throughout much of the Carrizo Plain and is not as fragmented or disconnected as depicted on adjoining strip maps to the northwest and southeast (Allen, [in press;] Brown, 1970; Ross, 1969). In addition, many more subparallel and branching traces are mapped on this segment. No doubt these differences are attributable, in part, to the better preservation of fault features and the lack of vegetation in this extremely arid region, though it is possible that this segment of the fault has behaved differently than other segments.

Minor fault features that probably resulted from the great earthquake of 1857 are preserved at a number of places along the Elkhorn Scarp; these small-scale features include remnants of pressure ridges (mole tracks), en echelon fractures, and slightly modified scarplets 1 to 3 feet high.

An unusual set of fault-bounded depressions, a few thousand feet long by 500 to 1,000 feet wide, near the northwest end of the Elkhorn Hills in sec. 34, T. 32 S., R. 22 E., may be graben developed by spreading of the uplifted unconsolidated Quaternary deposits that form the bulk of the hills. The curved shape of several of these graben may represent gradual distortion by progressive and repeated drag within the broad fault zone and adjacent to the main fault trace. The spreading of the Quaternary deposits combined with landsliding may also have produced the large elongate ridges that make up prominent elements of the Elkhorn Scarp in the Wells Ranch and Elkhorn Hills quadrangles. Possibly these elongate ridges, which lie along the southwest side of the main fault trace, have been displaced relatively northwest about 2 miles. Open trenches or cracks that occur in several undrained depressions in the Elkhorn Hills may be tension cracks related to the spreading of the Quaternary deposits.

For about 6 miles northwest of Camp Dix, the fault zone is partially obscured and the fracture pattern is confused by large landslides that have moved down the northeast flank of the Caliente Range to form large closed depressions. In this segment the main trace is clear, but subparallel and branching fractures on the southwest side may be modified or obscured by the landslides, and some fractures are related entirely to landsliding. Similarly, in the steep-sided canyon along parts of Santiago Creek and adjoining creeks on strip F, even the main trace of the fault has been obscured and modified by landslides.

The fact that there is no evidence for movement since 1857 in any part of the mapped area seems puzzling when segments farther north are undergoing relatively rapid rates of tectonic creep. Fences as old as 50 years cross the fault trace at several places between Cholame Valley and Camp Dix, but show no offset (Brown and Wallace, 1968). Micro-earthquakes recorded by Brune and Allen (1967) along the San Andreas fault in southern California are strikingly few in the Carrizo Plain region. In the same region, horizontal displacements of as much as 30 feet may have accompanied the 1857 earthquake, or may have resulted from a combination of sudden slip at the time of the earthquake and slower slip or creep in weeks or months immediately following the earthquake; and repeated offsets of similar magnitude presumably have occurred during the past 10,000 to 20,000 years (Wallace, 1968). This apparent contrast in rate and type of movement between the Carrizo Plain segment and more northerly segments is discussed more fully by Brown and Wallace (1968).

ANNOTATED REFERENCES

Allen, C. R., 1968, The tectonic environments of seismically active and inactive areas along the San Andreas fault system, *in* Conference on geologic problems of the San Andreas fault system: Stanford Univ. Pubs. Geol. Sci., v. 11, 374 p.
Two segments of the San Andreas fault have produced great earthquakes in historic time (1857, 1906) but are now relatively inactive, while the remaining three segments are the locus of numerous small earthquakes and fault creep. These two types of fault segments are discussed with their relationship to differing basement rock types, large bends in the fault, and areas of branching or en echelon faults.

Benioff, Hugo, 1955, Relation of the White Wolf fault to the regional tectonic pattern, *in* Oakeshott, G. B., ed., Earthquakes in Kern County, California, during 1952: California Div. Mines Bull. 171, p. 203–204.
The incompatibility of regional movements on the San Andreas fault and the Garlock-Big Pine faults with respect to movement on the White Wolf fault and to the big bend in the San Andreas fault in the San Emigdio Mountains is discussed in this paper.

Brown, R. D., Jr., Vedder, J. G., Wallace, R. E., Roth, E. F., Yerkes, R. F., Castle, R. O., Waananen, A. O., Page, R. W., and Eaton, J. P., 1967, The Parkfield-Cholame, California, earthquakes of June-August 1966—Surface geologic effects, water resources aspects, and preliminary seismic data: U.S. Geol. Survey Prof. Paper 579, 66 p.
Surface faulting, movement rates, engineering geology, and seismic activity along an active 23-mile segment of the San Andreas fault are described. Fault movements are related to a 5.5-magnitude earthquake and to its aftershocks of lower magnitude.

