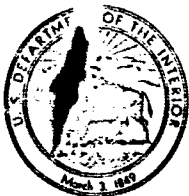


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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Interagency Report
NASA-133
January 1969

Mr. Robert Porter
Acting Program Chief,
Earth Resources Survey
Code SAR - NASA Headquarters
Washington, D.C. 20546

Dear Bob:

Transmitted herewith are two copies of:

INTERAGENCY REPORT NASA-133
GEOLOGIC EVALUATION OF RADAR IMAGERY,
CALIENTE AND TEMBLOR RANGES,
SOUTHERN CALIFORNIA*

by

Edward W. Wolfe**

The U.S. Geological Survey has released this report in open files. Copies are available for consultation in the Geological Survey Libraries, 1033 GSA Building, Washington, D.C. 20242; Building 25, Federal Center, Denver, Colorado 80225; 345 Middlefield Road, Menlo Park, California 94025; and 601 E. Cedar Avenue, Flagstaff, Arizona 86001.

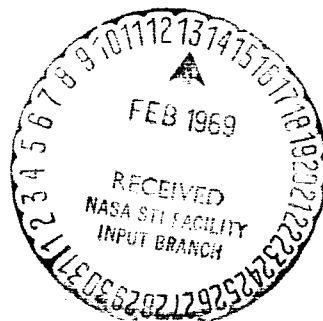
Sincerely yours,

William A. Fischer
Research Coordinator
EROS Program

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Task No. 160-75-01-46-10
**U.S. Geological Survey, Flagstaff, Arizona



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

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**U.S. Geological Survey, Flagstaff, Arizona

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Introduction

K-band radar imagery was flown on November 2, 1965 by NASA along northwest-southeast flight lines in the Caliente-Temblor Range area of southern California (figure 1). In one pass the plane flew along the southwest edge of the San Joaquin valley with the radar scanner looking southwest toward the Temblor Range and Carrizo Plain. In a second pass the plane flew along the northeastern flank of the Caliente Range with the radar scanner looking northeast so as to include part of the Caliente Range, the Carrizo Plain, and part of the Temblor Range in the image.

A strip approximately normal to the flight lines as well as to the regional geologic structure was selected for analysis. A report evaluating thermal infrared imagery in the same area has been previously submitted (Wolfe, 1968). Figure 2 is a generalized geologic map of the study area. The stratigraphic nomenclature used on the map and in this report is that of Dibblee (1962). A published geologic map by Vedder and Reperning (1965) was used in the Caliente Range, and unpublished maps by both T. W. Dibblee and J. G. Vedder were used to evaluate the imagery in the Temblor Range.

In the image area the Caliente and Temblor Ranges are underlain by steeply dipping clastic rocks of late Tertiary age. In addition, three basalt flows occur within the Caliente Range sequence. The Caliente and Temblor Ranges within the image area are largely mantled by soil or debris derived from the underlying strata, and extensive outcrops of bare bedrock are rare. The climate is arid, and vegetation is scanty.

Imagery

Figures 3 and 4 are line-scan displays showing the degree to which radar energy emitted by the scanner was reflected back to the scanner by the earth's surface. Areas of high reflectance are bright; those of low reflectance are dark. Figures 3a and 4a are like-polarized (HH); figures 3b and 4b are cross-polarized (HV) images. In figure 3 the scanner looked southwest toward the Temblor Range and Carrizo Plain. In figure 4 the scanner looked northeast across the Caliente Range and Carrizo Plain to the Temblor Range. Figure 5 is an aerial photograph of the Temblor Range portion of the area taken from about 35,000 feet on a midsummer day. Figure 6, an infrared image of the study area made shortly after sunrise on June 18, 1965, is included to show the similarity between the low angle look of the radar scanner and the effect of low angle early morning sunlight as recorded by differential warming of the earth's surface.

Specific features

Specific features in the radar imagery have been selected to illustrate the salient characteristics of the imagery. They are listed below with numbers that correspond to numbers imprinted on figures 3 and 4. Wherever appropriate, these features have also been numbered on figures 5 and 6 in order to facilitate comparison.

(1) Reef Ridge diatomite exposed on southwest-facing slope in radar shadow. Santa Margarita conglomerate to southwest; gravels of Tulare Formation to northeast.

(2) Bare southwest-facing slopes underlain by Reef Ridge diatomite. Dark only where in radar shadow.

(3) Dark band on radar image coincides with steep, bare, southwest-facing slope underlain by diatomite of Reef Ridge Formation and Monterey Shale. Arrows point to steep east-facing gully walls that face partly toward the radar scanner. Santa Margarita conglomerate caps the slope and underlies the relatively bright area northeast of this dark band in the radar image.

