NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

EARTH RESOURCES SURVEY PROGRAM

TECHNICAL LETTER NASA-77

Geologic Evaluation of Infrared Imagery of Highly Faulted Volcanic Terrane in Southeast Oregon

By

George W. Walker

U.S. Geological Survey
Menlo Park, California

June 1967

Prepared by the Geological Survey for the
National Aeronautics and Space Administration (NASA)
under Contract No. R-09-020-015

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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

Technical Letter
NASA-77
June 1967

Dr. Peter C. Badgley
Program Chief,
Earth Resources Survey
Code SAR - NASA Headquarters
Washington, D.C. 20546

Dear Peter:

Transmitted herewith is one copy of:

TECHNICAL LETTER NASA-77

GEOLOGIC EVALUATION OF INFRARED IMAGERY OF HIGHLY FAULTED VOLCANIC TERRANE IN SOUTHEAST OREGON*

by

George W. Walker**

Sincerely yours,

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-77

GEOLOGIC EVALUATION OF INFRARED IMAGERY OF HIGHLY FAULTED VOLCANIC TERRANE IN SOUTHEAST OREGON*

by

George W. Walker**

June 1967

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, Menlo Park, California

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GEOLOGIC EVALUATION OF INFRARED IMAGERY OF HIGHLY FAULTED VOLCANIC TERRANE IN SOUTHEAST OREGON

by

George W. Walker

Introduction

Nearly continuous infrared imagery in the 3-5 micron band, obtained from a single west to east overflight 20-30 miles north of the Oregon border and extending from Grants Pass through the Cascade Range to the Idaho border, is compared empirically with recently prepared geologic maps (Wells and Peck, 1961; Walker, 1963, Walker and Repenning, 1965, 1966). Both geologic and cultural features shown on the IR imagery are evaluated and comparisons are made with K band radar imagery of the area near Hart Mountain, Lake County, Oregon. Evaluation of the radar imagery along other parts of the IR flight line is contained in Technical Letter NASA-25 (Walker, 1966), which also contains several maps and photographs referred to here.

No surface temperature measurements have been made, nor are any data available on the emissivity of the surface materials, so that comparisons and discussion of results are entirely qualitative.

The infrared imagery was obtained on August 16, 1966, from 2230 hours to nearly midnight; sunset was at 2020 hours. The flight was at an altitude of 16,000 feet over a region mostly at 4000 to 5000 feet in elevation. The scale of the infrared image is about 1:88,000 parallel to the flight line and progressively smaller toward the margins. The image is highly distorted and in some short segments is weak and diffuse, perhaps due to atmospheric interference or possibly to erratic or faulty instruments. Throughout much of its length the area of the IR image coincides approximately with the area of the radar image (scale about 1:180,000) discussed in Technical Letter NASA-25. On the eastern end of the flight, however, the two images diverge and are separated by 10-15 miles near the Idaho border.

A brief resume of the geology along the flight path was presented in Technical Letter NASA-25, and is repeated here with only minor modification.

"The ... strip crosses an area noted for very extensive middle and late Cenozoic volcanism, including a north-south chain of inactive or dormant andesitic and dacitic volcanoes in the Cascade Range, several major silicic vent areas probably related to Miocene and Pliocene ashflows, several large volcano-tectonic depressions, well-developed mid-Tertiary and younger Basin and Range fault structures, and extensive surfaces of basalt that contrast with widespread sheets of welded tuff and tuffaceous sedimentary rocks. Soil and vegetation cover vary widely from extensive bare-rock outcrops to areas of deep soil and sparse to dense forests."

Several small areas that contain thermal springs and one thermal pond are present along the flight line, particularly near Klamath Falls, Hart Mountain, Alvord Lake, and Three Forks on the Owyhee River (Stearns, Stearns, and Waring, 1935; Groh, 1966). However, nearly all of the springs within the area covered by the infrared image are of moderate to small size, and surface temperatures in most springs are less than 80°C.

Thermal anomalies reflecting geologic features are related largely to the distribution of bare-rock outcrops, mostly of basalt or rhyodacite and quartz latite, and to extensive accumulations of basalt blocks and rubble in talus, landslides, or coarse lag gravels in stream beds.

