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SHUTTLE IMAGING RADAR-A (SIR-A) DATA ANALYSIS

FINAL REPORT

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1. ABSTRACT

We summarize work we have done on evaluating the utility of Shuttle Imaging Radar (SIR-A) data in several geological and environmental contexts. The study areas consisted of: (a) the Ozark Plateau of southern Missouri, where we found SIR-A data to be of little use in mapping structural features, because of generally uniform returns, (b) western Illinois, where we found little to be gained in terms of identifying land use categories by examining differences between overlapping SIR-A passes, and (c) southern Australia (Koonamore Station), where we found that SIR-A provided information on vegetation types that was not obtainable from Landsat MSS data alone. Specifically, high SIR-A returns in the Australian site were found to correlate with locations where shrubs increase surface roughness appreciably. The Australian study site results demonstrate the synergy of acquiring spectral reflectance and radar data over the same location and time. Data of these kind are especially important in that region, since grazing animals have substantially altered and are continuing to alter the distribution of shrublands, grasslands, and soil exposures. Thus, periodic, synoptic acquisition of MSS and SAR data would be of use in monitoring the dynamics of land-cover change in this environment.

2. INTRODUCTION

In this report we describe research done with SIR-A data covering: (a) the Ozark Plateau of southern Missouri, (b) an area of agriculture and scattered farmlands in western Illinois, and (c) the area surrounding the Koonamore Station in southern Australia. The Missouri site was chosen to test the utility of SIR-A to map structural features on a dissected plateau. The Illinois site was chosen because orbits 18 and 20 cross and we were interested in the increase in information content to be gained by varying the azimuth of radar data acquisition. Finally, the semiarid Koonamore area is of interest because soils, grasses, and shrubs are exposed on generally flat areas. We compared the information content contained in SIR-A as opposed to Landsat MSS data for the Koonamore area and found that each data set gives independent information. When combined, the data sets allow detailed mapping of land cover types in a region where grazing of shrubs and consequent destruction of the perennial vegetation has been a serious problem.

3. SIR-A DATA OVER SOUTHERN MISSOURI

As part of an ongoing project, we have been examining a variety of geophysical data covering southern Missouri in an attempt to understand the patterns and origins of crustal structures. The intent has been to first delineate the deep crustal structure using Bouguer and aeromagnetic anomalies, and to then see how these structures influence the patterns of fractures and drape folds found in the Paleozoic sedimentary rocks that cover the region. Extensive Mississippi Valley- type Pb-Zn-Cu sulfide ores occur in these rocks, with many researchers invoking a structural control over ore emplacement. Thus, an increased understanding of structural features and their origins is useful both from tectonic and resource points of view. The perspective we have chosen to delineate crustal structure is to process the potential field data in image format, using spatial filtering to interpolate between data locations (Arvidson et al. 1982; Guinness et al. 1983). For instance, Figure 1 is from Leff (1983) and shows a shaded relief Bouguer anomaly map of Missouri, together with locations of overlapping SIR-A, Seasat, and Landsat MSS data. The prominent structure running NW-SE is 120 km wide and has an amplitude of -30 milligals. It is best modelled as an excess crustal thickness of about 4 km at the Moho (Eddy, 1984). The presence of this structure, which we call the Missouri gravity low (MGL), is probably the reason that much of fracturing in the sedimentary cover trends NW-SE. For this work, the overlapping SIR-A, Seasat, and Landsat data (Figure 1) covering a portion of the

NE flank of this feature were examined to test which remote sensing data sets provide an increase in knowledge about fracture patterns in the area, particularly those that may have been controlled by the MGL. We also included NOAA 1 km elevation averages in the comparison.

The basic data sets used in the analyses are shown in Figures 2,3,4, and 5. Examination of the data show a number of NW-SE trending stream valleys in the region covering the MGL, suggesting structural control over the drainage system. No other lineaments could be found in the data other than those due to topographic control. Thus, the test of whether SIR-A is useful is the extent to which topography can be extracted. The Landsat data (Figure 3) essentially reinforce the information in the elevation data (Figure 2), with the addition of cultural information. Seasat data (Figure 4) are interesting because the 20 to 26 degree incidence angle leads to layover in the dissected stream valleys. In fact, the Seasat data can be used to map the boundary between the dissected areas and the interfluvial plains that are probably remnants of an extensive peneplain surface that covered the area in the early Tertiary Period (Figure 4). On the other hand, the layover precludes extraction of linear elements within the valley systems. SIR-A data (Figure 5), with an incidence angle of 48 to 53 degrees, provide little variation in return over the Ozarks. Topographic elements are subdued and most of the variance in return is due to land type. The low returns are from the flat valleys, which are dominated by farmlands. The higher returns are from the oak-hickory forests. The incidence angle for SIR-A is not sufficiently low to provide radar shadowing in this area. In sum, we could not find any structural information in the SIR-A data that could not be discerned in the elevation data.

In an attempt to extract further structural information from the elevation and remote sensing data we did a number of high pass directional filtering operations to emphasize linears in various azimuthal directions. Elevation data, which are not biased by illumination direction, proved to be most useful (Figure 6) and suggest that the post-Tertiary uplift that led to dissection of the Ozark Peneplain was confined to a polygonal crustal block bound by the Ouachitas, the Mississippi embayment, the Illinois basin, and a newly discovered contact between older gneiss and younger granites (Leff, 1983). Although SIR-A proved to be of little use in this region, our experiments were successful in terms of an increased understanding of broad cratonic deformation patterns in the midcontinent.

