NATURAL RESOURCES PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-30

U.S. Geological Survey
Department of the Interior

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

Technical Letter
NASA-30
July 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 3 copies of:

TECHNICAL LETTER NASA-30

PRELIMINARY EVALUATION OF RADAR IMAGERY

OF YELLOWSTONE PARK, WYOMING*

by

R.L. Christiansen**
K.L. Pierce**
H.J. Prostka**
E.T. Ruppel**

Sincerely yours,

William A. Fischer
Research Coordinator for
USGS/NASA Natural Resources Program

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Denver, Colorado

UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-30

PRELIMINARY EVALUATION OF RADAR IMAGERY OF YELLOWSTONE PARK, WYOMING*

by

R.L. Christiansen**
K.L. Pierce**
H.J. Prostka**
E.T. Ruppel**

July 1966

These data are preliminary and should not be quoted without permission

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, Denver, Colorado

U. S. Government Agencies Only

Preliminary Evaluation of Radar Imagery

of Yellowstone Park, Wyoming

by

R.L. Christiansen, K.L. Pierce, H.J. Prostka & E.T. Ruppel

SUMMARY

Preliminary studies of radar imagery in the Yellowstone Park area show that it has certain valuable use in regional geological reconnaissance. Foremost among these are its all-weather capability and wide areal coverage. Geologic features are best expressed by topographic irregularities and include lineaments (faults and fractures), contrasting stream drainage patterns and glacial deposits. Flow structures in rhyolite flows enable one to distinguish rhyolite flows from ash flows and basaltic lava flows, whereas distinctive stream dissection patterns enable differentiation between lava flows and ash flows.

Imprecisions and variability of scale are considered to be major disadvantages. Furthermore, there is no apparent expression of grain size, color or composition of rock types.

Preliminary evaluation of radar imagery of the Yellowstone Rhyolite Plateau

By

Robert L. Christiansen

As I have not yet done any field mapping in Yellowstone, this evaluation is based entirely on the general features of the rhyolite plateau as known from previous reconnaissance studies and is, therefore, preliminary. The most obvious uses of this imagery in relation to the Yellowstone plateau are those that are already well known in general. Because of the combination of small scale, high flight altitude, wide areal coverage, and pictorial representation, major structural units stand out readily. Such features as major fault-bounded blocks, sectors of the volcanic plateau, etc. are immediately recognizable. With only a moderate amount of additional study many other structural alignments can be observed such as faults affecting the topography (especially small grabens), master joints, and such geologically meaningful terrain features as stream terraces, glacial grooves, etc.

More specifically applicable to geologic study of the rhyolite plateau is the appearance on the imagery of surface flow-structure patterns on the rhyolitic lava flows. On more recent, undissected flows the structure is directly apparent as parallel concentric pressure ridges on the flow surfaces (Figs. 1 and 2). On older, more dissected flows a control of the flow structure on weathering and erosional features is visible, at least in many instances. Such flowage structures in rhyolitic lava flows have a characteristic form resulting from the high viscosity and typical flowage mechanisms in these lavas. Consequently, the rhyolitic lava flows can be readily distinguished on the radar imagery from the rhyolitic ash flows and basaltic lavas which form the remainder of the plateau. In addition, these features allow estimation of the vent areas and flow directions in the most favorably situated lava flows. Individual flows and eruptive domes can be outlined, at least approximately, by topographically expressed flow fronts (Figs. 1B and 2F) and by the internally consistent patterns of flow structures. The line of vents for the flows of the Madison Plateau is visible both from the points of focus of surface flow patterns and by the presence of a small graben along the line at its southern end.

Examination of the Yellowstone radar imagery shows that the relative degree of stream-dissection which is apparent on the images can be related to relative ages of the individual flow units. The pattern of dissection, as noted previously, also is related to lithologic type (lava flows <u>vs</u>. ash flows).

It should be emphasized that all of these features (except possibly the graben at the southern end of the Madison Plateau) are known from previous geologic studies, and that little basically new information has come from study of the imagery alone. However, if little were known beforehand of the geology of the area, except that it is a plateau region consisting principally of rhyolitic ash flows and lava flows, most of the areal features now known from previous studies could have been deducted at least approximately.

The principal disadvantage of the imagery is a tool for geologic study of this area is the imprecision and variability of scale resulting from non-topographic factors. This is especially disadvantageous because the flight parameters and certain critical data regarding the imagery are unknown because of security classification. There is virtually no information on the images regarding chemical or mineralogical composition; I can't distinguish basaltic lavas from rhyolitic ash flows. I have seen no features of geological significance on the images that are not visible also on aerial photographs of the same area but in turn cannot see some features that are visible on the photos. However, the fact that complete coverage of the area was obtained with so few passes, as well as the insensitivity of the imagery to minor atmospheric disturbances and the combination of factors resulting in such synoptic coverage in each image recommend the method as a potentially valuable tool for geological reconnaissance.