(4) Three small ridge crests high on northeast flank of Temblor Range. Dark areas are in radar shadow in figure 3. Note reversal of contrast in northeast-looking image (figure 4).

(5) Crest of Temblor Range.

(6) Northeast-facing slope underlain by Monterey Shale.

(7) Northeast-facing scarp at recently active trace of San Andreas fault.

(8) Fence at foot of Elkhorn Scarp bright in both northeast- and southwest-looking radar images. Tumbleweed piled against both sides of fence.

(9) Low hill underlain by claystone, sandstone, and conglomerate of the Morales Formation; bounded by broad alluviated areas.

(10) Hogback underlain by northeast-dipping basalt flow. Bright on steep southwest-facing side of ridge; northeast side, in radar shadow, is dark.

(11) Southwest-facing eroded edge of terrace mantled by old alluvium is bright in radar image.

(12) Northeast-facing eroded edge of terrace mantled by old alluvium is in radar shadow.

(13) Outcrops of shale facies of Bitterwater Creek Shale. These are relatively light-colored and are distinctly bright in aerial photograph. In radar image they are dark compared to surrounding alluvium and Santa Margarita conglomerate.

(14) Bright band in cross-polarized radar image (fig. 4b) coincides approximately with outcrop of Santa Margarita conglomerate. Band indistinct in like-polarized image (fig. 4a).

(15) Dark band in cross-polarized radar image (fig. 4b) coincides approximately with outcrop of Monterey Shale, which appears as distinctive light band on aerial photograph. Band indistinct in like-polarized image (fig. 4a).

(16) Northwest end of bright band in cross-polarized radar image (fig. 4b). Bright band coincides approximately with outcrop of Santa Margarita conglomerate west of the Temblor Range crest. Northwest of locality 16 in the image area, the Santa Margarita Formation consists predominantly of friable sandstone that appears less bright in figure 4b than does the conglomerate facies. Contrast between sandstone and conglomerate facies indistinct in like-polarized image (fig. 4a).

Interpretation

Effect of macrotopography

Throughout the study area the predominant factor controlling intensity of radar return is topography. Surfaces that face the scanner at high angles give strong reflections; surfaces that face the scanner at low angles (e.g. the nearly horizontal alluviated surface of the Carrizo Plain) give relatively weak reflections; surfaces that face away from the scanner or are in radar shadow give no reflections.

Comparison between figures 3 and 6 shows the close similarity between southwest-looking radar imagery and early morning post sunrise thermal infrared imagery, in which slopes preferentially warmed by the sun appear bright. Items 1 to 7 provide specific examples illustrating this similarity. The dominant features are northeast- and southwest-facing slopes that face approximately either toward or away from the scanner or the early morning sun and hence are, respectively, either bright or dark in figures 3 and 6.

Localities 4 to 7 are included in both the southwest- and northeast-looking radar images. Comparison at these points between figures 3 and 4 shows that tone boundaries are similar in the two images. However, in contrast to figure 3, the southwest-facing slopes of figure 4 are illuminated, and the northeast-facing slopes are in shadow.

Figure 4 includes a small portion of the Caliente Range. Features 9 to 12 demonstrate the strong influence of topography on radar returns. Radar illumination from the southwest caused the southwest-facing slopes to appear bright and the northeast-facing slopes dark.

The topographic control of radar reflection is evident in both the like- and cross-polarized modes, but tone contrasts related to slope orientation are stronger in the like-polarized mode (figures 3a and 4a).

Effect of microtopography

In addition to control of image brightness by gross topographic configuration, a limited relation apparently exists between microtopography and image brightness on the west flank of the Temblor Range. This relationship appears in all four radar images that comprise figures 3 and 4, but it is most evident in the cross-polarized, northeast-looking image (figure 4b). Features 13 to 16 illustrate the relationship between microtopography and radar reflection.

Two bright bands (14, 16) coincide approximately with outcrops of Santa Margarita conglomerate. Darker areas (e.g. 13, 15) are underlain by shale, sandstone, or sandy alluvium. In addition the two westernmost outcrops of shale facies of the Bitterwater Creek Shale (13) are slightly darker in figure 4b than the grass-covered alluvium that nearly surrounds them.

Examination of figure 5 shows that relief and dissection of the band of Monterey Shale (15) are similar to relief and dissection of the Santa Margarita conglomerate (14, 16). Hence the difference in radar reflection is not an expression of differing macrotopographic configuration.