4. CROSSING SIR-A IMAGES OVER ILLINOIS

SIR-A data for an area where swaths 18 and 20 cross (Lat. 38 N, Long. 88 W) were analyzed to determine the increase in information content obtained from two overlapping passes of differing flight directions (Figure 7). The diamond-shaped area of the crossover is about 100 km long. This area is quite flat, interrupted only by a few meandering rivers, and the land use is dominated by agriculture. Visual examination of the images demonstrate that rivers and other bodies of water give the lowest returns while forested areas give the highest returns. Agricultural fields show a range of returns, possibly as a functions of the type of crop being grown, the stage of growth (e.g., freshly planted), or varying soil moisture.

Analysis was done by digitally registering the crossover section of the two swaths by means of ground control points, and then generating an image of the differences between the swaths. Only a few significant features could be discerned in the picture difference image. The differences occur largely within agricultural fields and may be controlled by the strike of crop rows. No differences related to structures or rock types were found.

5. SIR-A AND LANDSAT MSS DATA OVER THE KOONAMORE STATION REGION, SOUTHERN AUSTRALIA

Shrublands occupy about 40% of the land area of Australia, with the principal shrub communities being: (a) Acacia shrublands, (b) shrub-steppes, areas dominated by Kochia Sedifolia and Chenopodiaceous shrubs such as Atriplex Vesicaria, and (c) Eucalypt shrublands or Mallee (Moore,1973). The physiognomy of the three shrublands types in the area is shown in Figure 8. Some 50 million sheep are supported on these shrublands. Some of these shrubs have not been regenerating because the sheep and rabbits consume their seedlings. Also, during periods of drought, the sheep eat the low shrubs. Thus, the land cover has been changing from shrubland to grass cover after rains or, during periods of drought, bare ground (Osborn,1935). The lack of shrub regeneration has been a problem of increasing concern since the mid-1850's. Thus, the ability to distinguish shrubs, grasses, and bare soil, as well as the ability to monitor the vegetation's condition would be a major contribution to land use control and inventory in Australia.

We tested the ability of SIR-A, combined with Landsat MSS, to map land cover types in and around the Koonamore station (Figure 9) (Lat: 32 deg., 15 sec. S; Long: 139 deg., 27 sec. E) (Green, in preparation). The station is a sheep grazing ranch that contains representative shrublands, grasses, and bare ground exposures found in southern Australia (Carrodus, 1965). Also, the 400 hectare T.G.B. Osborn Vegetation Reserve was established in 1925 in the Koonamore area. Sheep grazing stopped within the Reserve at that time and rabbits were finally eliminated in 1970. Thus, two land-use types can be found in the study area: the Station, where grazing continues, and the Reserve, where grazing has been stopped and both shrubs and grasses are beginning to reappear.

Ground determined reflectances of cover types common at Koonamore have been acquired by Graetz (1982) (Figure 10). Landsat MSS can distinguish bare soil from vigorous and non-vigorous vegetation. However, due to the similarity of the spectral signatures of grasses and shrubs in the vigorous and non-vigorous states, they should be difficult to distinguish, according to Graetz's data. On the flat terrain of Koonamore, SIR-A should detect mainly surface roughness. Therefore, SIR-A might be used to determine the physiognomic character of the shrubland, distinguishing bare or grass covered ground from shrub or tree covered areas. It can be hypothesized that radar could not be used to seperate a vigorous shrub from a non-vigorous one, or bare ground from that covered by vigorous grass, since the radar return in both cases may be similar.

SIR-A and Landsat MSS data, acquired on Nov. 13th and Oct. 16th, 1981, respectively, were co-registered and are shown in Figure 11. The brightness patterns in the SIR-A and Landsat MSS data are inversely correlated to a first approximation, revealing that: 1) shrub growth is generally rough and thus bright on the SIR-A image, but dark on MSS (due to non-vigorous condition), and that 2) bare ground is generally smooth and thus dark on the SIR-A image, but bright at MSS wavelengths. This correlation is demonstrated by a difference image between the Landsat and a complemented version of SIR-A, showing a generally flat field (Figure 12). On the other hand, there are a number of key areas that diverge from this correlation and are diagrammed in Figure 13. Dark regions in Figure 13 are areas of low radar return (smooth) and low MSS reflectance. These areas are interpreted to be covered by extensive, yet non-vigorous, low grass-like vegetation, or by lichen (Figure 13). One of these dark areas lies within the Osborn Vegetation Reserve, which is protected from grazing. Light regions in Figure 12 can be explained by an anomalously high radar return and/or an anomalously high MSS reflectance. Some paddock fences parallel to SIR-A orbit trace trace are revealed as light areas because of their high radar return. Other light areas in Figure 12 are interpreted (Figure 13) as being produced by vegetation that is significantly rougher than the surroundings while exhibiting slightly higher reflectances. These areas correspond well with areas of Eucalyptus cover (Figure 9). Eucalyptus is known to be larger than the surrounding vegetation and to have a physiologic character that maintains vigorous growth during rainless periods. Still other light regions in Figure 12 exhibit a high reflectance, yet their radar return is similar to the surroundings. Based on field data (Figure 9) these areas can be interpreted as eroded, bare soils. These areas are concentrated near the head station and near fence boundaries where sheep tend to concentrate or be concentrated.

Thus, when MSS and SIR-A data are combined in this area, grasslands, soil exposures, and shrub types can be delineated, and their condition determined. Results strongly support the simultaneous acquisition of radar and reflectance data over the same area in order to monitor the dynamics of land cover changes.

