FAULT ACTIVITY OF THE THREE POINTS AND PINE CANYON SEGMENTS, SAN ANDREAS FAULT ZONE, LOS ANGELES COUNTY, CALIFORNIA

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Investigations

Annotated fault maps of the Pine Canyon and Three Points segments of the San Andreas fault zone, in Los Angeles County have been prepared on orthophoto bases, at a scale of 1:12,000. Field mapping on stereopairs of aerial photographs as well as interpretation of several sets of aerial photographs has been the primary activity on this project.

Results

Mapping of fault traces and fault-related features within a 20 km stretch of the San Andreas fault zone that lies 15 km east-southeast of Gorman and 35 km west-northwest of Palmdale has been completed. Within the 114 square km area covered by the segment maps a cumulative total of more than 40 km of recently active fault traces and shear zones has been mapped.

An abundant and varied assemblage of geomorphic fault features and local geologic data provides extremely strong evidence for recent fault activity not only along the main trace of the San Andreas fault but also along many branch and secondary faults. Local widening of the fault zone is caused by faults clustered in complex concentrations of both right-stepping and left-stepping, en echelon, short fault strands. These zones of well-preserved faults are commonly less than 100 m wide but may be as much as 400 m wide, locally. Away from the San Andreas fault zone, longer faults (greater than 1 km) with well-preserved or youthful fault features occur both north and south of the main trace, although there appear to be more south of the fault.

Rocks of the pebbly arkose member of the Hungry Valley Formation (late Pliocene and early Pleistocene?) occur north of the San Andreas fault in the Pine Canyon area and appear to be offset right-laterally from lithologically similar rocks south of the fault which crop out 15 to 31 km to the west. The undivided rocks of the Hungry Valley Formation have apparently been offset about the same amount or at least within the same range of offsets.

The upper member of the Hungry Valley Formation north of the San Andreas fault is estimated to be offset right-laterally 12 to 27 km from like rocks south of the fault. The rocks north of the fault were deposited on early Miocene Neenach Volcanic rocks. Rocks of the Sandberg Formation, possibly late Pleistocene in age, derived from sources south of the San Andreas fault, were deposited on the upper Hungry Valley rocks north of the fault, and have subsequently been offset 6-9 km right laterally.

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The San Andreas fault, in the Three Points and Pine Canyon segments, has ample geomorphic and geologic evidence along it to demonstrate its recent activity. Within the 114 sq. km area of the segments a cumulative total of more than 40 km of recently active fault traces and shear zones has been mapped. Historic accounts bolstered by abundant field evidence indicates that the most likely time that movement last occurred on the faults was in 1857 at the time of the great Fort Tejon earthquake, estimated to have had a Richter magnitude of 8.0 or greater.

Intensive field work and stereoscopic investigation of a variety of aerial photographs was necessary to collect the evidence that readily indicates or can be inferred to suggest the existence and location of the faults. Mapping was done on large scale air photos and the data were transferred to orthophoto bases, with scales of 1:12,000, to produce the maps. In many locations the geomorphic features could only be seen on the ground using the air photos as a guide.

An abundant and varied assemblage of geomorphic fault features (annotated on the maps) and local geologic data provides extremely strong evidence for recent fault activity not only along the main trace of the San Andreas fault but also along many branch and secondary faults. Local widening of the fault zone is caused by faults clustered in complex concentrations of both right-stepping and left-stepping, en echelon, short fault strands. These zones of well-preserved faults are commonly less than 100 m wide but may be as much as 400 m wide, locally. Areas lacking evidence of surface faulting along the main trace are due either to recent alluviation or the activities of man which have modified the surface.

Away from the San Andreas fault zone, longer faults (greater than 1 km) with well-preserved or youthful fault features occur both north and south of the main trace, although there appear to be more south of the fault.

Rocks of the pebbly arkose member of the Hungry Valley Formation (late Pliocene and early Pleistocene?) occur north of the San Andreas fault in the Pine Canyon area and appear to be offset right-laterally from lithologically similar rocks south of the fault which crop out 15 to 31 km to the west. The undivided rocks of the Hungry Valley Formation have apparently been offset about the same amount or at least within the same range of offsets.

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Within the boundary of the segment maps most of the land south of the San Andreas fault is National Forest;most of the land north of the fault and more than half of it along the main trace is privately owned. The compelling geomorphic evidence, annotated on the fault maps, suggests that wise use of the land along the fault includes taking into account the likelihood of fault rupture and/or other surface disruption along the fault and the avoidence of building structures across or near the mapped traces. The major access road to most of the area is the Pine Canyon Road. Breaching by fault displacement of the many places where the road crosses the San Andreas fault seem inevitable. It is recommended, therefore, that in the event of a major earthquake along this stretch of the fault, local residents equip themselves to be self-sufficient for a period of isolation that might last from several days to two weeks.

INTRODUCTION

Annotated fault maps of the Pine Canyon and Three Points segments of the San Andreas fault zone, in Los Angeles County, have been prepared on orthophoto bases, at a scale of 1:12,000. The 20 km stretch of the San Andreas fault zone, discussed in this report, lies 15 km east-southeast of Gorman and 35 km west-northwest of Palmdale (see figure 1). With the preparation of the maps accompanying this report the mapping phase of an intensive Division study (see References for products) of the precise location and the history of activity of fault strands of the San Andreas fault zone, over a total length of 100 km, has been completed.