However, the differences in reflectance may have been produced by differing surface roughness. The shales are represented at the surface by debris consisting of flat shale plates ranging from silt size to an inch or more in diameter. The larger shale plates are smooth and have strong preferred orientation; they tend to lie with their longer axes parallel to the slope so that a relatively smooth, commonly grass-free surface (fig. 7) is exposed. Santa Margarita conglomerate, on the other hand, is represented by debris containing abundant metamorphic and granitic boulders. Presumably its rougher surface (fig. 8) causes extreme radar scattering, hence relatively intense reflection. Smoother surfaces such as those developed on the shale units may allow a greater degree of specular reflection; hence less energy is returned to the scanner. By the same reasoning, the slight difference in reflectance between the grassy alluvial apron at the foot of the Temblor Range and the low, barren, less intensely reflecting shale hills that project through it may have been caused by the slightly greater roughness (relative to wavelengths of about 1 cm.) of the surface underlain by alluvium. Difference in grass cover may be largely responsible for this particular contrast in radar reflection.

Conclusions

The prime factor controlling brightness in the Carrizo Plain radar images is slope orientation. Surfaces that face the scanner at high angles are bright; those that face the scanner at low angles are represented by intermediate tones; those that face away from the scanner are black in the radar images. Differences in radar reflection related to slope orientation are most distinct in the like-polarized (HH) images.

Microtopography exerts a subordinate effect that is most distinct in the cross-polarized (HV) images. In the Temblor Range the Santa Margarita conglomerate (relatively rough surface) is bright in the image, and the shale units (relatively smooth surface) are dark in the image.

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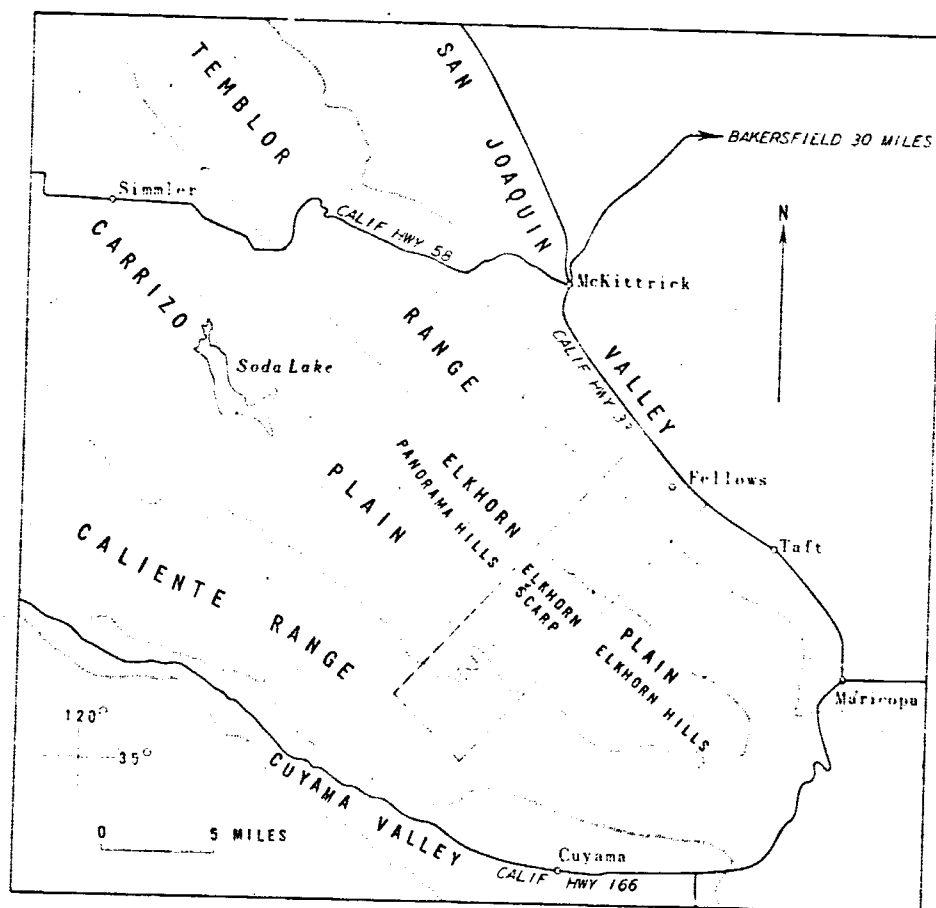


Figure 1. Index map showing major physiographic features and approximate outline of study area (dashed line).

