R-266

NASA CONTRACTOR
REPORT

NASA CR-150227

(NASA-CR-150227) PHOTOMORPHIC ANALYSIS TECHNIQUES: AN INTERIM SPATIAL ANALYSIS USING SATELLITE REMOTE SENSOR IMAGERY AND HISTORICAL DATA Final Report (Environmental and Regional Research) 268 p HC A12/MF A01 G3/43
N77-22581
Unclas
25109

# PHOTOMORPHIC ANALYSIS TECHNIQUES:
## An Interim Spatial Analysis Using Satellite Remote Sensor Imagery and Historical Data

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January 1977

Final Report

Prepared for:

NASA - GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

TECHNICAL REPORT STANDARD TITLE PAGE

| | | |
|---|---|---|
| 1. REPORT NO.<br>NASA CR-150227 | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |

4. TITLE AND SUBTITLE

Photomorphic Analysis Techniques: An Interim Spatial Analysis Using Satellite Remote Sensor Imagery and Historical Data

5. REPORT DATE

January 1977

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

Harold F. Keuper, Robert W. Peplies and Robert P. Gillooly

8. PERFORMING ORGANIZATION REPORT #

ERRA No. 74-17(R)-Y

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Environmental and Regional Research Associates, Inc.
P. O. Box 1274
Johnson City, Tennessee 37601

10. WORK UNIT NO.

11. CONTRACT OR GRANT NO.

NAS8-31329

12. SPONSORING AGENCY NAME AND ADDRESS

National Aeronautics and Space Administration
Washington, D. C. 20546

13. TYPE OF REPORT & PERIOD COVERED

Final
Contractor Report

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This work was sponsored by the Marshall Space Flight Center under the technical monitorship of the Data Systems Laboratory.

16. ABSTRACT

The objectives of this research were (1) to make the methodologies and procedures associated with the photomorphic approach more objective (as compared with prior intuitive and subjective classification) through analysis and evaluation of various machine-scanning and/or computer-based techniques; and (2) to examine in some detail the nature and extent of the actual or potential user-community for the approach and any by-products of employment of the approach, particularly, in the context of regional planning activities. The scope of the research includes a discussion of photomorphic analysis, selection of a 32-county test site centered on the Tennessee-Tombigbee Waterway, and techniques of tonal and textural signature analysis. The investigation included delimitation of photomorphic regions, especially as applied to Landsat imagery; inadequacies of existing classification systems; studies of tonal and textural characteristics, pattern recognition, and Fourier Transform analysis; and optical experiments. Hypotheses and methodologies were proposed and tested in the field; at least in part. It is concluded that the analysis methods investigated are useful, but are more sophisticated than most users are able to implement. Using sophisticated equipment and methods, the study makesspecific recommendations relative to the selected test site (the Tennessee-Tombigbee Waterway region). The report includes a comprehensive bibliography.

17. KEY WORDS

Remote Sensing; Optical Processing; Regional Analysis

18. DISTRIBUTION STATEMENT

Unclassified - Unlimited

J T Powell

J. T. Powell, Director, Data Systems Lab

| | | | |
|---|---|---|---|
| 19. SECURITY CLASSIF. (of this report)<br>Unclassified | 20. SECURITY CLASSIF. (of this page)<br>Unclassified | 21. NO. OF PAGES<br>265 | 22. PRICE<br>NTIS |

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

# TABLE OF CONTENTS

# LIST OF FIGURES

## LIST OF TABLES

# FOREWORD

The project final report which follows is an attempt to summarize the findings of a project entitled: "Develop Photomorphic Analysis Techniques and Define User Requirements." The project was initiated by Environmental & Regional Research Associates, Inc. (ERRA), of Johnson City, Tennessee, and was subsequently funded by the National Aeronautics & Space Administration (NASA) through the facilities of George C. Marshall Space Flight Center (MSFC), at Huntsville, Alabama, under NASA Contract No. NAS8-31329, dated effective 11 February 1975.

It is a difficult task, at best, to evolve a coherent statement of results achieved in the course of a research effort which consisted of such apparently diverse study elements. In the case of the present report, this difficulty has been compounded by the fact that the investigation, as it was originally proposed and as it has subsequently evolved, has quite obviously raised more questions than it has answered. While this is not an unusual feature of research directed at the apparent margins of an identifiable technological state-of-the-art, such recognition does little, if anything, to aid the investigators in the task of "justifying" the work carried out.

Therefore, the report which ERRA has written may be seen to be a blend of cautious optimism tempered by a clear recognition that, quite possibly, the project was based in large measure on an idea whose time has not yet come!

For the most part the project report follows the tentative outline as submitted as an Appendix to Monthly Progress Report No. 12/Bi-Annual Report No. 2 of the referenced contract, dated 23 February 1976. The report includes a final section of conclusions and recommendations regarding the research project and possible future modifications, extensions and extrapolations therefrom.

# CHAPTER I: NATURE AND SCOPE OF THE PROBLEM

## Problem Statement

The project for which this is the final report represents a continuation and extension of work by several investigators concerned with the delimitation of regional boundaries and other areal patterns through the use of spacecraft/satellite imagery and photography and verified by modified "ground truth" procedures. These areal patterns, called photomorphic units or photomorphic regions, had heretofore been intuitively and subjectively classified and mapped using various types of remote sensor returns, including CIR photography, radar, and black-and-white photography. In addition, promising photomorphic mapping results had been obtained previously from the employment of small-scale photomosaics, Apollo 9 color photography, and ERTS-1 (LANDSAT) imagery.

In general, the objectives and, hence, the problems upon which this project was based have been: (1) to make the methodologies and procedures associated with the photomorphic approach more objective through analysis and evaluation of various machine-scanning and/or computer-based techniques; and (2) to examine in some detail the nature and extent of the actual or potential user-community for the approach and any by-products of employment of the approach, particularly, in the context of regional planning activities.

The specific elements and work tasks of this project are considered in greater detail under the section entitled: "Specifications of the Present Investigation" below:

## Photomorphic Analysis

Introduction.--The concept of the region and the process of regionalization are vital concerns to all those disciplines which attempt to clarify the spatial distribution of both physical and cultural phenomena. As such, the foundations of regional analysis rest upon a diverse array of literature, including the fields of geography, geology, sociology, public administration, urban and regional planning, hydrology, development economics, and agriculture, to name but a few.

Although there appears to be no single approach to the definition and analysis of regions (see for example, Pattison, 1963; Hartshorne, 1959; and Harvey, 1969), there is clear evidence in the contemporary period of a trend to avoid philosophical differences and to attempt to evolve analytical methodologies which focus more on the "function" of regions than on the aspects of "form" which characterize earlier strategies. That is, human occupance and, in particular, planning for future human occupance of the surface of the earth has come to assume a larger and larger significance in the evolution of regional research approaches. While the distinction between regions of "fact" and regions "by act" (Dickenson, 1970) is probably as true today as it ever was; and while it is still likely that to "Westerners," particularly Americans, regions are mental constructs, while to "Easterners" regions tend to be more concrete objects (Grigg, 1967); common ground between these apparently divergent points-of-view is now based in large measure on the recognition that, whatever the mental and/or sensory perceptions involved, regions involve spatial envelopes in which humankind lives, moves and otherwise acts to order its overall environment; that is, to plan. Thus, one might infer that the most highly-prized information sought from regional analysis is the ability to distinguish between and among the region as it _was_, as it _is_, and as it _might become_. To many analysts, the proper route to this information is through a direct consideration of the specific relationships which exist between regional form (morphology) and regional function.

_Morphological/Functional Analysis_.--Well before the advent of aerial photographic interpretation as a tool for regional analysis, it was recognized that the most significant aspect of regional character was the interdependence of regional (areal) phenomena (Sauer, 1925). In addition, it was seen that "landscape," the total aspect of regional character, consisted of "a distinct association of forms, both physical and cultural" (Sauer, 1925; Leighly, 1965). Simply stated, these concepts, when applied to the various images produced by remote sensors, become very useful to regional analysis efforts.

Numerous researchers have used remote sensor returns, including air photos and spacecraft/satellite imagery, to describe and explain regional land use characteristics. Among others, Broeck (1932), Marschner (1959), Thrower (1966), and Hart (1968) employed air photos to systematically describe the morphological and functional traits of landscapes of a wide variety. Following the lead established by Marschner, Austin and others compiled _Major Land Resource Regions and Major Land Resource Areas of the United States_ for the Economic Research Service of the U. S. Department of Agriculture (Austin, 1965). More recently, in 1970 and 1971 there appeared a five-volume air-photo atlas of the United States (Baker and Dill, 1970 a & b, 1971 a,b, and c), in which the major agricultural regions and subareas of the United States were delimited by their photographic images. Somewhat unfortunately, however, no attempt was made in this series to regionalize whole landscapes, either cultural or physical. Instead, work until quite recently has, in the main, been limited to illustrating various individual landscape traits.

MacPhail noted that identifiable patterns of broad areas could be recognized in terms of similar patterns of tone and texture on photomosaics in work carried out in cooperation with the Chilean Development Corporation (MacPhail, 1971). These patterns appeared to be the result of a composite of several terrestrial features--field patterns, fence lines, drainage characteristics, crop types, surficial rock cover, surface configuration, vegetation, and other physical and cultural elements. The repetitive patterns of similar image characteristics (mainly tone and texture) were called <u>photomorphic units</u>. MacPhail stated that:

> . . . "Photomorphic" units provide useful supplementary information relating to land use. The photomorphic areas are composite photographic images of the cultural and physical landscape seen on photomosaics. Once delimited, the units are useful as a base for organizing small-area sampling of a large region. . . . The field samples yield detailed information on cropping techniques, land tenure, and size of proprietorships. The photomorphic areas also help to correlate several medium-scale thematic maps such as those of general land use, land capability, soil types and geomorphology. . . . The organization of a regional hierarchy of rural land types is a logical succession. This approach is useful to agricultural planners, land economists, soil scientists, agrarian reform technicians, and specialists in remote sensing.

Researchers have also investigated regional forms which appeared on radar returns of the Asheville Basin made by a Westinghouse aircraft in November, 1965. Similarities of texture and tone were used as criteria to identify these areas (Nunnally, 1968). These interpreted regions closely correspond to regions called "occupance formations" (i.e., regions defined according to similarities of assemblages of landholding types) depicted by Peplies in the same area (Peplies, 1968). Peplies noted that occupance formations could be equated to regions possessing similar planning problems. The method employed to identify these formations, however, was through field investigation and examination of large-scale air photos, a very costly and time-consuming approach.

Peplies and Wilson applied the photomorphic unit concept to an area in northern Alabama using an Apollo 9 photograph (Peplies and Wilson, 1970). They found that they could relate regional planning problems to the photomorphic units which they were able to identify in the area, especially if the large characteristics on the spacecraft photography were the result, at least in part, of the earth features involved in the problem (e.g., poor drainage conditions produced images which had a mottled appearance). They were also able to establish a classification of priorities for the identified planning problems on the basis of the photomorphic "regionalization." Peplies and Wilson found, further, that spacecraft photography was superior to either photomosaics or "exotic" sensor systems (e.g., radar) for photomorphic mapping purposes, because of (1) the large area covered, (2) a single solar gnomonic effect for the entire photograph, and (3) better resolution than radar, infrared, or other similar remote sensor returns.

The techniques employed in the delimitation of photomorphic areas by MacPhail, Nunnally, Peplies and Wilson, however, were largely subjective, and based to some degree on intuitive photo-interpretor reactions. Rehder (1973) and Alexander (1973) applied the photomorphic concept to ERTS imagery, but in a rather restricted and somewhat primitive manner. More recently, Peplies and Flynn completed a research effort aimed at making the conceptual photomorphic approach more objective (Flynn, 1974).

Peplies and Flynn recognized the problems inherent in the use of the intuitive approach to photomorphic units and developed a subjective classification system which is based on two photo elements--tone and texture (Peplies and Flynn, 1972). The classification was a modified version of a system developed by Barr and Miles for selecting engineering sites from radar imagery (Barr and Miles, 1970). Four tonal categories--dark, medium, light, and very light; and four textural categories--smooth, grainy, speckled, and rough were defined. It was believed initially that accuracy could be preserved in delineating and labelling the tonal and textural types identified on the photography by keeping the classification deliberately general. It was discovered, however, that this delineating factor <u>per se</u> was a major obstacle in and drawback to the investigation.

The subjective classification did serve three major functions. First, it served as a workable guideline for delineating photomorphic units. Second, it provided a means for describing and labelling the structural areas so delineated. Third, it provided a means whereby the interpreter (human or machine) could be "trained" to report image characteristics as they appeared on the spacecraft photography. Nevertheless, the subjective approach had significant drawbacks. In addition to that described above, one set of problems which can be identified as <u>perceptual</u> involve the "human judgement" factor between and among interpreters, and the other involves the question of size and shape of photomorphic units. The latter problem set was considered operational. To attempt to resolve both sets of problems, a test of microdensitometer-computer-printout techniques was undertaken.

Peplies and Flynn refined a computer program to determine the average densities of tones associated with areas (Peach, 1971a). The procedure followed was to have the microdensitometer read the density values of the Apollo 9 photograph in question. Readings were based on 50 micron settings (equivalent to a ground resolution of from 200-300 feet) at 50 micron raster settings. Median density readings were then determined for circular control areas. The size of the circle was determined by expanding circles with a common center at regular increments until a steady state (or knick point) of median values was reached. After performing the same operation at several locations, the circle size at which median values began to "level off" was accepted as standard.

It is believed that the sizes of circular control areas are environmentally modulated. For example, the circle size accepted for the Mississippi delta would be much smaller than a control circle for the Great Plains or the arid west where the frequency of image changes would be much smaller within the same size area. The circle size finally employed by Peplies and Flynn in the Mississippi Delta experiment consisted of 3,000 data points, or five square miles. <u>While the procedure described provides a satisfactory means whereby the average tonal density could be portrayed, a corresponding procedure has yet to be developed for the computer analysis of textural traits.</u>

It was against this background that the present project was initiated and carried out.

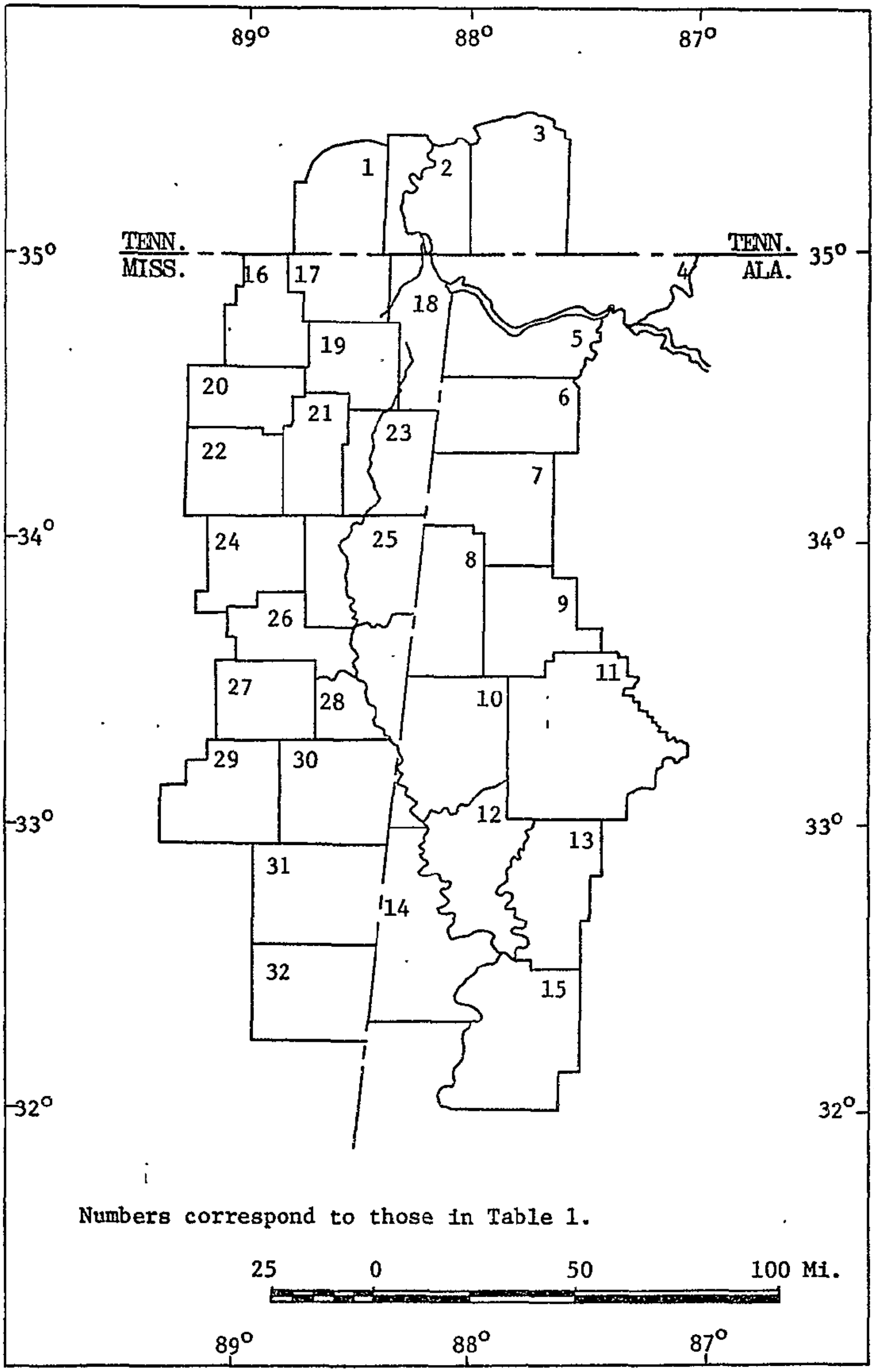
## Test Site Selection

Study Area.--Bearing in mind the research objectives and the contract mandates of the project, following preliminary consultation with MSFC Contracting Officer's Representatives (COR) and other project-related MSFC technical personnel, it was agreed that the general area of the proposed Tennessee-Tombigbee Waterway would serve most satisfactorily as a study area for the project. It was concluded, and so directed by the MSFC COR, that knowledgable parties within the management of the Tennessee-Tombigbee Waterway Development Authority (T-TWDA) be contacted and invited to assist ERRA in the selection and designation of specific test site localities within the T-TWDA area of concern and jurisdiction.

Discussions were held between ERRA and Mr. Bruce J. Hanson of the T-TWDA at Authority Offices in Columbia, Mississippi, to determine the specific data-gathering and analytical needs of the T-TWDA which might be served by the present project. It was Mr. Hanson's conclusion that the waterway area between Pickwick Landing Dam (Tennessee) in the north, and Demopolis, Alabama, in the south, represented the primary area of T-TWDA concern.

Consequently, the 32-county area depicted in Figure 1 and Table 1 was delimited as the general study area for the project. The selection of large-scale test sites was left to the discretion of ERRA project personnel inasmuch as the identification of such sites would largely be a function of, and, therefore, delimited on the basis of, the photomorphic mapping process itself. (A further constraint on the size and

Figure 1: 32-COUNTY PROJECT STUDY AREA



Numbers correspond to those in Table 1.

## TABLE 1

## IDENTIFICATION OF COUNTIES INCLUDED IN STUDY AREA

### TENNESSEE COUNTIES

| | |
|---|---|
| 2 | Hardin |
| 1 | McNairy |
| 3 | Wayne |

### ALABAMA COUNTIES

| | |
|---|---|
| 5 | Colbert |
| 9 | Fayette |
| 6 | Franklin |
| 12 | Greene |
| 13 | Hale |
| 8 | Lamar |
| 4 | Lauderdale |
| 15 | Marengo |
| 7 | Marion |
| 10 | Pickens |
| 14 | Sumter |
| 11 | Tuscaloosa |

### MISSIPSSIPPI COUNTIES

| | |
|---|---|
| 17 | Alcorn |
| 24 | Chickasaw |
| 26 | Clay |
| 23 | Itawamba |
| 31 | Kemper |
| 32 | Lauderdale |
| 21 | Lee |
| 28 | Loundes |
| 25 | Monroe |
| 30 | Noxubee |
| 27 | Oktibbeha |
| 22 | Pontotoc |
| 19 | Prentiss |
| 16 | Tippah |
| 18 | Tishomingo |
| 20 | Union |
| 29 | Winston |

Numbers Correspond to those on Figure 1.

extent of large-scale test sites was seen to be the operational characteristics and time availability of the MSFC optical bench facilities which were to be employed in various aspects of the investigation.)

## The "User Requirements" Parameter

Regional Planning Concerns.--By virtue of the emphasis placed upon the application of the photomorphic concept to the satisfaction of the data requirements of the user-community in the present project, it was an *a priori* assumption of the ERRA project personnel that attention should be addressed specifically to regional planning potentials for the photomorphic mapping concept. Peplies and Wilson (1970) had earlier determined the functional utility of the concept in this regard and it was deemed appropriate to further explore this crucial question.

Regional planning and management are direct extensions of the basic concepts of planning - the management and allocation of resources in specific time periods to meet specific goals and objectives - which focus at various jurisdictional levels on the use of private lands, the management of public lands, and the allocation of public funds.

The contribution of remote sensing technology to regional analysis has been well-documented of late (see, for example, ASP, 1975). The basic question to ask of the technology, however, is whether it can be directed and focused so as to provide data and information that will directly satisfy the needs of the planner and/or decision-maker who is responsible for implementing land-management policies within regions which are politically-defined. Both the effectiveness and the cost-savings associated with a particular data source, timeliness, compatibility with other information sources, and other features of data and subsequently derived information are the essential criteria for determining the potential usefulness of remote sensing tools (NRC, 1975; Peplies and Keuper, 1975).

Thus, a most essential question which governed the structure and conduct of the present project became the extent to which the application of the photomorphic concept satisfied the data and information requirements of a broad regional planning agency through the employment of data-gathering processes based upon hyper-altitude and satellite-based remote sensing systems.

## Specifications of the Present Investigation

The specific objectives and work tasks associated with the present project were as follows:

1. To expand and extend previous research efforts aimed at the recognition of tonal signatures pertinent to the derivation of photomorphic regions. It was intended that this objective/task would be accomplished, either in whole or in part, through the development of computer-microdensitometer algorithms which use tonal signature characteristics as a basis for pattern recognition and the delimitation of photomorphic regions useful for urban and/or regional planning purposes.

2. To expand and extend previously-suggested research aimed at the recognition of textural signatures pertinent to the derivation of photomorphic regions. It was intended that this objective/task would be accomplished, in whole or in part, through the development of, and experimentation with, optical bench/Fourier transform/computer

procedures not previously undertaken in connection with research of the type focused upon in this project. The optical bench facilities of MSFC were to be employed in this phase of the research effort. Since, as indicated above, the identification and delimitation of photomorphic regions had not heretofore been undertaken through employment of these procedures, close liaison between ERRA and MSFC became a critical requirement of this project phase so as to ensure maximum interchange of methodological development. It was agreed that such an interchange would assist the MSFC optical bench group with tasks involving assembly, fabrication, and calibration of the coherent optical equipment upon which this phase of the project was deemed to be highly dependent.

3. To expand and extend previously-suggested research directed at the derivation of procedures whereby tonal and/or textural signature recognition tasks could be accomplished via automatic classification techniques of various degrees of sophistication. It was specifically intended that this objective be accomplished via joint ERRA-MSFC consideration of the problems inherent in a union of such diverse procedures under the constraint of available automatic systems. Again, it was deemed essential to this objective that a close liaison be maintained between ERRA and MSFC.

4. To assist MSFC, by whatever means attainable, in the task of defining data types and formats and derivable information seen to be required by the user-community toward which the project was aimed (i.e., urban and regional planners). Although the photomorphic regional concept was to be the main thrust of this objective/task,

specification of user data requirements was not necessarily to be limited to consideration of the photomorphic concept per se.

The most satisfactory attainment of these objectives was perceived to be dependent upon experimentation involving the following elements:

A. Methods for defining tonal signatures as they appear on remote sensor returns through employment of a computer directly, or via a computer/microdensitometer interface;

B. Methods for defining textural signatures, especially through the use of the optical bench to generate power spectra for signature identification based on Fourier transform relationships;

C. Procedures whereby the two afore-mentioned tasks might be joined to automatically define photomorphic regions;

D. Analytical procedures for the examination of temporal changes and other variations associated with the sequential delineation and analysis of photomorphic regions;

E. Establishment of ground truth procedures for sampling and testing discernible variables seen to contribute to variations in characteristics between and among photomorphic regions; and

F. Specifically identifying the pragmatic value of the photomorphic concept as related to an operational regional planning organization of the T-TWDA type.

# CHAPTER II: PHASES OF THE INVESTIGATION

## Imagery Selection

The EROS "Browse File" located in the offices of the Maps and Surveys Branch of the Tennessee Valley Authority (TVA) was employed for the purpose of selecting LANDSAT imagery suitable to the needs of the investigation. The dominant selection criteria applied were: (1) sequentially derived images covering the full extent of the study area; (2) "zero," or minimal, cloud cover over the study area on all images; and (3) sequentially derived images for two distinct time periods sufficiently far apart to allow for experimentation with the detection of temporal change.

Suitable imagery, satisfying all three selection criteria, was located among that obtained during LANDSAT passes over the study area on Saturday, 17 November, and Thursday, 6 December 1973, and on Tuesday and Wednesday, 12 and 13 November 1974. Specification of the imagery selected is shown in Table 2.

The imagery chosen for analysis was procured from the EROS Data Center for both spectral Bands 5 and 7 and in both the 2.2 inch/5.588 cm (1:3,369,000) black-and-white film negative and the 29.2 inch/74.168 cm. (1:250,000) black-and-white positive paper print formats. It was believed that the 2.2 inch/5.588 cm. negative format would facilitate photomorphic analysis via the microdensitometer and that the 29.2 inch/74.168 cm. positive format would allow direct correlation with the readily available 1:250,000 topographic quadrangle sheets for the study area (see Table 3). A total of seven (7)

## TABLE 2

## SPECIFICATIONS OF LANDSAT IMAGERY EMPLOYED IN PROJECT

| Scene Identification No. | Microfilm Reel No. | Frame No. | Date |
|---|---|---|---|
| 1973 | | | |
| 81482155255N000 | 10018-0171 | 0157 | 17 November |
| 81482155325N000 | 10018-0172 | 0158 | 17 November |
| 81482155345N000 | 10018-0173 | 0159 | 17 November |
| 81501155805N000 | 10018-0813 | 0147 | 6 December |
| 81501155825N000 | 10018-0814 | 0148 | 6 December |
| 81501155855N000 | 10018-0815 | 0149 | 6 December |
| 81501155915N000 | 10018-0816 | 0150 | 6 December |
| 1974 | | | |
| 81842154305N000 | 10031-0041 | 0038 | 12 November |
| 81842154325N000 | 10031-0042 | 0039 | 12 November |
| 81842154355N000 | 10031-0043 | 0040 | 12 November |
| 81843154825N000 | 10032-0055 | 0122 | 13 November |
| 81843154845N000 | 10032-0056 | 0123 | 13 November |
| 81843154915N000 | 10032-0057 | 0124 | 13 November |
| 81843154935N000 | 10032-0058 | 0125 | 13 November |

## TABLE 3

## IDENTIFICATION OF 1:250,000 SCALE TOPOGRAPHIC SHEETS COVERING THE PROJECT STUDY AREA DEPICTED IN FIGURE 1

Blytheville, TN
Tupelo, MS-AL
West Point, MS-AL
Meridian, MS-AL
Hattiesburg, MS-AL
Columbia, TN
Gadsden, AL
Birmingham, AL
Montgomery, AL
Andalusia, AL

frames (in each of Bands 5 and 7) was required for complete coverage of the study area. Thus, a total of all or part of some 28 frames (14 each for 1973 and 1974) was required for the analytical portions of this project. Correspondence of the LANDSAT imagery and 1:250,000 quadrangles is shown in Figures 2 (1973) and 3 (1974).

## Photomorphic Regional Delimitation

Subjective Definition.--The subjective approach to the systematic delineation of photomorphic units (regions), as derived by MacPhail (1971) and as extended by Flynn and Peplies (1972; Flynn, 1974) was applied to the LANDSAT imagery covering the entire study area for the 1973 and 1974 time periods. With minor exceptions, as noted below, Band 5 imagery was used to delineate average tonal areas, while the Band 7 imagery was employed in the classification of texture and to clarify tonal boundaries where the Band 5 imagery was obscured for some reason. It should be noted that Band 7 seems to lend itself to the delineation of texture by virtue of the fact that it consists primarily of the invisible infrared portion of the electromagnetic (EM) spectrum. Since the visual portion of the EM spectrum (Band 5) allows the identification of discrete tonal patterns on the landscape, and since texture is defined as the repitition of tonal variations too small to be individually perceived and delineated; the Band 7 imagery serves well the purpose of identifying and delineating such textural areas without the adverse influence of those minute tonal variations. On the Band 7 imagery textural detail, particularly land/water interfaces, stands out in crisp and bold detail.

Figure 2: APPROXIMATE CORRESPONDENCE OF LANDSAT IMAGERY (TABLE 2) AND 1:250,000 TOPOGRAPHIC QUADRANGLE SHEETS (TABLE 3) OVER THE PROJECT STUDY AREA, 1973.

Digits given as I.D. numbers are the large, bold numerals recorded on the left-hand margins of the individual frames. Band 7 digits in brackets (). Names in brackets are for I.D. designation of 1:250,000 topographic sheets.