Infrared imagery

Most of the emitted thermal energy depicted graphically on the infrared image apparently resulted largely from differential absorption of solar energy on various surficial materials and the subsequent differential emission of this energy in the 3-5 micron band. In places, particularly on the west end of the image which was taken only an hour or two after sunset, faint residual solar effects apparently are shown by lighter (warm) west-facing fault scarps and hills which contrast with the slightly darker east-facing scarps. One small, light-colored (warm) thermal anomaly near the east end of the infrared image coincides with a small area containing several hot springs and here the energy source may result from underground heat being convected to the surface by thermal spring waters. Radiant thermal energy from surficial soil and rock outcrops is effectively masked by extensive timber cover in the western part of the flight line. The forest gives rise in places to a mottled image where trees are apparently widespread or in clumps (fig. 1 and 3), and to a moderately light-gray (relatively warm) smooth image where it is dense and uniformly distributed (fig. 2).

Agricultural farm lands show distinct differences in their energy emission characteristics; for example, some fields near Klamath Falls are relatively warm (light on the IR image), whereas adjacent fields are cool (fig. 3). Relative differences in the radar images also were noted for fields within the same area; no correlations with the IR image are possible, however, because image differences occur between different groups of fields and no data are available as to which fields were plowed and unplowed or planted and unplanted. Presumably the plowed fields, whose surficial material is uncompacted, are cooler than the unplowed or planted fields, according to data presented by Wallace and Moxham (1966).

Roads surfaced with blacktop paving or with basalt cinders are generally light (warm), as are paved and cinder covered roads described by Fischer and others (1964) in Hawaii. Most graded gravel and dirt roads are not recorded on the image, but a few are moderately dark (cool), perhaps partly as a result of the removal of vegetation. Most of these secondary gravel and dirt roads are completely invisible on the radar image of the same area.

Lakes and larger bodies of water on rivers and creeks, including Klamath Lake shown on figure 3 and Hart Lake shown on figure 1, form some of the lightest (relatively warmest) spots on the infrared image, whereas the flat, dry surfaces in playa lake basins are some of the darkest areas (fig. 4 and 7). Most of the playa surfaces are devoid of vegetation and consist of a light colored veneer of silt and clay with local patches of a white crust composed of saline minerals. Probably the playa sediments contain relatively larger amounts of water than the surrounding rocks.

The few hot spring areas along the flight line are not readily identified as thermal anomalies, perhaps largely because they occur in the highly distorted margins of the image. Several small, moderately bright (warm) spots visible on the imagery apparently coincide with hot springs a few miles west of the Idaho border near Three Forks on the Owyhee River (fig. 4); these spots may, however, result from other geologic features in the same area, such as extensive bare-rock outcrops or large talus slopes.

A number of small, point sources of thermal energy, denoted by sharply defined, bright spots, occur near Gold Hill, Medford (fig. 5), and Klamath Falls at the western end of the image. They undoubtedly result from cultural features, possibly large, hot trash burners at saw mills and, for the anomaly at Gold Hill, to rotary furnaces at a local cement plant.

Many flat-topped ridges and hills that are capped by basalt are relatively dark (cool) on the IR image, probably because of the emissivity characteristics of a sparse vegetation cover and a thin veneer of wind-blown silt or thin tuffaceous sediments which overlie the basalt. A bright thermal source occurs where the basalt crops out extensively along the scarps or sharp breaks in slope which surround the flat-topped hills, and similar bright areas characterize the aprons of coarse talus and landslide debris that mantle slopes below the basalt outcrops (figs. 4, 6, and 7). Such warm areas are particularly prominent on parts of Hart Mountain, on east-facing fault scarps west of Hart Lake, and in extensive large fault blocks adjoining Hart Lake on the southwest (fig. 1). The relatively dense, dark-colored basalt in outcrops and in talus piles probably absorbed comparatively large amounts of solar energy despite its vesicularity, in contrast to the lighter colored, more porous sedimentary and tuffaceous rocks which also support more vegetation. The basalt, both in outcrop and in closely packed talus blocks, may lose its absorbed thermal energy more slowly than other rock types. Also, upward migration of warm air through permeable talus piles and landslides composed of jumbled fault blocks may also increase the infrared emission. Hence, some fault scarps characterized by nearly continuous rims of basalt and by extensive talus piles on slopes below the rims are portrayed on the IR image as light (relatively warm) lines or bands.

