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DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

INTERAGENCY REPORT NASA-168

GENERALIZED GEOLOGIC EVALUATION OF SIDE-LOOKING RADAR IMAGERY OF THE TETON RANGE AND JACKSON HOLE, NORTHWESTERN WYOMING*

by

J. D. Love**

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

*Work performed under NASA Contract No. R-09-020-011
Task No. 160-75-01-43-10
**U.S. Geological Survey, Denver, Colorado

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Dr. Arch B. Park
Chief, Earth Resources Survey
Space Applications Program
Code SRR - NASA Headquarters
Washington, D.C. 20546

Dear Arch:

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INTERAGENCY REPORT NASA-168

GENERALIZED GEOLOGIC EVALUATION OF SIDE LOOKING RADAR IMAGERY

OF THE TETON RANGE AND JACKSON HOLE, NORTHWESTERN WYOMING*

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Sincerely yours,

William A. Fischer
Research Coordinator
EROS Program

*Work performed under NASA Contract No. R-09-020-011
Task No. 160-75-01-43-10
**U.S. Geological Survey, Denver, Colorado

GENERALIZED GEOLOGIC EVALUATION OF SIDE-LOOKING RADAR IMAGERY OF THE TETON RANGE AND JACKSON HOLE, NORTHWESTERN WYOMING

BY J. D. Love

Introduction

This study is a generalized geologic evaluation of lines, localities, and features of various types that are visible on a series of radar image strips covering the Teton Range and Jackson Hole in northwestern Wyoming. No attempt was made to collate a complete geologic map with the radar image at each locality.

Formation names, problems of geologic interpretation, and details of stratigraphy and structure that are not directly pertinent to a study of the imagery are omitted, but reference is made to publications that contain this type of supplementary information.

Comments

1. The like-polarized return image is much clearer than the cross-polarized return in the areas of high relief shown in figures 2-11.

2. The vegetation cover and the soil cover in the Jackson Hole area have a considerable effect on the tone of the images. These differences in tone are discussed in connection with individual figures, and should be useful in interpreting surficial geology in adjacent localities that have not been visited.

3. The direction in which the beam is pointed is of paramount importance in evaluating the quality and content of the image, This is, in fact, so important that it can influence judgments as to whether or not radar imagery is worthwhile in a given area and for certain types of rocks. Extreme contrasts in the quality of geologic information that is recorded in different images of a single area of moderate to high relief on a complex sequence of rocks as a result of beam direction are discussed in connection with figures 5, 6, and 9. Contrasting data on unconsolidated deposits in an area of low relief, such as locality X in figures 7 and 8, are likewise given.

Perhaps the most striking example of the effect of beam direction is a comparison of the clear details visible in Cretaceous bedrock geology at locality AU, figure 11 (where the direction was favorable), with the almost complete absence of detail in similar Cretaceous rocks with similar topography in the southeast corner of figure 9 (where the direction was unfavorable).

Another area, along the Absaroka thrust fault in figure 2, shows considerable detail where the beam angle and the slope angle are in the same direction. Yet in the same figure, along the trace of the Cache thrust northwest of Teton Pass, where the beam angle and the slope angle are in opposite directions, detail has been lost because the slopes show as white areas.

4. A serious criticism of the geologic value of radar imagery along straight line traverses such as those reviewed in this report is that they do not necessarily show geologic features in a manner suitable for accurate interpretation. It would be desirable, therefore, to experiment further to see what the maximum geologic interpretive potential of radar imagery might be. The first step is to devise a plan for the most effective and economical geologically oriented radar flight lines.

Radar images in areas of high relief are similar in some ways to relief maps such as figure 1, which was made by photographing with oblique light the reverse (blank) side of the AMS (Army Map Service) plastic relief map of northwestern Wyoming. The height and direction in which light was pointed can be compared with the altitude of the plane and direction of the radar beam. Prominent topographic features will have the same general appearance, even though vertical exaggeration on the AMS map is 2X.

Several areas known to include a broad variety of well-mapped geologic phenomena should be carefully selected. Plastic relief maps of these areas can then be studied by placing light in different horizontal and vertical positions so as to determine the direction and altitude of radar flight lines that might show the maximum geologic data. A series of images of each major type of geologic feature, using these various predetermined horizontal and vertical angles, should indicate the most effective orientation from a geologic standpoint. This knowledge can then be applied to the evaluation of radar images of unknown and poorly known terrains. In addition, such experimental data should indicate if radar imagery or oblique air photographs can provide the more complete and accurately interpretable geologic information, and what the cost differential would be in terms of time and money.

Geology of illustrated areas

Figure 1, a relief map, shows the approximate centers of the radar images in figures 2-11, and their relation to adjacent geographic and cultural features. This map serves two purposes: (1) as an index map, and (2) as one whose relief is used to illustrate an idea regarding planning the most effective radar lines for specific localities, areas, and regions. This is discussed in connection with comment 4.

Figure 2, is an area of contrasting relief, with mountainous features that terminate abruptly in some places and gradually merge with relatively flat alluvial plains in others. The radar image emphasizes this relief but, in addition, it distinguishes several geologic features. Part of this differentiation may be the result of selective vegetation patterns that are, in turn, influenced by the underlying geology.


110°
BEARTOOTH MTS
HEART MTN
Cody
MONTANA
WYOMING
YELLOWSTONE
VOLCANIC PLATEAU
Buffalo Bill Res.
Meeteetse
YELLOWSTONE NATIONAL PARK
GRAND TETON NATIONAL PARK
CARTER
44°
44
Jackson L.
TETON RANGE
Buffalo Fk
WASHAKIE
IDAHO
WYOMING
Teton Basin
JACKSON HOLE
Snake R.
Victor
Dubois
Wind R.
GROS VENTRE MTS
Jackson
HOBACK RANGE
Bull L.
110°
0
10
20
30
40
50 MILES

