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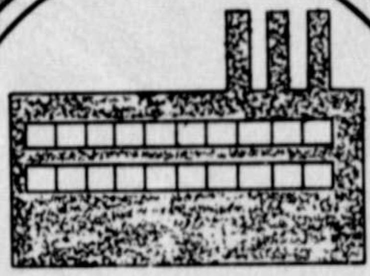

SPECIAL REPORT
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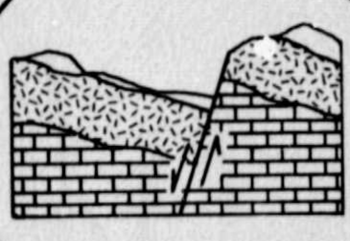
by RONALD W. MARRS



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University of Wyoming

Special Report:

Preliminary Analysis of the Beaver Creek and Ninemile Hill Areas, Wind River Basin, Wyoming using Image Ratios and Thematic Classification.

R. W. Marrs
Department of Geology
University of Wyoming
Laramie, Wyoming 82071

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NASA/Goddard Space Flight Center
Greenbelt, Maryland 20771

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16. Abstract

The Beaver Creek and Ninemile Hill areas in the southern Wind River Basin were analyzed via the General Electric Image-100 system. These analyses were compared to similar analyses performed independently by R. K Vincent of Geospectra Corporation and by N. M. Short of NASA/Goddard Space Flight Center. Ratioing procedures employing a combination of ERTS-MSS bands 4 and 5 reveal anomalies that might be related either to petroleum or to metallic mineralization. Geochemical sampling and field studies are in progress in these areas.

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INTRODUCTION

Research is continuing under an extension of ERTS-1 contract NAS 5-21799 for the purpose of investigating subtle tonal and textural anomalies visible on the ERTS imagery reported to be sometimes related to petroleum accumulations (Donovan and Noble, 1975; Collins and others, 1975).

Initially, a great number of subtle tonal and textural anomalies were identified for possible correlation with petroleum reservoirs. The study objective was to determine the reasons for the reported relationship between observed anomalies and oil fields. To approach this objective it is necessary to make an in-depth analysis of several of the subtle anomalies, studying their spectral and temporal characteristics and relationships to geologic features.

Consequently, it was necessary to limit the study to a few selected sites. Anomalies that were found to have an obvious relationship to non-geologic features or to obvious surface geologic features were first eliminated. Then, the anomalies that were very weak or questionable were eliminated. Finally, an attempt was made to choose from the remaining group several of the strongest anomalies, some of which were considered to have potential for being associated with known oil fields and for which some field data might be available. An effort was made to include several different types of anomalies in this select group. One such anomaly was the Ninemile Hill anomaly in the southern part of T. 33 N., R. 97 W., Wind River Basin, Wyoming (Figures 1 and 2).

This report details progress of the analysis of the first area studied, the Beaver Creek/Ninemile Hill area. The results appear promising, but must be considered inconclusive because the essential field work and geochemical analysis are not yet complete.

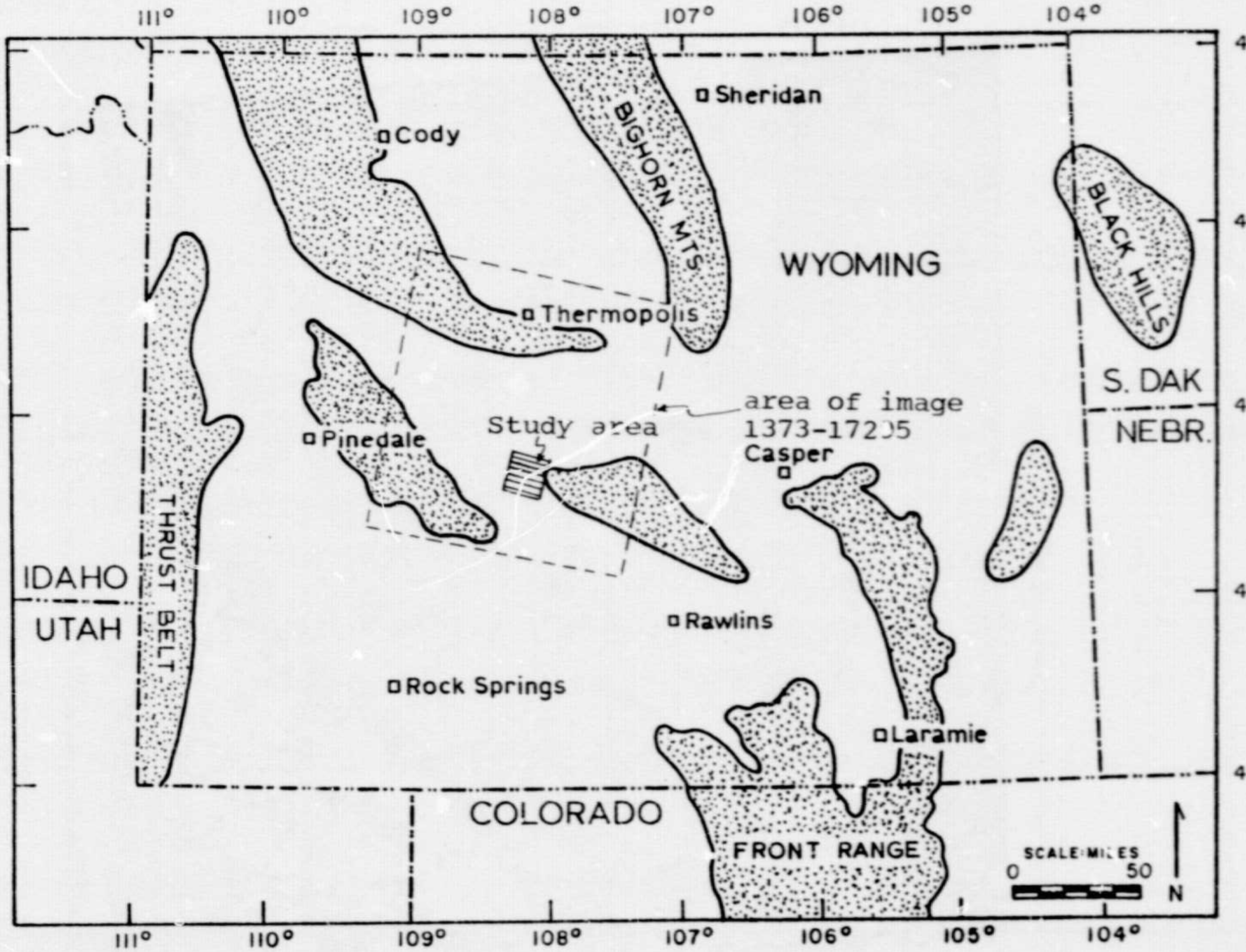

Figure 1. Index map showing the location of the Beaver Creek/Ninemile Hill test area and the area covered by image 1373-17295.

Figure 2. LANDSAT image 1373-17295 of the Wind River Basin, Wyoming. The area outlined was analyzed with the GE Image-100 system.

DISCUSSION

The Ninemile Hill anomaly is an oblong, smooth-textured area contrasting slightly with the mottled surroundings. This particular anomaly was not associated with a known oil field, but occurs in an area where numerous, small, oil fields have been found (Beaver Creek, Big Sand Draw, Dallas, Derby, etc.). The appearance of this anomaly on the LANDSAT image is such that it might be interpreted as a geomorphically or topographically anomalous area. Examination of the topographic maps of the area indicate that the "anomaly" does correspond roughly to the topographically positive area of Ninemile Hill. However, Collins and others (1974) report that many of the LANDSAT image anomalies associated with petroleum reservoirs appear to have a geomorphic expression. So, it was decided to examine the Ninemile Hill anomaly in greater detail to determine the precise nature of the anomaly. A study of this area via the GE Image-100 System was the first step of this analysis.

Just prior to beginning these analyses R. K. Vincent (1975) reported finding a surface anomaly associated with the Beaver Creek Oil Field which lies immediately northeast of the Ninemile Hill anomaly. It was decided to include the Beaver Creek area within the test region to allow both a comparison of anomalies and a comparison of enhancement procedures.

The appropriate portion of LANDSAT image 1373-17295 was input to the Image-100 computer and displayed at full resolution as a color composite on the video monitor (Figure 3). Each band was then contrast-stretched to provide maximum brightness resolution for the scene (Figure 4). The Ninemile anomaly appears somewhat enhanced on the contrast-stretched version of the image, indicating that the anomalous appearance of the Ninemile Hill area is not entirely due to texture. Instead, the anomaly must be expressed in part, as a tonal or brightness anomaly.