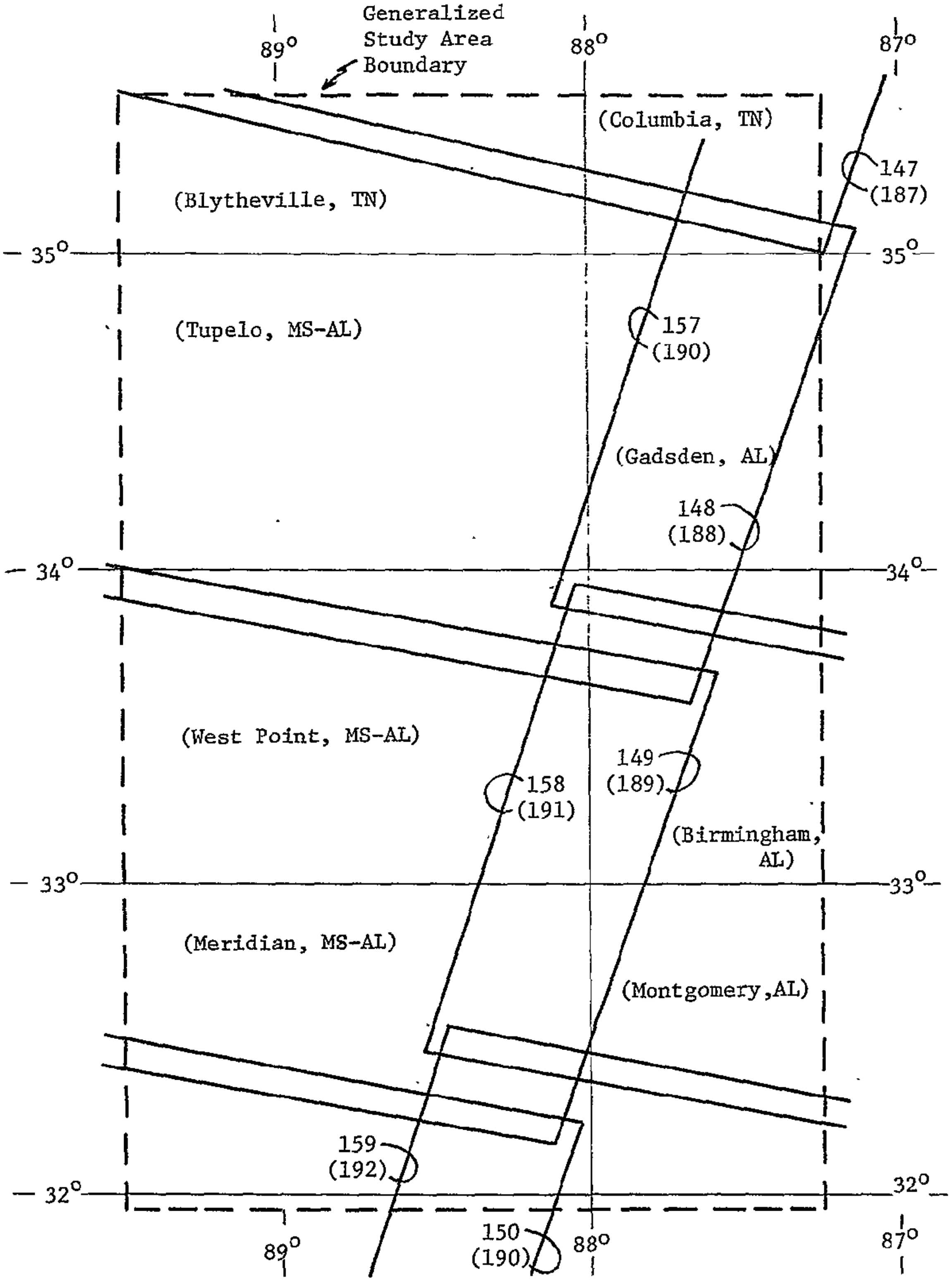
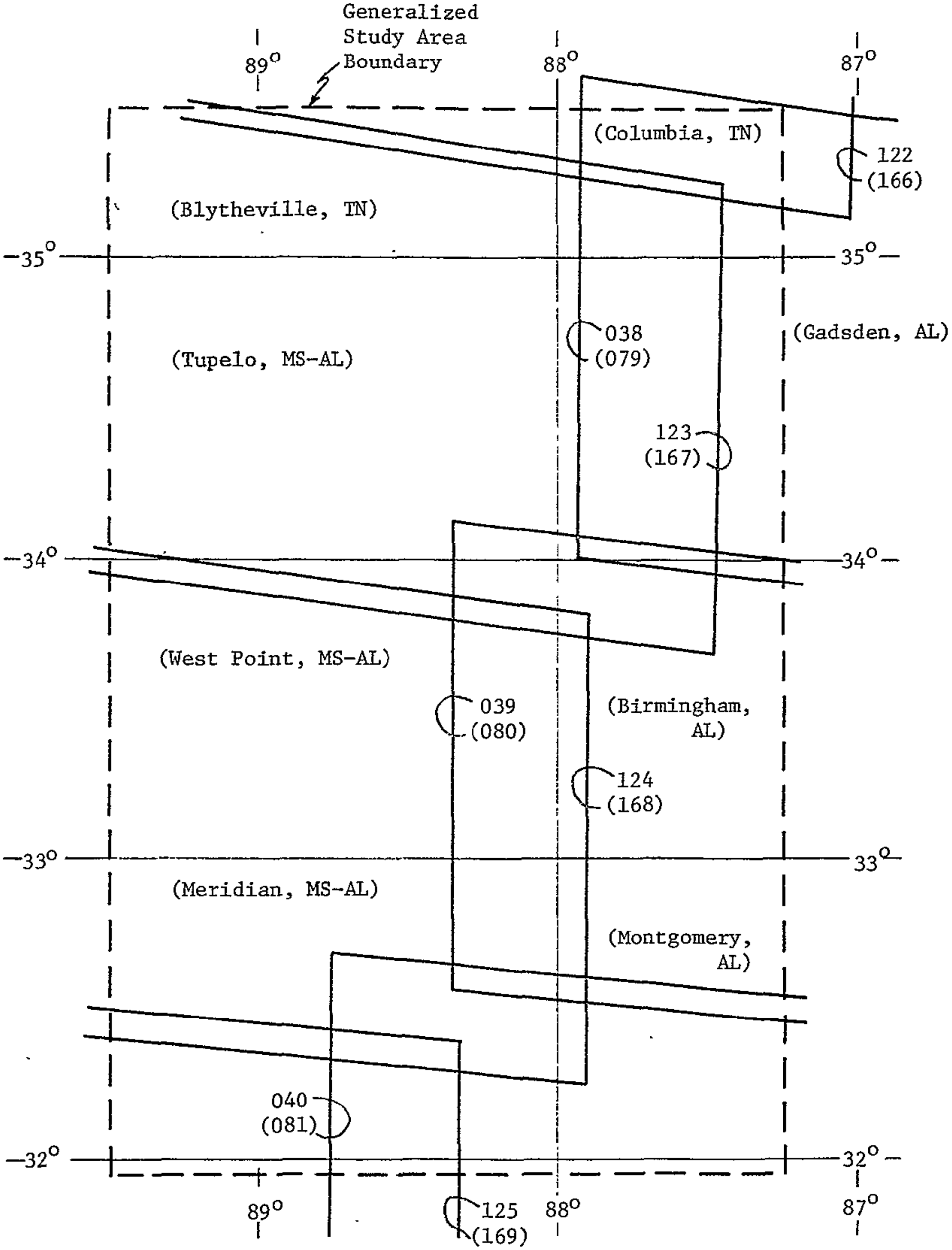


Figure 3: APPROXIMATE CORRESPONDENCE OF LANDSAT IMAGERY (TABLE 2) AND 1:250,000 TOPOGRAPHIC QUADRANGLE SHEETS (TABLE 3) OVER THE PROJECT STUDY AREA, 1974.

Digits given as I.D. numbers are the large, bold numerals recorded on the left-hand margins of the individual frames. Band 7 digits in brackets (). Names in brackets are for I.D. designation of 1:250,000 topographic sheets.



Two major problems continue to restrict the objectivity of this "intuitive" approach to photomorphic regional delimitation on the 29.2 inch/74.168 cm. imagery. These are (1) the inadequacies inherent in the categorization of both tone and texture as they have been derived and employed thus far in photomorphic analysis, and (2) the constraints imposed by the periodic requirement for interpretor decisions regarding category assignment, which decisions are highly subjective and, quite frequently, subject to physiological/emotional influences. Both problem areas, of course, underscore the need for a fully- or semi-automated procedure for the delineation of photomorphic regions, or, at least, for a more objective (and consistent) means of identifying and grouping tonal and textural characteristics on LANDSAT imagery.

A word concerning the quality of LANDSAT imagery and the effect of such quality on the photomorphic regionalization process appears significant at this time. The linearity introduced into the image itself by the sensor and/or processor scan lines hindered, at times, the establishment of a precise fix for a tonal and/or textural boundary. Indeed, on some images the scan lines were/are so apparent in the Band 5 range that even machine-processing techniques are subject to adverse influence. For reasons cited above, this condition is not nearly so extreme on Band 7 imagery, but the Band 5 imagery of the study area all contained clear, and often inhibiting, scan line traces. It is therefore emphasized that great care in the selection of imagery for use in photomorphic analysis is a prime pre-analysis requisite for all investigators. It should be noted, further, that the ultimate quality of 29.2 inch/74.168 cm. paper prints is by no means apparent when selecting imagery from the micro-film "browse file" medium.

Also, having learned the lesson in the hardest of all possible ways, the investigators here repeat the time-honored admonition to exercise great care in the handling of imagery. This is particularly crucial regarding the 2.2 inch/5.588 cm. negative "chips." Some of the images employed in this investigation became so scarred, scratched and otherwise damaged in the course of their repeated handling that, in addition to the scan line linearity spoken of above, an apparent "texture" quite alien to the area depicted by the imagery was sometimes mistakenly identified by microdensitometer scanning. While, as is pointed out below, procedural steps can be taken to minimize the adverse impact of the scan line content of imagery, there is no substitute for exercising proper care of the imagery from the start of an investigation. Once scratched, the imagery can only be expected to produce anlaytical data which is suspect, at best!

Classification System Inadequacies.--To be certain, one of the major inadequacies of the photomorphic regionalization process in its present state lies with its continuing dependence upon large-scale subjective decision-making. At least one factor contributing to such dependence lies in the tonal/textural classification system itself. The actual classification system employed was again a modified form of that system originally developed by Barr and Miles (1970) for the purpose of selecting engineering sites from small-scale radar imagery. As such, the system categorizes tone--the density of light passing through (recorded in) a unit area as determined by a pre-selected grayscale (ASP, 1960)--as "dark," "medium," "light," and "very light," the categories being labeled A, B, C, and D from dark to very light, respectively. In addition, the system classifies texture--the repetition of tonal variations to small to be individually discerned (ASP, 1960)--as "smooth," "grainy," "speckled," and "rough," designated 1, 2, 3, and 4, from smooth to rough, respectively. The primary deficiency of such a system lies with the tendency of the interpretor, as a single example, to look for a homogeneous tonal collection or concentration, inscribe a boundary about it, and then ask mentally to which tonal class the area so bounded belongs; rather than to delineate, say, an area of medium tonal intensity, *per se*. To be certain, the concept of a subjective classification system may be seen to be an extension of the previously-developed "intuitive" delineation process first considered by Flynn (1974). As such, one might be tempted to adjudge the process as virtually meaningless in any newly-assumed spatial context. If, however, the system is viewed as being but a single step in the process of developing a fully- or semi-automated procedure for delineating photomorphic units, then the subjectively delimited tonal "core" areas can be employed as "training sets" for the establishment of programmable machine standards for photomorphic unit classification (Arkadev and Braverman, 1967; Rosenfeld and Troy, 1970; Tou, 1969). It is believed by the investigators that, despite all other criticisms voiced, the core areas of both tonal and textural characteristics derived through the subjective delineation approach can be employed as a base for such training sets for both: (1) machine delineation of the tonal/textural aspects of photomorphic units (regions); and (2) derivation of specific algorithms for generating and analyzing data concerning the tonal/textural characteristics of photomorphic regions as they reflect the physical and/or cultural patterns of geographic areas as depicted on remotely-sensed imagery. Due to temporal and fiscal limitations imposed upon the present investigation, however, the extent to which these tentative conclusions may be borne out by further experimentation remains to be tested beyond this rather preliminary and speculative stage.

Subjective Tonal/Textural Decision-Making.--With regard to the utilitarian interpretation of the photomorphic classification system as employed herein, subjective decision-making processes and factors remain a serious problem standing in the way of conversion to a machine-based system. First, in order to facilitate adoption of the photomorphic region concept and approach by, say, a regional planning agency possessed of characteristically limited technical expertise and a relatively "low" technological capacity; the classification system would seem to be best if restricted to a minimum number of tonal/textural categories. As such, the present absence of satisfactory objective criteria for judging between and among the suggested minimum tonal (i.e., dark, medium, light, and very light) and textural (i.e., smooth, grainy, speckled, and rough) characteristics remains a substantial block. As a consequence of this shortcoming, each tonal/textural characteristic tends to be evaluated, either by interpretor or machine, relative to the tonal/textural characteristics immediately surrounding it. A direct result of this tendency is, therefore, a series of photomorphic regions in which many of the individual regions assigned the same classification--whether on a single image or a series of images--too often bear little resemblance to one another even though they may be relatively homogeneous in terms of their definable grayscale characteristics. It is clear to the investigators that, at the current state-of-the-art, a similar photomorphic classification assigned to two or more photomorphic regions does not necessarily mean that the landscape signature(s) responsible for the tonal/textural characteristic(s) is/are similar!

Second, tonal/textural characteristics often change so gradually across an image of even 1:250,000 scale that it is often impossible to fix a boundary position. As a consequence, boundary differences associated with temporal or other changes (e.g., atmospheric, camera, processing, etc.) are most difficult to identify on sequential images and could, therefore, be extremely difficult to treat quantitatively in a systematic manner.

Third, the tonal/textural criteria employed in determining the composition of a photomorphic region appear to be scale-dependent. Comparison of a 2.2 inch/5.588 cm. (1:3,369,000) negative image-even under intense magnification, and the 29.2 inch/74.168 cm. positive print obtained from that same negative should clearly illustrate this feature for even the untrained eye. As no adequate criteria for dealing with such scalar variations exist at present, the composition of photomorphic regions delineated, in terms of the blend of discrete tonal/textural characteristics of which they are assumed to be comprised, often varies considerably from one portion of the image to another (Haggett, 1965). For example, a drainage area which may appear to be part of a broad tonal/textural area in one photomorphic region, may very well stand out as a separate photomorphic region in another image of the same geographic area. Linear features and patterns appear to be far more subject to this condition than do areal features and patterns, but, lacking a precise interdependent spatial and scalar criterion for the delineation of discrete tonal/textural areas, no readily applicable solution to this procedural problem seems immediately apparent (Tobler, 1968).

Finally, substantial qualitative variations in overlapping images for the same geographic area can adversely effect the photomorphic regionalization process. At times such variations in image quality caused a single photomorphic region to be tonally/texturally classified under one category on one image and under a different category on the overlapping image! It is unclear at this time whether the qualitative changes which occur between consecutive images of the same geographic area are due to atmospheric conditions; variation in sun angle with respect to the imaging system; film; or transmission, reproduction, and processing anomolies; some combination of these factors; or to a totally different cause. In any event, this type of difference tends to introduce exogenous variables over which the photomorphic classification system has virtually no control and, as such, may very well hinder, if not obviate, development of a standardized computer delineation program. One possibility for corrective action may lie with a machine registration system which calibrates the classification procedure to a single photomorphic region in each image before the entire geographic area is photomorphically classified (i.e., a modified "training set" approach).

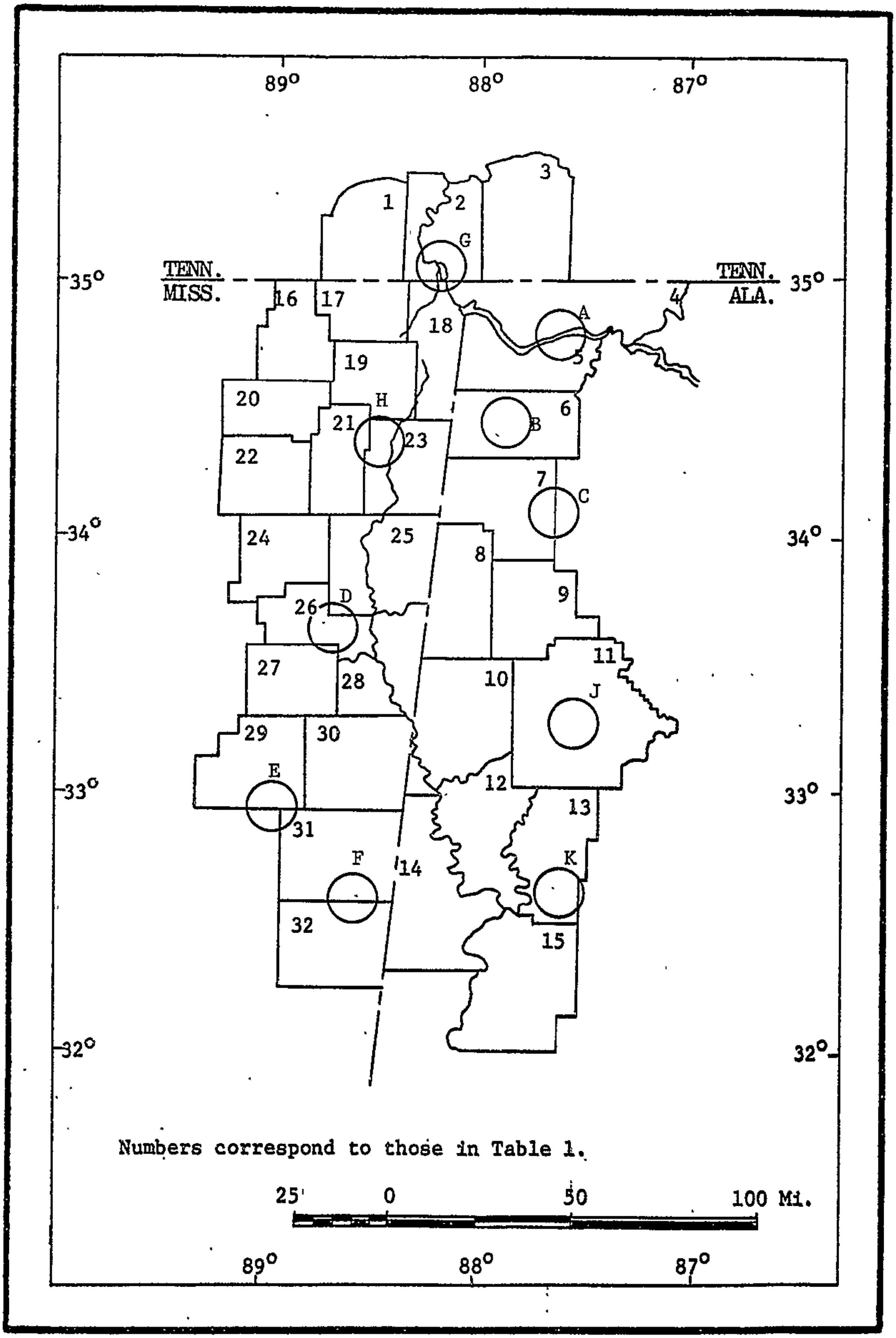
Given these constraints and problem areas, the sections immediately following deal with the experimentation regarding tonal and textural characteristics carried out in the course of this project. It should be noted here that while the initial task performed in the project involved the subjective delineation of photomorphic regions for the entire 32-county project study area on mylar overlays attached to the 29.2 inch/74.168 cm. imagery for both 1973 and 1974; due to time and other constraints associated with the project, certain portions of the experimentation reported below was confined to a series of ten arbitrarily established circular "windows" scattered throughout the study area so as to include a variety of landscape characteristics. Hence, certain analytical and evaluative tasks addressed in the sections which follow treat the process of photomorphic regional delimitation and analysis in toto, while others refer only to data obtained with respect to the ten test windows.

The reader is cautioned of this point so as to avoid confusion between conclusions which are restricted to small sample areas as opposed to those which are broader in implication. For convenience alone, most illustrations accompanying this portion of the report draw from examples of window-focused analysis. Figure 4 shows the approximate location of the various study "windows" within which intensive study was carried out.

Tonal Characteristics.--In any image-interpretation process certain ordered steps are taken and definite factors are analyzed. Initially, the more obvious visible features are noted and, subsequently, other more subtle features are noted and analyzed (Stone, 1964). By this approach, as analysis proceeds, some of the background of implied features and various cultural impacts on the physical landscape surface can be derived from an image. MacPhail (1971) has previously noted the manner in which such an interpretive process with respect to photomorphic units has yielded strong correlation between and among the photomorphic regions and such factors as present land use, soil and geomorphic characteristics, moisture characteristics, drainage patterns, and population density. These correlations stem in large measure from the variations in tone, texture and pattern on the image being analyzed. Of the three factors identified, tone is by far the easier to work with, this being the result of substantial previous experimentation.

Tone can be evaluated in two ways: in terms of discrete tone and in terms of average, or representative, tone (Haralick and Bissell, 1970.) Image areas which appear to be composed of a single discrete tone (as is the case with very small areas on most types of remotely sensed imagery) are likely

Figure 4: APPROXIMATE LOCATION OF STUDY WINDOWS IN PROJECT AREA.



Numbers correspond to those in Table 1.

to be indicative of shadowing, or of reflection, or of the delineation of specific natural or cultural features of a reasonably broad extent. The average, or representative, tone of an area, on the other hand, is likely to be indicative of the general reflecting characteristics of the local terrain surface (Barr, 1968). For example, as pointed out by MacDonald (1969), the average tone on radar imagery taken over vegetated areas is dependent upon the spacing of individual trees, the spacing of branches (in large-scale imagery), the size and density of leaves (in the case of deciduous vegetation at appropriate times of the year), and the orientation and slope configuration of the overall plant community. In non-vegetated regions, or under semi-arid to arid environmental conditions, the average graytone on imagery depends upon such things as the scattering characteristics of the terrain as influenced by surface roughness, geometric orientation, and/or effective angle of incidence of the sun's illuminating rays.

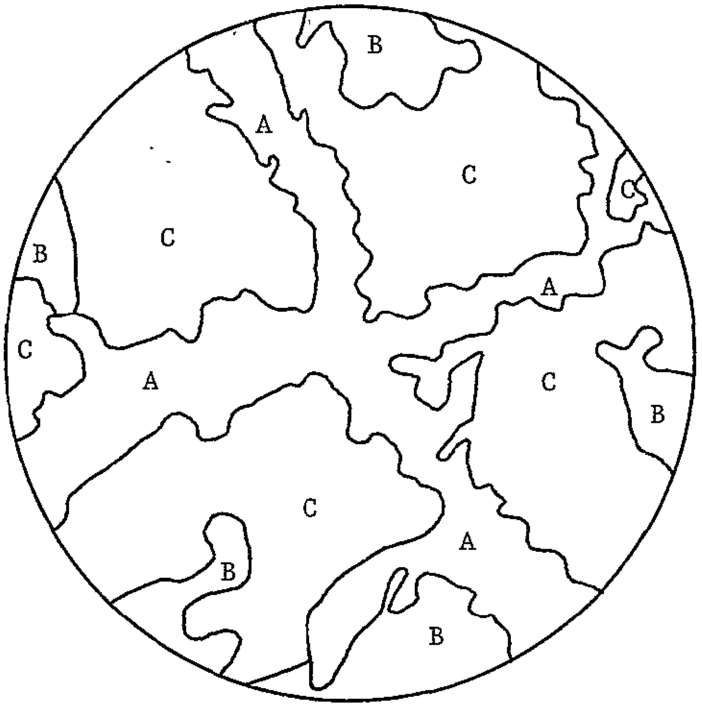
These same characteristics of tone appear to obtain in the case of photomorphic regions as delineated in the course of the present study. That is, in the case of the subjective determination of tonal characteristics it appears that the interpretor, rather than identifying discrete tones over areas of some considerable extent, mentally averages all tones present in the assignment of a tonal classification to the photomorphic region under scrutiny. Thus, the visual process involved in identifying and delineating a photomorphic region consists of two sequential steps. First, the interpretor establishes the category (i.e., dark, medium, light or very light) of average tone with which he is dealing. Second, the interpretor determines where--either precisely or generally--the average tone under consideration changes to yet another average tone. At such a position, the boundary between the photomorphic regions is drawn. Obviously such a technique is best accomplished under the constraint of a standard, minimum mapping unit. In the case of this investigation such a mapping unit was approximately .8 inch/2 cm. in diameter.

In the case of the computer/microdensitometer interface employed by Flynn (1974), however, it now appears that the imposition of the small aperture of the microdensitometer (i.e., 25 and/or 50 raster) on the tonal evaluative phase of photomorphic regional delineation actually results in a process of characterizing such photomorphic regions via the discrete tonal procedure (Haralick and Bissell, 1970). That is, even though the microdensitometer-derived tonal data is ultimately evaluated against a complete 256-tone grayscale and photomorphic regional boundaries are assigned on the basis of a mechanical averaging of dominant tones; the fact remains that the original "viewing" of tones by the microdensitometer is, by definition, a process of identifying, measuring and storing discrete tonal characteristics. As such, it is highly likely that, without further experimentation regarding this matter, conclusions concerning tonal characteristics of photomorphic regions which are made by "jumping" back and forth between the subjective and machine procedures are in the main non-comparable!! In other words, there is every reason to suspect that, at the current state-of-the-art of photomorphic regionalization (at least insofar as considered in the course of the present study), conclusions regarding the tonal characteristics of photomorphic regions ought properly to be viewed as unique cases only. As such, the potential contribution to broad-based regional studies, in which the focus is invariably on the comparability of conclusions between and among areas, is likely to be marginal, at best.

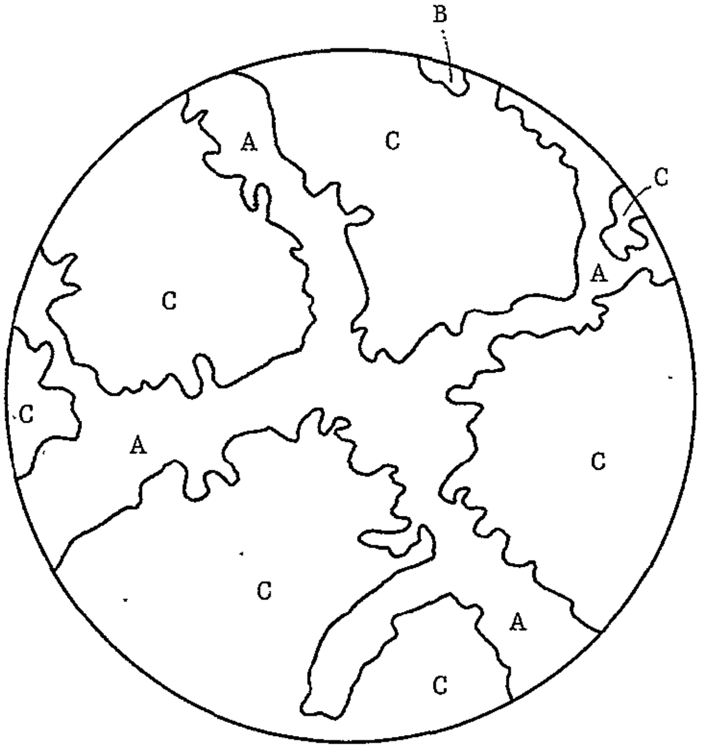
These limitations notwithstanding, precise tonal perception does not appear to adversely effect the crucial issue of the placement of boundaries for photomorphic regions. If a photomorphic region is to be conceived of as a "real" entity, then it must be assumed to have clear and determinable limits which, although subject to temporal variation, ought to be easily recognizable as dividing one such photomorphic region from another. This, of course, is a feature which is expected of all regional boundaries (Chorley and Haggett, 1967). Figure 5 shows the boundaries of 1973 and 1974 tonal areas within Study Window E, located northeast of Philadelphia, Mississippi at the study area boundary (see Figure 4). It can be clearly seen that although there is some substantial disparity between the specific tonal classifications assigned to portions of the area (e.g., the southeastern portion of the window area); there is, nevertheless, a high degree of correspondence between the actual configuration of tonal regions in the window area for 1973 and 1974. Tonal characteristics for study windows A-D and F-K, inclusive, are found in Appendix A of this report.

On the basis of the present investigation it appears that the semi-automated procedure for defining and analyzing tonal characteristics of photomorphic units is applicable in a wide variety of terrain conditions and, thus, warrants further experimentation, particularly directed at the improvement of the computer program which is employed to determine "average" tonal characteristics (Peach, 1971a). Briefly, in this procedure (Flynn, 1974) the size of a control (sampling) area is determined by expanding the radius of a circular "mask" at regular concentric increments,

Figure 5: TONAL CHARACTERISTICS OF STUDY WINDOW "E", 1973 and 1974.



1973



1974

(Figure 6). Median values of all of the Band 5 microdensitometer-recorded tonal values within each of the concentric circles are recorded. The ultimate size of the control area circle is that which is equivalent to the lowest value of a "steady state" of the median tonal values for all of the sample sites (see Figure 7).* After the control circle size has been determined the entire area within the control area is again scanned via the microdensitometer. The computer printout of this scan can then be compared with the subjectively-derived photomorphic regions to determine areas of correspondence and variance.

According to the magnitude of the variance between the two "views" (i.e., human and machine) of the tonal characteristics of the photomorphic region under scrutiny further analysis becomes possible. Among other procedures, analysis of variance between the two approaches can determine whether the photomorphic areas which are defined manually and/or mechanically belong to one or another population grouping. At least two classes of photomorphic tonal areas are easily differentiated: primary and secondary. Primary tonal areas are defined as those which are recognizable on the basis of similarity of the admixtures of tonal values. By way of contrast, secondary tonal areas appear to be areas of tonal changes. The distinction between such primary and secondary tonal areas is not dissimilar to the process of determining the variance in regional homogeneity between regional "cores" and "boundary zones" (Chorley and Haggett, 1967; Crowe, 1938;

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*It should be noted that, owing to imagery characteristics which may vary slightly from one sequential image to the next, more than one control area size may result for the same photomorphic unit under current procedures.

Figure 6: COMPUTER PRINT-OUT OF CIRCULAR MASK

Letters inside of outlined irregular circle represent density readings. Statistical values of central tendencies are shown along the bottom of the diagram. By expanding the circular mask until a "steady state" is reached (as defined in Figure 7), a standard mask is revealed that can be used for the entire image under examination.

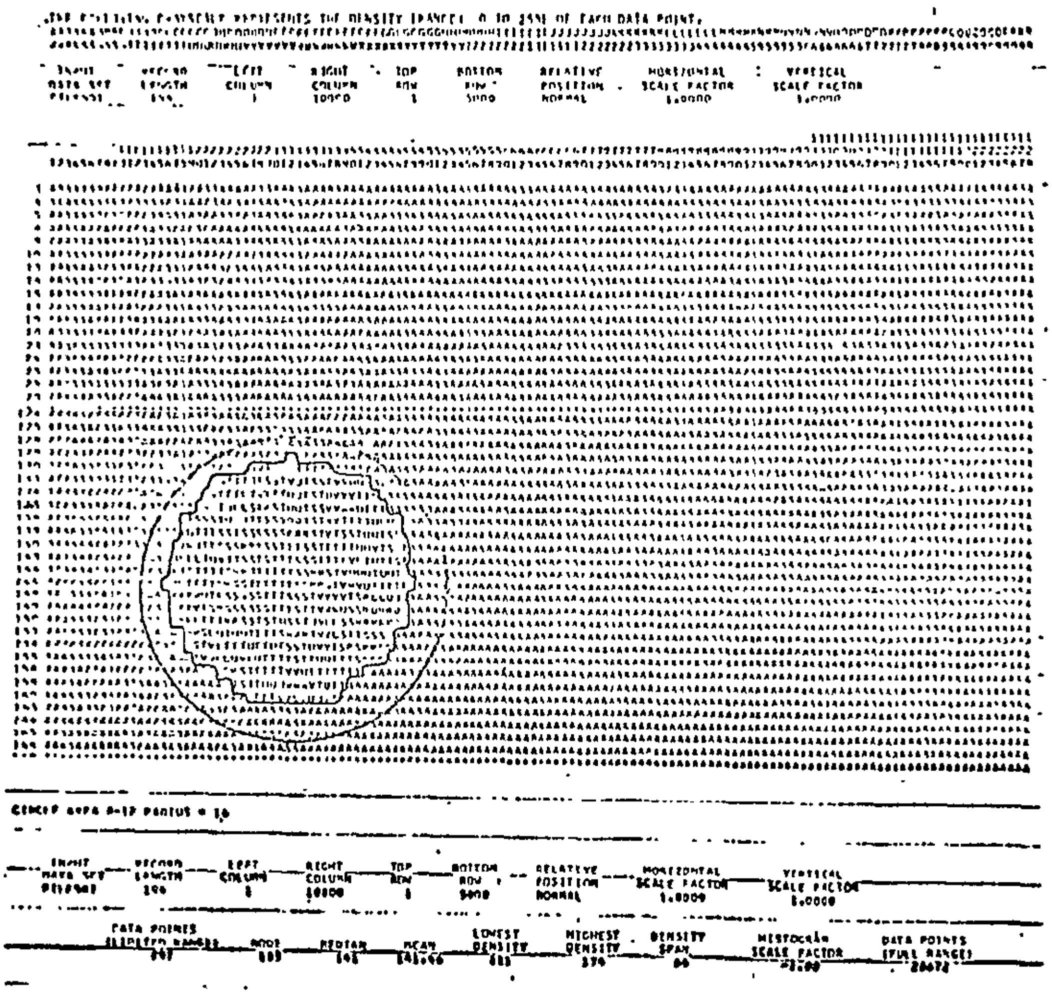

Figure 7: MEDIAN DENSITY VALUES FOR DIFFERENT SIZED CONTROL AREAS.