Figure 1

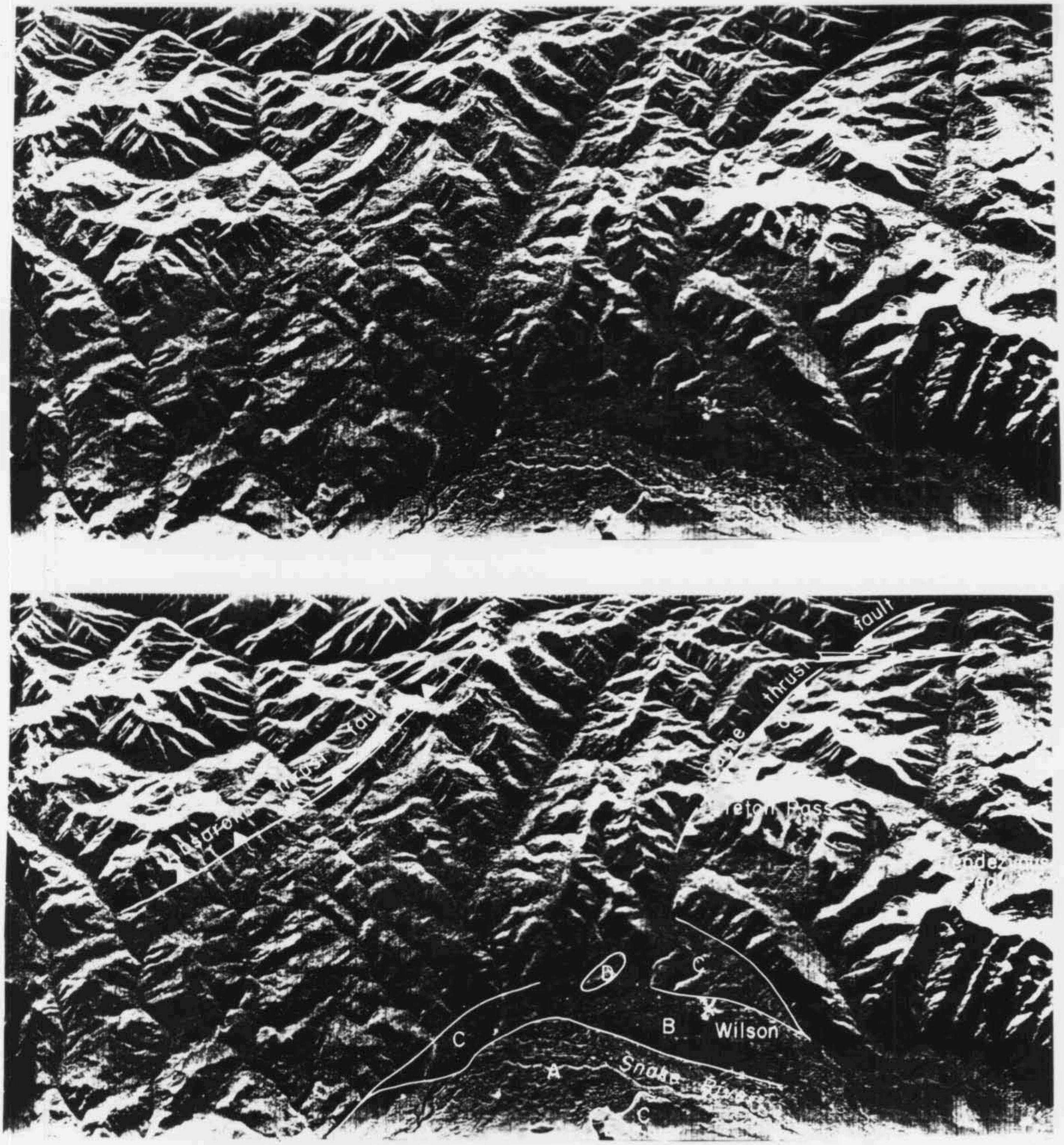


Figure 2

3

Site A is a gravel surface constituting the modern alluvial flood plain of the Snake River. The deposit is chiefly of quartzite boulders and sand, with only a thin intermittent cover of soil. The gravel is unconsolidated and well-watered; it supports a thick growth of large cottonwood trees that are not present in such density elsewhere in the area. This difference in vegetation is recorded on the image.

Contrasting with site A is site B, a soil mantle on an alluvial plain slightly higher and older than A; the soil is thicker and more continuous than at A. Much of the area of B is cleared of trees and has been turned into hay meadows. This vegetation difference, the soil mantle, and the absence of meander scars give the image in area B a tone and texture easily distinguishable from that of A.

Site C is a loess mantle, probably 10,000-20,000 years old, that overlies outwash gravels from an earlier glaciation. It is 50-200 feet above, and is somewhat older than, the alluvial flood plains of A and B. On the mountainward side, the loess is increasingly mixed with talus, slopewash, and reworked older glacial debris. The soil is fertile and supports patchy growths of aspen and conifers. The sharp east boundary of this deposit at the town of Wilson and the sharp arcuate western boundary northwest of Wilson may be either Pleistocene fault scarps or erosional features.

Site D is a plug of rhyolitic material and obsidian which is very poorly exposed, because of dense coniferous vegetation, alluvial slopewash, and formless glacial deposits. Even though the relief is low, the plug is moderately conspicuous on the radar image.

Site E is a knob of hard Paleozoic carbonate rocks surrounded by alluvial gravel; that on the southwest side is part of deposit A and on the north side, C.

F is a segment of the northern part of the Absaroka thrust fault, a major structural feature that extends for 150 miles north and south through western Wyoming. Rocks on opposite sides of the fault have strikingly different appearance on the radar image. This contrast apparently is not caused by vegetation but is a reflection of differences in topography developed or different types of bedrock. On the southwest side, the northwest part of the overriding thrust plate (which moved northeastward here) is composed of Triassic and Jurassic red beds, limestones, and sandstones, whereas the southeast part is composed of Paleozoic sandstones and carbonate rocks. Both segments override the same sequence of soft sandstones and shales in the Lower Cretaceous section.

G marks a part of the Cache thrust fault, the trace of which follows a sharp valley. Paleozoic rocks on the north (sawtooth) side were thrust southwestward over a complexly faulted sequence of Paleozoic and Mesozoic strata. The image shows none of these relationships, probably because the beam angle and slope angle are in opposite directions and as a consequence the slopes are recorded as white areas.

Figure 3. The most conspicuous feature of this area, apart from its high relief, is the linear termination of interstream spurs along the west edge of the Teton Range in the vicinity of Alta, Wyoming. Unfortunately, the radar image is somewhat obscured by marginal light and dark zones ("ringing") that do not reflect anything on the ground. There also is severe foreshortening of features on the west margin of the image--the margin nearest the instrument--resulting in a linearity that is more apparent than real. On the basis of distortion patterns shown in figures 5, 6, and 9, it seems probable that if a second image had been made of the Alta area, with the instrument pointed west, the linear termination of spurs would not appear as conspicuous.

The sharp lineament between points A and B is a topographic break that cannot be explained by stream erosion (which goes almost at right angles, westward across it), or by glaciation (glaciers, likewise, went directly west). The most logical explanation of this lineament is faulting. There are no bedrock outcrops on the A side of the lineament. Spreading westward from the mouth of each stream where it crosses the lineament is a large alluvial fan composed of sand and gravel, capped by a loess and soil mantle. On the B side of the lineament, the bedrock is Paleozoic carbonate capped by thin discontinuous remnants of rhyolite welded tuff, pumice breccia, or flow rock of Pliocene (?) age. All these rocks are covered in part by colluvium and other types of Quaternary debris.

The geology of the area is shown on a map by Pampeyan and others (1967); no fault is indicated along the lineament but no explanation is given therein for the origin of this feature. It is characterized by alinement of the ends of west-projecting spurs of alluvium and bedrock. A recent geophysical study (Malahoff and Moberly, 1968, fig. 7) shows a fault in this general vicinity but evidence for it is not discussed. Modern fans are not offset, so if the lineament represents a fault, it must be older than the fans, yet younger than the alluvial spurs on side B. The fans, themselves, are unusually large as compared with their upstream drainage areas and have abnormally steep westward gradients. These features suggest that development of the fans may have been triggered by relative downfaulting of the valley on the west.

Most of the white areas of high relief in the image are Paleozoic carbonate rocks that dip gently westward on the west flank of the Teton Range.

Figure 4 is a radar image of the north end and west flanks of the Teton Range, both of which were partly buried by Pleistocene rhyolitic welded tuff. The geology is very complex; some of it is conspicuous in the radar image and some is not. For example, Precambrian rocks (PC) in the Rammel Mountain area are hard to distinguish from Paleozoic (P)