6. SUMMARY AND IMPLICATIONS

We have done work on evaluating the utility of Shuttle Imaging Radar (SIR-A) data in several geological and environmental contexts. The study areas consisted of:

(a) the Ozark Plateau of southern Missouri, where we found SIR-A data to be of little use in mapping structural features, because of generally uniform returns;

(b) western Illinois, where we found little to be gained in terms of identifying land use categories by examining differences between overlapping SIR-A passes;

(c) southern Australia (Koonamore Station), where we found that SIR-A provided information on vegetation types that was not obtainable from Landsat MSS data alone. Specifically, SIR-A returns enabled the discrimination of the physiognomic character of vegetation and the growth conditions in the and the growth conditions in the Australian study-site. These results demonstrate the synergy of acquiring spectral reflectance and radar data over the same location and time. Data of these kind are especially important in that region, since grazing animals have substantially altered and are continuing to alter the distribution of shrublands, grasslands, and soil exposures. Thus, periodic, synoptic acquisition of MSS and SAR data would be of use in monitoring the dynamics of land cover change in this region.

7. REFERENCES CITED

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8. FIGURE CAPTIONS

FIGURE 1 - The locations of the coverage of the remote sensing data used in this study are represented by the boxes in this image. The boxes have been overlaid on a shaded relief image of Bouguer anomaly values to show basement features underlying the remote sensing data.

FIGURE 2 - This physiographic map of Missouri is based on a shaded relief image of topographic data. The topographic data are from NOAA and represent 30 second point elevations, or the average elevation within a box 30 seconds on a side. This yields a resolution of approximately one kilometer, the same scale as the gravity anomaly data.

FIGURE 3 - A 3X3 low-pass filtered Landsat image covering an area in southeast Missouri. The St. Francois Mountains, a complex of 1.4 Ga granites and rhyolites, appear in the center of the frame. Bright areas are stream valleys and flat areas that are usually cultivated.

FIGURE 4 - A portion of the Seasat frame studied, reproduced here shrunk by a factor of four. The highly textured area corresponds to dissected slopes and stream valleys. The smooth areas adjacent to the dissected slopes (denoted by the arrows) correspond to the return from a remnant Tertiary peneplain of the Ozark Plateau. The layed-over feature in the upper left is Mudlick Mountain; this feature also appears in the lower right of the Landsat frame in Figure 3. The white box encloses an area 15 km by 33 km. Mudlick Mountain can also be seen in the lower right-hand corner of the

Landsat image shown in Figure 3. In fact, the Seasat frame covers roughly the bottom half of the Landsat image.

FIGURE 5 - The SIR-A image studied is shown here, shrunk by a factor of four. The St. Francois Mountains are visible as gentle swells in the lower right of the image. Dark areas are stream valleys and flat, farmed areas. The arrow points to the bright return of a lead refinery in the Viburnum Trend Lead District. This frame overlaps with the northern half of the Landsat image shown in Figure 3.

FIGURE 6 - Directionally filtered topographic images are shown here in comparison with a shaded relief image of Bouguer anomalies. The filtered topographic images reveal a strong southeast component for linear features in this region. The Bouguer anomaly image shows a similar southeast trend for basement features as well.

FIGURE 7 - SIR-A passes in Illinois. Swath 20 (above) and Swath 18 (below) are shown. Look direction is toward the top. Each swath is 50 kilometers wide. Arrows denote the same features in the different frames.

FIGURE 8 - Relative physiognomy of dominant vegetation found at Koonamore Station, South Australia. Genus names are given. The foliage of both the Eucalyptus and the Acacia stand too high to be directly grazed by either sheep or rabbits.

FIGURE 9 - Map of major vegetation communities in the Koonamore area, typical of much of semi-arid Australia. Dashed lines are

fences sperating various paddocks. North is toward the top of the map. The Osborn Vegetation Reserve was fenced from sheep in 1925. Based on a map from Carrodus (1965).

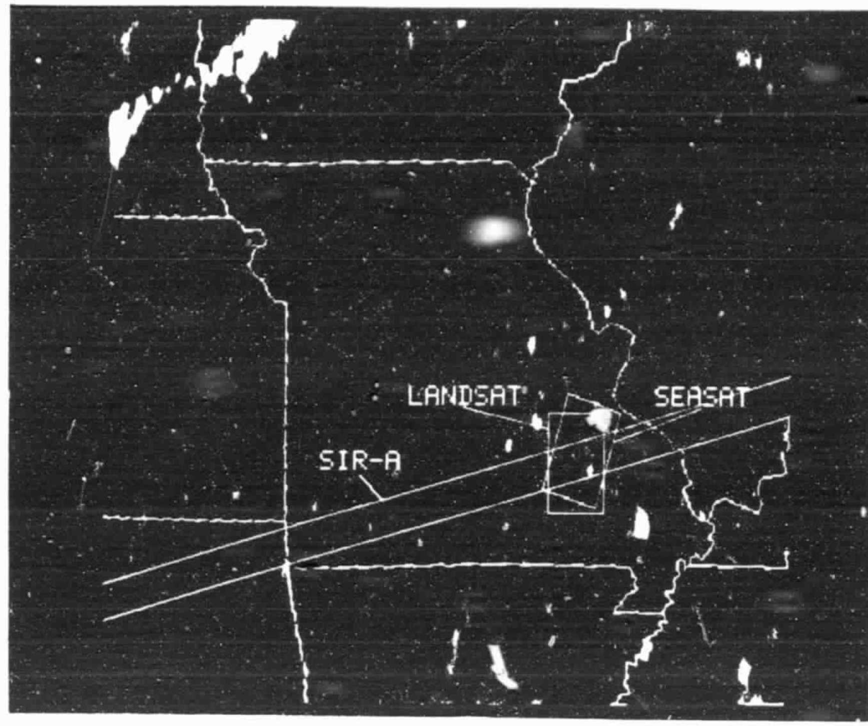
FIGURE 10 - Reflectances of various cover types common at Koonamore. These spectra are averaged from many reading taken in the field with a handheld radiometer recording in the four Landsat MSS bands. Bare eroded ground exhibits the highest reflectance in all bands. Grass and shrubs show similar reflectances in both the vigorous and non-vigorous states. Based on data from Graetz (1982).

