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POTENTIAL OF RADAR REMOTE SENSORS AS TOOLS IN RECONNAISSANCE GEOMORPHIC, VEGETATION AND SOIL MAPPING

July 1968

Prepared by the U.S. Geological Survey for the
National Aeronautics and Space Administration (NASA)
under NASA ~~Contract No.~~ 14-08-0001-10848,
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WASHINGTON, D.C. 20242

Interagency Report
NASA-125
July 1968

Mr. Robert Porter
Acting Program Chief
Earth Resources Survey
Code SAR - NASA Headquarters
Washington, D.C. 20546

Dear Bob:

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INTERAGENCY REPORT NASA-125

POTENTIAL OF RADAR REMOTE SENSORS AS TOOLS IN

RECONNAISSANCE GEOMORPHIC, VEGETATION AND SOIL MAPPING*

by

David S. Simonett**

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Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

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*Work performed under NASA Contract No. 14-08-0001-10848, Task 160-75-01-32-10

**Center for Research in Engineering Science, University of Kansas, Lawrence, Kansas

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POTENTIAL OF RADAR REMOTE SENSORS AS TOOLS IN RECONNAISSANCE GEOMORPHIC, VEGETATION AND SOIL MAPPING*

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SUMMARY

In reconnaissance mapping of vegetation, soils and geomorphic surfaces in remote, difficult-of-access and under-developed areas in tropical and arctic latitudes, aerial photographs have extensively been used to aid ground studies. Over recent years, studies using non-photographic remote sensors, particularly infra-red and radar have shown that these systems, used in concert with photography, may add materially to the information available and thereby improve the efficiency of ground reconnaissance. This report focuses attention on side-looking radar as a tool for such reconnaissance. Since radar imagery may be obtained in swaths up to 40 miles wide, largely independent of the weather, its usefulness for reconnaissance-mapping needs careful evaluation.

A review is given of recent studies with radar on: (1) the mapping of lineaments, and lithologic units and its use as a surrogate for 1:24,000 scale maps in hydrologic analysis; (2) the mapping of vegetation types, especially in relation to structure, and; (3) its successes and shortcomings as an adjunct to photographs in soil reconnaissance surveys.

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POTENTIAL OF RADAR REMOTE SENSORS AS TOOLS IN RECONNAISSANCE GEOMORPHIC, VEGETATION AND SOIL MAPPING

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Introduction

In reconnaissance mapping of vegetation, soils and geomorphic surfaces in remote, difficult-of-access and under-developed areas in tropical and arctic latitudes, aerial photographs have extensively been used to aid ground studies. Over recent years, studies using non-photographic remote sensors, particularly infrared and radar, have shown that these systems, used in concert with photography, may add materially to the information available and thereby improve the efficiency of ground reconnaissance. This report focuses attention on side-looking radar as a tool for such reconnaissance. Since radar imagery may be obtained in swaths up to 40 miles wide, largely independent of the weather, its usefulness for reconnaissance-mapping needs careful evaluation.

Radars with characteristics suitable for broad-scale vegetation and related surveys have been developed for military purposes in the past two decades. Because most of the images produced in the past by these radars have not been available to the scientific community, their potential as survey tools is not widely known. Recently, in connection with studies funded by the National Aeronautics and Space Administration, U.S.A., over 300,000 square miles of the U.S. have been flown with several radar systems. Since many of these recent studies remain unpublished, or have received only limited distribution in the United States, it has seemed appropriate to bring them to the attention of a wider audience at an international meeting such as this.