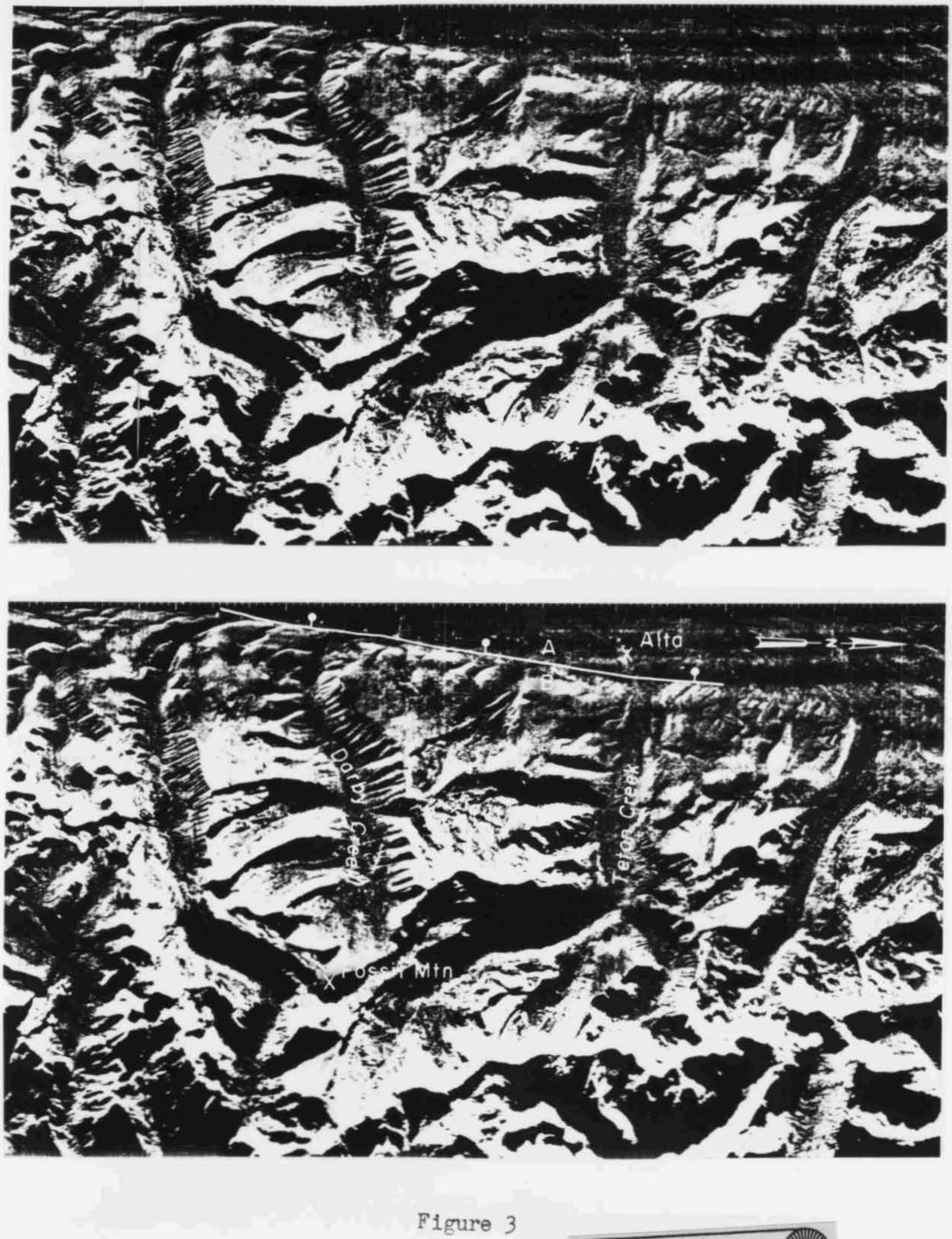


Figure 3

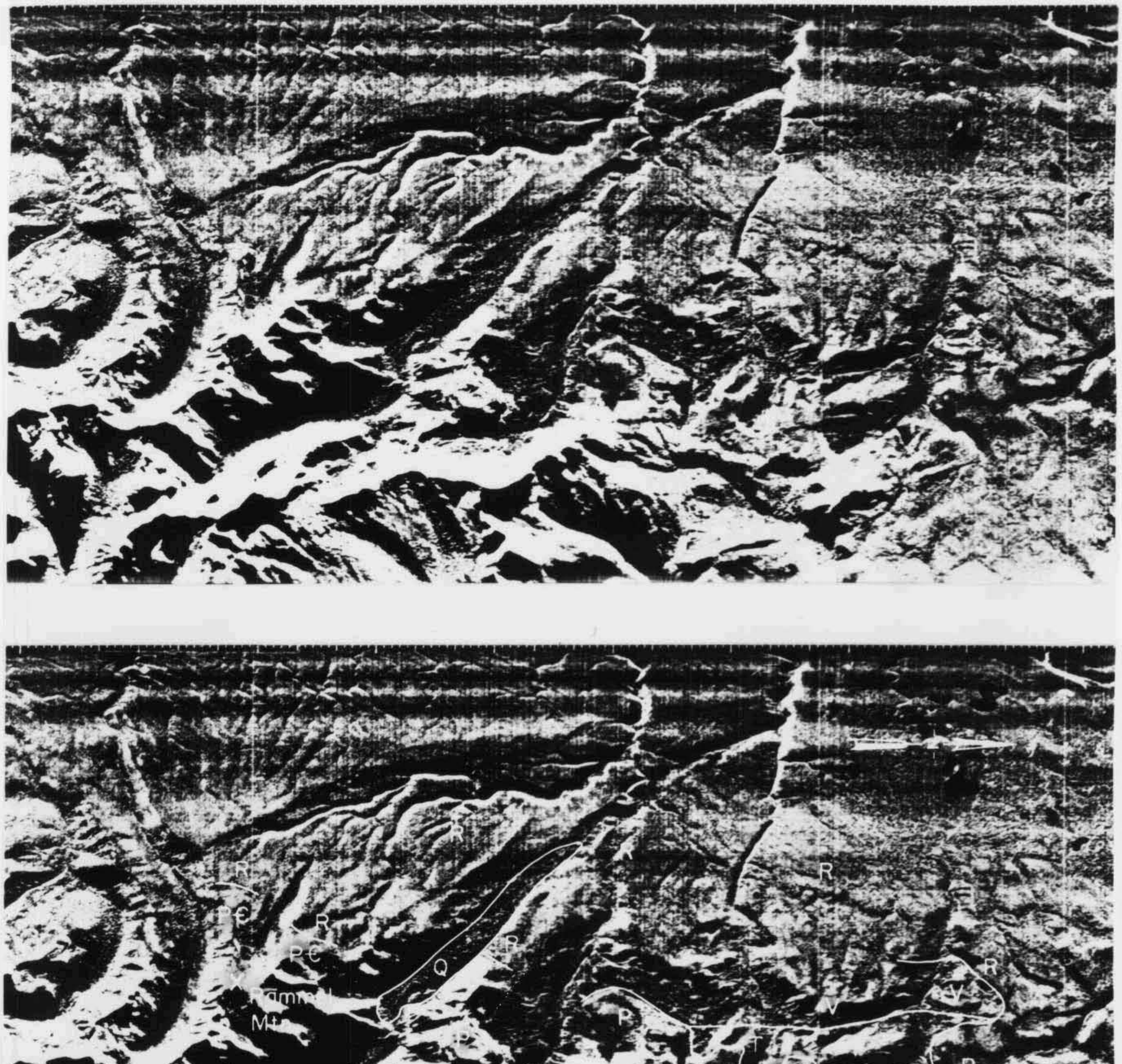


Figure 4

carbonate rocks farther north, whereas the Pleistocene rhyolitic welded tuff (R), perhaps because of its characteristically dense lodgepole pine forest cover and moderately smooth bedrock surface, is readily distinguishable in most places from Precambrian, Paleozoic, Mesozoic (Triassic siltstone red beds M), Paleocene conglomerate (T), and Miocene (?) basaltic pyroclastic rocks (V). The Triassic red beds (M) are not distinguishable from the Paleocene conglomerate. The Quaternary valley fill (Q), composed chiefly of boulders, gravel, and sand derived from Precambrian and Paleozoic rocks, has a distinctive tone that is made more conspicuous by the flat topographic expression of the deposit.

In the vicinity of Survey Peak, steeply dipping sparsely vegetated Paleozoic carbonate rocks that form sharp north-northwest-trending hogbacks can be observed very clearly to the point where they disappear beneath flat-lying densely wooded (lodgepole pine) Pleistocene rhyolitic welded tuff.

Figure 5 is of the northern part of Jackson Hole, with the Teton Range in the southwest corner and rhyolitic rocks of southern Yellowstone National Park at the north end. The part of the Teton Range included here consists of an area of high relief cut in northeast-dipping Paleozoic rocks (P), chiefly carbonates, and the underlying Precambrian crystalline and metamorphic rocks (PC) in the core of the range. In the southwest part of the figure is the Forellen normal fault along which Paleozoic strata on the west side were dropped several thousand feet against Precambrian crystalline and metamorphic rocks. To the left of the word "Forellen," on the radar image, ribs of Paleozoic carbonate rocks can be seen turning up steeply against the fault. Elsewhere in this area the Precambrian and Paleozoic rocks are not consistently distinguishable on the image.

In the northern part of the area of figure 5, a late Pleistocene rhyolite flow (F), whose front has a conspicuous topographic expression, overlaps older Pleistocene rhyolitic welded tuff (R). The tone of the two is similar but flow features are distinguishable in the younger unit on the like-polarized image (compare with figures 6 and 9).

Faults of the Hering Lake fault system (Love, 1961) offset the Pleistocene rhyolitic welded tuff south of Beula Lake. Only one rock unit is involved and the faults are distinguished on the image only by their topographic expression (compare with figures 6 and 9).

North of Jackson Lake is a swarm of south-trending subparallel ice scour lines (S), only a few of which are indicated on figure 5 (compare with figure 9), that cut indiscriminately across Pleistocene rhyolitic welded tuff (R) and Cretaceous sandstone and shale (K).

