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KANSAS ENVIRONMENTAL AND RESOURCE STUDY: A GREAT PLAINS MODEL

JANUARY 1974

Type II Progress Report for the
Period August 1, 1973 through January 31, 1974

Prepared for:

National Aeronautics and Space Administration
Goddard Spaceflight Center
Greenbelt, Maryland 20771

Contract No. NAS 5-21822

THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.
2385 Irving Hill Rd.—Campus West Lawrence, Kansas 66044

I

KANSAS ENVIRONMENTAL AND RESOURCE STUDY
A GREAT PLAINS MODEL

Ground Pattern Analysis in the Great Plains

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Contract No. NAS 5-21822, Task 6

II

Semi-Annual ERTS-A User
Investigation Report

Type II Progress Report
for the Period August 1, 1973 through January 31, 1974

NASA Contract NAS 5-21822

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ERTS-A Proposal No.: 60-8

Task Number: 6

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16. Abstract

The purpose of this investigation is to locate large-scale ground patterns and anomalous patterns in Kansas using ERTS-A imagery and optical data processing techniques. This report describes the spatial frequency and orientational curves that were obtained for various sample areas in Kansas using ERTS-A imagery as the input to an optical data processing system. Manual interpretation of the orientational curves was described in a previous report. Appropriate data processing schemes were used to derive numerical parameters from these curves. These parameters are used in pattern recognition schemes to locate large-scale ground patterns and anomalous patterns in Kansas. The results reported here indicate that spatial frequency analysis of ERTS imagery can be used to accurately discriminate between large-scale ground patterns in Kansas.

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PREFACE

The objectives of this investigation are:

A. Mapping the surficial geology of selected sites in Kansas from multispectral imagery, and identification of anomalous patterns;

B. Search for large-scale ground patterns by spatial frequency analysis.

An optical processing system is used in this investigation to produce ground pattern spatial frequency and orientation information using ERTS-A imagery as input. Interpretation of the information is done with respect to known geologic features and other cultural and vegetation features. Appropriate data processing schemes are used to derive numerical descriptors of these features and these descriptors, in turn,are used in pattern recognition schemes. This investigation will then provide a mapping technique of large-scale geologic ground patterns as well as other large-scale ground patterns in Kansas.

The manual interpretation of the spatial frequency and orientational information derived from the ERTS-A imagery has been completed and reported previously. The quantitative analysis of this information is described in this report. The results described here show that spatial frequency analysis can be used to accurately discriminate between large-scale ground patterns.

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SECTION 1.0

INTRODUCTION

The spatial frequency analysis in this investigation involves the determination of spatial frequency and orientational information from large-scale ground patterns using ERTS-A imagery as the input to an optical data processing system. Previous Type II progress reports on this investigation have described the geology and physiography of Kansas, optical data processing theory, the data obtained from the optical data processing of ERTS images, and the manual interpretation of these data with respect to the geology and physiography of Kansas.

This report will concentrate on the quantitative analysis of the data obtained from the optical data processing system. Specifically, this report will describe the physiographic and geologic patterns that exist in Kansas, it will review the spatial frequency and orientational information derived from ERTS-A images using the optical data processing system, it will cover the derivation of physiographic descriptors or parameters from these data, and it will describe the accuracy of these parameters in predicting large-scale ground patterns and the existence of anomalous patterns in Kansas.

To obtain more significant information from the spatial frequency analysis an experimental design was established and has been essentially completed. The sample areas for the experiment were methodically chosen from regions within the state which exhibit specific geologic/physiographic characteristics. The procedure used in this experiment is outlined below.

A. Determine the number and extent of various geologic/physiographic regions in Kansas from known geologic/physiographic information.

B. Select an adequate number of sample areas within each region.

C. Investigate the effect of snow cover on the ability of ERTS-A imagery to display physiographic information. (To study this effect, equivalent sample areas are chosen from imagery without snow cover and again from imagery with snow cover).

D. Obtain spatial frequency characteristics from the selected sample areas.

E. Determine features of spatial frequency data which will allow determination and classification of physiographic regions from ERTS-A imagery.

F. Investigate ability of spatial frequency data to provide reliable physiographic classification using different classification algorithms.

Following this procedure, eight regions of Kansas were chosen as most representative of certain distinctive physiographic or geologic provinces. Ten sample areas were chosen from each of these regions. Each sample area is circular with a diameter of approximately 23 miles. Spatial frequency data were taken twice for each of these sample areas-once using an image when the area was snow-covered and once using an image from the area when it was not snow-covered.

Spatial frequency and orientational curves for approximately 150 sample areas were obtained using the optical data processing system. Appropriate data processing schemes are used to derive numerical parameters from these curves, and these parameters are used as descriptors of the sample areas. These parameters may be used then to categorize the sample areas in terms of different physiographic or geologic provinces. The preliminary findings of the categorization experiment will be presented here and the final conclusions will be presented in a later report.

SECTION 2.1

ERTS IMAGE SPATIAL FREQUENCY ANALYSIS

The following section is a review of the work reported in the previous Type II ERTS-A Progress Report. This section will cover the geologic/physiographic categories in Kansas, the spatial frequency analysis of sample areas that were chosen in each of these categories, and the optical data processing system that was used in the spatial frequency analysis of these sample areas. This section will also include several examples of the spatial frequency and orientational curves obtained from the optical processor and our interpretation and analysis of them. For a full discussion of these items refer to the Type II Progress Report for the Period February 1973-July 1973, NASA Contract NAS5-21822.

SAMPLE SITE LOCATION

Areas of similar geologic make-up in Kansas correlate very well with the eight physiographic regions in Figure 1. By definition, each region contains similar landforms caused by similar geomorphic processes. In addition, each region can be considered a geologic region since it contains outcrops of the same dominant lithology and the same geologic age. In many cases, these regions also possess the same general land-use. Thus the selection of sample sites for spatial frequency analysis of geologic ground patterns was based on these eight physiographic-geologic regions.

Ten sample sites were selected for each of the eight regions and two analyses were performed for each site, one with snow-cover and one without. The actual dates of acquisition of the images used in this study was contingent upon cloud cover and of course the presence of snow. As many as possible of the non-snow analyses were performed on images recorded during the summer and early fall of 1972. The snow-covered images were acquired during the following winter. For a few sample sites cloud free images with snow cover were not available, thus the sample set is not entirely complete.

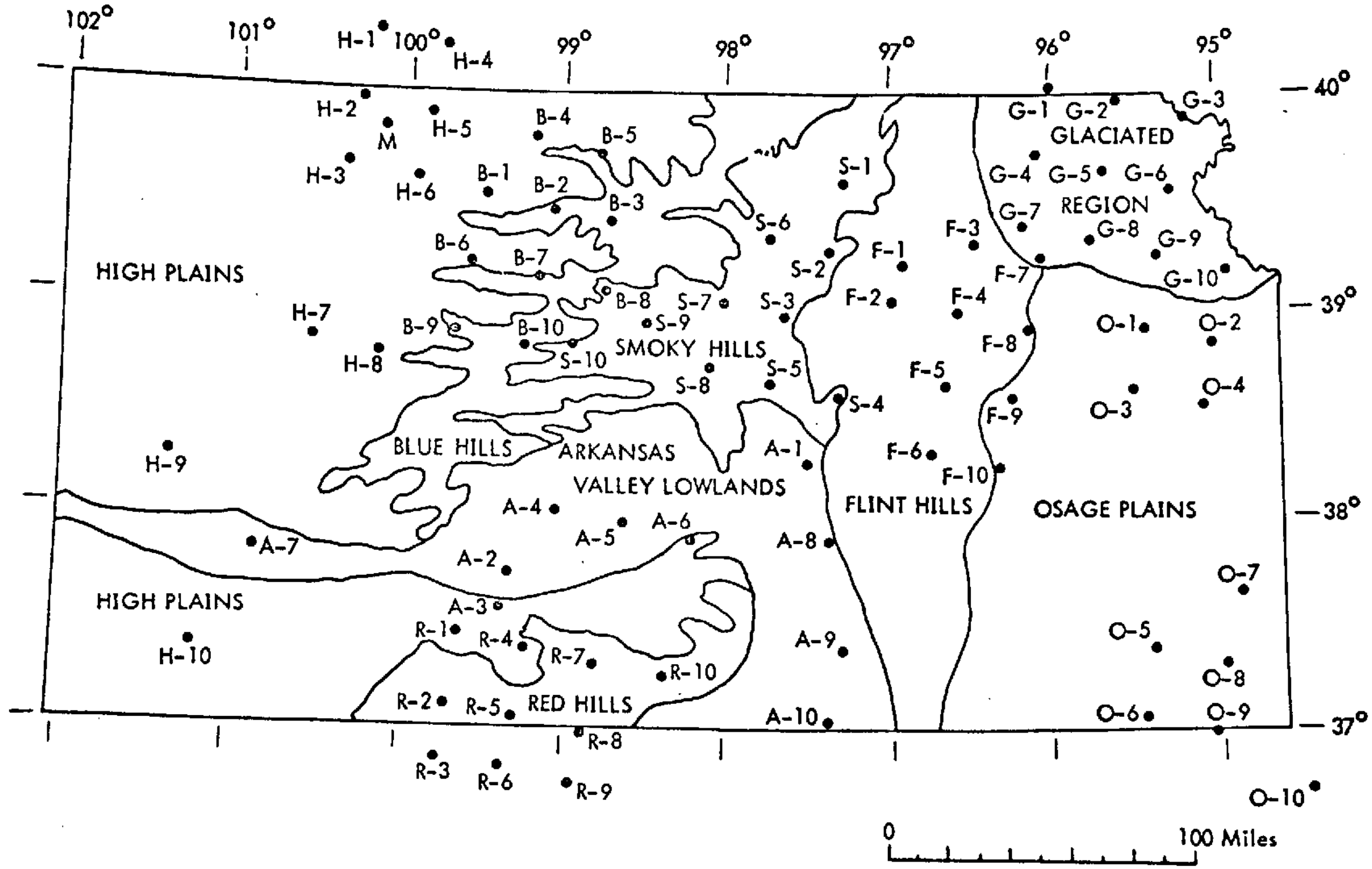


Figure 1. Physiographic Regions of Kansas (Adapted from Schoewe, 1949) with Sample Site Locations.

The size of the area analyzed at each site is approximately 23 statute miles in diameter and the spacing of the sites was controlled by the size of the geologic region. Smaller regions such as the Glaciated Region were almost completely sampled; in larger regions, the sampling was more scattered. Also some sample sites cross over into neighboring states but remain in the same geologic region.