FIGURE 11 - Landsat MSS (above) and SIR-A (below) images of Koonamore area, coregistered, showing the same area as vegetation map (Figure 9). Landsat MSS produced as standand false color composite, with bands 4,5 and 7 printed as blue, green and red, respectively. Bright and dark tones on the radar image show areas of high and low radar return, respectively. Since the terrain is generally flat, variations in radar return are thought to reflect surface roughness changes. Notice high radar return from the east-west fences and from the builings of the head station.

FIGURE 12 - Difference image between an averaged Landsat MSS image (bands 4,5,6 and 7 averaged)and a complemented SIR-A image. Dominant flat field reveals that the MSS and the SIR-A images are inversly correlated to a first approximation. Vegetation is generally rough and shows low reflectance, while bare ground is generally smooth and shows high reflectance. Areas that deviace from this general relationship appear as bright or dark tones and

are diagrammed and interpreted in Figure 13.

FIGURE 13 - Interpretation map of Figure 12. Dark areas in Figure 12 are areas of low radar return (smooth) and low reflectance and are interpreted as grass-like vegetation or lichen. This interpretation is supported by these areas being within the Osborn Vegetation Reserve or to the south of the east-west trending fence, which probably restricts grazing of this grass-like vegetation by sheep. Light areas are areas of anomalously high radar return and/or anomalously high MSS reflectance. One of these areas of low radar return (smooth) and very high MSS reflectance is near the head station and together with other areas is interpreted to be eroded bare soil. Other light areas in Figure 12 exhibit high radar return (rough) and high reflectance and are interpreted to be Eucalyptus, see Figure 9.



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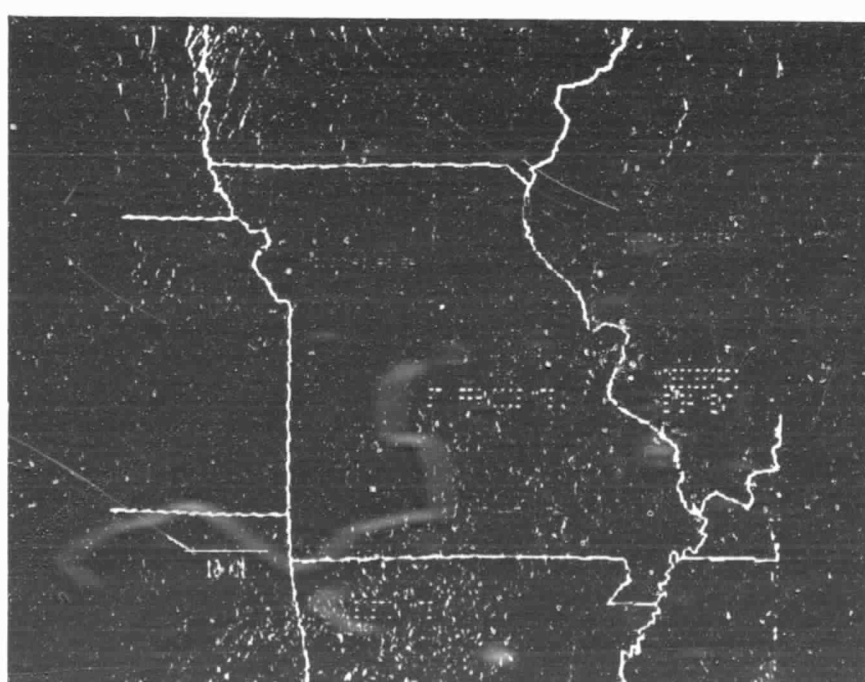
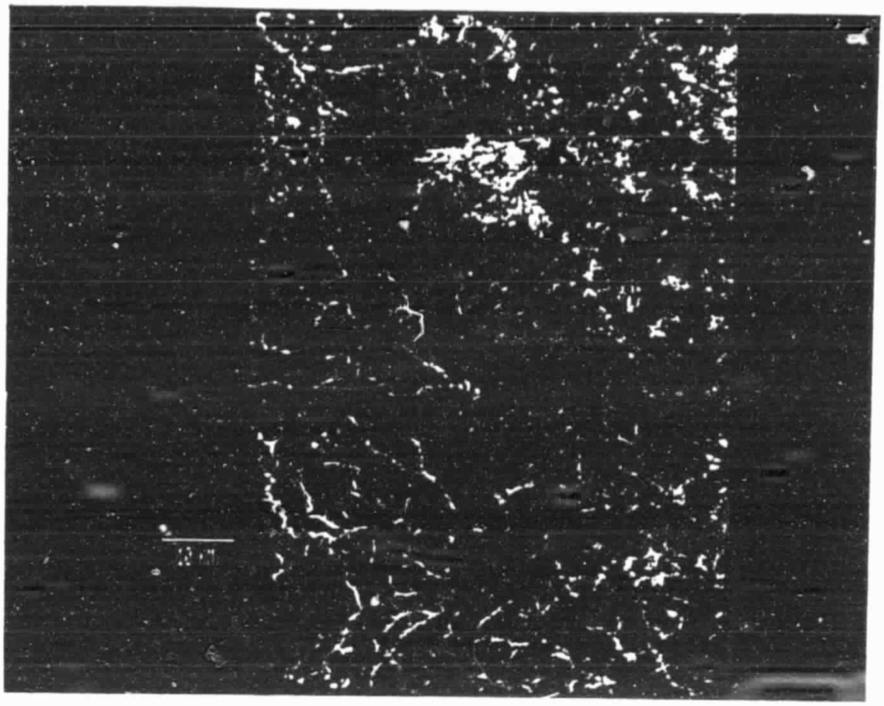