Comments on relation of radar imagery to surficial geology in Yellowstone Park

By

Kenneth L. Pierce

General Statement

The radar imagery presents a synoptic and moderately detailed picture similar to a very detailed <u>shaded</u> <u>relief</u> <u>map</u>. Although the making of a detailed "shaded relief map" by radar imagery is an impressive accomplishment in itself, features recognizable on the radar imagery can also be clearly seen on the high-altitude AMS photography. Nevertheless, the radar imagery portrays the topography very clearly, and is not complicated by many of the other features shown by black-and-white photographs. It may be that larger-scale imagery determined by long wave-length radar offers better possibilities of determining parameters more closely related to the geology (lithology, textures, compaction, etc.) of the surficial materials. For instance, it might pick up low morainic ridges on forested areas; such features are not recognizable on the radar imagery or black-and-white photography. Following is a list of features related to the surficial geology that show up dramatically on the radar imagery.

A. <u>Glacial streaming of bedrock and glacial debris</u>

1) Upper Gallatin, Fawn Creek, and other valleys in the Gallatin Range show streaming by ice converging down valley (89-#1).

2) Upland areas show marked streaming in the Two Ocean Plateau area (94-#5) the Heart Lake area (94-#4) and near the north end of Jackson Lake (94-#2) See Fig. 1C.

3) The broad Mt. Everts upland shows the gradual change in flow direction from northwest to north (94-#2, 94-#3).

4) The streaming of glaciers down into the Lamar River Valley from a major source of ice in the Buffalo Plateau area of the Beartooth Mountains (94-#3).

5) On the rim of Bechler Canyon, streaming and erosion of the rhyolitic flows by Pinedale glaciers is shown in a band several miles wide (Fig. 2C). In the unglaciated area on either side of this band, the ridges and furrows formed during the time of lava flowage are clearly seen (Fig. 2E); these ridges and furrows commonly intersect the lineation formed by glacial streaming at a high angle (89-#1, 89-#2).

6) In the Bechler country in the southeast corner of the Park, streaming of topography by Bull Lake glaciers is

well displayed beyond the area covered by the rhyolitic flows or the later Pinedale ice (Fig. 2A) (89-#1, 89-#2). It seems clear that the rhyolitic flows advanced across a topography that was glaciated in Bull Lake time as indicated by Richmond (1964, U.S. Geol. Survey Prof. Paper 435-T, fig. 116).

7) In the Gardners Hole area, glacial streaming obliquely away from the Gallatin Range and toward Mammoth is suggested by pattern in dark gray. This area is a grassland of glacially streamed till (89-#2).

8) Between Yellowstone Lake and the Grand Canyon of the Yellowstone, grooving by a glacier flowing to the southeast is intersected at nearly right angles by lade Quaternary fault scarps (94-#3).

B. Lake sediments and basin fills

1) Hayden Valley shows up as a slightly darker oval area, with fine texturing due to fine dissection by erosion (89-#3).

2) The West Yellowstone obsidian-sand plain appears to be slightly darker than the bordering terrain underlain by volcanic rocks, and presents a rather featureless undissected surface (89-#1).

3) The upper Yellowstone Valley-floor is richly textured by flood plain scrolls, ox-bows, meanders and a forest-meadow contrast. This part of the valley was partly filled with sediment during glacial times (94-#6).

C. Glacial Moraines

1) Near the south end of Jackson Lake large end moraines and a large pitted outwash plain are suggested by the radar imagery (94-#7).

2) The narrow tongue of ice that lapped out just beyond the mouth of Madison Canyon is faintly shown (89-#1).

3) Pinedale moraine forms a poorly defined semi-circle beyond the mouth of Bechler Canyon (Fig. 2D) (89-#1).

4) Timbered Island, a Bull Lake moraine surrounded by Pinedale outwash shows up very sharply just southeast of Jenny Lake in Jackson Hole. This area is contrasted to the surrounding grassed terrace by being timbered and having morainic topography. (94-#7, 94-#2).

D. Terraces

1) In Jackson Hole, two Pinedale outwash terraces are well displayed and show a uniform tone. Scarps at the edges of these terraces are shown very sharply along the Snake River (94-#7, 94-#2).

Preliminary general evaluation of radar imagery in Yellowstone Park

By

Harold J. Prostka

Topography is the most prominent feature revealed by the radar imagery; in general, the lightest tones are on those surfaces which intercept the radar beam nearly perpendicularly. Conversely, the darkest areas are those which intercept the beam at very small angles. The overall effect is like seeing the country in strongly oblique lighting. Superimposed on this is the effect of vegetation cover; lighter tones where vegetation is sparse, darker where vegetation is heavier. Consequently, areas above timberline are light, and forested areas and meadows are darker. Color of vegetation does not show up; for example, dark evergreen trees and light meadows which contrast strongly on ordinary air photos have about the same tone in radar. Apparently, grass blades and pine needles reflect radar beams about equally well. These two parameters, topography and vegetation density, seem to account for all of the tonal variation in the imagery.

