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TECHNICAL REPORT 74-5

INVESTIGATION OF LINEAMENTS ON SKYLAB AND ERTS IMAGES OF PENINSULAR RANGES, SOUTHWESTERN CALIFORNIA

December 1974

by

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and

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ABSTRACT

Northwest trending faults such as the Elsinore and San Jacinto are prominently displayed on Skylab and ERTS images of the Peninsular Ranges, southern California. Northeast, north-south, and west-northwest trending lineaments and faults are also apparent on satellite imagery. Field investigations have shown that several of the lineaments represent previously unmapped faults. Other lineaments are due to erosion along foliation directions and sharp bends in basement rock contacts rather than faulting. The northeast trending Thing Valley fault appears to be offset in a right-lateral sense 700-1300 meters by the south branch of the Elsinore fault near Agua Caliente Hot Springs. Larger horizontal displacement along the Elsinore fault further northwest may be distributed along several faults which branch from the Elsinore fault in the Peninsular Ranges. The northeast and west-northwest trending faults are truncated by the major northwest trending faults and appear to be restricted to basement terrane. Limited data on displacement direction suggests that the northeast and west-northwest trending faults formed in response to an earlier period of east-northeast, west-southwest crustal shortening. Such a stress system is consistent with the plate tectonic model of a subduction zone parallel to the continental margin suggested for the late Mesozoic and early Tertiary.

INTRODUCTION

The crystalline basement terrane of the Peninsular Ranges in southwestern California is composed of late Mesozoic plutonic rocks and associated roof pendants of metamorphosed Paleozoic and Mesozoic rocks (Jahns, 1954). Northwest trending faults, notably the San Jacinto and Elsinore faults, (Figs. 1 and 2) dominate the structure of the Peninsular Ranges. These faults have been considered a part of the San Andreas system by Crowell (1962), although we follow Hill (1965) who uses the term San Andreas set for the same group of faults. Most of the previous mapping in basement terrane has been at reconnaissance scales (1" = 1 mile and less), and early studies were without the benefit of aerial photography. Recently acquired small-scale imagery from Skylab, ERTS, RB-57 and U-2 aircraft, as well as larger scale color aerial photos, has provided a new look at this region.

Prominent northeast trending lineaments were pointed out by Lowman (1969) in Gemini and Apollo photos. These are apparent in the Skylab and ERTS images reproduced in Figs. 3 and 4, as are the northwest trending Elsinore and San Jacinto faults. A number of east-west lineaments and one north-south lineament are also visible. As shown on Fig. 2, some of these lineaments have been mapped as faults, many others have not.

This paper summarizes some of the findings of on-going field investigations in an attempt to determine the nature of the lineaments not explained by previous geologic mapping (see also Merifield and Lamar, 1974). Some have proven to be faults by the presence of well-developed breccia zones, slickensided shear surfaces and rarely, displaced contacts. The Henderson Canyon lineament (Fig. 2) is the result of erosion along foliation. The origin of other lineaments has not yet been determined. Field work, which is essential to determining their origin, is hampered by limited vehicular access and the dense growth of chaparral, and displacements are difficult to establish owing to the lack of distinctive lithologic contacts.

Considerable use has been made of previous mapping and compilations of Merriam (1955, 1958), Larson (1948), Everhard (1951), Rogers (1965), Strand (1962), Gastil, et al (1971), Weber (1963) and Jennings (1973).

