UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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# GEOLOGIC INTERPRETATION OF INFRARED IMAGERY OF THE PEND OREILLE AREA, IDAHO*

by

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**U. S. Geological Survey, Denver, Colorado

## FORWARD

The infrared imagery described in this report was acquired by HRB Singer, Inc., on contract to the U. S. Geological Survey. It is a product of a Reconofax IV scanner imaging in the 3-5 micron portion of the infrared spectrum. Studies of the data were conducted under the Geologic Applications Program of the NASA Earth Resources Survey Program as Task No. 160-75-01-44-10 entitled "Ground Truth Investigations".

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## Introduction

Infrared imagery covering an area about 7 miles wide and 36 miles long in the Lake Pend Oreille area, Idaho (Site #110) (Fig. 1) was collected on August 8, 1966 by HRB-Singer, Inc. under sub-contract to the U. S. Geological Survey. The image was recorded between 2151 and 2202 MDT, about 1 1/2 hours after sunset on the highest peaks, and was collected on Mission 4027-23, Flight 7, using a Reconofax IV instrument with no filter.

The imagery has been compared with 1) geologic maps made by the writer (Harrison and Jobin, 1965; unpublished map of the Elmira quadrangle) and by Allan B. Griggs (unpublished map of the eastern half of the Spokane 1° x 2° sheet) of the U. S. Geological Survey; 2) vertical aerial black and white photographs taken in 1946 under a contract to the Topographic Division of the U. S. Geological Survey; and 3) oblique black and white aerial photographs of part of the area taken on September 4, 1933, by Miller Cowling of the 116th Photo Section, Washington National Guard.