Geomorphic Reconnaissance

Recent geomorphic studies with radar imagery have concentrated on the mapping of lineaments and lithologic discriminations not obtained with aerial photography. Kover (1967) reports on a number of unpublished studies by the U.S. Geological Survey in which major lineaments and other structures not previously known to exist even in well-mapped areas were found with radar imagery. Dellwig et al (1966) used low resolution radar imagery to map major lineaments in the Boston mountains of Arkansas. J.N. Kirk (personal communication) has located many unmapped lineaments on radar images of the Ouachita Mountains in Arkansas and Oklahoma. In areas of very low relief Rydstrom (1967) has noted that minor topographic expression of deep-seated faults and other structures not normally detected on air photographs, may be observed on radar images when the illumination angle is near grazing. H.C. MacDonald (personal communication) has found a close correlation between lineaments detected on aerial photographs and radar near Lawrence, Kansas. However, more lineaments were noted on the radar imagery than on the photographs and certain long lineaments seen on the radar appeared as small segments only in the photographs. The detection by radar of lineaments is not uniformly so successful, however, as observed by Wise (1967) in a study in Pennsylvania.

Fischer (1963) notes that thin sand veneers have been detected with radar imagery which were not evident on air photographs, and this has been confirmed in an unpublished USGS study reported in Kover (1967). Dellwig and Moore (1966) found that differences between alluvial drainages in a complex bajada at Pisgah Crater, California, were better detected on radar than on photographs. Dellwig et al (1965) and Ellermeier et al (1967) have found that radar imagery is very sensitive to micro and meso surface roughness in flat playa lakes as a function both of the wavelength of the radar and the penetrating capabilities of the radar system. MacDonald et al (in press) noted in Arizona that radar and photographs each continued information the other lacked: a major fault and certain soil texture differences were better expressed on the radar image than on the photo.

McCoy (1967) has demonstrated that radar imagery may be used directly instead of maps for derivation of hydrologic parameters in drainage basins. Very high correlations (r = .98 and higher) were obtained between stream-lengths and drainage basin areas determined from radar imagery and maps at a scale of 1:24,000. He has also demonstrated that a considerable potential exists for obtaining both these measures automatically through use of flying spot scanners with radar images.

Numerous additional references to geologic and geomorphic studies are to be found in a radar bibliography for geoscientists prepared by Walters (1967). The bibliography contains 240 references and a detailed cross-referenced index.

Vegetation Reconnaissance

Studies on the effect of vegetation on radar returns have been made by Cosgriff et al (1960), Ellermeier et al (1967), Lundien (1966), Moore and Simonett (1967), Morain (1967), Morain and Simonett (1966, 1967), Simonett et al (1967), and Simonett and Morain (1965). Multiple-polarization K-band imagery has been studied in a wide range of climatic and topographic environments in the United States, and in all areas some influence of vegetation on radar returns was observed.

Methods for the interpretation of vegetation on images have included analysis of tone and texture as well as use of an image discrimination, enhancement, combination and sampling system (IDECS) developed at The University of Kansas. The techniques used include tri-color image combinations, generation of probability density functions to quantify variations in gray scale level between types; and the employment of a data space sensor to help distinguish between vegetation types which the eye normally distinguishes only with difficulty on a radar image (Simonett, 1966; Morain and Simonett, 1967).

The results of these studies indicate that radar may have a role in: (1) preparation of small-scale, regional, or reconnaissance maps of vegetation type, particularly where there are pronounced structural differences between plant communities; (2) delimiting vegetation zones that vary with elevation; (3) tracing burn patterns of previous forest fires; (4) delimiting the altitudinal timberline; (5) identification of species by inference in areas characterized by monospecific stands; (6) possible discrimination of structural subtypes in cut-over, burned, and regrowth forest; (7) deriving estimates of vegetation density in sparsely vegetated areas; and (8) supplementing very high altitude low-resolution photography in which textural differences related to vegetation are weakly expressed. Not all of these are equally likely of success, but all are worthy of further study.

Although images produced at long wavelengths have not yet been studied, laboratory studies by Cosgriff et al (1960) and Lundien (1966) suggest that a combination of short and long wavelengths, together with multiple polarization would permit better delineation of natural plant communities, including structural subunits, than is presently feasible with radar imagery.

Soil Reconnaissance Studies

There is no literature on the utility of radar images in soil mapping, other than an oblique mention in Beatty et al (1965). Consequently, studies were begun in 1965 by the author and Dr. James Thorp at the University of Kansas to test the value of different radar wavelengths and polarizations in soil reconnaissance. One study, with a K-band system, is reported here.