Field mapping on stereopairs of aerial photographs as well as interpretation of several sets of aerial photographs has been the primary activity on this project. The work was divided so that Barrows mapped the eastern three-fourths of the Pine Canyon segment (in plate 1) which abuts the Lake Hughes segment completed by Beeby (1977, 1979). Kahle mapped the western one-fourth of the Pine Canyon segment (in plate 1) and the east half of the Three Points segment. The fault map of the entire Three Points segment (plate 2) includes information gathered while mapping the geology of the west half of the segment (Kahle, 1979). Although during the study, emphasis was placed upon faults and features associated with surface faulting, geologic units also were mapped where their distribution or attitude could contribute to interpretation of the presence or activity of faults. On the maps (plates 1 and 2) selected geologic units are

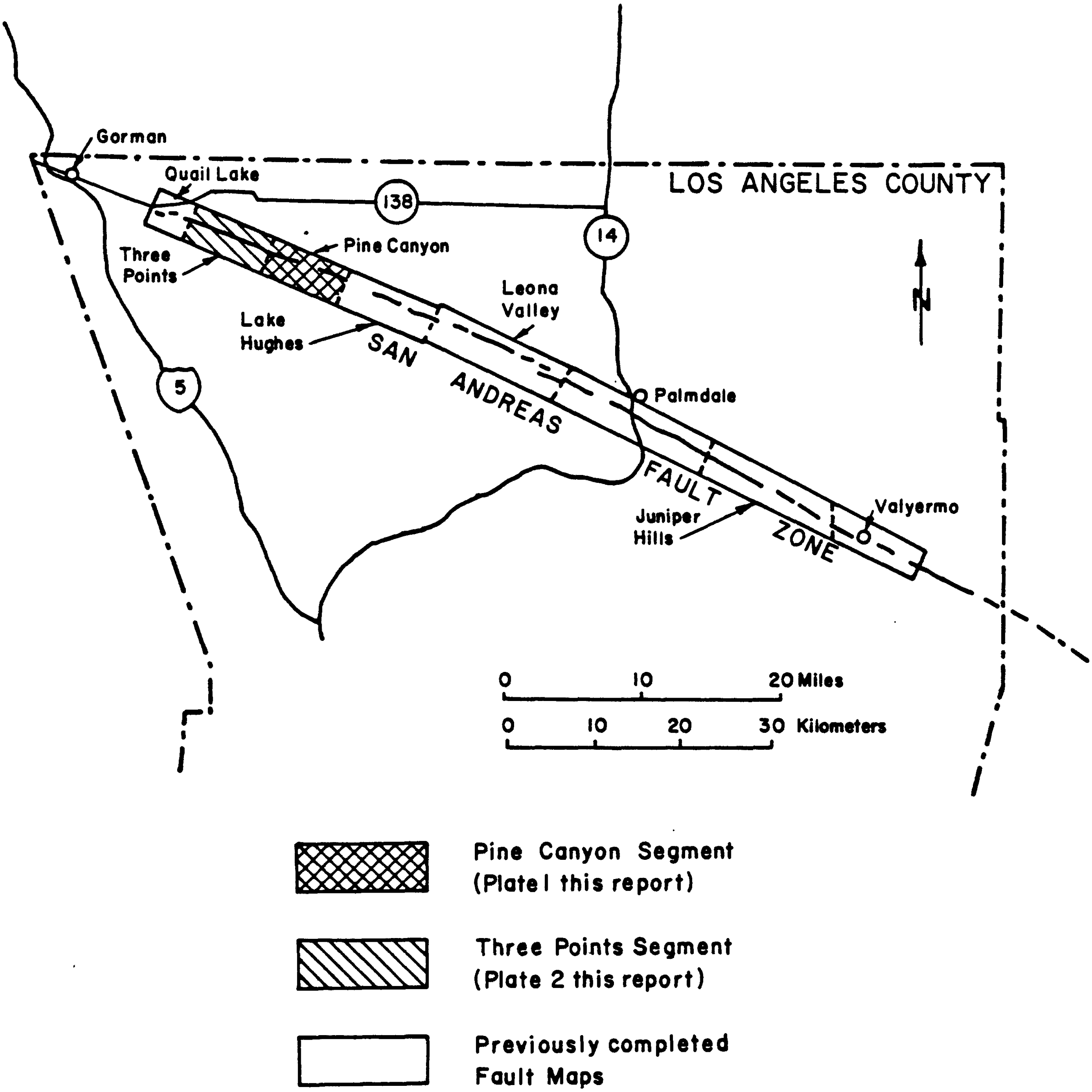

Figure I. Index map. Location of Pine Canyon and Three Points segments of San Andreas fault zone in Los Angeles County.

denoted by symbols and arrows that point to specific localities or by symbols that indicate a broad area of outcrop, rather than by conventional geological boundaries.

EVIDENCE FOR FAULTING

General

Although uncommon, the best evidence for faulting is, of course, an actual exposure of a fault. Where exposed, faults often display contrasting rock types that have been juxtaposed by fault movement. Locally, exposed fault planes exhibit dark gray, red-brown, or black clayey gouge that is commonly moist. However, it is much more typical for the primary evidence for faulting to consist of an array of distinctive geomorphic features or contrasts in soil, vegetation, or the depth to the water table. The purpose of the annotations on the fault maps is to record specific features that demonstrate, or imply, the presence of a fault. Citing the local evidence in this manner supports and amplifies, and in some cases justifies, the placing of fault lines on the maps.

Explanation of the Map Symbols

The current usage of symbols on the annotated fault maps is derived from that of Kahle, Smith, and Beeby on the Leona Valley (1975a) and Palmdale (1975b) segments of the San Andreas fault. Although revised, the following definitions correspond closely to those of Barrows (1977), Beeby (1977), and Kahle (1977).

