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EVALUATION OF RADAR AND INFRARED IMAGERY OF SEDIMENTARY ROCK TERRANE, SOUTH-CENTRAL YELLOWSTONE NATIONAL PARK, WYOMING*

by

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CONTENTS

ILLUSTRATIONS

FOREWARD

This report discusses infrared imagery (3-5 micron) obtained by the HRB Singer Corporation using a Reconofax IV imaging scanner on contract to the U. S. Geological Survey.

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ABSTRACT

Side-looking radar imagery (K-band) and night-time infrared imagery (3-5μ band) were compared over the same sedimentary terrane of south-central Yellowstone National Park to determine if either type of imagery could be used 1) in differentiating rock types and 2) delineating structural features.

Although sedimentary rocks of greatly contrasting composition occur in the area none had detectable tonal characteristics on either types of imagery. This is believed to be due, in part, to masking by vegetation. Flay lying volcanic rocks having smooth topographic profile were readily detectable on both radar and IR imagery. Quaternary surficial deposits were easily detected in IR imagery.

Numerous faults of large displacement were not detected by either form of imagery except where the faults were expressed by topography.

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Introduction

Sedimentary formations ranging in age from Devonian to early Tertiary are exposed in an area of approximately 100 square miles in the south-central part of Yellowstone National Park (fig. 1). Many major rock types -- limestone, shale, sandstone, conglomerate, quartzite, and chert -- are represented. The area is bounded on the west, north, and east sides by the erosional edge of a thick pile of Tertiary volcanic rocks. Small patches of the volcanics also occur within the area, as does a variety of Quaternary surficial deposits.

Structural features include several large folds and fault blocks. Displacements on some faults are as much as 10,000 feet, and strata of sharply contrasting lithologies are juxtaposed on opposite sides of the fault zones. The structures in the sedimentary rocks project northward and northwestward for unknown distances beneath the younger volcanic rocks. The volcanic sequence has been involved in the faulting in some places, but the movements along other faults have been entirely prevolcanic.

The above observations were made as part of a detailed surface mapping program conducted in the area during the summers of 1966 and 1967. Because of heavy vegetation and a thick cover of surficial deposits throughout much of the area, significant geologic features in the sedimentary rocks were difficult to outline except by foot traverses at selected intervals. Many large faults, for example, occur in relatively broad valleys whose floors and nearby slopes are mantled by alluvium or glacial and landslide debris which obscure the actual fault traces. Good exposures of bedrock are generally limited to the tops of ridges.

An evaluation of radar and infrared imagery was made to determine their effectiveness in the differentiation of major rock types and the detection of structural features in a terrane of sedimentary rocks. In particular, close attention was given during the present study to characteristics of the imagery that might provide clues to the more precise locations of faults. The radar imagery (multiple-polarized, HH polarization) was obtained in October, 1965 with equipment developed by the U. S. Army Electronics Command. The infrared imagery (3-5 micron range) was recorded using a Reconofax IV system and Tri-X film by representatives of H. R. B. Singer under Contract, Project No. 4027, Missions 19 and 20. These missions were flown during the mid-evening hours of August 13 and 14, 1966. The evaluation was based only on visual inspection of the images.

Parts of the remote sensing imagery are reproduced in figures 2, 3, and 4. Superimposed on these are generalized geologic maps as determined from on-the-ground observations. The general conclusion is that the remote sensors provide a fair representation of the physiography of the region, but do not offer especially significant data for the distinction of rock types and structures within the sedimentary sequences. Specific correlations between distinctive features shown on the imagery and actual geologic features can be made in many places, but in general this is owing to the fact that geology and physiography commonly are closely related. It should be noted that conventional aerial photographs likewise do not provide a clear representation of the geologic features in this particular area, though they are somewhat more useful for geologic mapping than the radar and infrared imagery.

Items selected for further discussion are given in the following paragraphs.