Two attempts were made to extract the anomalous region by thematic classification, but these were not satisfactory and efforts to improve the classification by adjustment of the classification criteria failed to yield significantly improved contrast between the anomalous area and the surrounding area. Finally we decided to try ratioing procedures because Vincent (1975) had reported good results with band 5/ 4 ratios.

Several ratio combinations were tried and it was determined that the combination $\frac{(4-5)}{(4+5)} \times 2$ (Figure 5) provided optimim contrast enhancement in the suspected anomalous areas. However, the $\frac{(6-7)}{(6+7)} \times 8$ combination showed some contrast improvement (Figure 6) and the $\frac{(4-5)}{(4+5)} \times 4$ ratio was also very good (Figure 7). The oval-shaped Beaver Creek anomaly is quite apparent on each

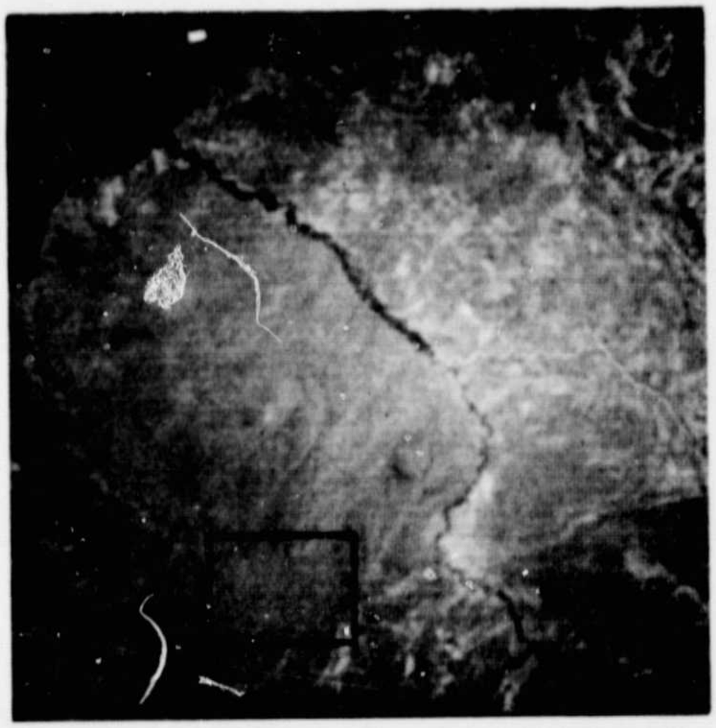

Figure 3. The Beaver Creek/Ninemile Hill area displayed in the standard false-color mode on the Image-100 system. The area outlined in black encloses the Ninemile Hill anomaly.

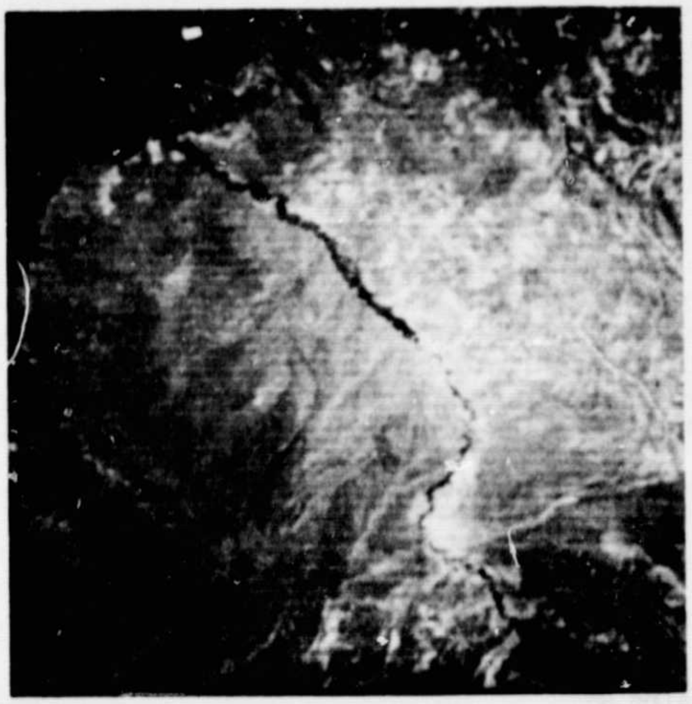

Figure 4. Contrast-stretched color-composite image of the Beaver Creek/Ninemile Hill area.

Figure 5a. Ratio $\frac{(4-5)}{(4+5)}$ X 2 shows both the oval-shaped Beaver Creek anomaly and also a much larger dark area to the west with a kidney-shaped light area in its center. The southernmost portion of this large anomaly corresponds to the Ninemile Hill anomaly. Also, a spotty, light-toned anomaly extends northwest from the oval-shaped Beaver Creek anomaly.

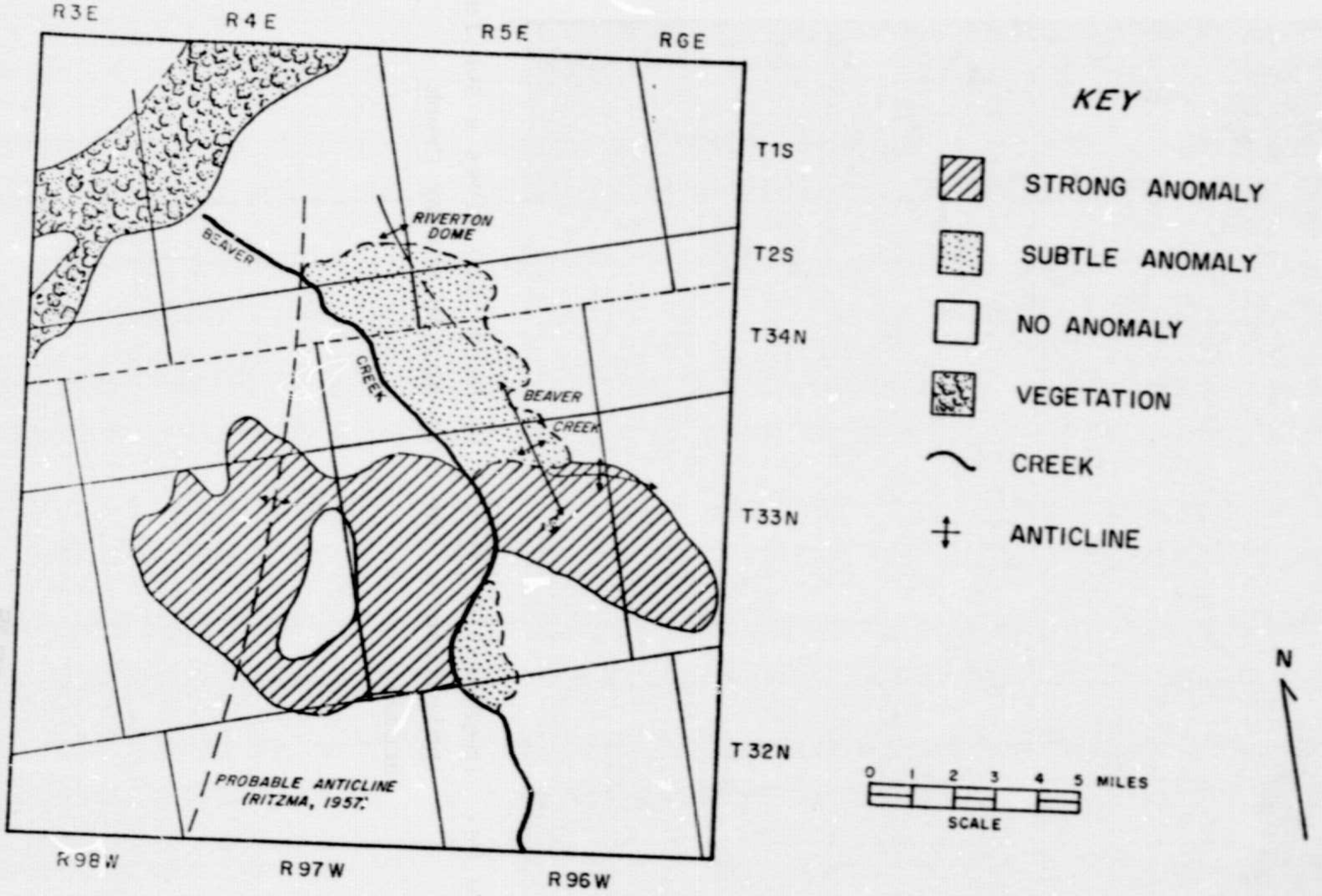

Figure 5b. Interpretation of ratio $\frac{(4-5)}{(4+5)}$ X 2 showing outlines of light-toned and dark-toned anomalies.