Figures 2, 3 and 4 summarize some observations on the identification of soil associations on this imagery in a portion of Woods County, Oklahoma. Figure 2 shows three classes of vegetated and bare sand dunes in the county. Experienced radar interpreters with a good soils-geomorphology background usually can distinguish these three types on the radar film transparencies. Bare dry sand is a good absorber of energy in the radar wavelengths. Hence it yields very little backscattered return and appears black on a film positive (Figure 5). Vegetated dunes and sand sheets return more energy and have a lighter image tone. They also have a distinctive texture which along with the topographic undulations of the dunes aids in their detection.

Figure 3 shows four soil associations in Woods County, Oklahoma: Vernon badlands, salt plains, Lincoln-Yahola (flood plains), and river terraces. The first three are distinguishable with ease on the radar imagery, the fourth with some difficulty. The Vernon badland association typically has a steeply convex valley side plunging into a narrow almost flat-floored valley. Its rough valley walls clad variously in small trees, grass, sagebrush or exposed gypsum are easily delineated on the radar imagery. The salt plain association is a bare saline river wash with a distinctive light tone on the radar image. The flat Lincoln-Yahola flood plains association is covered with mixed grass, sagebrush and occasional trees. While the association as a whole is easily mapped, its component soil series cannot be detected. The river terraces association usually can be separated from the flood plains, but again its several soil series cannot be noted. In other regions we have found it more difficult to distinguish terraces from flood plains, for example, in the Kansas and Waukarusa valleys near Lawrence, Kansas. The ability to distinguish river terraces on radar imagery varies in relation to the environment and the radar look angle, being easiest at low angles of illumination, and where the vegetation differs on the terrace and flood plains.

Figure 4 shows four additional soil associations in Woods County, Oklahoma, which could not be distinguished from one another although collectively they could be separated from the associations mapped in Figures 2 and 3. The associations shown in Figure 4 include soils which would be classified as Udic Argustolls, Typic Ustochrepts, and Haplic Calciustolls.

The inability to discriminate between these soil associations on the radar image, let alone the series of which they are composed, is in many ways to be expected, in an area so completely given over to cultivation. Lundien (1966) and Simonett et al (1967) indicate that radar is much less sensitive to soil texture variations within a field than it is to crop and soil moisture and other differences between adjacent crops. Field patterns are dominant on this radar imagery and mask any weakly-expressed soil information. In reaching this conclusion, however, it is not proper to further deduce that radar imagery, per se, is of little utility in distinguishing between any but extreme soil differences of the type indicated if Figures 2 and 3. Radar imagery of grazing land in the Flint Hills of Kansas shows some sensitivity to differences in height and types of grass and weeds. Discrimination might thus be achieved where the native vegetation varies in its seasonal response on different soils. This remains to be studied.

A K-band radar image showing a vegetated coastal sand strip backed by sand dunes along part of the Oregon coast (Figure 5), is included to show the close relation between vegetation cover on dune sands and the radar return. Field studies of the coastal sand strip show that those areas which are dark are relatively free of marram grass and other vegetation, while the areas which are lighter have a denser cover. Dry bare sand, as noted above, absorbs almost all the incident radar energy. Within the dune field, bright returns come from clumps of sitka spruce, lodgepole pine, and other conifers, and wispy gray tones coincide with pioneer regrowth in flat areas where the water table is near the surface.

To summarize these observations, it is clear that the information obtainable from this radar imagery for soil mapping is distinctly uneven in both distribution and quality, for while it is sometimes possible to make clear distinctions between adjacent soils even at the series level, and more usually at the association level, there are many instances when neither is feasible. Separation of soil groups at the association level is more likely in untilled and sub-humid to arid regions, than in cultivated or densely forested humid lands. To put these conclusions in another way, where extreme differences occur in adjoining plant structures, in soil or plant moisture content, in soil texture, in topography, and--in areas of scanty vegetation--small-scale surface roughness, then discrimination on the radar image of soil units closely tied to these differences will usually be possible. Lesser differences will not be so easily detected, especially in cultivated areas, and careful timing of aircraft flights to coincide with the greatest seasonal vegetation contrasts will be necessary.