Differentiation of Rock Types

No specific criterion for the differentiation of various kinds of sedimentary rocks could be established on the basis of visual inspection of radar and infrared imagery within the area of the present study. This is well illustrated by the fact that in some portions of the map areas labelled "PM" (figs. 2, 3, 4), thick units (1,000 feet or more) of such contrasting rock types as bright red thin-bedded shale and massive gray crystalline limestone occur along the same slopes or ridges, yet appear as a uniform rock mass throughout. This may be partly the result of the "masking" effect of forest cover in many places, but even where the rocks are well exposed the same color tones seem to exist on the remote sensing imagery.

Similarly, few differences in representation could be detected between areas underlain by sedimentary rocks and those underlain by volcanic rocks. In general, however, the volcanic rocks, because they are flat-lying and not as susceptible to mass-wasting, exhibit a smoother topographic profile than the more irregularly eroded sedimentary rocks (for example, note area of volcanic rock exposures directly south of Heart Lake in figures 2 and 3).

Areas of Quaternary surficial deposits are well-defined by infrared imagery in many places, particularly flat, alluvium-floored meadows near streams and lakes. Several such meadows contain scattered patches of standing water a few inches deep which apparently cool rapidly during the early evening hours. Hence, these features show up nearly black on the infrared film (fig. 3 and 4). Meadows without standing water, but which still contain a high percentage of near-surface moisture, are shown by somewhat lighter color tones. Lakes and large streams are white on the infrared imagery, because they maintain a more uniform temperature and are relatively warmer than their surroundings during the night.

A small area of hot spring activity is easily detected on figure 3 (locality 5).

Delineation of Structural Features

The numerous faults of large displacement that occur within the sedimentary rock terrane are not detectable on the radar and infrared imagery (figs. 2, 3, and 4), except where the fault traces may coincide with conspicuous topographic features such as an abnormally straight stream channel or an abrupt cliff face. In the latter cases, however, the image is apparently produced by the topographic feature itself rather than being an indication of any sharp discontinuity in the character of the bedrock on opposite sides of the fault, or of any other physical property of the fault zone. If abrupt lithologic changes were being detected, for example, then many of the faults that cross smooth upland surfaces eroded directly on the sedimentary rock units should be particularly well displayed on the remote sensing imagery. They are not.

Hot or cold water spring activity, a common phenomenon along many faults, appears to have been sparse or absent along the major fault zones observed during the present study. Such springs, if present in abundance and arranged in a linear pattern, would probably be detected by the remote sensors, especially infrared. Since large segments of many faults are concealed in alluvium-covered valleys, any moisture issuing from the buried fault zones would probably be dispersed laterally into the surficial deposits and thus would not produce conspicuous alignments.

It should be noted that not all linear features shown on the infrared and radar imagery are controlled by structure in the underlying bedrock. For example, the small, northeasterly aligned features east and south of Heart Lake, and also at the southeast corner of figure 2 (localities labelled "1"), are known from ground observations to be of glacial origin. Likewise, many straight stream channels (especially conspicuous on figure 2) appear not to be primarily of structural origin.

