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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA-45
August 1966

Dr. Peter C. Badgley
Chief, Natural Resources Program
Office of Space Science and Applications
Code SAR, NASA Headquarters
Washington, D.C. 20546

Dear Peter:

Transmitted herewith are 2 copies of:

TECHNICAL LETTER NASA-45

GEOLOGIC EVALUATION OF RADAR IMAGERY:

SAN ANDREAS FAULT ZONE FROM STEVENS CREEK,

SANTA CLARA COUNTY TO MUSSEL ROCK, SAN MATEO COUNTY, CALIFORNIA*

by

Robert D. Brown Jr.**

Sincerely yours,

W A Fischer

William A. Fischer
Research Coordinator
Earth Orbiter Program

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Menlo Park, California

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-45

GEOLOGIC EVALUATION OF RADAR IMAGERY: SAN ANDREAS FAULT ZONE FROM STEVENS CREEK, SANTA CLARA COUNTY TO MUSSEL ROCK, SAN MATEO COUNTY, CALIFORNIA*

by

Robert D. Brown, Jr.**

August 1966

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Prepared by the Geological Survey for the National Aeronautics and Space Administration (NASA)

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Menlo Park, California

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Geologic evaluation of radar imagery:

San Andreas Fault Zone from Stevens Creek,

Santa Clara County to Mussel Rock, San Mateo County, California

by

Robert D. Brown, Jr.

INTRODUCTION

Side-looking radar imagery along the San Andreas Fault Zone provides a useful test of the radar technique and of its applicability to geologic problems.

The San Andreas Fault Zone is a major tectonic feature 600 miles or more in length. It trends generally northwestward from the Gulf of California in northern Mexico to Point Arena on the northern California coast. Rocks of profoundly different character and age are found in juxtaposition on opposing sides of the fault zone, and geologic evidence shows that the block southwest of it has moved northwestward relative to its counterpart across the fault zone. Although the total displacement and the antiquity of the fault zone are both uncertain, available geologic evidence suggests a total horizontal displacement of more than 150 miles and a record of movement extending about 60 million years into the past. The largest documented historic displacement in the San Andreas Fault Zone--21 feet--occurred near the head of Tomales Bay north of San Francisco during the 1906 earthquake, but slow creep of opposing blocks, amounting to a few tenths of an inch per year, has been observed and measured at a number of localities along the zone, and on related faults branching from it.

Fracturing within the fault zone is distributed along a series of nearly parallel or anastomosing faults that vary in age of movement and in amount of total relative displacement. This complex zone of movement varies in width from a few tens of feet to several thousand feet. Because of its width and complexity, it is termed the San Andreas Fault Zone, and is distinguished from the San Andreas Fault--the surface trace of most recent (in many places, historic) movement. A distinction is also made between the San Andreas Fault Zone, a relatively narrow linear feature, and the San Andreas system, which includes major faults that branch from or cross the San Andreas Fault at acute angles, and that extend tens or scores of miles from the San Andreas Fault Zone. The faults which comprise the San Andreas system are genetically and geographically related to the San Andreas Fault Zone and are thought to be a product of the same crustal forces as those which caused displacement along that fault zone.

General evaluation of radar imagery for geologic interpretation: Side-looking radar imagery can be interpreted geologically in much the same fashion as conventional black and white photography. The effect obtained is that of photographs taken at low sun angles. Radar, unlike conventional photography, is unimpaired by cloud cover or haze, and relatively clear images are obtainable under varying atmospheric conditions. The screening effect of vegetation, which in conventional black and white photography masks detail in rocks at the surface and in topography, is greatly reduced or eliminated in the radar image. Radar imagery along the San Andreas Fault Zone seems to enhance the photographic contrast between unconsolidated geologic units and bedrock; thus, alluvium, lacustrine deposits, landslide debris, and similar units appear dark in tone, and contrast sharply with more consolidated bedrock units. Different kinds of bedrock units, however, are indistinguishable on the radar imagery except where such units engender a characteristic form of topographic expression. On the whole, radar imagery compares favorably with conventional black and white photography in resolution, contrast, and ease of geologic interpretation. The side-looking angle accentuates topographic features, particularly linear features that are parallel or oblique to the line of flight.