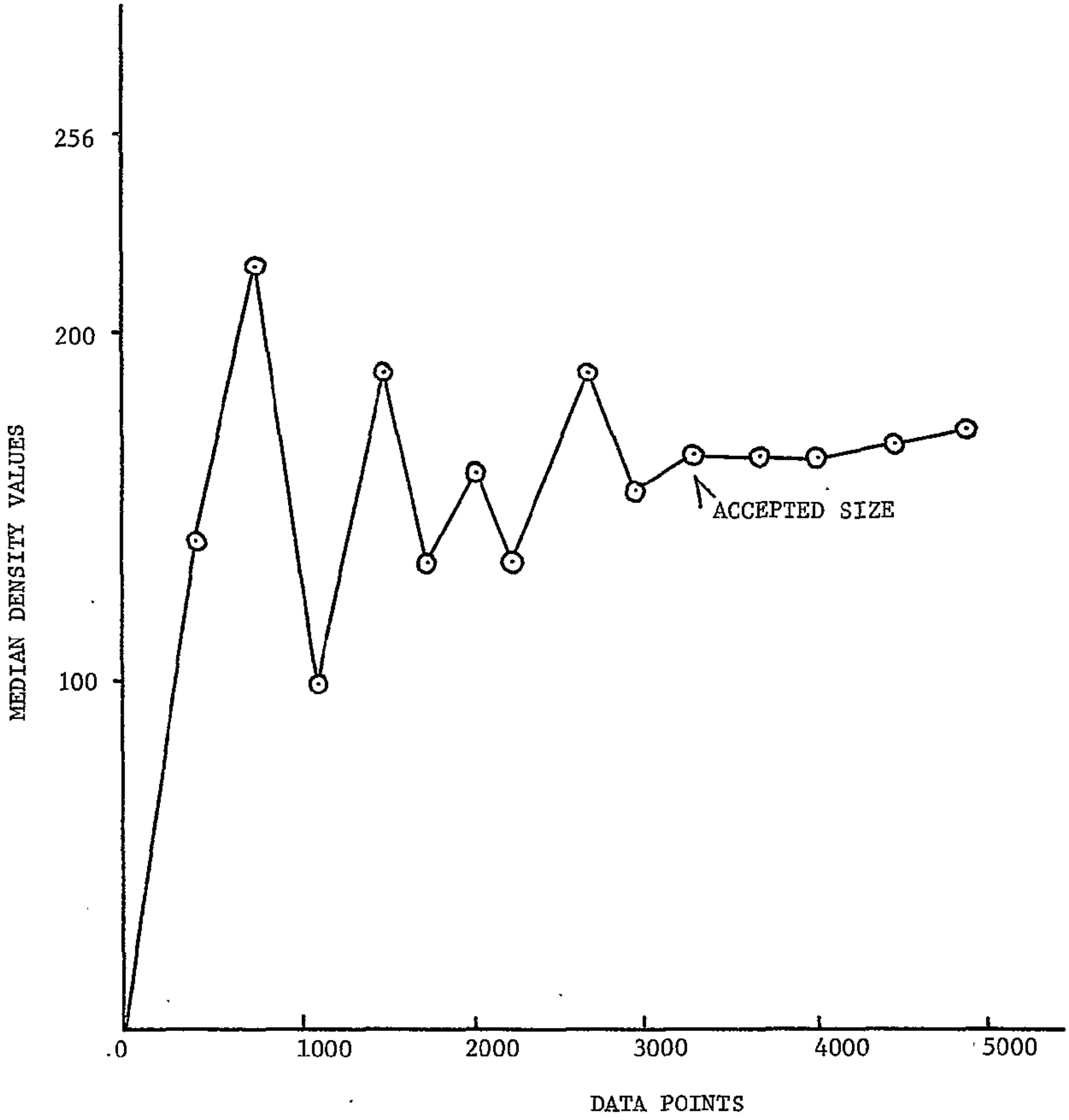

Chart displays how "steady state" is reached as control area circle is expanded by regular increments. Example is from previous Mississippi delta experiments. A circle size of approximately 3,300 data points representing 5 square miles on the ground was accepted as the circle size to be used for control for the entire Apollo 9 image under examination in this case.

Poore, 1956). The precise sequence in this analytical procedure is: (1) delimitation of primary tonal areas and characterization according to various central tendencies of the tonal densities, including means, medians, modes and analysis of histograms of the tonal values; and (2) delimitation and determination of the central tendency characteristics of secondary tonal areas.

Textural Characteristics.--Although texture has been defined as the repitition of tonal variations too minute to be discerned as discrete individuals (ASP, 1960); a large proportion of previous research has been based on the assumption that tone and texture were more or less independent concepts. In the present investigation this same basic approach was one of the fundamental initial assumptions. At this juncture, however, there appears to be increasing evidence that tone and texture are not independent of one another and should, therefore, not be arbitrarily separated for analytical purposes (Haralick and Bissell, 1970). The advantages of hind-sight as a basis for definition of research strategies is, of course, a "discovery" made by numerous investigators--apparently regardless of previous experience!

Early image texture studies have involved both manual and machine procedures. As was noted above, the present investigation was initially based upon employment of Band 7 imagery for the determination of textural qualities of photomorphic regions which were previously given tentative definition on the basis of Band 5-focused analysis of tonal variation. More sophisticated early textural analyses have employed autocorrelation functions (e.g., Kaizer, 1955), power spectra (e.g., MacDougall, 1968; Chevallier, et.al., 1968); and a variety of other statistical and/or mathematical methods (e.g., Bixby, et.al., 1967). Each of these early exploratory investigations enjoyed some degree of success, but the present evidence suggests that little more was known about texture, per se, after these experiments than had been known before. The reason for this appears to be that, to date, few texturally-focused studies have attempted to specifically define, characterize, or model texture. Rather, these studies employed only a general mathematical transformation which assigns numbers to a transformed image in a non-specific manner.* Further, other investigators, including Rosenfield and Troy (1970), have examined texture from a local (micro) point-of-view. That is, the study was concerned with differences in "coarseness" of objects with the same texture which were induced by different magnifications. As such, a specific definition of texture itself was not a major thrust of their work.

By way of contrast with the investigations cited above, Haralick and Bissell (1970), have approached the examination of texture from the point-of-view that tone and texture are not independent concepts. Rather, there appears to be an inextricable relationship between the two elements. In the context of any remotely-sensed image, both tone and texture are always present; although at times one of the properties can be dominant. By this view, the basic relationship between independent concepts of tone and texture and the concept of tone-texture as a single entity is roughly as follows: when a defined region of an image has little variation in terms of discrete graytones, the dominant feature of that region is tone. Conversely, when a region contains a wide variation of features of discrete graytones, the dominant feature of that region is perceived to be texture. Crucial to

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*A rather penetrating discussion of the pitfalls associated with the use of the Fourier transform, for example, including second order statistical problems can be found in Bremerman (1968).

this distinction are the size of the region, the relative sizes of discrete features within the region, and the total number of such discrete features. As the number of discernible tonally discrete features decreases, the tonal property will become predominant. In fact, Haralick and Bissell (1970) note, further, that when the size of the region, or areal unit under study, approaches the size of a single resolution cell (i.e., approximately 250-300 feet in the case of LANDSAT imagery), so that a single discrete feature is apparent, the only property present is tone. On the other hand, as the area being examined becomes greater in physical extent, and as, thus, the number of distinguishable graytone features increases, texture becomes the dominant property. It would appear to the present investigators that this preliminary conclusion is of vital concern as regards the question of the extension of the photomorphic concept. For, in order for the photomorphic concept to have significant functional utility to the regional planner, the concept must clearly be capable of dealing effectively with tonal/textural qualities across a broad range of regional sizes. As has been noted elsewhere (e.g., Peplies and Keuper, 1975), the data and information needs of the regional planning agency are dependent upon a variety of investigative procedures ranging from micro- to macro-regional focus. Under the present constraints of the photomorphic concept, the implication of changing dominance between and among two signature elements (i.e., tone and texture) can be enormous. If, on the one hand, tone is the only property apparent at micro-regional levels, and if, on the other hand, texture becomes dominant as the region under investigation becomes larger; and if, as has heretofore been the case, tone and texture are treated as independent concepts; then the conclusions drawn by the micro-focused and the macro-focused studies characteristically performed by the regional planning agency are non-comparable (if not mutually exclusive)! Therefore, the present investigators deem it crucial that means for interfacing tonal and textural evaluation be concentrated upon in any future research concerning the photomorphic concept.

As a preliminary step to this interface task, the entire area* under study for this project was further examined according to its textural variation between and among four categories (i.e., smooth, grainy, speckled and rough) by superimposing the Band 7 imagery on the Band 5-derived tonal photomorphic regional maps. In this manner the specific configuration of photomorphic regional boundaries is clarified.

The results of the present investigation's consideration of texture as a quality of photomorphic regions appears to corroborate the Haralick and Bissell (1970) assumption that tone-texture is a single, interrelated property of regional signatures. Figure 8 shows the delimitation of textural photomorphic regions for the area designated Window E in the study area for 1973 and 1974. Note first that there is a significant variation between the 1973 and 1974 textural qualities, particularly in the southeastern one-half of the area. Further, in comparing Figures 5 (tone) and 8 (texture) for Window E it can be seen that in the 1973 imagery tonal and textural boundaries vary widely, again particularly in the southeastern one-half of the window. By way of contrast, however, in comparing tonal and textural characteristics as delimited for 1974, it can be seen that virtually all

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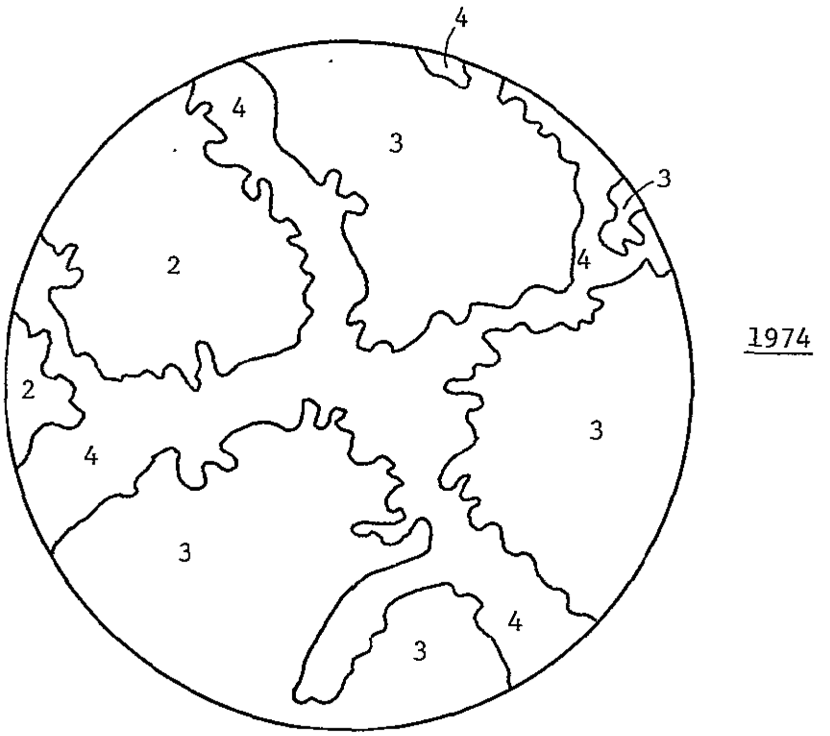
*As was stated above concerning the tonal delimitation process, while the entire 32-county project area was subjected to textural analysis, reporting of the experimentation below is, again, confined to the circular "windows" scattered throughout the study area (Figure 4).

Figure 8: TEXTURAL CHARACTERISTICS OF STUDY WINDOW "E", 1973 and 1974.



significant boundaries coincide throughout the window area. Hence, again, the conclusion of a close interrelationship between tone and texture is once more underscored. A comparison of the 1973 and 1974 textural characteristics for remaining study windows in Appendix B with the tonal characteristics of windows (Appendix A) reveals that in a majority of cases tonal variations can be accounted for by textural differences and vice versa.

Further preliminary textural analysis in the present study roughly approximated the procedures employed by Flynn (1974).

1973 & 1974 Photomorphic Regions[*].--Following consideration of and experimentation with tone and texture as individual ingredients in photomorphic regional signatures, the present study turned its attention to the question of the composite tonal/textural qualities inherent in the photomorphic regions themselves. Experimentation in this regard followed that proposed by Flynn (1974) with little deviation.

By both human and machine procedures for the delineation of photomorphic regions, the qualitative variance between LANDSAT imagery for 1973 and 1974 appears to have a substantial bearing on the regionalizing process. In particular, the density variance from one image to the next (either between sequential images for the same time frame, or between corresponding images for different time periods) seems to mitigate against the drawing of directly comparable conclusions regarding photomorphic characteristics. Further, the linearity in images created by the scanning process of the satellite and information retrieval systems imposes a block on machine procedures. In this latter case, however, it was discovered that a simple

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[*] Once again, for convenience, discussion here is confined to the photomorphic regions delimited in the ten study "windows" (Figure 4) which were the focus of later intensive investigation.

90-degree rotation of the image under investigation, prior to microdensitometer scanning, was a sufficient corrective action to minimize the prominence of the scan lines.

It is believed that the illustrations which follow make abundantly clear the extent to which the image density variance blocks the photomorphic process at present.

Regarding tonal qualities, note in Figure 9, that despite the overall "pattern" similarity between the 1973 and 1974 photomorphic characteristics of Window E there is a rather dramatic change from "dark" (A) to "medium" (B) tone in the central "X"-shaped area between the two images. Note also the almost complete absence of "medium" (B) tones in the peripheral areas of the 1974 image. Note, further, in Figure 10 how the area of "very light" (D) tone in the north central portion of Window A for 1973 is converted to an area of "light" (C) tone in the 1974 image. Finally, in Figure 11, note the substantial variance in tonal qualities between the 1973 and 1974 images for Window C.*

Respecting textural characteristics of photomorphic regions, note the apparent switch from "grainy" (2) to both "speckled" (3) and "rough" (4) between 1973 and 1974 images of Window D (Figure 12). Note also the tonal change for the central area of the image. Similar textural shifts are apparent in Windows A (Figure 10) and E (Figure 9) noted above. It is noteworthy that almost exclusive recognition and identification of "smooth" (1) texture is confined to areas of water bodies, although the Meridian (MS) Naval Air Station (Window F, Appendix C) also was classified as "smooth" in both images.

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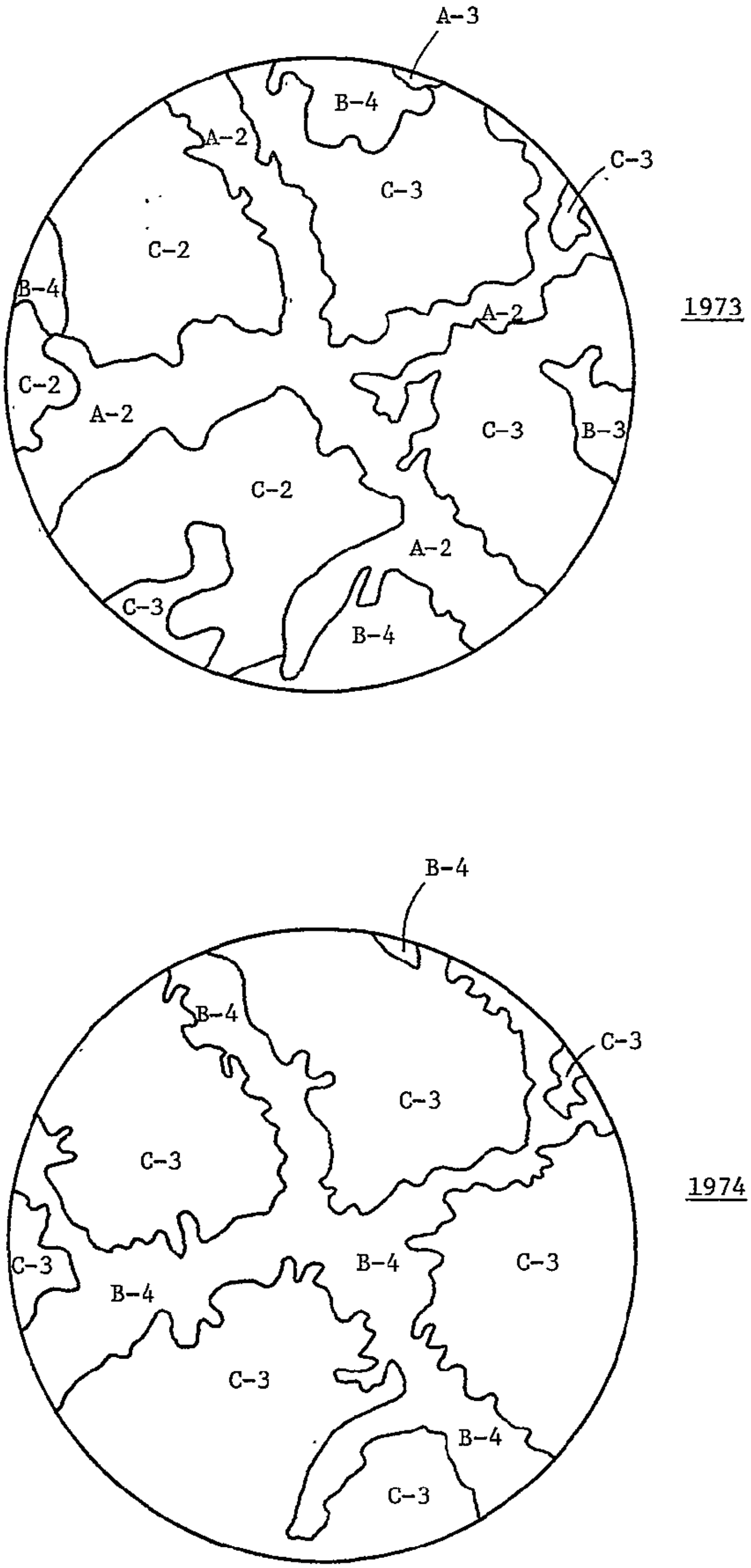
*Appendix D shows the general regional characteristics of the various study windows as derived from the 1:250,000 topographic sheets.

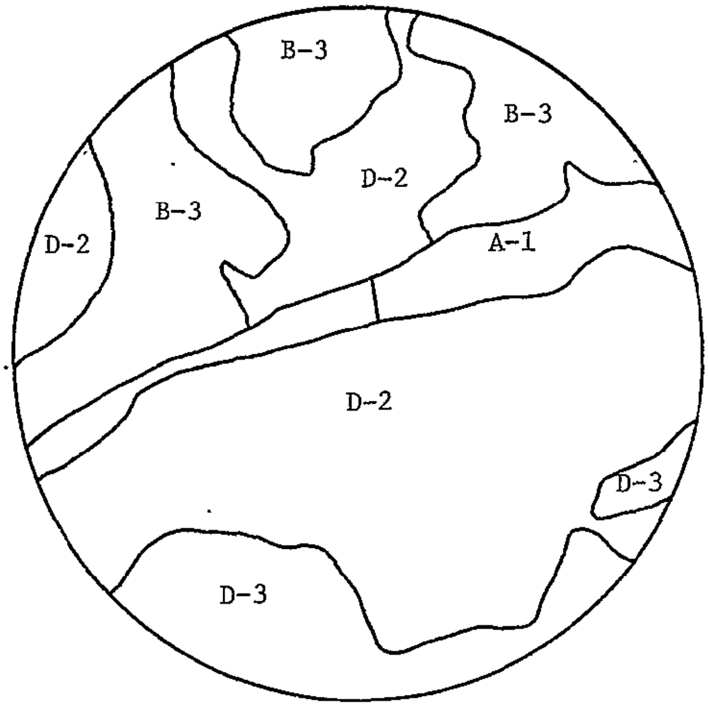
Figure 9: PHOTOMORPHIC REGIONS, STUDY WINDOW "E", 1973 and 1974.



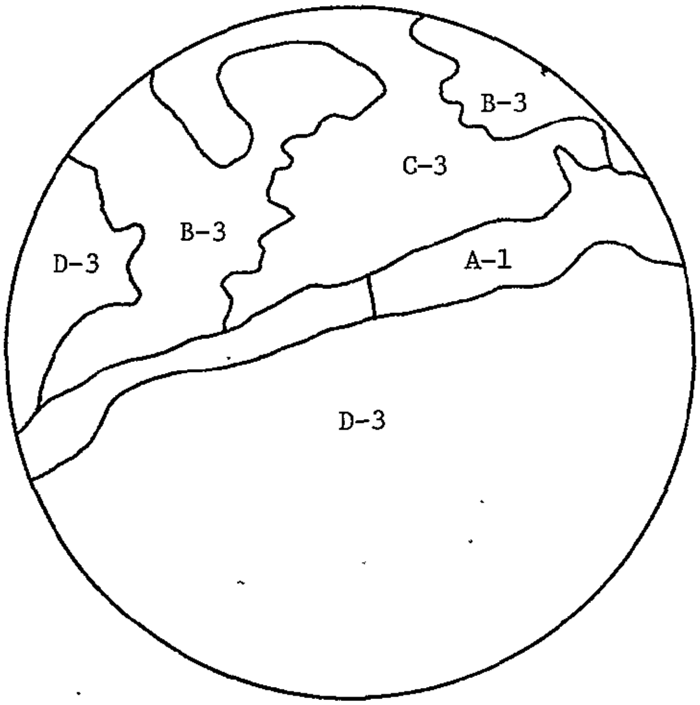
1973

1974

Figure 10: PHOTOMORPHIC REGIONS, STUDY WINDOW "A", 1973 and 1974.

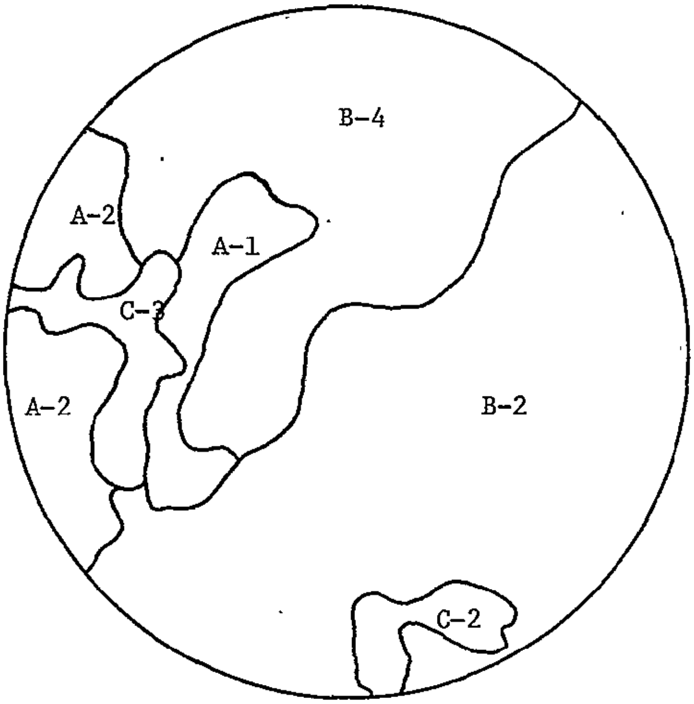


1973

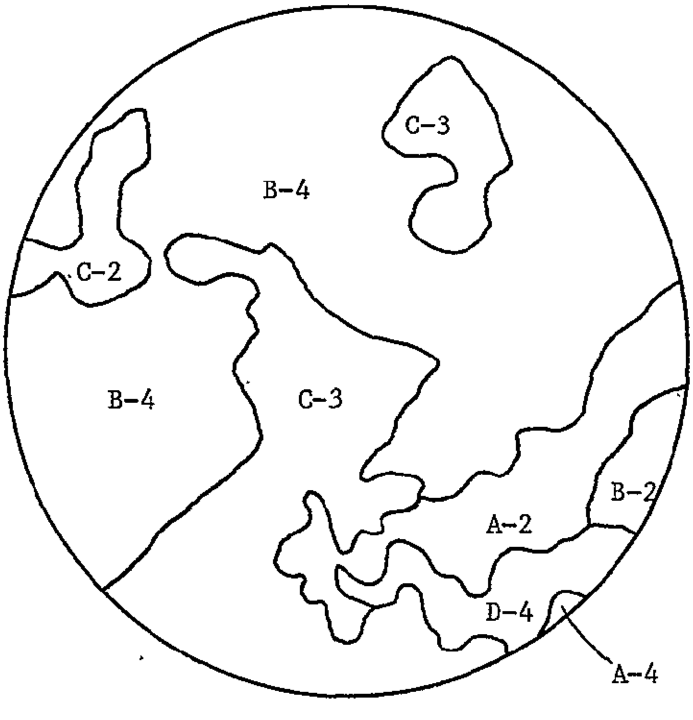


1974

Figure 11: PHOTOMORPHIC REGIONS, STUDY WINDOW "C", 1973 and 1974.

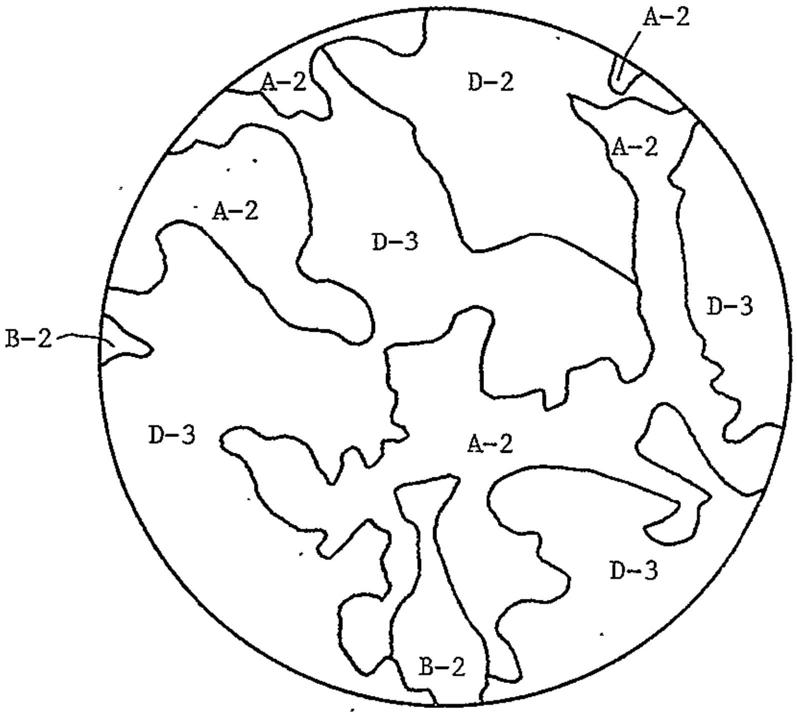


1973

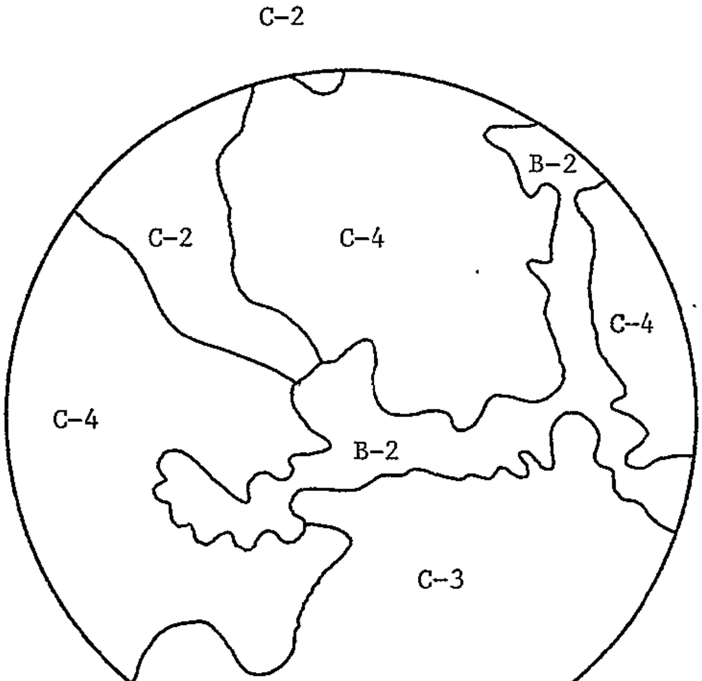


1974

Figure 12: PHOTOMORPHIC REGIONS, STUDY WINDOW "D", 1973 and 1974.