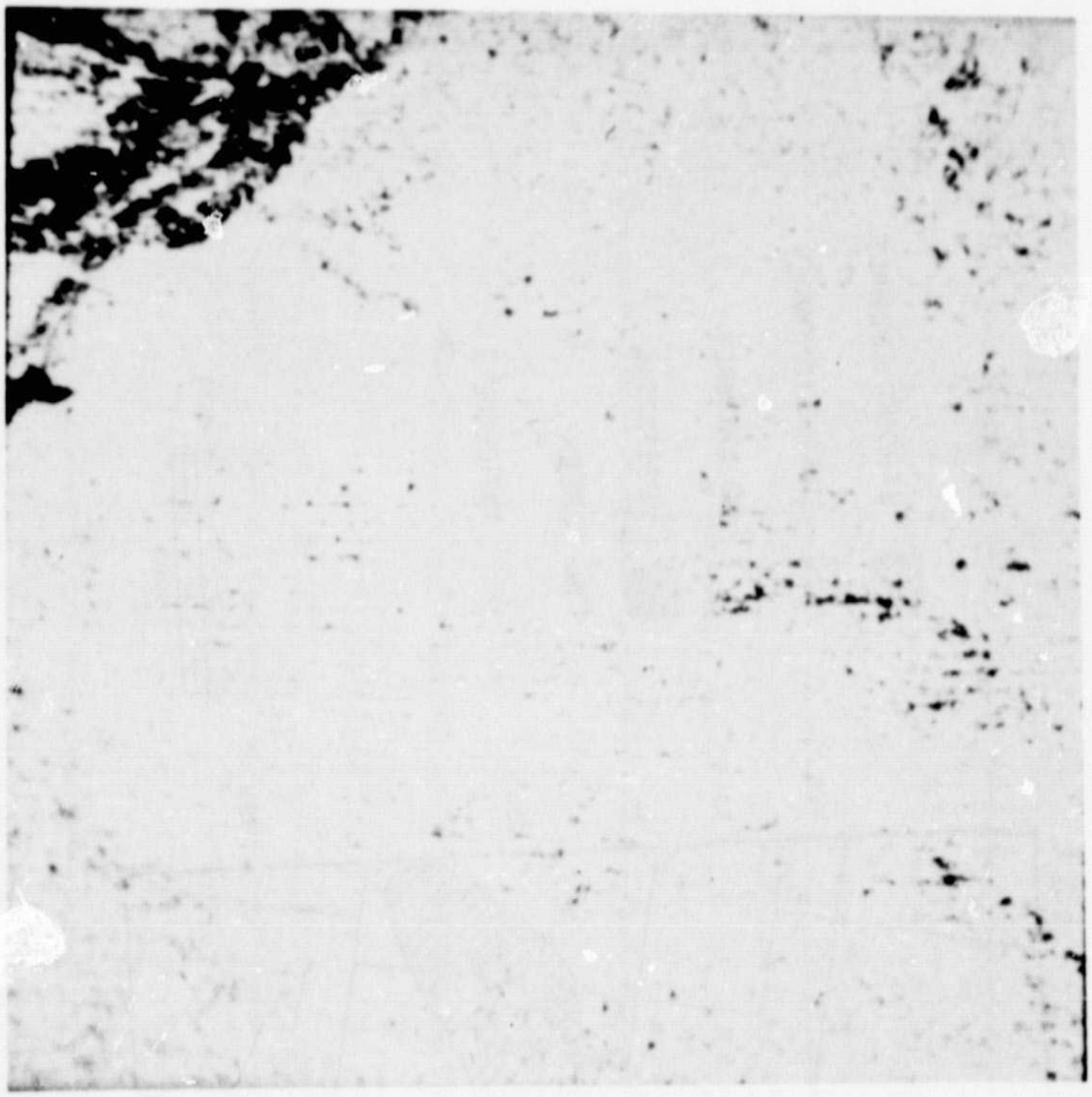

Figure 6a. Image ratio $\frac{(6-7)}{(6+7)}$ X 8 which also gives a subtle indication of the oval-shaped Beaver Creek anomaly.

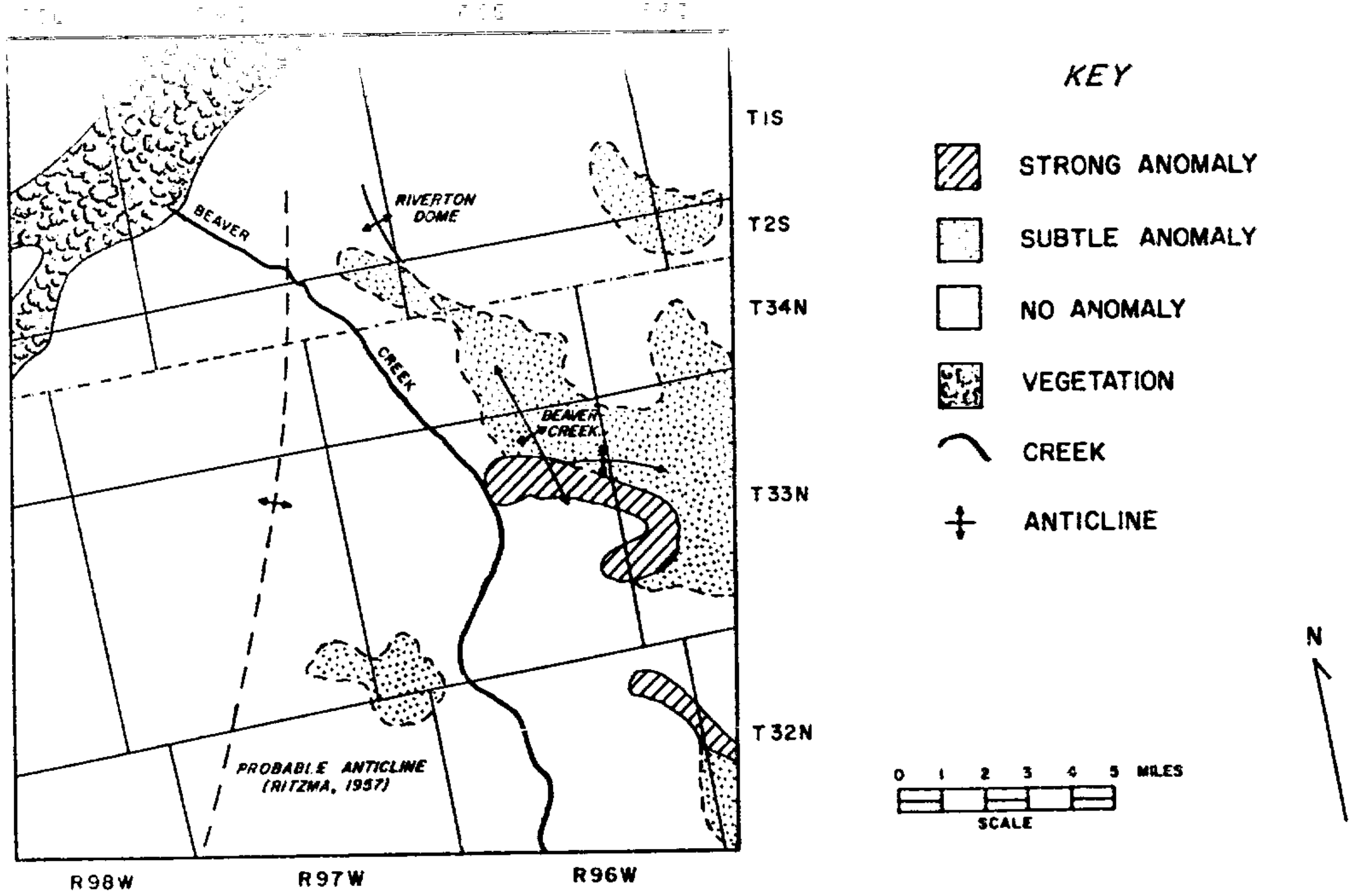

Figure 6b. Map interpreted from image ratio $\frac{(6-7)}{(6+7)}$ X 8. Only the oval-shaped Beaver Creek anomaly and a small linear anomaly to the southeast are apparent.