For all sample sites except one, MSS 5 images were used in the analysis. This band was judged to contain the most information pertinent to the investigation. The lone exception is a sample site in northwest Kansas where all four MSS bands were available for analysis. This site contains an area of well-developed parallel drainage and all four bands were analyzed to determine the relative merits of each band.

Sample site center points are plotted in Figure 1 and each site has an alphanumeric identifier. The letter refers to the geologic region in which the sample site occurs and the numbers identify the ten sample sites in that region. A snow-covered sample is assigned a number that is ten more than its non-snow counter part. Thus in the case of "0-6" for instance, "0" refers to the Osage Plains region, "6" refers to the sixth sample site; "0-16" refers to the same sample site that occurs on a snow-covered image. The curves that result from the analysis of these samples are given the same designations. The sample site in the High Plains region which is analyzed on all four MSS bands is designated "M" in Figure 1.

Detailed analysis of each sample site was performed and the results of this analysis were presented in the previous Type II report on this investigation. For a discussion of the physiography and geology of Kansas see Appendix A.

FREQUENCY DECOMPOSITION OF SAMPLE AREAS

Each sample area on the ERTS image is composed of ground patterns of characteristic spatial frequencies and orientations. The spatial frequencies here refer to variations of density on the image as a function of distance. Hence, if we decompose the image sample area into its component frequencies and plot their intensity; and if we plot the "strength" of preferred orientations in the image versus angle, we have described the sample area by a set of numbers. The purpose of the quantitative phase of this investigation is to determine how accurately this may be done.

The optical data processing system used in this investigation accomplishes this decomposition of the sample area into a set of numbers which describe the spatial spectrum of the sample area and indicates the "preferred" orientations of the large-scale ground patterns. (For a more detailed discussion of the theory involved in optical data processing of images see the previous Type II Progress Report on this investigation.)

Each of the sample areas on the ERTS images is used as the input to an optical data processing system. The complete system was described in the previous Type II report and Appendix B contains a short description of the system. A block diagram of the optical data processing system along with the pattern recognition portion of the system is shown in Figure 2. Figure 3 expands on the part of Figure 2 enclosed in dashed lines.

Using this optical processor, spatial frequency and orientational curves are derived for each sample area. Examples of these curves for a few sample areas are presented in Figure 4. The interpretation below the curves refers to the orientational curve. The spatial frequency curve in each case is the staircase-type curve that falls off in amplitude at higher frequencies. The curve that fluctuates significantly in amplitude is the orientational curve.

The manual interpretation of the orientational curves indicated that this analysis produced a valid characterization of the orientation of stream patterns and other features.

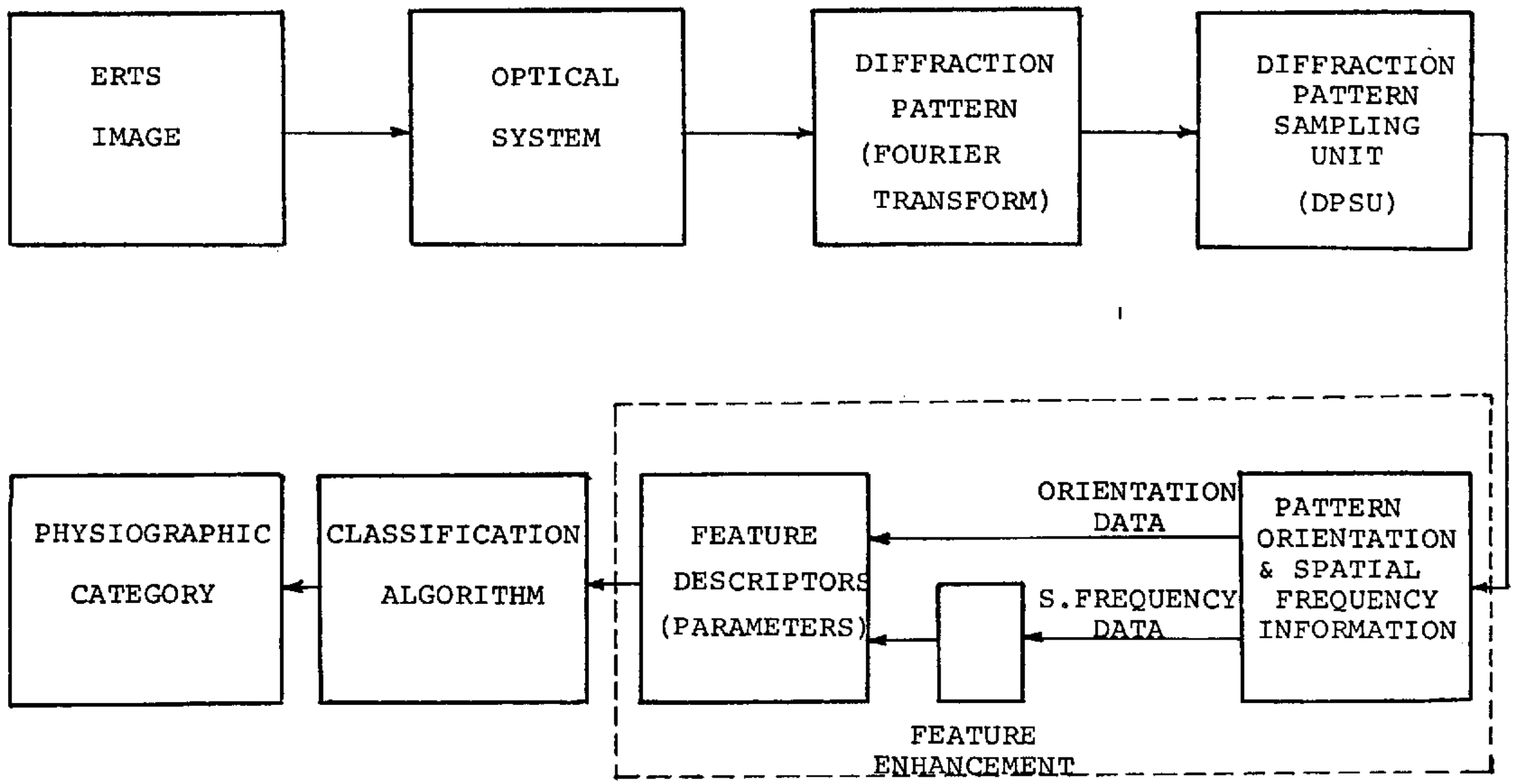


Figure 2. Block diagram of optical processing and pattern recognition system.

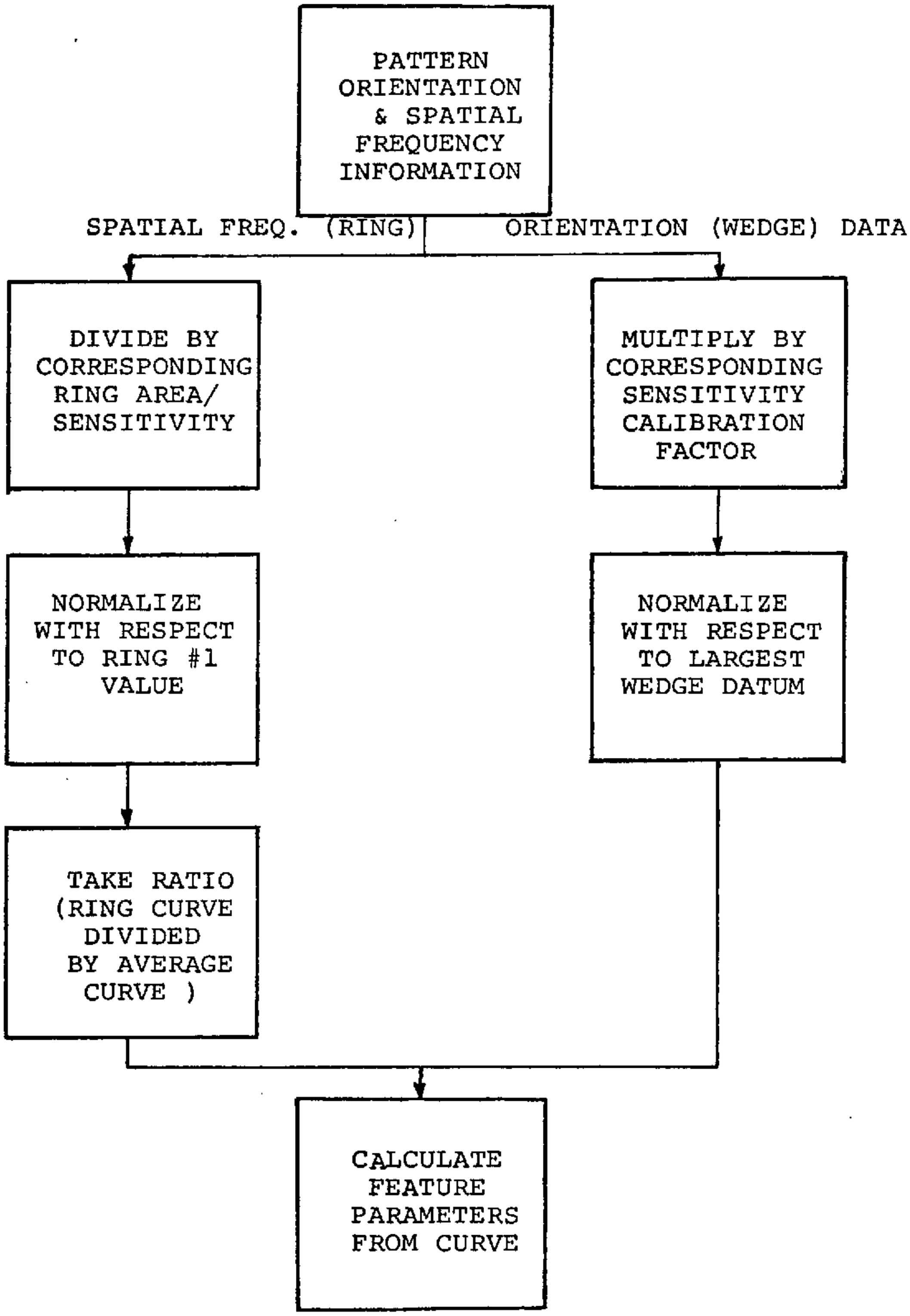
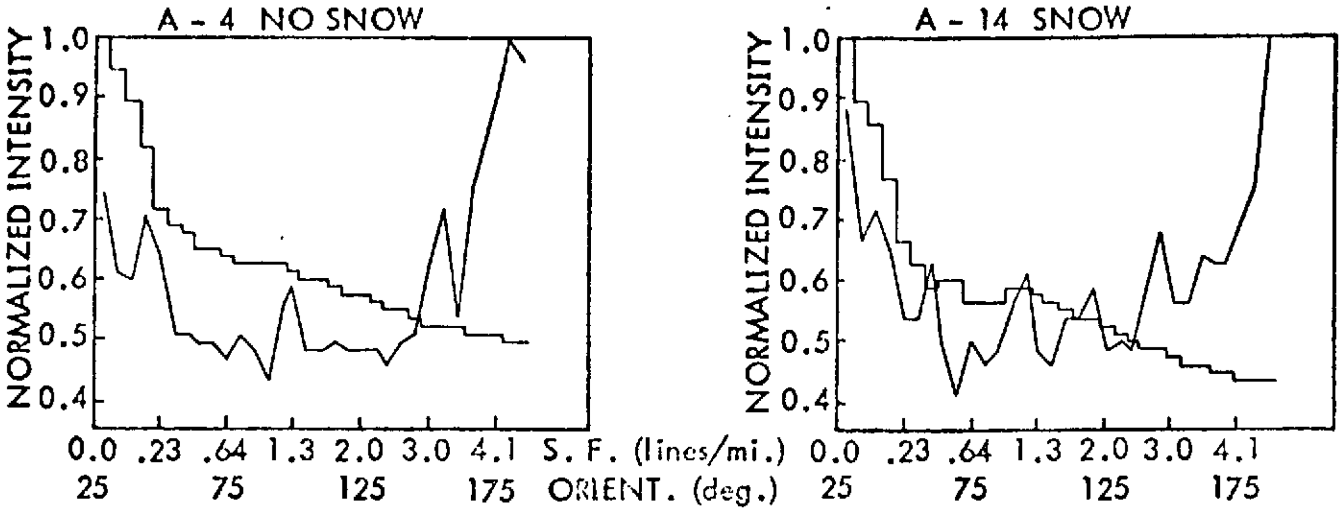
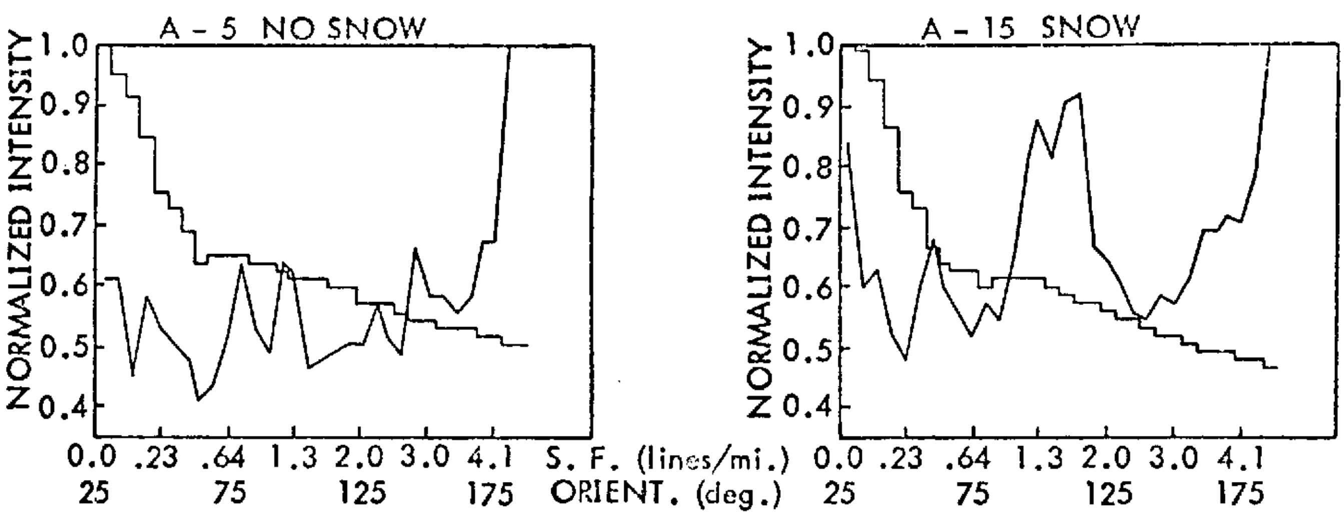