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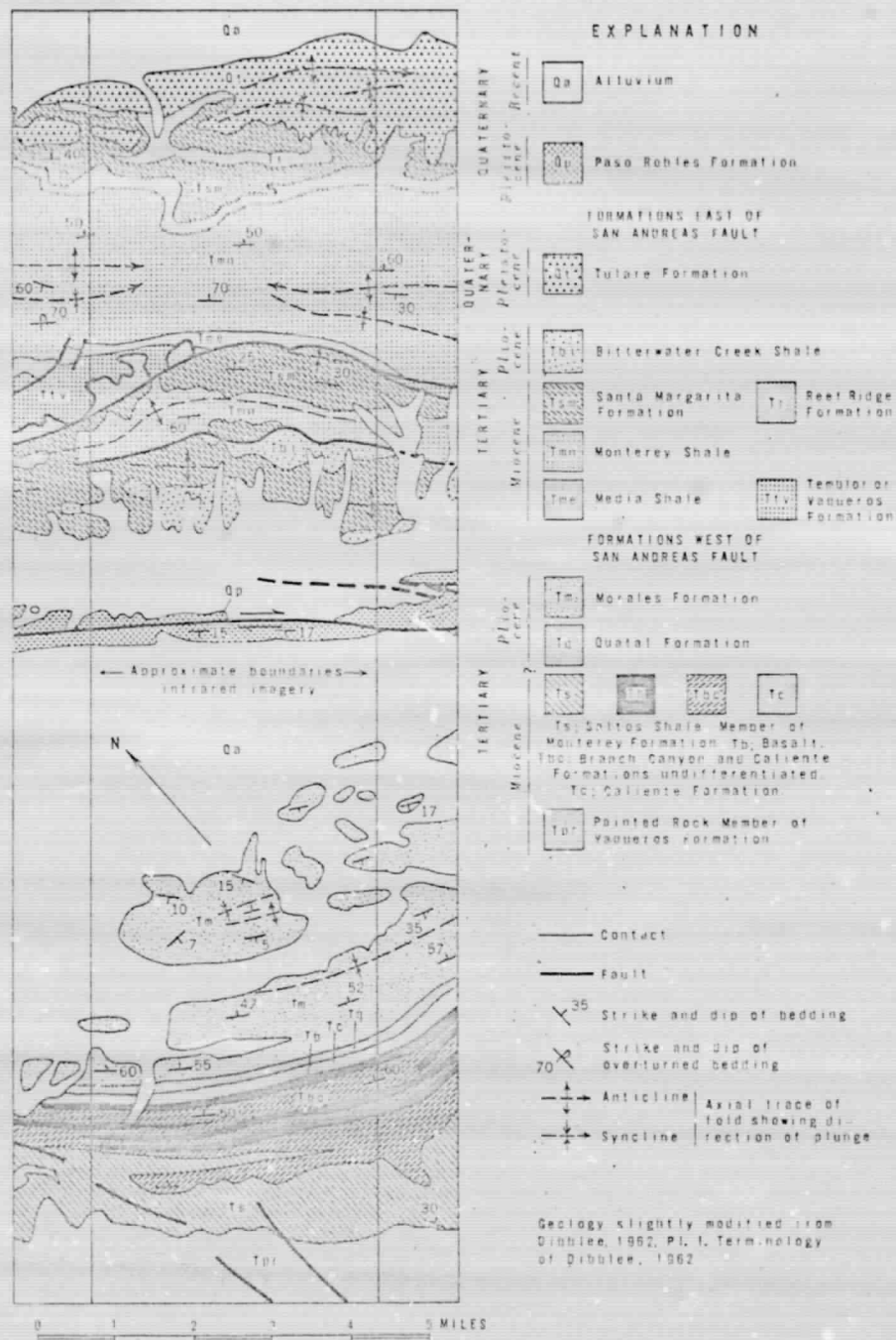


Figure 2. Generalized geologic map of study area.