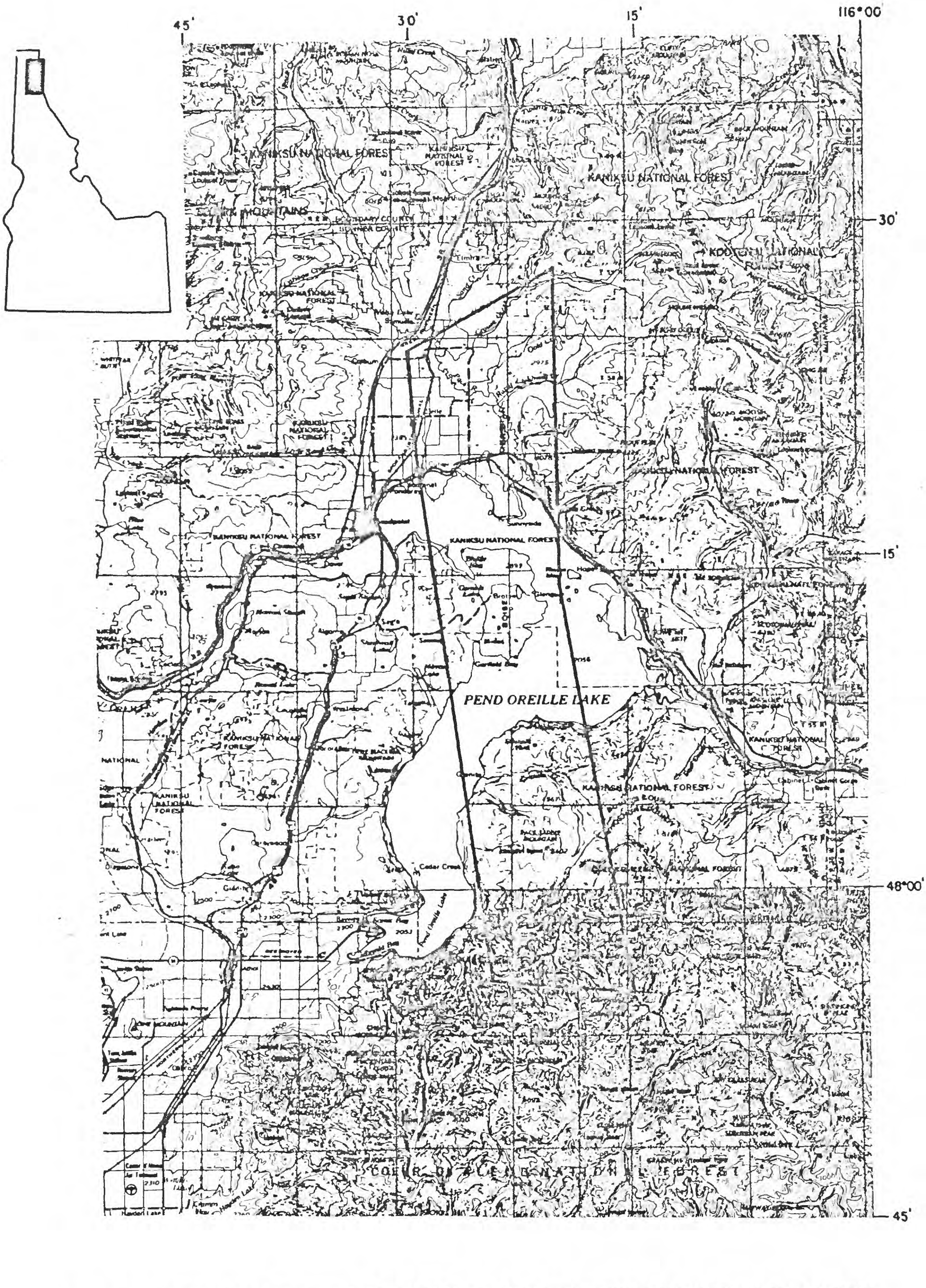



Figure I. INDEX MAP SHOWING LOCATION OF AREA COVERED BY INFRARED IMAGERY

## Geology and Geography

The area spanned by the infrared imagery (Fig. 2) includes a variety of rock types (Fig. 3) and physiographic provinces (Fig. 4). Most of the area is mantled either by moderately dense to dense evergreen forests or by scattered to dense brush; about a third of the land in the Purcell Trench has been cleared. Perhaps 5 percent of the area contains bedrock exposures, and about 25 percent contains a thin cover of bedrock chips that are essentially in place over the bedrock from which they are being derived.

The area is underlain by a thick sequence of old metasedimentary rocks (the Precambrian Belt Series) that has been intruded by dioritic to gabbroic sills of Precambrian age, and by dioritic to granitic dikes, stocks, and a batholith of Cretaceous age. Cambrian sedimentary rocks are exposed in a few places south of Pend Oreille Lake. Glacial moraine and outwash fills most of the mountain valleys and covers some of the lowlands in the Purcell Trench. Glacial lake beds and wind blown sand and silt fill lowlands of the Purcell Trench north of Pend Oreille Lake. Recent alluvium occurs in the lower parts of mountain streams, along the lake shore, and along the meandering courses of streams in the Purcell Trench.

The dominant structures of the region are faults. The Hope Fault and its branches represent a crustal break that has about 8 miles of right lateral displacement and several thousand feet of vertical displacement (Harrison and Jobin, 1963, p. K28-K29). South of the branching Hope Fault are block faults (Harrison and Jobin, 1965; Allan B. Griggs, written communication, 1966), of which only a few of the major ones are shown on the geologic sketch map.