1973



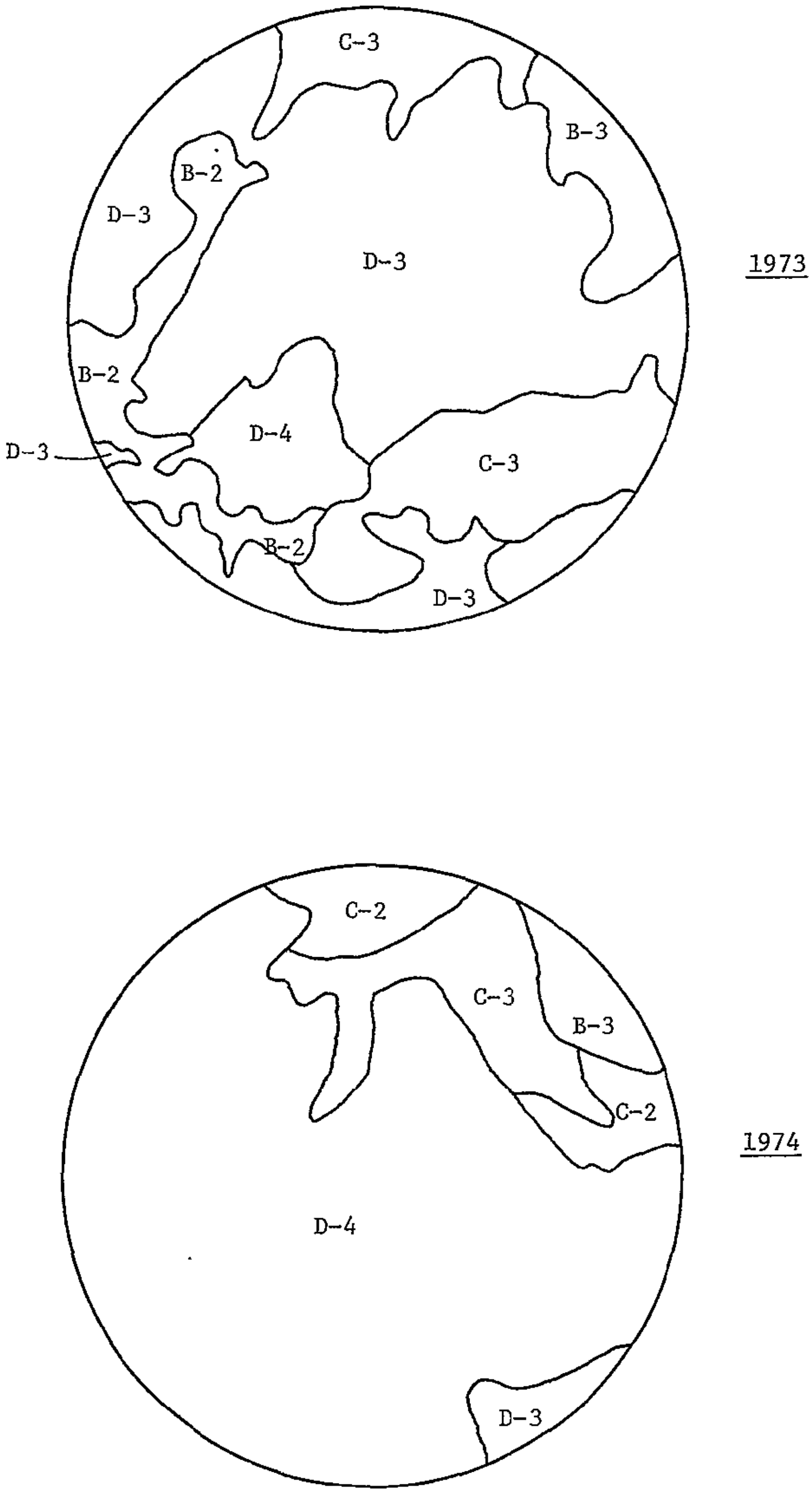
1974

Perhaps the greatest divergence between photomorphic regional characteristics for 1973 and 1974, however, is apparent in the case of study window K (Figure 13). In fact, study window K has troubled the present investigators throughout the study inasmuch as it appears to violate not only the fundamental assumptions upon which the study was based, but, in addition, appears to contradict virtually every conclusion drawn regarding photomorphic regional characteristics in the course of the study! The area represented is a rural district lying south of Greensboro, Alabama (northeast of Demopolis) in the southern portion of the study area. As such, the investigators had expected that it would exhibit those general tonal and textural characteristics which had already been identified in connection with other rural areas. Such, however, was not the case, for reasons which are as yet unclear. More is said concerning this anamolous study window in the sections below.

In any event, the delimitation of photomorphic regions for 1973 and 1974, both in the context of the study windows and for the entire study area, illustrates many of the same characteristics as were described by Flynn (1974). In a spatial sense, the areas delineated on the LANDSAT imagery are homogeneous regions; that is, they appear to exhibit similar tonal and/or textural characteristics within the limits of the procedures employed. Dark tones tended to be associated with water bodies, high soil moisture content, similar soil characteristics and rural land uses. Conversely, light tones tended to be associated with those areas where urban and/or urban-related land uses had covered, or otherwise obscured, natural (i.e., physical) landscape features with cultural (i.e., man-made) characteristics.

From a textural standpoint, the greater the degree of human occupance and, hence, modification of the natural landscape, the greater the tendency

Figure 13: PHOTOMORPHIC REGIONS, STUDY WINDOW "K", 1973 and 1974.



toward "speckled" or "rough" textures (see particularly study window J, Appendix C).

It is apparent that the photomorphic regional characteristics, as delineated on the basis of such tonal and textural variations, represent signatures of various phenomena on the surface of the earth. Further, it seems obvious that the varying degree of interaction between physical and cultural processes accounts for a substantial proportion of the variance in appearance between and among the photomorphic regions and between photomorphic regions for the same vicinal location at different times. Thus, it was concluded that a further consideration of automated procedures for the delimitation and analysis of photomorphic regions might very well be expected to yield useful information for the planning user-community, for it was apparent that a variety of cyclical and seasonal, natural and cultural, long- and short-term changes in the characteristics of areas on the surface of the earth were, indeed, being derived via the photomorphic regionalization of LANDSAT imagery.

## Tonal/Textural Interfacing

One preliminary conclusion which resulted from the tonal and textural experimentation outlined above dealt with the relationship between the components of photomorphic regional signatures—tone, texture, and pattern. Previous work by the present investigators and others (e.g., Flynn, 1974; MacPhail, 1971) was based in large measure on the assumption that tone, texture, and pattern were separately definable signature elements. Further, these three elements of any signature have, for the most part, been interpreted as being only three among many such ingredients in any remotely-sensed imagery. Indeed, the standard to date, as noted by Estes and Simonett (1975) has been that:

> Imagery represents energy reflected, emitted and/or transmitted from many parts of the electromagnetic spectrum and is recorded in many shapes, sizes, and scales. Basic image interpretation is essential to the efficient and effective use of those data.
>
> Although many articles and texts differ as to the number of basic elements they include, there is general agreement on six: size, shape, shadow, tone (or color), texture, and pattern. Three other elements which are often included with these six...are site, association, and resolution.

Hence, while some degree of mutual interdependence between and among these various elements has always been accepted*; nevertheless, quite possibly because most of our present techniques of image analysis were evolved in connection with very large-scale air photos wherein a large number of individual <u>objects</u> and other details are clearly discernible, the tendency remains to look for individual elements in small-scale imagery in much the same way. That is, the usual form for small-scale imagery analysis involves the separation of tone, texture, and pattern into three discrete interpretive stages. The method remains very closely akin to the search procedure known as the "convergence of evidence" (ASP, 1960). By this procedure <u>a priori</u> knowledge of specific objects on the surface of the earth leads rather quickly to the interpretation of large-scale aerial imagery by human operators or machines. Such a procedure does not necessarily work with the same degree of accuracy when dealing with objects as they appear (or, more particularly, as they do not appear) on satellite imagery. As Flynn (1974) has suggested, the combination of the

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*Such interdependence is very often understated or only tacitly accepted, but it is interesting to note that virtually all photographic and remote sensing glossaries frequently use one or more properties of supposedly independent elements to "define" yet another element.

small scale and attendant lack of precise resolution inherent in much satellite imagery is its greatest disadvantage for broad regional analysis if standard photo-interpretive procedures are employed.

If, on the other hand, as Hartshorne (1939) noted so many years ago, landscapes are amenable to a kind of <u>Gestalt</u> psychology (i.e., the whole being greater than the sum of its parts); then this same small-scale characteristic can become the primary advantage of satellite imagery because it necessitates an approach which emphasizes viewing <u>assemblages of image characteristics</u> rather than identifying discrete signatures of objects. And if, as Haralick and Bissell (1970) contend, tone and texture are not separable, but must be treated as a single concept; then, perhaps, the combination of tone and texture into a single element for analysis allows for a clearer recognition of pattern. That is, a tentative conclusion of the present study is that rather than proceeding along a course which might be stated:

> Intepretation of tone + interpretation of texture + interpretation of pattern <u>yields</u> partial understanding of landscape;

we should proceed along a more limited course which might be stated:

> Interpretation of tone/texture <u>yields</u> understanding of pattern which, in turn, contributes to the understanding of landscape.

It may very well be that pattern, even as it is presently defined on the basis of methodologies developed in conjunction with analysis of large-scale imagery, is the single most clearly identifiable landscape feature on satellite imagery. Inasmuch as numerous investigators have already explored the possible implications of tone and/or texture on patterns in a sequentially-structured satellite image analysis format (see, for example, Estes & Simonett, 1975), it occured to the present investigators to reverse the procedure and to tentatively explore the implications of pattern on tone/texture.

Pattern Recognition.--Students of the various earth sciences have always laid great stress on the pattern, or spatial arrangement, of objects as an important clue to their origin and/or function. Indeed, as stated in the Manual of Photographic Interpretation (ASP, 1960), the trained observer appreciates the significance of aerial photography "chiefly through his understanding of patterns on the earth's surface."

Further, in work which lay some of the important groundwork for the present investigation, MacPhail (1971) underscored the significance of pattern in the very definition of photomorphic units themselves. He stated that:

> In studying the 1:100,000 photomosaics and photomaps, it was apparent that broad identifiable patterns appeared that in many cases were repetitive. Such air photo images are, of course, composites of the geometry of the fields and fence lines, the patterns of drainage, and the tone ranges related to land use, rock outcrops, soil moisture and vegetation. We set out to use these composite patterns as our basic criteria in categorizing rural landscapes. The tonal variation related to land use, whereas the field sizes and arrangements pertained directly to property size and the history of settlement. Obviously, the drainage patterns and densities correlated closely with underlying geomorphological characteristics.

In a very real sense, the entire domain of remote sensing involves the recognition of patterns. Until very recently, however, geography and related disciplines have depended upon human observational skills (especially as set forth in the well-developed body of techniques for photo interpretation and analysis of images) in order to achieve some uniform sense of pattern recognition. Although such techniques are well suited for producing subjective information (upon which planning and related activities still depend to a high degree), the analysis of remotely sensed images is largely restricted to the type of qualitative evaluation and interpretation outlined above. As noted by Steiner and Salerno (1975), in such an analytical framework, provided, of course, that suitable information can be presented to the interpretor for his reference, he can employ his skills to "see through" (or reason "around") such factors as camera vignetting, sunlight/cloud differences, wet/dry variations, and processing variables. He is also able to apply a background of knowledge which is independent of the actual image content, often without *a priori* thought as to the precise definition of such additional knowledge.

The time is rapidly approaching, however, when the volume of the imagery available for interpretation and information extraction makes machine processing of data, on an automatic basis, a procedural necessity. For example, with the advent of multiband, multi-spectral imagery, inter-band interpretation becomes increasingly difficult for the human interpretor regardless of his apparent skill. An increasingly typical problem in such image analysis is indicated by Tanguay et.al. (1969):

> The maximum number of bands that could be handled and examined simultaneously in a convenient manner was six bands, and ideally only four bands. Attempts were made to visually examine the 12 visual bands simultaneously, but the information obtained in the first few bands was forgotten by the time the 10th, 11th or 12th bands were being examined.

The literature of pattern recognition *per se*, and of automated procedures for the recognition task, has grown substantially in the past several decades and has been contributed to by a wide range of research disciplines which heretofore were perceived as having very little else in common. Among others, books, reports and review articles by Andrews (1972), Arkadev and Braverman (1967), Casey and Nagy (1971), Centener and Hietanen (1971), Duda and Hart (1973), Gose (1969), Haralick (1969), Kovalevsky (1970), Patrick (1972), Sebastyen (1962), Steiner (1970), Tou (1969) and Young (1971), appeared to constitute a reasonably broad base from which to proceed in the present investigation.

In the context of the pattern recognition discipline which has grown up in recent years, very often the word pattern is not used in a sense "normal" to the geographer and/or the human photointerpretor. That is, pattern does not refer to a repeated sequence of specific characteristics, e.g., easily recognizable shapes, etc. In the special nomenclature of the pattern recognition researcher, the pattern which one wishes to recognize is defined as the specific entity which the recognition task seeks to identify, count, or locate in the imagery under analysis (e.g., tanks in a wooded terrain; diseased trees in an orchard; effluent in a stream; various geological features; fields planted with specific crops; etc.). To a considerable extent, the pattern which is being searched for or measured will depend upon the nature of the specific analytical task involved. Thus, caution must be exercised in the transfer of a pattern recognition procedure to an analytical framework other than that in which the procedure was evolved. This admonition notwithstanding, the pattern recognition aspects of the present study were pursued by virtue of the tonal/textural/pattern linkage outlined above.

It must be clearly understood that pattern recognition is not restricted to the detection and classification of spatial patterns. In a mathematical sense, a pattern is simply a set of numerical valves, each value describing the state of a particular feature. (Such sets of numerical values are commonly referred to as feature vectors.) It is therefore possible to apply basically the same recognition techniques in such fields as medical diagnosis and numerical weather prediction. An example of a nonspatial pattern in remote sensing is a set of signals obtained in several wavelength bands. In such a case what emerges is a spectral pattern. It is important, therefore, that a distinction be made between spatial pattern recognition and multispectral pattern recognition. It appears obvious that a complex analytical situation may require the use of both spatial and spectral information. In certain cases, as well, a third category of information (temporal) may also be required. On the basis of the present investigation the tentative conclusion has been that photomorphic analysis of LANDSAT imagery may very well be such a complex case requiring a full variety of information for pattern recognition purposes.

Fourier Transform Analysis.--A major step in the analysis of tonal/textural (i.e., pattern) characteristics involved the present investigators in spatial frequency analysis via coherent optics as proposed by MacDougall (1968). What is involved in this analytical procedure, essentially, is a data-processing system which is relatively recent in development and, as noted in the objectives to the present study, potentially very useful in the analysis of very large two-dimensional arrays such as photographs or other remotely-sensed images. Among other applications, the system can reveal important pattern characteristics of the original image by examination of the two-dimensional Fourier transform spectrum of the image.

An excellent treatment of the mathematics, nature and operation of Fourier transform and Fourier analysis is found in Shulman (1970) and in Francon (1963), as well as other standard references. In essence, the nature of the transform involved is basically as follows: Most nonsinusoidal periodic waves can be expressed in terms of sine-wave component of different frequencies. One advantage of this type of analysis is that each sine-wave component can be more easily handled according to the laws governing sine-wave calculations. The results of analysis for each of the component sine waves can then be readily combined to form the final analysis. An equation expressing the components of such a periodic wave is known as a Fourier series and can be expressed as:

$$y = f(x) = A_0 + A_1\cos X + B_1\sin x + A_2\cos 2x + B_2\sin 2X$$
$$+ A_3\cos 3x + B_3\sin 3x + . . . A_n \cos nx + B_n\sin nx.$$

The variable (x) may then be analyzed as a <u>position</u> function, or, by a simple conversion, as a <u>time</u> function, or as any component function of the periodic wave.

The basis of coherent optical data processing is that Fourier transform relationships exist between the front and back areas of lenses. It is the Fourier transform which is used to resolve a given function into its exponential components. The Fourier transform contains both amplitude and phase information for each and all of the spectrum components. In general, the formula for the two-dimensional Fourier transform (i.e., $F(u,v)$) of, for example, the light amplitude distribution (i.e., $A(x_1,y_1)$) in a plane perpendicular to the optical axis and at a distance d in front of the lens, is given by the formula:

$$F(\omega) = F(u, v) = \iint A(x_1, y_1) e^{-j2\pi(ux_1 + vy_1)} \, dx_1 \, dy_1$$

The essential components of such an optical processing system are a point source of coherent light, lenses, and planes for signal or input images and for recording. The basic configuration of such a system is shown in Figure 14. Once assembled, the system operates basically as follows:

1. A laser source if focused on a pinhole to provide a point source of coherent light (The pinhole is required because it is in fact this light which is imaged in later stages. The smaller such a pinhole source, the higher the system resolution.)

2. The light from the pinhole is collimated by lens $L_c$ to form a parallel beam.

3. This beam is then directed onto an input transparency at $P_1$, giving an emergent wave $E_1$.

4. The Fourier lens, $L_1$, images the Fourier transform of input $P_1$ at $P_2$. This image now represents the power spectrum (or, the spectral density) of the square of the wave.*

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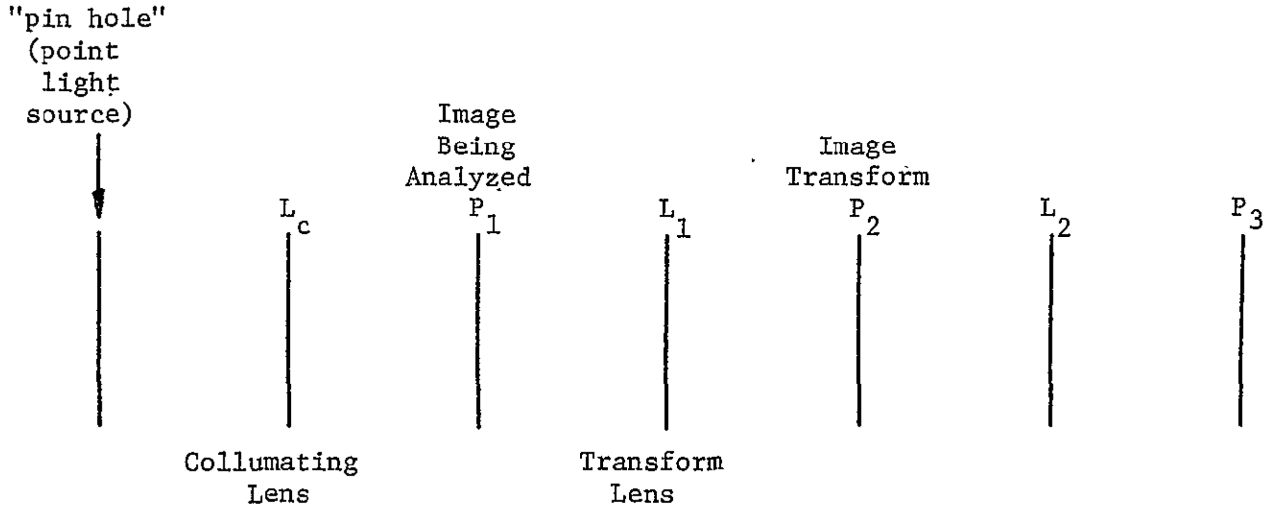
*In electrical engineering power in watts is equal to the square of the voltage divided by the resistance (i.e., $P = E^2/R$, $P \approx E^2$) or power is proportional to the square of the voltage. In optics the intensity of the light (power) is proportional to the square of the light amplitude (i.e., $I \approx A^2$). The power spectrum is, thus, the magnitude of the Fourier transform squared, and can be noted $|F(\dot{\omega})|^2$. (Shulman, 1970; Levi, 1968).

Figure 14: BASIC OPTICAL IMAGE PROCESSING SYSTEM (After MacDougall)



As an additional analytical step:

5. A further lens, such as $L_2$, can be inserted into the system to image the resultant power spectrum into its Fourier transform (i.e., the Fourier transform of a Fourier transform) which is the reconstituted signal.

For purposes of the experiments conducted in connection with this project, however, step 5 was omitted and an optical system of the type shown schematically in Figure 15 was assembled for the investigator's use by personnel in the optical bench facilities at MSFC.*

## Optical Experiment No. 1

The basic types of features which become apparent in the Fourier spectrum of a remotely-sensed image are in large measure due to the seemingly random nature of terrain and other physical landscape factors versus the structured (ordered) nature of manmade cultural features. Objects of a given size are characterized by a spatial frequency equal to the reciprocal of their width. Further, arrays of objects are characterized by a spatial frequency equal to the reciprocal of the array spacing. The features of interest, therefore, are of the following types: (1) magnitude of the two-dimensional Fourier spectrum at given spatial frequencies; (2) ratio of magnitudes at two different spatial frequencies, and (3) textural properties of various regions within an image can also be described in the frequency domain. By producing Fourier transforms of such regions, statistics for analysis are generated by performing an annular scan at particular radius values

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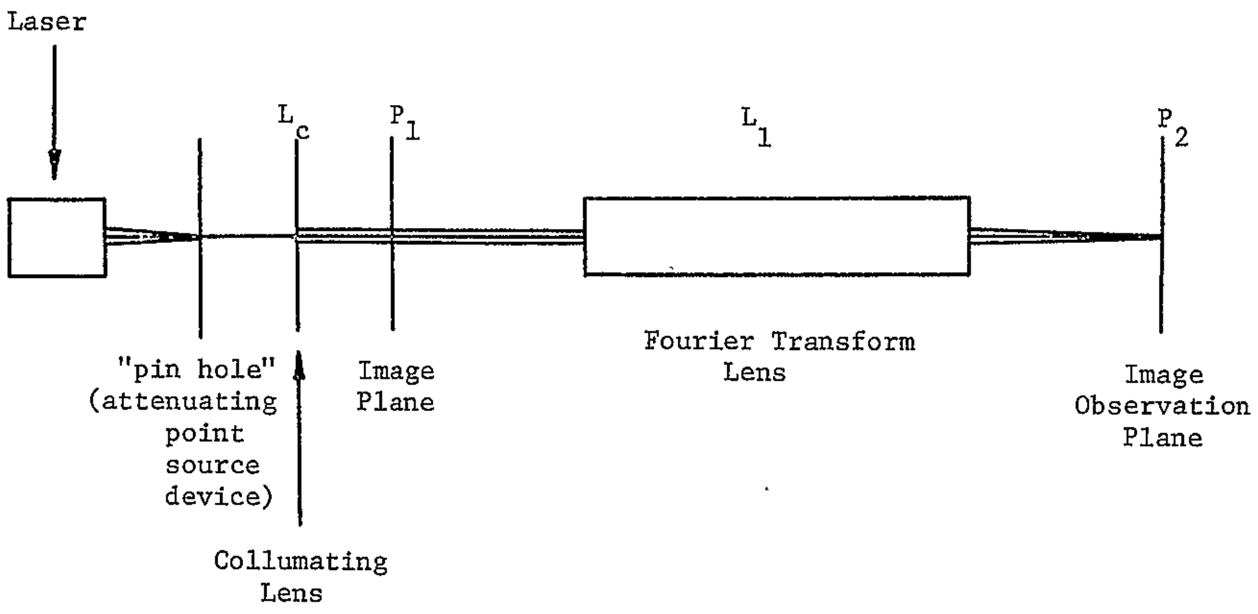
*The Fourier transform lens ($L_1$) employed was the Tropel Model 700-488.0 with an effective focal length of 23.58 inches (59.89 cm.) and a coherent resolution of 100 cycles/mm.

Figure 15: SCHEMATIC DIAGRAM OF OPTICAL SYSTEM EMPLOYED IN PHOTOMORPHIC REGIONAL STUDY.



or all radius values simultaneously (i.e., integrating over all radius values); or by performing a radial scan which samples along particular radius vectors or integrates over all angles.

A series of circular masks were placed over the LANDSAT image negatives (2.2 in./5.588 cm.) which allowed the passage of light only through the particular study window under consideration. Then, for each study window and for both 1973 and 1974 the image was illuminated and a 64-element wedge-ring (32 wedges; 32 rings) photodetector (Figure 16) was placed in the image plane (position $P_2$ of Figure 15) beyond the transform lens ($L_1$)* By manually switching to and from each of the 64 detector elements the power (frequency) displayed on each element was recorded. Then, by statistically analyzing the resultant data, graphs of the annular and radial characteristics of the window for 1973 and 1974 were constructed for purposes of visual comparison (see Figure 17). The assumption in this experiment was that any apparent divergence between the frequency distributions for 1973 and 1974 would be indicative of changes in the patterning of the image over the time span between LANDSAT images and could, hence, be employed as a basis for the analysis of change within the various photomorphic regions delineated in the area visible through the window.

Unfortunately, a series of problems seemed to plague the experiment from the start. Among other problems involving minor computer malfunctions, it was quickly apparent that the experiment was severely constrained by a series of variable factors over which little, if any, control could be exercised, some mechanical and some procedural. Primary among such

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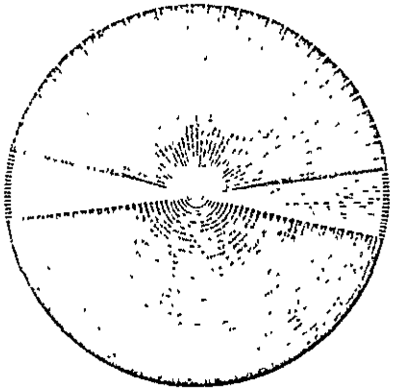
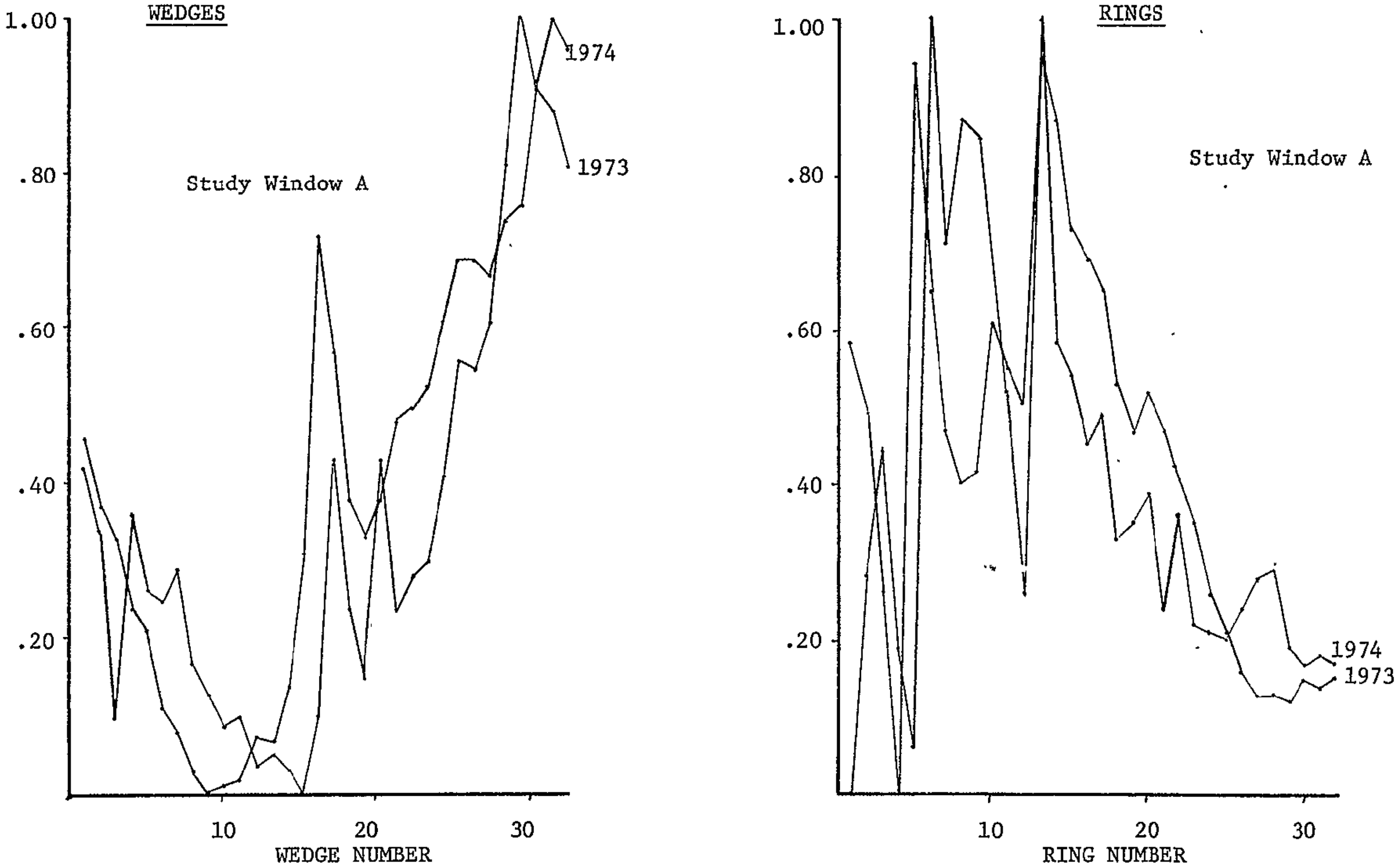
*The photodetection system employed was the Recognition Systems, Inc., Model DPSU-1, linked directly with the MSFC Optical Bench Facility computer for instantaneous printout of both the annular and radial frequency data.



| Ring No. | Outer Radius in Mils | Spatial-Frequency Limits in Line Pairs/mm (24.5 in. focal length lens, 6328Å) |
|---|---|---|
| 1 | 4.0 | 0.2 |
| 2 | 9.6 | 0.6 |
| 3 | 16.5 | 1.1 |
| 4 | 24.5 | 1.6 |
| 5 | 33.6 | 2.2 |
| 6 | 43.8 | 2.8 |
| 7 | 54.9 | 3.5 |
| 8 | 67.0 | 4.3 |
| 9 | 80.0 | 5.2 |
| 10 | 94.1 | 6.1 |
| 11 | 109.0 | 7.1 |
| 12 | 124.8 | 8.1 |
| 13 | 141.5 | 9.1 |
| 14 | 159.1 | 10.3 |
| 15 | 177.6 | 11.4 |
| 16 | 196.9 | 12.7 |
| 17 | 217.2 | 14.0 |
| 18 | 238.3 | 15.4 |
| 19 | 260.3 | 16.8 |
| 20 | 283.1 | 18.3 |
| 21 | 306.9 | 19.8 |
| 22 | 331.5 | 21.4 |
| 23 | 356.9 | 23.0 |
| 24 | 383.2 | 24.7 |
| 25 | 410.4 | 26.5 |
| 26 | 438.5 | 28.3 |
| 27 | 467.4 | 30.2 |
| 28 | 497.2 | 32.2 |
| 29 | 527.9 | 34.1 |
| 30 | 559.4 | 36.1 |
| 31 | 591.8 | 38.2 |
| 32 | 625.0 | 40.3 |

Figure 16: 64 ELEMENT WEDGE-RING PHOTODETECTOR.

Figure 17: SAMPLE OF SEMI-PROCESSED WEDGE-RING DATA DERIVED BY OPTICAL EXPERIMENT No. 1.



exogenous factors were: (1) density variation between 1973 and 1974 image negatives, thus, apparently, changing the content of study windows without evidence of change in the area imaged by LANDSAT; (2) variation in window mask placement between 1973 and 1974; (3) variation in the north-south and east-west alignment of the image negatives for analysis; (4) minor distance variation in the placement of image negatives before the Fourier transform lens; (5) minor variation in the placement of image negatives perpendicular to the collimated light beam; (6) vibration in the optical bench room, apparently caused by external air-conditioning systems, which had the effect of periodically mis-aligning optical bench elements; and (7) variations in readings taken of the same image at various times, apparently due to an error introduced into the photodetection device when subjected to heat build-up from long periods of operation. Owing to time and fiscal considerations, the experiment was terminated without conclusive evidence of inherent value in such an approach to the analysis of photomorphic regions over time. In general, however, on the basis of conclusions drawn in earlier research by Chalmers *et.al* (1970), Lendaris and Stanley (1970), Pincus, (1969), Tanaka and Ozawa (1972), and others, the present investigators feel reasonably confident in the conclusion that, under properly controlled circumstances and given sufficient time for such experimentation, further consideration of such spatial frequency analysis may yet provide results useful in the further clarification and application of the photomorphic regional concept.

## Optical Experiment No. 2

A second, more successful, experiment was conducted along the lines suggested by MacDougall (1968), and by Holmes *et.al*. (1968).