Grain size: No distinction between various fragmental materials. Coarse breccias and till look about the same as limestone and lake silt.

Color: Color differences do not show up; for example, unvegetated pale gray limestone cliffs near the NE entrance are indistinguishable from dark brown volcanic breccia. Along Lamar River near confluence with Cache Creek there are white hot springs deposits on dark gray basalt; these both look the same in radar.

Composition: No tonal distinction between basalt, breccias, limestone, travertine, or surficial deposits.

The usefulness of radar imagery of this type in deciphering geology is limited to those geologic features which have distinctive topographic expression such as terraces, landslide deposits, hummocky moraine, glacial grooving, and Quaternary faults. Radar imagery does not delineate these features any better than ordinary air photos. Radar imagery has the added disadvantages of being oblique which gives a foreshortened view, back slopes are totally dark, and the imagery cannot be viewed in stereo.

The advantage of radar imagery over aerial photos is the absence of interference due to haze, uneven lighting, and cloud cover. Hence there is a uniformity of tone that is impossible to achieve by ordinary photography. A possible application of this feature would be in determining topography of planetary bodies having dense cloud cover (Venus?)

Perhaps a longer wavelength radar beam would yield imagery that would be more useful geologically. A longer wavelength presumably would penetrate vegetation and thin soil cover and might be able to differentiate fragmental materials in the size range 1 m. - 1 mm.

Preliminary evaluation of radar imagery, southern Gallatin Range and vicinity (Flights 89-#1, 89-#2, 89-#3, 94-#2)

By

Edward T. Ruppel

Radar imagery in this area discloses many features or possible structural origin, suggests a gentle northward dip to the layered rocks -- and suggests the presence of layered rocks, and in places permits separation of bedrock and surficial units. But there do not seem to be too many differences in the images produced by rocks of different kinds.

The most striking features are those of possible structural origin-lineaments of different trends that cut both pre-Tertiary and later rocks, and in places continue through areas known to be blanketed by surficial deposits. These include an apparent system of northeast and northwest trending lineaments (Fig. 5), and north-trending lineaments (Fig. 4). The northeast-northwest system had earlier been recognized in the Precambrian rocks at the south end of the Gallatin Range, where the drainage is incised along northeast-northwest lines; in this area the lineaments are thought to reflect jointing in the crystalline rocks, but this has not yet been demonstrated by field mapping. The trends are also reflected in the general grain of topography in the southern part of the Gallatin Range, most of which is underlain by Paleozoic and Mesozoic sedimentary rocks. The same pattern of lineaments appears on the radar imagery in the area north of the Madison River and west of Madison Junction (89-#1, 89-#2), in the upper reaches of Arrow Canyon (89-#3, 94-#2), and, less distinctly, near Shoshone Lakes (Fig. 1D) (94-#2), where the northeast trend is dominant; all of these areas are underlain by rhyolite, and similar lineaments are suggested faintly elsewhere in the rhyolite area.

The geologic control of the northeast-northwest lineament system is not known, but geologic mapping in the Precambrian crystalline rocks and the pre-Tertiary sedimentary rocks of the southern Gallatin Range should resolve the problem there and provide information that can be extended to the study of the lineaments in the rhyolite. There is a good possibility that the northeast-northwest lineament system is a joint system in the Precambrian rocks, reflected through or imposed on the younger rocks by later movement; if this is so, the areas of rhyolitic rocks cut by northeast-northwest lineaments could well be underlain by pre-Tertiary rocks.

The north-trending lineaments (Fig. 4) are best defined in the southern part of the Gallatin Range (89-#1, 89-#2), where they 1) control a prominant system of north-south stream channels on the west side of the Range, extending through the Range west and northwest of Electric Peak to the Yellowstone River Valley; and 2) control the striking east face of the Range above Gardners Hole. The lineament along the east face of the Gallatin Range is known to be a high angle fault, but the amount and direction of displacement remains to be determined by geologic mapping; the lineament continues southward into the rhyolite, west of Shoshone Lake, and to the northern end of the Tetons in the vicinity of Forellen Peak.

Two other north-trending lineaments also show on the radar imagery east of the Gallatin Range. The first (89-#2) extends southward from west of Mammoth Hot Springs along the canyon of Obsidian Creek to Gibbon Canyon; faint traces suggest that it extends across the Rhyolite Plateau through the area of Shoshone Lake to Beula Lake and Hering Lake. The second (89-#3, 94-#2), a group of parallel lineaments, extends southward through and near Arrow Canyon, along the east side of Shoshone Lake (Fig. 1E), and possibly to the canyon of the Lewis River.

Of these four north-trending lineaments, only part of one, along the east face of the Gallatin Range, is known to be a fault. The significance of the others is unknown but should be resolvable by geologic mapping. The lineaments appear to be closely associated with the principal areas of hot springs and geysers.