Figure 3. Detail of portion of Fig.2 enclosed in dashed lines.



A-4. Long E-W wheat fields dominate the scene resulting in a high peak at 175°. Peak at 150° is possibly due to NE trending sandhill belt along the Arkansas River that lacks fields.

A-14. Snow cover is light and fields still dominate the scene producing a curve similar to A-4. A peak in the spatial frequency curve is the result of 2-3 mile wide belt of rangeland in the southern part of the area.



A-5. Long E-W fields again prevail producing a curve with a high peak at 180°. A spatial frequency peak is due to a 2 mile wide stretch of uncultivated lowlands in the northern part of the area.

A-15. Snow cover appears to accentuate field, pasture, and range patterns creating a peak at 90° in addition to the one at 180°. The peak at 110° appears to be due to N-trending drainage that is more apparent on this image.

Figure 4. Spatial frequency and orientational curves from two sample areas.

SECTION 2.2

PHYSIOGRAPHIC PATTERN DESCRIPTORS (PARAMETERS)

This section will describe how the spatial frequency curves were modified and how parameters which describe the features in these modified curves, as well as the orientational curves, are derived.

The spatial frequency curves described in the last section were modified to enhance their ability to display features of interest. An average spatial frequency curve was calculated for the 80 non-snow sample areas. The point by point ratio between this curve and each individual spatial frequency curve was determined and these values were plotted. Two of these modified curves are shown in Figures 5 and 6. These figures show that the relative amplitudes of the various spatial frequency components are greatly emphasized. We will show in the next section that these modified spatial frequency curves characterize the sample areas very well.

FEATURE PARAMETERS

To reduce the amount of information present in the spatial frequency and orientational curves, various data processing schemes were developed to extract parameters from them. These parameters describe the geologic or physiographic features giving rise to fluctuations in the curves. To determine how well these parameters characterize each sample area, they may be used to categorize the sample areas by using the parameters as input to pattern classification algorithms.

For the purposes of this phase of the investigation, the range of spatial frequencies was divided into two bands. Band 1 contains spatial frequencies between 0.0 and 1.5 lines/mile, and band 2 contains spatial frequencies between 1.7 and 4.5 lines/mile. This division essentially separates information due to high frequency fluctuations such as occur in stream patterns in rough terrain, and low frequency information such as occur due to field patterns. This division of frequencies appears to correspond to a natural break at approximately 1.5 lines/mile.

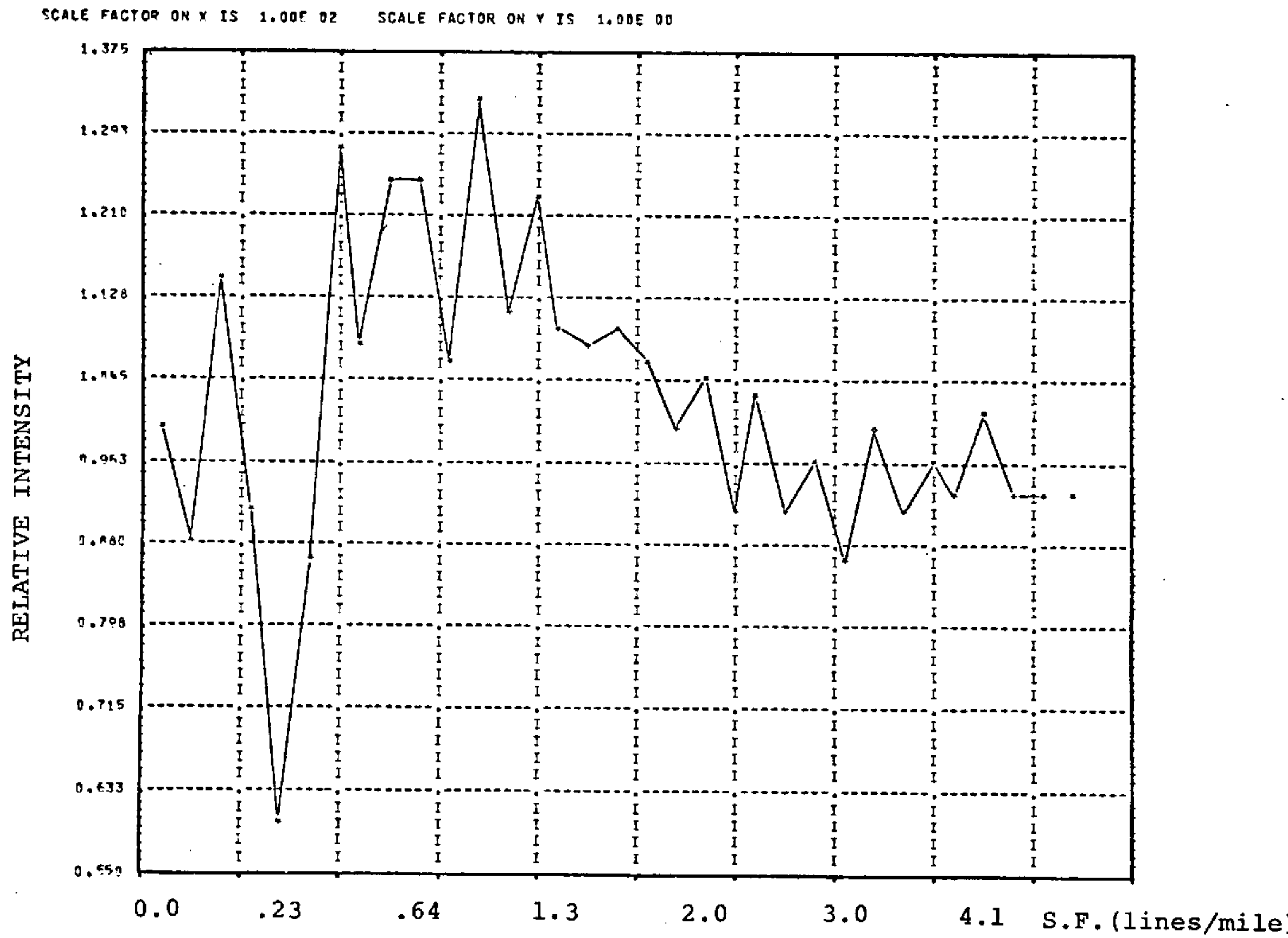


Figure 5. Modified spatial frequency curve from area A-4.