Brown, R. D., Jr., and Wallace, R. E., 1968, Current and historic fault movement along the San Andreas fault between Paicines and Camp Dix, California, *in* Conference on geologic problems of the San Andreas fault system: Stanford Univ. Pubs. Geol. Sci., v. 11, 374 p.
Between Paicines and Cholame, rates of movement at the fault zone are determined from offset fences, and recent activity is shown by fresh breaks in pavement. South of Cholame the most recent break along the fault shows no evidence of movement for at least 50 years, although this segment was active during the great Fort Tejon earthquake of 1857.

Brune, J. N., and Allen, C. R., 1967, A micro-earthquake survey of the San Andreas fault system in southern California: Seismol. Soc. America Bull., v. 57, no. 2, p. 277–296.
Micro-earthquakes (magnitude (M) <3) and ultramicro-earthquakes (–1.5 < M < O) recorded at several stations along the San Andreas fault indicate that the fault segment from Cholame south to Valyermo is relatively quiet—although it is known to be the site of the Fort Tejon earthquake of 1857. The frequency of micro-earthquakes correlates well with that of larger seismic events.

Carman, M. F., Jr., 1964, Geology of the Lockwood Valley area, Kern and Ventura Counties, California: California Div. Mines and Geology Spec. Rept. 81, 62 p.
This paper briefly describes geomorphic features along the San Andreas fault near Cuddy Valley.

Crowell, J. C., 1962, Displacement along the San Andreas fault, California: Geol. Soc. America Spec. Paper 71, 61 p.
Previously described displacement along the fault is reviewed, and suggested cumulative displacements of hundreds of miles are proposed for parts of the fault in southern California.

Crowell, J. C., 1964, The San Andreas fault zone from the Temblor Mountains to Antelope Valley, southern California: Am. Assoc. Petroleum Geologists—Soc. Econ Paleontologists and Mineralogists, Pacific Sec., and San Joaquin Geol. Soc., Guidebook, Bakersfield, Calif., 1964, p. 7–39.
The accompanying road log describes geomorphic features along the San Andreas fault zone and the maps show traces of the fault based on geologic evidence.

Dibblee, T. W., Jr., 1962, Displacements on the San Andreas rift zone and related structures in Carrizo Plain and vicinity (California), *in* Guidebook, Geology of Carrizo Plains and San Andreas fault: San Joaquin Geol. Soc. and Am. Assoc. Petroleum Geologists—Soc. Econ. Paleontologists and Mineralogists, Pacific Sec. (field trip), 1962, p. 5–12.
The geomorphology of the Carrizo Plain area, including the San Andreas fault zone, is described briefly; the contrasting geology on opposite sides of the fault is discussed at length. The accompanying road log further describes some of the topographic features along the fault and their origins.

Fletcher, G. T., 1967, Post late Miocene displacement along the San Andreas fault zone, central California, *in* Guidebook, Gabilan Range and adjacent San Andreas fault: Am. Assoc. Petroleum Geologists—Soc. Econ. Paleontologists and Mineralogists, Pacific Sec., Field Trip, 1967, p. 74–80.
Rocks now in the vicinity of the Pinnacles are correlated with those in the Temblor Range, and geologic relations that suggest 160 miles of right-lateral movement since late Miocene time are described.

Hill, M. L., and Dibblee, T. W., Jr., 1953, San Andreas, Garlock, and Big Pine faults, California—a study of the character, history, and tectonic significance of their displacements: Geol. Soc. America Bull., v. 64, no. 4, p. 443–458.
Evidence for large-scale cumulative right-lateral movements on the San Andreas fault is presented, and the tectonic relation of the Garlock and Big Pine faults to the San Andreas fault is discussed. A description of topographic features in the fault zone is included.

Lawson, A. C., and others, 1908, The California earthquake of April 18, 1906—Report of the State Earthquake Investigation Commission: Carnegie Inst. Washington Pub. 87, v. 1, pt. 1, 254 p.; pt. 2, p. 255–451.
This report contains photographs and descriptions of the San Andreas fault within the area of the strip map in a chapter entitled Pajaro River to the north end of the Colorado Desert, v. 1, pt. 1, p. 38–47, by H. W. Fairbanks.

Meade, B. K., and Small, J. B., 1966, Current and recent movement on the San Andreas fault, *in* Bailey, E. H., ed., Geology of northern California: California Div. Mines and Geology Bull. 190, p. 385–391.
Horizontal and vertical movements on various segments of the San Andreas fault are reported, including the one from the 35th Parallel to Cajon Pass, on which no significant dislocations were detected.

Noble, L. F., 1926, The San Andreas rift and some other active faults in the desert region of southeastern California: Carnegie Inst. Washington Year Book 25, 1925–1926, p. 415–428; reprinted 1927, Seismol. Soc. America Bull., v. 17, no. 1, p. 25–39.
This paper is one of the earliest in which distinction is made between the San Andreas fault zone and the San Andreas fault.