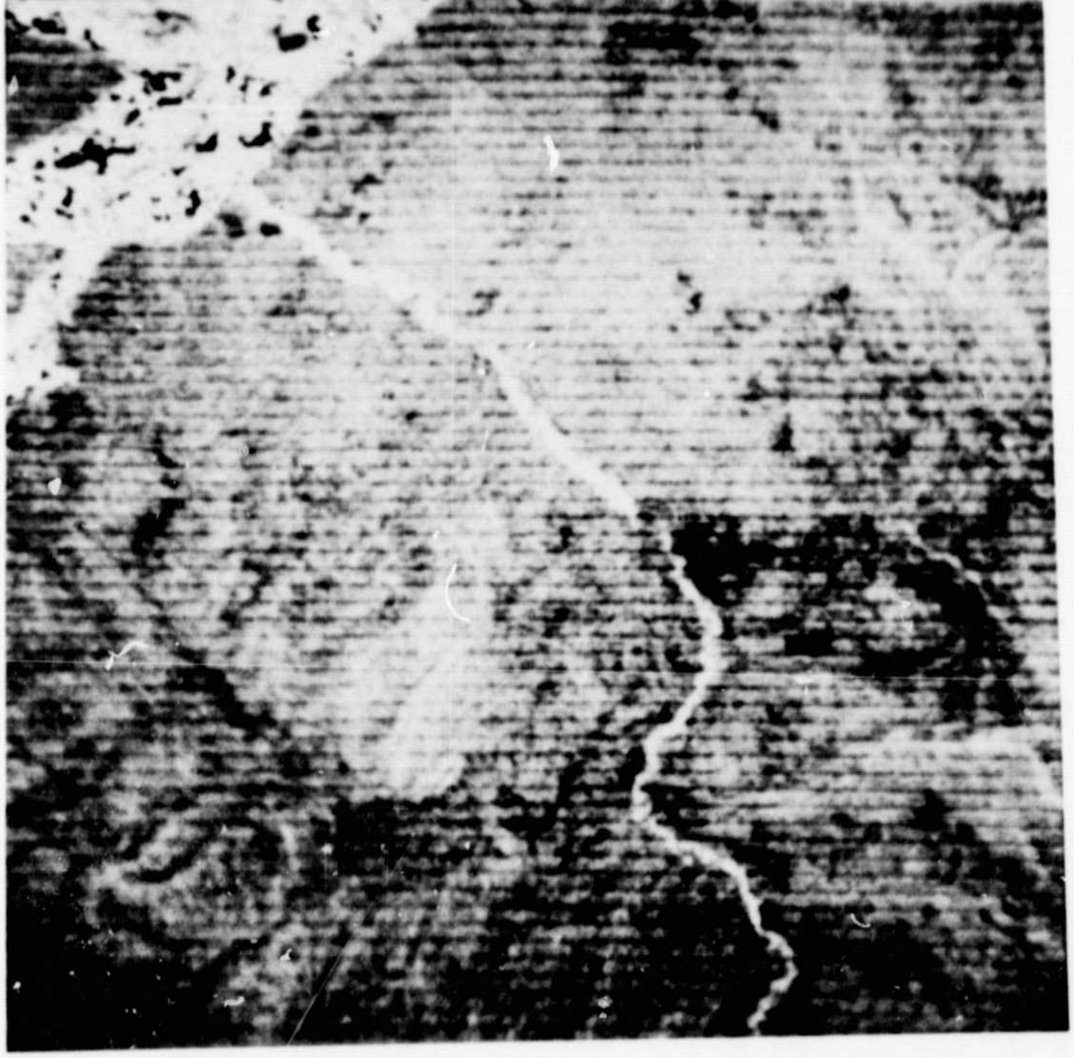

Figure 7a. Image ratio $\frac{(4-5)}{(4+5)}$ * 4 showing oval-shaped dark anomaly in the Beaver Creek area (right of center) and other more subtle anomalies indicated by ill-defined dark regions. The dark areas are interpreted as regions anomalously rich in iron oxides (reddish in color). Ratio $\frac{(4-5)}{(4+5)}$ * 4 is the ratio of the difference/sum of LANDSAT bands 4 and 5 (green and red) with the gain increased 4 times.

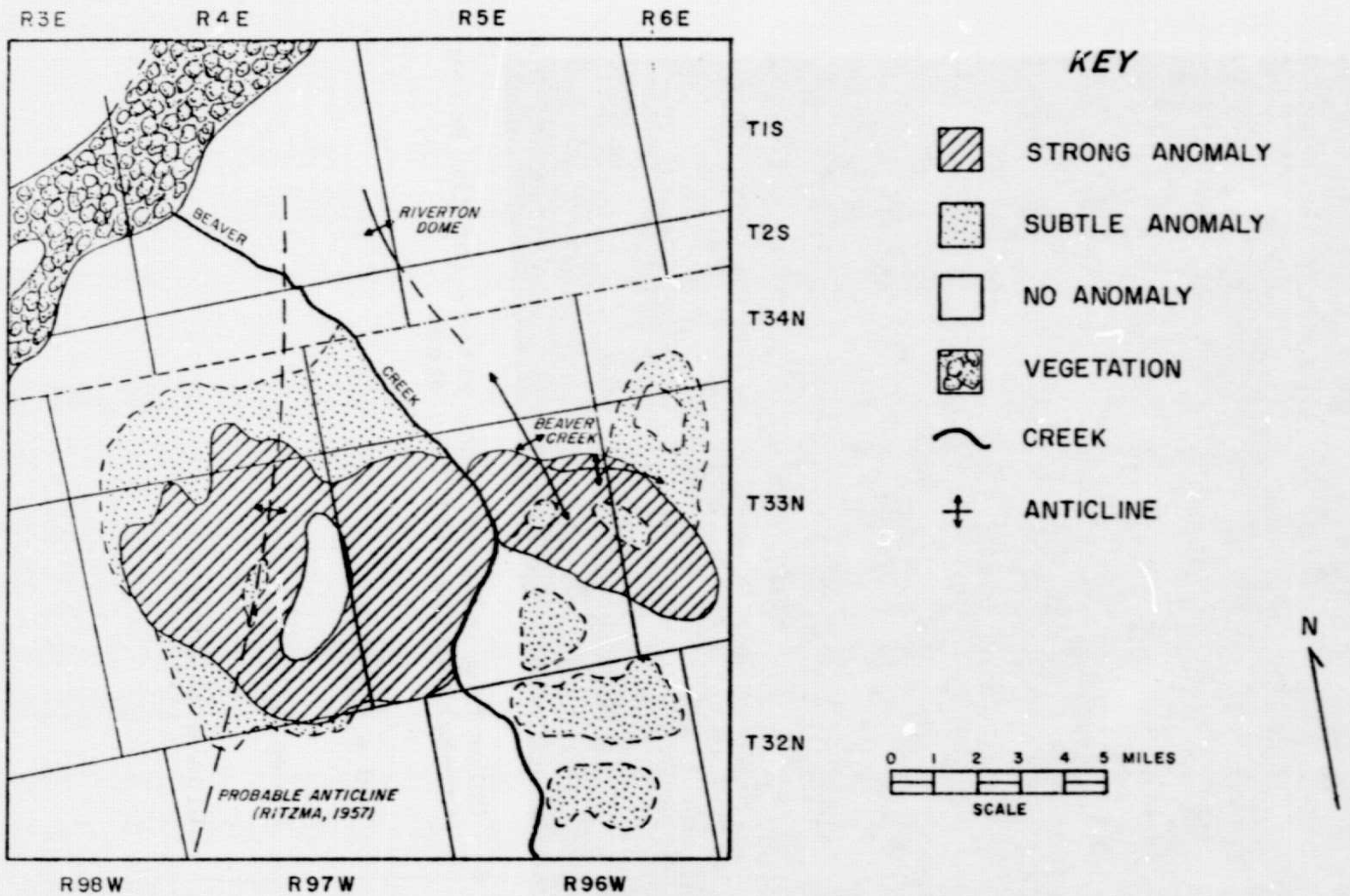

Figure 7b. Map interpreted from $\frac{(4-5)}{(4+5)}$ X 4 ratio (Figure 20a) showing anomalies to structural features.