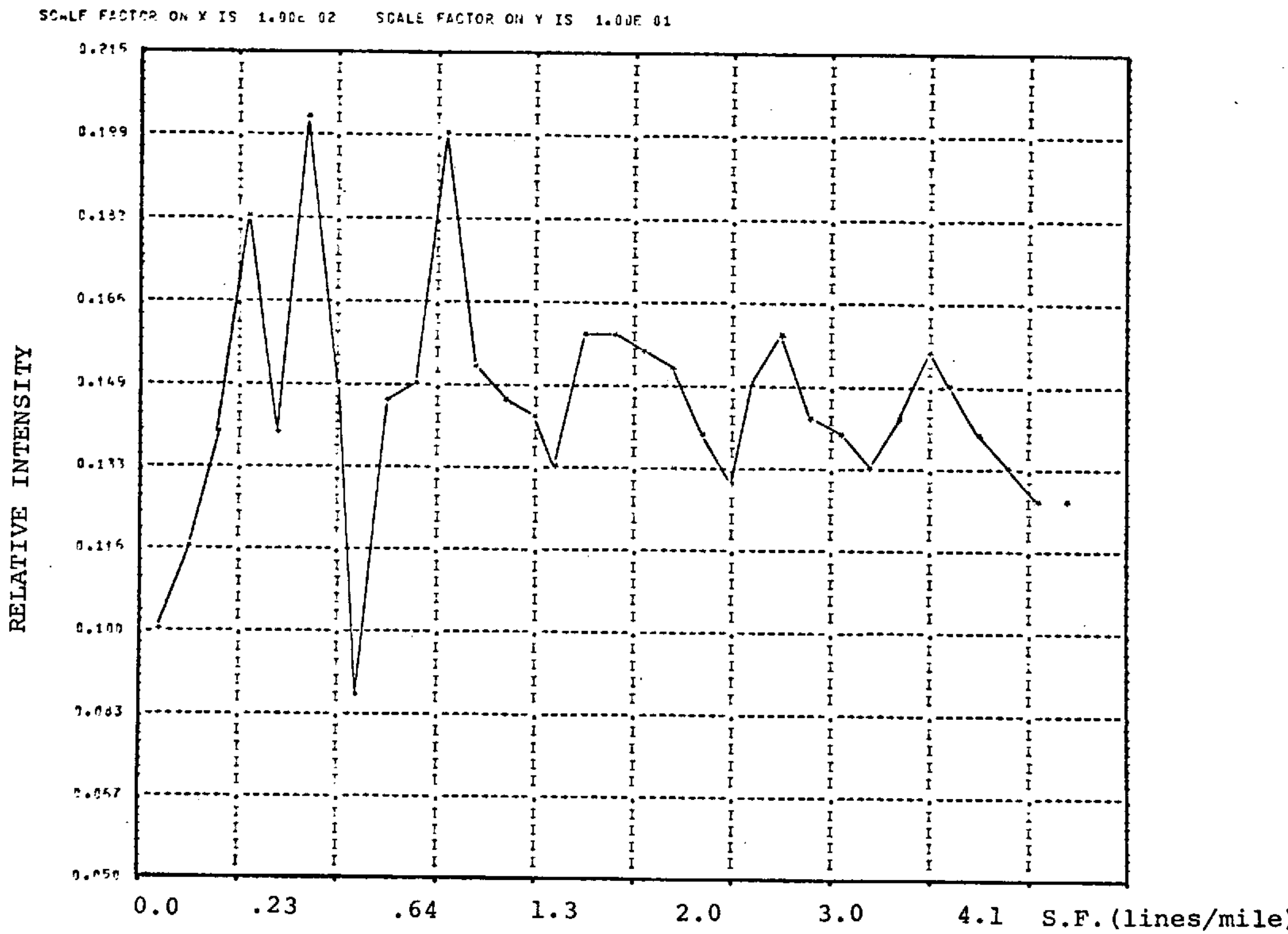


Figure 6. Modified spatial frequency curve from area A-5.

Similarly, the range of orientational data was divided into four sectors—each corresponding to 40 degrees (see Appendix B figure 2B). Sector 1 provides data on pattern orientations that produce distributions between 25 and 65 degrees clockwise from true north, sector 2: 65-105 degrees, sector 3: 105-145 degrees, and sector 4: 145-185 degrees.

Parameters are extracted from the spatial frequency and orientational curves in each range.

The following parameters were calculated from the spatial frequency and orientational curves for each of the bands or sectors listed above.

Orientation parameters:

DAV	Average value of the curve in the 40° sector
RMSD	Root Mean Square Deviation of curve from overall average in each sector
AREA	A. Area of curve above overall average in sector B. Area of curve below overall average in sector
PEAK	Number of peaks or "spikes" in curve in sector
PAKS	Number of data points above average in sector

Spatial frequency parameters:
(These parameters are derived from the modified spatial frequency curve)

DAV	Average value of the curve in each frequency band
RMSD	Root Mean Square Deviation of curve from overall average in each band
AREA	A. Area of curve above overall average in band B. Area of curve below overall average in band
DARA	A. Area of curve above the value 1.0 in band B. Area of curve below the value 1.0 in band
DYNR	DYNamic Range of curve in band
SLOPE 2	A regression line is calculated for the curve in band 2. The slope of this line is obtained.

Each parameter for all 80 non-snow and 68 snow sample areas was plotted versus their appropriate sample area category as obtained from Figure 1. Five of these parameter plots are shown in Figures 7-11 on the following pages. Three separate parameters are listed and two of these parameters are repeated for the 68 snow sample areas.

The notation '(R)' or '(W)' preceding the parameter name denotes the parameter as a spatial frequency (Ring) or Orientational (Wedge) parameter respectively.

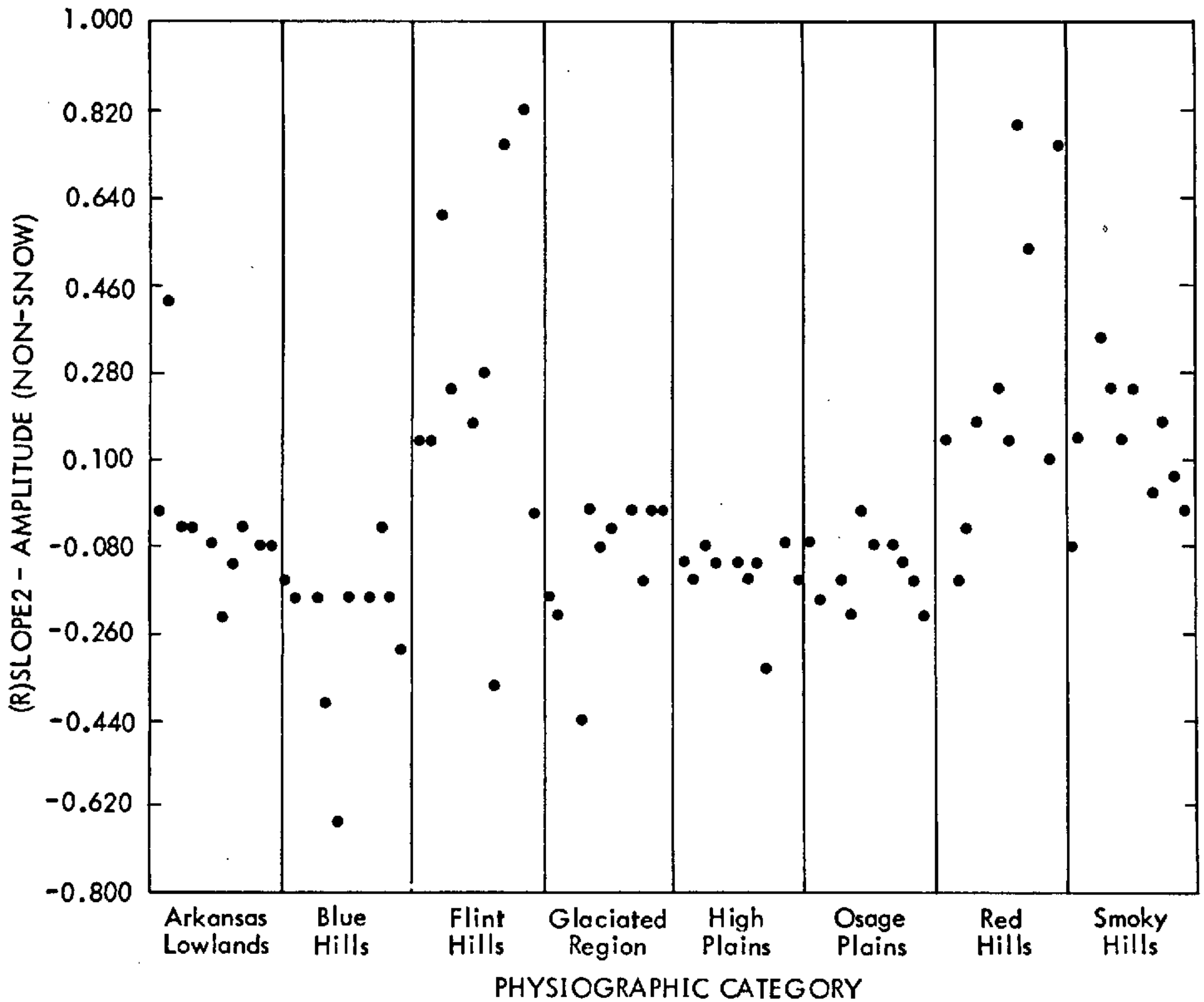


Figure 7. Parameter Plot Using the Parameter (R) SLOPE2.