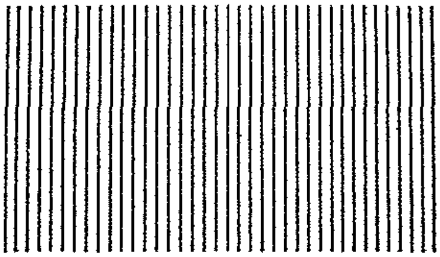
It is apparent that certain spatial patterns give rise to distinctive power spectra. Many spatial processes at work on the surface of the earth, however, do not appear to produce this result. The typical power spectrum is a field of light with no apparent peaks other than an X- and Y-axis corresponding to the aperture in the input plane ($P_1$). This type of spectrum, however, does contain a great deal of information which can be extracted by measuring intensity at various points in the field and subsequently carrying out various operations on a digital computer. Such, for example, was the case with the microdensitometer/digital computer experiments carried out by Flynn (1974) and which represented a portion of the tonal characteristics portion of this investigation using the computer program developed by Peach (1971a). In many respects this system seems to hold promise as a significant application of remotely-sensed imagery.

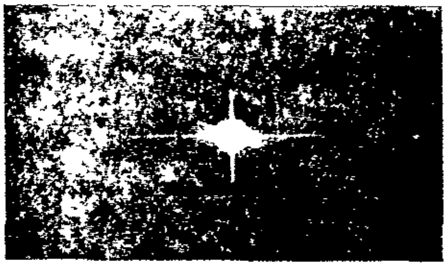
Figure 18 shows an example of power spectrum output from the optical processing system shown in Figure 15. The principal involved here is that when coherent light is passed through a transparency of the vertical line pattern each line becomes the source of a fresh disturbance and, thus, a new train of light waves. These new wave fronts reinforce each other and form wavefronts in phase for angles where

$$\sin \alpha = n\lambda/D$$

where $\alpha$ is the angle from the normal to the plane, n corresponds to the "orders" of the diffraction (i.e., a series 0, 1, 2, 3....), $\lambda$ is the wavelength of the incident light and D is distance. Thus, the zero order wave will continue in the direction of the incident wave, first order waves will leave at an angle which is

$$\sin^{-1} \lambda/D$$





The four power spectra at the right of the page are of a vertical line pattern, part of which is shown immediately above. The frequencies of the original input image increase, or the wavelengths decrease from the top of the page to the bootom. The frequencies are 16, 25, 37.5, and 50 lines per inch. The first and second spectra are enlarged 2.1 times, the third 3.0 times, and the last 2.5 times.

The spectra are useful also to illustrate system precision, in that there is apparent additional information around the dc component, and in one case (frequency 25) there is a fairly strong diagonal effect. These all arise from the nature of the original input diagram-transparency of a card with lines ruled with a felt-tip pen. Parts of the original diagram were apparently not so carefully ruled, and, thus, apparently introduced additional information. The diagonal effect may also be due to a fingerprint on the input film material.

(After MacDougall, 1968.)

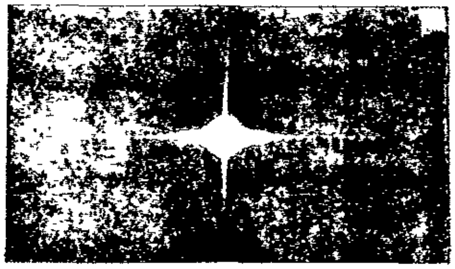
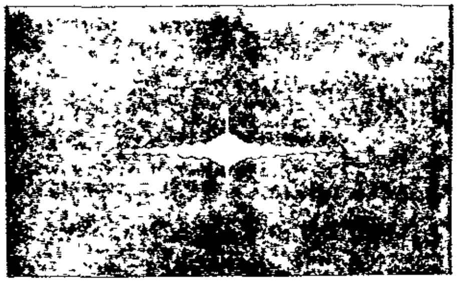


Figure 18: SAMPLE OF OPTICAL SYSTEM POWER SPECTRUM OUTPUT.



above and below the normal to the plane, second order waves at an angle which is

$$\sin^{-1} 2\lambda/D$$

and so forth.

When these various wavefronts are passed through the Fourier transform lens, they focus on or around the optical axis of the system, the exact location depending upon the angle of incidence to the lens, and thus, the order of the diffraction at the vertical line pattern in position $P_1$ (Figure 15).

The zero order fronts focus as a dot on the optical axis, referred to as the dc component of the spectrum. The first and second order (and perhaps higher order) waves focus as dots above and below the optical axis at a distance which approximates the image plane distance times the tangent of the angle of deviation above or below the normal. The separation of higher order dots is inversely proportional to the distance between the ruled lines in the transparent image, or directly proportional to their spatial frequency (Preston, 1968). The image thus represents the power spectrum of the original line pattern. Disregarding the dc component (which represents the mean ($\bar{X}$) normally subtracted in digital computation), there will appear two strong dots, mirror images of each other above and below the optical axis and corresponding to the principal spatial frequency or wavelength of the ruled line spacing. The further series of dots beyond these two result from higher order diffraction at the input image, and correspond to the harmonics of the basic spatial frequencies. These higher order dots have less intensity because there is less contribution from each line diffraction as the order increases (Francon, 1963).

The resultant configuration of spectral peaks which correspond to more or less regular ground patterns can be classified as being of two basic types: (1) clear arrays of distinct points; and (2) considerably higher power in certain directions but as a "smear" rather than a series of points (MacDougall, 1968). It should be apparent that the first type of pattern will arise from more equally-spaced lines or points in the image, such as plowed fields and crops, particularly orchards. The second type of pattern is much more difficult to interpret. Figure 19 shows the original image and the power spectrum for an agricultural area near Asheville, North Carolina. Two regular spatial patterns are apparent on the image--the orchard and the furrows in the plowed field. The spectrum shows the second of these very clearly as a series of distinct points corresponding to the basic spatial frequency of the furrows plus harmonics. The orchard is only barely visible in the spectrum as four points around the dc component. It is less apparent than the furrow pattern because: (1) the frequency is lower, and thus closer to the dc and the spectra of random spatial elements which tend to obscure it; (2) the power of this frequency is lower, that is, the contrast between trees and the surrounding area is not as high as in the case of the plowed field. In Figure 20 the original image and the power spectrum for an area of orchards and a portion of a sewage treatment facility near Miltipas, California, is shown. Again the spectrum shows a distinct pattern which corresponds to the rectangular arrangement of the orchards. Examination of the imagery reveals that the orchards are not all aligned in the same way. This is also apparent in the spectrum, particularly at the frequencies somewhat farther out from the dc component. By way of contrast, Figure 21 shows an agricultural area, again near Asheville, North Carolina, and its spectrum in which there are at least five apparently different orientations of high frequency information. Examination of the original image shows that each of those orientations corresponds to the orientation of orchard areas within the rather random pattern of agricultural fields.

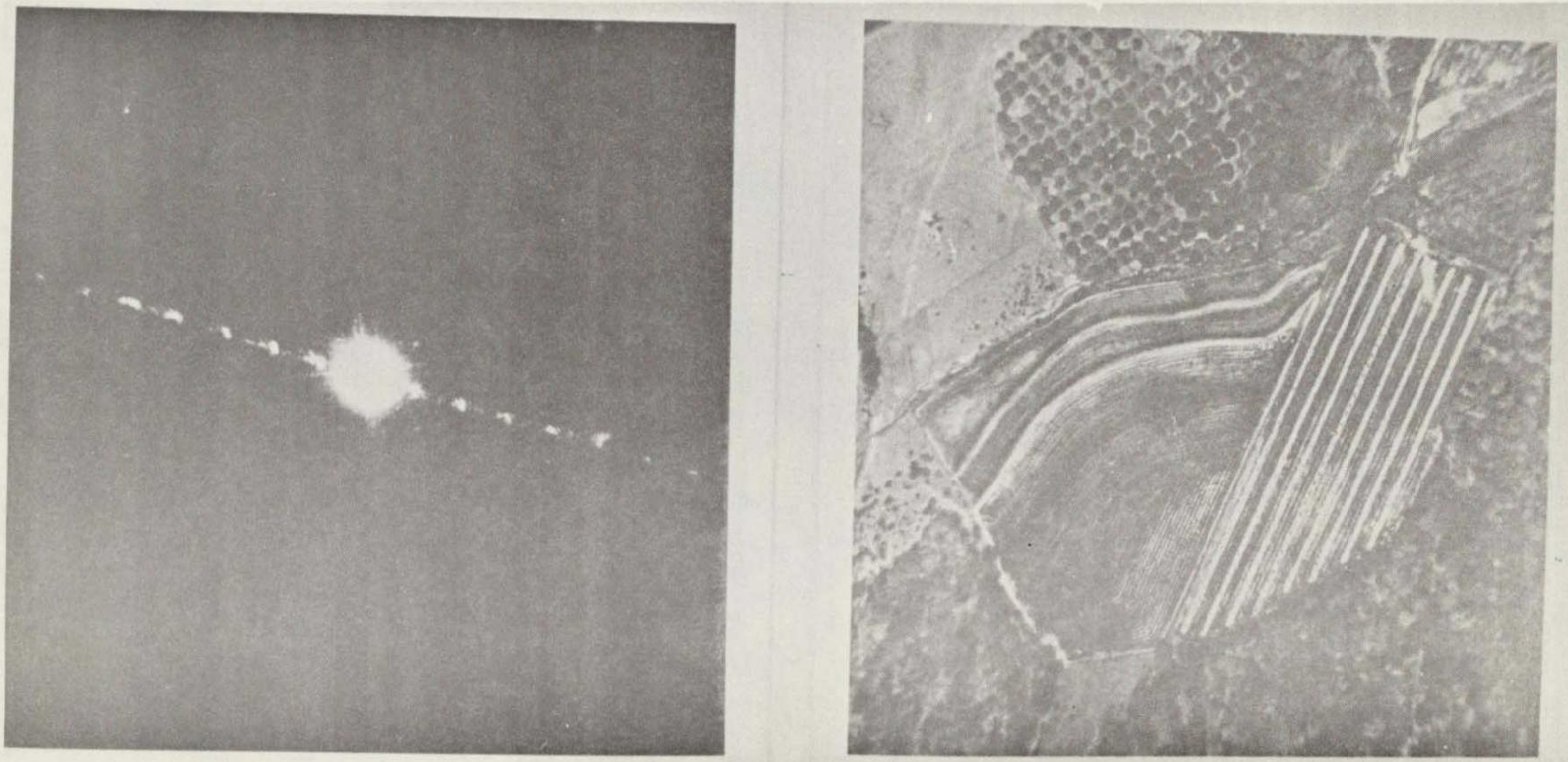


Figure 19: OPTICAL POWER SPECTRUM: NEAR ASHEVILLE, NC.

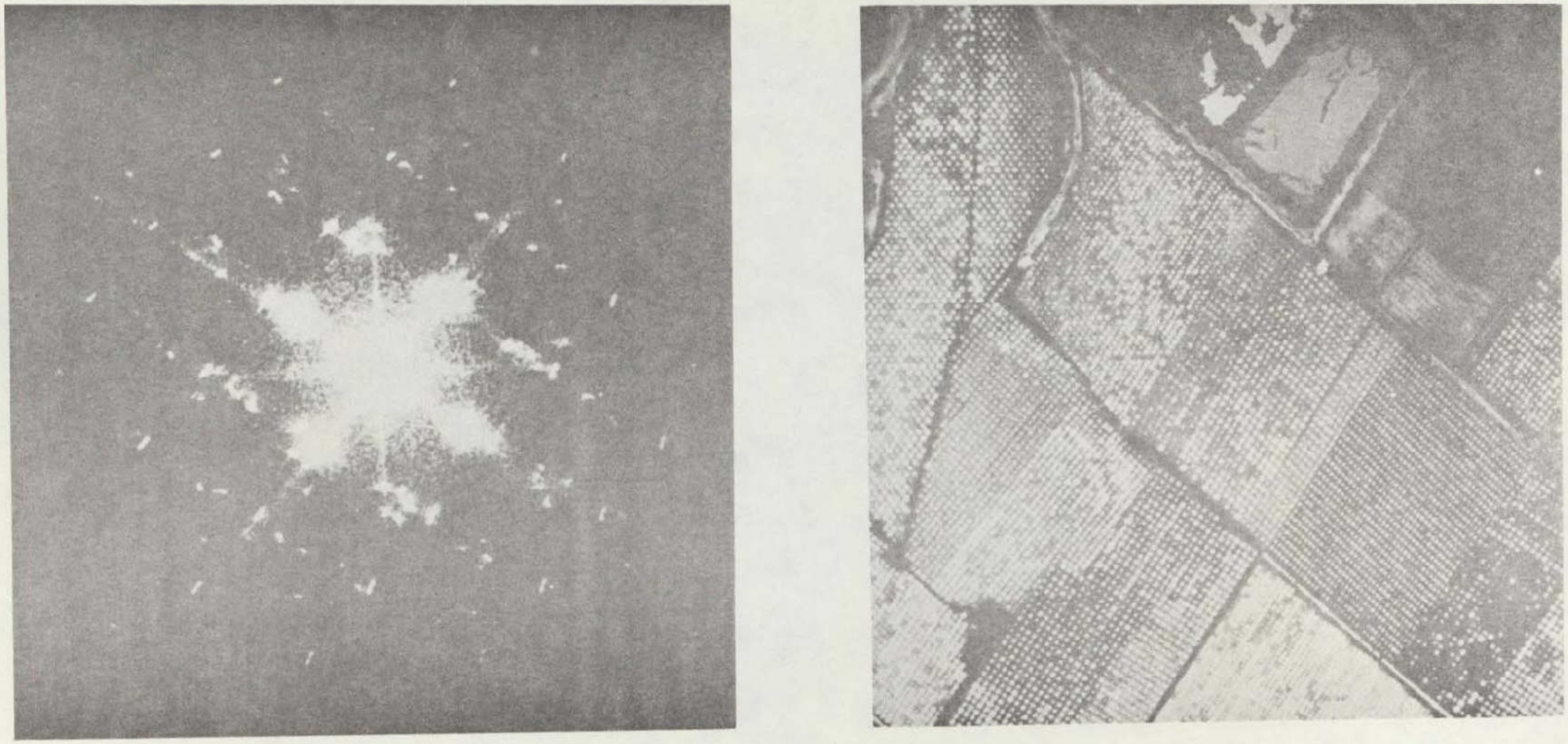
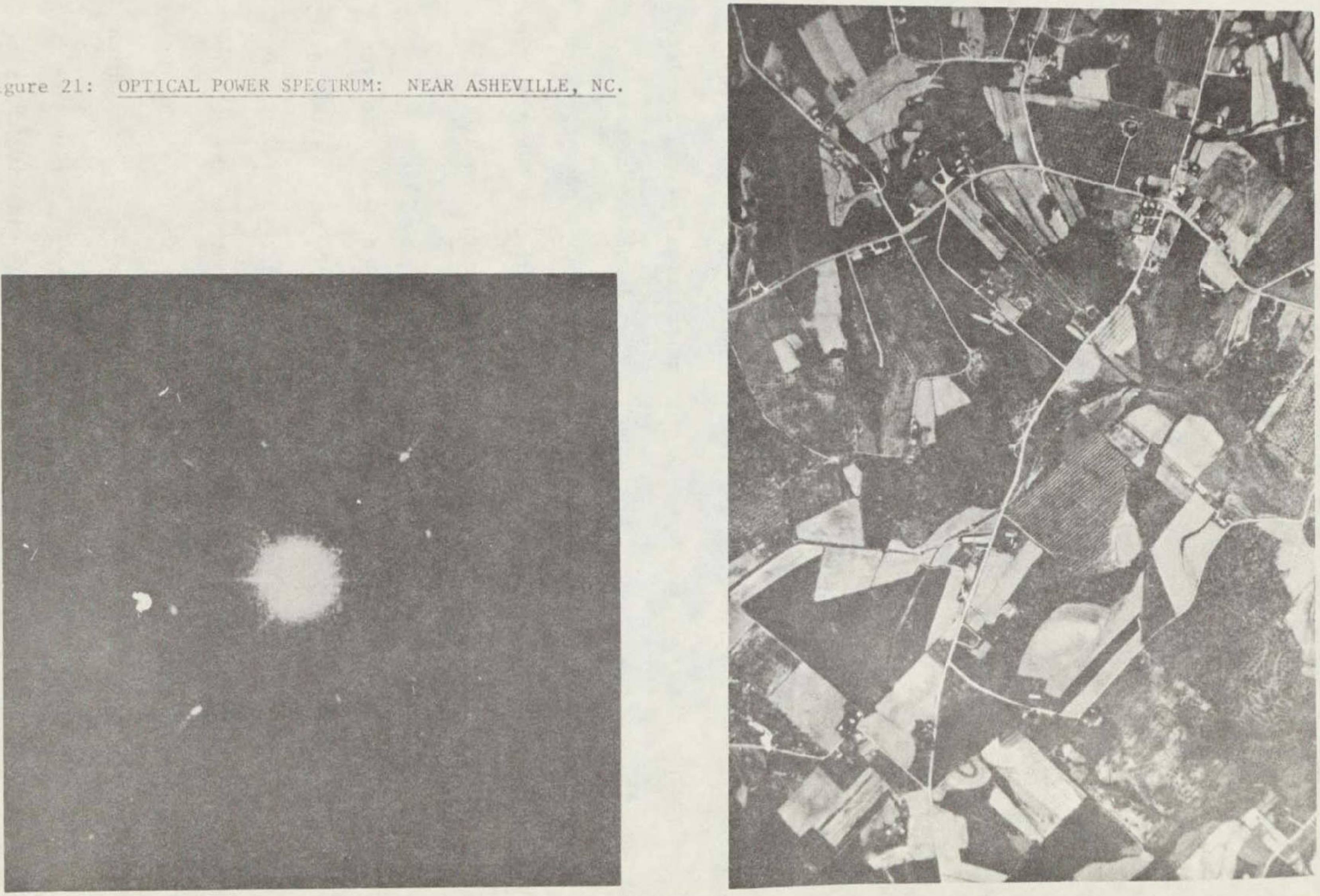


Figure 20: OPTICAL POWER SPECTRUM: NEAR MILTIPAS, CA.

Figure 21: OPTICAL POWER SPECTRUM: NEAR ASHEVILLE, NC.

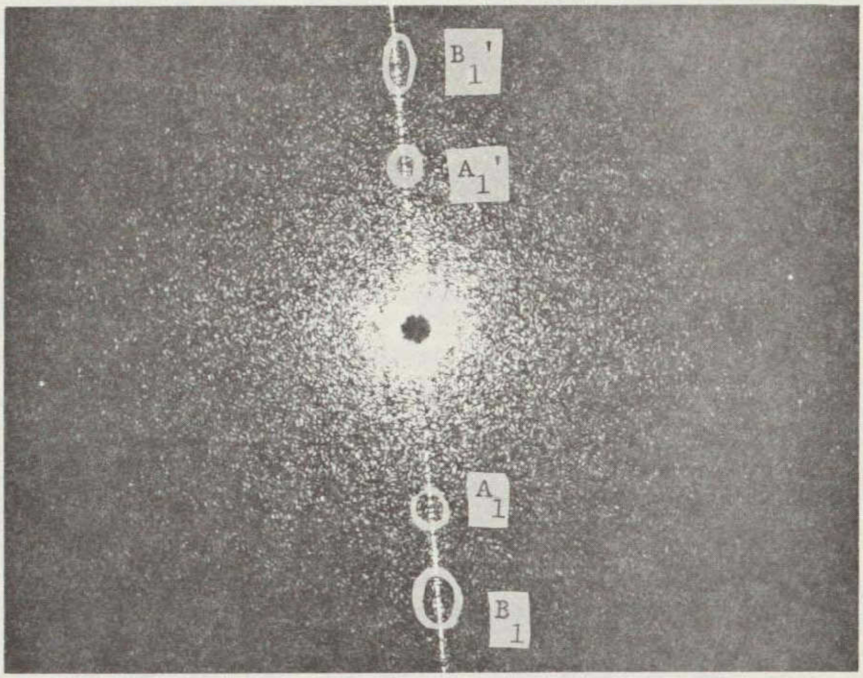


A possible further value of the power spectrum analysis is the fact that the spatial regularity on a suitable image appears so distinctly in its spectral output. This means that the necessary resolution of a scanning device and computer storage space in an automated interpretation system would be considerably reduced. For example, considering Figure 19, in order to categorize the patterns of orchards in the spatial (i.e., image) domain one would be required to examine of the order of one million locations (1,000 x 1,000), but in the frequency domain some 10,000 (100 x 100) or less would apparently be adequate.

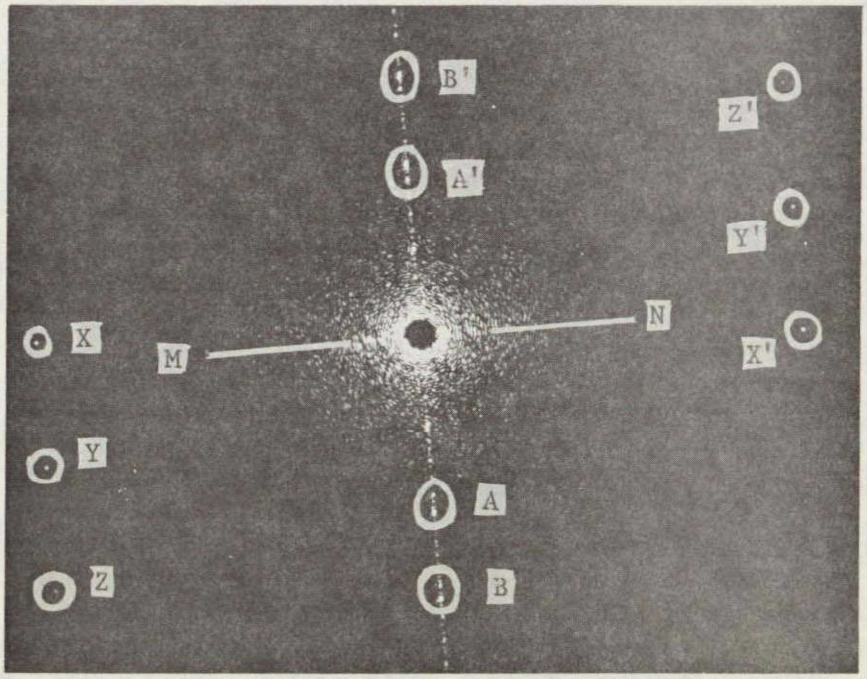
The only necessary modification to the optical system shown in Figure 15 for this experiment is the replacement of the photodetector and analyzer with a Polaroid film pack unit at position $P_2$. In complete darkness, the power spectrum of the image is then displayed on the exposed film. This process was repeated for each study window for both the 1973 and 1974 masked Band 5 imagery. The power spectra thus generated are displayed in several of the figures following and in Appendix E to this report.

Figure 22 shows 1973 and 1974 Band 5 optical power spectra for the area designated study window D, located west of West Point, Mississippi, in an area straddling the Clay/Oktibbeha County boundary (see Window D, Appendix D). Note first of all the marked contrast between the relative clarity of the 1974 (bottom) and 1973 (top) spectra. The 1973 spectrum seems to have been clouded to a heavy degree by system "noise" for which the investigators have been unable to account. It may be that what is characterized as noise is actually a reflection of the wide diversity of tonal characteristics for the 1973 image as noted earlier (see window D in Appendix A).

Figure 22: <u>POWER SPECTRA FOR STUDY WINDOW D, 1973 & 1974</u>.



1973



1974

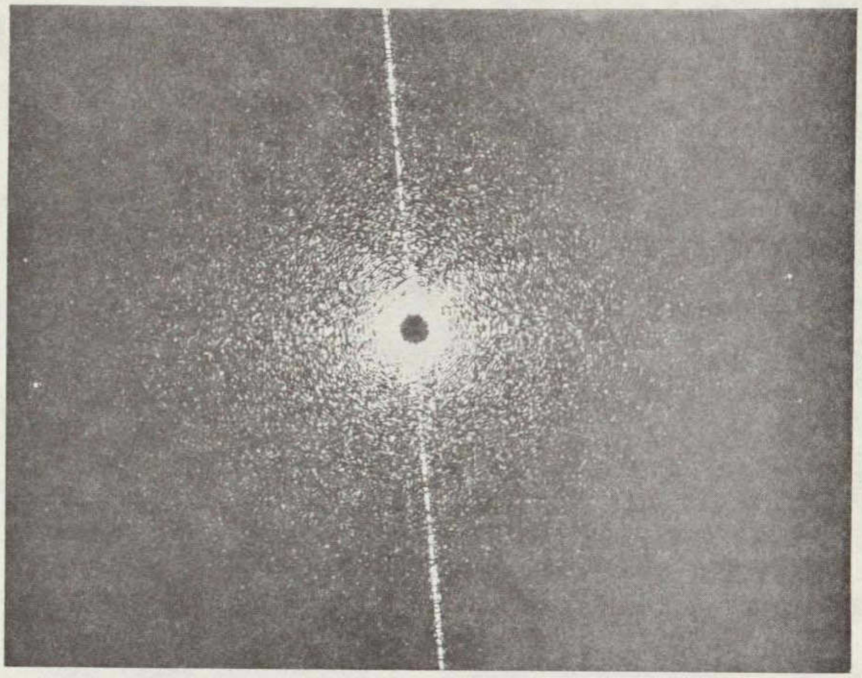
A second feature worthy of note in Figure 22 is the apparent secondary axis, nearly parallel to the optical axis (denoted by the line MN). Notice that the apparent trend line is either lacking in the 1973 spectrum, or it has again been obscured by noise. The investigators tend to believe that since this apparent axis lies parallel to the optical axis it might be the result of scan lines readily visible in the 1974 image and not nearly so prominent in the 1973 image of the same area. In any event there does not appear to be any readily identifiable surface-of-the-earth characteristic by which to account for this trend line.

A third feature of Figure 22 is the set of three corresponding points (X & X', Y & Y' and Z & Z') lying equidistant from one another as mirror images near the edge of the spectrum frame. These points occur on all power spectra for all study windows and are therefore assumed to be associated with the visible "edge" of the opaque black paper circular masks by which the windows were bounded. An interesting point, however, is that these "dots" are almost invariably more visible in the 1974 than in the 1973 images.

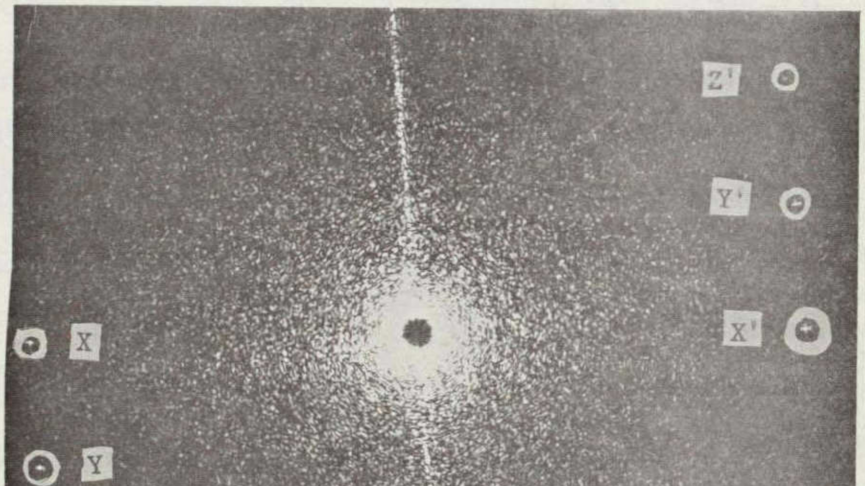
A final feature of note in Figure 22 are the pairs of points A-A' and B-B' (in the 1974 spectrum) and $A_1$-$A_1$' and $B_1$-$B_1$' (in the 1973 spectrum). Notice that the appearance of these indications of higher order information are much more clear in the 1974 spectrum where they are not obscured by apparent noise as they are in the 1973 spectrum. The landscape features causing this phenomenon are not clearly apparent in the imagery, but, may well be the result of the textural variation within the window area.

Figure 23 shows the 1973 and 1974 power spectra for study window F, centered on the Meridian (MS) Naval Air Station. It had been assumed by the investigators that the three runways of the facility which

Figure 23: POWER SPECTRA FOR STUDY WINDOW F, 1973 & 1974.



1973



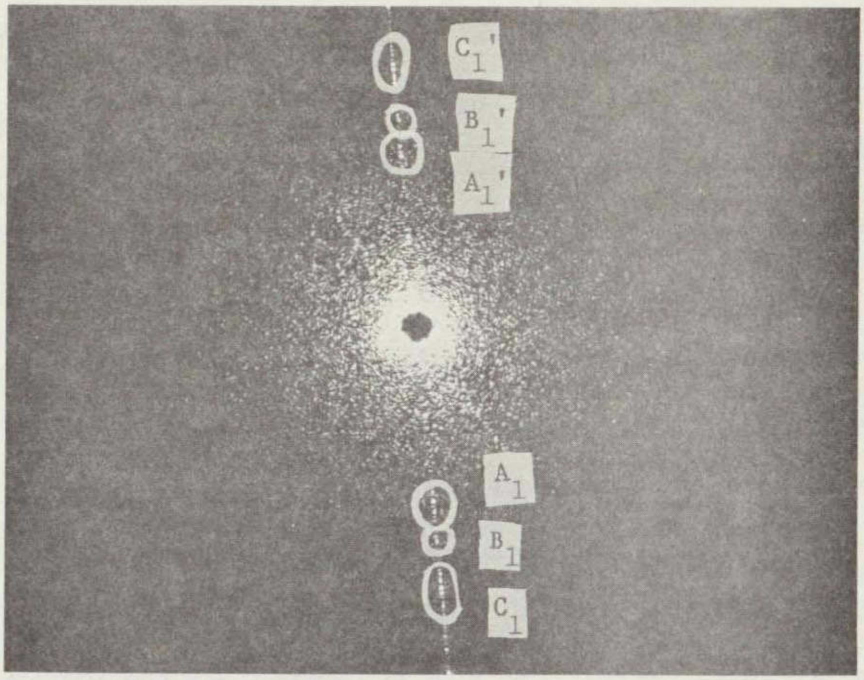
1974

are so clearly visible on the imagery and which had been delimited as a separate photomorphic region by earlier experimentation, would exhibit some clear evidence in the power spectra. Such, however, was either not the case, or such evidence once more is obscured by system noise. Notice also in Figure 23 the absence (or obscurity) of clearly observable points above and below the optical axis as seen in Figure 22. Finally, notice once again the clear evidence of corresponding points X-X', Y-Y' and Z-Z' circled near the 1974 spectrum frame. As indicated above, these points appear with varying clarity on all spectra for all windows, but the apparent cruciform shape of these points is unique to study window F.