Additional studies employing multiple wavelengths, polarizations and radar band-widths may show that it is possible to better this level of discrimination of soil units. Even if this is not the case, the overall perspective provided by radar coverage of large landscape units will be a valuable addition in reconnaissance surveys.

Acknowledgements

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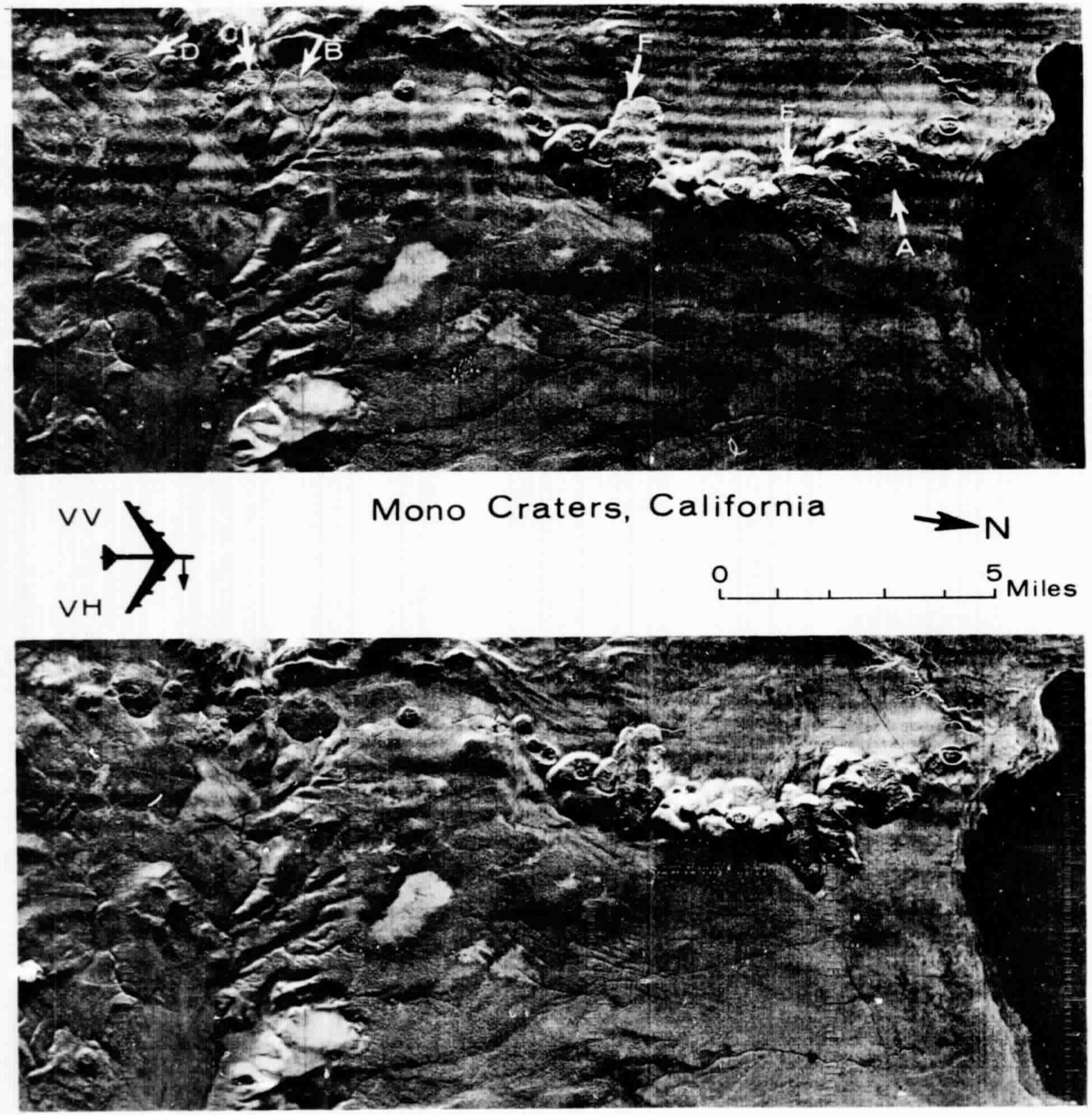


Figure 1.