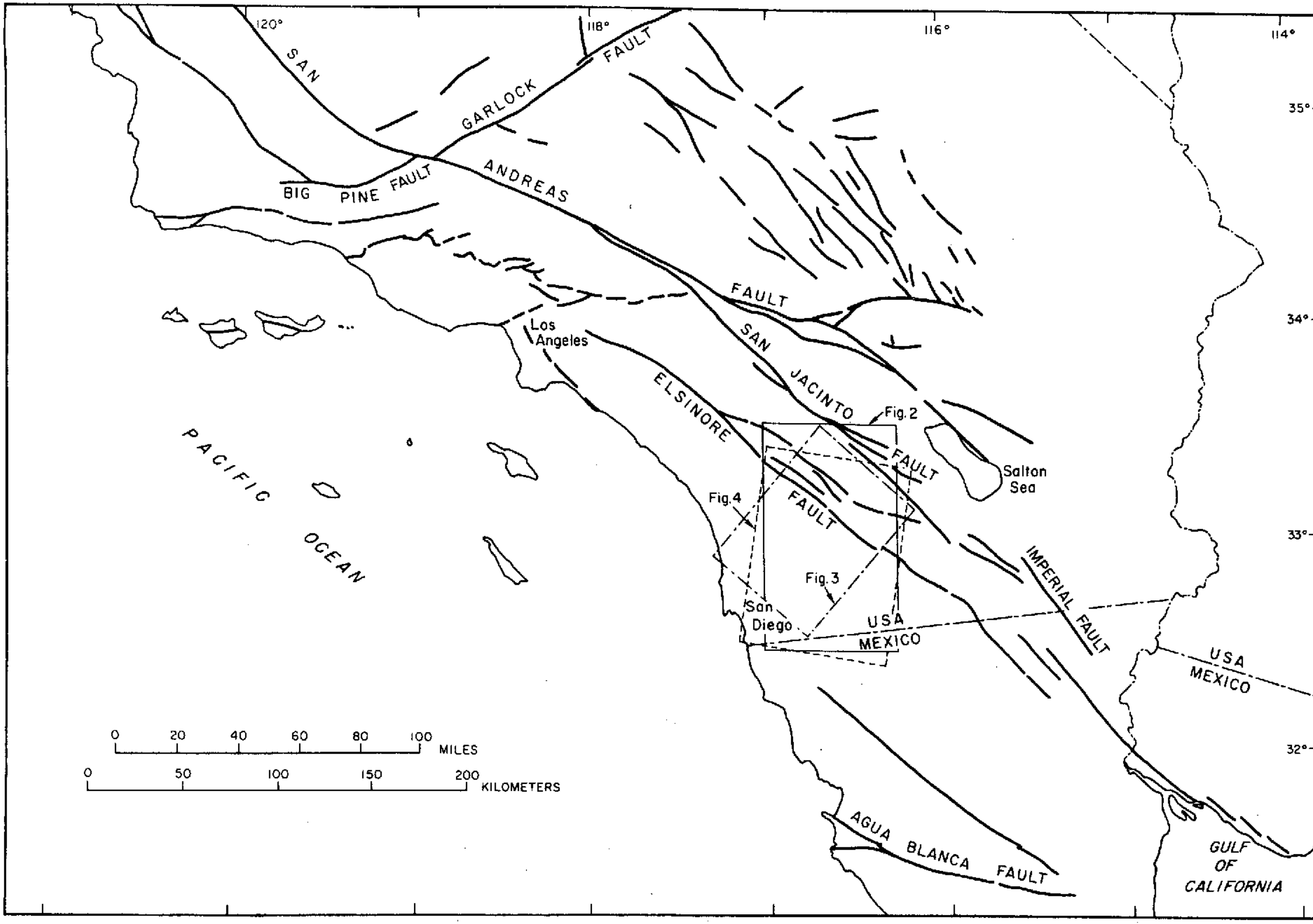

Fig. 1 - Index map showing major faults and area covered by fault and lineament map (Fig. 2), Skylab image (Fig. 3) and ERTS image (Fig.4). Redrawn from Proctor (1973).