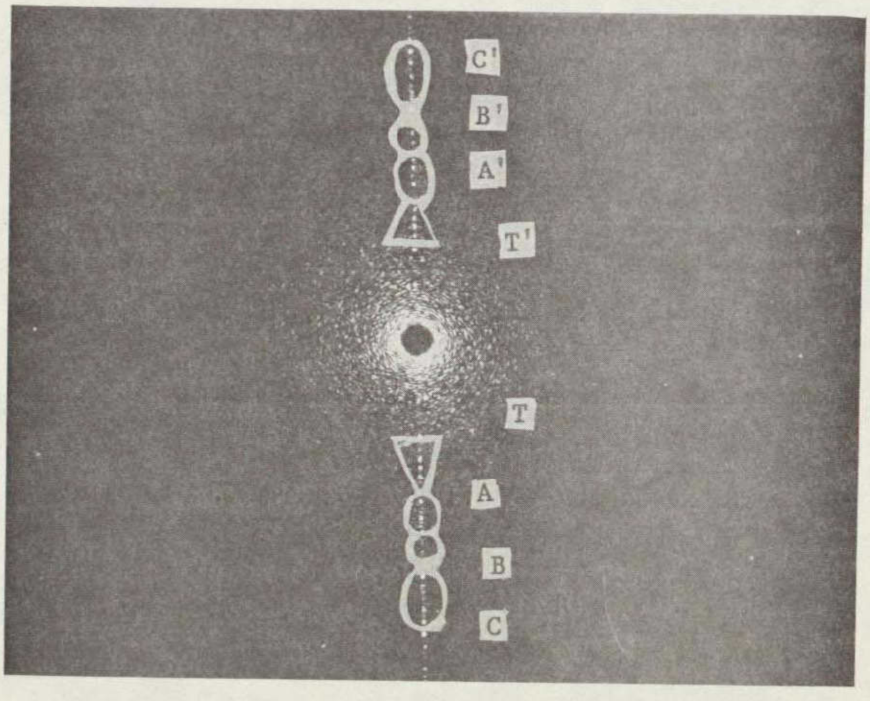
Figure 24 displays the optically derived power spectra for study window J located over the city of Tuscaloosa, Alabama. Of particular interest here is the set of clearly discernible mirror image points (A-A', B-B' and C-C' for 1973, $A_1$-$A_1$', $B_1$-$B_1$', and $C_1$-$C_1$' for 1974 above and below the optical axis. As indicated above, these points clearly represent higher order frequencies and are quite probably related to the street pattern of the city and urbanized area. Of note, however is the set of points marked by triangles T and T' on the 1974 spectrum which are apparently absent from the 1973 spectrum. Close examination of the Band 5 imagery at 1:250,000 scale does not reveal any significant changes in the configuration of the urban area which might account for the "new" higher order information in 1974.

These distinct spectra reflect spatial difference in an image, and the more the difference (i.e., the more the contrast), the stronger the intensity in the spectrum corresponding to that frequency and direction. To make full use of such spatial signatures, then, one must, among other factors, be aware of the gray level characteristics corresponding to a particular type of feature in a particular sensing system. Some earlier research has

Figure 24: POWER SPECTRA FOR STUDY WINDOW J, 1973 & 1974.



1973



1974

been directed toward these differences, both in the present investigation and, for further example, by Gates (1964) and by Legault and Poleyn (1964) and more recently by Holmes et.al. (1968) and by Hord and Gramenopoulos (1971). This characteristic gray level by sensing wave band is termed the "spectral signature," where the term spectrum refers to the sensing waveband. Given a set of spectral signatures a choice of sensing systems, an optical processing system, and a scanning and computing system, it should be possible to produce not only a close estimate of the types of objects on the ground (from their spectral signatures), but also some indication of their relative frequency on the area they cover (from the spectrum) (MacDougall, 1968). Further, as noted by Haralick and Bissell (1970), some objects can be expected to exhibit characteristic spatial ordering patterns, so it might well be possible to identify a phenomenon (and to monitor changes over time) not only by a spectral signature but also by a spatial signature. This would considerably increase the reliability of an estimate of landscape characteristics generated by an automatic processing system.

For purposes of comparing images, either of differing areas (as between and among the study windows) or of different time periods (as between 1973 and 1974 images for a single window) it is obvious that further investigation is required. Since the return to a sensing system from a surface or object on the surface of the earth varies with the waveband of the sensor and the characteristics of the surface itself, it may be expected that spatial differences in the image and the output from such an optical processing system will also vary considerably. This expectation might be fruitfully tested by applying such methods as those suggested by Holmes, et. al. (1968), employing cathode ray viewing of the power spectra with the dc component "filtered" out by placing it "off camera,"* or by applying the same sort of microdensitometer scanning process as was employed in the photomorphic regional delimitation process earlier to the power spectra themselves and comparing the contrasting tonal/textural characteristics of image and Fourier transforms. Such experimentation, however, is well beyond the limitations imposed upon the present study. In any event, the concept of the coherent optical system for imagery analysis, does appear to be a considerably less time and dollar expensive, and, perhaps, an even more efficient system for discriminating and comparing the information content of imagery obtained by different sensing systems.

## Summary and Conclusions Concerning Photomorphic Regional Investigation

There can be little question as to the functional utility of hyper-altitude and spacecraft (including satellite) imagery in the context of regional analysis. Current and recent-past research has, it would seem, demonstrated beyond a doubt that, as remote sensing systems have become more and more sophisticated, their application to the solution of man's earth-bound problems has dealt more and more effectively with the apparent data and information needs of the decision-makers.

Equally, the authors believe, the photomorphic regional concept, when applied to the returns obtained from LANDSAT imagery (as in this study) can be extremely useful in the satisfaction of the data and information needs of regional planning, as a specialized branch of problem-solving and decision-making. The photomorphic regional concept has repeatedly

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*It should be noted that some limited experimentation with these procedures was conducted in the course of this investigation, but not to any extent sufficient to draw hard and fast conclusions as to validity.

demonstrated its functional utility in terms of describing and, indeed, explaining the various morphological characteristics of broad regional landscapes-both natural and cultural.

Further, there appears to be strong evidence that the photomorphic regional concept/remote sensing imagery interface can achieve most dramatic results when employed through experimental and applied research tasks dealing with coherent optical processing equipment of varying degrees of sophistication.

Several problems, however, are abundantly apparent on the basis of the present investigation. The authors feel most strongly that there is substantial room and need for continued experimentation so as to bring to a fuller level of understanding those parties who have heretofore dealt with regional analysis and planning problems on a rather restricted basis. At times it appears as if the very worst aspects of our specialized educational and research systems have closed off doors which, though logically associated with problem-solving tasks, lead to unfamiliar paths.
That is, even though there has been widespread research undertaken in the area of determining the extent to which remote sensing and planning are interrelated; the fact remains that there is so very little apparent coordination of such research and so very much need for such coordination!

This is, of course, nothing new to our society in general, and there is little reason that we should have expected its absence from the rapidly emerging remote sensing/planning field. Nevertheless, at this juncture the authors can only express their hope that corrective action is applied to this matter at the earliest possible time. It will be no easy task to assemble and finance the research teams to carry out coordinated research in the areas only briefly touched upon herein. It will require the acquisition of new skills, the bringing together of diverse backgrounds and the employment of research techniques and technologies which have been directed at varying areas of recondite focus. The end result, however, can be expected to produce fresh, new insights into man's problems of planning for orderly occupance of areas on the earth's surface.

With specific regard to the photomorphic regional investigation here reported, the authors would state as follows:

1. The photomorphic regional concept can indeed, be useful in terms of analysis of regional characteristics as imaged on LANDSAT returns.

2. There is a need for more time to allow further investigation of the ultimate contribution to photomorphic analysis which can be expected from pattern recognition, coherent optics, and related research.

3. It appears that an automated system for the identification of landscape characteristics is, indeed, not very far in the future and that the computer procedures herein explored can be expected to yield more fruitful results when modified so as to incorporate both tonal and textural parameters into a simultaneous analytical process.

4. There is some question as to whether or not the LANDSAT imagery can yield the most beneficial results for regional planning purposes because of various scale/resolution problems (discussed in more detail in Chapter IV).

5. Because of time and fiscal constraints, the present authors were not in a position to explore as fully as possible the optical bench

applications and their potential contribution to the photomorphic concept. Suffice it to say that, under more carefully controlled circumstances, a repitition of the experiments herein conducted might prove to be both too complex and too expensive for immediate application to the operational characteristics of the representative regional planning agency. Such constraints, however, do not obviate the need for such further investigation.

6. There was insufficient time to explore the extent to which the photomorphic regional concept has the potential to bridge, or not bridge, the inventory-to-analysis gap in regional studies. Again, such research work would be most beneficial inasmuch as it might be expected to contribute heavily to the solution of the scale/resolution problems suggested above.

7. Finally, the exact extent to which the photomorphic concept can produce meaningful results in the area of analysis of temporal change remains unclear at this juncture.

In the chapter which follows, the results of the ground truth investigation (carried on parallel to the photomorphic regional analysis tasks) are reported.

# CHAPTER III: GROUND TRUTH INVESTIGATION

## Introduction

The acquisition of empirical data has always been an integral part of research efforts. Only recently, however, have investigators questioned their procedures and methodologies in the sense of "what happens" during the process of transforming data into usable information. This line of questioning has led to the formation of a number of new subfields, and in some cases whole disciplines. Among others, the formalas opposed to substantivefield of general systems theory, which had strong direction by the biologist, von Bertalanffy (1962) is one such discipline. Associated with general systems theory are such areas of inquiry as organization theory and information theory (Rapaport, 1956; Rapaport & Horvath, 1959).

In the earth and social sciences, there are several well-established traditional sources of data. The U.S. Census, among others, is a most important data source from which environmental information can extrapolated.

Mental images play an important role in the process of changing data into information. For the average person a mental image is the result of cultural background and social environment. The scientist produces a mental image as a result of training and various frames-of-reference with which he is familiar. In geography, for example, it is now recognized that "mental" maps have great behavioral impacts on whoever produces them (Gould & White, 1974). The study of environmental perception is now beginning to show that a major portion of the geographical and operational "worlds" are the direct result of what people _think the world is like, rather than what actually exists_.

Concomitant with developments in the field of environmental perception, semanticists have recognized that communications can produce a variety of meanings from the same sentence. Pike (1964) has initiated research in an area he calls _tagmenics_, recognizing at least three forms of meanings associated with the simple ideas expressed in sentences--particles, waves, and systems.* Thus, the field of mental impression is expanding on a number of discipline research fronts.

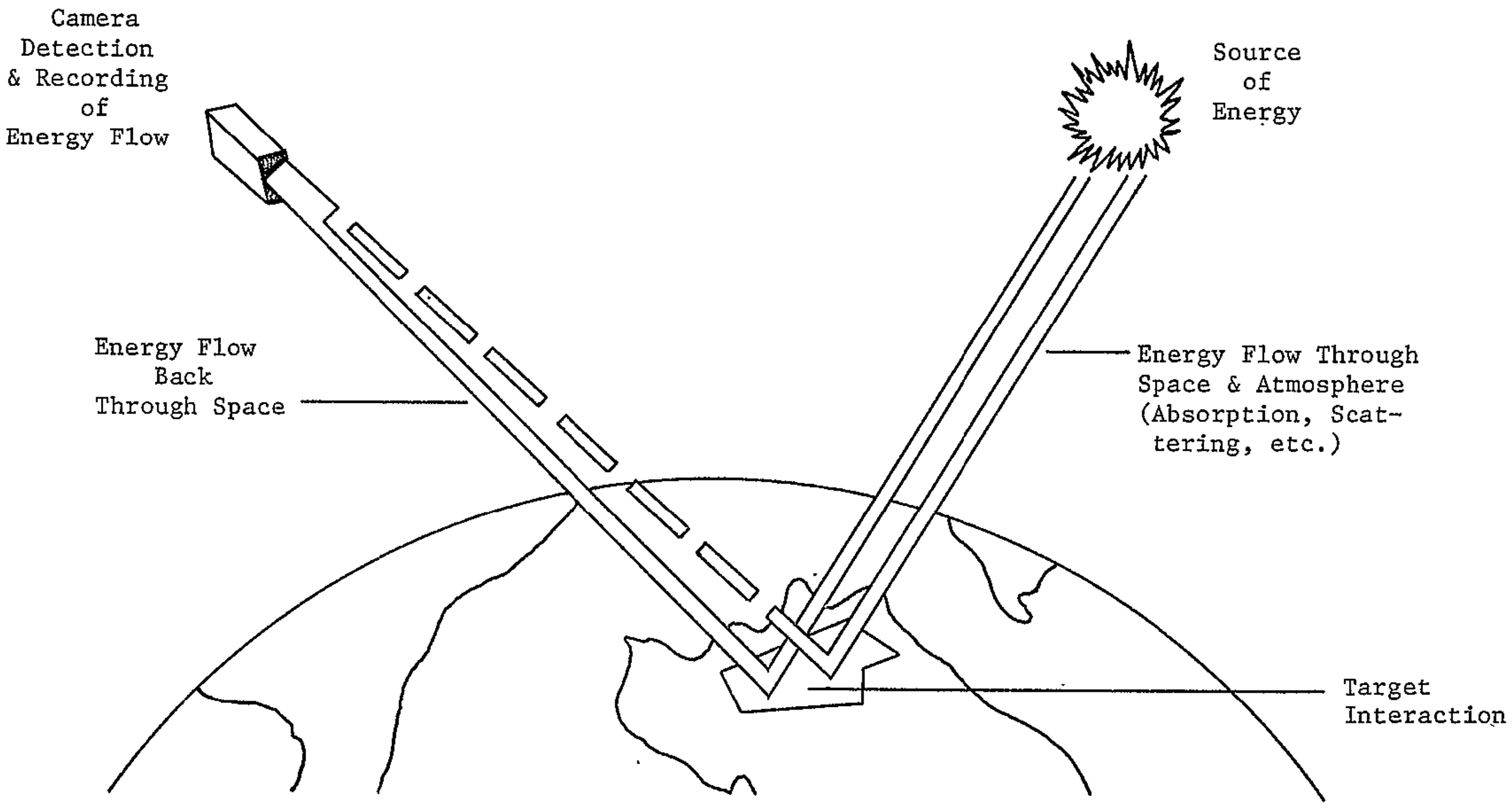
Communication problems are also associated with photographic images. In a sense a photographic image is simply a record in a fixed number of spectral bands of a happening(s) at a moment in time. The interpretation of _what exists_ on a photograph can be approached from a number of points-of-reference. The most frequently used is that known as _object-interpretation_. Objects on photographs, whether taken from ground perspectives or from the perspectives of aircraft or spacecraft platforms, are interpreted on the basis of size, shape, tone/color, pattern, associations and so forth (Rabben, 1960). In the recent past, great attention has been given over to the interpretation process associated with different realms of recorded data falling outside of the visual part of the

EM spectrum, including ultraviolet, infrared, and microwave bands. In many cases the use of these "extravisual" portions of the EM spectrum precludes the technique of objectinterpretation because objects are not recognized as they exist in the visual band. Olson (1962) has recommended that another interpretive procedure be employed; that being the interpretation of the energy flow profile, that is, to examine the characteristics and interactions that take place among the source, atmosphere, target, and the recording devices and the EM radiation being recorded (Figure 25).

Information is also gained from photographs and other remote sensor returns via a third procedure. This procedure, called multi-spectral or multi-band interpretation, is analogous to the methods used in Gestalt psychology where it is recognized that "the whole is greater than the sum of the parts." With the multispectral procedure two or more remote sensor returns can produce more information when viewed in concert than can be gained by viewing the returns separately.

The Photomorphic Concept Reviewed.--With the advent of air photomosaics and spacecraft photography, another photographic interpretation procedure was developed. This process, called the photomorphic concept, recognizes that data, which is to be converted into information, can be extracted from the composite traits of tone and/or colors, texture, and patterns produced on hyper-altitude photomosaics and spacecraft image returns. These returns and others (e.g., radar and thermal infrared) produce image structures which can be recognized in terms of their small-scale characteristics and/or low-resolution qualities. These qualities appear to have implications which are related to large-area spatial characteristics

Figure 25: ENERGY FLOW PROFILE (After Olson).



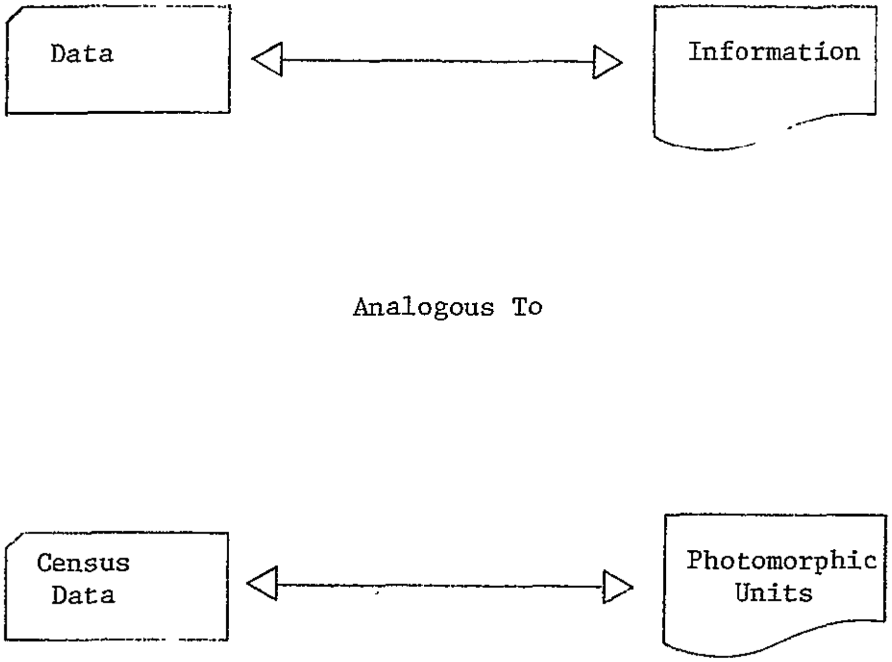
which, in turn, have morphological traits which can be detected by remote sensing devices. Many of the form traits which are directly visible can be linked to specific regional planning problems and can, subsequently be given a priority classification with respect to area planning policy(s). Of equal significance is the fact that many functional traits which are invisible as morphologic traits can be indirectly depicted through surrogate procedures. For example, population characteristics are normally "invisible" on spacecraft or hyper-altitude photography, but housing traits (a proxy for population) are not. Thus by locating various residential forms, for example, it is possible to predict associated characteristics of population information of great value for planning purposes.

## Objectives of Research Task

The general objective of this research task was to confirm the procedures tested for gaining viable planning data from the delimitation of photomorphic units. The specific procedure followed in this task, however, was the reverse of that which is normally followed. Instead of using photomorphic data and proceeding to the extraction of planning-type data and the empirical (ground) verification of that data, the procedure here is that with Census and other historical data, it is possible to reconstruct what (1) the tonal qualities of images and (2) the textural properties of photomorphic units _should_ be like. In other words, the procedure here described is more akin to the "prediction" of photomorphic characteristics than to the process of empirically checking photo interpretation results. In short it is suggested that data can, indeed, be converted to information and that _the process is reversible_ at least with respect to photomorphic analysis (Figure 26).

G-2

Figure 26: DATA-INFORMATION LINKAGES.



Heretofore, photomorphic investigations of data-information linkages have proceeded in the "traditional" direction, i.e., from photomorphic regions to Census-type data. There is obviously no value in obtaining information which is already known. However, there is apparent value in (1) confirming that the procedure can be duplicated by proceeding from Census data to photomorphic units, for such a procedure can then be used to calibrate the reverse (normal) procedure, (2) measuring deviations from the model of expected target signatures produced from Census data, and (3) producing a methodology and technique to view unknown areas for which Census data is not available or unreliable.

Even before carrying out an investigation of this type several constraints were recognized. Among the more significant is the fact that photomorphic regions are "environmentally-modulated." That is, there are constraints which the local environment has on its respective photomorphic units. From this standpoint it is necessary to view the third point mentioned above with great caution; that is, regions which are widely separated, but which appear similar, may, in fact, be the result of a totally different complex of factors.

It is believed, however, that large-scale areal data can be compared to smaller areas, and vice versa, if the two are associated <u>within</u> each other. That is, the large-scale situation exists as a subset of the smaller-scale traits (Haggett, 1965). At the present time, the best organized and most readily available data concerning large-area small-scale situations are produced by the Bureau of the Census. Only a portion of the Census information, however, is directly appropriate to the examination of morphological traits. Nevertheless, some Census data, as indicated above, can be employed as surrogates through which it is believed an infinite number of morphological expressions are identifiable.

Furthermore, it is recognized that Census data are really location-specific, but are not categoricallyspecific with respect to point situations. To be sure it is possible to "narrow" Census data to Minor Civil divisions. This procedure, however, would be very costly to the regional planning agency. County data, on the other hand, is available to every researcher from library sources.

Hypothesis to be investigated.--The hypothesis to be investigated here is that Census and other historical and map data can be used to predict the appearance of photomorphic units.

Because this hypothesis is related to the pattern recognition procedures discussed earlier, it is organized around a number of sub-hypothetical situations. The first of these sub-hypotheses is that the major and minor tone characteristics are related to major and minor spectral traits of landscape characteristics, thus producing a hierarchical order. These characteristics are believed to be place-(environment) and time-modulated, especially with respect to rural landscapes.* Thus, a second sub-hypothesis is that if the second part of the first sub-hypothesis is true, then different tonal situations can be used to describe the same areal locations at different time periods. Obviously, therefore,

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*It is interesting to note that small-scale views of urban locations such as those which are obtained from LANDSAT or Skylab, produce basically the same tonal patterns throughout the year.

a series of catalogued tonal signatures can be "constructed" for standard Census traits. Further, any deviation from the expected construct will in itself be of great value, especially in terms of preliminary identification of some unknown trait associated with an area.

As suggested earlier, however, tones do not exist by themselves. Depending on the way tones are spatially arranged on a photograph and the manner in which they are viewed (i.e., depending on the resolution), the frequency of tones will become textural patterns. Like tones, textures are to some degree predictible with respect to knowledge of the spatial arrangements and geometry of landscapes. That is, there are macro-, meso- and micro-texture patterns.* Texture, too, is environmentally- and temporally-modulated, and is dependent on the constrasts existing between and among the various tonal value which certainly change from season-to-season, from year-to-year and even over longer spans of times. But it is the belief of the investigators that textural changes in relation to spatially-defined units are seemingly more "permanent" than tonal qualities because of the earth-traits responsible for textures (MacPhail, 1971). For example, field patterns are texturally-definable; crops are not. Detection of vegetation of any type is based largely on tonal spectral traits, and although the tonal traits of vegetation may change throughout the growing (and non-growing) seasons, the constrasts will themselves produce apparent basic differences between and among fields.

The third sub-hypothesis here is that structural traits on photographic images can be predicted from Census and/or library and other similar

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*The ordering presented here is in the simplest form. It is believed that a greater number of hierarchical positions can be defined.

materials. (Structural traits are herein defined as arrangements of objects). These predictions can be made in relation to expected linear, area, and/or point features. These latter, however, will tend to either (1) form parts of discrete areal features or (2) be included within large, smooth areal entities because of the resolution of the LANDSAT system.

If the previous sub-hypotheses can be verified, then it should be possible to predict from Census-type materials the types of power spectra (textural traits) that should be obtained for objects and from photomorphic units (the fourth sub-hypothesis).

A fifth sub-hypothesis is based on the preceding four sub-hypotheses; that is, the procedure of predicting photomorphic patterns needs to be hierarchical, beginning with the largest macro-situation and advancing to the micro-scale patterns. In other words, as an investigation proceeds in step-wise fashion, the procedural tactics need to be "tightened" through heavier emphasis on appropriate quantitative methods.

## Methodology of the Investigation

Introduction.--Any scientific investigation is based on two parts, philosophy and methodology(ies). The first of these is a matter of belief, which in most cases cannot be either proven or disproven. The philosophy, naively stated represents a point-of-departure. The methodology leading to or from a philosophy can be questioned and is, therefore, subject to close scientific scrutiny.

The beliefs of the experimentation herein reported are that "meaningful" patterns (in the sense of pragmatic usefulness, or functional utility) exist in the similarity of data and/or information patterns that are found on remote sensing returns taken from high-altitude and space platforms. As previously and hereafter shown, these patterns--photomorphic units--can often have significant relation to physical, social and economic planning problems. As stated earlier, however, the techniques whereby photomorphic patterns can be described and explained remain somewhat "tricky."

It has been demonstrated many times that the levels of classification of objects interpreted on photographs are related to temporal elements; the point being that one of the foundations of planning is the management of change over time. The element of change, to a large degree, is a quality (and in some cases a quantity) which is critical for individual well-being, and there are certain change ingredients which have been recognized by the general society (e.g., biological rhythm, disaster (often short-term), renewal, revolution, etc.).

Regionalization and classification.--As stated in the introductory chapter above, the regional concept has been a central theme in modern geography and other disciplines concerned with spatial phenomena. There have been many controversies surrounding this theme, for some people have accepted it without question while others have criticized the existence of the concept and its place within science. The confusion surrounding the concept has, furthermore, been exaggerated by its liberal use in forms such as regionalism and regional planning. While there is some interplay among the terms region, regionalism, and regionalization;

the focus here is largely toward regionalization as a method of investigation; and region as a product thereof (Grigg, 1967).

In a manner of speaking there are two types of regions which are of concern here--the natural regions (accepted here in its broadest context) which exist on the surface of the earth, and the "reflections" of these regions as they exist on a photographic (or other type of remote sensing) return--the photomorphic region. The techniques and methodologies developed and outlined below are directed at the "frontier" which joins real earth regions (and traits thereof) to the characteristics which are clearly discernible as photomorphic patterns.

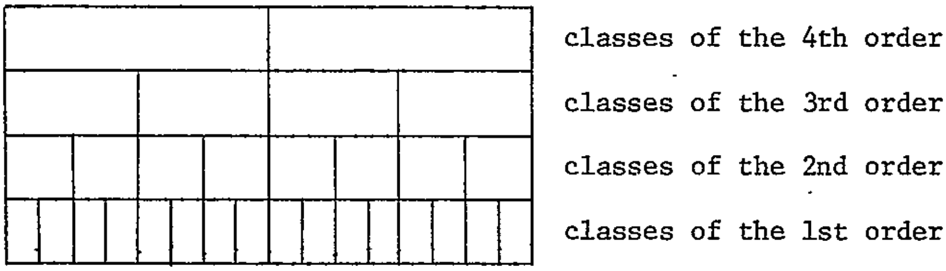
Although a number of regional approaches have been suggested by various investigators, a promising tactic currently gaining recognition is to realize the similarities between regionalization and classification processes, and that an area with a given set of characteristics is a type of individual (an areal class) to be classified and categorized. This process can be carried out through classification or logical division (see Figure 27). The former procedure is analogous to the inductive approach while the latter is a deductive methodology.

Grigg (1967) set forth several principles of regionalization which were used in the classification of the area under study in this project. These are:

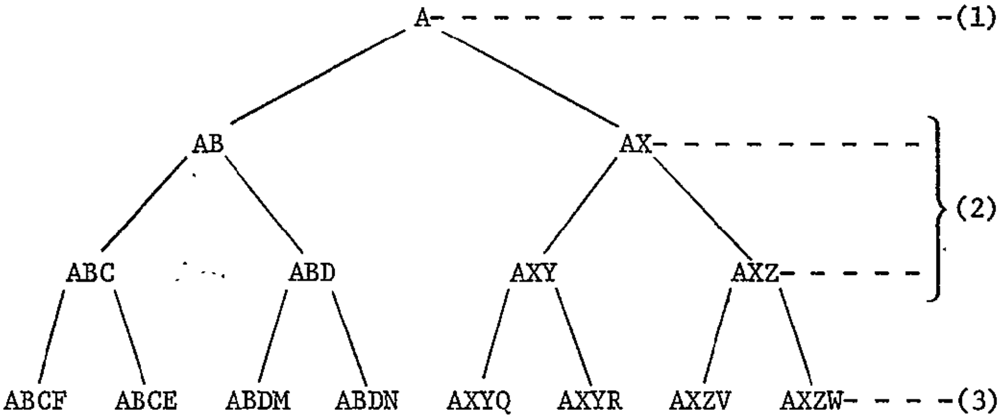
> (1) Classifications should be designed for specific purposes; they rarely serve two purposes equally well.
>
> (2) There exist differences in kind between objects; objects which differ in kind will not easily fit into the same classification.
>
> (3) Classifications are not absolute; they must be changed as more knowledge is gained about the objects under study.
>
> (4) The classification of any group of objects should be based upon properies which are properties of those objects. It follows, then, that differentiating characteristics should be properties of the objects being classified.

Figure 27: <u>CLASSIFICATION & LOGICAL DIVISION</u>.

A <u>Classification</u>: each rank of classes is a <u>set</u> or <u>category</u>



B <u>Logical Division</u>



(1) summum genum

(2) subaltern genum or constituent species

(3) infima species

(5) When dividing, the division should be exhaustive and the classes formed should exclude each other.

(6) When dividing, the division should proceed at every stage (and as far as possible throughout the division) upon one principle.

(7) The differentiating characteristic, or principle of division, must be important for the purpose of division.

(8) Properties which are used to divide or classify in the higher categories must be more important for the purposes of the division than those used in the lower categories.

Using the principles set forth by Grigg, an attempt here was made to use logical division to classify what might be photomorphic units based upon Census criteria which appear to represent hierarchical classes in relation to significant planning purposes. In addition, the process of establishing the data associated with the probable hierarchical classes also provides the foundation for linking the image characteristics with the landscape traits, i.e., the "ground truth."

Levels of categorization.--Based on the five sub-hypotheses presented above, the methodological procedure of this investigation was divided into three levels of categorization. The first level is associated with identifying general physiographic, drainage, vegetation, open lands, and survey patterns which have broad spatial implications and general planning values. These data are easily obtainable from library sources via simple map analysis techniques. Some deviations can result from this procedure. For example, vegetation masks over some of the other spatial traits.

To some degree (but not necessarily entirely) the traits considered at a first-level classification are those which have the largest (or poorest) resolution levels and are associated with the intuitive method of depicting differences which are apparent on photographic images. These spatial patterns are discernible at levels of classification which would correspond to the grossest types of granularity--a black-white situation of classification. Their overall geometric patterns would thus coincide with general textural traits on photomorphic regions.

Often the first-level characteristics have long-lasting temporal traits. With the exception of meteorological conditions especially clouds, the temporal scale of the features observed is often associated with geological time scales. To be sure, at this stage of the research only a few of the broad characteristics and their relationships to temporal situations can be identified. Given time, it is expected that more factors can be depicted that relate to the overall patterns.

Second and Third-Order Patterns.--One key that can be used to identify second-level and third-level patterns is that they are found *within* first-level patterns. Thus, included here are characteristics which have an impact on the general first-order traits. These involve both textural and tonal traits. Included, among others, are general land use situations and surrogates for population traits (including degrees of urbanization, population densities, and other similar factors).

The third-level conditions are largely tonal factors which can be used to construct spatial (texture) conditions at higher orders. In a significant way the conditions which give rise to third-order traits are unique and limited in specific areal extent (e.g., more exact land use situations, exact crop-combinations, low-order central places, mining facilities, and micro-physiographic features.)

## Procedure for Testing Hypothesis and Methodology

The approach outlined above was employed through the use of a two-step procedure: (1) simple cartographic analysis, and (2) statistical analysis of Census data. The ultimate full-scale testing of the hypothesis (and sub-hypotheses), however, will require considerably more time than was available in connection with the present project.