Figure 2



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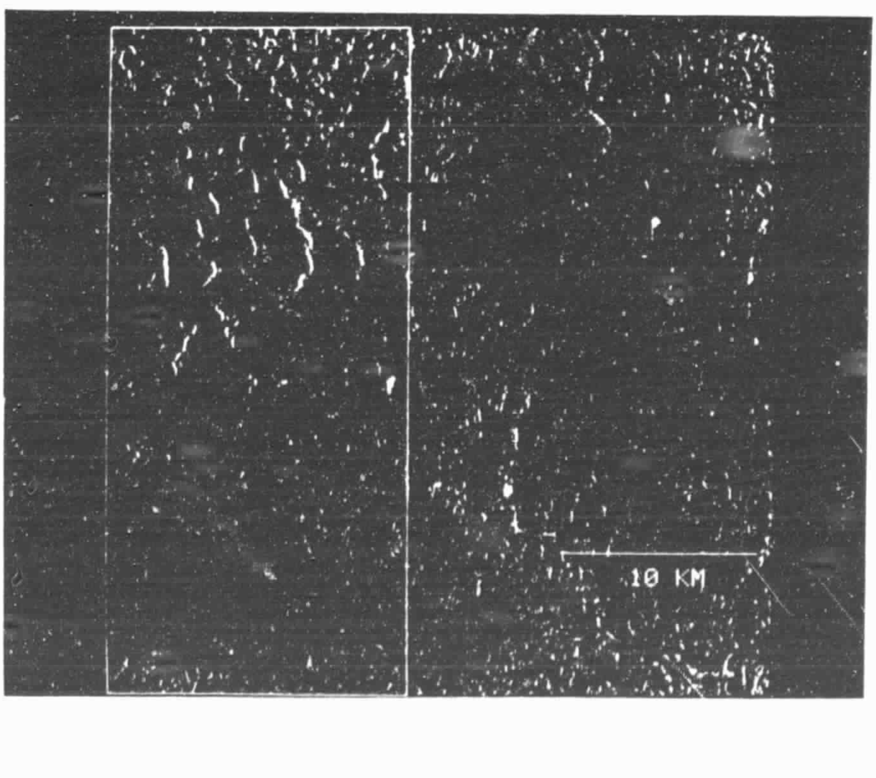

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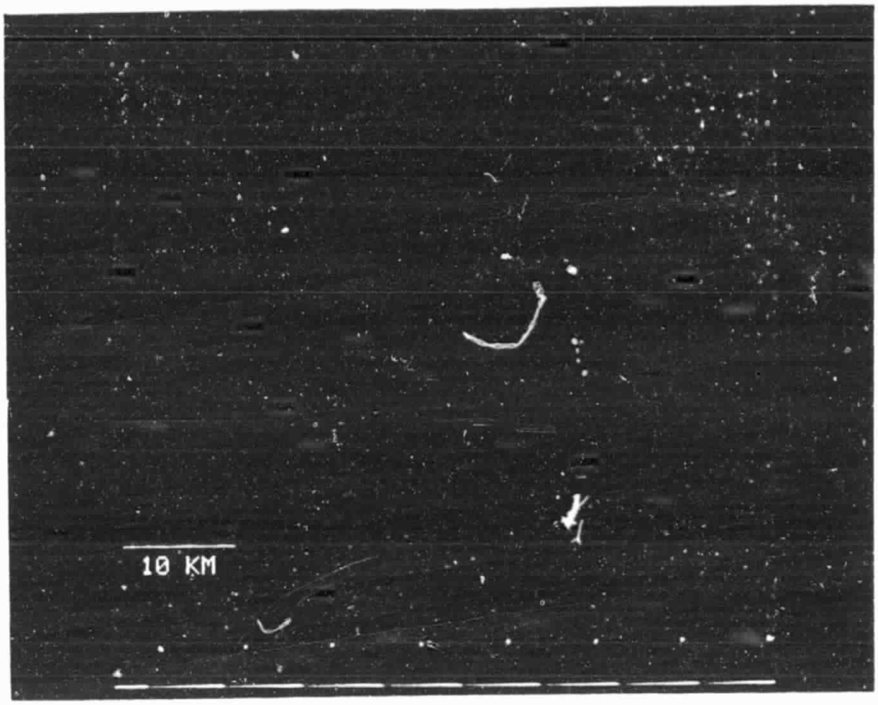