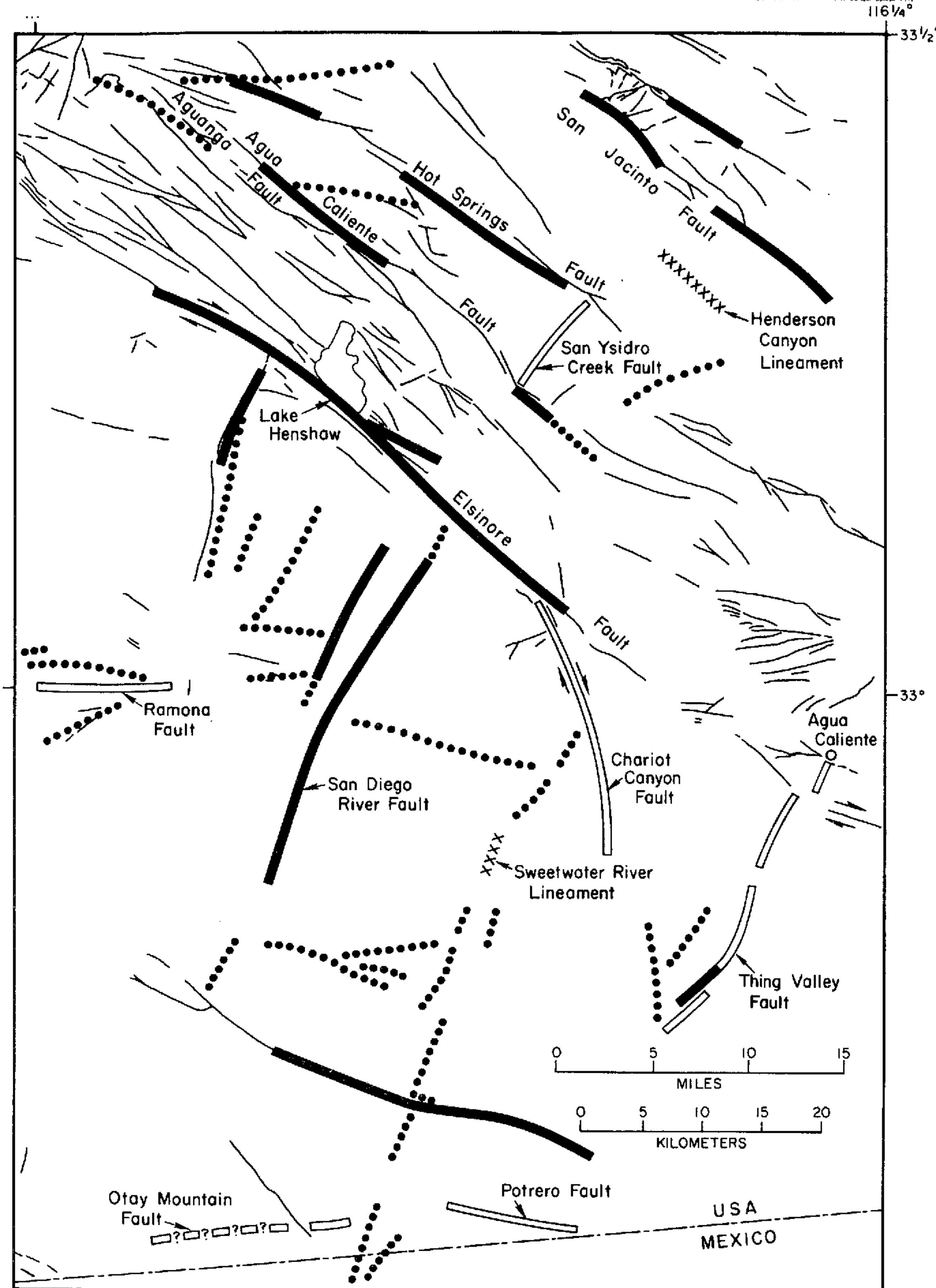

Fig. 2 - Faults and lineaments visible on Skylab and ERTS imagery of southwestern California. Solid lines: faults shown on Strand (1962), Rogers (1965), and Jennings (1973); Heavy lines: on sattelite images; Light lines: faults do not appear. Open lines: previously unmapped faults. Dotted lines: Lineaments of unknown character. XXXX: Lineament not due to faulting.

Fig. 3 - Portion of Skylab 3, September 1973, Frame 87-111, 190B camera image southwest of Borrego Springs. See Fig. 1 for area covered. Abbreviations: B.S.: Borrego Springs; C.C.F.: Chariot Canyon fault; O.M.F.: Otay Mountain fault; S.D.R.F.: San Diego River fault; T.V.F.: Thing Valley fault.

Fig. 4 - Western portion of ERTS image 1106-17504, November 6, 1972, between Borrego Springs and San Diego. Abbreviations: A.C.: Agua Caliente Hot Springs; B.S.: Borrego Springs; C.C.F.: Chariot Canyon fault; E.F.: Elsinore fault; L.H.: Lake Henshaw; O.M.F.: Otay Mountain fault; S.D.: San Diego; S.D.R.F.: San Diego River fault; T.V.F.: Thing Valley fault. See Fig. 1 for area covered.

NORTHEAST TRENDING FAULTS AND LINEAMENTS

The northeast trending San Ysidro Creek fault was first recognized, and named, as a prominent 7 kilometer (4 mile) long lineament on satellite images (Merifield and Lamar, 1974). Discovery of exposures of gouge up to 7 meters (20 feet) wide with striated shear surfaces parallel to the lineament demonstrates the existence of the fault. Data are insufficient to determine the slip direction on the San Ysidro Creek fault, but striations on shear surfaces suggest predominantly horizontal (strike-slip) movement. The ends of the San Ysidro Creek fault appear to terminate against northwest trending faults.