In the southeast corner of figure 5, the lumpy topography is on coarse bouldery morainal debris that bounds the east margin of Jackson Lake. Northwest of the lake is a large area of landslide debris (L)

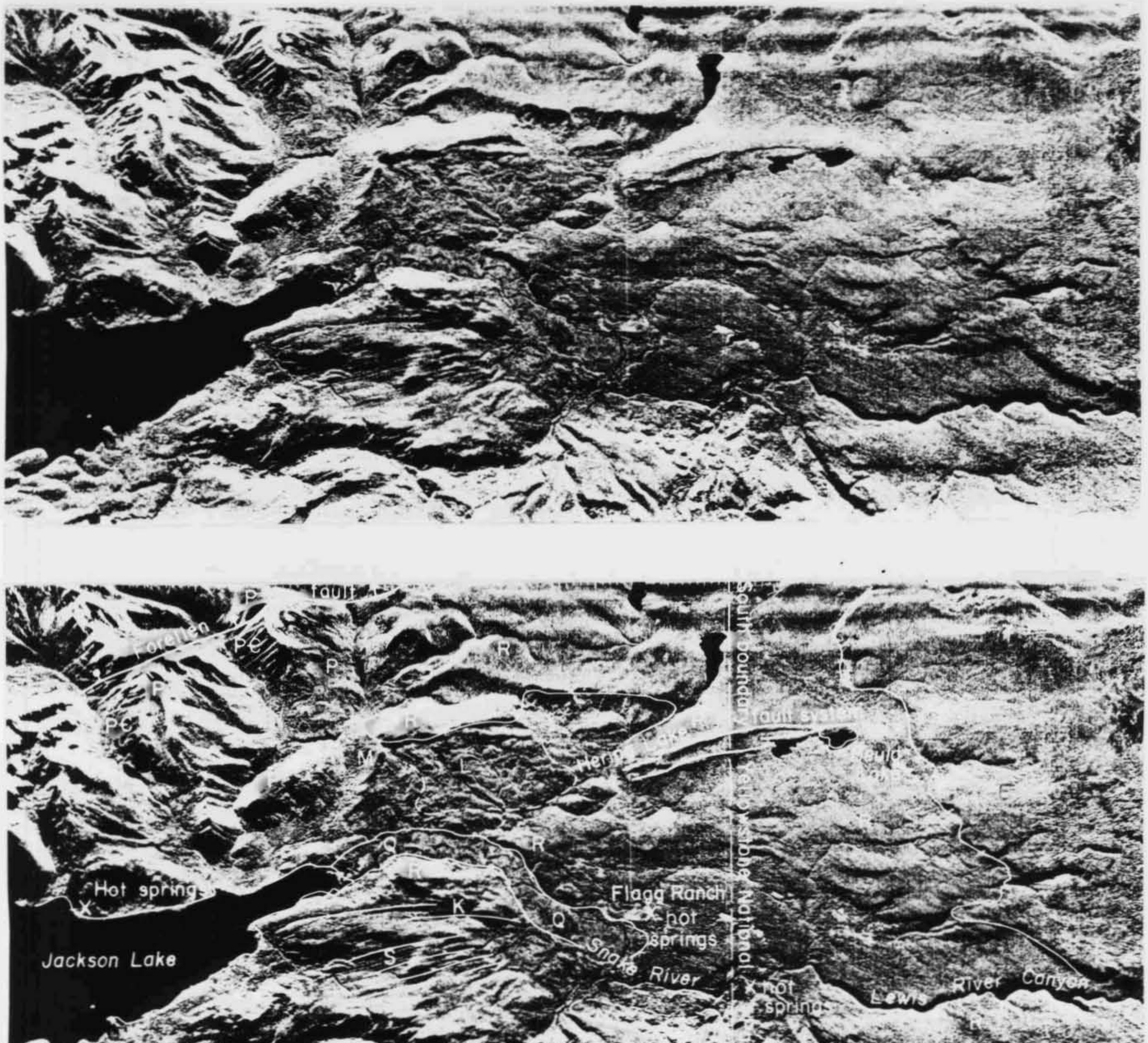

Hot springs
Jackson Lake
Flagg Ranch
hot springs
Snake River
hot springs
Lewis River Canyon
fault system

Figure 5

that involves Triassic and Jurassic red beds and gray shale (M) and Pleistocene rhyolitic welded tuff (R; compare with figures 6 and 9). Another smaller conspicuous landslide area is east of the Flagg Ranch hot springs and south of the Yellowstone National Park boundary. Here the upper part of the slide involves Pleistocene rhyolitic welded tuff and the glide planes are in Cretaceous shale.

Extending north from Jackson Lake along the Snake River is a flood plain of boulders (Q) that terminates southeast of the Flagg Ranch hot springs. The tone of this deposit is similar to that of the rhyolitic welded tuff and the deposit is distinguished chiefly on the basis of its flat surface. Trees are sparse and clustered and most of the vegetation is short grass.

Several localities of hot springs are present but are not distinctive on either the like-polarized or cross-polarized image. This is interesting because of the different rock types associated with the springs. The springs on the west shore of Jackson Lake emerge from Paleozoic carbonate rocks, the Flagg Ranch hot springs from Pleistocene rhyolitic welded tuff, and those inside Yellowstone National Park from Paleozoic sandstone overlapped by rhyolitic welded tuff.

Figure 6, a west-looking image, contrasts with figure 5, which is east-looking. Both images include several of the same significant features and record them with different intensities. For example, the Hering Lake fault system is much more prominent in figure 6, even though the image is somewhat compressed (see also fig. 9). The big landslide area (L) south of the faults is likewise compressed in figure 6. Although the extent of this landslide is much more definitive in figure 5, the headwall scarps are more conspicuous in figure 6. Two sets of Pleistocene rhyolite flow fronts (RO, RY) are visible in figure 6; the older, southern one (RO) also is visible in the area covered by figure 5. They are much clearer in the radar images, especially in figure 6, than on vertical air photos, probably because the oblique angle of the radar beams emphasizes the topography. A topographic lineament of uncertain origin (F) in Pleistocene rhyolitic welded tuff (R) suggests a fault. This being an area of dense timber and poor exposures, the presence of a fault may be difficult to establish on the basis of ground investigations.

Figure 7 illustrates well the value of radar imagery in studying and portraying certain types of Pleistocene features. Love and Reed (1968) discussed the image and the geology of this and adjoining areas. The steep east face of the Teton Range is largely of Precambrian crystalline and metamorphic rocks (PC). The break in slope at the east base of the range marks the buried trace of the Teton normal fault, along which the mountain block moved up relative to the Jackson Hole block; differential movement amounted to 20,000 feet or more. Overlapping the fault in all but a few places (fig. 8) are Quaternary deposits of several types. These likewise lap against the sides of faulted and glaciated buttes that project above the floor of Jackson Hole.