The presence of sedimentary rocks in the Gallatin Range is suggested in the radar imagery by what appear to be bands of outcrop and by large, gently sloping areas that suggest -- and are -- dip slopes. There do not seem to be any significant differences in the appearance of different sedimentary rocks in the imagery -- the shaly rocks on Electric Peak look about the same as the massive limestone, dolomite, and quartzite farther south. However, the nature of the topography differs somewhat in the two areas, and the area underlain by shaly rocks is rougher appearing and lacks the larger, smoothed and rounded slopes and surfaces of the areas underlain by massive rocks. The area underlain by Precambrian crystalline rocks -- gneisses, primarily -- appears on the imagery to be more subdued and rounded than it actually is, and the image of these rocks is more gray than that of the younger rocks; the Precambrian crystalline rocks appear to have an appreciably different radar image than the younger pre-Tertiary rocks in the Gallatin Range.

E. Marked late Quaternary incision of drainage and headward erosion of tributaries

1) Grand Canyon of the Yellowstone and tributary valleys (94-#4).

2) Lake Creek and Tower Creek (89-#3).

F. Gross morphology of mountains as shown on the radar imagery

1) (The Absaroka Mountains are erosional mountains carved from gently dipping early Tertiary volcanic rocks.) They typically display high sharp ridge crests, clifted upper slopes, and moderately wide U-shaped valleys. The valleys are widely separated and form a coarse-textured topography. The mountains and valleys are bulkier than those of the Gallatin Range (94-#6).

2) (The Gallatin Range is carved from gently dipping Paleozoic and Mesozoic limestone, shale, dacitic intrusives, sandstones, and at the south end of the range, granitic rocks.) In the range, upland flats are joined by sharp ridges, and the valleys are moderately wide and U-shaped. The valleys are closer spaced than those of the Absaroka Mountains, thus forming a finer textured gross topography (89-#1).

3) (The Teton Mountains are formed from granitic rocks and have been recently uplifted by movement along a fault at the eastern margin of the range.) The range displays jagged ridges and peaks, with deeply inset U-shaped valleys which show greater curvature at the base of the "U" than in the Absaroka Mountains. The trace of the valleys and ridges is more irregular than the smooth trend of the Absaroka and Gallatin Ranges. (94-#2).

G. Quaternary faulting

Fresh scarps in all the Quaternary fault systems recently described by Dave Love (1961, Geol. Soc. Amer. Bull. v. 72, p. 1749-1764) are clearly displayed on the radar imagery (Fig. 3). It might be added that if Dave Love had not recently announced the presence of these faults, this radar imagery might have been instrumental in bringing these faults to the attention of geologists. In unexplored regions of the earth (or other planets) radar imagery can readily "sense" Quaternary faulting.

1) Mirror Plateau fault system, with faults trending NW-SE (94-#6, 94-#5).

2) Yellowstone Falls fault system, with faults forming large scarps and troughs trending NW-SE (94-#4) (Fig. 3).

3) Solfatura fault system (89-#3).

4) Lamar fault (94-#6, 94-#5).

5) Gallatin range-front fault and associated faults east of range (89-#2). The faults east of the range are reflected through Pinedale glacial till.

6) Around the south margin of the Gallatin Range, Quaternary structural features form a rectangular pattern, but offset, if any, is difficult to determine (Fig. 4). At present it is not known which features are fault scarps, joints etched out by erosion, and glacial grooves. (89-#1, 89-#2).