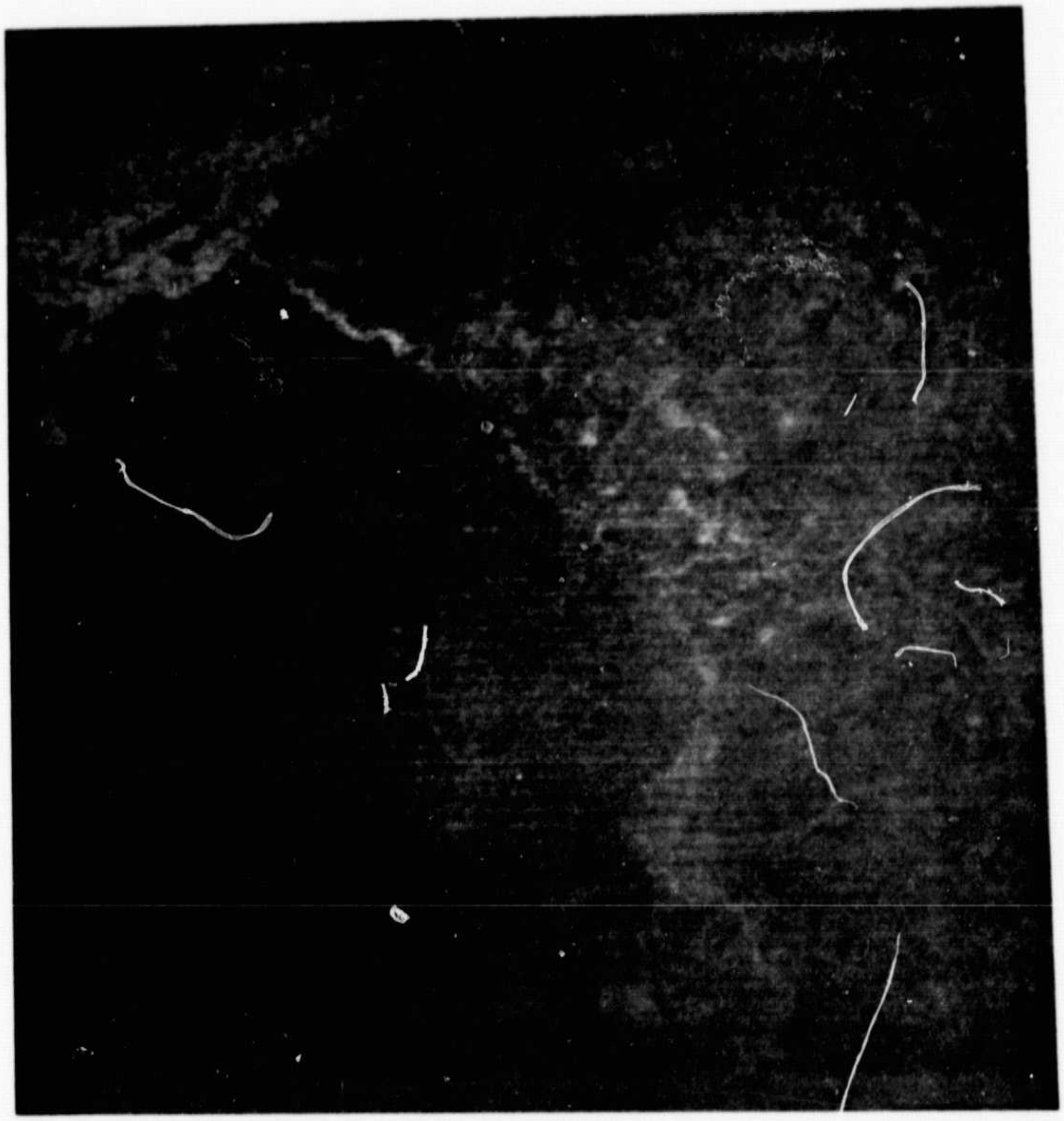

Figure 8. Color composite of image ratios for the Beaver Creek/Ninemile Hill test area.

$$\text{Red} = \frac{(4-5)}{(4+5)} \times 4$$

$$\text{Green} = \frac{(5-6)}{(5+6)}$$

$$\text{Blue} = \frac{(6-7)}{(6+7)} \times 4$$

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of the three ratios and on the color composite of ratios (Figure 8). Comparison of the three ratios with R. K. Vincents $R_{5,4}$ ratios (Figure 9) suggests that the $\frac{(4-5)}{(4+5)}$ X 4 combination is most similar to his 5,4 ratio except that the light and dark areas are reversed. Examination of our $\frac{(4-5)}{(4+5)}$ X 4 ratio image (Figure 5) shows the oval-shaped Beaver Creek anomaly and the dark-colored, southwest-trending, linear features corresponding to similar, light zones on Vincent's 5,4 ratio and hypothesized to be possible zones of hydrocarbon leakage (the iron oxide being formed by re-oxidation of pyrite which might be formed by hydrogen sulphide associated with hydrocarbon seeps; Vincent, 1975, p. 142). The dark spots rimmed by light rings (Vincent, 1975, p. 142) are not apparent on our $\frac{(4-5)}{(4+5)}$ X 4 ratio (Figure 5a), but might be correlated with the lightest area within the light-toned anomaly which is enhanced on the $\frac{(4-5)}{(4+5)}$ X 2 ratio image (Figure 6a). Vincent's "dark spots" could not be located precisely because of the poor resolution of the reproduction. However, if his "dark spots" correspond to the "light spots" on our ratio they may also be enhanced by thematic classification from a training set (Figure 10). The large, dark-toned anomalies may also be further enhanced by training on the dark areas in the ratio image and superimposing the extracted ratio theme on the original contrast-stretched image, (Figure 11).

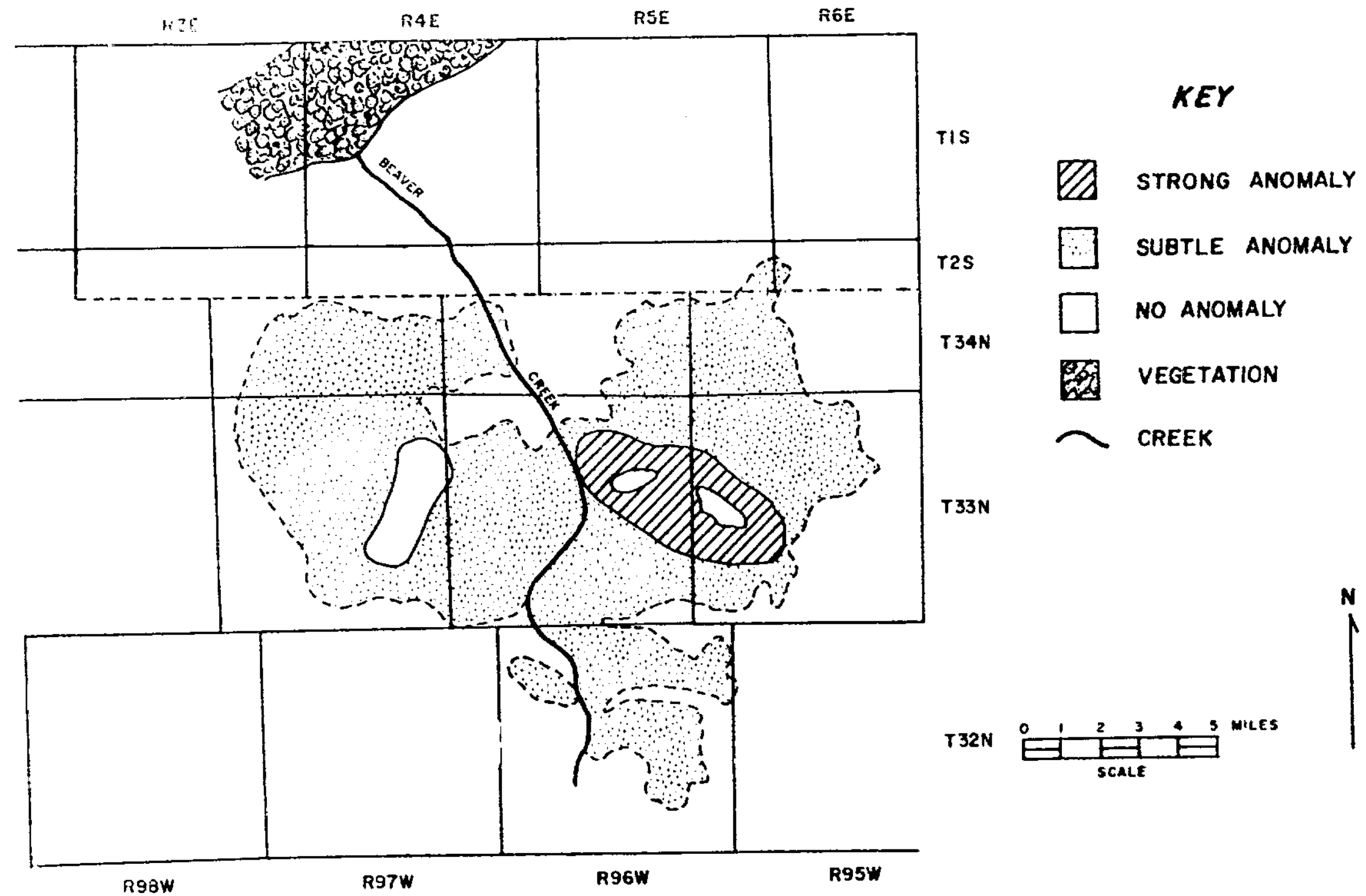

Figure 9. Light and dark anomalies detectable on Vincent's $R_{5,4}$ ratio (as reproduced in Oil and Gas Journal, 1975, p. 141, Figure 1b).