Using all available data that could be gathered from conventional sources, but particularly from the U. S. Census, the researchers attempted to logically construct a set of photomorphic patterns as they _should_ exist within the test area. To avoid any bias, the investigators handling this portion of the project avoided any visual contact with the imagery being photomorphically analyzed. However, some prejudice was built into the testing procedure. Some _a priori_ knowledge was necessary in the analyzing of geographic traits of the area. This is not deemed an overly adverse situation, however, because the use of Census data _per se_ would also be responsible for some type of bias.

_A priori_ photo interpretation experience with photomorphic analysis was also necessary. Although it is reasonable to assume that first-level photomorphic traits will be apparent to almost anyone, the more subtle characteristics of second- and third-order traits are only apparent to an experienced photo interpretor. Thus, to attempt to "visualize" and predict photomorphic patterns necessitates knowledge of both photo interpretation and photomorphic analysis procedures. Naturally this would tend to bias the analysis procedure when proceeding in the opposite direction, i.e., "developing" photomorphic patterns from Census and map data.

A third bias entered the process because one of the investigators had previous experience analyzing detailed photomorphic units in one small section of the test region in the context of another research project (Peplies and Wilson, 1970). An awareness of this made the investigator extra cautious in analyzing the library materials. However, it is not to be assumed that he had completely eliminated his previous knowledge of what tonal and textural signatures of the study region should look like. The question of how much previous experience is permissible with respect to the type of analysis proposed here is a question for another research project.

The specific procedure followed included the following:

(1) Transposing map data which was assumed to be relevant to the project from several library sources, but particularly from the National Atlas (1970), to base maps of the test region. The materials assembled included maps of (1) surface configuration (Hammond's map of landforms), (2) soil, (3) drainage, and (4) vegetation (after Kuchler).*

(2) At the second-order level various types of population data (serving as surrogate for landscape forms) were statistically analyzed and mapped for the study area. For the different data standard deviations from means were calculated for the study area. The assumption was made that standard

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*One other landscape element, the township-and-range survey system, was considered herewith but was not mapped because it was assumed to have widespread distribution throughout the region.

deviations of 2 or more (positive or negative) would be significantly different from the general pattern, and would thus be portrayed differently on the image.

The four major types of data analyzed included:

(1) total population;

(2) rural population;

(3) urban population; and

(4) rural population densities.

Of least importance and meaning with respect to this type of analysis is the total population. Urban population could be meaningful in certain limited situations. Most important are rural population and rural population densities. Because of time and financial constraints only County Census data was used. Certainly Minor Civil Division data would have been more revealing, but would have been prohibitively expensive.

(3) Third-order data was also gained from Census materials. This data was concerned largely with cadastral information which had some type of temporal permanence. Specifically, the number of farms, land in farms (proportion of the total land), value of farm land, crop-combinations and other related data was considered. Here, too, the method of approach was to differentiate counties in terms of standard deviations.

In summary, the purpose is to determine, a priori, the appearance of photomorphic units. The basic for this approach is geographic logic. Should the descriptions match the actual situation completely (a situation which is not entirely expected, nor desired), then it would be possible to eliminate some factors from further research. If, however, a great deviation results, then it is possible that the hypothesized "reverse" approach to photomorphic analysis may be completely nullified as an active concept. Such an eventuality could even throw doubt on the usefulness of the photomorphic concept *per se*.

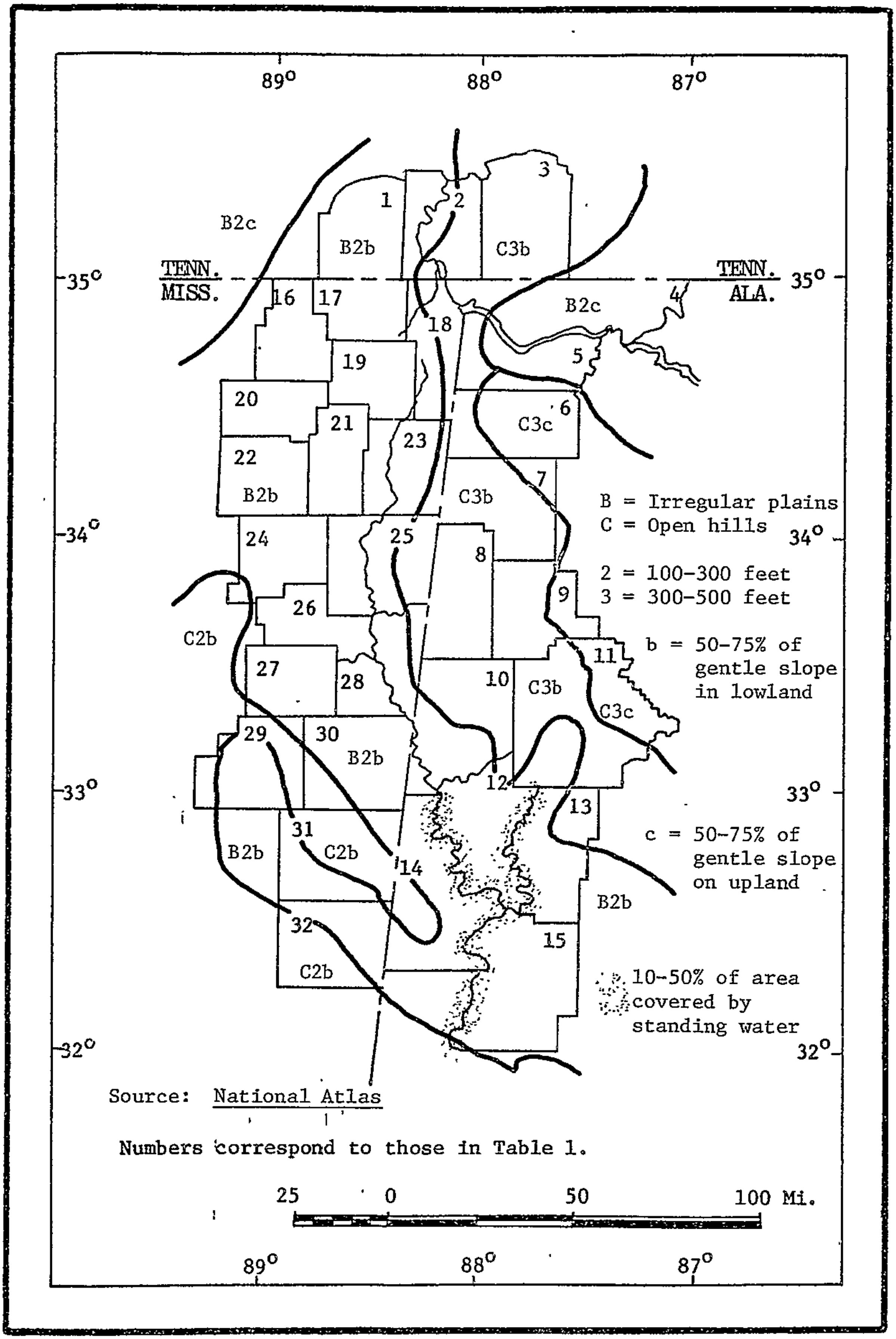
## Test Region

*Introduction*.--Although some earlier information has been reported with respect to the composition and location of the study area, it is related here in detail because of the fact that selection of a test area is actually secondary (if not tertiary) to the major purposes of this project. A deliberate attempt was made *not* to emphasize the geography of the location; in many respects *any* area on the surface of the earth could have been used for the photomorphic analysis.

The study area for "testing" the methodology herein proposed was the Tennessee-Tombigbee Waterway system and the surrounding counties; including thirty-two counties (see Figure 1 and Table 1) in eastern Mississippi (MS), western Alabama (AL), and a small section of south-central Tennessee (TN).

*Physical traits*.--Several contrasting physiographic regions extend into and through the area. The so-called Black Belt region is of central focus (Figure 28). Other regions include the cuesta hill lands, which are part of the general cuesta region in the southeastern United States (Fenneman, 1938), surround the Black Belt region. The eastern part of the region is within that area known as the "Eastern Interior Uplands;" the boundaries of which are not specifically delineated, however. The underlying bedrock includes sedimentary rocks of Cretaceous and Upper Paleozoic origins. Solution-type rocks and resultant caverns and caves (karst-type topography) are located within the northeastern sections of the

Figure 28: SURFACE CONFIGURATION



Source: National Atlas

Numbers correspond to those in Table 1.

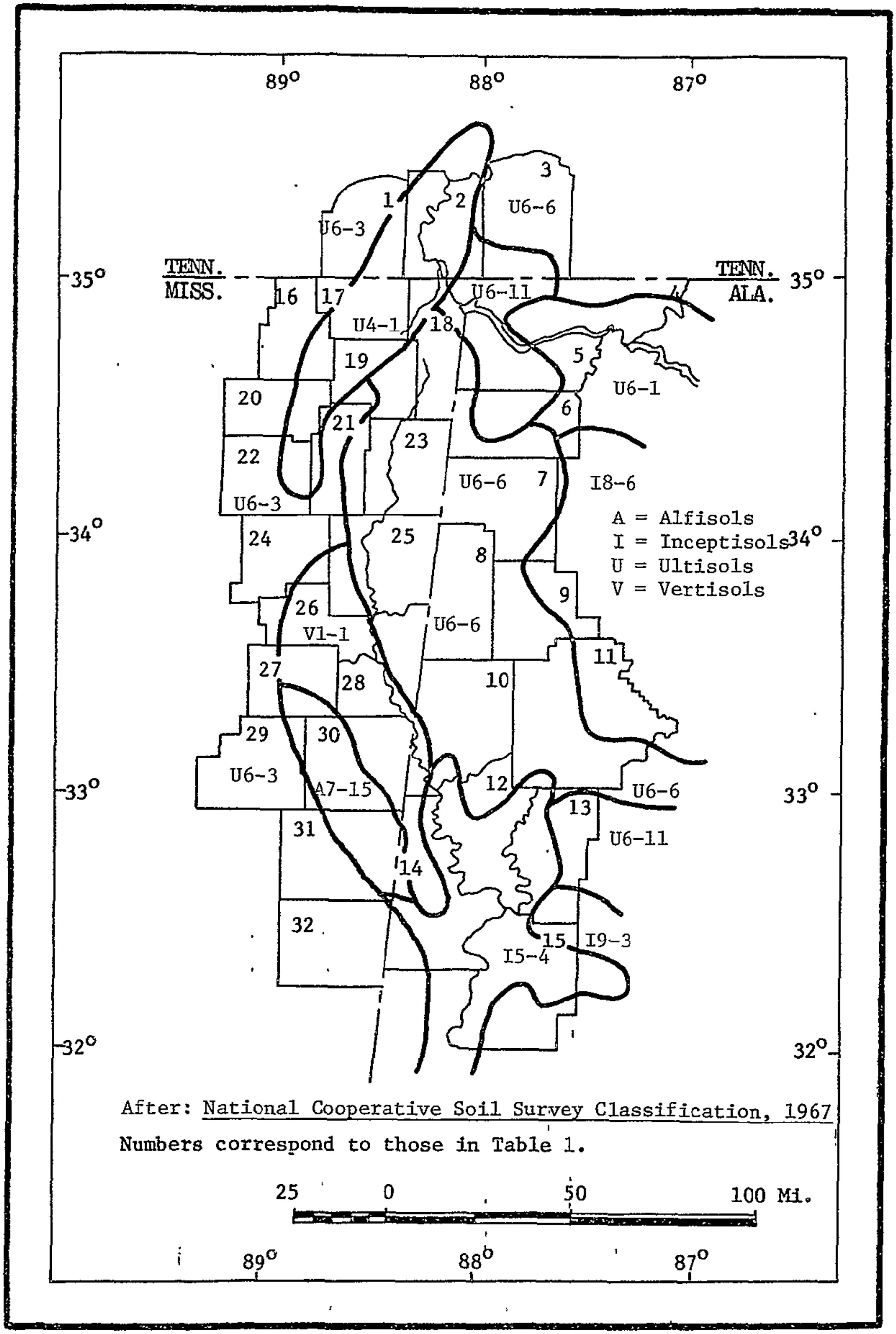
study area. Such features include dolines and uvala-like features on ridges or dissected uplands.

Soils in the study area are largely classified as ultisols--soils with clay accumulation and low base supply (Figure 29). In and around the main trunk stream, however, small areas of vertisols and alfisols can be located. The former soils have a high content of montmoriplonite (a type of expandable clay which is therefore self-mulching). Alfisols, in contrast, are gray-brown soils with medium to high base supplies and subsurface horizons or clay accumulation. Located in the extreme southern part of the region are a type of low-humic clay soils generally classified as inceptisols. These soils are generally useful for pastures and woodlands.

Vegetative communities which extend through the area are of two major types--the Black Belt (Liquidambar-Quercus-Juniperus) and the oak-hickory-pine forest community (Quercus-Carya-Pinus) (Figure 30). A small community similar to the latter is located on the northern fringes of the study region--oak-hickory forest (Quercus-Carya)--and along the major river are the southern floodplain forest communities (Quercus-Nyassa-Taxodium). From field work it has been determined that this latter community is much more extensive than has been mapped by cartographers (National Atlas, 1970, p. 90-91); it has been found to exist along the complete course of the Tombigbee River and its major tributaries.

Surface water systems are of a generally uniform nature throughout the study area. A coarser and denser network of streams exists to the east and north of the main course of the Tombigbee River than is found to the west (Figure 31). Slope and physiography plays a significant role here, *i.e.*, the flatter lands to the west tend to retain runoff while the

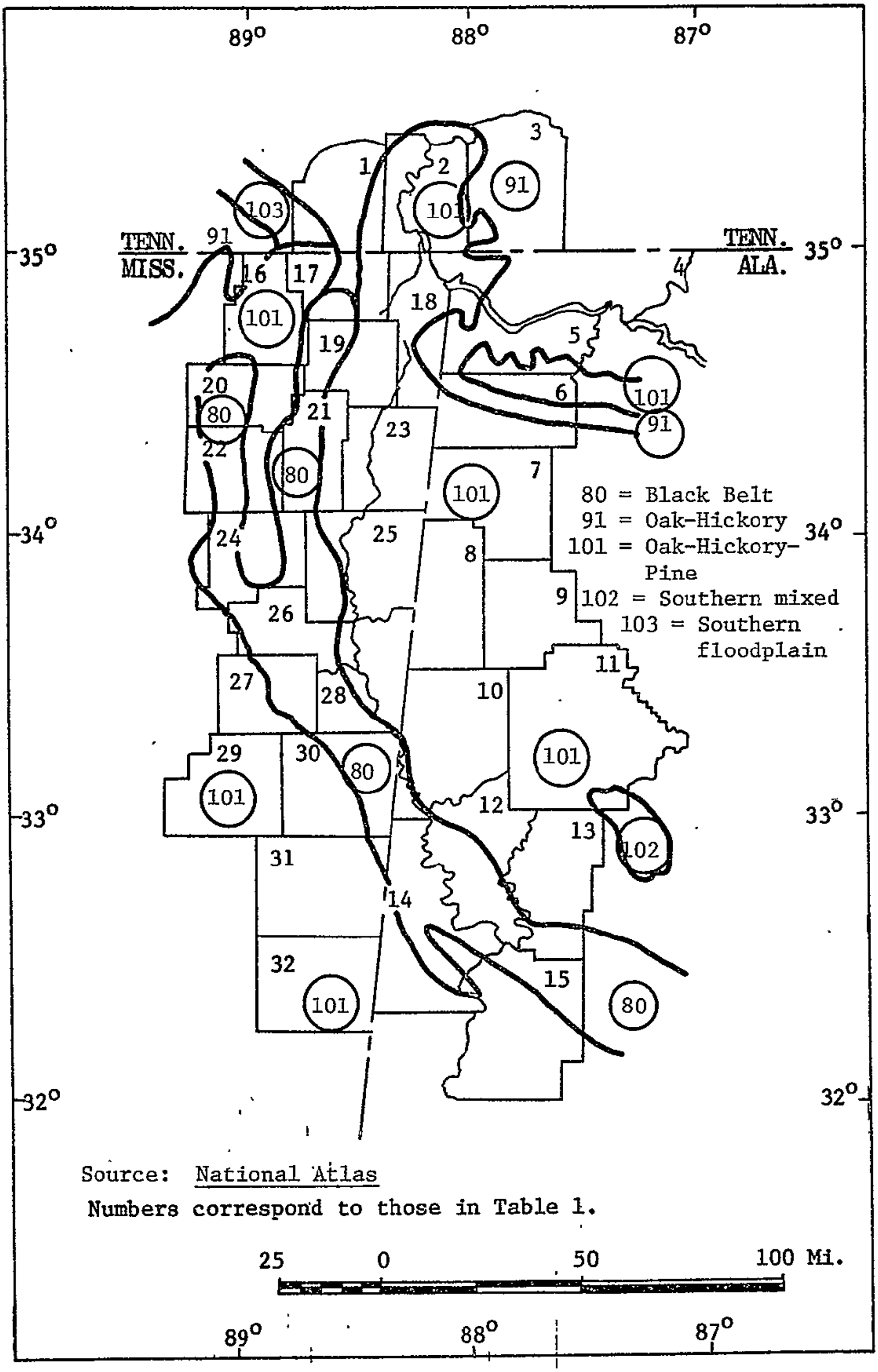
Figure 29: SOILS



After: National Cooperative Soil Survey Classification, 1967

Numbers correspond to those in Table 1.

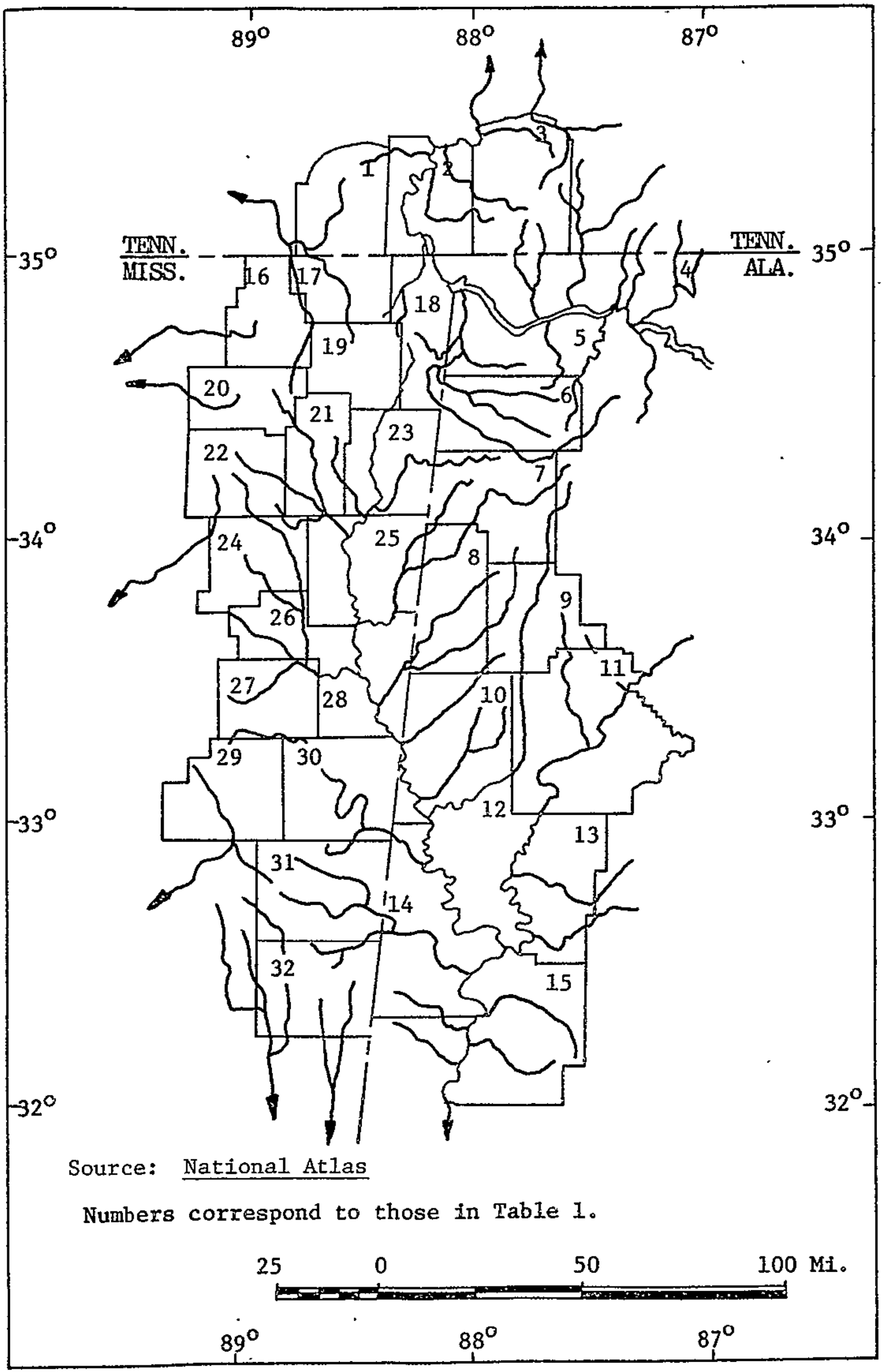
Figure 30: VEGETATION COMMUNITIES



80 = Black Belt
91 = Oak-Hickory
101 = Oak-Hickory-Pine
102 = Southern mixed
103 = Southern floodplain

Source: National Atlas
Numbers correspond to those in Table 1.

Figure 31: DRAINAGE SYSTEMS



Source: National Atlas

Numbers correspond to those in Table 1.

eastern sections encourage greater hill and channel erosion. The average annual runoff amounts range between eighteen (18) to twenty-three (23) inches (45.7-58.4 cm.) per year, increasing from west to east. The possibility of catastrophic floods is rather great in the area. A mean annual flood potential between 10 and 20 thousand cubic feet per second has been estimated for the area (National Atlas, 1970). Thus, the flood damage potential of the area is second in magnitude only to the Mississippi Delta.

A factor having an impact on the amount of runoff experienced in an area is the permeability of the underlying rock. Throughout most of the study area unconsolidated aquifers, consisting of sand and gravel in interfluval valleys, are typical. However, the east-central counties of the area are underlain with sandstone, including some unconsolidated sand. Carbonate rocks--limestones--are characteristic of the northeastern counties. All of these geological traits tend to impede the base flow of the surface drainage system, but it is doubtful if the underlying materials could significantly change the flooding conditions resulting from the catastrophic thunderstorms and/or hurricanes.

The environmental-chemical qualities of the drainage system in the study area show no adverse characteristics. The general prevalent concentration of dissolved minerals in the surface water is less than 100 parts per million. During construction of the Tennessee-Tombigbee canal system it is possible that the environmental quality of the waterway system may be degraded, especially by increasing the sediment concentration. At this time, the sediment concentration is less than 2000 parts per million. After construction, however, it is likely that concentrations of dissolved minerals and sediments could approach past moderate levels.

Cultural aspects.--Morphological aspects of cultural traits in the study area are of two types: (1) traits which are directly apparent (i.e., visible) and (2) traits which serve as surrogates for other characteristics. Among the traits which are directly apparent are major land uses, survey lines, transportation arteries, mining sites, and settlement forms (rural and urban). Of these, major land use is one of the more apparent morphological features.

The total population of the study area in 1970, according to the Census, was 884,395. Of the total population, 381,198 (43.1 percent) were classified as urban; 503,197 (56.9 percent) were rural. The proportion of the rural population classified as rural non-farm was 83.7 percent (approximately 421,000). Among the various counties in the study area, the ratio of the rural nonfarm population to rural population ranged from a low of 66.0 percent (Kemper County, MS) to a high of 95.4 percent (Tuscaloosa County, AL) (See Table 4). The mean proportion of rural population of the study area which is classified as rural non-farm is 82.3 percent; one standard deviation is 7.08 percent. The latter fact indicates that the proportion of all rural to rural non-farm is high for the study area in general. As would be expected the highest proportions existed in counties where there are urban centersLauderdale, MS, Tuscaloosa and Colbert, AL.

Average rural population densities in the study area vary from a low of 12.5/sq. mile (7.8/sq. kilometer) to a high of 56.4/sq. mile (35.1/sq. kilometer). Correlations here do not necessarily relate to the degree of urbanization, but urban counties generally have high average densities.

According to the patterns discussed by Marschner (1950) and later revised by Anderson (1967), five major land use patterns are associated

## TABLE 4

## POPULATION TRAITS -- 1970

| STATE<br>County | Total Population | Urban Population | Rural Population | Rural Non-Farm Population | Average Rural Density (Population/Sq. Mile/ Population/Sq. Kilometer) |
|---|---|---|---|---|---|
| TENNESSEE | | | | | |
| Hardin | 18,212 | 5,576 | 12,636 | 10,246 | 21.5/13.4 |
| McNairy | 18,369 | 3,495 | 14,874 | 11,202 | 26.1/16.2 |
| Wayne | 12,365 | -- | 12,365 | 10,562 | 16.7/10.4 |
| ALABAMA | | | | | |
| Colbert | 49,632 | 28,850 | 20,782 | 19,021 | 34.8/21.7 |
| Fayette | 16,252 | 4,707 | 11,545 | 9,802 | 18.4/11.4 |
| Franklin | 23,933 | 7,814 | 16,119 | 13,404 | 25.0/15.6 |
| Greene | 10,650 | 2,805 | 7,845 | 6,511 | 12.5/ 7.8 |
| Hale | 15,888 | 3,371 | 12,517 | 9,775 | 18.9/11.7 |
| Lamar | 14,335 | -- | 14,335 | 12,942 | 23.6/14.7 |
| Lauderdale | 68,111 | 34,031 | 34,080 | 29,868 | 51.4/32.0 |
| Marengo | 23,819 | 10,348 | 13,471 | 11,789 | 13.7/ 8.6 |
| Marion | 23,788 | 6,241 | 17,547 | 15,417 | 23.6/14.7 |
| Pickens | 20,326 | 2,851 | 17,475 | 15,288 | 19.7/12.2 |
| Sumter | 16,974 | 3,044 | 13,930 | 11,324 | 15.2/ 9.5 |
| Tuscaloosa | 116,029 | 85,875 | 30,154 | 28,760 | 22.6/14.0 |
| MISSISSIPPI | | | | | |
| Alcorn | 27,179 | 11,581 | 15,598 | 12,651 | 38.5/24.0 |
| Chickasaw | 16,805 | 5,722 | 11,083 | 8,874 | 21.9/13.6 |

## TABLE 4 (Cont.)

## POPULATION TRAITS -- 1970

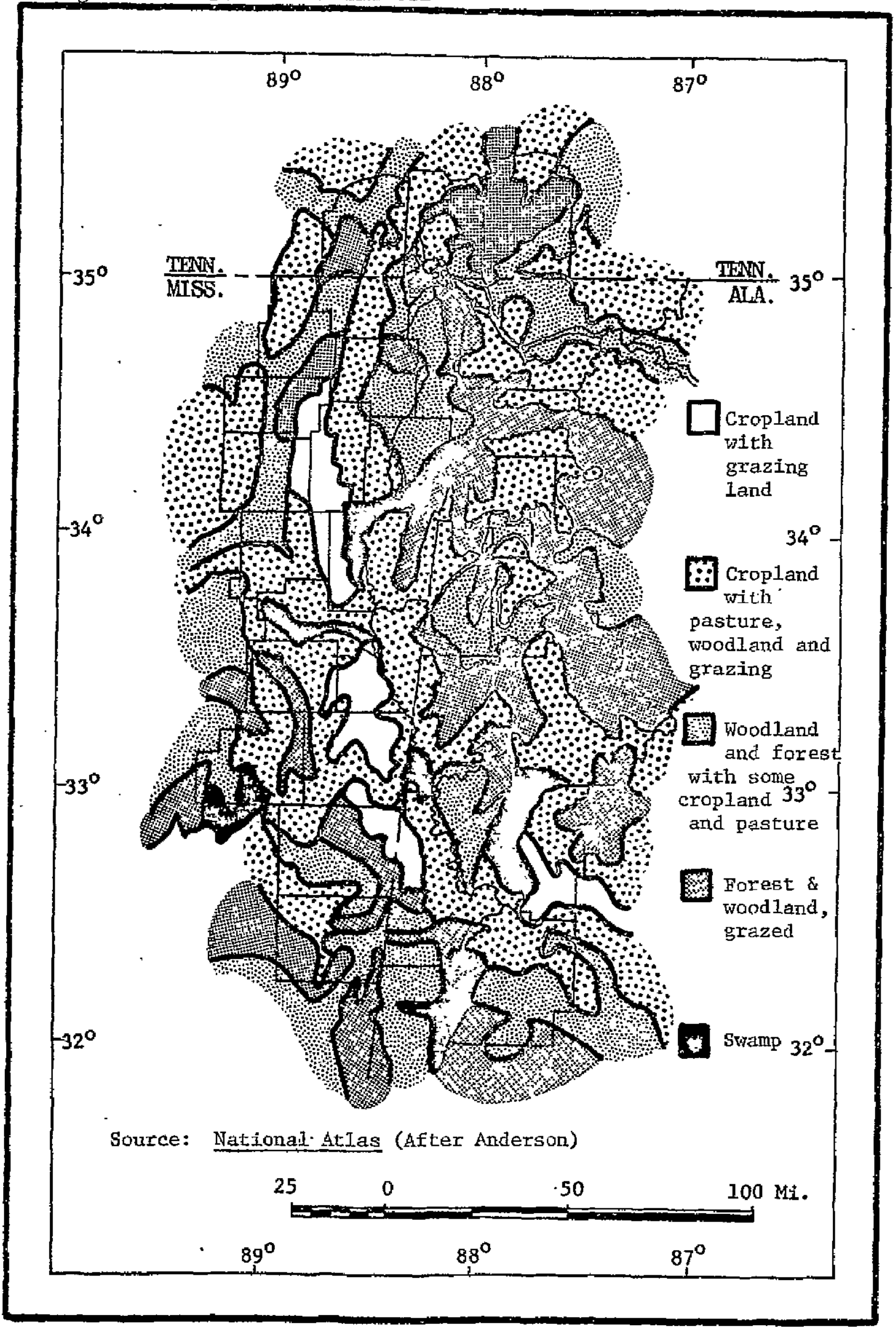
| STATE<br>County | Total Population | Urban Population | Rural Population | Rural Non-Farm Population | Average Rural Density (Population/Sq. Mile/ Population/Sq. Kilometer) |
|---|---|---|---|---|---|
| MS (Cont.) | | | | | |
| Clay | 18,840 | 8,714 | 10,126 | 8,250 | 24.4/15.2 |
| Itawamba | 16,847 | 2,899 | 13,948 | 11,621 | 25.7/16.0 |
| Kemper | 10,233 | -- | 10,233 | 6,757 | 13.5/ 8.4 |
| Lauderdale | 67,087 | 45,083 | 22,004 | 20,628 | 31.0/19.3 |
| Lee | 46,148 | 20,471 | 25,677 | 22,624 | 56.4/35.1 |
| Lowndes | 49,700 | 23,869 | 19,831 | 16,988 | 39.0/24.3 |
| Monroe | 34,043 | 13,393 | 20,650 | 16,996 | 26.8/16.7 |
| Noxubee | 14,288 | 2,612 | 11,676 | 7,745 | 16.8/10.4 |
| Oktibbeha | 28,752 | 15,964 | 12,788 | 10,890 | 28.1/17.6 |
| Pontotoc | 17,363 | 3,453 | 13,910 | 10,255 | 27.1/17.2 |
| Prentiss | 20,133 | 5,895 | 14,238 | 11,216 | 34.0/21.2 |
| Tippah | 15,852 | 3,482 | 12,370 | 9,277 | 26.6/16.6 |
| Tishomingo | 14,940 | -- | 14,940 | 12,922 | 33.7/21.0 |
| Union | 19,096 | 6,426 | 12,670 | 9,457 | 30.0/18.6 |
| Winston | 18,406 | 6,626 | 11,780 | 8,498 | 19.4/12.1 |

with the study area. These are (1) cropland with grazing land, (2) cropland with pasture, (3) woodland and forest with some cropland and pasture, (4) forest and woodland, grazed, and (5) swamp (Figure 32). The pattern of these areas follows the general configuration of the Black Belt physiographic region. Respectively, the cropland with grazing land, cropland with pasture, and woodland and forest form the "core." In turn, these areas are surrounded by the third and fourth classes mentioned above. However, the forest and woodland grazed (4th category) dominates the eastern portion of the study area, while the third category is located mainly in the western reaches of the study region.