Oakeshott, G., B. 1964, Earthquakes in the San Andreas fault zone, Maricopa to Elizabeth Lake: Am. Assoc. Petroleum Geologists—Soc. Econ. Paleontologists and Mineralogists, Pacific Sec., and San Joaquin Geol. Soc., Guidebook, Bakersfield, Calif., 1964, p. 41–46.
Historic earthquakes along part of this strip map are reviewed, and a description of the effects of the great Fort Tejon earthquake of 1857, based on earlier accounts, is included.

Radbruch, D. H., Bonilla, M. G., Lennert, B. J., Blanchard, F. B., Laverty, C. L., and Cluff, L. S., 1966, Tectonic creep in the Hayward fault zone, California: U. S. Geol Survey Circ. 525, 13 p.
Evidence for tectonic creep along the Hayward fault zone is presented.

Rogers, T. H., and Nason, R. D., 1967, Active faulting in the Hollister area, *in* Guidebook, Gabilan Range and adjacent San Andreas fault: Am. Assoc. Petroleum Geologists—Soc. Econ. Paleontologists and Mineralogists, Pacific Sec., 1967, p. 102–104.
Active tectonic creep along the Calaveras fault zone in the Hollister area may be related to similar creep along the San Andreas fault zone southeast of San Juan Bautista. Evidence for this type of dislocation is illustrated.

Tocher, Don, 1960, Creep on the San Andreas fault [California]—Creep rate and related measurements at Vineyard, California: Seismol. Soc. America Bull., v. 50, no. 3, p. 396–404.
This paper describes the nature of active fault movement at a winery about 100 miles northwest of the north end of this segment of the San Andreas fault.

Upson, J. E., and Worts, G. F., Jr., 1951, Ground water in the Cuyama Valley, California: U.S. Geol. Survey Water-Supply Paper 1110–B, 81 p.
This paper includes a brief description (from reports by long-time residents) of ground breakage in eastern Cuyama Valley resulting from an earthquake around 1900.

Wallace, R. E., 1968, Notes on steam channels offset by the San Andreas fault, southern Coast Ranges, California, *in* Conference on geologic problems of the San Andreas fault system: Stanford Univ. Pubs. Geol. Sci., v. 11, 374 p.
Presents evidence for recurring movements along the same fault breaks and evidence that movement is right-lateral and spasmodic in the Carrizo Plain area.

Wood, H. O., 1955, The 1857 earthquake in California: Seismol. Soc. America Bull., v. 45, no. 1, p. 47–67.
Quotes from contemporary accounts and other old reports that describe the strongest earthquake in southern California since the arrival of the Spaniards.

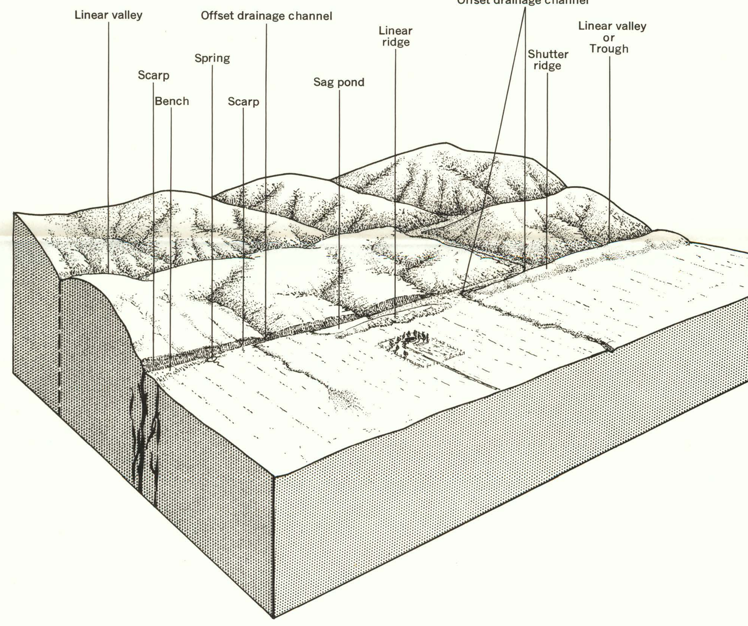
EXPLANATION

Fault traces

Solid line, field or photogeologic evidence of recent movement shown by scarp lines, trenches, sag ponds, spring lines, and vegetation contrasts

Dashed line, less obvious evidence of recent movement, but very probably a fault break

Brief notes along fault breaks indicate locations where features mentioned are especially clear. Visible fault features are not limited to the locations noted, but are present to some degree all along the mapped fault lines



BLOCK DIAGRAM SHOWING LANDFORMS PRODUCED ALONG RECENTLY ACTIVE FAULTS

MAP SHOWING RECENTLY ACTIVE BREAKS ALONG THE SAN ANDREAS AND RELATED FAULTS BETWEEN CHOLAME VALLEY AND TEJON PASS, CALIFORNIA

By
J. G. Vedder and Robert E. Wallace
1970

Other recently active breaks that have not produced distinctive surficial features may be present

For sale by U.S. Geological Survey, price $1.00 per set