From the sample examined here, the polarized, radar image (figure 1A) seems most useful. The depolarized image is a helpful supplement, however, and in this geologic study it was found to be particularly valuable in screening out signal reflections from culture along densely populated parts of the San Francisco Peninsula. Note, for example, areas "a" and "b" on figure 2, which correspond to unusually bright areas on figure 1A. These two bright areas and other smaller bright spots scattered along the lowlands bordering San Francisco Bay seem to represent signal reflections from clusters of similar structures or from individual structures. Both areas appear normally illuminated in figure 1B, and, in general, figure 1B tends to subdue cultural detail without appreciable loss of detail in topography. Because of the lower contrast of the depolarized print, some tone differences are more easily detected in it than in the polarized print, a characteristic which renders the depolarized print useful for some kinds of geologic interpretation.

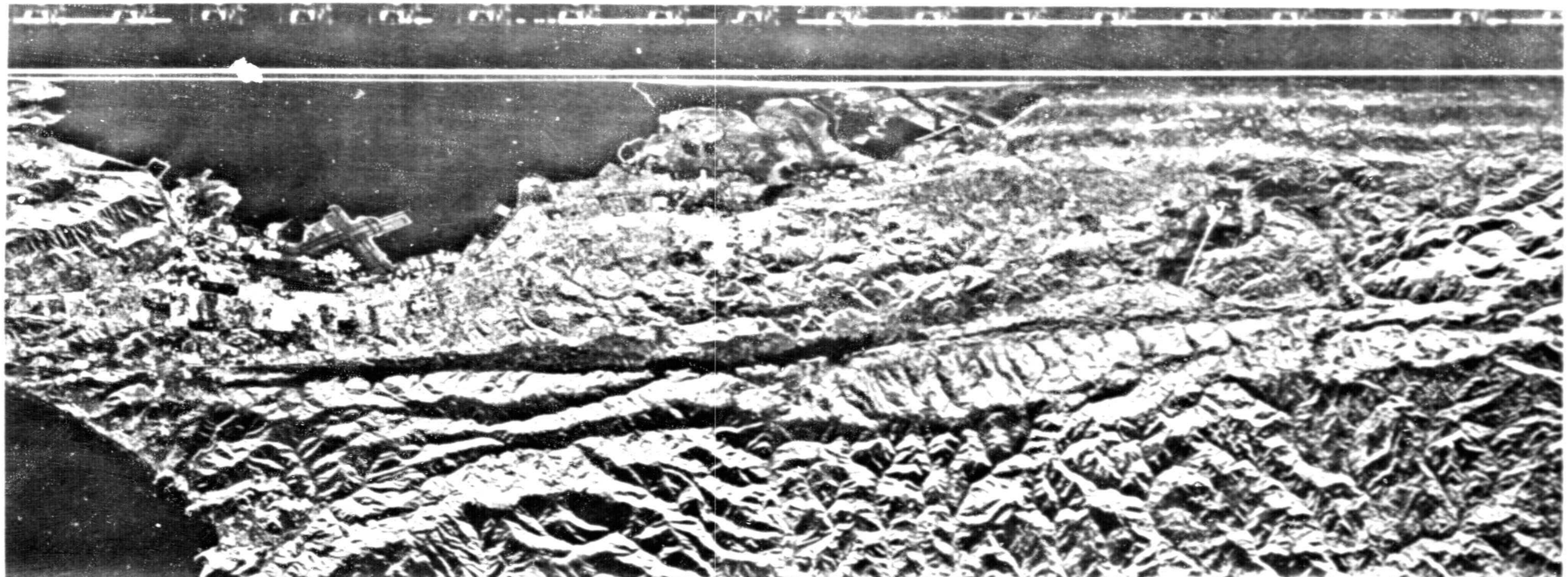
Interpretation - Stevens Creek to Mussel Rock: Figures 1A and 1B show polarized and depolarized views respectively of a 27-mile-long segment along the San Andreas Fault Zone. The area shown is about 10 miles wide. Figure 2, drawn from figure 1A, illustrates the kinds of geologic information that can be derived from radar imagery.

The most obvious geologic feature is a long, narrow trench formed within intensely fractured rocks of the San Andreas Fault Zone. This trench is occupied by San Andreas Lake and Crystal Springs Reservoir. That it is a major tectonic feature is well demonstrated in figure 1A by the contrast in relief, land forms, and drainage on opposite sides of it. The most recent tectonic movements along the trench (and hence also along the fault zone which it expresses) are relatively young, for well established drainages terminate at the trench or turn abruptly and flow along it. Detailed examination of imagery of the southern part of the trench, using low magnifications, shows that some movement is geologically very recent; evidence of this is shown by sag ponds, offset stream channels, examples of recent stream piracy, and shutter-ridges which block entrenched drainage systems.