Stream beds paved with a coarse lag gravel of vesicular to dense basalt boulders are dark in photographs and appear relatively warm (light) on the infrared image, probably mostly because of emission of absorbed solar energy. Many of the stream beds are bounded by bare basalt outcrops, which also add, at this scale, to the high emissivity. In contrast, dry stream channels that are paved with lighter colored silt, sand, and pebbles derived from rhyodacite, tuffaceous sedimentary rocks, and ash-flow tuffs, are dark on the IR image; this suggests differences in 1) absorption of solar energy, 2) water content of the alluvium, 3) textural or mineralogical properties resulting in different thermal properties, 4) or perhaps density of vegetation between the basaltic and nonbasaltic alluvium. Relatively warm (light) areas along parts of the Owyhee Canyon near Three Forks apparently coincide with outcrops and scree slopes in rhyodacite or quartz latite that are partly devoid of vegetation and soil cover.

Comparison with radar imagery of Hart Mountain area

Comparison of the infrared imagery of the Hart Mountain area (fig. 7) with radar imagery and a geologic map of essentially the same area (figs. 1 and 3, Tech. Letter NASA-25) demonstrates significant differences in image sharpness and clarity and in expression of geologic features. The infrared image is neither as sharp nor is contrast as great, so that many geologic and physiographic features are not as clearly defined even though the IR image used in the comparison is more than twice the scale of the radar image. The large- and small-scale normal faults related to the Warner Valley fault-block basin (or volcano-tectonic depression), most of which are reflected by pronounced physiographic scarps or other linear features, are better defined on the radar image. The sense of relief on the scarps is almost completely lost on the infrared image, as is the layering in basalt flow sequences on several of the high fault scarps; both these features are fairly well defined on the radar image. A few dense black shadow areas on the radar image of the west face of Hart Mountain exhibit a faint, but as yet uninterpreted, thermal emission pattern on the infrared image.

References cited

Fischer, W. A., Moxham, R. M., Polcyn, F., and Landis, G. H., 1964, Infrared surveys of Hawaiian volcanoes: Science, v. 146, no. 3645, p. 733-742.

Groh, E. A., 1966, Geothermal energy potential in Oregon: Oregon Dept. of Geology and Mineral Industries, The Ore Bin, v. 28, no. 7, p. 125-135.

Stearns, N. D., Stearns, H. T., and Waring, G. A., 1937, Thermal springs in the United States: U. S. Geol. Survey Water-Supply Paper 679-B, p. 59-191.

Walker, G. W., 1963, Reconnaissance geologic map of the eastern half of the Klamath Falls (AMS) quadrangle, Lake and Klamath Counties, Oregon: U. S. Geol. Survey Field Studies Map MF-260, scale 1:250,000.

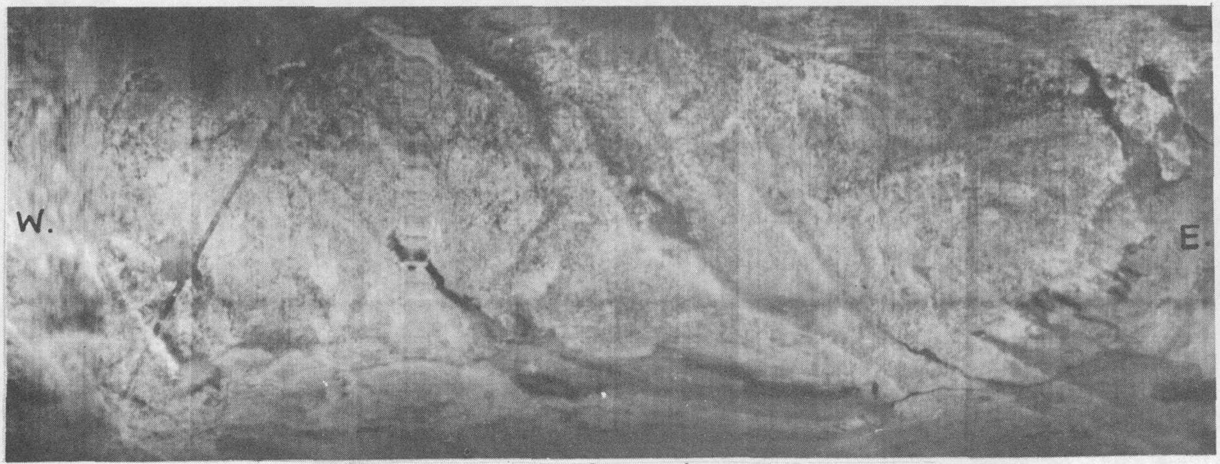
_____ 1966, Evaluation of radar imagery of highly faulted volcanic terrane in southeast Oregon: U.S. Geol. Survey Tech. Letter NASA-25.