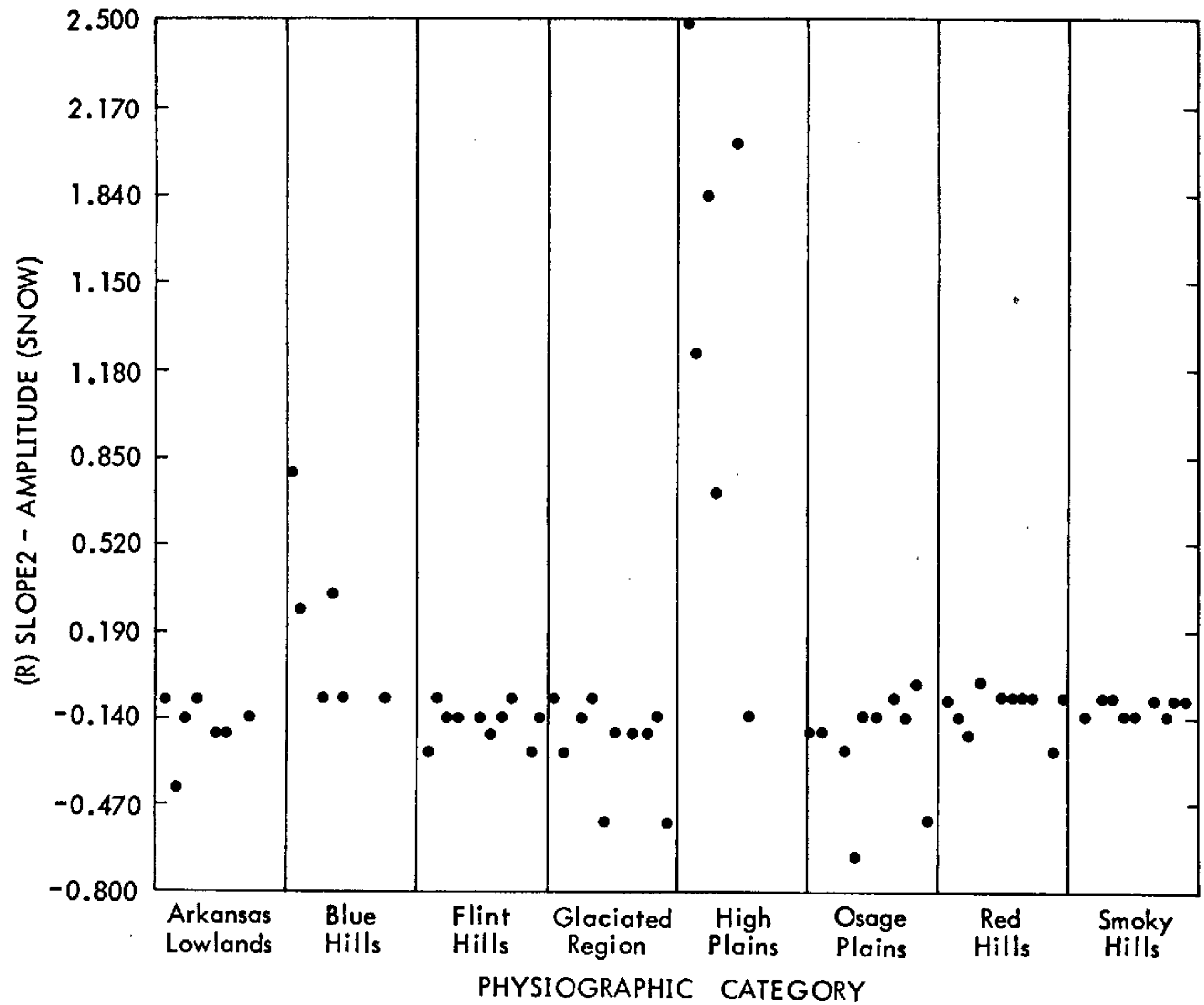


Figure 8. Parameter Plot Using the Parameter (R)SLOPE2 for the Snow-covered Sample Areas.

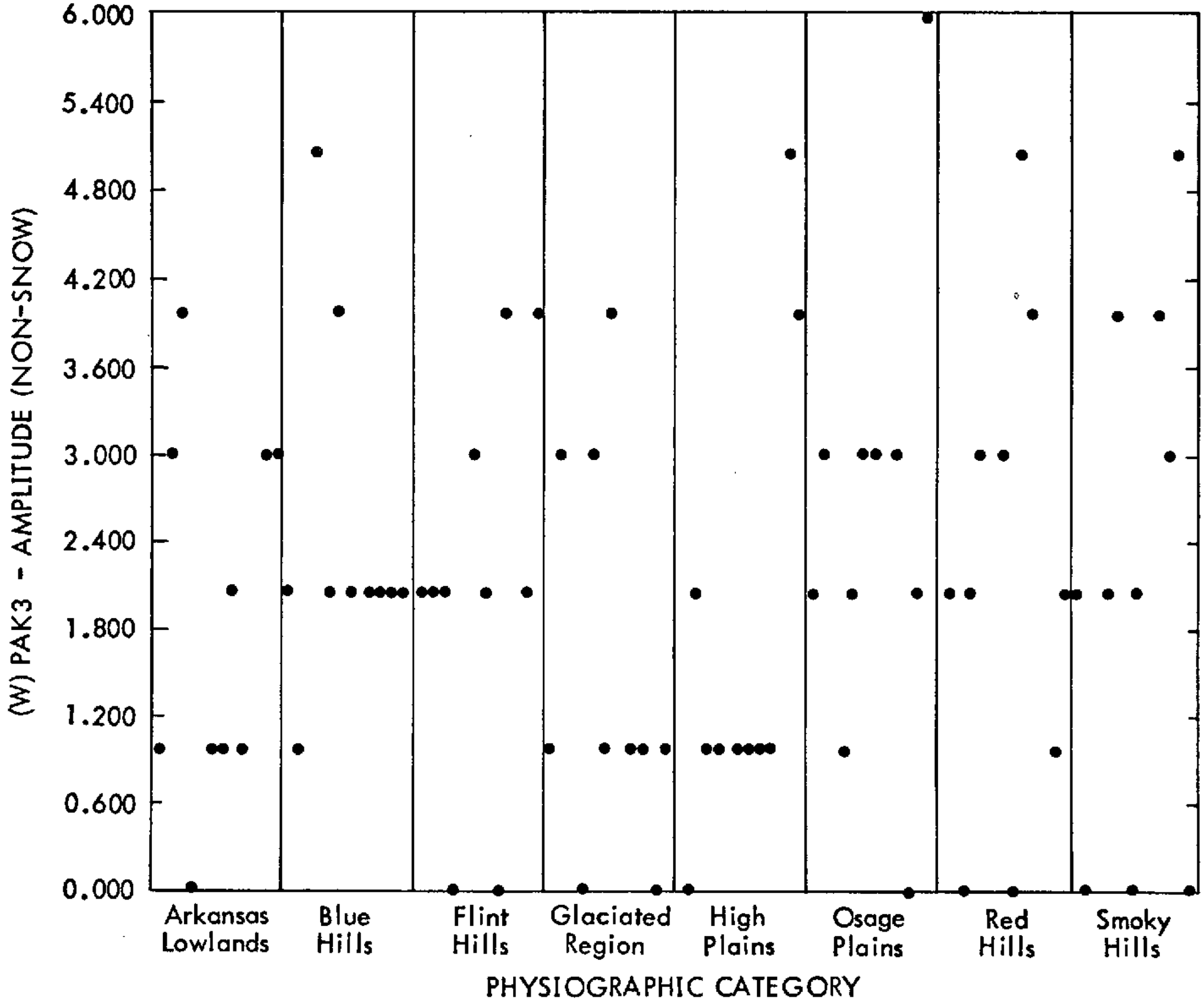


Figure 9. Parameter Plot Using the Parameter (W) PAK3.

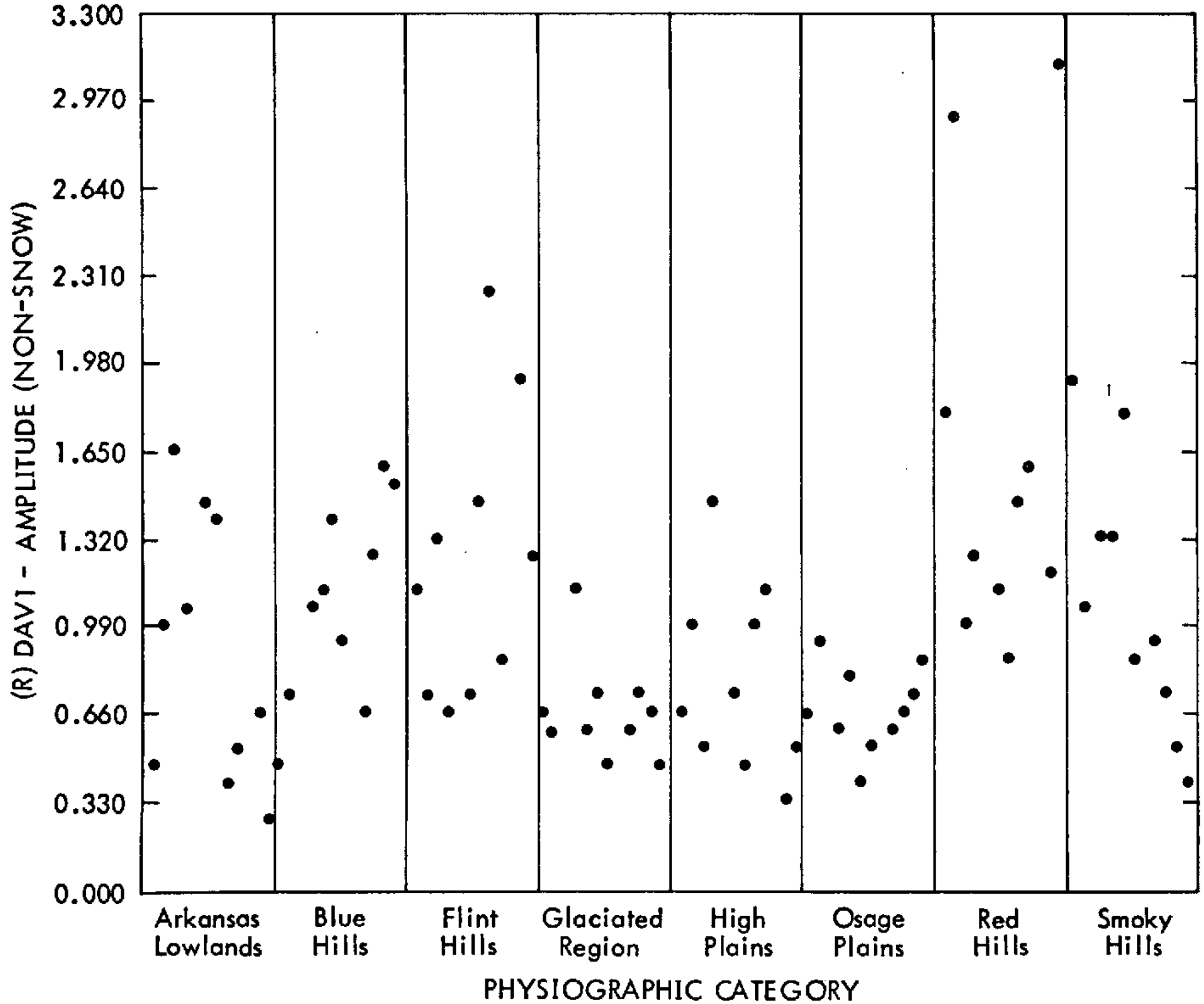


Figure 10. Parameter Plot Using the Parameter (R) DAV1.