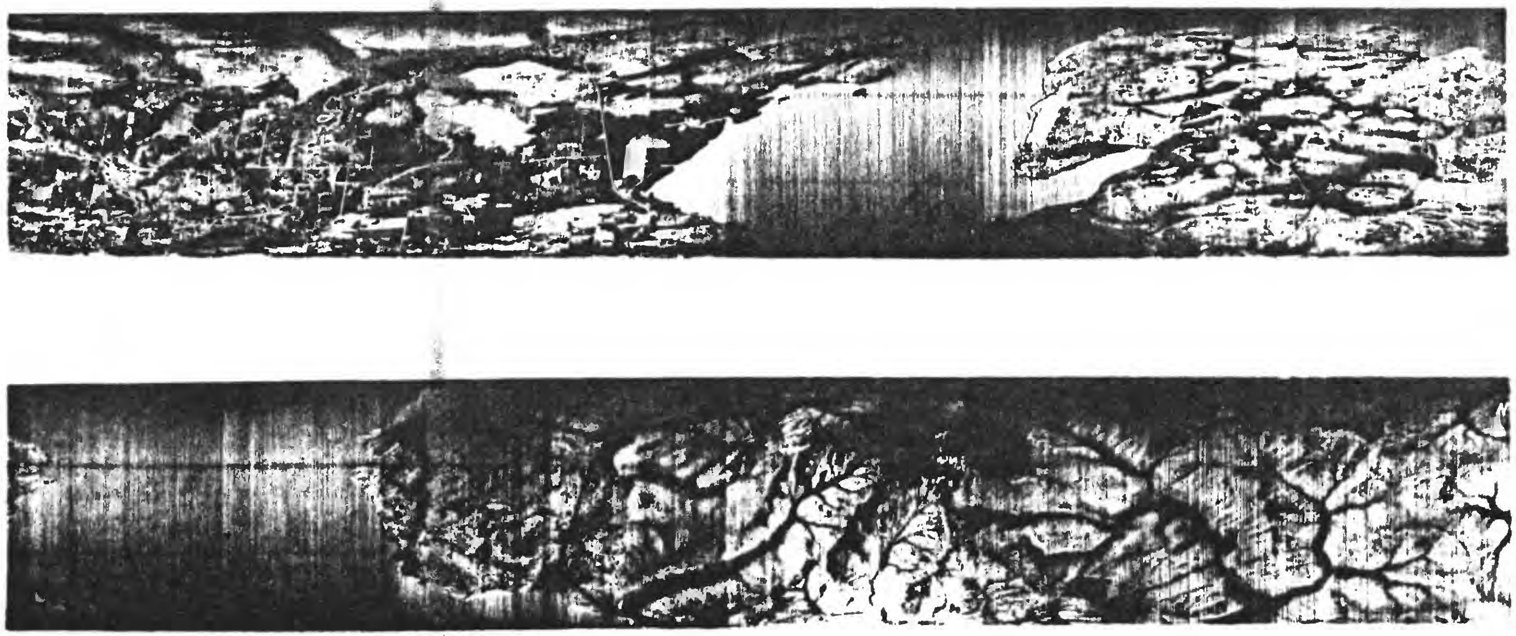


FIGURE 2. INFRARED IMAGE, PEND OREILLE AREA, IDAHO.