Walker, G. W., and Repenning, C. A., 1965, Reconnaissance geologic mpa of the Adel quadrangle, Lake, Harney, and Malheur Counties, Oregon: U. S. Geol. Survey Misc. Geol. Inv. Map I-446, scale 1:250,000.

_____ 1966, Reconnaissance geologic map of the west half of the Jordan Valley quadrangle, Malheur County, Oregon: U. S. Geol. Survey Misc. Geol. Inv. Map I-457, scale 1:250,000.

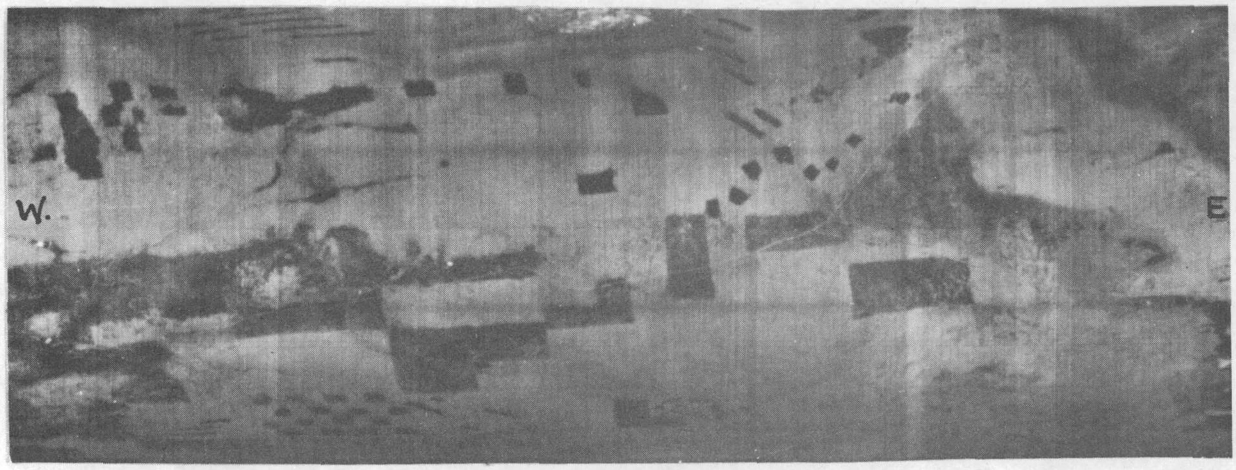
Wallace, R. E., and Moxham, R. M., 1966, Use of infrared imagery in study of the San Andreas Fault System, California: U. S. Geol. Survey Tech. Letter NASA-42.

Wells, F. G., and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U. S. Geol. Survey Misc. Geol. Inv. Map I-325, scale 1:500,000.



5 miles - Approx.

Figure 1. Mottled image in area of widespread or clumped trees. Northeast-trending dark (cool) strip at west end of image is a gas line right-of-way, in which timber has been stripped and soil cover disturbed.



5 miles - Approx.

Figure 2. Moderately light-gray (relatively warm) smooth infrared image present where timber cover is dense and uniformly distributed; logged areas appear dark (cool) on image.