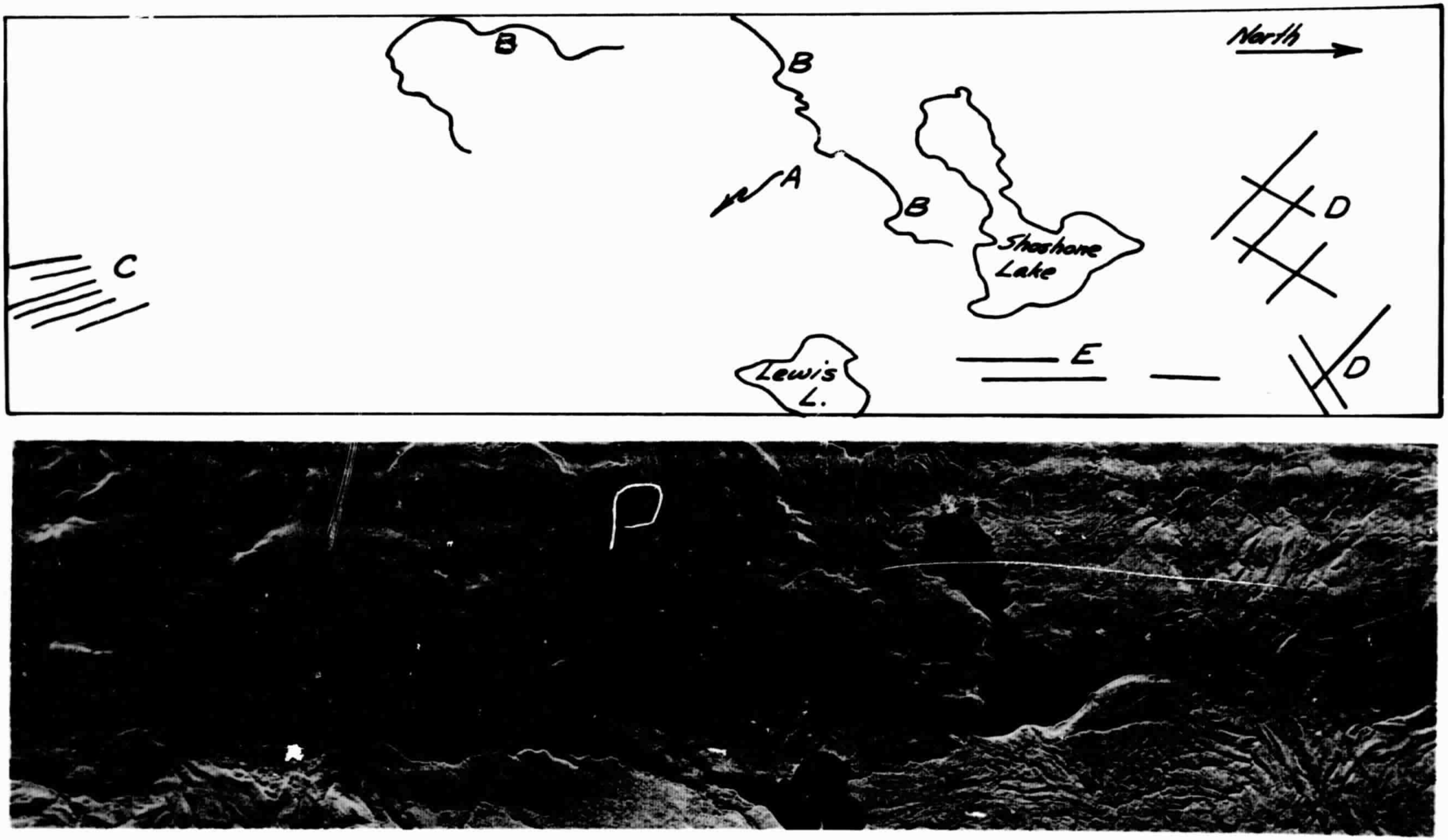


Figure 1. Part of Pitchstone Plateau. A) flow structure; parallel concentric pressure ridges in flow B) flow fronts; C) glacial streaming; D) NE and NW trending lineaments; E) North-trending lineaments (orgin of D and E uncertain, will be checked in the field)