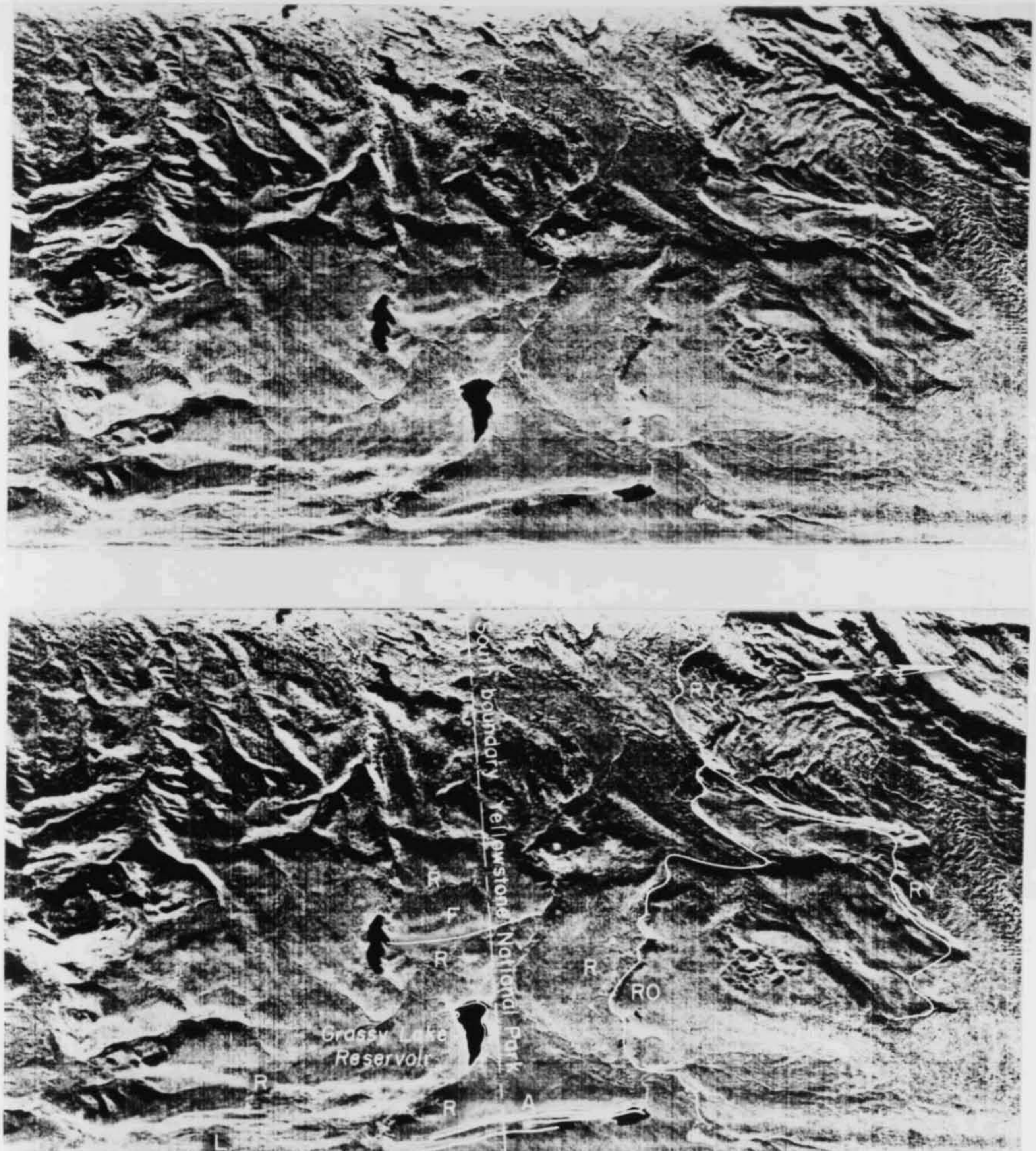

boundary Yellowstone National Park
Grassy Lake Reservoir
R
F
R
R
R
R
RO
RY
RY
L
A

Figure 6

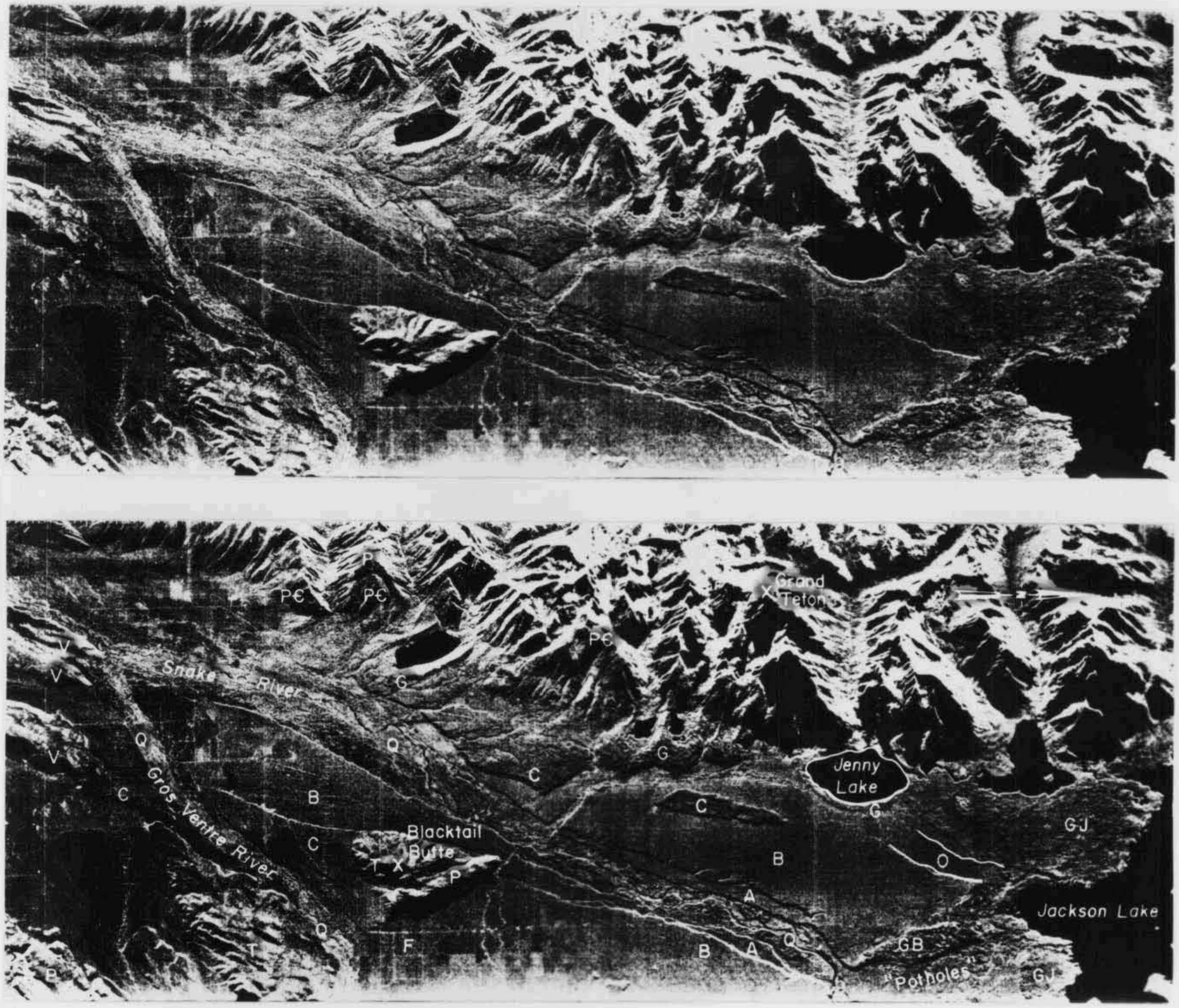

Grand Teton
Snake River
Gros Ventre River
Blacktail Butte
Jenny Lake
Jackson Lake
"Potholes"

Figure 7

These buttes are composed of several rock types, such as Pleistocene andesite and basalt (V), Pliocene limestone and tuff (T), and Paleozoic carbonate rocks (P). The Pliocene and Paleozoic rocks on Blacktail Butte look very much alike on the image. The triangular shape of the butte is the result of faulting and subsequent scouring by an early or middle Pleistocene southward-moving ice sheet.

Many middle and late Pleistocene features and deposits are strikingly displayed on the radar image and their succession of development of interrelation can be interpreted. The oldest of these conspicuous deposits are topographically prominent remnants of till and outwash capped by loess (C). Those closest to the Tetons are covered with a dense growth of lodgepole pine, whereas the one south of Blacktail Butte is bare. This accounts for a somewhat different texture and tone of the image.

Lapping against these old remnant hills of bedrock, moraines, and outwash debris are extensive flat gravel outwash plains (B), bare of loess and trees. The most conspicuous and widespread of these surfaces spreads southward through Jackson Hole from the south edge of the Burned Ridge moraine (GB), of late Pleistocene age, and was formed as the ice north of the moraine melted. This moraine is lumpy and heavily timbered with conifers, and so, on the image as well as on the ground, it presents a striking contrast to the bare outwash plain to the south.

During the final stages of melting of the ice north of the Burned Ridge moraine, knob and kettle topography developed in an area locally known as the "Potholes," shown in the northeast part of figure 7. Following this cane the most recent ice advance, probably about 10,000 years ago (Love and Reed, 1968). It is marked by a series of moraines that emerged from canyons in the Tetons and left circular morainal deposits (G) ringing the lakes along the west margin of the floor of Jackson Hole. The moraines support a dense stand of conifers, whereas the outwash extending out from the moraines is bare of trees. This vegetation pattern, as well as the characteristic lumpy topography of the moraines, sets these features apart on the image.

The largest of these very young morainal deposits is the Jackson Lake moraine (GJ) which is likewise heavily timbered with conifers. This moraine was breached at locality O and an outlet channel for the Snake River developed, then was abandoned as other outlets (not visible in figure 7) were cut through the moraine farther northeast.