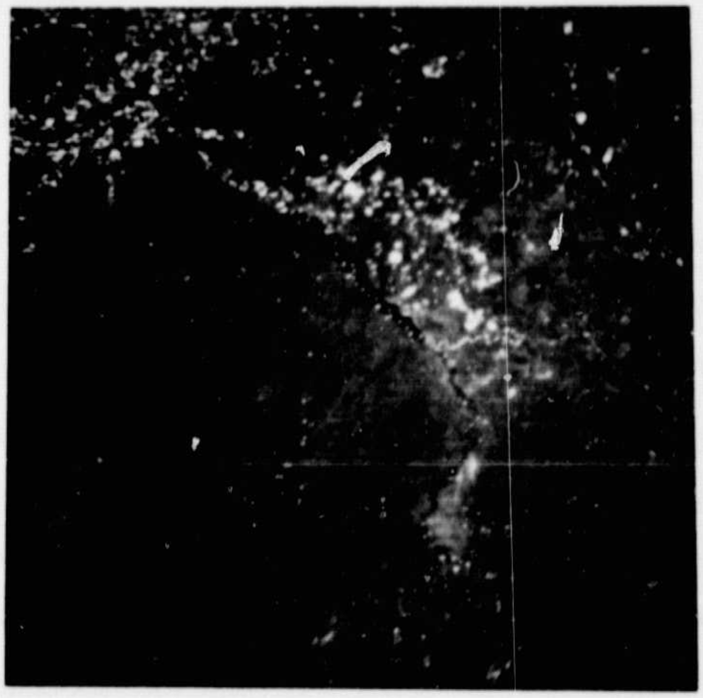

Figure 10. Lightest spots within a generally light-toned anomaly are enhanced by thematic classification according to a training set.

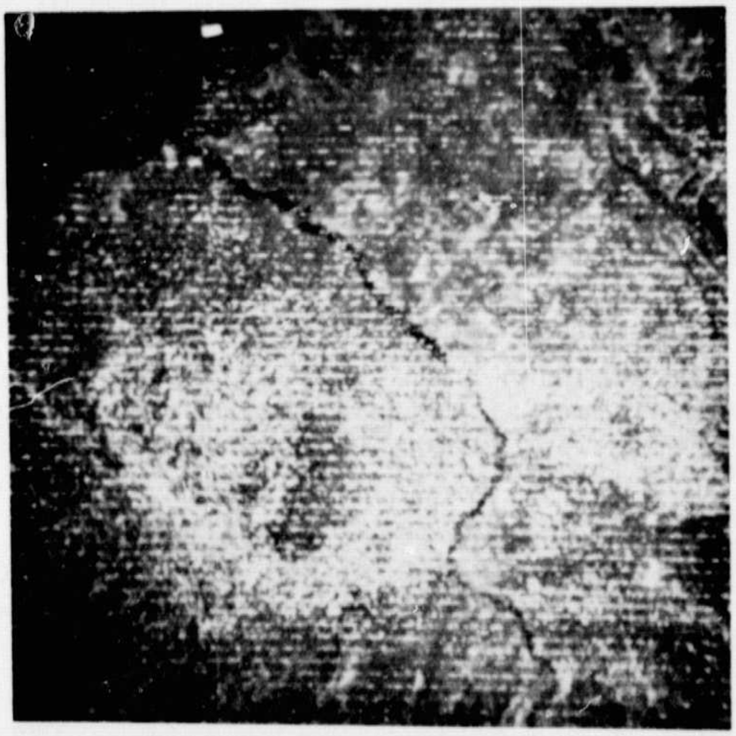

Figure 11. An enhanced presentation of the anomalous (iron oxide-rich?) areas prepared by thematic classification of the dark areas from the $\frac{(4-5)}{(4+5)}$ X 2 ratio superimposed on the original contrast-stretched color-composite image.

We were able to make still another enhancement comparison because a third ratio product was provided us by Dr. N. M. Short of the NASA/Goddard Space Flight Center (Figure 12). The image ratio provided by Dr. Short is also a band 5/4 ratio and shows much the same pattern as Vincent's 5/4 ratio and our $\frac{(4-5)}{(4+5)}$ X 4 ratio. This third ratio covers a somewhat larger portion of the image than ours and includes outcrops of Triassic redbeds (arkose) to the east and southwest of the test area. These appear much the same as the oval-shaped Beaver Creek anomaly which is in an area of Tertiary outcrop. Interestingly, Dr. Short's ratio shows several small anomalous areas lying both south and north of the Beaver Creek anomaly (Figure 12). The significance of each of these anomalies may best be assessed throught careful field work and by correlation with published data (geochemical and geological). Such assessments are in progress but will require some time for completion. Preliminary comparisons and analyses have brought forth several interesting facts:

1. All band 5/band 4 ratios enhance the strong, oval-shaped anomaly along Beaver Creek, but this anomaly lies south and east of the Beaver Creek Oil Field (compare Figure 13).

2. The large, light-colored anomaly detected on the $\frac{(5-4)}{(5+4)}$ X 2 ratio shows better correspondence with the Beaver Creek Oil field than any of the other anomalies.

3. Differences between ratios may be largely due to changes in vegetation. We used image 1373-17295. Vincent and Short both used image 1013-17294.

Figure 12a. Band 5/band 4 ratio image of the Beaver Creek/ Ninemile Hill area (density sliced?). (Courtesy of NASA/GSFC Information Extraction Division and Dr. N. M. Short)