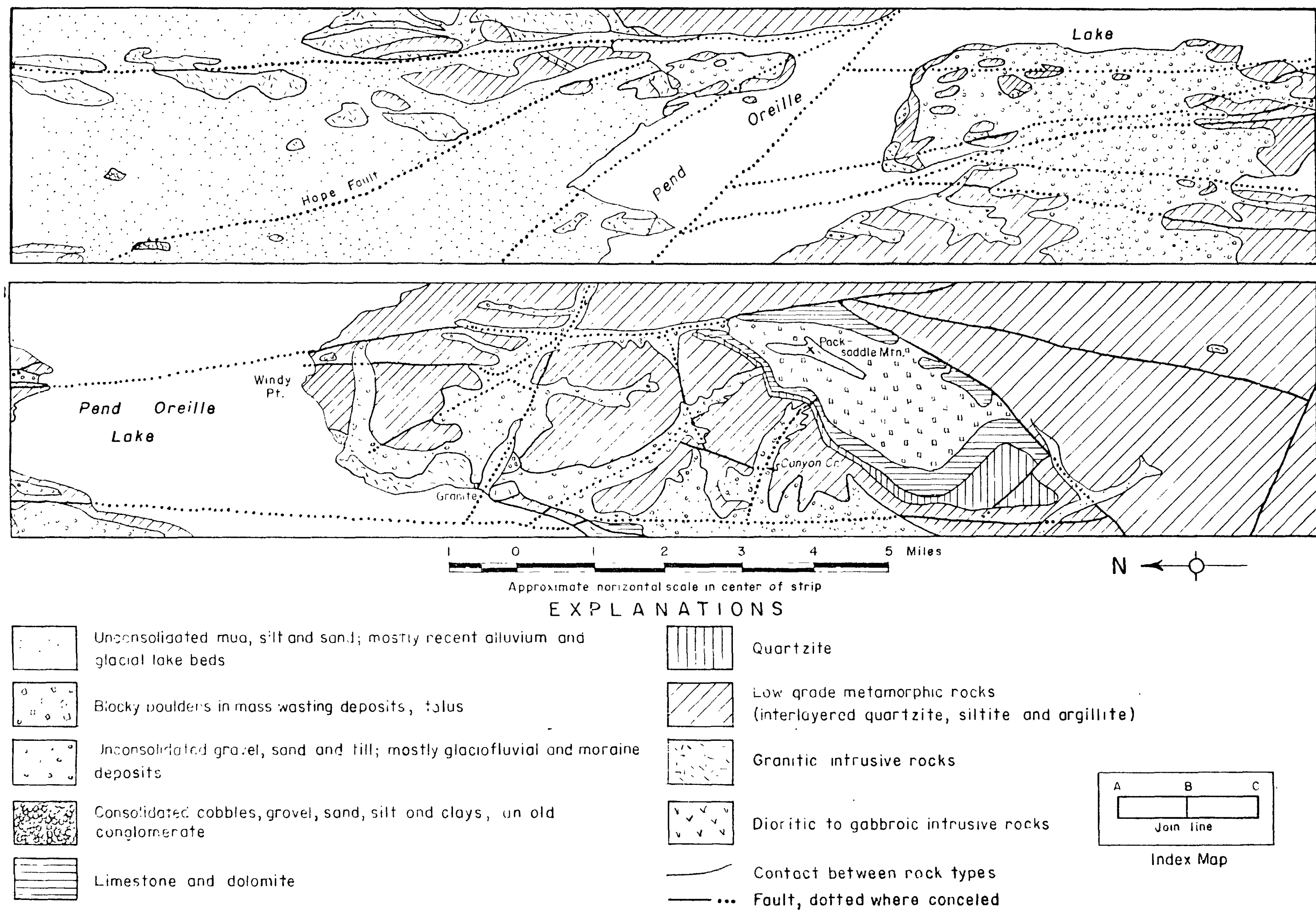



Figure 3. GEOLOGIC SKETCH MAP OF AREA COVERED IN FIGURE 2.