During and after the melting of ice behind the Jackson Lake moraine, successively younger stages of terraces developed (Love and Montagne, 1956, p. 169); these are clearly visible on the radar image of the Snake River course. Surface A, composed of gravel without a loess cover, is related to the first major episode of melting of the ice behind the Jackson Lake moraine. Later melting of ice and diversion of outlets to Jackson Lake were responsible for development of a surface (Q) along and slightly above the present Snake River. A comparable surface flanks the

Gros Ventre River; both are essentially all gravel with little loess or soil cover. They support a stand of cottonwood trees, which contrasts with the bare terrace surfaces on both sides. The differences in vegetation, topography, abundance of water, and braided channelways make this surface (Q) readily distinguishable on the image.

Fault scarps within this area are discussed in connection with figure 8.

Figure 8 is a good example of the value of having two sets of radar images of the same area but with the opposite look-directions. The west-looking figure 8 records very clearly the latest Pleistocene fault scarplets that cut alluvial fans northwest and southwest of Jenny Lake (Love and Montagne, 1956; Love and Reed, 1968) and the scarps south of Blacktail Butte that offset loess 12,000-15,000 years old (Love and Taylor, 1962; Love, 1965, p. 42). These scarps are difficult or impossible to distinguish on the east-looking imagery shown in figure 7.

A somewhat puzzling contrast in the east- and west-looking images is shown in the area of the Flat Creek alluvial fan (FC). This fan is of Quaternary age and has a very thin discontinuous soil cover on gravel composed chiefly of Paleozoic rocks. It merges with silt and clay swamp deposits (S) along a sharp line (X). This line is marked by very little change in elevation but a considerable difference in vegetation from common hay-meadow types of grass to coarse swamp grass. Few ponds of standing water are present in this part of the swamp. The various features described here are clearly visible in figure 8 but are inconspicuous in figure 7. The reason for this contrast is not known.

Another feature of figure 8 demonstrates the need for caution in interpretation. For example, the Paleozoic carbonate rocks at P look like a series of northwest-dipping hogbacks, whereas, on the ground, the rocks are complexly faulted and the fault and fracture lines have been exploited by southwestward-moving ice that scoured out elongate parallel giant grooves. Where the scour lines and bedrock structures diverge, the result is a series of anomalous-appearing cross-lines, such as those in the extreme southeast corner of the image. The hogback appearance is intensified by near-side foreshortening of the image.

A different kind of distortion, that can occur a considerable distance from the margins of radar images, is demonstrated by the rhomboid shape of the fields at F, east of Blacktail Butte. On the ground and in figure 6 these are rectangles.

The Pliocene tuff and limestone sequence (T) does actually dip west and on the radar image looks very much like the ice-scoured Paleozoic rock outcrops, only some of which dip west.

Figure 9 overlaps most of the area of figure 5 and extends to the east. Both images are east-looking, yet there are conspicuous differences. For example, the east-facing scarps of the Hering Lake fault