AV - Aligned Vegetation. A linear arrangement or concentration of trees, brush, or grass commonly conspicuous on air photos. The line of plants, usually taller than the adjacent vegetation, is assumed to coincide with a fault because of more abundant soil moisture or more favorable soil texture.

B - Bench. A level, or nearly level, linear, narrow strip of terrain that appears shelflike along a slope. The long axis of a bench may slope considerably. Typically interrupts the smooth curvature of the slope profile. Apparently formed by oblique components of lateral movement on a fault that transects a slope such that relative upward movement of the downslope side decreases the slope angle to a limiting case defined as horizontal normal to its long axis. In contrast, if the upward movement of the downslope side continues beyond flattening the slope a trench (T) develops.

BC - Beheaded Channel. Drainage channel which terminates abruptly at or near a fault trace. Its upper reaches have been disrupted or displaced by faulting so that a corresponding channel on the upslope side of the fault can no longer be identified. Each is marked on the map at the point of termination. The displaced upper reach may be identified as a detoed channel (DT) if it survives.

CD - Closed Depression. Any concavity of the land surface with enough visible relief to trap water. The smaller basinlike features commonly contain fine silt or mud-cracked clayey soil within their confines. Closed depressions containing water and lying along a fault are also called sag ponds but are still designated as CD on the fault maps. Large closed depressions in the current segments include natural and man-modified ponds or lakes. Closed depressions identified on the map are believed to be the result of tectonic processes only.

DD - Deflected Drainage. Drainage channel deflected abruptly at the fault trace. May be due to tectonic and/or erosional processes. Usually used to designate the point at which at least two preexisting channel segments have joined because of erosional processes or because they have been moved close enough to one another by tectonic processes for erosion to link them together. Apparent offsets may be ambiguous where this symbol is used. Where offsets are clearly defined the offset channel symbol (OC) has been used.

DS - Displaced Surface. A rectilinear or curvilinear, steplike offset in a broadly uniform area that is gently to moderately sloping such as an alluvial fan or floodplain. The smoothness of a profile of the surface normal to the trend of the offset is interrupted at the offset. The slope angle may change across the line of offset. The downslope part of the surface may also have been uplifted so that an upslope-facing scarp has developed along the line of offset. Steep or abrupt offsets are commonly labeled as fault scarps on the maps.

DT - Detoed Channel. Drainage channel whose downslope end or toe terminates at a fault trace. Caused when movement along the fault is sufficient to displace the lower reach of a channel beyond the influence of the upper reach. The displaced lower reach could become a beheaded channel (BC) if it survives. Detoed drainages are marked on the map at the point of termination at or near the fault trace.

G - Fault Gouge. Soft, uncemented, pulverized, or clay-lake material found along a fault plane. It is formed by crushing and grinding of adjacent rocks as well as by subsequent decomposition and alteration. Denoted on the fault map because these are places where fault exposures can be examined and verified.

LD - Linear Depression. A linear closed depression whose length is at least twice its width. Resembles a swale but is closed at both ends.

LG - Linear Gully. A small ravine or gully eroded along a fault trace so that its long dimension nearly coincides with the trend of the fault.

LR - Linear Ridge. Elongated ridges parallel and adjacent to the fault trace. A linear ridge may occur on either side of a fault trace. Where parallel faults are close together linear ridges commonly occur between the fault traces.

MZ - Moist Zone. Areas along faults that are damp, muddy, and characterized by the presence of reeds, mosses, or abundant willows, etc., but at the time of the field visit did not exhibit flowing or open water (as does a spring). A result of the damming effect of a fault plane on ground water forcing it to rise to the surface.

N - Notch. A small saddle-like indentation in the profile of a ridge that is crossed by a fault commonly at a high angle to the trend of the ridge. These features commonly define the older as well as the most recent fault traces and may be due solely to erosion of shattered material along the fault. When combined with other evidence, they help to accurately delineate the most recently active faults.

OC - Offset Channel. Drainage channel of intermediate size (well-established as opposed to a gully) that has been offset laterally or vertically by movement along a fault. Along the San Andreas fault, such channels commonly indicate right-lateral displacement which may be the result of more than one episode of movement on the fault. Shown on the map by two leader lines indicating the location where channels intersect the fault trace, or by one leader line where offset is too small to delineate.

OG - Offset Gully, Short drainage channel or shallow ravine offset by lateral movement on a fault. Youthfulness of gullies implied by limited drainage area and shallowness of channel suggest recent activity upon faults that offset them. Shown on the map where the gully intersects the fault trace.

OR - Offset Ridge. An elongated or narrow ridge or spur formed across a fault by erosional processes and subsequently offset by movement on the fault. Some offset ridges may also be the result of movement on newly formed faults.

PA - Ponded Alluvium. An accumulation of alluvial debris along a channel or in a closed depression where movement along a fault has disrupted drainage courses or locally decreased the stream gradient. A shutter ridge (SR) may also block a drainage causing ponding of alluvium.

RC - Rock Contrast. Exposures of a fault or shear zone where dissimilar rock types can be seen on opposite sides of the fault.

SR - Shutter Ridge. Uplifted or horizontally shifted ridge that shuts off through-going drainage by blocking channels of streams that previously flowed across a fault. A shutter ridge blocking a channel will cause ponding of alluvium until an outlet for the drainage is reestablished. If, at the time of observation, a channel skirts the end of a ridge it is called a linear ridge even though it may once have been a shutter ridge. Some shutter ridges are breached by the cutting of a new channel in line with the established upslope channel, isolating the offset portion. Such a feature would still be called a shutter ridge.