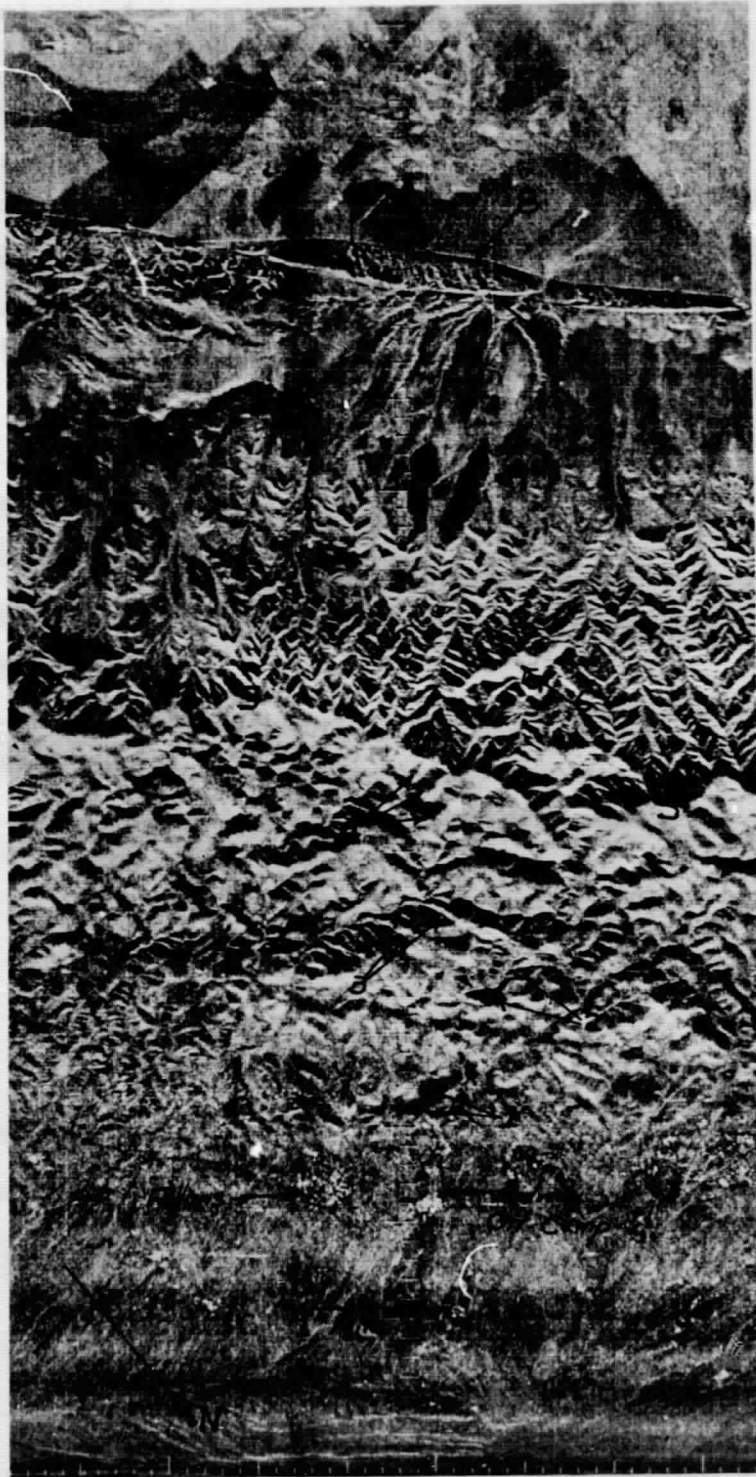


Figure 3a. Like-polarized (HH) radar image of the Temblor Range and Carrizo Plain. Scanner looking southwest.