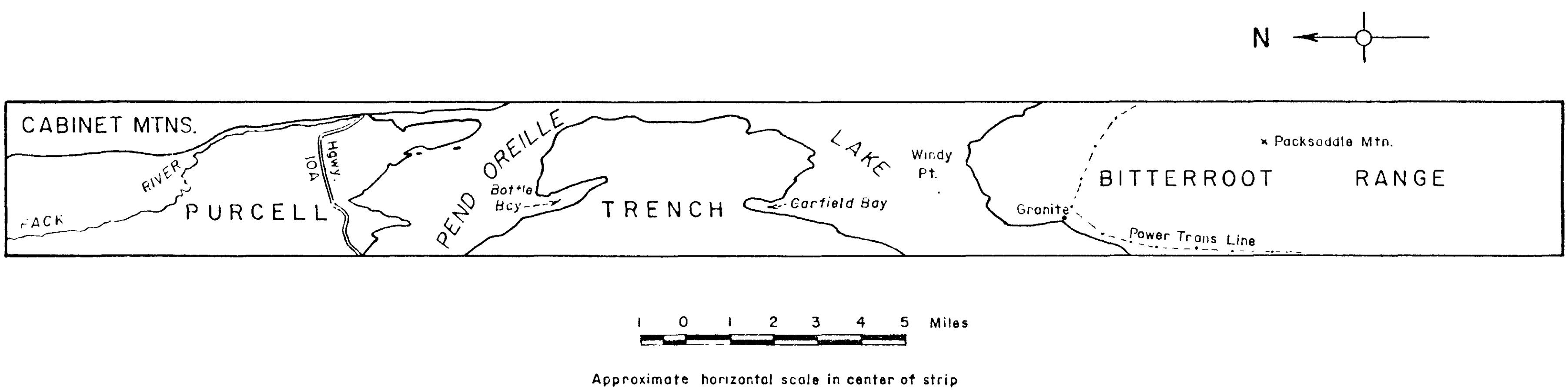



Figure 4. INDEX TO PRINCIPAL GEOGRAPHIC FEATURES

## Imagery as Related to Ground Features

The relative radiation intensity (tone) of various features identifiable on the image was determined by using the eye plus a reading glass as a crude densitometer and making mental adjustments for visible variations (light and dark vertical bands, Fig. 2) in reception (knob twiddling) during collection of the image. These observations are summarized in Table 1. Four supplemental observations are perhaps obvious but are listed here for completeness:

1. Features in the central part of the film strip show a brighter tone than similar features nearer the top and bottom edges of the strip.

2. Relative intensity is greater for a given linear feature as the feature approaches an attitude perpendicular to the flight line.

3. Relative intensity is greater for a given planar feature as the feature approaches an attitude perpendicular to the "line of sight" of the instrument.

4. The "double oblique" effect caused by the method of scan and imagery collection results in images that are difficult to work with. This effect adds further variables to a complicated problem, variables that would be eliminated or more simply dealt with in rectified images.

Table 1. Relative radiation intensity (tone) of various features identifiable on the infrared image.

| | |
|---|---|
| Darkest (Coolest) | Cleared land; recent (1 - 2 years old) gravel roads; power line cuts |
| | Drainage lines in bottom of V-shaped valleys |
| | Drainage lines and lower slopes of broad valleys |
| | Deeper parts of large lake |
| | Paved roads approximately parallel to flight line; older gravel roads |
| | Heavily timbered or brushy slopes and ridges |
| | Outcrop, or near outcrop partly covered by thin rubbly colluvium |
| | Non-vegetated blocky talus of quartzite and siltite |
| | Paved roads approximately perpendicular to flight line |
| | Shallow streams, ponds, and lakes |
| Brightest (Warmest) | Non-vegetated large (4 - 6 ft on a side) blocks of granodiorite in a mass-wasting deposit |

Observable direct relations of the image (Fig. 2) to geologic features (Fig. 3) are few. The drainage pattern is well displayed. Where the drainage is related to faults or contacts, these geologic features can be identified on the image, just as they can be on black and white aerial photographs. Bold bedrock outcrops are not readily distinguished from outcrops of similar rock that are partly covered by timber, brush, or unconsolidated rocks. Broad areas of partly covered or bold bedrock outcrops are generally distinguishable in the mountainous regions by their relatively lighter tone, but this does not hold consistently for the bedrock knobs and hills that stick up through the unconsolidated rocks in the lowlands of the Purcell Trench. Differences among the many rock types generally are not distinguishable on the infrared image. Some exposures of talus and mass-wasting deposits that are not covered by brush or timber do show up as bright spots on the infrared image, and at least one of these warmer areas is of such intensity that it warrants further study.

One of the basic questions raised by the imagery is whether the irregular spots of high intensity thermal radiation shown on Packsaddle Mountain reflect a geothermal anomaly or are an effect peculiar to some factors of the surface geology. Therefore, the following few paragraphs will describe more fully rock types exposed on Packsaddle Mountain and closely related rock types elsewhere in the area.

Talus and other mass-wasting deposits are exposed in many parts of the area, but only a few deposits are large enough to be mapped at the scale (1:62,500) of the published maps (see Harrison and Jobin, 1965, for example). Three of these large areas of talus or mass-wasting deposits are within the view field on the image (cf. Figs. 2 and 3) -- one near Windy Point, one near Granite, and a very large one around Packsaddle Mountain. The Windy Point and Granite deposits are mostly 1-ft blocks and smaller cobbles of siliceous siltite and/or quartzite from the Burke and Revett Formations of the Belt Series. The Packsaddle Mountain deposit is mostly 4-6 ft and smaller blocks of granodiorite forming a mass-wasting sheet over most of a Cretaceous intrusive plug. Both the granite and Packsaddle Mountain deposits may contain permanent ice in them because ice-cold springs flow from the deposits. One such spring issues within a few 10's of feet of the top of Packsaddle Mountain. Rock streams are common in the mass-wasting deposit on Packsaddle Mountain, and many of them contain no timber in a heavily timbered area. The sliderock at Windy Point and Granite are dribbling down across the same bedrock unit from which the sliderock is forming. On Packsaddle Mountain granodiorite bedrock crops out high on the mountain ridges and crest; the mass-wasting deposit has crept downhill and now covers most of the granodiorite as well as some of the Cambrian quartzite and limestone that form a resistant ledge rimming the mountain about 1000 feet below the crest (Fig. 6). A few of the rock streams have moved downhill far enough to choke the drainage below the outcrops of Cambrian rocks and form streaks of granodiorite blocks below the ledge.