SW - Swale. An elongated, narrow, shallow trough-like depression with gently sloping, similar sides. A swale is open at one or both ends and may be situated on relatively flat ground, along hillsides or across ridges. A nearly filled trench (T) may qualify as a swale.

T - Trench or Trough. An elongate, narrow, depression with moderately to steeply sloping sides and an asymmetrical or open U-shaped transverse profile. Trenches are most commonly direct expressions of a fault trace and may occur on relatively flat ground or along hillsides. Trenches differ from benches (B), which they commonly join, in that the downslope side is always raised above the trench bottom. The same symbol is used for both trench and trough because they are genetically similar with a trough being a larger version of a trench.

VC - Vegetation Contrast. A linear boundary defined by a difference in the type, growth rate, or abundance of vegetation due to a shallower ground water table on one side of a fault. Commonly seen on aerial photos but also visible in the field, especially where trees or thicker brush grows on one side of a fault.

 Fault Scarp. An abrupt change in the surface of land consisting of a step or steep slope due to offset of the surface by fault movement. Bar and ball indicates the side with lower elevation. Can be caused by predominantly lateral offset,

particularly on sloping surfaces, or may be the result of vertical or oblique readjustments of local blocks along a fault. Fault scarps are especially suggestive of recent fault activity if they face upslope on an alluvial fan or other depositional surface.

Other symbols (Th↗) are used on the fault maps to identify and show the location of selected geologic units. The stratigraphic relationships, sources of contained clasts, and descriptions of units identified in this report are covered in the Open-File Report of the Quail Lake-Three Points area (Kahle, 1979). These are listed below:

dgn	-	Diorite gneiss complex
qm	-	Quartz monzonite complex
gr	-	Granitic rocks
gr/gn	-	Mixed granitic and gneissic rocks
Tnv	-	Neenach Volcanic Formation, undivided
Th	-	Hungry Valley Formation, undivided
Thu	-	Hungry Valley Formation, upper member
Tha	-	Hungry Valley Formation, pebbly arkose member
Qs	-	Sandberg Formation
Qoa	-	Older alluvium
Qot	-	Older terrace deposits (older alluvium)
Qsw	-	Slope wash

These units, and others described in this report, were important for identifying and locating certain faults and for estimating the amount of movement on the San Andreas fault in the areas mapped.

Aerial Photography

With the exception of careful and critical field evaluation, aerial photography is doubtless the single most valuable tool used in the search for faults and the evidence of faulting. Hundreds of aerial photographs, in stereopairs, were used in the preparation of the fault maps of two segments. Commonly, the use of magnifying stereoscopes enlarged the effective scale of the photos from two and a half to six times. Under these conditions individual bushes and boulders can easily be distinguished on the largest scale photos, which allows for very precise plotting of field data.

It is felt that a record of the specific dates, flights, scales, and types of aerial photos used in the present study may help the interested reader to obtain similar photos to supplement field study in order to critically evaluate specific faults that may affect individual sites. All of the photos used in the present study are listed in Table 1.

Table 1. AERIAL PHOTOGRAPHY USED IN PREPARATION OF THE FAULT MAP OF THE PINE CANYON AND THREE POINTS SEGMENTS OF THE SAN ANDREAS FAULT

DATE FLOWN	FLOWN BY	AVAILABLE FROM	DESIGNATION	NOMINAL SCALE	TYPE
1928	Fairchild	Whittier College	C-300	1:20,000	Black and White
1940	Fairchild	Whittier College	C-6500 (AXJ)	1:20,000	Black and White
1966	WRD-USGS	USGS	WRD 5D6	1:12,000	Black and White
1968	USAF	USGS	027V	1:113,000	High Altitude (U-2) B & W
1968	Geotronics	LA County Eng.	Soil Survey #175	1:24,000	Black and White
July 1969	Mark Hurd	USFS	EUX	1:15,840	Color
June 1971	I.K. Curtis	I.K. Curtis (prints-CDMG)	DMG 71-1	1:12,000	Low Sun B & W
October 1976	I.K. Curtis	CDMG	DMG 76-1	1:6,000	Black and White
October 1976	I.K. Curtis	CDMG	DMG 76-2	1:12,000	Color

Field Work

Field work consisted of walking out nearly the entire length of the main trace of the San Andreas fault and nearby faults. One aspect of following the trace of the San Andreas fault through the thick vegetation was the discovery of numerous features that cannot be detected upon even large-scale aerial photos. The thick brush or heavy forest that covers much of the terrain, within the segments, limited access to some faults inferred from aerial photos but these faults could commonly be visited where access was provided by roads or creek canyons. Another aspect of field work consisted of attempting to locate and/or verify faults mapped by previous workers within the segments.

PINE CANYON SEGMENT

by Allan G. Barrows

Introduction

The map of the Pine Canyon segment (plate 1) of the San Andreas fault zone extends 10.9 km along the fault and depicts all faults found or inferred within an area of nearly 57 sq. km. Pine Canyon is a long narrow valley that lies along the San Andreas fault between Portal Ridge on the north and the brushy to forested slopes of Sawmill Mountain on the south. The Pine Canyon segment lies immediately west of the previously completed Lake Hughes segment (Beeby, 1977; 1979). Although most of the land south of the San Andreas fault lies within the Angeles National Forest more than half of the land crossed by the trace of the fault within the Pine Canyon segment is privately owned. I have benefited from discussions, with my collegues James Kahle and David Beeby, of the geology and aspects of faulting in adjacent segments. I would also like to thank Pine Canyon residents Wandalee and Kenneth Thompson for their hospitality and for the useful information about the area they enthusiastically shared with me.