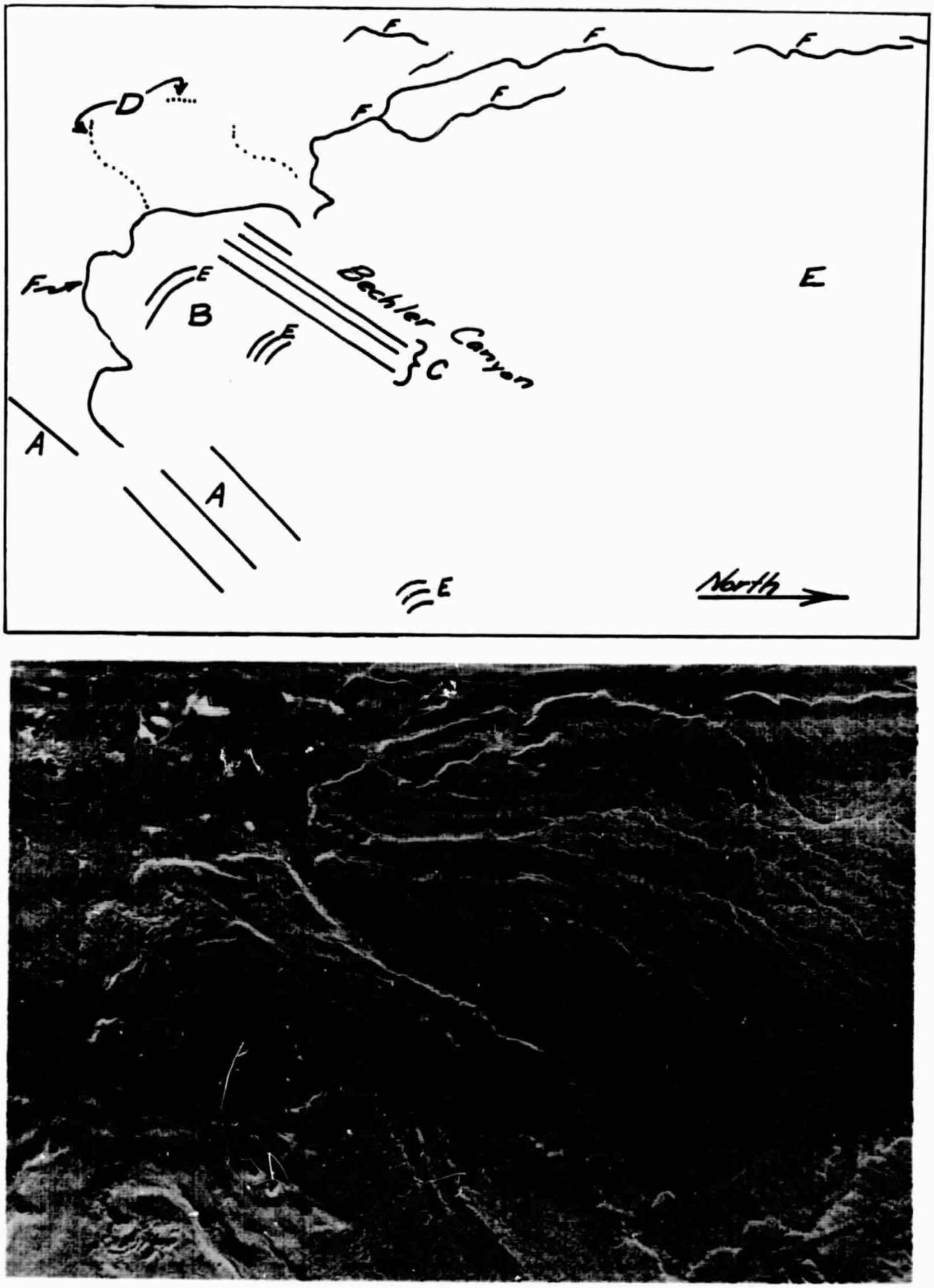


Figure 2. Bechler Canyon area. Bull Lake glacial streaming (A) on basalt, overlain by rhyolite flows (B) that show Pinedale glacial streaming (C). Pinedale moraine forms a poorly defined semi-circle beyond the mouth of Bechler Canyon (D). Note pressure ridges in rhyolite flows(E) and flow fronts(F).