Two faults which are part of the San Andreas system can be identified in the radar imagery by their physiographic expression. One of these, the San Mateo Fault, branches northwesterly from the San Andreas Fault Zone near the north end of Crystal Springs Reservoir, and its trace follows the course of San Mateo Creek. The other, the Pilarcitos Fault, extends from San Pedro Valley on the Pacific Ocean to Stevens Creek, and the fault trace marks a distinct topographic line along the upper part of Pilarcitos Creek and along the upper part of the southwestern slope of Cahil Ridge.

The Pilarcitos Fault, like the San Andreas Fault Zone, separates rocks of markedly different lithology, and some geologic evidence supports the contention that this fault was once the major break in the San Andreas system. Some of this evidence is suggested by detail visible on the radar imagery. For example, along the northwestern part of the fault, the upland mass that constitutes Montara Mountain (quartz diorite and granodiorite) is juxtaposed against a deeply dissected terrain that is underlain by relatively weak and relatively heterogeneous cataclastic rocks, greenstone, and chert. The topographic lineation that marks the Pilarcitos Fault clearly separates the massif of Montara Mountain from weaker and less resistant rocks to the northeast. A similar juxtaposition of rock types is shown in Cahil Ridge. a few miles to the southeast. There, relatively indurated and erosion-resistant sandstone along the crest and northeast slope of the ridge is in fault contact with softer, more easily eroded shale southwest of the fault. On the radar imagery, the moderately dissected upland of Cahil Ridge is easily distinguished from deeply eroded rocks across the fault to the southwest. This distinction is accentuated by a southwest-facing escarpment, somewhat modified by erosion, which rises from the Pilarcitos Fault toward the summit of Cahil Ridge.

Bedrock units can seldom be positively identified by either conventional black and white photography or by radar imagery, but radar--like conventional photography--can be used to delineate bedrock units with characteristic structural forms, or with characteristic physical or chemical properties provided those properties are reflected in some manner by the land surface. Thus, in the previous section, differences in the resistance to erosion of juxtaposed rock units helped define several fault traces. A crude and generalized geologic map can be derived from the radar imagery, using topographic form as an index to underlying rock units. For example, in figures 1A and 1B at least three rock units can be recognized and roughly delineated: I) a rock mass (granodiorite and quartz diorite) that is highly resistant to erosion and which forms the prominent mass of Montara Mountain, II) a widespread heterogeneous unit, moderately to deeply dissected by erosion, which underlies most of the hilly area on figure 1A, and III) a relatively unconsolidated rock unit fringing the shores of San Francisco Bay and filling the lower end of San Pedro Valley; this unit is typically expressed by lowland areas. Geologic data from field investigations show that each of these three units is a composite of several rock types which can be separately delineated by geologic field methods. The composite nature of unit II is discernible in the radar imagery, but the contrasts in expression of the several components are too poorly defined to permit a further subdivision. The high quality of the radar imagery makes it seem likely that similar imagery, at a lower altitude, could provide the basis for a more detailed geologic map.