Geologic Setting

Geologically, two generally contrasting basement-rock terranes border the San Andreas fault in the Pine Canyon segment, although at many places similar-appearing rocks can be found on both sides of the fault. Previous workers in the region, including Dibblee (1967), Ross (1972), and Beeby (1979), have described the rocks north of the San Andreas fault as medium- to coarse-grained equigranular to moderately gneissic quartz monzonite to granodiorite. South of the San Andreas fault, on the other hand, lies a more varied and complex terrane that is dominated by dark gray diorite gneiss which contains abundant marble and other metasedimentary rock inclusions and that has been intruded by white quartz monzonite or other granitic rocks. These rocks extend westward into the Three Points segment (plate 2) as far as Oak Flat south of the community of Three Points.

In general, the foliation within the diorite gneiss complex (dgn on the map) strikes subparallel to the San Andreas fault, especially near the fault. In most places the foliation dips away from the fault although there are several areas where gentle dips toward the fault were observed. Tabular, white, coarsely crystalling marble bodies are common along the northern slope of Sawmill Mountain as far west as Shake Canyon. Just east of Lower Shake Campground, where the dip of the marble bodies coincides approximately with the slope of the mountainside, a relatively large area of marble crops out.

Along the north side of the San Andreas fault very small, highly sheared slivers or wedges of volcanic clast-bearing pebbly to cobbly sandstone and thin-bedded gray green siltstone (denoted as Th on plate 1) are exposed in roadcuts and streamcuts as far east as Bushnell Summit. These rocks are correlated with Hungry Valley Formation of late Pliocene and possibly early Pleistocene age. It is not possible from the very limited exposures of these rocks to determine the counterparts south of the San Andreas fault from which they have been right-laterally offset. In the discussion of the Three Points segment the offset of up to 31 km of other members of the Hungry Valley Formation is discussed.

Older alluvial units (Qoa) such as alluvial fan and terrace deposits which are abundant and widespread in most of the previously mapped segments are scarce to non-existent within the Pine Canyon segment. The general lack of these deposits severely limits the information available for determining recency of activity along faults. In the description of faults that follows the rare places where older alluvial deposits do exist, such as at Bushnell Summit, are discussed.

The rolling, grass- or brush-covered surfaces of low relief upon Portal Ridge, at Keeler Flats, and, in places, along the crest of Sawmill Mountain are analogous to similar surfaces that are better preserved in the Lake Hughes segment wherein Beeby (1979, plate 1) mapped them as weathered surfaces. The several closed or nearly closed depressions along the top of Portal Ridge lie upon one of these surfaces. Weathering of the equigranular granodiorite in this area is very deep, as seen in road cuts, and evidently there is so little local relief that drainage is poorly developed on top of the ridge. These surfaces do not appear to be terraces cut by erosion and, therefore, cannot be used to infer earlier stages in the geomorphic development of the terrain in the Pine Canyon segment. A similar surface in granitic rocks occurs in the vicinity of Tweedy Lake, near the western end of the segment, where some evidence of fault control appears to be present (plate 1).

Fault Activity

With the exception of a few, possibly very old, faults that lie entirely within the basement rocks all faults shown on plate 1 are probably related to movements along the San Andreas fault and, as such, are considered as lying within the San Andreas fault zone. Naturally, this includes not only the San Andreas fault itself, which is also known as the main trace or most recently active trace, along which surface disruption occurred during the 1857 Fort Tejon earthquake, but also includes subparallel faults on Sawmill Mountain as well as in Pine Canyon.

San Andreas Fault

Along much of its length within the Pine Canyon segment the San Andreas fault occurs as a simple, narrow, single fault trace along which the granitic rocks of Portal Ridge are juxtaposed against the gneissic rocks of Sawmill Mountain. At several places, denoted by G for gouge on plate 1, actual exposures of the San Andreas fault can be examined. A typical example is the streamcut exposure 0.7 km east of Lower Shake Campground. At this locality the medium- to coarse-grained equigranular, "salt and pepper" granodiorite on the north is faulted against greenish gray to dark gray and black diorite gneiss on the south. Here the black and/or brick red gouge at the fault contact ranges from 0 to 4 cm in thickness. Within a distance of less than a meter from the fault the primary igneous and/or metamorphic textures in the rocks, although smashed, are not greatly disturbed by shearing. Near this locality the deeply gullied, bold roadcut with badland erosional aspects in granodiorite, along the north side of Pine Canyon Road east of the mouth of Shake Canyon, exposes granodiorite that is crushed (grain-boundary separation) but only weakly sheared such that primary textures are not obliterated.

The basement rock relations in the exposure described above suggest a simple history of faulting that is contradicted in areas where deformed older alluvial deposits along the fault have not yet been removed by erosion. At Bushnell Summit and along the Sawmill Mountain Truck Trail, near its junction with the Pine Canyon Road, a moderately stratified, well-consolidated deposit of poorly sorted older alluvium has been foldedinto a syncline whose axis parallels the San Andreas fault.

Another fault-bound deposit of older alluvium, in this case on the north side of the main trace, lies along Pine Canyon Road near the Roadside Rest. This deposit contains abundant blocky marble debris probably derived from landslides originating across the San Andreas fault to the south. Erosion along the branch fault by the present creek in Pine Canyon has exposed brecciated greenish basement rock in the creek bed west of the Roadside Rest. Downcutting has isolated the older alluvium-capped block between Pine Canyon Road and the San Andreas fault.

One other notable exposure of the San Andreas fault was formed very recently by deep gullying of ponded alluvium as a result of rapid stream flow at the mouth of Heryford Canyon just west of Hidden Lake. The San Andreas fault in this vicinity is vertical and separates sandy arkosic alluvium on the north from contorted, clayey, organic, ponded alluvium on the south.