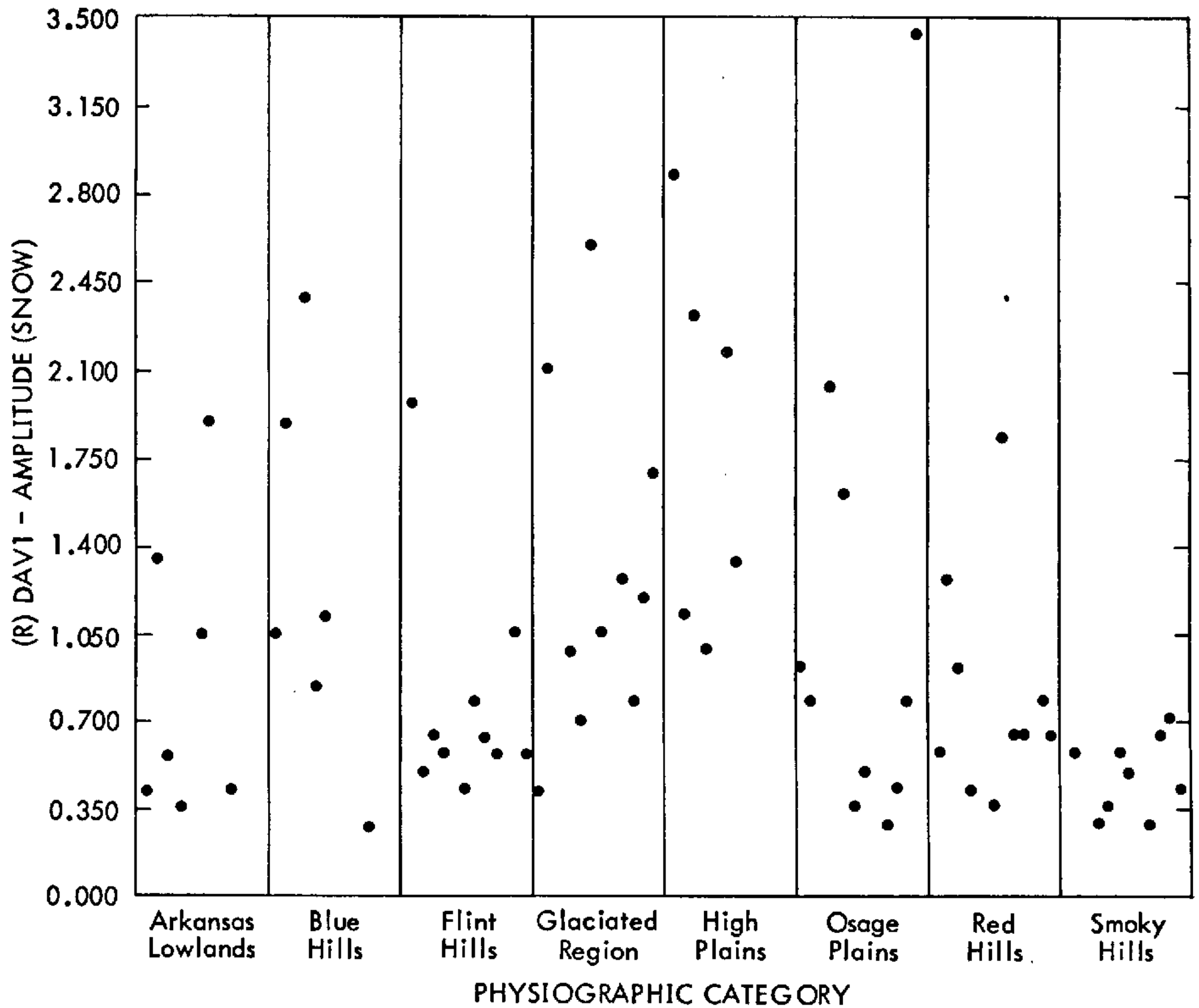


Figure 11. Parameter Plot Using the Snow-covered Sample Areas.

SECTION 2.3

CLASSIFICATION RESULTS AND ANALYSIS

Decision boundaries may be inserted into the parameter plots shown in the last section based on the distribution of the amplitudes of the parameter. If there is a clear relationship between the amplitude of the parameter and the physiographic characteristics of the sample area, then this decision boundary will discriminate between 2 large-scale physiographic ground patterns.

This was done for the parameter labelled SLOPE 2 and the results of this scheme are shown in Figure 7. As mentioned previously, SLOPE 2 is merely the slope of the regression line for the modified spatial frequency curve for the frequencies in band 2. As can be seen from the plot showing the parameter SLOPE 2(Figure 7), a decision boundary may be inserted at approximately zero slope which effectively separates the various categories. Sample areas from categories of relatively high spatial frequency content (Flint Hills, Red Hills, Smoky Hills) yield a positive slope, whereas sample areas from the other categories yield a negative value of this parameter.

This identification experiment resulted in an accuracy of 92.5% with only 6 incorrect identifications based on the original categorization of the sample areas. Sample sites represented by a square were identified as belonging to the category comprising the Flint Hills, Red Hills, and Smoky Hills; sample sites represented by a triangle were identified as belonging to the category comprising the Arkansas Valley Lowlands, High Plains, Osage Plains, Blue Hills, and the Glaciated Region.

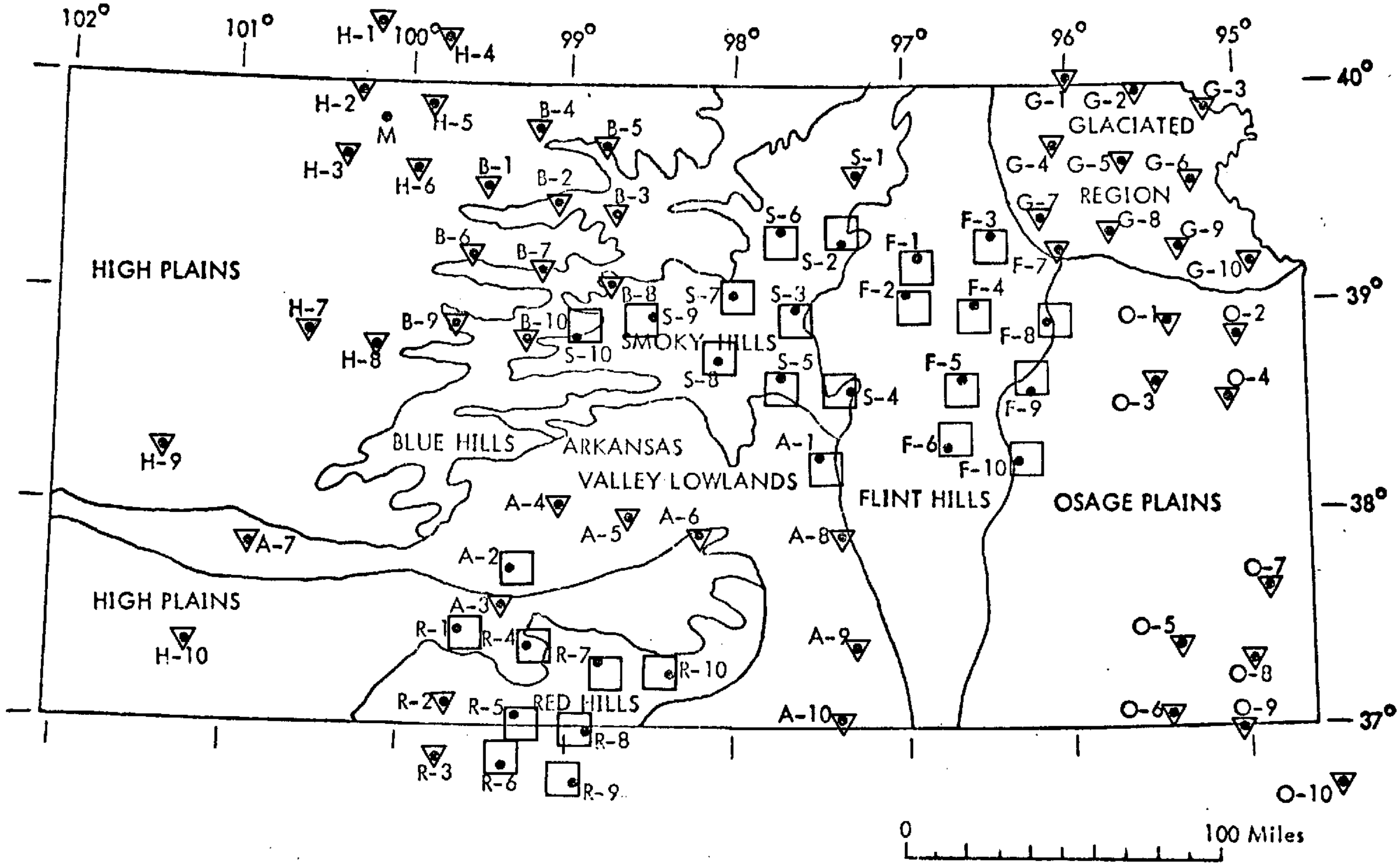


Figure 12. Classification of sample areas in terms of a decision made on the value of the Parameter SLOPE 2 for each sample area.

SECTION 3.0

PROGRAM FOR NEXT REPORTING PERIOD

During the next reporting period this investigation will be concluded. A final report will be issued which will include a summary of the work done on this project, plus the results and the analysis of these results. Conclusions, based on the manual interpretation of the spatial frequency information obtained from the optical processing system, and based on the quantitative analysis of this information, will be presented.

Work will continue during the next reporting period on the pattern recognition experiment that is presently being conducted. This experiment is based on the quantitative information mentioned above. Using various pattern recognition algorithms, we hope to accurately classify large-scale ground patterns and anomalous patterns that exist in Kansas.

An experiment is also planned to determine the bands of spatial frequencies that contain the most information with respect to specific ground features. Additional data from optical processing of the ERTS image sample areas will be taken using a reduced spatial frequency scale. Using these additional data, we hope to be able to specify which frequency bands are most significant in terms of the large-scale ground patterns in Kansas.

SECTION 4.0

CONCLUSIONS

The evidence presented in this report establishes that optical data processing of ERTS-A images can be used very successfully in identifying large-scale physiographic patterns in Kansas. It was shown that large scale physiographic patterns were identified easily based on the quantitative analysis of the information derived from the optical processing of the ERTS-A images.

It appears that the band of frequencies between 1.7 and 4.5 lines/mile contain most of the information on the physiographic character of large-scale ground patterns in Kansas. Further experiments will be conducted along these lines as stated in section 3.0.

Major conclusions based on this investigation will be presented in the Type III final report due in May, 1974.

SECTION 5.0

RECOMMENDATIONS

The recommendation presented here is repeated from the previous Type II report on this investigation.

We have only one recommendation concerning the NASA operation of the ERTS-A system. This recommendation concerns the quality of reproduction of the ERTS images we receive. Our standing order is for 70 mm negative images of MSS band 5. As a general rule these negatives are so dense as to make reproduction in our photographic laboratory very difficult.