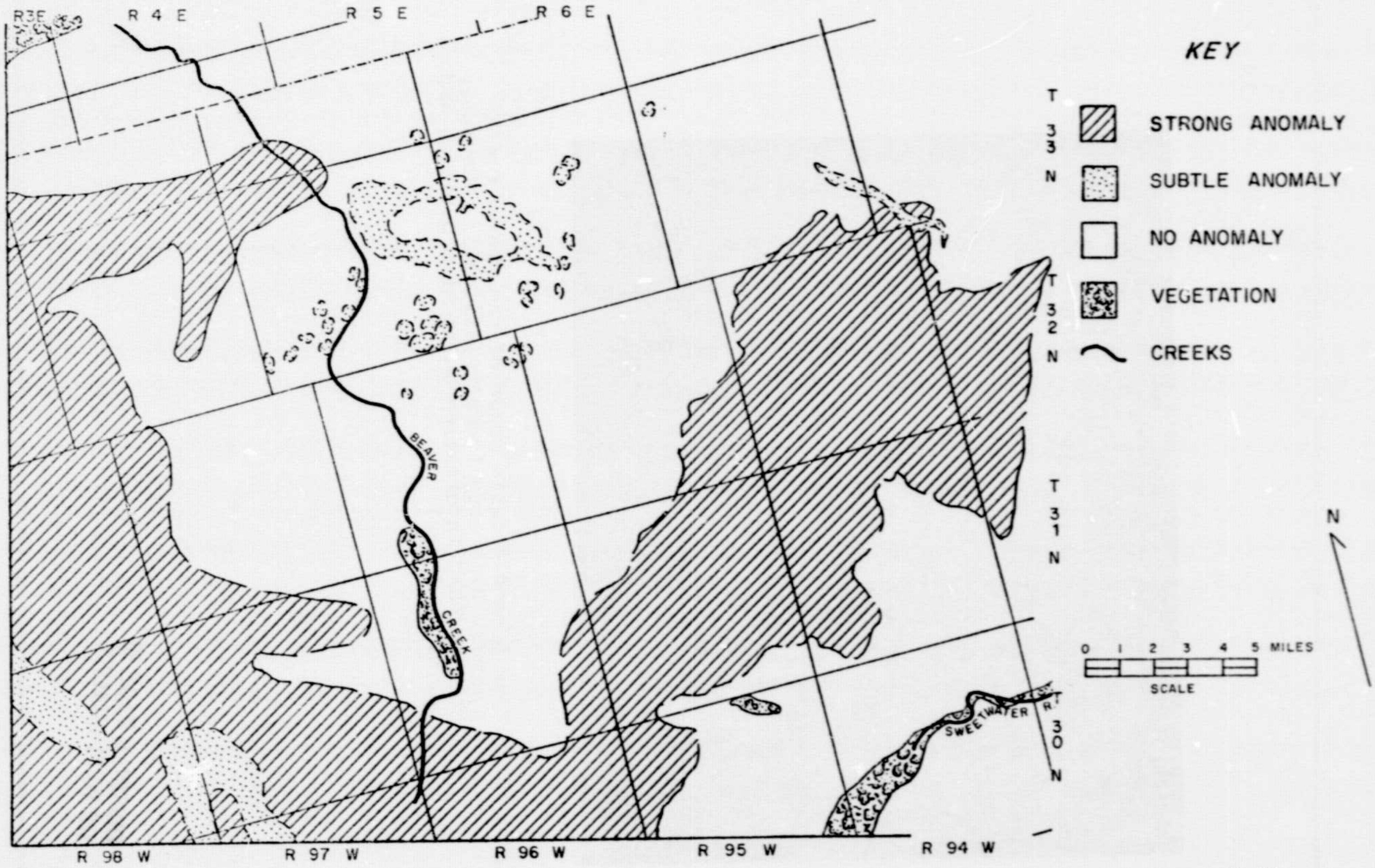

Figure 12b. Map of light and dark anomalies from Band 5/Band 4 ratio produced at NASA/ Goddard Space Flight Center. Numerous small, light areas can be seen surrounding the oval-shaped anomaly.

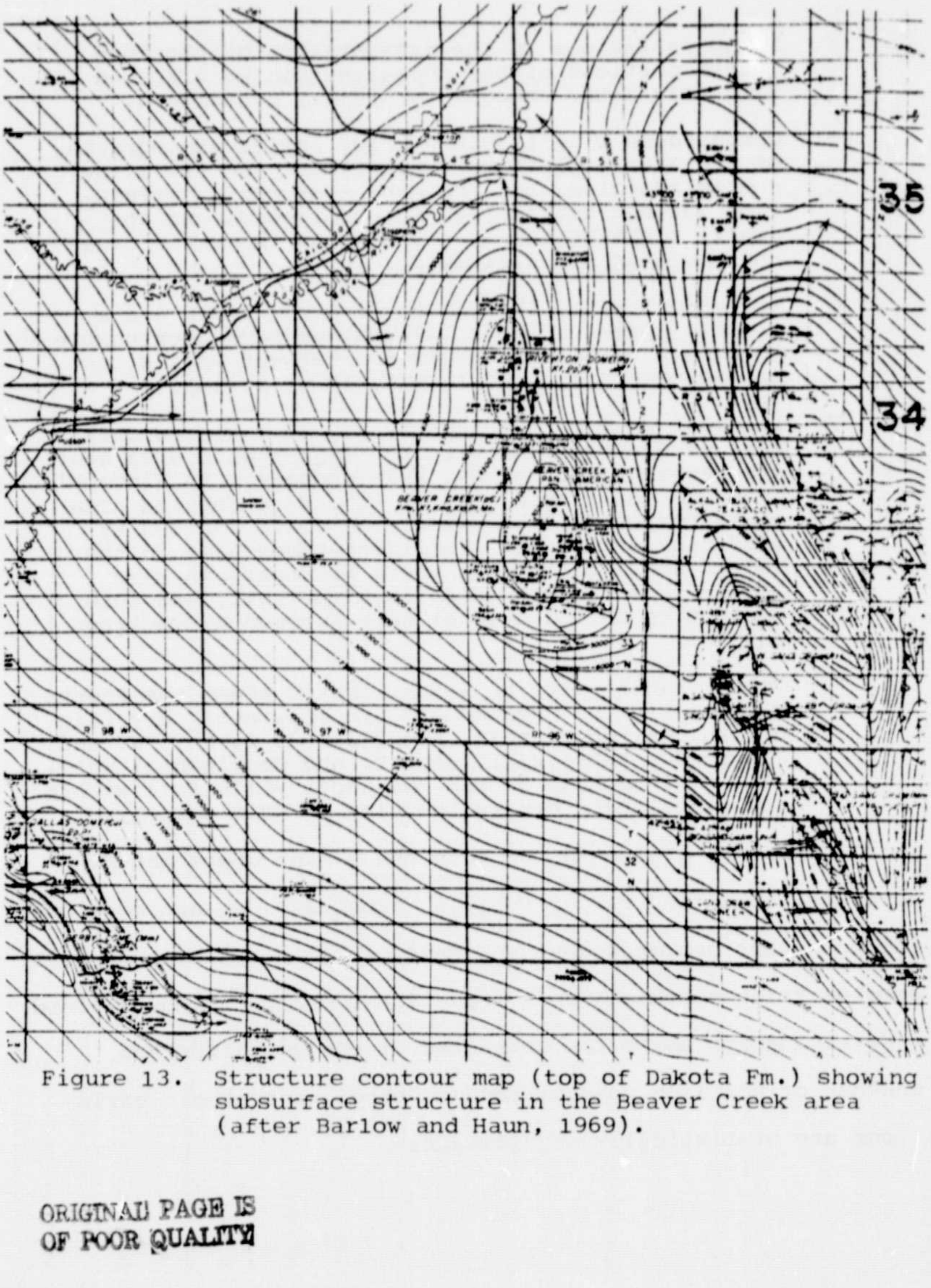

Figure 13. Structure contour map (top of Dakota Fm.) showing subsurface structure in the Beaver Creek area (after Barlow and Haun, 1969).

4. Large variations in the presentation of the more subtle portions of the anomalies can be affected with very minor changes in display parameters.

5. Comparisons with 1:30,000 color aerial photographs of the area suggest no explanations for the large, subtle anomalies but indicate a probable correlation between small playa lakes or ponds and the small, light anomalies detected on the ratio image and thematic classification.

6. Individual wells in the Beaver Creek Field are so closely spaced (Figure 14) that we have been unable to make a definite correlation between well sites and anomalous spots (Vincent, 1975, p. 142).

7. The most interesting anomaly is the large anomaly west of Beaver Creek with the light-toned area near its center. Apparently, this anomaly fits Vincent's proposed model very nicely. The dark colored area would represent iron-oxide rich soils derived by oxidation of pyrite. The light-toned area in the center would be an area where hydrocarbons have leached the reddish color from the soil, and this would then be the area of most intense hydrocarbon seepage.

8. Unfortunately several wells located along the southeastern side of the anomaly are apparently dry (Figure 15, Whitehall well, sec. 31, T 33 N, R 96 W, and Figure 30, Pubco well, sec. 2, and Continental well, sec. 8, T 32 N, R 97 W). No known wells fall within the light-toned central portion of this anomaly.

A complete evaluation of both the Beaver Creek and Ninemile Hill anomalies is currently in progress. We are continuing to gather geologic data and have gathered a number of soil samples for geochemical analyses. These analyses should yield a determination as to the character of the anomalies and whether or not iron compositions or other mineralogic variations are statistically significant.