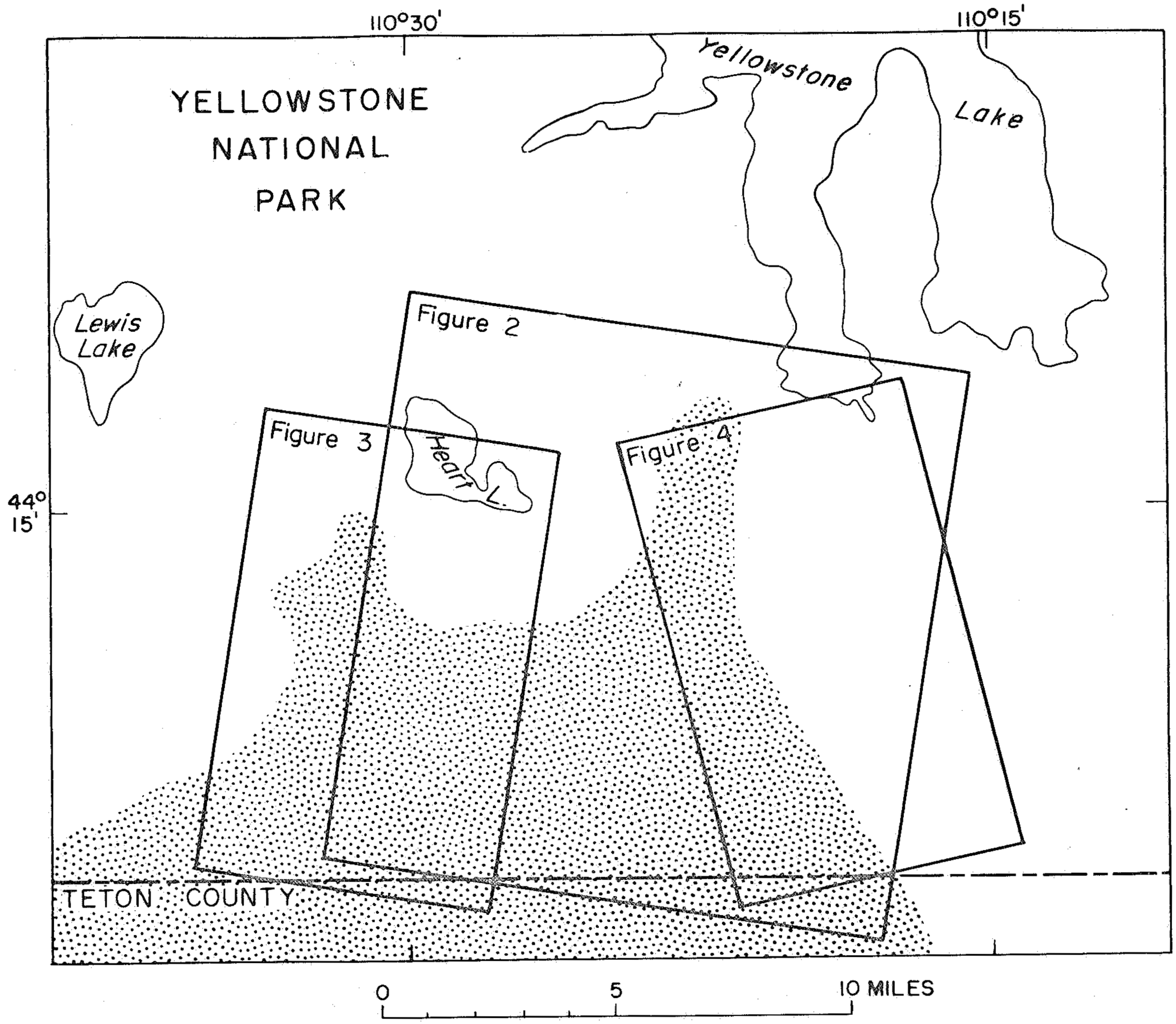

Figure 1.--Index map of south-central Yellowstone National Park, Wyoming, showing areas covered by remote sensing imagery in figures 2, 3, and 4. Stippling indicates area in which exposures are chiefly of pre-volcanic sedimentary rocks.