The northeast trending San Diego River Valley southwest of the Elsinore fault forms a 30 kilometer (20 mile) long lineament separated 10 kilometers (6 miles) from the southwest of the end of the San Ysidro Creek fault. Although the San Diego River lineament and San Ysidro Creek fault are approximately aligned, enlarged Skylab imagery, as well as larger scale air photographs, clearly show that these features do not connect. The northeast termination of the San Diego River lineament appears to occur south of the Elsinore fault.

Some previous maps (Sauer, 1929; Miller, 1935; California Department of Water Resources, 1967; Jennings, 1973) have shown a fault or inferred fault along the San Diego River, while others (Everhart, 1951; Merriam, 1958; Strand, 1962; Rogers, 1965) have not. Miller (1935) and Sauer (1929) base the existence of a fault on the straight trend of the canyon and differences in elevation between the relatively flat to gently rolling bedrock surfaces on opposite sides of the canyon. Julian Mesa on the southeast side of the San Diego River lies about 150 meters (500 feet) above the northwest side (Sauer, 1929). Fitzurka (1968) mapped an area along the San Diego River at the confluence with Cedar Creek (116° 44'W; 32° 59'N). The displacement of contacts between Julian Schist and plutonic rocks on opposite sides of the river suggests 300 to 600 meters (1000 to 2000 feet) of right separation. Our field work substantiates the apparent separation observed by Fitzurka, but no direct evidence of faulting has been discovered. The contacts may actually curve beneath alluvial cover. In what may be an analogous situation, intrusive contacts along the Sweetwater River in Cuyamaca Rancho Park curve to the right as they cross the river valley, and no distinct break is evident. Thus, the Sweetwater lineament (Fig. 2) corresponds to the axis of a small flexure or perhaps shear (slip) fold.

One of the most prominent lineaments seen on satellite imagery stretches for 20 kilometers (12 miles) in a north-northeast direction through Thing Valley in southeastern San Diego County. Breccia, fault gouge and slickensided shear surfaces were discovered along the lineament (Merifield and Lamar, 1974). One hundred meters (330 feet) of right separation was measured on the fault at the southwest end of Thing Valley, and fieldwork and study of large-scale air photos suggests as much as 1 kilometer (0.6 mile) of right separation of mixed metamorphic and igneous rocks at the northeast end of Thing Valley. The latter separation, however, may be explained at least in part by contacts curving nearly parallel into the fault.

Although the exact relationships are obscured by alluvium, the north end of the Thing Valley fault south of Agua Caliente Hot Springs appears to be displaced 700-1300 meters (2300-4300 feet) in a right-lateral sense by the south branch of the Elsinore fault, as mapped by Merriam (1955) and Buttram (1962). It is impossible to prove that the Thing Valley fault was ever continuous across the Elsinore fault, but previous alignment is suggested by similar attitudes of the fault segments (Merifield and Lamar, 1974). The north end of the Thing Valley fault abuts the north branch of the Elsinore fault at Agua Caliente Hot Springs.

EAST-WEST TRENDING FAULTS

In addition to northeast trending faults, several east-west to west-northwest faults have been identified. The most prominent of these was mapped by Weber (1963). It stretches over 40 kilometers (24 miles) in a west-northwest direction from El Cajon to Campo. Our attention was drawn to additional lineaments of this trend by studies of Skylab, ERTS and RB-57 photos. Evidence for faulting has been found for three of these lineaments which have been referred to as the Potrero, Otay Mountain and Ramona faults (Merifield and Lamar, 1974). A 120 meter (370 feet) left separation of 40°

northeast dipping flows in the Santiago Peak volcanics is demonstrable on the eastern portion of the Otay Mountain fault, but the sense of slip is indeterminant. Displacement and senses of slip are unknown on the other faults of this trend. Large displacements would probably have been recognized by previous mapping. Displacements on the order of hundreds of meters or less are likely. Additional work on these faults is required, as well as on other prominent lineaments that have not yet been investigated in the field.