Features providing geomorphic evidence of faulting along the main trace are relatively common but more difficult to observe than in previously mapped segments because of the dense brush that covers much of the ground along the fault. Identifying multiple strands in areas where oak and pine trees grow thickly along the fault is only possible by means of field work because the faults cannot be observed on even the large scale, low-sun photos.

In several places where geomorphic features such as scarps, benches, and troughs are not preserved along the main trace of the fault the location of the trace can be closely approximated because of the moist zones associated with dammed ground water. A useful guide to fault location in this case is the presence of reedlike ryegrass (Elymus glaucus glaucus according to Wandalee Thompson, personal communication, 1980). Since this plant only grows where near-surface water is present it was rarely encountered in the Pine Canyon area away from faults except in a few places where springs exist in the walls of ravines on Portal Ridge where water seeps out along the base of the deeply weathered zone in granodiorite.

Because they are easily obliterated by depositional processes certain geomorphic features such as small closed depressions and shallow-sided troughs are not likely to remain in existence for a long time and, as such, can be inferred to have formed or been renewed during the faulting which accompanied the Fort Tejon earthquake of 1857 along this stretch of the San Andreas fault. Evidence of lateral components of faulting in the Pine Canyon segment is much less common than features such as scarps, benches, and depressions that commonly form by vertical components of fault movement. Offset stream channels between Bushnell Summit and Hideaway Canyon are probably the best evidence of right-lateral faulting in the segment. At no place, however, can a simple single offset likely to have resulted from the 1857 fault movement be measured. Although he measured no offsets along the San Andreas fault between Corona Del Valle, west of Three Points, and Leona Valley, Sieh (1978, figure 5) implies that right-lateral offset ranging from 3.5 to 6 m is likely to have occurred in the Pine Canyon segment at the time of the 1857 Fort Tejon earthquake.

Geomorphic and geologic evidence along the Los Angeles County stretch of the San Andreas fault strongly implies that future surface faulting along the fault is most likely to coincide with the present trace. Places where the fault trace has been inferred across areas where modern alluvial fans and stream deposits have buried the fault since it last broke the surface in 1857, especially in the eastern part of the Pine Canyon segment, are likely to exhibit a variety of distributive features that are concentrated near but not necessarily upon the inferred trace.

Sawmill Mountain Fault

The Sawmill Mountain fault is a continuation of the fault mapped by Dibblee (1961; 1967) and mapped and named by Beeby (1979, p. 23) in the Lake Hughes segment. Just north of the Maxwell Truck Trail the Sawmill Mountain fault crosses a deeply weathered terrain of white equigrandular granitic rocks. The gently rounded contours of aligned swales, displaced surfaces and upslope-facing scarps reveal the location of the fault across the brushy slopes near the top of Sawmill Mountain. It is probable that the unnamed fault, northwest of the named trace is mechanically related to the Sawmill Mountain fault because it exhibits similar features and a similar strike.

Beeby (1979, p. 24) compared the variety and freshness of the features along the Sawmill Mountain fault in the Lake Hughes segment with those on the 1857 trace of the San Andreas fault and concluded that it could have been active very recently as a result of movement along the San Andreas fault. In addition, faulted slopewash deposits, possibly of Holocene age, along the Sawmill Mountain fault were mapped by Beeby in the Lake Hughes segment (1979, plate 1).

Within the Pine Canyon segment, however, the features that demonstrate the presence and location of the fault are mostly erosional across the deeply weathered terrain along the top of Sawmill Mountain. There is no conclusive evidence, in the area covered by this report, that there has been recent activity along the Sawmill Mountain fault. The fault may simply be relatively easy to follow because of the deeper erosion along the line of weakness it forms in the granitic rocks.

Shake Canyon Fault

This fault was mapped as an unnamed fault by Dibblee (1967, plate 1). It is herein named the Shake Canyon fault because it crosses Shake Canyon in the vicinity of Upper Shake Campground. The best exposures of the Shake Canyon fault are in large cuts along the Sawmill Mountain Truck Trail in the 0.5 km between Hideaway Canyon and the junction with the road to Upper Shake Campground. In the roadcuts where the fault dips moderately (45° to 60° SW) it separates a white granitic basement complex mixed with abundant metasedimentary gneissic inclusions on the northeast from a massive, brown, well-consolidated, old slopewash or alluvium, which contains a boxwork of caliche-filled cracks, on the southwest. The Shake Canyon fault can be followed for nearly 3 km through very brushy country. A continuation of the Shake Canyon fault to the east could not be found along the Maxwell Truck Trail. Therefore, there does not appear to be any physical connection between the Shake Canyon fault and the Sawmill Mountain fault, although they are both likely to have formed in response to vertical movements associated with concomitant lateral faulting along the San Andreas fault. No evidence of lateral slip was found along the Shake Canyon fault which appears to be simply a normal fault along which the ridge to the north has risen relative to the partially alluviated area south of the fault.

<u>Unnamed Faults</u>

South of the San Andreas fault on the northern slope of Sawmill Mountain several short faults were mapped on the basis of geomorphic features that interrupt the profile of the slope. These faults strike more northerly than the San Andreas fault and they all exhibit north-side-up attitudes. It is probable that many more minor faults cross the slope of Sawmill Mountain but they are impossible to observe because of the very thick vegetation and the lack of geomorphic expression.