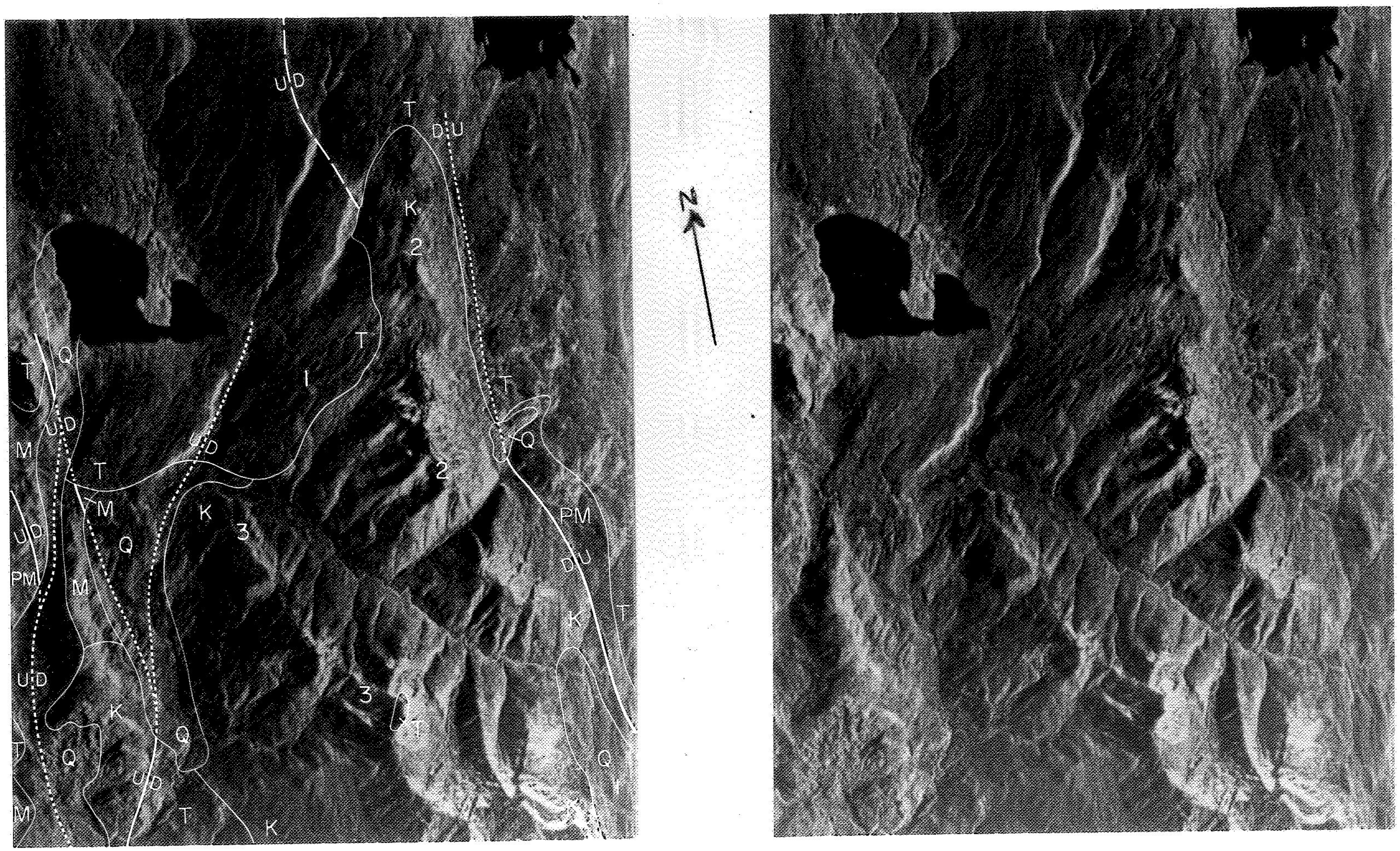

Figure 2.--Radar imagery (portion of Flight 94, Run 4) of a part of south-central Yellowstone National Park, Wyoming. Geologic map symbols: P - Paleozoic sedimentary rocks; M - Traissic and Jurassic sedimentary rocks; PM - Paleozoic, Triassic, and Jurassic sedimentary rocks; K - Cretaceous sedimentary rocks; T - Tertiary volcanic rocks; Q - Quaternary surficial deposits. Faults shown by heavy lines (U - upthrown side; D - downthrown side; dashed where inferred; dotted where concealed). Numbered localities: 1 - glacial features; 2 - eastward dipping strata along Chicken Ridge; 3 - westward dipping strata along Big Game Ridge. Scale is variable; south edge of Heart Lake is approximately 2 miles long.