Talus at Windy Point shows on the infrared imagery as a lighter colored streak (Fig. 2), but it is not striking -- perhaps because it is partly covered by timber and partly shaded from the infrared instrument by the sharp ridge that forms Windy Point. Light-colored near-vertical streaks down the steep cliffs in the area appear to correspond with streaks of sliderock.

The deposit at Granite is partly covered by moderately dense timber and is also partly shaded from the instrument view. It is not identifiable on the image.

The Packsaddle Mountain deposit shows irregular spots and streaks of the highest intensity recorded on the image (Fig. 2). An enlargement of the Packsaddle Mountain imagery is shown in Figure 5, and a black and white aerial oblique photo of approximately the same area is shown in Figure 6. The striking correspondence between the light colored areas on Packsaddle Mountain shown in both pictures is obvious. The light colored streaks are rock streams and other untimbered areas in the mass-wasting deposit. Even the small streams of granodiorite blocks that spill down across Cambrian and Belt rocks are identifiable on the infrared image. Of interest is the fact that many of the light spots on the conventional photo (Fig. 6) are accented by the light snow cover on them. Of further interest is the fact that the outcrops of granodiorite on top of Packsaddle Mountain and in the cirque wall, although light colored on the infrared image, do not approach the intensity of infrared emission of rubble of the same granodiorite.