In Pine Canyon a fault that diverges from the San Andreas fault west of the Roadside Rest parallels the San Andreas for nearly 2.5 km and may continue farther eastward although no fault features were found there. The brecciated, greenish basement complex along this fault is exposed in the creek bed west of the Roadside Rest and was mentioned in the San Andreas fault discussion. The fault is characterized by numerous notches, linear gullies, and scarps which permit the inference that lateral faulting has occurred along this branch of the San Andreas fault relatively recently. The fault is exposed in cuts (marked "G" on plate 1) on Blaisdell Road. North of the fault an ancient rock-slide deposit, along which Blaisdell Road was built, terminates near the fault. This deposit may have formed during an earthquake because similar deposits that could be attributed to heavy rainfall-related slope failure are nearly non-existent along the north side of Pine Canyon. A large landslide near the eastern boundary of the map may also have been triggered by an earthquake.

East of Tweedy Lake a questionable fault is shown on the map based on a series of moist zones and notches which occur in an area of anomalous topography in deeply weathered granitic terrane. This fault does not appear to continue eastward. However, it may continue westward to Tweedy Lake, although the evidence there is ambiguous. The fact that ground water, in multiple drainages of low relief, rises to the surface along this trend and notches occur on several ridges along the same trend, suggests that a fault near the surface may be the reason for the features.

With the rare exceptions shown on plate 1 faults could not be located in the Broad Canyon and Kings Canyon areas of the map even though exposures are very good. This contrasts with the maps of Dibblee (1961; 1967, plate 1) wherein he mapped curved faults down the center of Broad Canyon and Kings Canyon. A dissected and gently tilted old alluvial deposit near the junction of the Sorber Motorway and Kings Canyon does contain a short fault but this fault could not be followed in Kings Canyon. Dibblee (1967, figure 73) interpreted the curved fault he depicted in Broad Canyon as a southward-dipping thrust fault which is a mechanically reasonable interpretation. However, no fault could be found in Broad Canyon and, other than the fact that the canyon exists, no other physical evidence of faulting could be found.

THREE POINTS SEGMENT

by James E. Kahle

Introduction

The fault map of the Three Points segment of the San Andreas fault zone extends about 10.9 km along the fault in a strip 5.2 km wide and depicts the faults and related features within an area of nearly 57 sq. km. The faults and fault features of the west half of the Three Points segment are derived from a geologic map of that half segment contained in a previous report by Kahle (1979, plate 2). Most of the data on faults and fault features were gathered when the geologic mapping was done. Detailed mapping of the faults and selected geologic units present in the east half of the Three Points segment, based on the stratigraphic concepts developed during the previous work (Kahle 1979), was used to complete the fault map (plate 2). Reconnaissance mapping of the geology and the detailed mapping of faults and fault-related features provided a fairly complete picture of the structural and stratigraphic relationships within the area.

Geologic Setting

The geology of the east half of the Three Points segment is similar to that of the west half with a few significant differences. North of the San Andreas fault, no rocks of the Quail Lake Formation (Kahle, 1979; Dibblee, 1967), as mapped in the west half, are present in the east half. Rocks of the upper member of the Hungry Valley

Formation (Thu) and the Sandberg Formation (Qs) (Kahle, 1979) extend only a short distance into the east half from the west and are not found elsewhere in either segment. Rocks of the Hungry Valley Formation, as mapped by Kahle (1979) in the Quail Lake area, do not occur south of the San Andreas fault in the Three Points segment. North of the San Andreas fault limited, sliver-like exposures of the undivided Hungry Valley Formation (Th) are exposed locally, adjacent to the fault. The most easterly exposures occur near the east end of the Three Points segment and in the western part of the Pine Canyon segment. Rocks of the arkose member of the Hungry Valley Formation (Tha) occur at one location in the western quarter of the Pine Canyon segment (see plate 1). Both of these units are apparently offset, by cumulative displacement along the San Andreas fault, from exposures of the Hungry Valley Formation mapped by Kahle (1979) near Quail Lake and by Crowell (1950, 1952) in the Hungry Valley area, south of Gorman. Rocks of the arkose member occur at two localities south of the San Andreas fault. One location is 15 km west-northwest of the Pine Canyon location and the other is 31 km west-northwest so that the total offset may range from approximately 15 to 31 km. The undivided rocks of the Hungry Valley Formation occur in locations that suggest a similar offset, approximately 15-30 km.

The upper member of the Hungry Valley Formation (Thu) mapped north of the San Andreas fault is presumed to be offset from 12 to 27 km from like rocks south of the fault. The 12 km figure is based on measurement of the offset from similar rocks mapped by Jennings (1953) which occur south of Quail Lake. The 27 km figure is based on the distance between rocks of the upper member mapped by Crowell (1952) south of Gorman and the rocks of the upper member in the Three Points area. This member may be younger than Pliocene, perhaps early or middle Pleistocene in age. Rocks of the Sandberg Formation derived from south of the San Andreas fault were deposited on these Hungry Valley rocks and have been subsequently offset 6-9 km suggesting that the Sandberg is considerably younger and may be late Pleistocene in age.

Rocks of a quartz monzonite complex (qm) that underlies Liebre Mountain, south of the San Andreas fault, extend to the vicinity of Oak Flat south of Three Points where the quartz monzonite has intruded a diorite gneiss complex (dgn). The area of mixed gneissic and granitic (quartz monzonite complex) rocks extends eastward from near Oak Flat into the Pine Canyon segment where gneissic rocks are predominant.