K-BAND RADAR IMAGERY OF MONO CRATERS, CALIFORNIA

Throughout this north-south oriented chain of recent volcanics the contrast between lavas and the flanking ash and cinder covered terrain is similar in the VV and VH-polarized K-Band radar images. However, the return from the crater (A), the lava domes (B, C, D) and the coulees (E, F) is relatively lower in the VH image than in the VV image. These areas are devoid of vegetation and have extreme surface roughness consisting in a large part of a jumble of large blocks, which may contribute to this differential depolarization.

East of the crater chain patterns related to various vegetation types are visible.

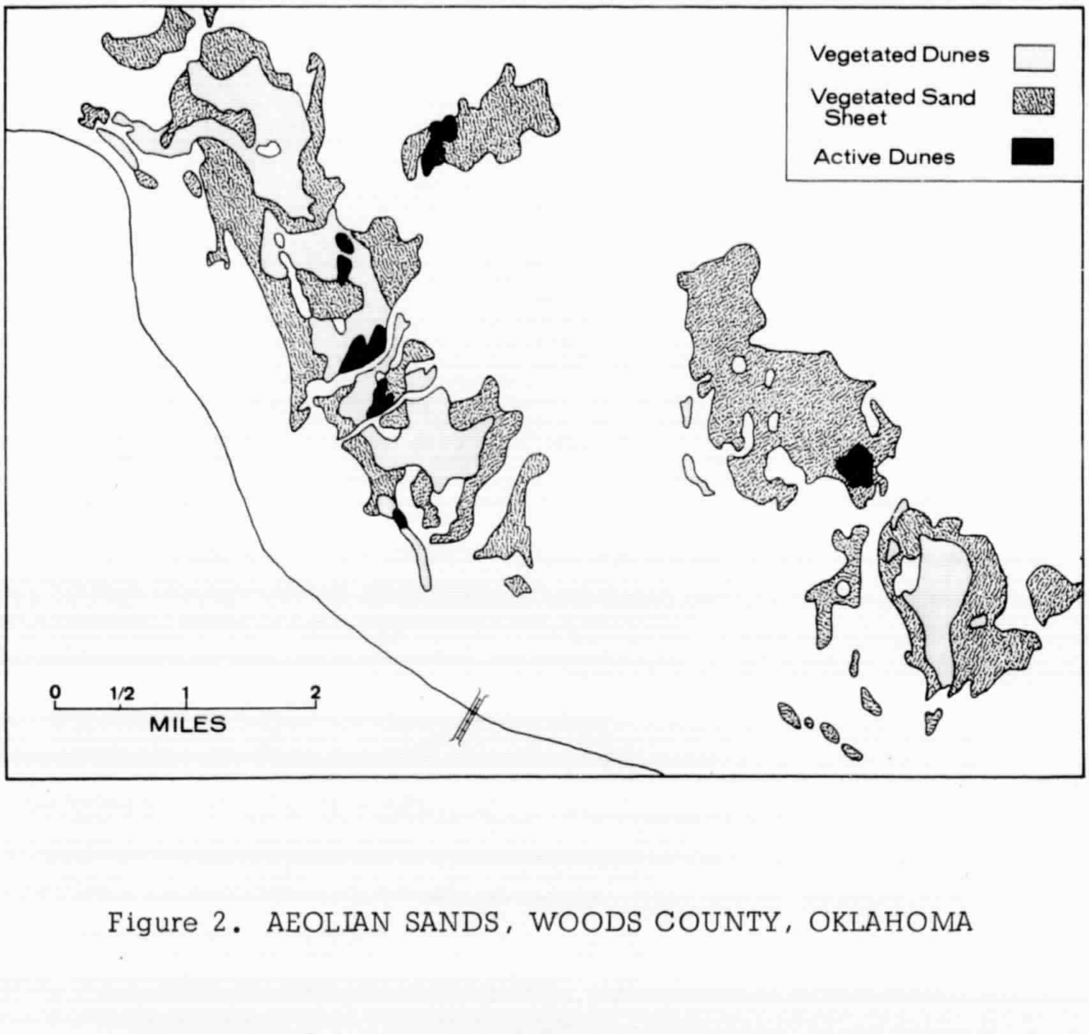


Figure 2. AEOLIAN SANDS, WOODS COUNTY, OKLAHOMA

The soils of the Vegetated Dunes are the Tivoli Fine Sand, dune phase (15-25% slopes) and Dune Sand (stabilized). The Vegetated Sand Sheet occurs on the Tivoli Fine Sand, and the Active Dunes are bare sand with 15-25% slopes. These three soil groups are usually, but not always distinguishable on K-band radar imagery.