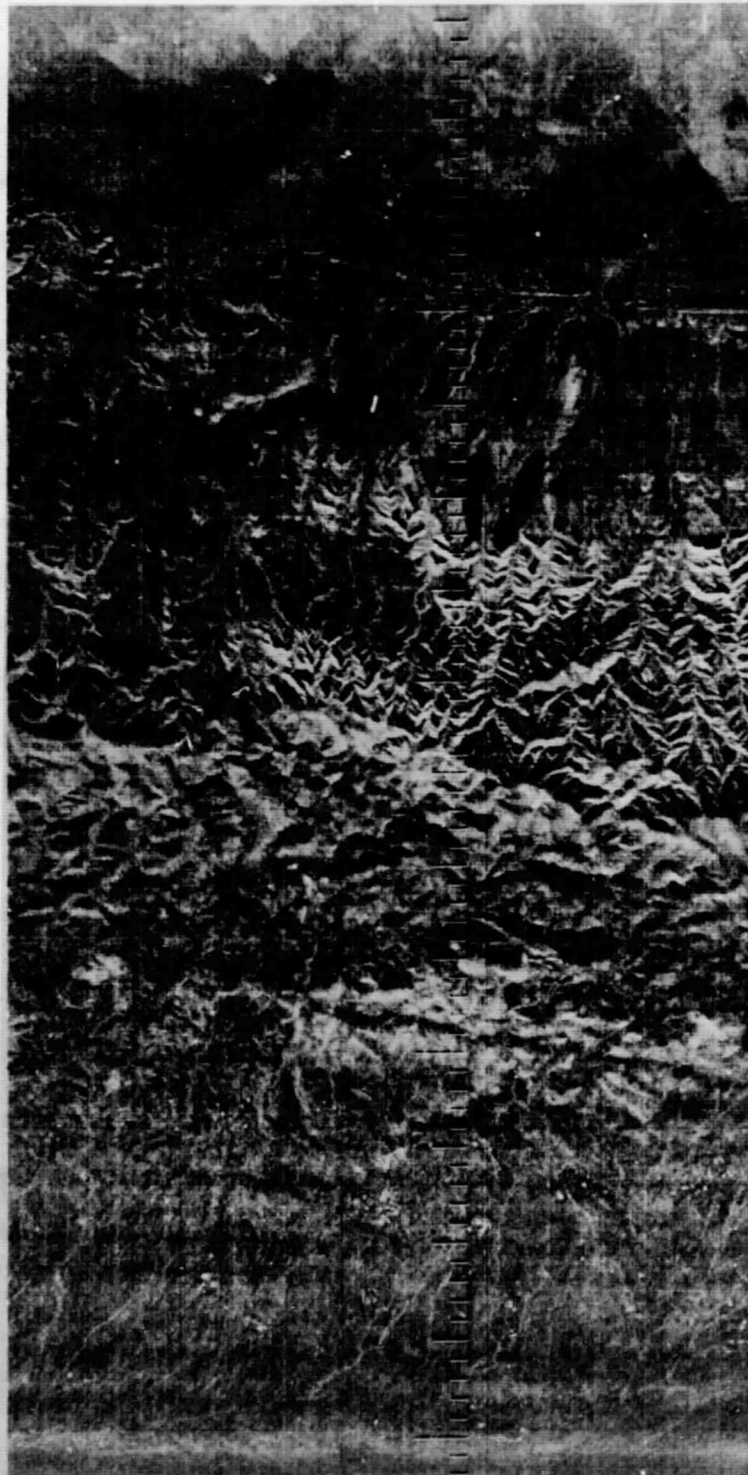


Figure 3b. Cross-polarized (HV) radar image of the Tumbler Range and Carrizo Plain. Scanner looking southwest.