In the vicinity of Oak Flat, south of the community of Three Points and the San Andreas fault, an area of anomalous topography, labeled a possible ancient landslide, is outlined on the map. No evidence other than topography was found to indicate that this is a landslide. Quartz monzonite (qm) and rocks of the diorite gneiss complex (dgn) appear to be undisturbed within the outlined area and in the adjacent terrane. A contact between these rocks, which traverses the "slide" area does not appear to be offset. An area of older alluvium consisting of coarse, stream-deposited debris, partly derived from the terrane south of the San Andreas fault, lies just north of the fault in this area. The older alluvium is adjacent to and appears to be offset from its source terrane south of the fault by movement along the San Andreas fault. Rust (1980) refers to this older alluvium as "a large landslide which has been bisected and offset...by displacement on the main trace of the fault" but several lines of evidence suggest that this may not be so. What appears to be the offset landslide mass on air photos includes rocks of the Hungry Valley Formation overlain by the stream-deposited debris from south of the fault. The debris contains additional rock types, such as hornblende diorite, quartz and gneiss, which were not recognized within the area south of the fault outlined as a possible ancient landslide.

Rocks of the Neenach Volcanic Formation (Tnv) (Matthews, 1976; Dibblee, 1967) occur north of the San Andreas fault, over the entire length of the segment. These rocks do not extend eastward very far into the Pine Canyon segment where they lie depositionally on granitic rocks (gr) which are widely exposed in the Three Points segment and the Pine Canyon segment.

Fault Activity

The structure of the mapped area is dominated by the recently active trace of the San Andreas fault. Folding and faulting apparently associated with repeated movement along the San Andreas fault characterizes areas adjacent to the main trace. Away from the main trace of the San Andreas fault some subsidiary or secondary faults show selected reactivation on short segments.

Faults often are defined by contrasting rock types that have been juxtaposed by fault movement. In the Three Points segment, where few exposures of the faults are present, it is much more typical for the primary evidence of faulting to consist of an array of distinctive geomorphic features, such as fault scarps, closed depressions, linear ridges, or offset channels (plate 2).

San Andreas Fault

For the purposes of this report the San Andreas fault zone is defined as that zone within which the traces of recent surface faulting can be identified in the field. This includes the main trace and the traces of many subsidiary and branch faults where the evidence of faulting is relatively fresh. A close genetic relationship of the main fault to the subsidiary and branch faults is inferred and, therefore, these faults are included within the San Andreas fault zone which varies in width from a single trace in places to a zone as wide as 0.25 km locally, rarely 0.5 km wide. Many of these features were probably

formed or freshened by the surface rupture accompanying the great earthquake of January 9, 1857.

Fault traces within the San Andreas fault zone are defined by a variety of geomorphic features, which have been cataloged in previous referenced reports on the fault zone and are discussed above in the section on evidence for faulting. With few exceptions, the San Andreas fault in the Three Points segment is not a narrow, well-defined, single trace but is commonly a complex network of sub-parallel, multiple, or left- and right-stepping traces of en echelon, discontinuous, or scattered branch faults within a zone commonly less than 150 m wide. A few recently active branch faults or subparallel faults may extend beyond this limit locally. In some places recent alluvial deposits or man-made fill mask the fault and its location must be inferred from displaced surfaces or from the composition of younger alluvial deposits apparently offset from nearby source areas that are located across the fault.

Faults South of the San Andreas Fault

South of the San Andreas fault in the Three Points area, no Tertiary rocks are present but Quaternary deposits aid in recognizing a few branch and subsidiary faults. Other faults may be present but are concealed by alluvium, heavy brush, or talus.

In the west half of the Three Points segment several faults cut the quartz monzonite basement complex south of the San Andreas fault. One fault can be traced from a point about 0.2 km due E. of Robinson Canyon and 0.25 km S. of Pine Canyon Road to about 0.15 km S. of Pine Canyon Road and 0.1 km E. of Horse Camp Canyon, a distance of about 0.5 km. Another can be traced from 0.15 km W. of Cow Spring Canyon and 0.1 km S. of Pine Canyon Road eastward for about 0.75 km. These discontinuous faults have displaced the downhill (north) side upward, forming long hillside trenches subparallel to the trend of the San Andreas fault. Locally alluvium is being deposited in these trenches and in a few closed depressions. These faults, because of their fresh appearance and a few locations where younger alluvium appears to be offset, must be considered active.

<u>Faults North of the San Andreas Fault</u>

A severely deformed and moderately faulted assemblage of Tertiary sedimentary and volcanic rocks overlain by terrace deposits and recent alluvium occurs north of the San Andreas fault. Debris from the upland to the south of the fault is burying the Tertiary rocks and is being deposited so rapidly that the lower reaches of a few tributary drainages have been blocked, forming undrained depressions. This rapid alluviation has buried most evidence of recent faulting that may have been present, except very close to the San Andreas fault itself.

A few faults cut the rocks north of the San Andreas fault but, with a few exceptions, do not appear to cut younger rocks. Two exceptions are located near the center of the Three Points segment east of Cow Springs Canyon. One, about 0.65 km N. of Pine Canyon Road has displaced Tertiary rocks and rocks of the Sandberg Formation along a fault that can be traced for about 1 km. Younger alluvium may also be affected by movement on this fault. About 1.45 km N. of Pine Canyon Road, another short fault cuts the granitic basement and the overlying Neenach Volcanic Formation. This fault is marked by a fault trench over most of its length and locally alluvium is being ponded along its trace. This fault appears very fresh from geomorphic evidence and is classified as active even though the evidence shown on the geologic map of the area (Kahle, 1979) would suggest otherwise.

Faults shown on the map north of the San Andreas fault and northwest of Tentrock Canyon occur in rocks of the Neenach Volcanic Formation and the Quail Lake Formation (Kahle, 1979) only and do not have any evidence of Quaternary displacement associated with them. All other faults shown have some evidence to suggest Quaternary activity.

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