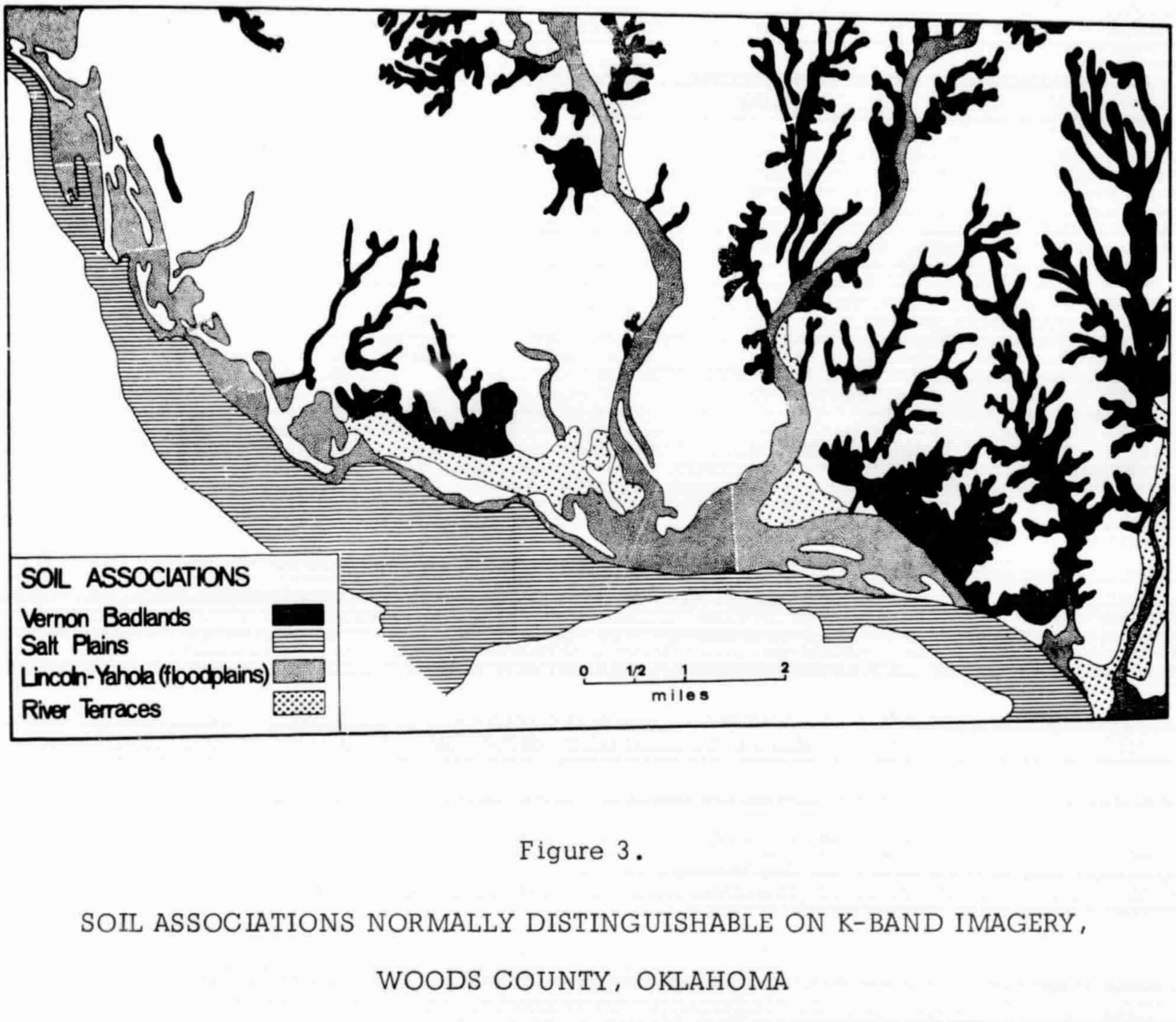


Figure 3.