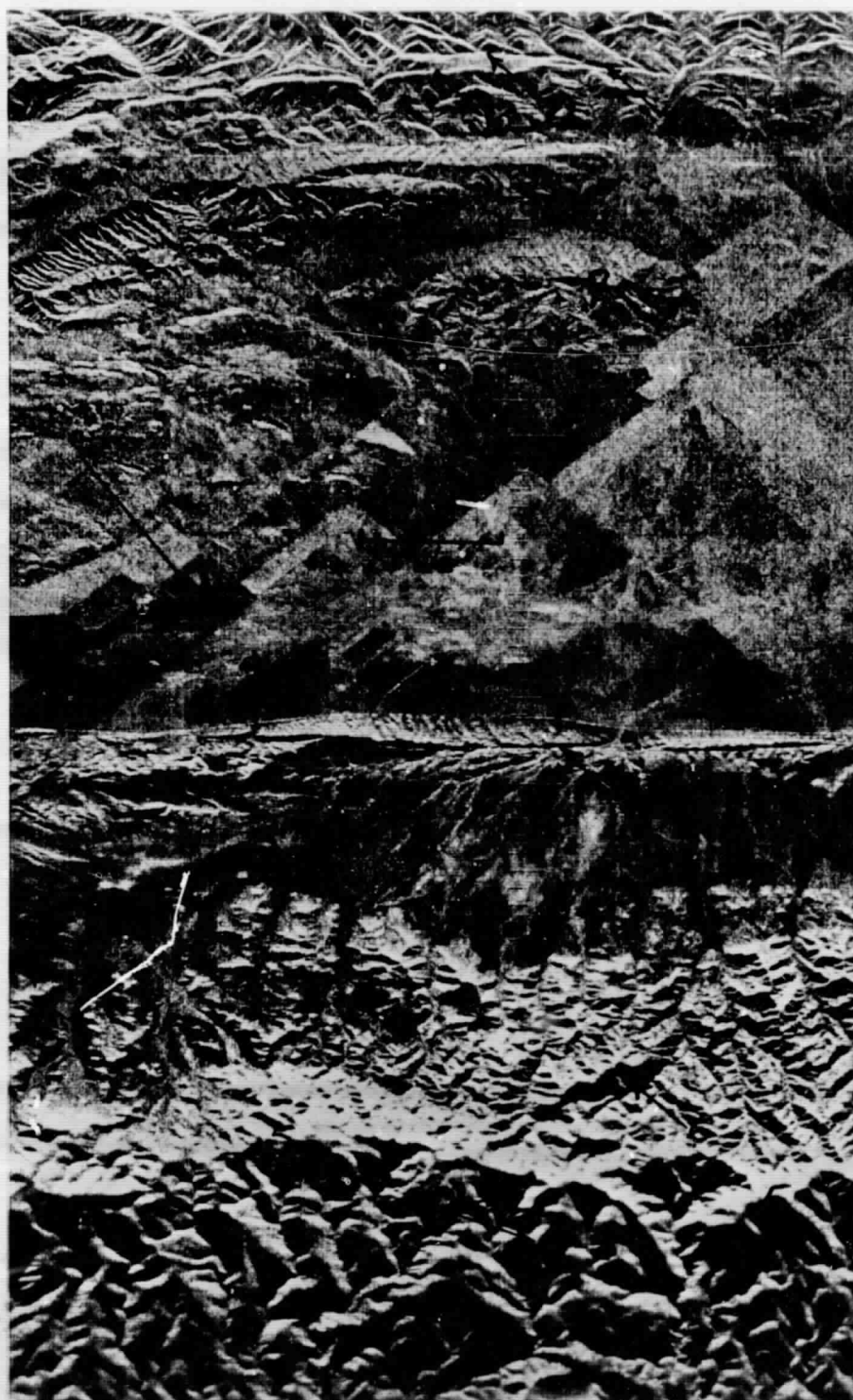


Figure 4a. Like-polarized (HH) radar image of Carrizo Plain and parts of adjoining Temblor and Caliente Ranges. Scanner looking northeast.