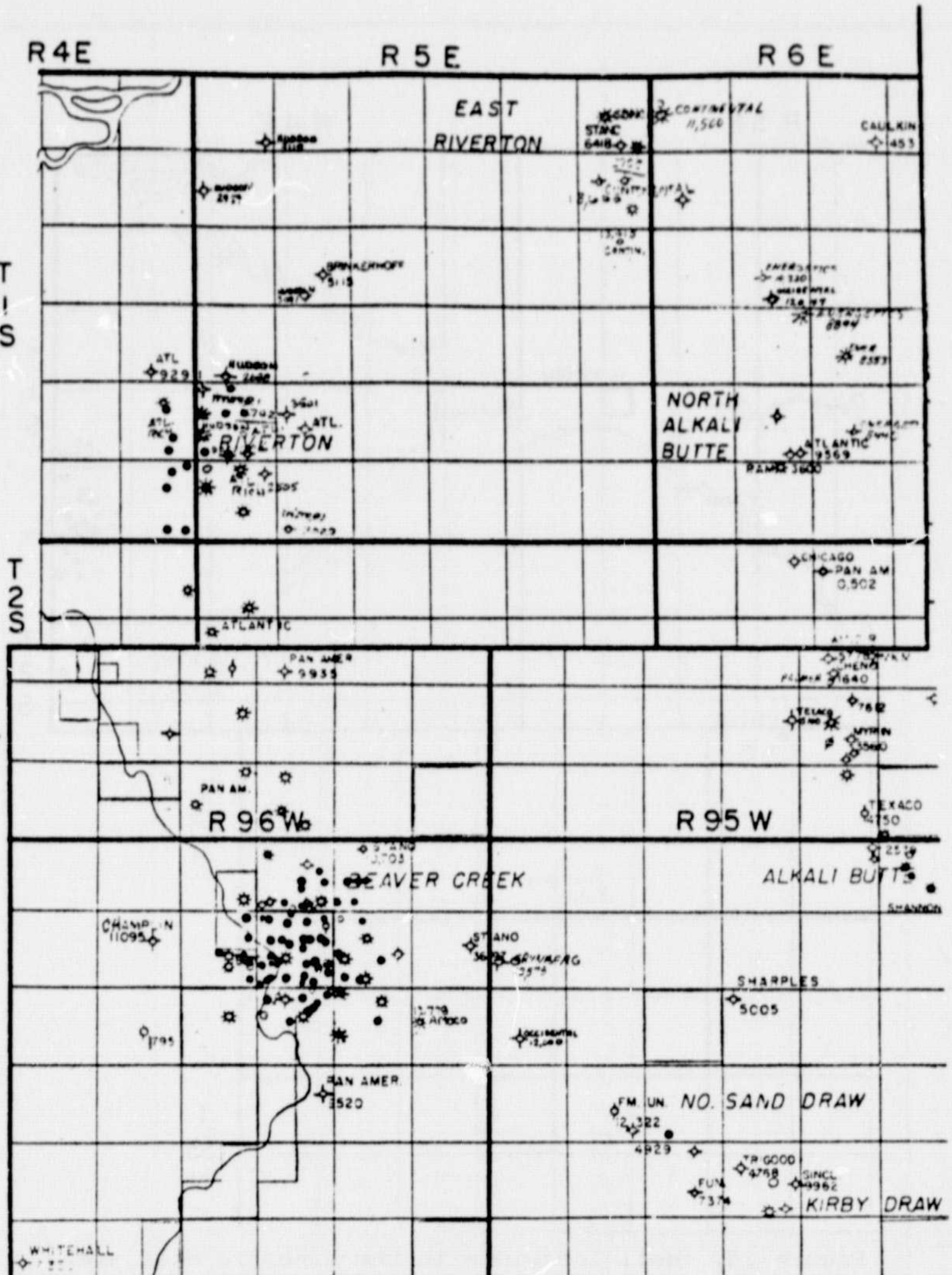

Figure 14. Well locations in the Beaver Creek area. The oval-shaped anomaly extends southeastward from the area of greatest concentration of wells.

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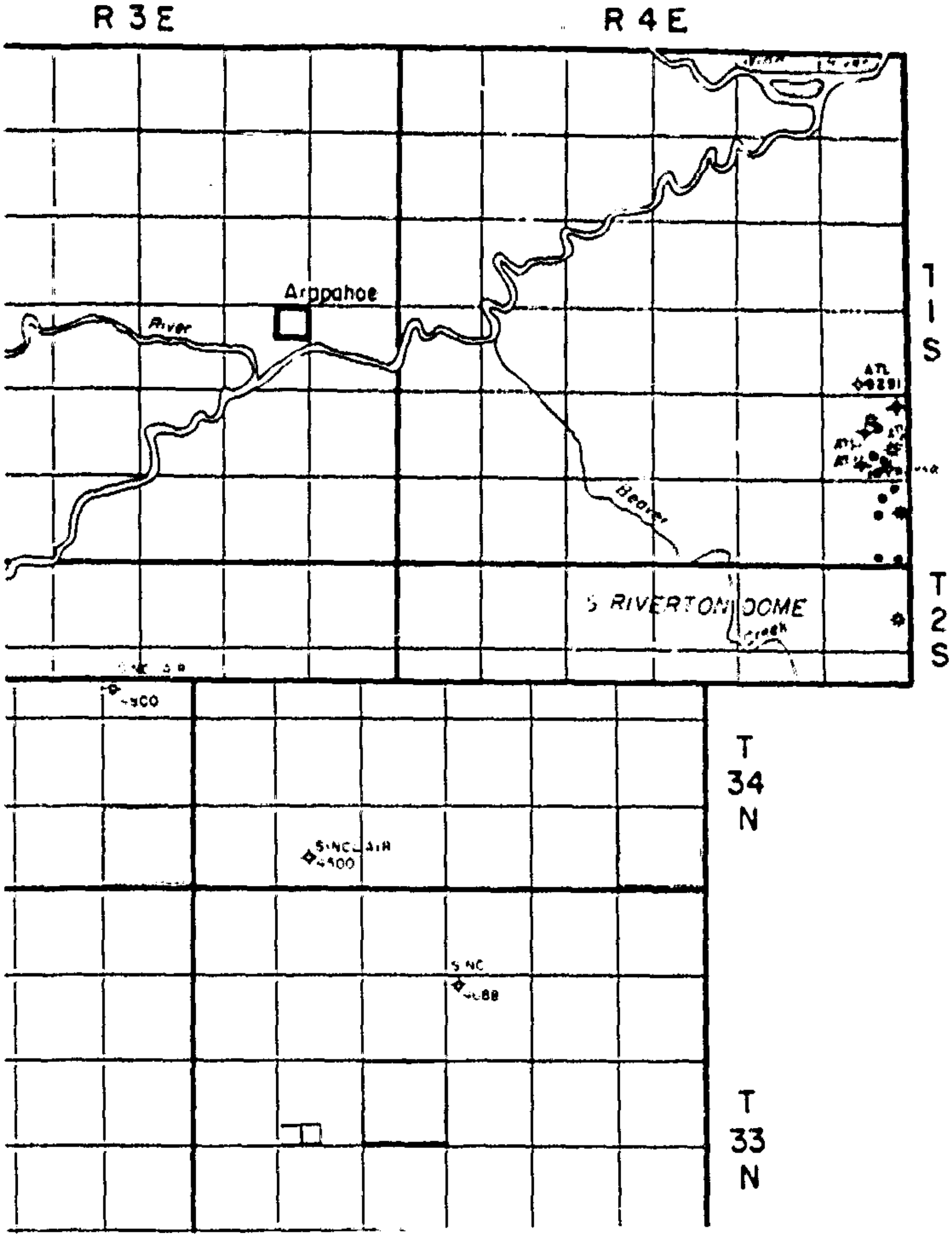

Figure 15. Well locations in the Ninemile Hill area. The large, dark anomaly lies mostly in townships 32 and 33 north and ranges 96 and 97 west.

Late note:

The Beaver Creek/Ninemile Hill area was visited in the field during the week of April 21-25, 1975. Ground observations were made regarding the nature and appearance of the rocks, soil, and vegetation in the area as well as the land use. Scintillometer readings were taken and the area was then observed and photographed from the air.

Results of all these observations indicate that the anomalies located through image-ratioing are lithologically significant but are not directly related to petroleum or uranium.

1. The light-toned anomaly extending from the Riverton Dome to Beaver Creek oil field (Figure 5, T 1 and 2S, R 5 E and T 33 and 34 N, R 96 W) is a result of the high reflectance from barren areas where light-colored sandstones, claystones, and bentonite beds are exposed on steep slopes and by reflectance from small, dry, playa lakes. Subtle variations within this area and around its periphery appear to be related to variations in the density of vegetation (particularly sagebrush).

2. The prominent oval-shaped anomaly trending southeast from the Beaver Creek oil field represents an area of dark-red soils derived from an unusually red sandstone of the Wind River Formation. The red sandstone is exposed in this area as a combined result of low-dip structure and the topography. This anomalously red region and its correlation with the oval-shaped anomaly is particularly apparent from the air. The darkest part of the anomaly (near the junction of Beaver Creek and Sand Draw) corresponds to the site of a major installation at the Beaver creek oil field. The development in this area has destroyed much of the natural vegetation allowing the underlying, red soil to be better exposed. Light spots within the dark, oval-shaped anomalies correspond to flat, open, grassy areas where there is little or no sagebrush.

3. The large, dark anomaly west of Beaver Creek (encompassing the Ninemile Hill anomaly) is also an area of red soils but the effect on the image ratio may be reduced by the more dense vegetation in this area. The light-colored area in the center of the large anomaly corresponds to a topographically positive area (Ninemile Hill) that has somewhat less vegetation, a buff-colored, sandy soil, and a less-dense drainage pattern. The light-colored soil is derived from a buff-colored sand unit overlying the red sandstone and its exposure in this area appears to be controlled by topography.

4. Scintillometer readings were taken at various locations throughout the study area. No radiometrically anomalous areas were found.

5. Except in the case of the large oil field installation at the junction of Beaver Creek and Sand Draw the oil installations do not contribute significantly to the reflectance values nor do they affect the vegetation patterns noticeably. Light spots on the image enhancements were not correlated with well sites.

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