Because of the nature of the optical data processing system which is the core of this investigation we require positive images of a high gamma. Thus, the normal 70 mm positive images provided by NASA to ERTS users are unsatisfactory for our study. This is no great problem since we have an in house photographic laboratory capable of such reproduction from suitable negatives. However, the 70 mm negatives we receive from NASA Goddard are generally extremely dense.

In addition to the difficulty encountered in the reproduction of these dense negatives, it seems that a good portion of the dynamic range of the negative must be on the shoulder of the film's H & D curve. If this is true then the effective gamma of the negative is reduced and our attempt to produce high gamma positives is made even more difficult.

We would appreciate any effort on the part of NASA Goddard to improve the recording level of the 70 mm duplicate negatives.

APPENDIX A

GEOLOGY AND PHYSIOGRAPHY OF KANSAS

Kansas lies within the Stable Interior, a large geologic province of North America occupying most of the region between the Appalachians and the Rocky Mountains. This area has suffered little in the way of intense tectonic activity since early Cambrian sediments were first deposited approximately 600 million years ago. The area which is now Kansas was the site of shallow seas during a good portion of this period. The result has been the formation and preservation of sedimentary formations (sandstones, shales, and limestones) which cover the much older pre-Cambrian basement rocks. The total thickness of these sedimentary rocks is nowhere more than 9500'. This sedimentary cover is thin when compared to sedimentary thicknesses in other parts of the country where sedimentary basins may be 20,000' to 30,000' deep.

The sedimentary formations in Kansas are relatively thin and exhibit a slight but persistent westward dip at the surface. The present day streams and rivers of the state flow in a generally eastward direction from the piedmont of the Rocky Mountains to the Missouri and Mississippi Rivers. This reflects the uplift and eastward tilting of much of the state which occurred with the formation of the Rocky Mountains. Thus the surface elevation of the state increases from the eastern border to the western boundary ranging from less than 800' to more than 4,000'. In traveling in a westward direction across the state, one not only gains elevation but crosses the outcrops of progressively younger sedimentary rocks. Because of the westward dip of the rock units and the subsequent erosion, they are arranged in a stairstep fashion with each upward step representing a younger sedimentary unit.

The lithologic makeup of a rock unit, its structural attitude and the weathering forces operating upon it determine the landforms that will form in the area of its outcrop. Because of the westward dip of sedimentary rocks in Kansas, and their layer-cake arrangement, much of the surface of the state is characterized by a series of eastward facing escarpments or cuestas. These features occur where a relatively resistant unit (such as a limestone) crops out. Such a unit tends to produce a landform having a steep eastern face and gentle western slope. This gentle back slope often extends across the outcrop of an overlying, less resistant unit (such as a shale) to the base of the escarpment formed by the next resistant unit. These escarpments are dissected by the erosive effects of the many eastward flowing streams and as a result have an irregular appearance on a map or aerial photo. But on a larger scale they maintain a general north-south orientation which is at right angles to the prevailing dip direction of the exposed rock units.

Lithologic differences are responsible for the various physiographic regions generally recognized in Kansas which are shown in Figure 1. In the eastern part of the state are the Osage Plains which are made up of a series of eastward-facing escarpments formed by outcrops of Pennsylvanian limestones and shales. The Flint Hills are actually a large escarpment formed by outcrops of a series of chert-bearing Permian limestones that are very resistant to erosion. The Dakota sandstone outcrops (Cretaceous) form the Smoky Hills upland in the North Central part of the state. Likewise, the Blue Hills are formed by outcrops of Upper Cretaceous limestones and chalks.

Beyond the Blue Hills lie the High Plains which are formed by the accumulation of sediments derived from the erosion of the Rocky Mountains to the west. Numerous aggrading streams swept eastward during the Tertiary carrying and depositing sand and gravel and forming a vast outwash plain, that is today the present land surface. Even younger deposits occur in the various prairies and lowlands associated with the Arkansas River. Some of these areas are covered with wind blown sand in the form of dunes, both stabilized and active. In the south-central part of the state are the Red Hills or Cimarron breaks marking the border of the High Plains in the vicinity of the Cimarron River, which together with its tributaries eroded into the red Permian siltstones and shales which underlie the High Plains in that area. The extreme northeast corner of the state was occupied by the Kansan glacier during the Pliestocene. As a result, the landscape was resculptured to some extent and the area was covered to varying depths by glacial deposits.

STRUCTURAL GEOLOGY

The structure of Kansas is subtle for the most part, seldom being dramatically expressed on the surface. This should be kept in mind when considering remote sensors as tools in mapping the geology or structure of Kansas.

Although faulting and folding are not intense or widespread in Kansas, joints are. According to Billings (1942), "Joints may be defined as divisional planes or surfaces that divide rocks and along which there has been no visible movement parallel to the plane or surface". As Merriam (1963, p. 254) states, "Little work has been done on jointing in Kansas, although the joints are extensively developed". Ward (K.G.S. Bulletin 191, pt. 2) in 1968 did a study of joint patterns in the Southern Flint Hills and he concluded, among other things, that the joint patterns measured showed a close correlation to regional tilting and may have been produced at the time of the tilting. He also states that, "The present drainage patterns appear to be closely related to and may be determined by the joint pattern", (Ward 1968, p. 21). He adds, like Merriam before him that "more work concerning midcontinent joint systems is justified" (Ward 1968, p. 21).

Stream patterns have long been known by geologists to reflect the underlying structures, faulting, folding and jointing. Such deformation tends to rupture competent formations creating planes of weakness along which weathering activities are accelerated and through which streams have a tendency to flow, taking advantage of the destructive work already done for them. Thus, by studying topographic patterns in an area, insight can be gained concerning the geologic structure.

Many studies have been performed by geologist using aerial photographs as an aid in structural analysis. Kelley (1960) mapped regional fracture systems for a large area of the Colorado Plateau using aerial photography. Boyer and McOwen (1964) working in Texas established a relationship between fracture patterns observed on the ground and linear features on aerial photographs. Likewise, in the Appalachian Plateau, Lattman (1958) established a correlation between bed rock joint systems and linear features on aerial photographs. These studies and many others like them involve the visual detection, measurements, and evaluation of linear features or lineaments. Such studies are limited by the interpreter's ability to detect lineaments and may be handicapped by a biased evaluation of their significant. Spatial frequency analysis may provide a means of detecting and measuring linear features on imagery which would not ordinary be detected by visual means. In addition, such analysis would not be guided by any preordained knowledge of the geologic structure, and the results would be unbiased. The small scale of the imagery used in this study negates the detection of actual fractures or joints on the ground. However, the layer linear features associated with stream traces and topographic alignments can be detected and will provide most of the information concerning geologic structure.

LAND USE

Land-use in Kansas is predominately devoted to agriculture. However, the type of agriculture practiced varies across the state, due to climate, soil, landform, and availability of water. Agricultural land-use can be correlated fairly well with the physiographic regions of Figure 1. The area east of the Flint Hills, namely the Osage Plains and the Glaciated Region, is characterized by mixed farming of the corn belt type, with generally small fields and pastures and a variety of crops grown - including corn, soybeans, milo, etc. Hay is an important crop in some areas of the southern part of this area and stock farming is a common practice. To the west lies the Flint Hills region with its areas of bluestem prairie. It is predominately a ranching area specializing in finishing out transient cattle brought in from western and southwestern ranges. The Blue Hills and Smoky Hills are also large cattle grazing regions, especially in the rougher areas where cultivation is impractical. In this same regard the Red Hills region of the south-central part of the state is also an important ranching area. Much of the arable area in the western two-thirds of the state is devoted to the raising of wheat, with the most extensive wheat growing areas in the level and fertile lowlands associated with the Arkansas River. Much wheat is also grown on the level uplands of the High Plains and in favorable areas in the Smoky Hills and Blue Hills. However, dry farming is in common practice in the western part of Kansas, where rainfall is deficient. Dry farming involves practices designed to catch and conserve the available moisture. Toward this end, dry farming often involves the fallowing of fields for one or two years in order to build up a reserve of soil moisture. Thus in any given year in the western part of the state, a sizable portion of the cultivated land will be free of planted crops. Much of the High Plains is also devoted to the grazing of cattle especially the rougher lands along streams. The southern High Plains of Kansas is an important grain sorghum growing area.

Irrigation is important in parts of western Kansas. The largest and most extensive area of irrigation is centered around Garden City, reaching from Scott City southward into Meade County and westward along the Arkansas River. This area is underlain by a sedimentary basin containing thick deposits of the Tertiary Ogallala formation. This formation is largely sand and gravels derived from the Rocky Mountain in Tertiary time. Its porous and permeable nature make it an excellent aquifer (water yielding formation) and it feeds the many irrigation wells in this area. Several crops are grown here including corn, wheat, soybeans, alfalfa, and sugar beets. Other irrigated areas in the High Plains regions also rely on the ground water stored in the Ogallala. The more recent deposits of alluvial material in the valley of the Arkansas River are also important aquifers. The tell-tale signs of irrigation on areal photos are the circular fields produced by pivitol sprinkler systems. The circular fields are quite large (1/2 mile in diameter) and are discernible on ERTS imagery as well.

The Arkansas River valley also contains areas of sand hills. In most of these areas, the sand hills or dunes are stabilized and covered by natural vegetation. Some areas are active however with dunes in formation and smaller areas of wind erosion called blowouts. Because of the rolling topography of these sand hill tracts, many are uncultivated and used as grazing areas.

On an area basis, non-agricultural land use is, of course, secondary in Kansas. The remaining land area is largely tied up in cities and towns, reservoirs and their surrounding management areas, military installations, wildlife refuges and mining areas. These land uses are largely self-explanatory. However, land use related to mining activity requires further elaboration.

Among the minerals and rocks mined in the state are lead, zinc, coal gypsum, salt, volcanic ash, limestone, sand, gravel, and clay. In addition, the state is an important oil and gas producer. Of these activities; salt, lead, and zinc mining is performed under ground. Most of the other products are mined by quarrying operations that are generally small in areal extent. The exception is the procurement of coal which is done by strip mining. Large areas in southeast Kansas bear the effects of strip mining in the form of long parallel mounds of dirt and rock which represent the overburden removed to reach the underlying coal seam. Lakes occupy many of these abandoned strip pits today and are used as a recreational resource in the area. The reclamation of strip mined land is an important issue in Kansas where the practice is in use and being expanded to new areas.