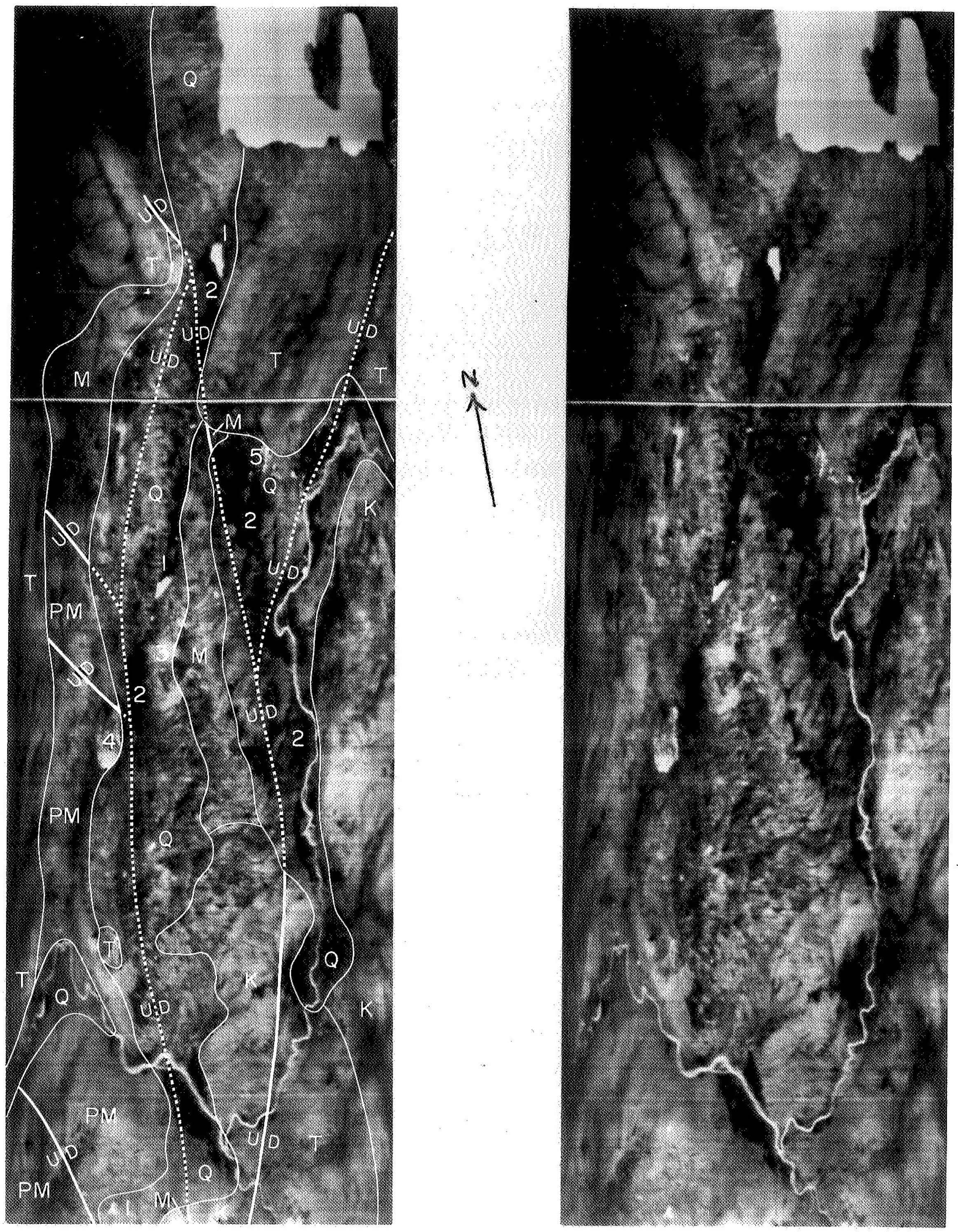

Figure 3.--Infrared imagery (H. R. B. Singer, Project No. 4027, Mission 21, Pass 4, 2125-2144 hrs., August 14, 1966) of western part of sedimentary rock terrane, south-central Yellowstone National Park, Wyoming. See figure 2 for explanation of geologic map symbols. Numbered localities: 1 - shallow lakes; 2 - swampy meadows; 3 - fresh landslide scars and debris; 4 - bald knob of steeply inclined (eastward) chert and quartzite; 5 - hot springs. Scale is variable; south edge of Heart Lake is approximately 2 miles long.