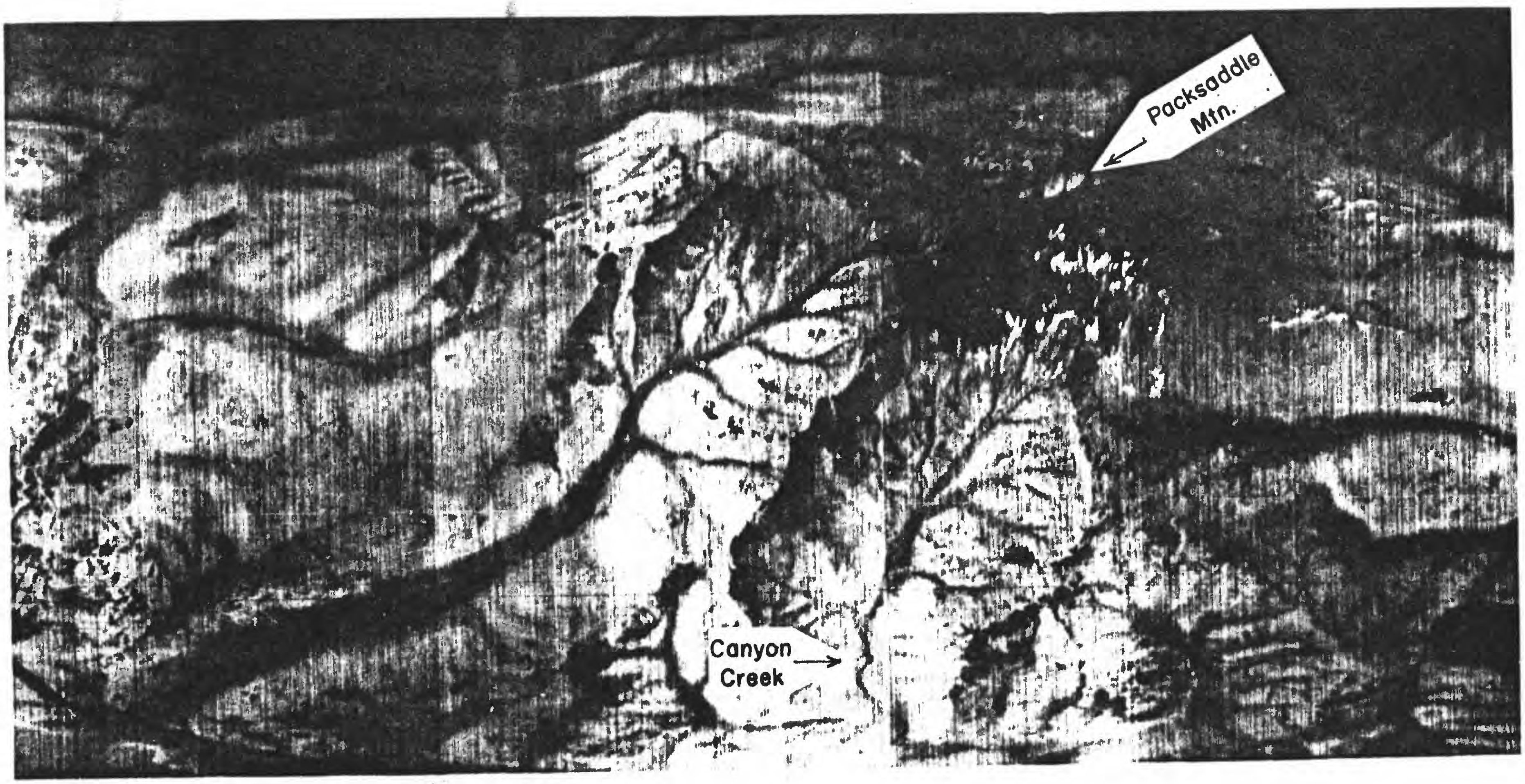
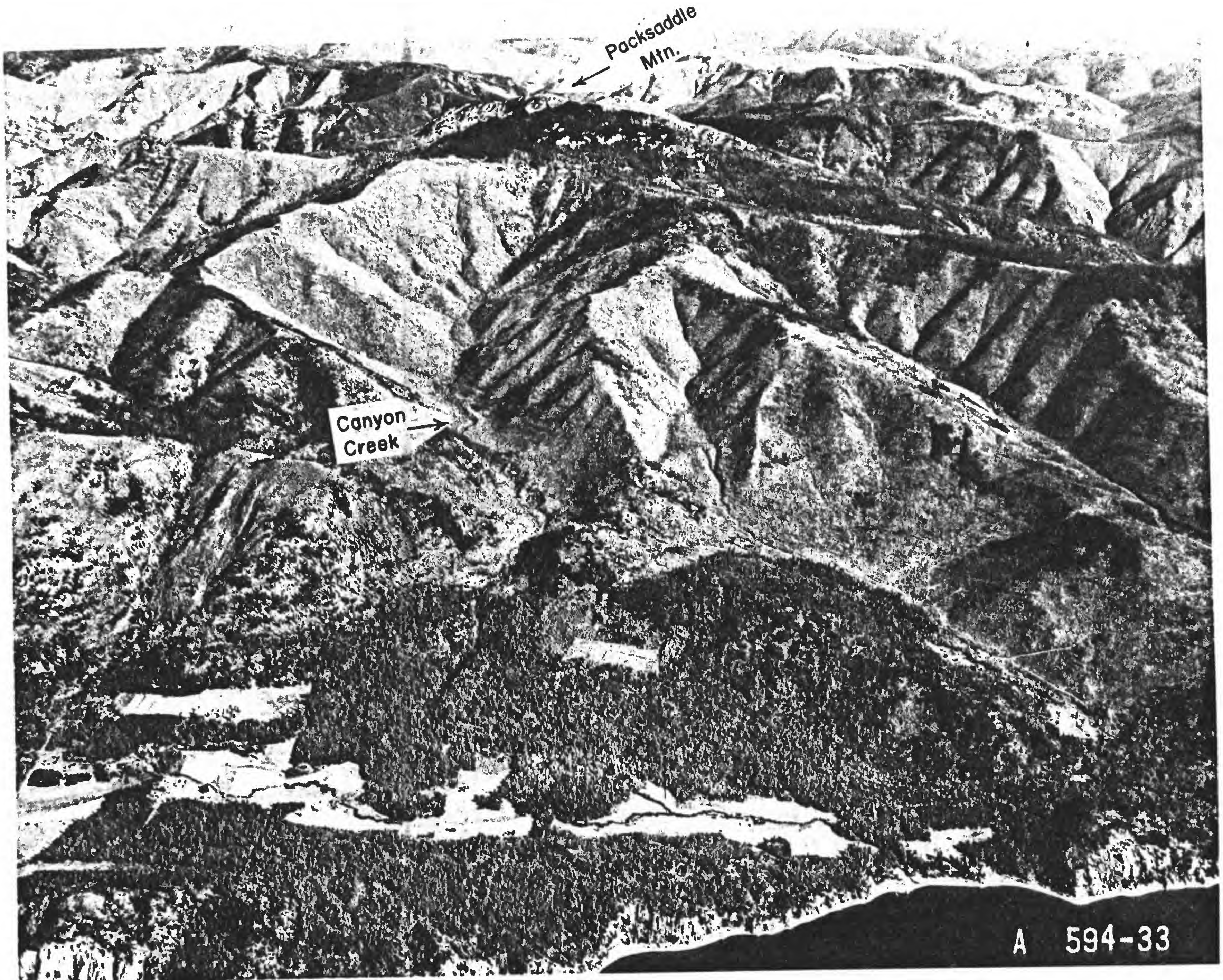