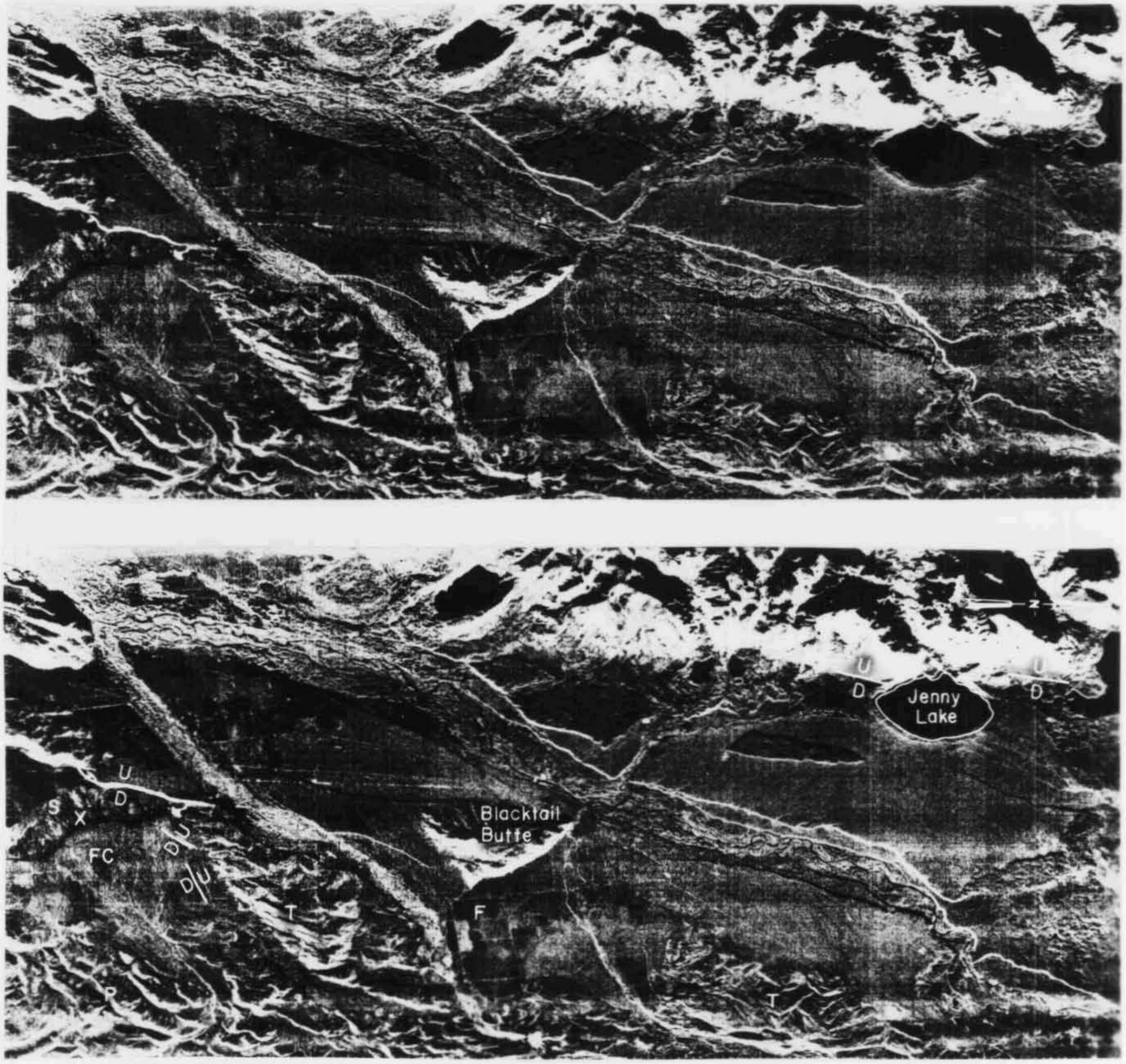


Figure 8

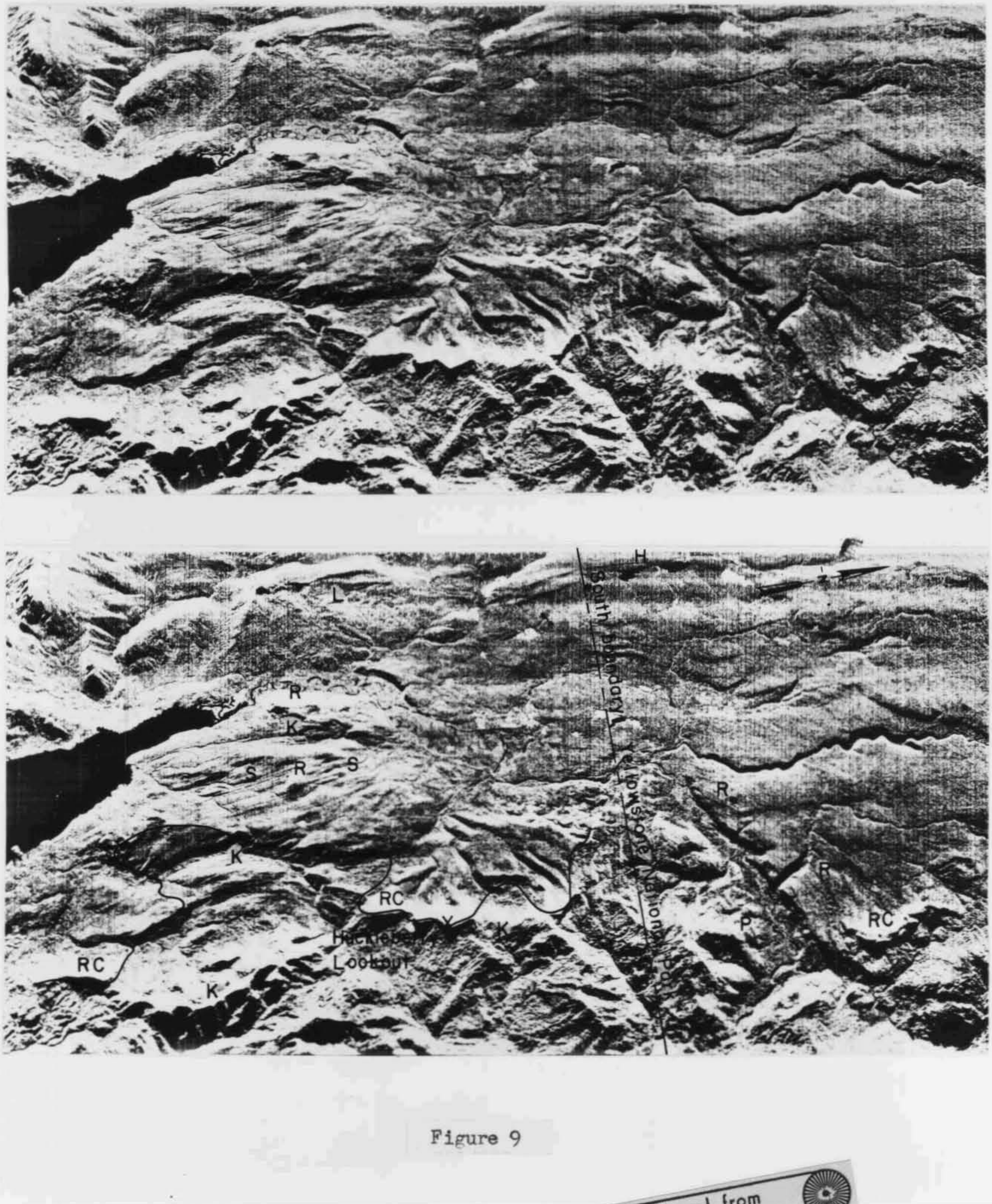


Figure 9

system (H) are barely recognizable in figure 9 because they are closer to the flight line and hence produced no radar shadows as in figure 5. In this connection, also, a comparison with figure 6, a west-looking image, shows an extreme contrast in recording of the fault lines--a result of maximum back-scatter from the east-facing scarps.

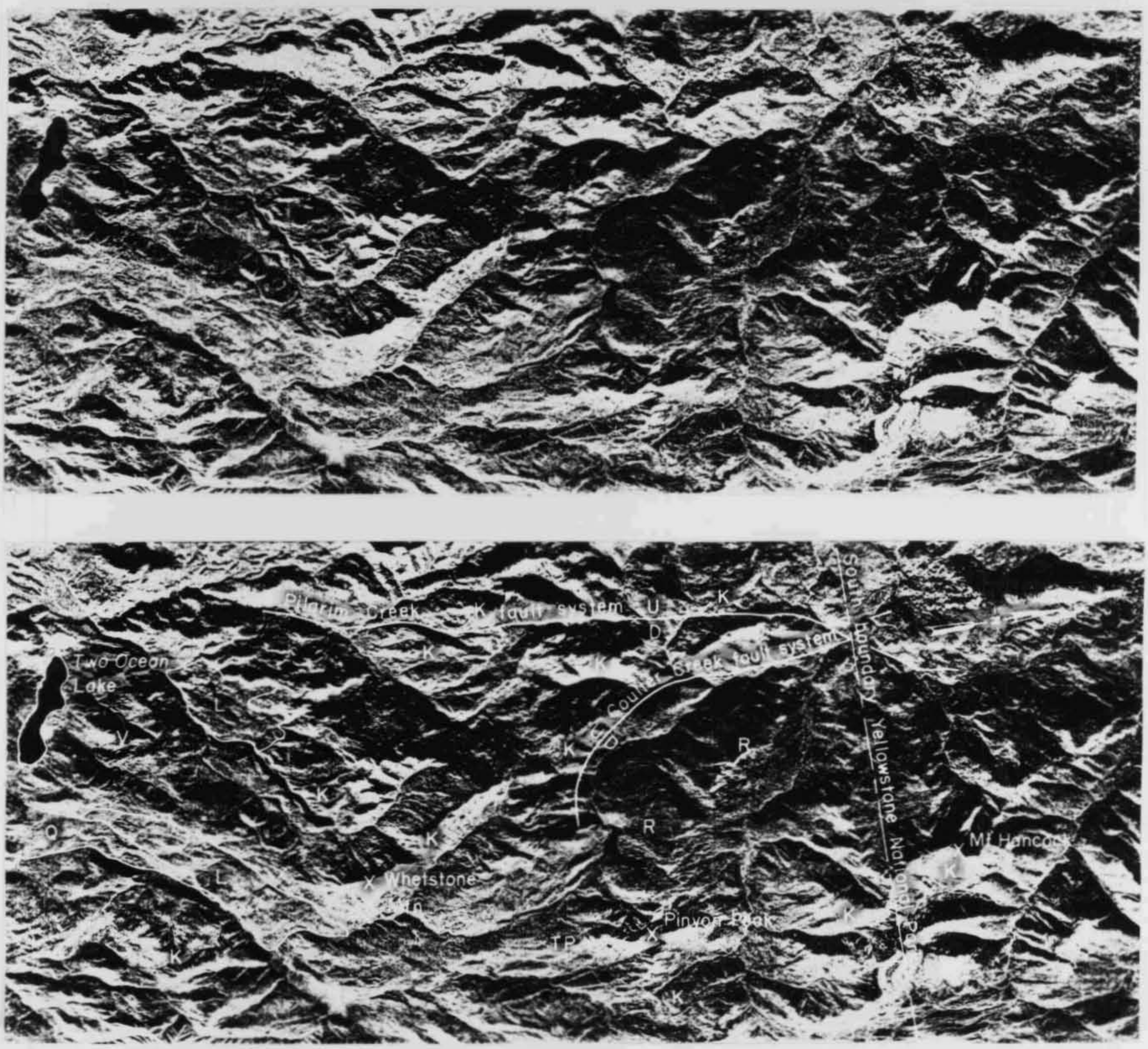
The large landslide area (L) that is quite clear-cut in figure 5 is poor in figure 9. On the other hand, the adjacent glacial scour lines (S), cut by southward-moving ice, that extend without deviation across Cretaceous sandstone and shale and Pleistocene rhyolitic welded tuff are subdued in figure 5 and have more detail in figure 9.

The most conspicuous feature of figure 9 is the series of cuesta slopes of west-dipping Pleistocene rhyolitic welded tuff (RC) alined for 25 miles from north to south. These acquired their west dip as a result of subsidence of Jackson Hole. Later glaciation and faulting have, in many places, obscured their original prominence. The oblique radar image brings out the cuestas in a way that vertical air photos do not. Some cuestas resemble outcrops of adjacent Cretaceous rocks that have been folded into sharp anticlines and synclines. This resemblance, however, is simply one of coincident topography. None of the structural detail is discernible in the Cretaceous and older sedimentary rocks. As was noted in figure 5 in the vicinity of the Forellen fault and in Cretaceous and Paleocene rocks of figure 11, when the angle of the beam is optimum for recording linear ridges of folded rock, they can be observed in the image, so it is probable that east of the cuestas the beam angle was not favorable.

North of the Yellowstone National Park boundary, the cuesta slopes appear to have been overlapped on the west and south sides by younger rhyolites (R) that have not been tilted.

Figure 10 shows the response of the radar beam to wide variety of stratigraphic, structural, topographic, and surficial features. The Pleistocene rhyolitic welded tuff (R) has the same appearance as that in figures 4, 5, 6, and 9. It is covered with the same dense lodgepole pine forest that is present at the other localities. Conglomerate and sandstone of Cretaceous (K) and Paleocene (TP) age are indistinguishable on the image (in places, they are difficult to distinguish on the ground). The extensive areas of landslide debris (L), on the other hand, can readily be recognized on the image by their concentrically lumpy surface configuration.

Bedding in Cretaceous and Paleocene rocks is conspicuous southeast of Mount Hancock, south of Pinyon Peak, and west of Whetstone Mountain. Major fault systems, such as Pilgrim Creek and Coulter Creek, are not conspicuous, but can be delineated if one knows where to look. The Quaternary flood plain gravel is distinguishable. It has very little soild cover and the vegetation consists of patches of cottonwood, aspen, and coniferous trees. The Oligocene and Miocene mafic volcanic rocks (V) are not distinctive on the image.