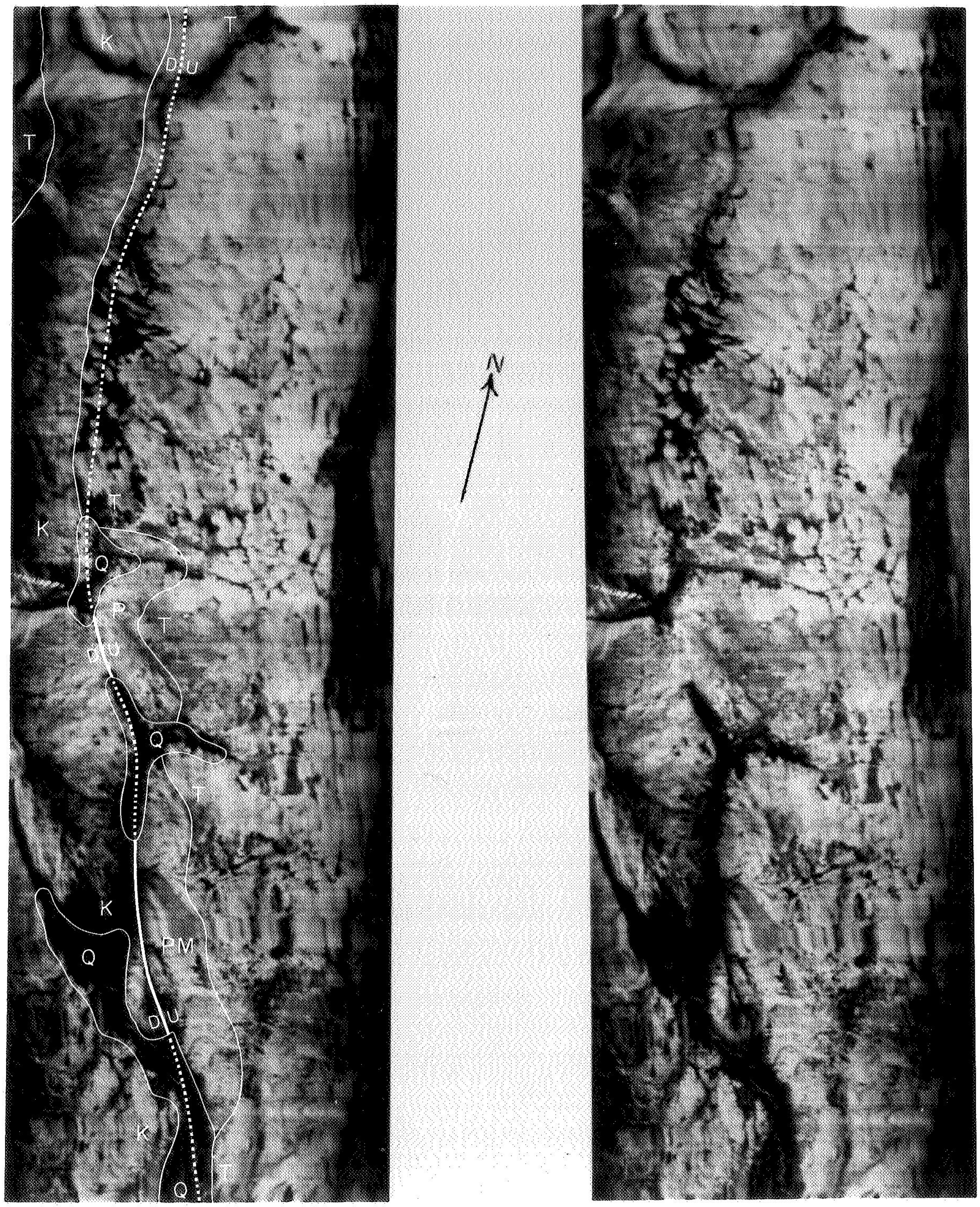

Figure 4.--Infrared imagery (H. R. B. Singer, Project No. 4027, Mission 19, Pass 3, 2137-2202 hrs., August 13, 1966) of eastern edge of sedimentary rock terrane, south-central Yellowstone National Park, Wyoming. See figure 2 for explanation of geologic map symbols. Scale is approximately the same as for figure 3.