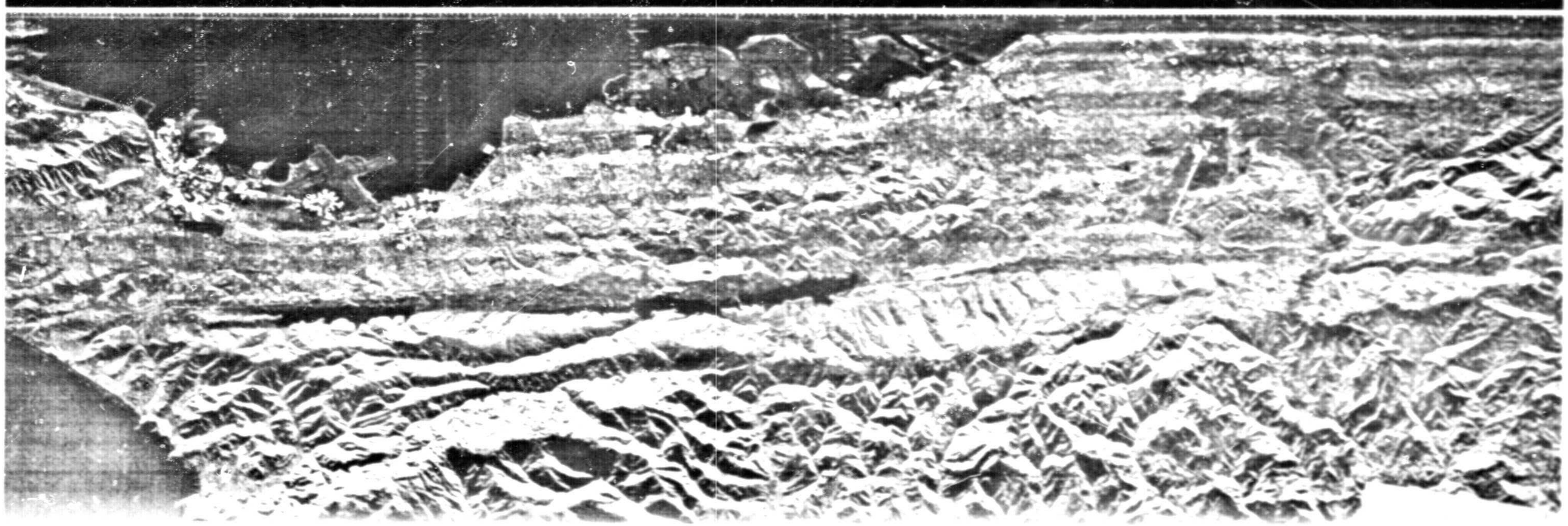


Figure 1A- Radar photograph of San Francisco Peninsula, Mussel Rock to Stevens Creek (ca. 27 miles), polarized.

Figure 1B- Radar photograph of San Francisco Peninsula, Mussel Rock to Stevens Creek, de-polarized.

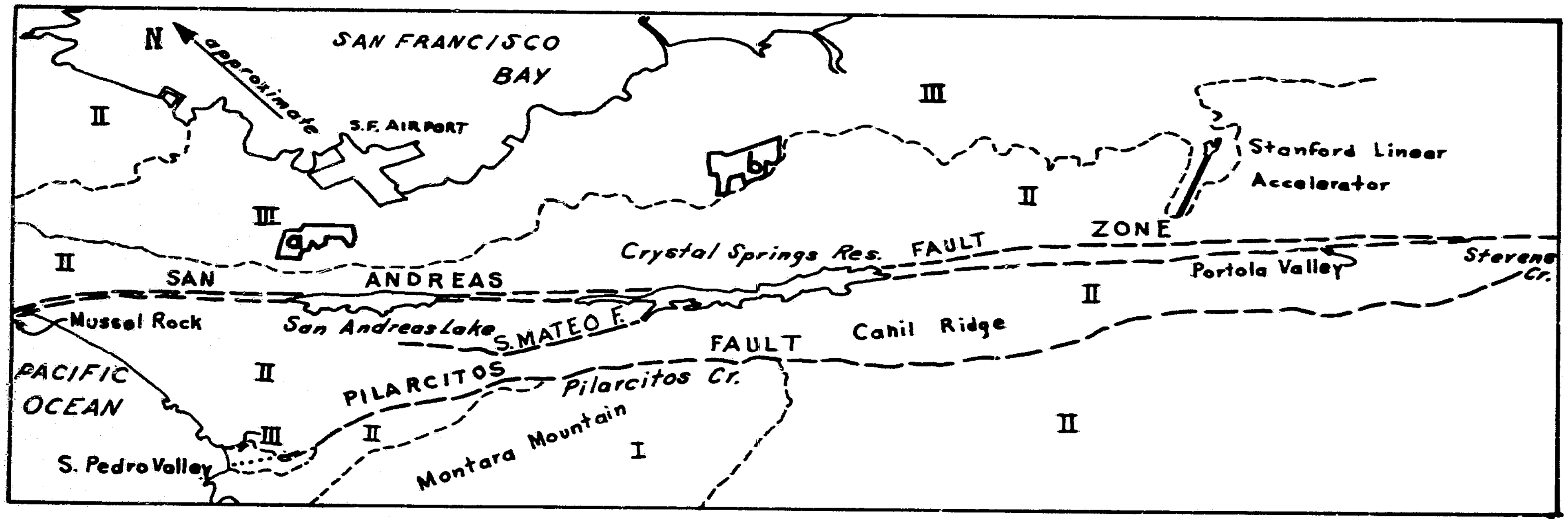


Figure 2 - Geologic sketch map based on Figures 1A and 1B. Light dashed lines show geologic boundaries; heavy dashed lines show faults; Roman numberals refer to geologic units described in text: "a" and "b" refer to cultural areas described in text.