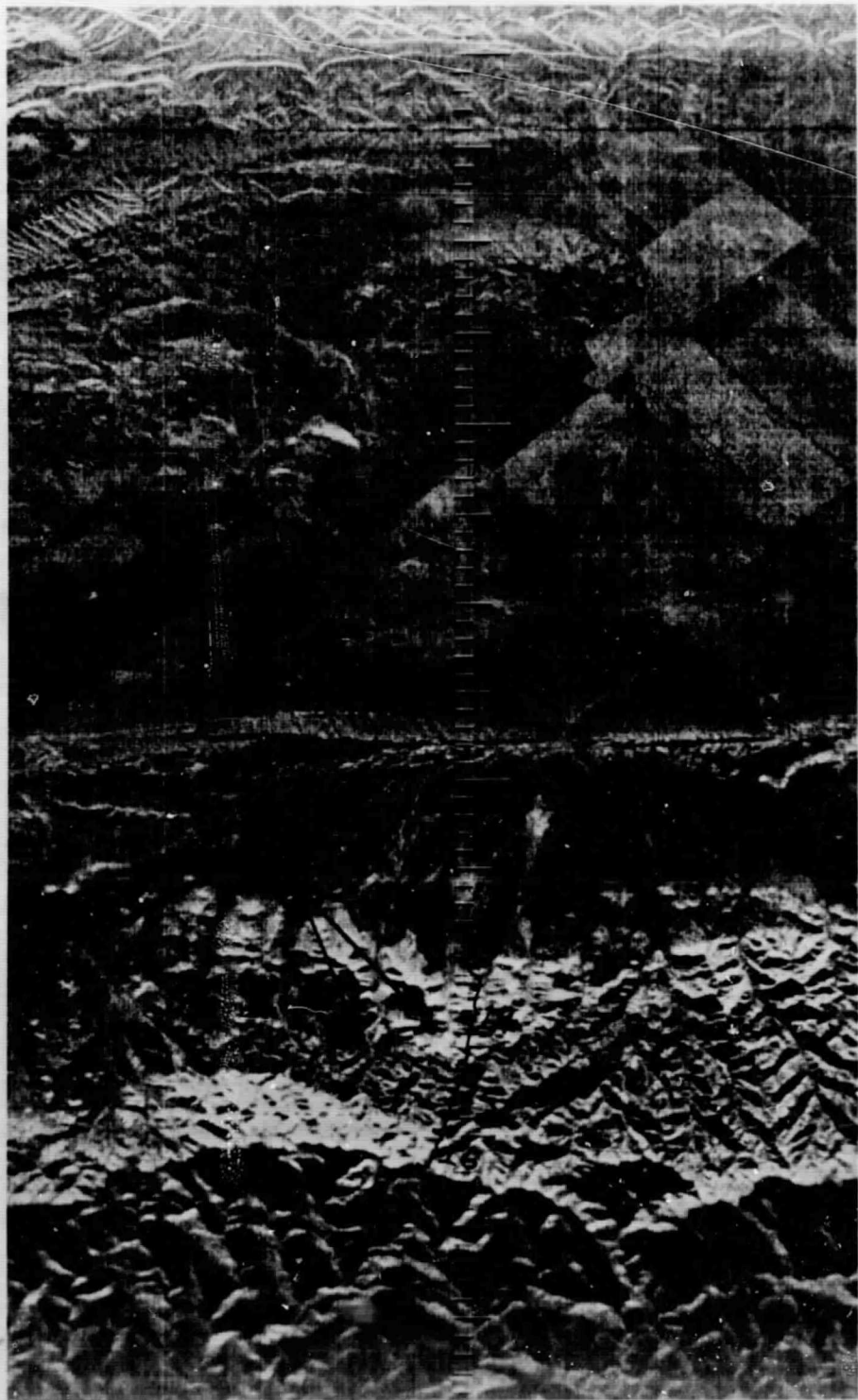


Figure 4b. Cross-polarized (HV) radar image of Carrizo Plain and parts of adjoining Temblor and Caliente Ranges. Scanner looking northeast.



Figure 5. Small scale aerial photograph of Temblor Range southwest of Fellows.



Figure 6a. Post-sunrise thermal infrared image - Temblor Range.



Figure 6b. Post-sunrise thermal infrared image - Temblor Range and Carrizo Plain.



Figure 6c. Post-sunrise thermal infrared image - Carrizo Plain and Caliente Range.

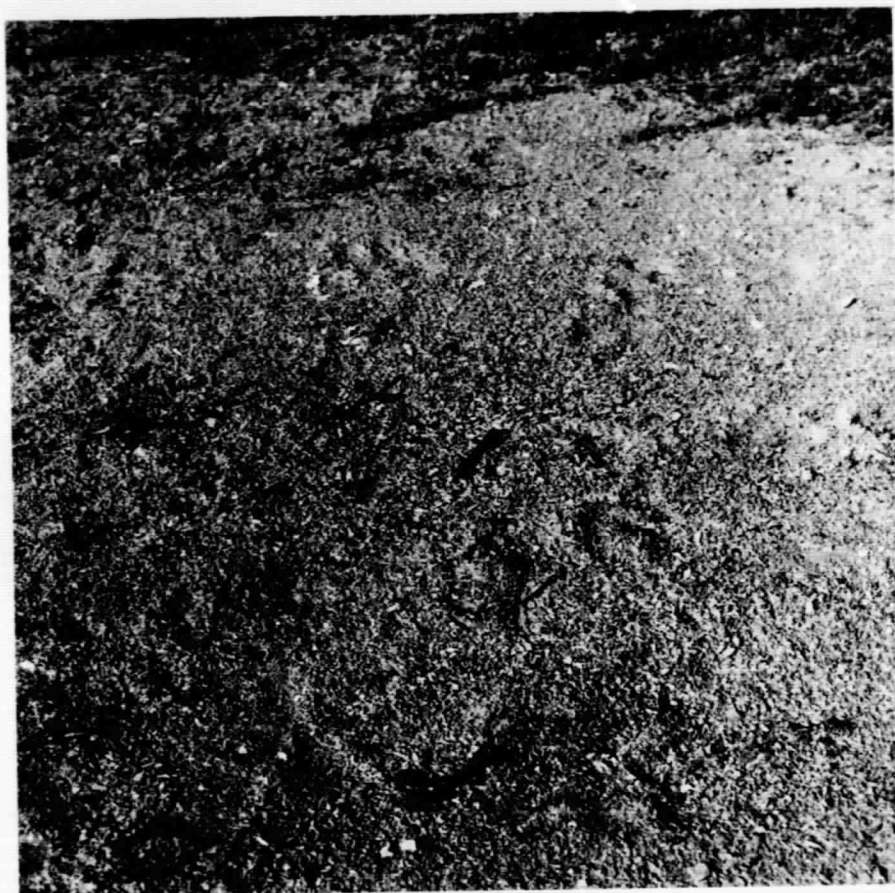


Figure 7. Surface underlain by Bitterwater Creek Shale in image area,
Temblor Range.



Figure 8. Surface underlain by Santa Margarita conglomerate in image area,
Temblor Range.