FIGURE 5. ENLARGED INFRARED IMAGE OF PACKSADDLE MOUNTAIN.


Packsaddle Mtn.
Canyon Creek
A 594-33

## Conclusions and Recommendations

Stefan's law for emission of radiant energy is:

$$W = e\sigma T^4$$

where W is the rate of emission, e is emissivity of the surface (measured from zero to unity), $\sigma$ is a constant, and T is the Kelvin temperature (Sears, 1947, p. 383). As applied to a given rock type, e is larger for fragments than for whole slabs and $\sigma$ is a constant that can be ignored when comparing fragments of rock with a slab of the same rock to determine relative rates of emission. Thus, given equal surface temperature, the law explains the well known phenomena that fragments radiate their heat energy more quickly and cool faster than a slab of the same material.

The writer's tentative conclusion is that the Packsaddle Mountain anomalies are not indicative of a geothermal anomaly. For this to be true, the T of the blocks at the time the imagery was made would have to be significantly higher than that of the outcrop. Assuming that the thermal conductivity of a given block is the same as the outcrop during the relatively short daily period of heating, then the total absorbed radiant energy for the blocks can be much greater per unit area as viewed on an image or photo because the blocks are being heated on two or more sides whereas the outcrop is being heated essentially on only one. Even though e for the blocks is unquestionably slightly greater than e for the outcrop and the heat loss more rapid in the blocks, the imagery may have been taken so soon after sunset that the blocks were in a total heat energy state significantly higher than that of the outcrop. Because the rate of emissivity is a function of the surface T to the fourth power, small differences in surface T could make significant differences in brightness recorded on the infrared image. The heated "dead" air in the spaces between the blocks might also aid in maintaining temperarily a higher T in the blocks.

A simple test of the theory is possible. If the same area can be reflown under the same approximate conditions but much later after sundown, then Stefan's law requires that the blocks be cooler than the outcrop. A laboratory experiment on a small slab and crushed pieces of the granodiorite could also be designed to examine the shape of the radiant energy decay curves as well as to measure the absolute surface T of the samples following limited exposure to radiant energy.

The ability to recognize a true geothermal anomaly on the imagery is important to geologic application of such data. The writer strongly recommends that one or both of the above tests be performed as an aid in clarifying geologic interpretation of infrared imagery.

## References Cited

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Sears, Francis Weston, 1947, Principles of physics, Volume I: Cambridge, Mass.; Addison-Wesley Press, Inc.