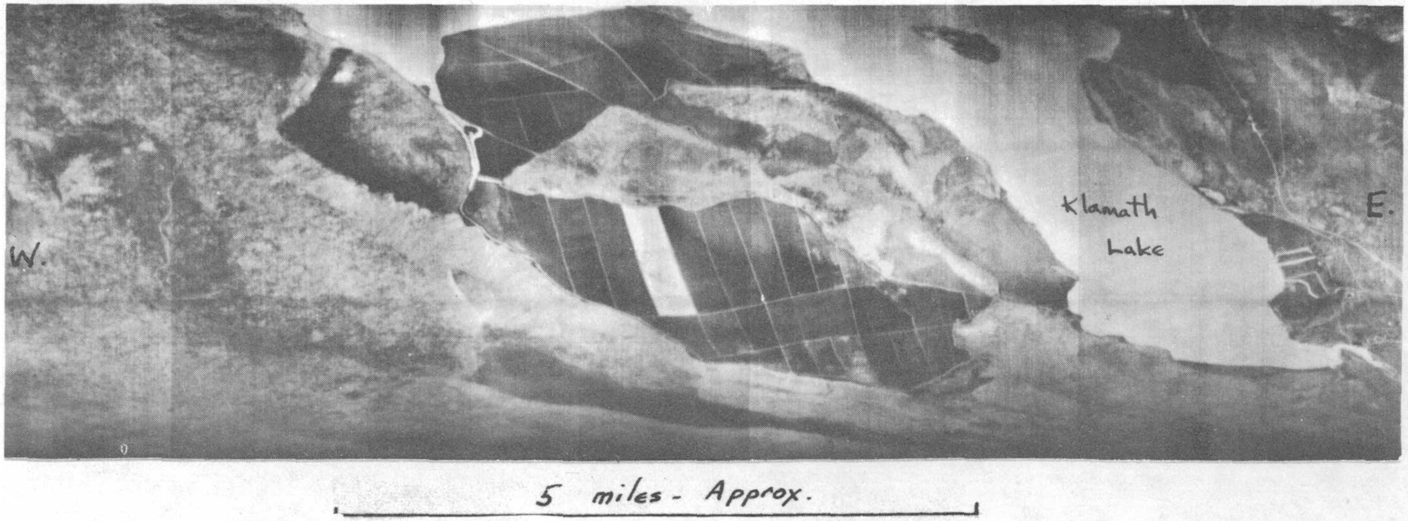


Figure 3. Area of agricultural fields west of Klamath Lake (relatively warm). Mottled, moderately warm pattern at west end of image probably represents open yellow pine forests. At east end of image, paved (blacktop) highway crosses dark (cool) area north of Klamath Falls; the dark area is mostly grass covered valley fill with some plowed areas.

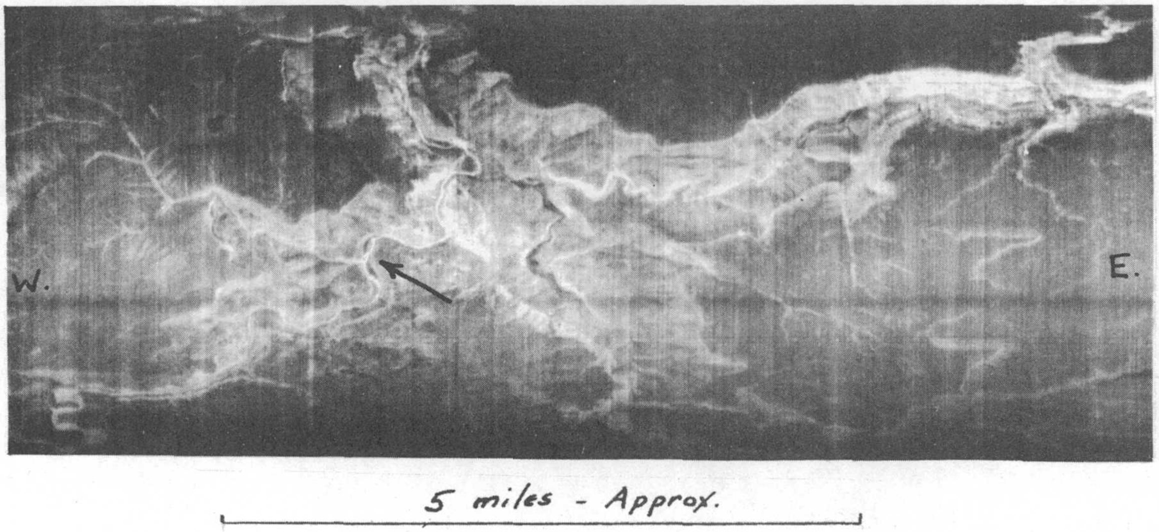


Figure 4. Part of infrared image at confluence of the North, Middle, and South Forks of the Owyhee River (Three Forks), about 7 miles west of the Oregon-Idaho border. Extensive, nearly flat-lying sheets of basalt crop out at margin of dark (cool) areas along top of image and in zig-zag, light (warm) line in southeast quarter of image. Most of dark (cool) areas above and locally below basalt are characterized by light colored tuffaceous sediments and more abundant sagebrush, rabbit brush, and desert grasses. Extensive outcrops and scree slopes of rhyodacite or quartz latite in light (warm) area in valley at center of image. Light (warm) spots, indicated by arrow, coincide with an area containing several hot springs. Dark (cool) spot in northwest corner of image is a light colored playa.