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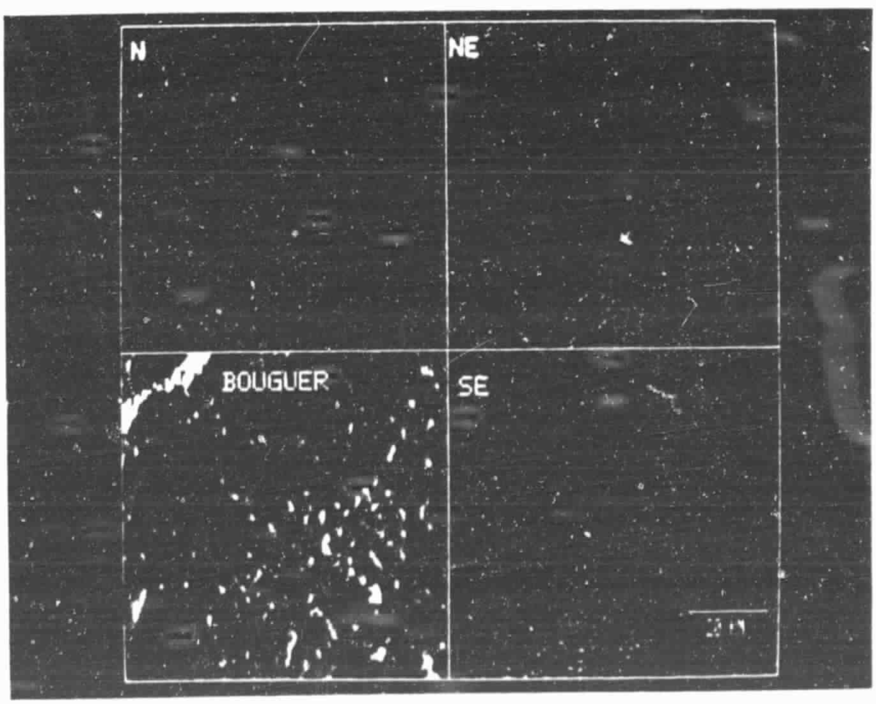