GEOLOGIC PATTERNS ON ERTS IMAGERY

In satellite imagery of an area such as Kansas with low relief, subtle geologic structure and extensive land-use, the geologic ground pattern that is most apparent is that caused by stream patterns. Pattern and frequency of streams are important indicators of the rock-type upon which they are developed. In addition, they are strongly influenced by geologic structure. Spatial frequency analysis of ERTS imagery lends itself to the study of drainage patterns by detecting those patterns which display a preferred orientation or spacing. Curves that result from such analysis may contain "signatures" that are attributable to basic geologic parameters. In addition, insight may be gained concerning structural trends by detecting stream orientations that may be influenced by joints and other structures. Such insight would be useful since little knowledge is available concerning joint trends in Kansas and their significance.

Use of spatial frequency analysis in the study of stream patterns should be guided by a knowledge of the manner in which stream patterns are expressed on ERTS imagery and how this expression varies from place to place in the state as a result of changing rock-type, landuse, climate and natural vegetation.

In Kansas, stream courses are generally expressed on ERTS imagery in four different ways:

1. Riparian Vegetation

In the eastern half of the state are many stream valleys that support denser and higher stands of vegetation than do the surrounding uplands. Cottonwoods, willows and other trees and shrubs which require large amounts of water thrive near streams that are perennial or contain water during much of the year. Such streams are relatively easy to identify on ERTS-1 images with the MSS5 band giving the best expression. On this band, riparian vegetation generally appears much darker than surrounding fields and grasslands. In the western half of the state the increased dryness restricts this type of vegetation to only the major perennial streams such as the Arkansas River and the lower Smoky Hill.

2. Pure Topographic Enhancement

Several areas in the state are largely uncultivated. For the most part, these are ranching areas that are covered with both natural and introduced grasses. Trees and shrubs are generally lacking even along streams in many of these areas. The absence of distractive patterns caused by fields and gross vegetation differences permit the enhancement of topography by differential illumination of slopes of varying orientation. This expression can be found on images covering the Kansas Flint Hills, as well as the Red Hills, Smoky Hills and dissected regions adjacent to larger streams in the High Plains.

Topographic Enhancement of drainage patterns has a much broader application in the winter at times of deep snow cover. The snow has the effect of giving the landscape more uniform reflecting properties by masking over areas of different crop and vegetation type. As a result, slope orientation becomes more critical in determining the amount of sunlight reflected to the ERTS-sensors. The lower sun angle in the winter serves to further enhance the topography. Thus an area in which stream patterns are not normally discernible may display them fully when snow-covered.

3. Land-Use

Differing land-use between stream valleys and uplands can often accentate stream patterns. This can come about in a number of ways. One involves bottom land cultivation in an area of upland grazing and occurs in association with the major streams in the Flint Hills and other hilly areas, where the level fertile flood plains offer the most desirable farming areas.

Another method by which land-use reflects stream patterns occurs in the western part of the state and is the opposite of the previously mentioned method. It is best desplayed in the High Plains and dissected High Plains area where stream valleys are often rough and lack flood plains. In this case the level upland areas offer the most ideal conditions for cultivation. The valleys which are usually too rough or rocky for farming are used as pasture.

4. Direct Stream Expression

In some situations, the actual stream beds can be delineated on ERTS imagery. This occurs in two ways. In the eastern portion of the state the larger streams usually contain water throughout the year and can often be discerned on the MSS 6 and MSS 7 bands of ERTS imagery due to the low return of infrared energy from water bodies. Thus the larger streams are often dark in comparison to the surrounding countrysides.

In a different manner, actual stream beds in the western and south-central part of the state are also expressed on ERTS imagery. In this situation, it is the dry stream beds which give a distinctive appearance. These dry streams are choked with sand, which highly reflects energy in the visible region and produces a bright appearance on MSS 4 and MSS 5 images which contrast well with the less bright appearance of surrounding fields and vegetation.

APPENDIX B

OPTICAL PROCESSING SYSTEM DESCRIPTION

In this section we will present a description of the optical processing system used for spatial frequency analysis of the ERTS images. The optical processor has three main elements: a laser, optics, and a Recognition Systems, Inc., Diffraction Pattern Sampling Unit (DPSU). The system configuration is shown in Figure 1B. An ERTS-A 70 mm positive transparency is used as the input for this system. The optical processing system can be regarded as a two step system. First, an area of the ERTS transparency (sample area) is illuminated by the incident laser beam. This beam is focused by the lens (dashed lines, Figure 1B) so that the point source produced by the spatial filter is imaged at a distance z + f in front of the lens. The resulting light intensity distribution at this point is the optical Fourier transform or amplitude frequency spectrum of the portion of the ERTS image illuminated by the beam. Second, the intensity distribution (frequency spectrum) of the ERTS image is sampled by the DPSU.

The DPSU consists of a 64 element photodiode array (shown in Figure 2B) used to detect the light intensity incident upon each element, and electronics which amplify and digitize the output from each diode in the array. The diode array is composed of 32 wedge-shaped photodiodes and 32 annular ring photodiodes. The intensity distribution across each photodiode is recorded. The data from the optical processor are then used in a computer program and are calibrated, printed, and plotted.

The spatial frequency in the transform plane is related to other system parameters by:

$$s = r/d\lambda$$

where
- s = spatial frequency in transform plane
- r = distance in transform plane measured from optical axis
- d = distance from image transparency to detector
- λ = wavelength of laser radiation = 6328 Angstroms

The spatial frequency obtained from this calculation is converted to ground spatial frequency using image to ground scale. The resulting curves which are plotted by the computer program are then $|c(f)|^2$ or intensity vs. frequency and $|c(\phi)|^2$ or intensity vs. angle. These are plotted in terms of ground spatial frequency in cycles per mile and direction in compass degrees from north.

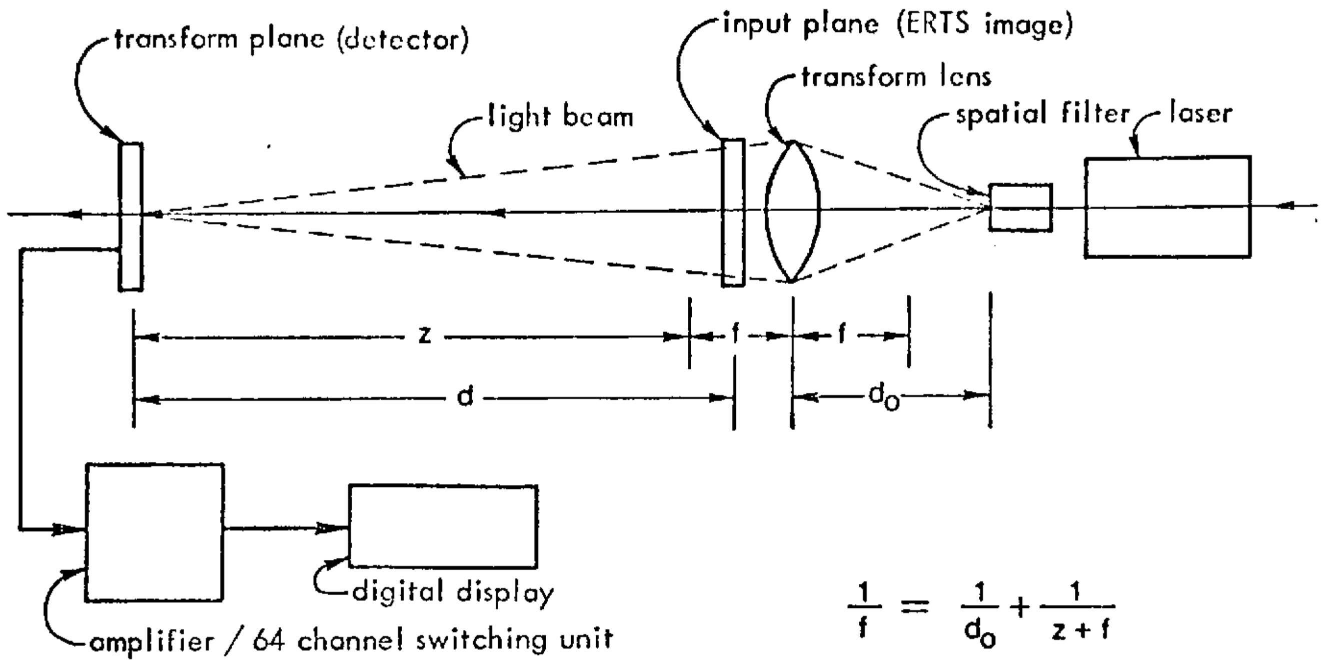


Figure 1B. System configuration

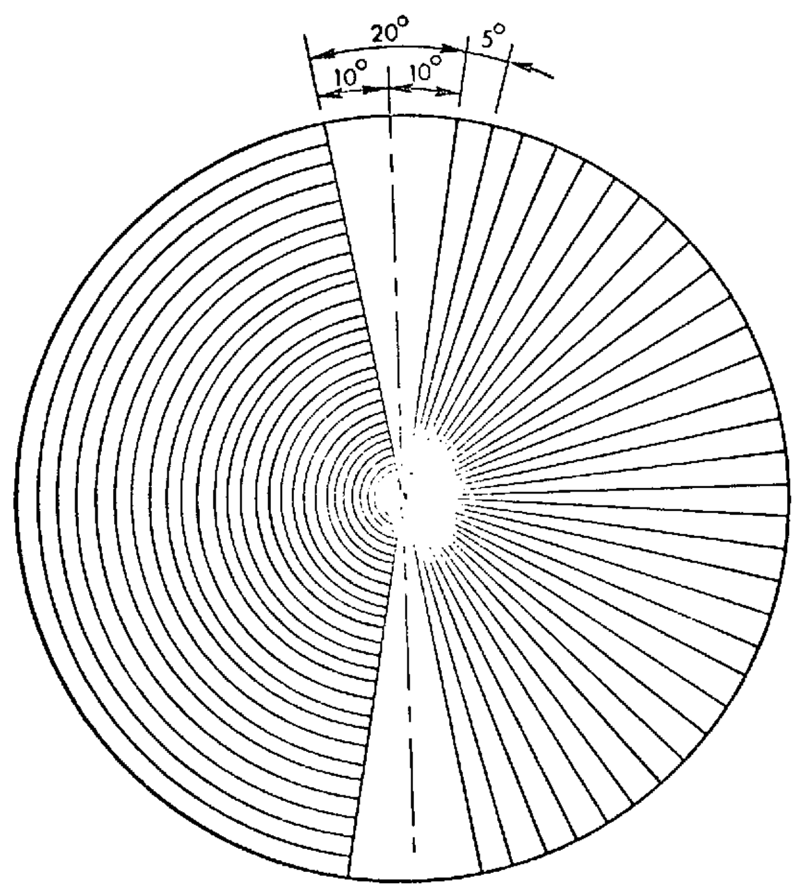


Figure 2B. Detector geometry

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