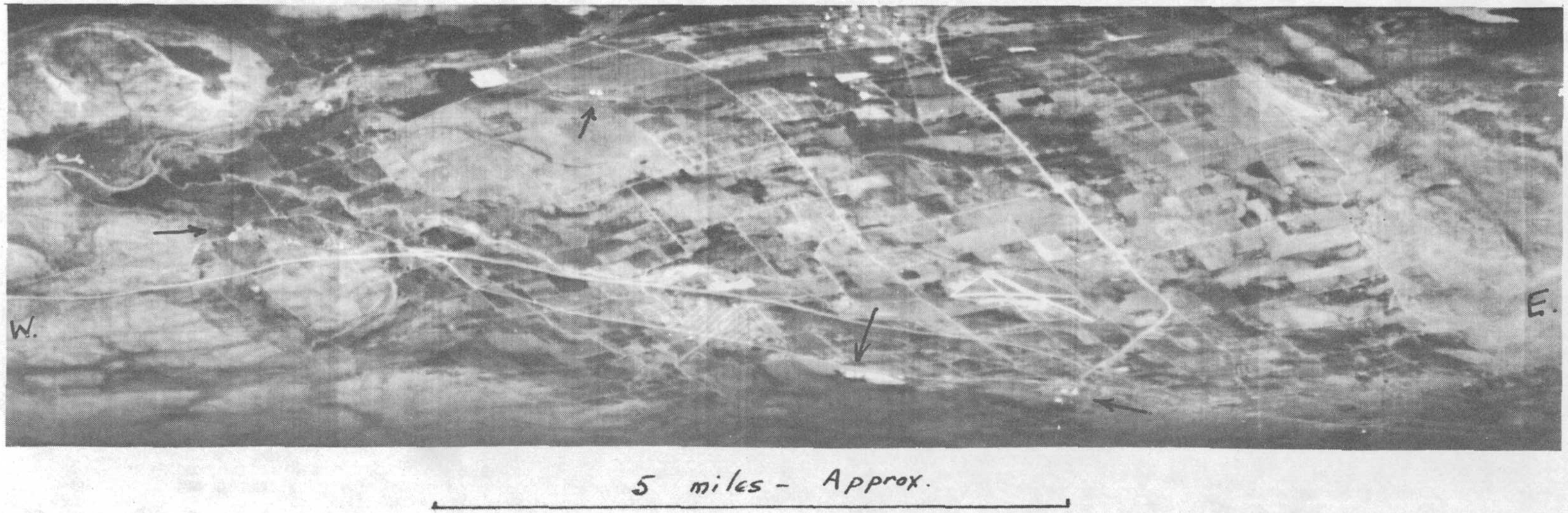


Figure 5. Medford Valley, with Medford Airport at right center of image. In northwest corner is Table Rock showing bright (warm) rim and talus slopes of basalt. At east end of image, west-facing scarps appear somewhat lighter (warmer) than east-facing scarps, probably denoting faint residual solar effects. Sharply defined bright thermal spots -- see arrows -- probably result from trash burners at saw mills and other similar man-made heat sources.