Figure 6

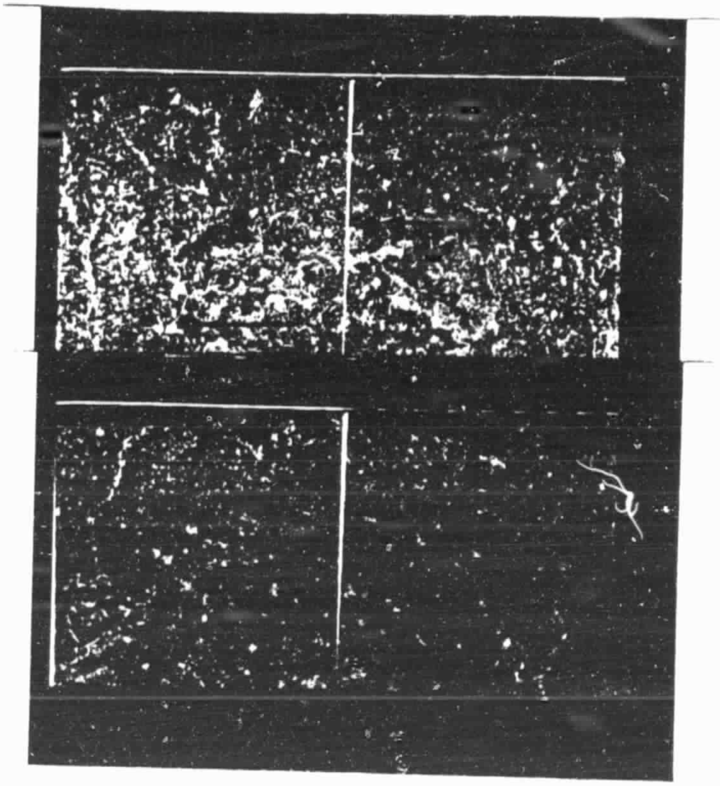

Figure 7

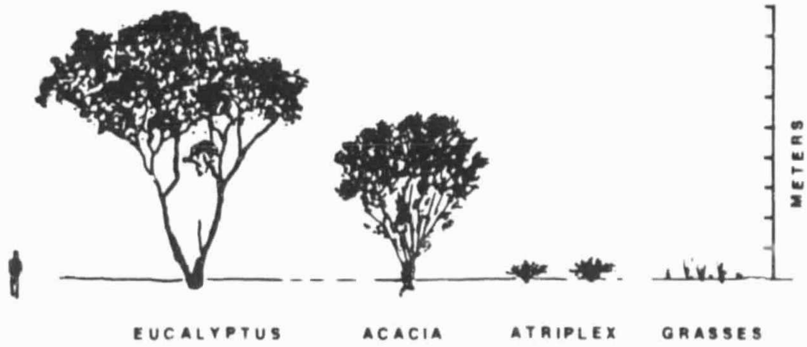

Figure 8

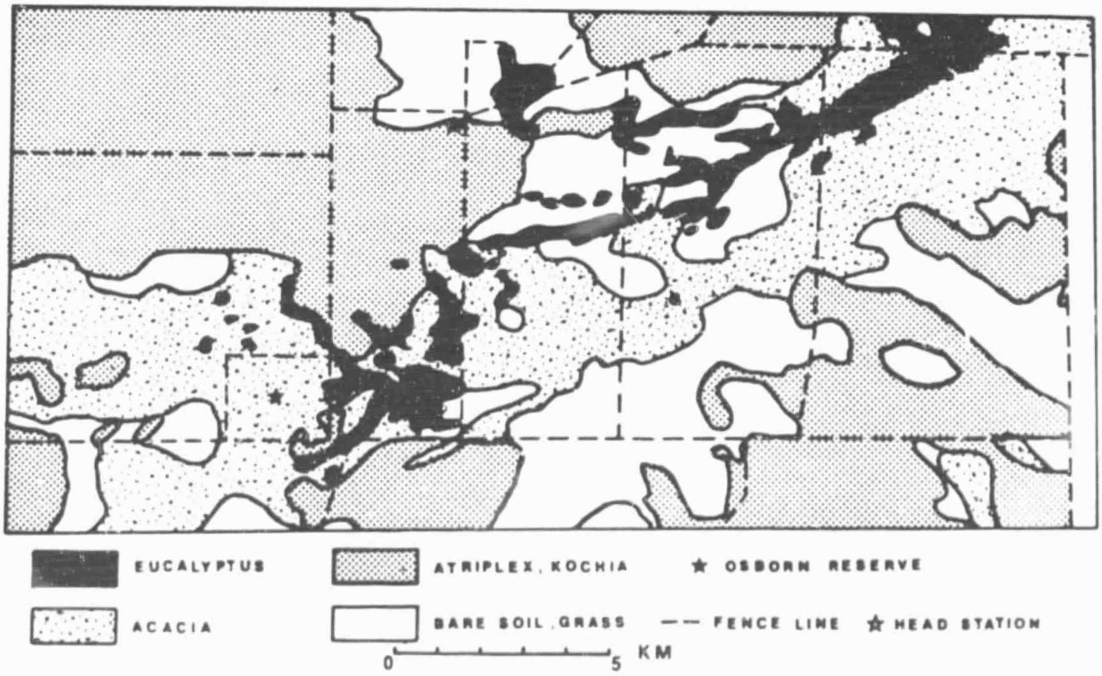

Figure 9

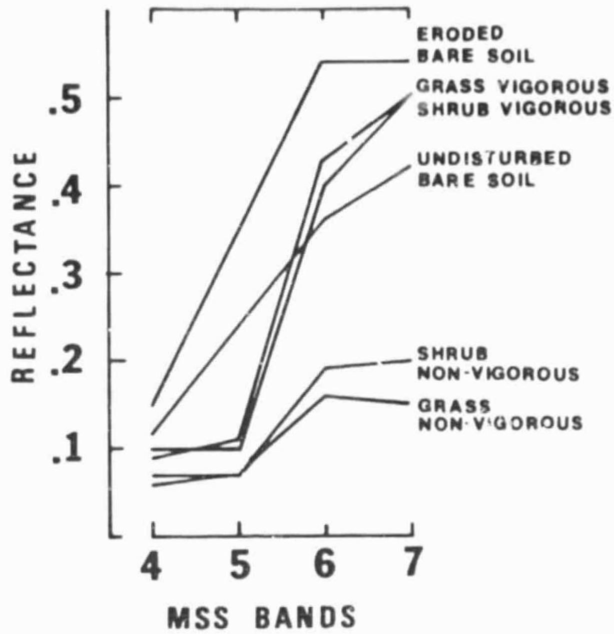