Pilgrim Creek fault system
U
D
Two Ocean
Lake
Whetstone
Pinyon Peak
TP
Mt Hancock
South boundary Yellowstone National

Figure 10

Figure 11, of the Enos Lake area, is an example of radar imagery that is almost ideally oriented to portray the maximum surficial sculpturing as well as bedrock geology of an area. This image is effective because a considerable part of the geology and topography is linear in a north-south direction, whereas the beam was west-looking, almost at right angles to the grain of the landscape.

The configuration of the land surface in the area is deceptive; from an interpretive standpoint: the eastern third is one of high relief that appears superficially to be somewhat linear in a north-south direction. Actually, the part with high relief involves rocks of Precambrian (PC), Paleozoic (P), and Eocene and Oligocene (V) ages, but these rocks continue on to the west into the area of much lower relief. The major structural feature is the Buffalo Fork thrust fault, along which Paleozoic and Precambrian rocks composing the core of the partly buried Washakie Range were shoved westward onto vertical and overturned strata of the Harebell Formation of latest Cretaceous age (K). These Cretaceous rocks are overlapped, with an angular unconformity of about 90°, by the Pinyon Conglomerate (TP). The fidelity of the image is illustrated at point AU, east of Gravel Peak, where the angular unconformity is represented by the converging lines.

A zone of conglomerate in the Harbell Formation (HC) is conspicuous in the southern part of the area. Trending obliquely across the conglomerate is a series of parallel glacial scour lines that represent giant grooves cut by southward-moving ice from Yellowstone National Park. These lines are visible the entire length of the image and cut across as well as along many types of folded and faulted bedrock. Linear scouring is intensified where ice moved parallel to strike of soft beds in the Harebell Formation, as at the locality directly east of AU.

One of the most interesting and unusual features of this area is the partly exhumed Enos Lake "chaos" (C), which consists of jumbled, randomly oriented blocks and masses of Paleozoic rocks, chiefly Madison Limestone, that were buried by Eocene and Oligocene igneous and pyroclastic rocks (V) after the jumbling occurred. On the radar image the "chaos" shows no definite pattern. Its origin is not known and it has not been described in the literature.

Minor faults cutting pyroclastic rocks in the northeastern part of the area are shown by sharp topographic lineaments.

An elongate area of soil-covered flood plain (Q) along the Buffalo Fork River is conspicuous in the southeast part of the area. Much of the flat area is damp and swamp grass is common, although there is little standing water.

The line B, near the east edge of the image, is a cliff cut in a sequence of basalt lava flows. The flat surface above (east of) this cliff is the upper surface of the lavas, exhumed by southward-moving ice. This ice also cut the next cliff east of B, in bedded volcanic deposits.

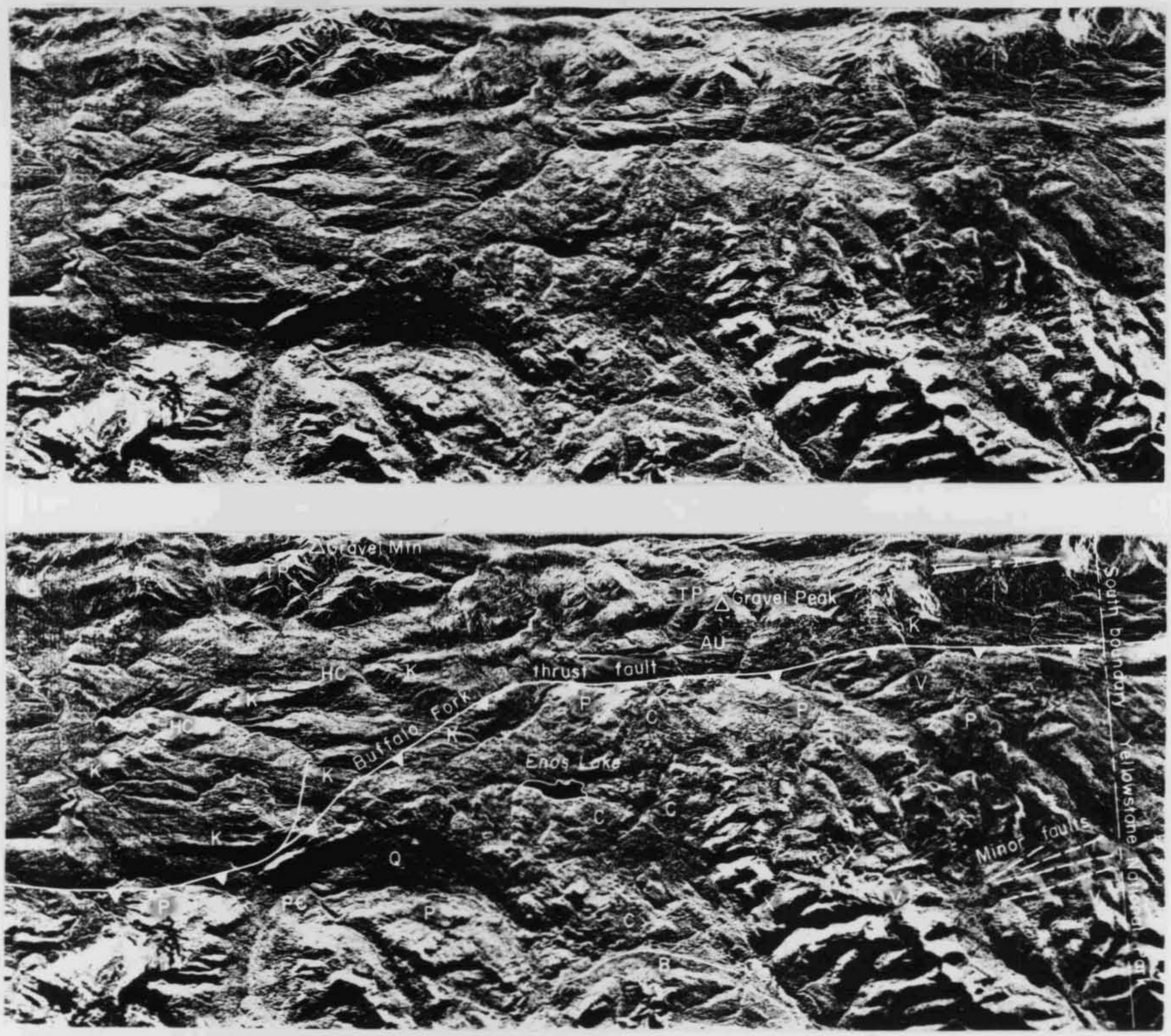

Gravel Mtn
TP
Gravel Peak
AU
K
HC
thrust fault
Buffalo Fork
P
C
Enos Lake
Q
PC
B
V
Minor faults
South boundary Yellowstone

Figure 11

References cited

Love, J. D., 1961, Reconnaissance study of Quaternary faults in and south of Yellowstone National Park, Wyoming: Geol. Soc. America Bull., v. 72, no. 12, p. 1749-1764.

_____ 1965, Section along ditch at Stop D-3, in Jackson Hole National Elk Refuge, Wyo., in Northern and middle Rocky Mountains, Guidebook for Field Conf. E, INQUA, VIIth Congress: p. 42.

Love, J. D. and Montagne, John, 1956, Pleistocene and Recent tilting of Jackson Hole, Teton County, Wyoming, in Wyoming Geol. Assoc. 11th Ann. Field Conf. Guidebook, 1956: p. 169-178.

Love, J. D., and Reed, J. C., Jr., 1968, Creation of the Teton landscape--the geologic story of Grand Teton National Park: Grand Teton Nat. History Assoc., 120 p.

Love, J. D., and Taylor, D. W., 1962, Faulted Pleistocene strata near Jackson, northwestern Wyoming, in Short papers in geology, hydrology, and topography: U. S. Geol. Survey Prof. Paper 450-D, p. D136-D139.

Malahoff, Alexander, and Moberly, Ralph, Jr., 1968, Effects of structure on the gravity field of Wyoming: Geophysics, v. 33, no. 5, p. 781-804.

Pampeyan, E. H., Schroeder, M. L., Schell, E. M., and Cressman, E. R., 1967, Geologic map of the Driggs quadrangle, Bonneville and Teton Counties, Idaho, and Teton County, Wyoming: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-300.