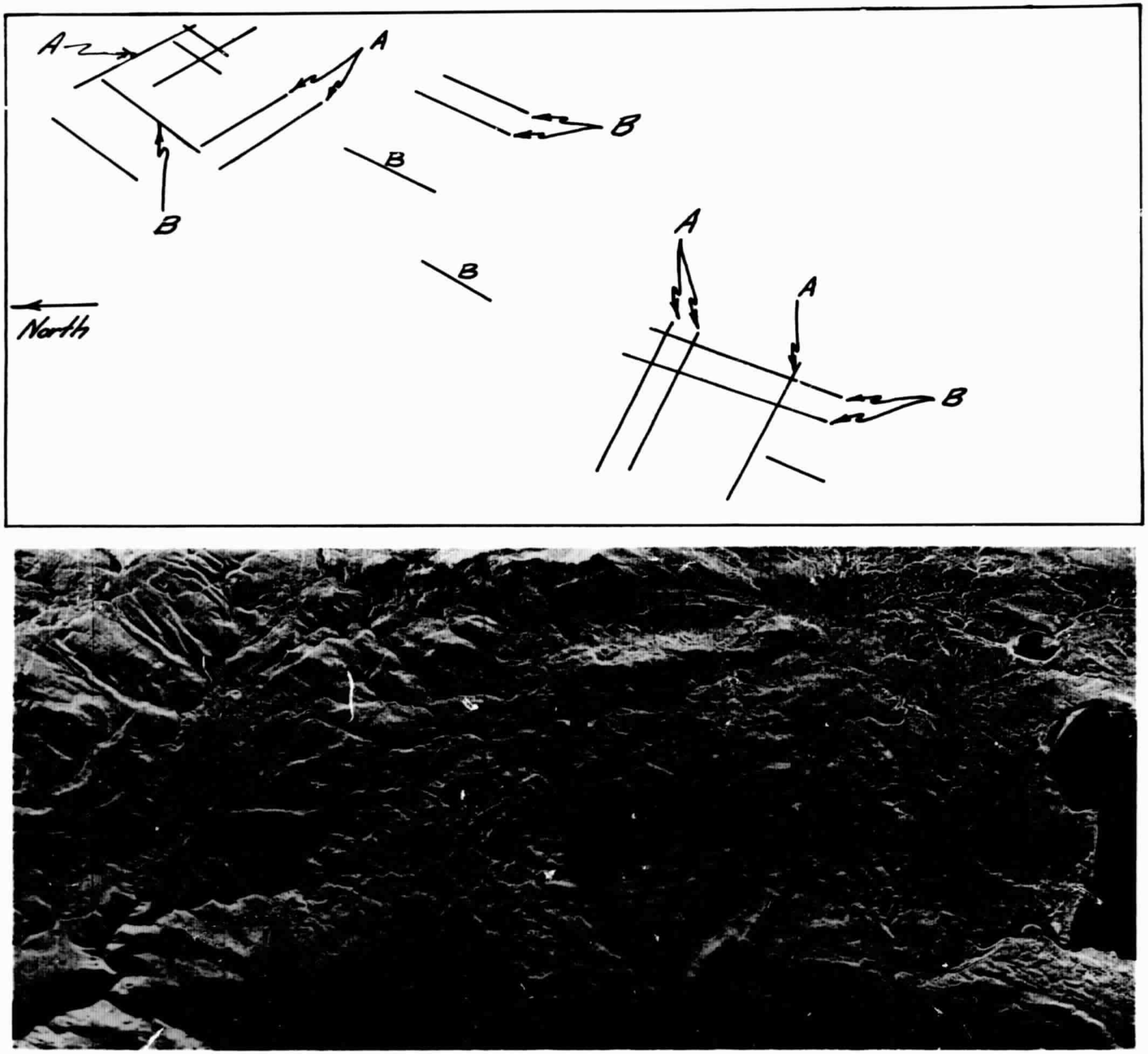


Figure 3. Area SE of Grand Canyon of the Yellowstone. Shows intersections of (A) northwest trending lineaments (Quaternary fault traces) and (B) northeast trending lineaments (glacial streaming)

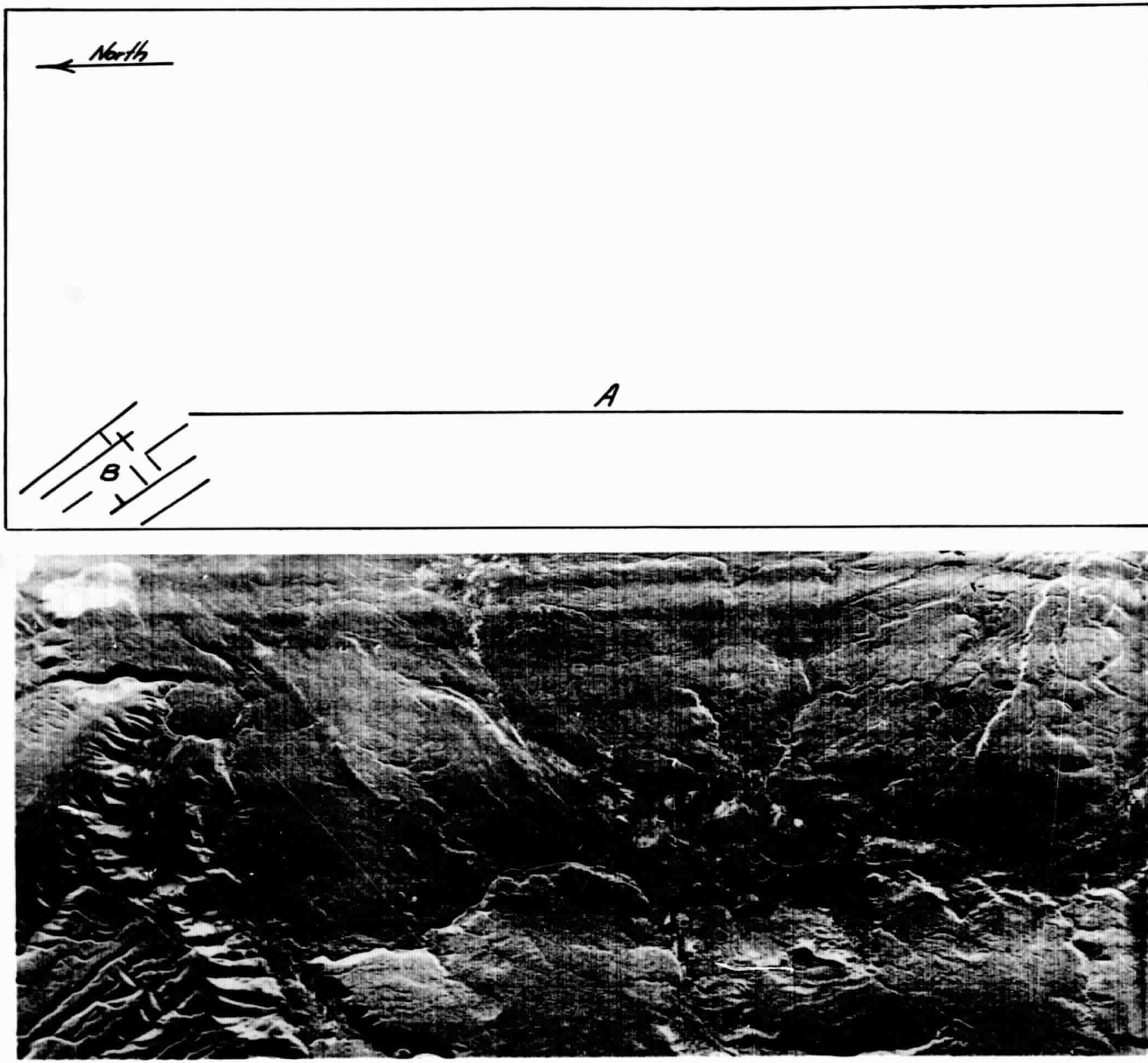
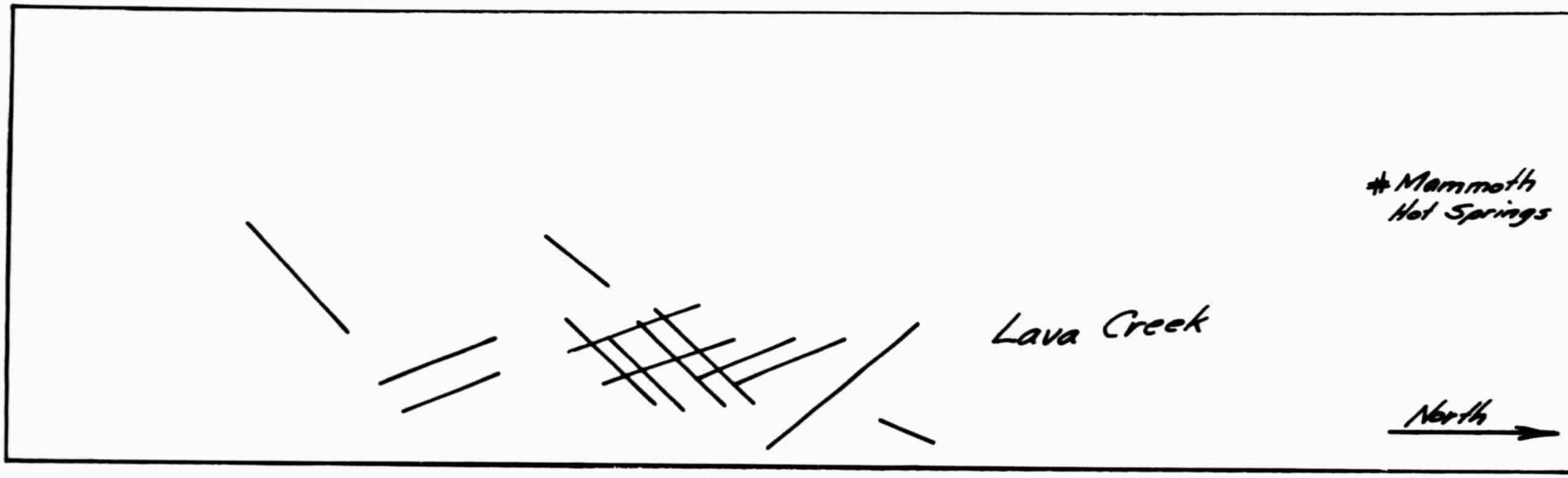