Figure 10

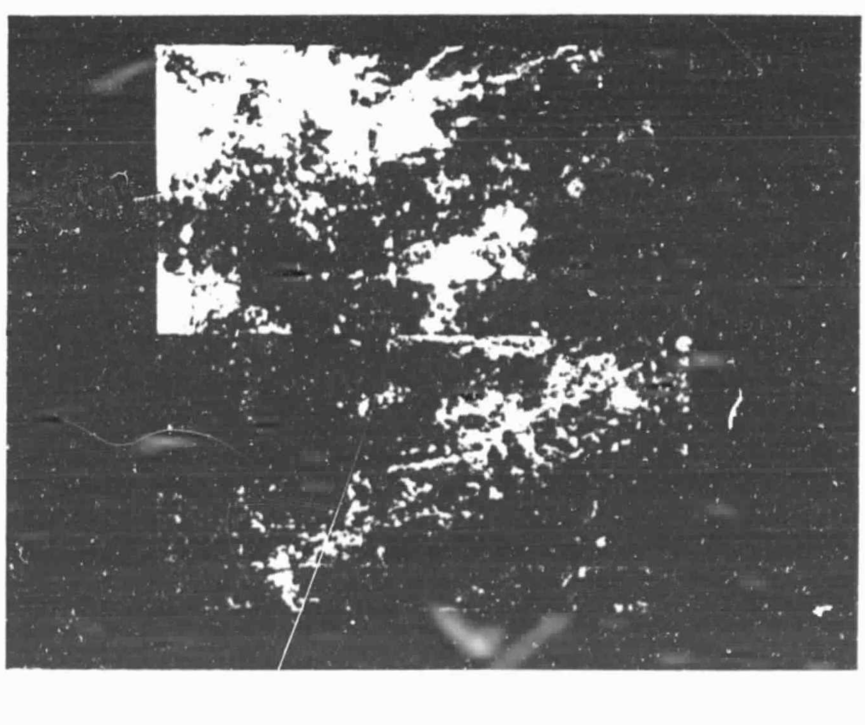

Figure 11

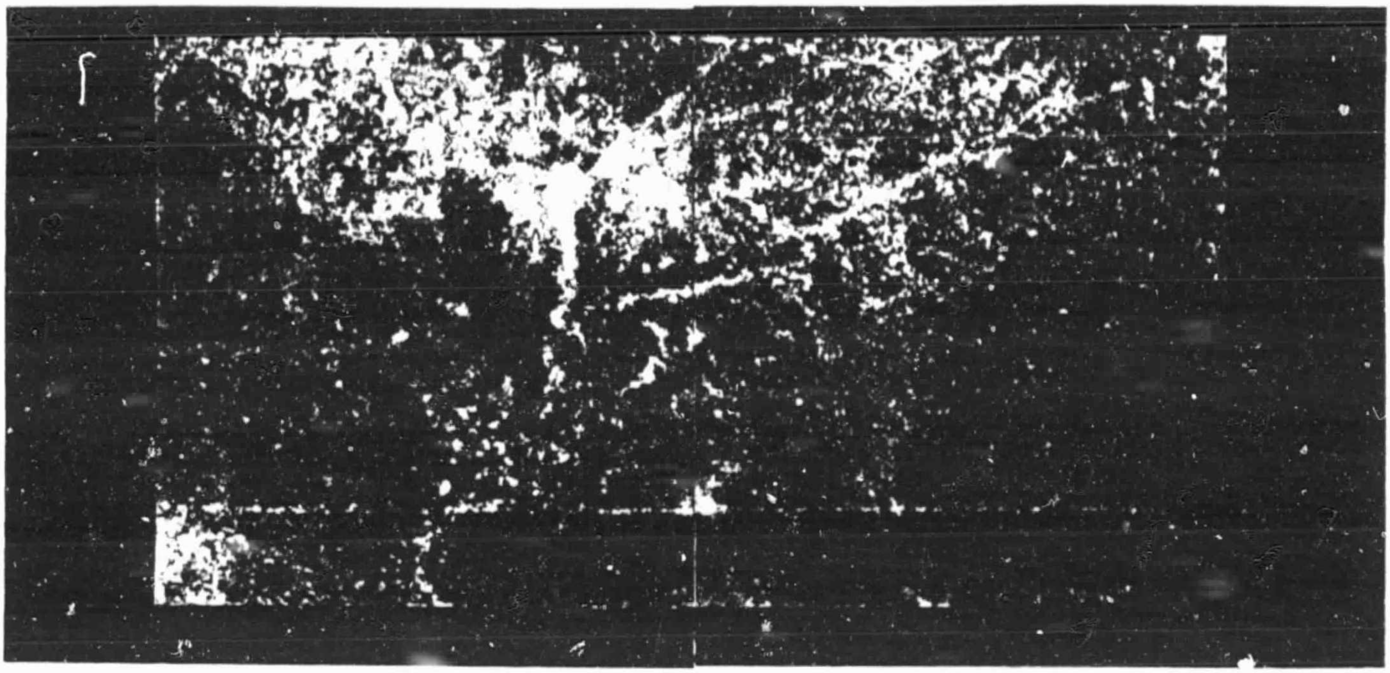

Figure 12

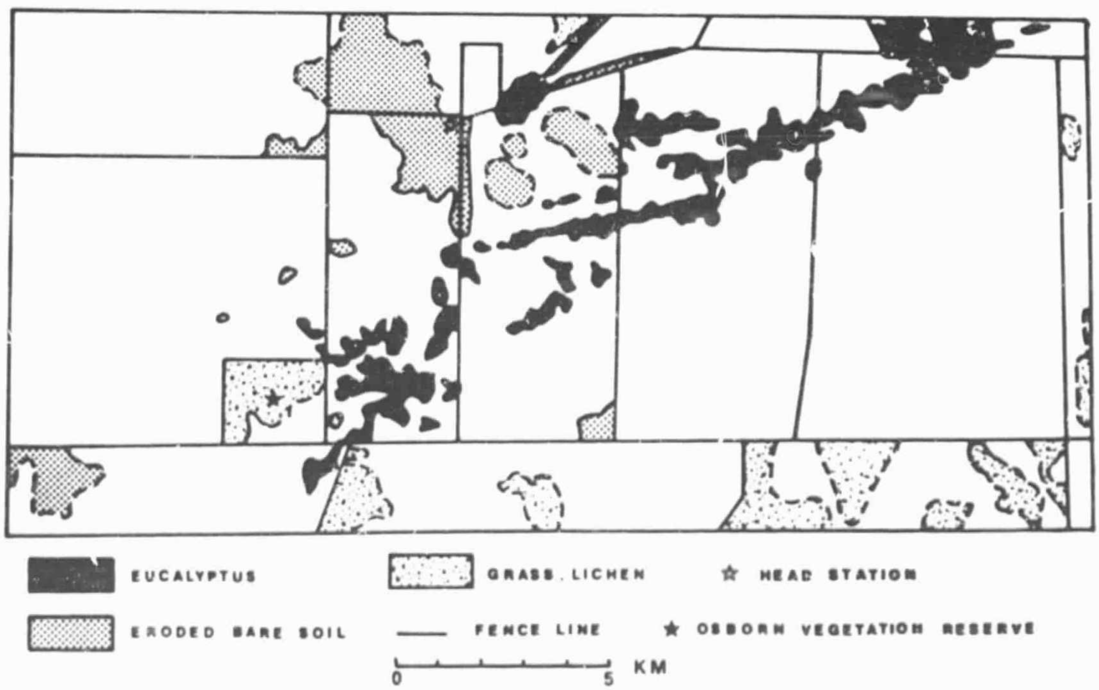

Figure 13