SOIL ASSOCIATIONS NORMALLY DISTINGUISHABLE ON K-BAND IMAGERY, WOODS COUNTY, OKLAHOMA

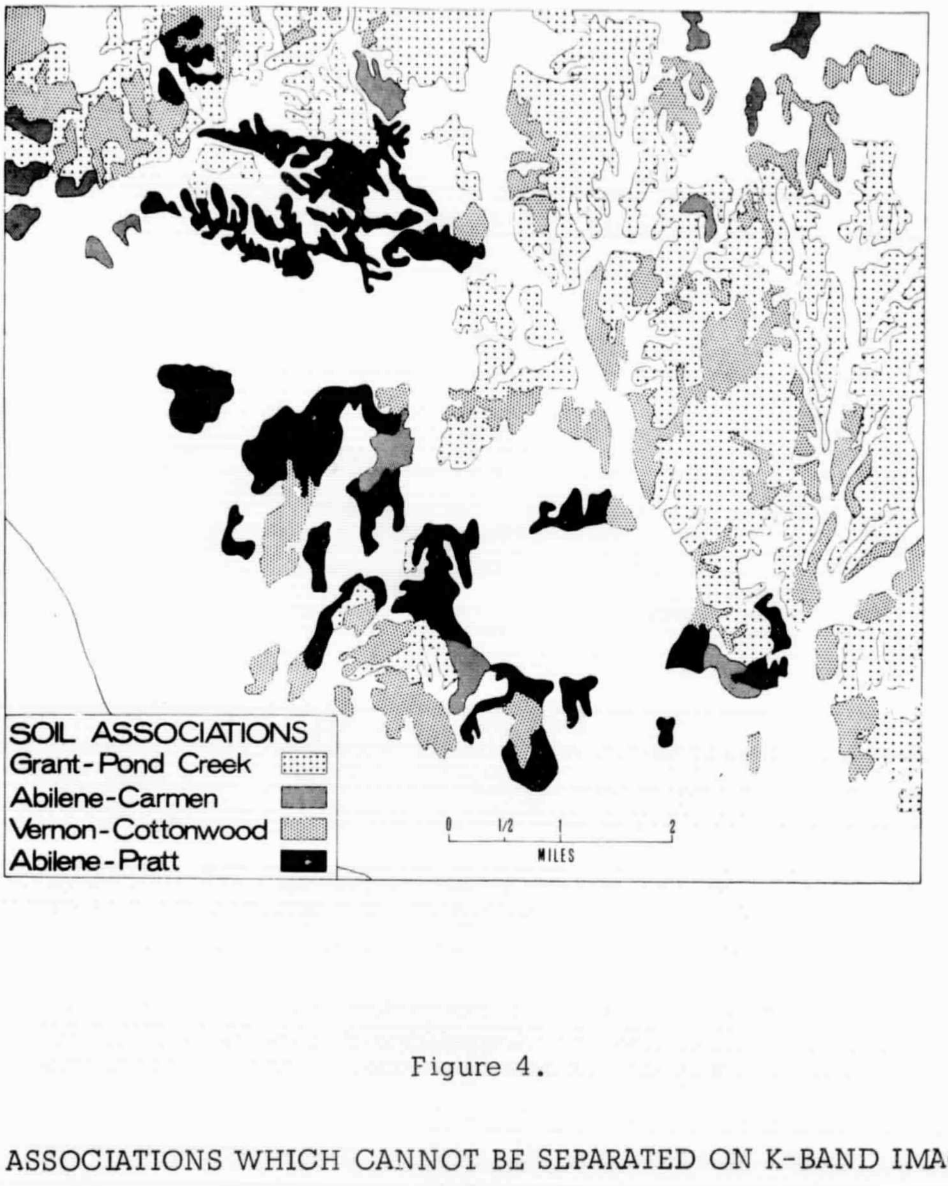


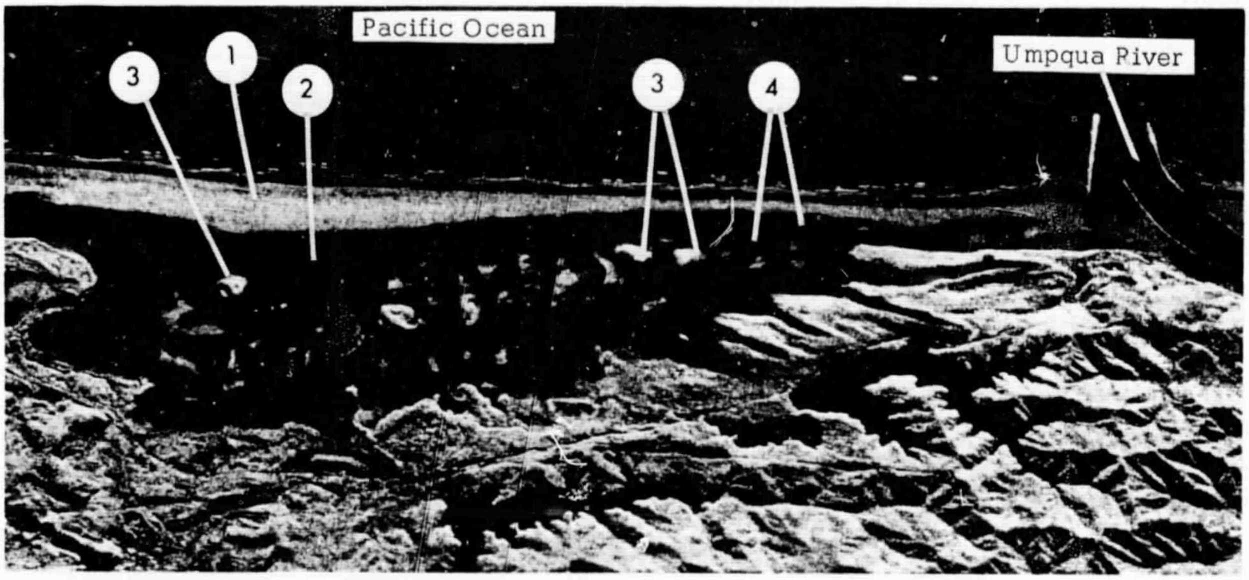
Figure 4.

SOIL ASSOCIATIONS WHICH CANNOT BE SEPARATED ON K-BAND IMAGERY, WOODS COUNTY, OKLAHOMA

Figure 5.

K-BAND RADAR IMAGE OF

SAND DUNE AREA SOUTH OF THE UMPQUA RIVER, OREGON



1. Foredune vegetated by European and American dune grass. Brighter areas are more densely covered.
2. Open sand (unstabilized).
3. Stabilized dune surface predominantly vegetated by Sitka Spruce and other conifers.
4. Trough between dune ridges vegetated by shrubs and grasses.