Figure 4. South end of Gallatin Range, showing north-trending lineament (A) and NE and NW-trending lineaments (B).



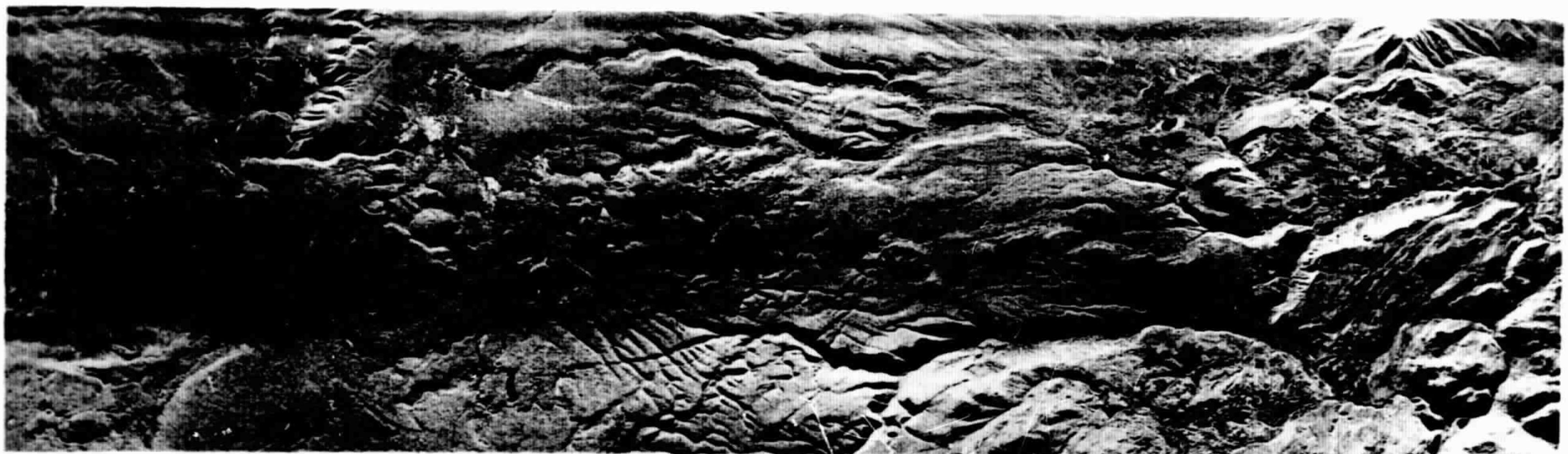


Figure 5. Area south of Mammoth Hot Springs showing NE & NW- trending lineaments, possibly reflecting jointing in underlying Precambrian crystalline rocks.