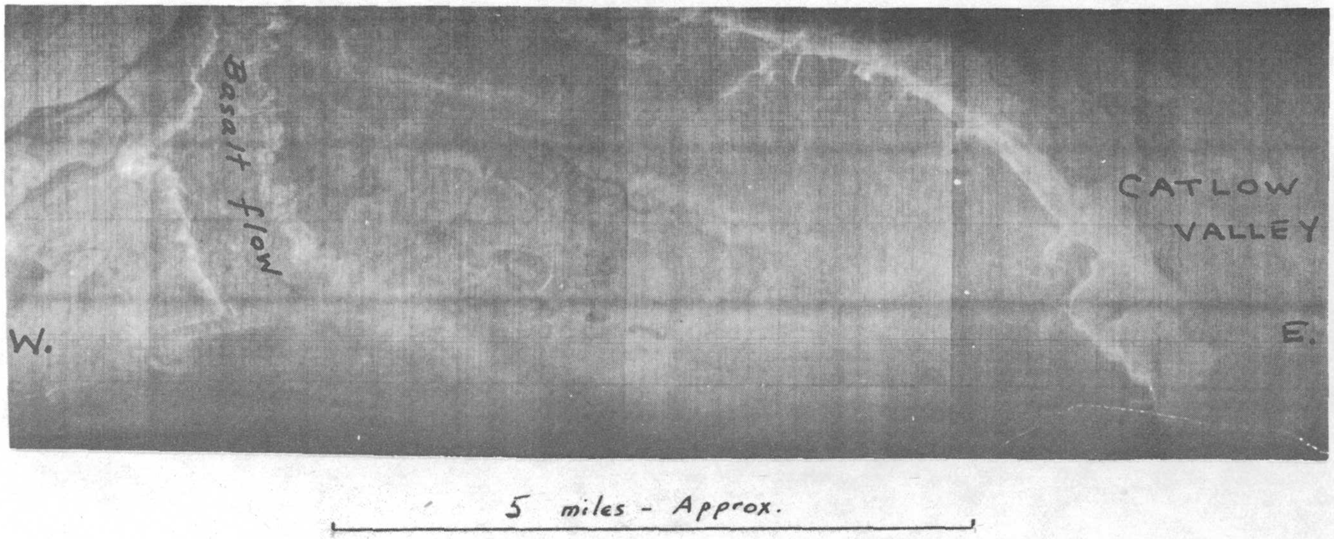


Figure 6. Part of infrared image just west of Catlow Valley. Light relatively warm) northeast-facing fault scarp along margin of Catlow Valley composed of nearly continuous basalt outcrops. Basalt talus below rim also appears relatively warm. Alluvium along stream channels, unconsolidated Quaternary lake sediments and alluvium in Catlow Valley, and small centrally located playas are dark (cool). Small intense light spots and irregular streak in southeast corner of image probably represent flaws.

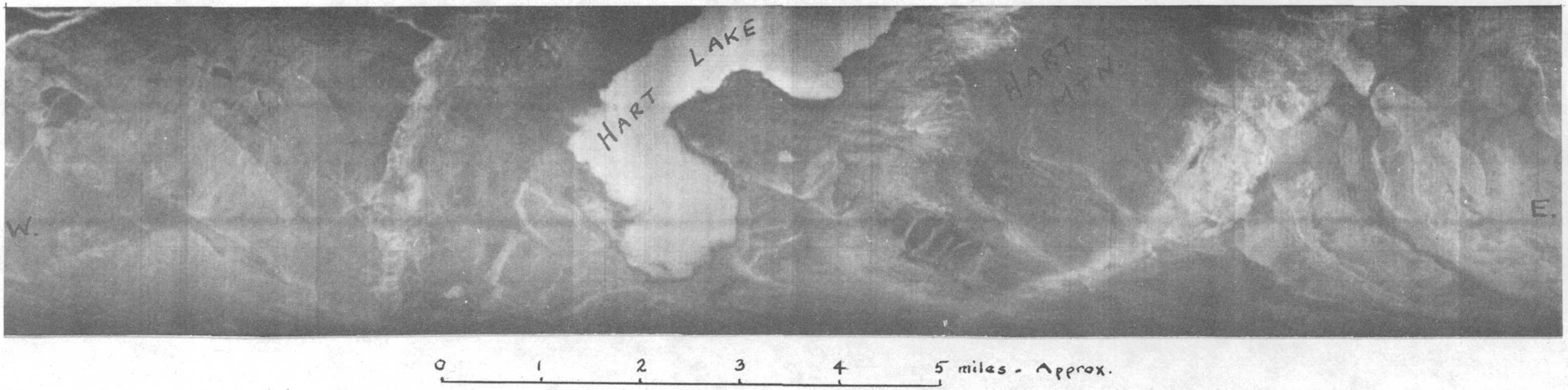


Figure 7. Infrared image of the Hart Mountain area, Lake County, Oregon. Light (warm) line at west end of image is a paved (blacktop) road that corsses two dark (cool) playas. Playa walls are solid basalt outcrop and appear light (warm) on the image. Dark (cool) area with northeast-trending light (warm) streaks at the south end of Hart Mountain is a large, broken fault block. Northwest-trending dark (cool) streaks mostly define alluvium along stream drainages in small grabens or in fault zones.