ELSINORE AND CHARIOT CANYON FAULTS

The northwest trending Elsinore fault zone extends a distance of 200 kilometers (125 miles) from just north of the Mexican border to the northeast end of the Santa Ana Mountains (Strand, 1962; Rogers, 1965). Apparent offset of facies and thicknesses within Paleocene sediments along the Elsinore fault in the area northwest of Lake Elsinore suggests 30 to 40 kilometers (20 to 25 miles) of right-slip (Lamar, 1961; Yerkes and Campbell, 1971; Sage, 1973). In contrast, Dr. Robert V. Sharp (1968; personal communication, 1972) has reported that displaced cataclastic zones within the plutonic rocks along the margins of Vallecito Valley, 110 kilometers (70 miles) southeast of Lake Elsinore, limits the amount of right-slip on the Elsinore fault to about 5 kilometers (3 miles) or less. The cataclastic zones are probably at least as old as Middle Cretaceous (Sharp, 1967). Weber (1963) has also noted that basement rocks in the Julian area, directly north of Vallecito Valley, display only about 600 meters (2000 feet) of right separation. The possible right separation of 700-1300 meters (2300-4300 feet) on the Thing Valley fault by the south branch of the Elsinore fault noted above is consistent with relatively small right-slip on the Elsinore fault in the Vallecito Valley area.

The investigation of another lineament identified on satellite imagery may help explain discrepancies in displacement between different segments of the Elsinore fault. This north-south trending feature branches from the Elsinore fault between Lake Elsinore and Vallecito Valley and appears prominently on Skylab (Fig. 3) and ERTS (Fig. 4) images. It was studied and named the Chariot Canyon fault by Allison (1974a, 1974b), who reports 8 kilometers (5 miles) of right separation based on the distribution of Julian

Schist and plutonic rocks.

Our examination of a number of exposures in Chariot Canyon did not reveal a single fault separating Julian Schist on the west from granitic rocks on the east, but a broad shear zone appears to encompass the canyon. Steeply dipping slickensided shear surfaces were observed to strike between north-south and N30°W. The foliation in schist and gneiss is locally undulatory, but has a general strike conformable with the shear surfaces and the trend of the canyon.

Several northwest to east-west trending faults appear to splay off from the Elsinore fault southeast of Lake Elsinore (Rogers, 1965). Additional right-slip on the northwest segment of the Elsinore fault zone could be distributed on these faults. Mann (1955) has described stream offsets and horizontal slickensides on faults in the Temecula area. These and other faults, including the Agua Caliente, continue for a number of kilometers to the southeast (Rogers, 1965). Detailed published maps of the area between that described by Mann (1955) and the Borrego Desert are not available for study. However, Rogers (1965) shows abrupt changes in basement rock type across the Agua Caliente, Lancaster, and Aguanga faults.

DISCUSSION

The relatively small displacement reported on the southern portion of the Elsinore fault appeared to be inconsistent with the large displacement reported on the northern portion. However, north of Lake Elsinore, the fault zone is comparatively narrow. South of Lake Elsinore, displacement is very likely spread over the broad zone of sub-parallel faults in the Lake Henshaw region, notably the Agua Caliente, Aguanga and Agua Tibia faults. Furthermore, if additional right-slip can be attributed to the recently investigated Chariot Canyon fault, the small displacement on the Elsinore fault in Vallecito Valley is understandable.

Of particular interest to this discussion is the relationship of the northeast and east-west trending faults now under study to the northwest trending faults of the San Andreas set. Nowhere is the northwest set cut by the other sets, and the northeast and east-west sets we have investigated to date are restricted to pre-Tertiary rocks. Hence, there is a possibility that the northeast and east-west sets represent an older strain system, unrelated to the presently active one, with east-northeast, west-southwest crustal shortening. On the basis of north-south trending thrust faults and mylonitic zones, Sharp (1968) has also suggested an earlier period (Middle Cretaceous to Eocene (?)) of east-west crustal shortening in the eastern Peninsular Ranges. The plate tectonic model of a subduction zone parallel to the continental margin during the Mesozoic (Hamilton, 1969; Hill, 1971) is also consistent with earlier east-west crustal shortening.

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REFERENCES

Allison, M. L., 1974a, Geophysical studies along the southern portion of the Elsinore fault: M.S. thesis, San Diego State University, 229 p.

Allison, M. L., 1974b, Tectonic relationship of the Elsinore fault zone and the Chariot Canyon fault, San Diego County, California: Abstracts with program, Geol. Soc. Am., Cordilleran Section, p. 138.

Buttram, G. N., 1962, The geology of the Agua Caliente Quadrangle, California: M.S. thesis, Univ. of Southern Calif.

California Department of Water Resources, 1967, Ground water occurrence and quality: San Diego Region: Calif. Dept. of Water Res. Bull. 106-2, 233 p.

Crowell, J. C., 1962, Displacement along the San Andreas fault, California: Geol. Soc. Am., Spec. Paper 71, 61 p.

Everhart, D. L., 1951, Geology of the Cuyamaca Peak Quadrangle, San Diego County, California: Calif. Div. Mines and Geol., Bull. 159, p. 51-115.

Fitzurka, M., 1968, Geology of a portion of the San Diego River Valley, California: Senior thesis, San Diego State Univ.

Gastil, R. G., Phillips, R. P., and Allison, E. C., 1971, Reconnaissance Geologic Map of the State of Baja California: Geol. Soc. Am., scale 1:250,000.

Hamilton, W., 1969, Mesozoic California and the underflow of Pacific mantle: Geol. Soc. Am., Bull.,V. 80, p. 2409-2430.

Hill, M. L., 1965, The San Andreas rift system, California and Mexico; in the world rift system: Canada Geol. Survey Paper 66-14.

Hill, M. L., 1971, Newport-Inglewood zone and Mesozoic subduction, California: Geol. Soc. Am., Bull., V. 82, p. 2957-2962.

Jahns, R. H., 1954, Geology of the Peninsular Ranges Province, Southern California and Baja California: in Calif. Div. Mines and Geol., Bull. 170, Ch. 2, p. 29-52.

Jennings, C. W., 1973, State of California, preliminary fault and geologic map, scale 1:750,000: Calif. Div. Mines and Geol., Preliminary Report 13.

Lamar, D. L., 1961, Structural evolution of the northern margin of the Los Angeles basin: Ph.D. thesis, U.C.L.A., 142 p.

Larsen, E. S., Jr., 1948, Batholith and Associated Rocks of Corona, Elsinore, and San Luis Rey Quadrangles, Southern California: Geol. Soc. Am. Memoir 29.

Lowman, P. D., 1969, Apollo 9 multispectral photography: geologic analysis: NASA Goddard Space Flight Center, Greenbelt, Md., X-644-69-423.

Mann, J. F., 1955, Geology of a portion of the Elsinore fault zone, California: Calif. Div. Mines and Geol., Spec. Report 43, 22 p.

Merifield, P. M., and Lamar, D. L., 1974, Lineaments in basement terrain of the Peninsular Ranges, Southern California: presented at First International Conference on New Basement Tectonics, in press in Proceedings volume.

Merriam, R., 1955, Geologic map of Cuyapaipe Quadrangle, California, scale 1/62,500: unpublished map (Cuyapaipe Quad. presently designated Mt. Laguna Quad.).

Merriam, R., 1958, Geology and mineral resources of Santa Ysabel quadrangle, San Diego County, California: Calif. Div. Mines and Geol., Bull. 177, 42 p.

Miller, W. J., 1935, Geomorphology of the southern Peninsular Range of California: Geol. Soc. Am., Bull., V. 46, p. 1535-1562.

Proctor, R. J., 1973, Map showing major earthquakes and recently active faults in the southern California region: in Geology, Seismicity and Environmental Impact, Assoc. Eng. Geol., Special Publ.

Rogers, T. H., 1965, Geologic map of California, Santa Ana Sheet: Calif. Div. of Mines and Geol.

Sage, O. G., Jr., 1973, Paleocene geography of the Los Angeles region: in Proc. Conf. on Tectonic problems of the San Andreas Fault System, Stanford Univ. Publ., Geol. Sci., V. XIII, p. 348-357.

Sauer, C., 1929, Land forms in the Peninsular Range of California as developed about Warner's Hot Springs and Mesa Grande: Univ. Calif., Pubs. in Geography, V. 3, p. 199-290.

Sharp, R. V., 1967, San Jacinto fault zone in the Peninsular Ranges of southern California: Geol. Soc. Am., Bull., V. 78, p. 705-730.

Sharp, R. V., 1968, The San Andreas fault system and contrasting pre-San Andreas structures in the Peninsular Ranges of southern California: in Proc. Conf. on Geologic Problems of the San Andreas Fault System, Stanford Univ. Publ., Geol. Sci., V. XI, p. 292-293.

Strand, R. G., 1962, Geologic map of California, San Diego-El Centro Sheet: Calif. Div. of Mines and Geol.

Weber, F. H., 1963, Geology and mineral resources of San Diego County, California: Calif. Div. Mines and Geol., county report 3, 309 p.

Yerkes, R. F., and Campbell, R. H., 1971, Cenozoic evolution of the Santa Monica Mountains-Los Angeles basin area: U.S. Geol. Survey, open file report.