The study area is distributed among sections of four BEA economic regions (Figure 33). A BEA region consists of an SMSA or similar area that serves as a center of trade and the surrounding counties that are economically related to the center (Regional Economic Analysis Division, 1975). It is interesting to note that only one of the study area's large central places is the center of its own BEA, and, in most cases, the sections of the BEA within the study area are marginal to their respective central trade places. The centers for the study area are: (1) Memphis--one county, (2) Huntsville--eight counties, (3) Birmingham--fifteen counties, and (4) Meridian--five counties. The latter center is the only one lying within the study region.

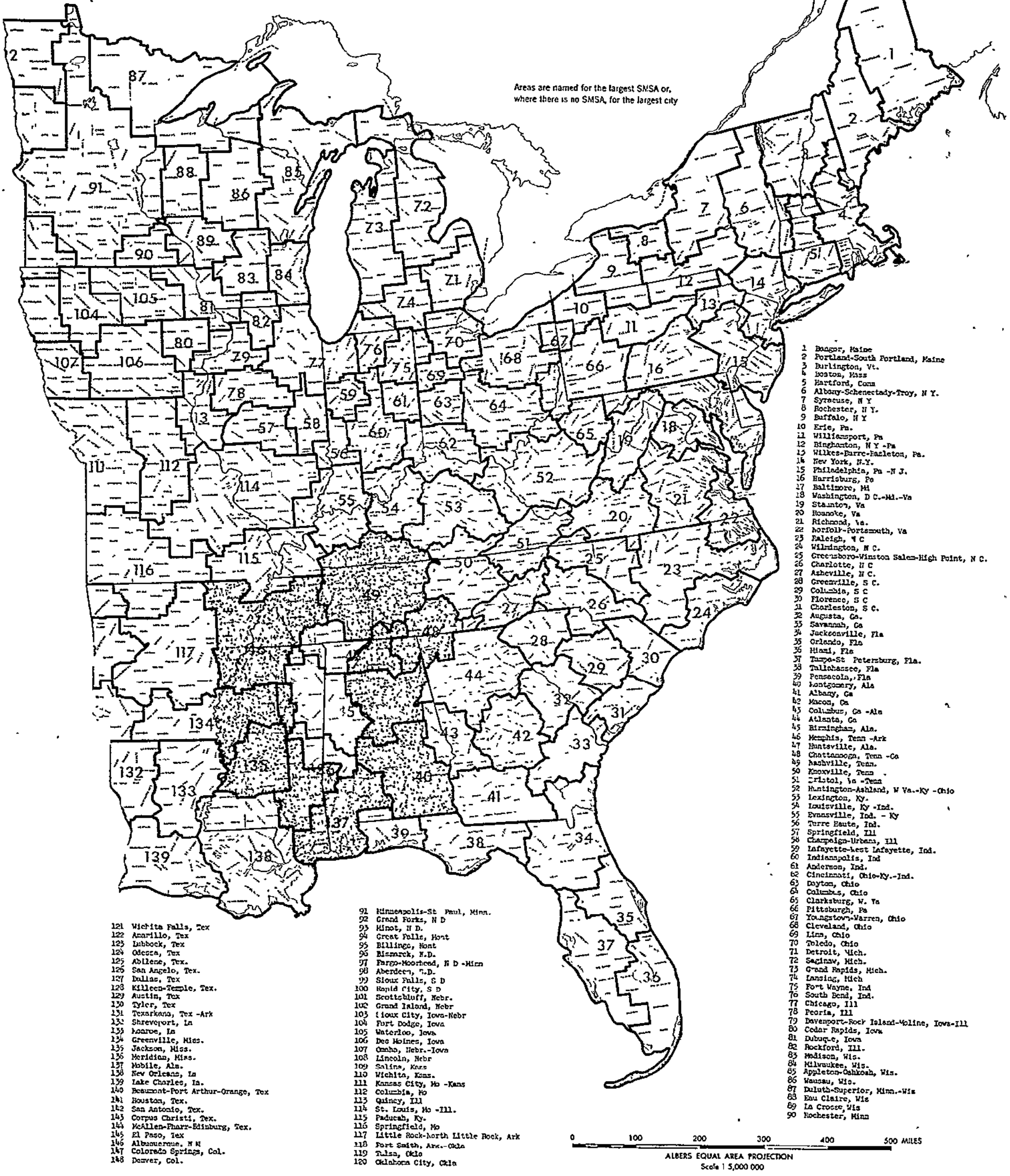
As would be expected, marginal areas of the major centers of the BEA reflect traits which are more traditional and rural. Service, governmental, wholesale, transportation, and manufacturing would be more likely to appear in the largest trade centers. Agricultural, mining and forestry activities will most likely occur on the margins. The significance of agriculture in the area is expressed in part by the fact that total

Figure 32: GENERALIZED LAND USE



Source: National Atlas (After Anderson)

Figure 33: BEA ECONOMIC REGIONS


Areas are named for the largest SMSA or, where there is no SMSA, for the largest city

| | |
|---|---|
| 1 | Bangor, Maine |
| 2 | Portland-South Portland, Maine |
| 3 | Burlington, Vt. |
| 4 | Boston, Mass |
| 5 | Hartford, Conn |
| 6 | Albany-Schenectady-Troy, N Y. |
| 7 | Syracuse, N Y |
| 8 | Rochester, N Y. |
| 9 | Buffalo, N Y |
| 10 | Erie, Pa. |
| 11 | Williamsport, Pa |
| 12 | Binghamton, N Y -Pa |
| 13 | Wilkes-Barre-Hazleton, Pa. |
| 14 | New York, N.Y. |
| 15 | Philadelphia, Pa -N J. |
| 16 | Harrisburg, Pa |
| 17 | Baltimore, Md |
| 18 | Washington, D C.-Md.-Va |
| 19 | Staunton, Va |
| 20 | Roanoke, Va |
| 21 | Richmond, Va. |
| 22 | Norfolk-Portsmouth, Va |
| 23 | Raleigh, N C |
| 24 | Wilmington, N C. |
| 25 | Greensboro-Winston Salem-High Point, N C. |
| 26 | Charlotte, N C |
| 27 | Asheville, N C. |
| 28 | Greenville, S C. |
| 29 | Columbia, S C |
| 30 | Florence, S C |
| 31 | Charleston, S C. |
| 32 | Augusta, Ga. |
| 33 | Savannah, Ga |
| 34 | Jacksonville, Fla |
| 35 | Orlando, Fla |
| 36 | Miami, Fla |
| 37 | Tampa-St Petersburg, Fla. |
| 38 | Tallahassee, Fla |
| 39 | Pensacola, Fla |
| 40 | Montgomery, Ala |
| 41 | Albany, Ga |
| 42 | Macon, Ga |
| 43 | Columbus, Ga -Ala |
| 44 | Atlanta, Ga |
| 45 | Birmingham, Ala. |
| 46 | Memphis, Tenn -Ark |
| 47 | Huntsville, Ala. |
| 48 | Chattanooga, Tenn -Ga |
| 49 | Nashville, Tenn. |
| 50 | Knoxville, Tenn |
| 51 | Bristol, Va -Tenn |
| 52 | Huntington-Ashland, W Va.-Ky -Ohio |
| 53 | Lexington, Ky. |
| 54 | Louisville, Ky -Ind. |
| 55 | Evansville, Ind. - Ky |
| 56 | Terre Haute, Ind. |
| 57 | Springfield, Ill |
| 58 | Champaign-Urbana, Ill |
| 59 | Lafayette-West Lafayette, Ind. |
| 60 | Indianapolis, Ind |
| 61 | Anderson, Ind. |
| 62 | Cincinnati, Ohio-Ky.-Ind. |
| 63 | Dayton, Ohio |
| 64 | Columbus, Ohio |
| 65 | Clarksburg, W. Va |
| 66 | Pittsburgh, Pa |
| 67 | Youngstown-Warren, Ohio |
| 68 | Cleveland, Ohio |
| 69 | Lima, Ohio |
| 70 | Toledo, Ohio |
| 71 | Detroit, Mich. |
| 72 | Saginaw, Mich. |
| 73 | Grand Rapids, Mich. |
| 74 | Lansing, Mich |
| 75 | Fort Wayne, Ind |
| 76 | South Bend, Ind. |
| 77 | Chicago, Ill |
| 78 | Peoria, Ill |
| 79 | Davenport-Rock Island-Moline, Iowa-Ill |
| 80 | Cedar Rapids, Iowa |
| 81 | Dubuque, Iowa |
| 82 | Rockford, Ill. |
| 83 | Madison, Wis. |
| 84 | Milwaukee, Wis. |
| 85 | Appleton-Oshkosh, Wis. |
| 86 | Wausau, Wis. |
| 87 | Duluth-Superior, Minn.-Wis |
| 88 | Eau Claire, Wis |
| 89 | La Crosse, Wis |
| 90 | Rochester, Minn |
| 91 | Minneapolis-St Paul, Minn. |
| 92 | Grand Forks, N D |
| 93 | Minot, N D. |
| 94 | Great Falls, Mont |
| 95 | Billings, Mont |
| 96 | Bismarck, N.D. |
| 97 | Fargo-Moorhead, N D -Minn |
| 98 | Aberdeen, S.D. |
| 99 | Sioux Falls, S D |
| 100 | Rapid City, S D |
| 101 | Scottsbluff, Nebr. |
| 102 | Grand Island, Nebr |
| 103 | Sioux City, Iowa-Nebr |
| 104 | Fort Dodge, Iowa |
| 105 | Waterloo, Iowa |
| 106 | Des Moines, Iowa |
| 107 | Omaha, Nebr.-Iowa |
| 108 | Lincoln, Nebr |
| 109 | Salina, Kans |
| 110 | Wichita, Kans. |
| 111 | Kansas City, Mo -Kans |
| 112 | Columbia, Mo |
| 113 | Quincy, Ill |
| 114 | St. Louis, Mo -Ill. |
| 115 | Paducah, Ky. |
| 116 | Springfield, Mo |
| 117 | Little Rock-North Little Rock, Ark |
| 118 | Fort Smith, Ark.-Okla |
| 119 | Tulsa, Okla |
| 120 | Oklahoma City, Okla |
| 121 | Wichita Falls, Tex |
| 122 | Amarillo, Tex |
| 123 | Lubbock, Tex |
| 124 | Odessa, Tex |
| 125 | Abilene, Tex. |
| 126 | San Angelo, Tex. |
| 127 | Dallas, Tex |
| 128 | Killeen-Temple, Tex. |
| 129 | Austin, Tex |
| 130 | Tyler, Tex |
| 131 | Texarkana, Tex -Ark |
| 132 | Shreveport, La |
| 133 | Monroe, La |
| 134 | Greenville, Miss. |
| 135 | Jackson, Miss. |
| 136 | Meridian, Miss. |
| 137 | Mobile, Ala. |
| 138 | New Orleans, La |
| 139 | Lake Charles, La. |
| 140 | Beaumont-Port Arthur-Orange, Tex |
| 141 | Houston, Tex. |
| 142 | San Antonio, Tex. |
| 143 | Corpus Christi, Tex. |
| 144 | McAllen-Pharr-Edinburg, Tex. |
| 145 | El Paso, Tex |
| 146 | Albuquerque, N M |
| 147 | Colorado Springs, Col. |
| 148 | Denver, Col. |

ORIGINAL PAGE IS
OF POOR QUALITY

agricultural earnings gained for each of the BEA's are significantly higher than the average for the nation as a whole. Only three percent of the total earnings in the U.S. is gained from agriculture. In the BEA segment of the study areas it is higher: Birmingham BEA--4.0%; Memphis BEA--11.3%; Huntsville BEA--6.5%; and Meridian BEA--6.2%. Thus, since the study area is peripheral to the BEA regions, the economic concern of the area is directed toward rural activities--crop and animal agriculture and forestry.

The concept of the BEA region also sheds light on another related subject--the organization and hierarchy of central places. As mentioned above, with the exception of Meridian, MS, all of the major trade centers are located at some distance outside of the study area. This fact is further illustrated by the size of secondary trade centers in the area, and also by the general orientation of the road network. The orientation of the road network in the eastern part of the area is toward Birmingham and Huntsville. In the western portion of the study area, the focus is on Memphis and Meridian, displaying a distinctive north-south major axis. The secondary centers within the study area include: Tuscaloosa AL, Columbia, Tupelo and Corinth, MS, and the quad-cities of Florence, Sheffield, Tuscumbia and Muscle Shoals, AL. These centers are located in a fairly regular pattern at distances of between sixty and eighty miles (96.6-128.7 km.) apart. In between these secondary centers are smaller places, towns, villages, and hamlets. Two distinctive patterns of lower-order centers is apparent in the region. A fine-to-medium density pattern exists in the eastern section of the study area; towns are on the order of thirty to forty miles (48.3-64.4 km.) apart. Villages and hamlets in the eastern segment are located at shorter distances apart, lying generally between towns. In contrast, western towns lie approximately twenty miles (32.2 km.) apart. In addition, the flat terrain permits more expression of the township-and-range system in the western section, even though both the eastern and western areas are within the territory surveyed after the adoption of the rectangular system (i.e., except for the Tennessee section of the study area).

Crop and animal agriculture dominates the study area. Among the more important crops in the study region are cotton, hay, and soybeans. Wood products and pulp wood lumbering are significant in the forested regions. Beef cattle and calves are found in association with most crop-raising regions.

## Classification System

Bunge (1962) first made the suggestion among geographers that there is no essential difference between the scientific process of classification and the spatial analytical process of regionalization. To Bunge and others regionalization is a taxonomic process: the variables according to which data is divided are various spatial attributes, and the classes (regions) produced have spatial extent. That is, in a manner of speaking, regionalization becomes a "filter" through which data flows to become ordered. This ordering makes further research possible. It appears obvious that some sort of "ordering model" is essential to a clearer understanding of regional characteristics.

Weaver (1954) developed a land-use classification model based on the agricultural combination of crops grown in an area. He realized that crops in areas such as the "American Corn Belt" included more than corn alone, and sometimes included other crops which were as important as corn (or even more important).

The statistical procedure developed by Weaver was basically very simple. It involved the selection of crops which are to be included in the analysis and/or the grouping of these same crops. The selections in each area are then represented as percentages of the total cropped land in the county (or other spatial unit). The crops (or groups of crops) are arranged consectively according to the percentage of the total agricultural area (county) which they cover. Subsequently, Weaver compared the actual range of crop-combination ratios with a series of model ratios. That is, in a system where one crop dominated the scene, that crop would, of course, theoretically occupy 100 percent of the cultivated land area. If on the other hand, a two-crop situation dominated the landscape, then ideally 50 percent of the cultivated land would be devoted to each crop. This process is continued for each of the crop-combinations, reducing the percentages each time. The actual ratios can then be compared with the theoretical models, and the agricultural area (county) can be compared to the grouping which best fits the actual situation. The method for attaining the solution involves an application of statistical variance which can be expressed by the formula:

$$\sigma^2 = \frac{\Sigma d^2}{N} = \frac{\Sigma(X_i - \overline{X})^2}{N}$$

The mean $(\overline{X})$ is termed the "expected value" in an array of numbers. In his formulation Weaver substitutes the theoretical ratio for the expected value.

Since Weaver first introduced his procedure, other researchers have modified it. Coppock (1964), for example, extended the Weaver method to the whole range of agricultural activity by converting livestock and crop production to common units and thus differentiating between various intensities of production by weighting the values, the weighting factors being based on labor requirements measured in annual man-days of work. Naturally these weighting factors were derived from normalized labor requirements, but they tend to be realistic only in a local regional sense. Even then differences may exist among individual farmers and sizes of farms (economies of scale).

Another variation of the original Weaver approach to crop- and livestock-combination regions was developed by Thomas (1963). In the Thomas method a statistical method was adjusted to consider all available data for the calculation of the variance for each crop-combination. For example, using the Weaver method for a two-crop situation, the procedure might be as follows for a county which has five principal crops occupying 38, 20, 13, 10, and 9 percent of the total cropland, respectively:

$$\frac{(50 - 38)^2 + (50 - 20)^2}{2} = 522$$

The Thomas method yields the following for the same data:

$$\frac{(50 - 38)^2 + (50 - 20)^2 + (0 - 13)^2 + (0 - 10)^2 + (0 - 9)^2}{5} = 281$$

The Thomas method, thus, approximates a more realistic situation than the Weaver approach.

Peplies (1968) employed the Weaver approach for regional classification. He, however, used types of landholding combinations rather than crops or livestock in his study of the Asheville Basin area. Among other things he was able to show that the Weaver approach to understanding the combination of phenemona which occupy an area can be used for things other than crops and/or livestock. Peplies later agreed that the Thomas approach showed greater promise and was reality-focused realistic than that procedure originally developed by Weaver. The significant factor here is not the procedure used as much as the variables employed in the classification procedure.

MacPhail and Lee (1972) developed a list of variables specifically designed for use in conjunction with photo-morphic analysis in the TVA region. The list includes the following (some of which are available from Census-type data and were used in this study):

a) Physical:

Soil, type, geomorphic class, erosion intensity.

b) Hydrological:

Drainage pattern, drainage density, lake levels, degree of siltation, channel characteristics.

c) Biological:

Forest association, reforestation, afforestation, other natural cover.

d) Agricultural:

Rural land use, settlement pattern, farm size and/or field size, land tenure; incidence of crop disease, agricultural year (by crop), density of farm-to-market road network.

e) Rural Non-Agricultural:

Commercial, manufacturing, mining, recreation, and other land uses.

f) Others:

Residential, suburban residential, CBD and commercial strips, shopping centers, industrial, transportation, service areas, open spaces and green belts.

Some five sets Census of Agriculture (1970) data which were considered likely to have photomorphic expression in the Tennessee-Tombigbee Waterway study area were reviewed: (1) general areal land use combinations, (2) specific crop-combinations (in area), (3) sales of general products, (4) total receipts for sales of agricultural products, and (5) land in farms (in contrast to other land uses).

With respect to the latter factor (land in farms in contrast to other uses), it is to be noted that there is some negative correlation (-0.5677) between the percentage of land in farms and the total area of the counties in the study area based on 1970 Census data (Table 5). That is, the larger the county in the study area, the greater the possibility that there is less land in farms. However, in the Black Belt counties there is a strong positive correlation (0.7050) between the proportion of land in farms in relation to the size of the counties. While in the low hills areas (to be explained in detail later) where larger proportions of lands are in a variety of uses--forest lands, government properties, or urban lands--the correlation is weak (-0.3889). This is one basis for a "grand" photomorphic division of the region.

## TABLE 5

## LAND AREA OF COUNTIES IN THE STUDY AREA AND PROPORTION OF LAND IN FARMS

| STATE<br>County | Land Area (Sq. Miles/Sq Kilometers) | Land in Farms (Percent) |
|---|---|---|
| TENNESSEE | | |
| Hardin | 587/ 944 | 45.1 |
| McNairy | 569/ 915 | 59.3 |
| Wayne | 739/1,189 | 37.1 |
| ALABAMA | | |
| Colbert | 596/ 956 | 47.2 |
| Fayette | 627/1,009 | 32.5 |
| Franklin | 644/1,036 | 46.0 |
| Greene | 627/1,009 | 53.1 |
| Hale | 662/1,065 | 53.6 |
| Lamar | 605/ 973 | 31.0 |
| Lauderdale | 662/1,065 | 58.5 |
| Marengo | 978/1,573 | 56.2 |
| Marion | 743/1,195 | 35.8 |
| Pickens | 887/1,427 | 36.0 |
| Sumter | 915/1,472 | 33.0 |
| Tuscaloosa | 1333/2,145 | 20.5 |
| MISSISSIPPI | | |
| Alcorn | 405/ 651 | 64.3 |
| Chickasaw | 506/ 814 | 60.4 |

## TABLE 5 (Cont.)

## LAND AREA OF COUNTIES IN THE STUDY AREA AND PROPORTION OF LAND IN FARMS

| STATE<br>County | Land Area (Sq. Miles/Sq. Kilometers) | Land in Farms (Percent) |
|---|---|---|
| MISSISSIPPI (Cont.) | | |
| Clay | 414/ 666 | 59.0 |
| Itawamba | 541/ 870 | 42.0 |
| Kemper | 757/1,218 | 41.3 |
| Lauderdale | 708/1,139 | 34.7 |
| Lee | 455/ 732 | 71.2 |
| Lowndes | 508/ 817 | 57.8 |
| Monroe | 769/1,237 | 55.8 |
| Noxubee | 695/1,118 | 66.1 |
| Oktibbeha | 454/ 730 | 57.3 |
| Pontotoc | 501/ 806 | 65.1 |
| Prentiss | 418/ 672 | 69.3 |
| Tippah | 464/ 746 | 64.3 |
| Tishomingo | 443/ 712 | 35.3 |
| Union | 422/ 679 | 63.4 |
| Winston | 606/ 975 | 46.0 |

The fourth factor mentioned above (the total receipts for sales of agricultural products) was thought to be a surrogate for agriculture intensity, and thus would be indicated as a part of photomorphic patterns. However, sales in the study area in 1970 ranged from $2,512,417 to $13,761,376, the mean value for the sale of agricultural products for the study area being $6,079,906 (See Table 6). After performing a thorough map and Census analysis of these data it was observed that the gross receipts from the sale of agricultural products is <u>not</u> necessarily a measure of agricultural intensity; nor is it necessarily an indicator of the "economic health" of the county. With regard to the former, those counties in the study area where income is gained largely from livestock are not necessarily counties where agricultural incomes are high. For example, Franklin County, AL, reported a high gross sale for agricultural products (see Table 2), but this income is largely from the sale of poultry (broilers) which does not net a high profit for individual farms. The correlations between mean farmer income and the total sales of agricultural commodities was very low (.3214) for the counties in the study area.

The sale of agricultural products from farms was analyzed for each of the counties in the study region using the Thomas approach. Four general categories were analyzed: (1) sales of livestock (L); (2) crops (C); (3) forest products (F); and (4) other agricultural commodities (O) as revealed by the 1970 Census. The combination of sales gained for products is largely a livestock-crop (LC) combination. Only six of the thirty-two counties in the study area reported sales from livestock (L) mainly, and none from crops or forest or other agricultural products alone. As already indicated, the high proportion of sales from Franklin County,

## TABLE 6

## RECEIPTS FROM SALES OF AGRICULTURAL PRODUCTS - 1970

| STATE<br>County | |
|---|---|
| TENNESSEE | |
| Hardin | $ 4,052,638 |
| McNairy | 6,293,834 |
| Wayne | 2,512,417 |
| ALABAMA | |
| Colbert | 7,248,153 |
| Fayette | 3,305,052 |
| Franklin | 10,353,825 |
| Greene | 3,971,583 |
| Hale | 8,035,851 |
| Lamar | 3,163,857 |
| Lauderdale | 8,405,278 |
| Marengo | 6,601,447 |
| Marion | 5,306,143 |
| Pickens | 7,250,991 |
| Sumter | 4,718,827 |
| Tuscaloosa | 4,824,673 |
| MISSISSIPPI | |
| Alcorn | 4,369,327 |
| Chickasaw | 6,864,449 |

## TABLE 6 (Cont.)

## RECEIPTS FROM SALES OF AGRICULTURAL PRODUCTS - 1970

| STATE<br>County | |
|---|---|
| MISSISSIPPI (Cont.) | |
| Clay | $ 5,799,595 |
| Itawamba | 6,413,730 |
| Kemper | 3,006,730 |
| Lauderdale | 2,650,881 |
| Lee | 13,761,376 |
| Lowndes | 7,829,707 |
| Monroe | 8,715,075 |
| Noxubee | 10,484,023 |
| Oktibbeha | 5,947,011 |
| Pontotoc | 7,689,184 |
| Prentiss | 6,233,297 |
| Tippah | 5,809,252 |
| Tishomingo | 3,266,400 |
| Union | 5,570,592 |
| Winston | 4,101,749 |

AL, is largely poultry-based. Marion County, AL, and Itawamba County, MS, enjoy large sales from poultry also, while Wayne County, TN, is noted for hogs. Only Winston and Oktibbeha Counties, MS, are noted for sales of cattle in relation to other animals. Cattle predominate in all other counties of the study area, i.e., those counties classified as livestock-cropland (LC).

It is believed that the most significant factors related to the photomorphic regionalization of a large agricultural area are the general and specific land use characteristics. For a general view, four classes of land on farms were investigated--cropland, woodlands, pasture, and other lands. The combination of these classes form three sets of combinations in the study area: (1) cropland-woodland-pasture (CWP); (2) cropland-woodland (CW); and cropland-pasture (CP). Twelve (12) counties are of the CWP class, eighteen (18) counties are of the CW class, and two (2) counties are classified as CP (Table 7). The majority of the CWP class are located in the southern and northern sections of the study area. Lee County, MS, (probably the wealthiest agricultural county in the study area) and Pickens County, AL, are classified as CP.

Specific crop traits in the study region are: soybeans (S); field corn ($C_F$); cotton ($C_T$); hay (H); and wheat (W). Seventeen (17) of the counties in the study area are classified as S-$C_F$-$C_T$-H (Table 8). Seven (7) counties are devoted to a S-$C_T$-H combination and two (2) counties are classified as SH counties. The rest are individually classified as H-$C_F$, $C_T$-H, and H counties. Spatially the S-$C_T$-H counties form a "solid core" in the center of the study area; the S-$C_F$-$C_T$-H counties are interspersed amont these sections.

## TABLE 7

## CLASSIFICATION OF MAJOR LAND USES IN COUNTIES AFTER THOMAS - WEAVER APPROACH

| STATE<br>County | |
|---|---|
| TENNESSEE | |
| Hardin | CW |
| McNairy | CW |
| Wayne | WC |
| ALABAMA | |
| Colbert | CW |
| Fayette | WC |
| Franklin | CW |
| Greene | WCP |
| Hale | CPW |
| Lamar | CW |
| Lauderdale | CW |
| Marengo | CWP |
| Marion | WC |
| Pickens | PC |
| Sumter | WCP |
| Tuscaloosa | WC |
| MISSISSIPPI | |
| Alcorn | CW |
| Chickasaw | CWP |

Types:

Cropland - (C)
Pasture - (P)
Woodland - (W)
Other - (O)

Order indicates 1st, 2nd, and 3rd levels of importance of land use in counties.

## TABLE 7 (Cont.)

## CLASSIFICATION OF MAJOR LAND USES IN COUNTIES

## AFTER THOMAS - WEAVER APPROACH

| STATE<br>County | |
|---|---|
| MS (Cont.) | |
| Clay | CWP |
| Itawamba | WC |
| Kemper | CWP |
| Lauderdale | WCP |
| Lee | CP |
| Lowndes | CWP |
| Monroe | CW |
| Noxubee | CPW |
| Oktibbeha | CPW |
| Pontotoc | CW |
| Prentiss | CW |
| Tippah | CW |
| Tishomingo | CW |
| Union | CW |
| Winston | CWP |

# TABLE 8

## CLASSIFICATION OF SPECIFIC CROPS ACCORDING TO THOMAS -WEAVER APPROACH

| STATE<br>County | |
|---|---|
| **TENNESSEE** | |
| Hardin | S $C_F$ H $C_T$ |
| McNairy | S $C_F$ $C_T$ H |
| Wayne | H $C_F$ |
| **ALABAMA** | |
| Colbert | $C_T$ S H W |
| Fayette | $C_T$ $C_F$ S H |
| Franklin | $C_T$ H $C_F$ S |
| Greene | $C_T$ S H $C_F$ |
| Hale | S H $C_T$ |
| Lamar | $C_T$ S $C_F$ H |
| Lauderdale | $C_T$ S H $C_F$ |
| Marengo | S H $C_T$ $C_F$ |
| Marion | $C_F$ $C_T$ H S |
| Pickens | S $C_T$ H $C_F$ |
| Sumter | H $C_T$ S $C_F$F |
| Tuscaloosa | $C_T$ H |
| **MISSISSIPPI** | |
| Alcorn | S $C_T$ $C_F$ H |
| Chickasaw | S $C_T$ H |

Crops:

Soybeans - S

Field Corn - $C_F$

Cotton - $C_T$

Hay - H

Wheat - W

Order indicates 1st, 2nd, 3rd, and 4th, levels of importance of crops in counties

# TABLE 8 (Cont.)

# CLASSIFICATION OF SPECIFIC CROPS ACCORDING TO THOMAS - WEAVER APPROACH

| STATE<br>County | |
|---|---|
| MS (Cont.) | |
| Clay | S H |
| Itawamba | S $C_T$ $C_F$ H |
| Kemper | H $C_F$ $C_T$ S |
| Lauderdale | H |
| Lee | S $C_T$ |
| Lowndes | S H $C_T$ |
| Monroe | S $C_T$ H |
| Noxubee | S H $C_T$ |
| Oktibbeha | H S |
| Pontotoc | S $C_T$ H |
| Prentiss | S $C_T$ |
| Tippah | $C_T$ $C_F$ H S |
| Tishomingo | $C_T$ $C_F$ H S |
| Union | S $C_T$ $C_F$ H |
| Winston | H $C_F$ $C_T$ |

Although the combinations of crops as revealed by Census materials are true for a single year, it is anticipated that particular crop changes occur among farms between growing seasons. That is, farm regions devoted to cotton during one year can be changed to soybeans, hay, or other crops the next year. Some crops, however, because of established farm marketing systems would, by necessity, be more inclined to remain somewhat stable within a county; while hay, a crop grown in association with livestock, would tend to be less stable.

## Summary of Study Region

The study area for this investigation is oriented largely toward agricultural pursuits. These economic directions involve both crop and livestock agriculture. Physical factors such as surface configuration, soil moisture and soil traits, and climatic factors play an important role with respect to this type of agricultural production. Other factors, such as the size of farms, the amount of capital available and other cultural traits, play roles respecting the agricultural economic health of the area.

The density of vegetation correlates negatively with the amount of land in farms. That is, the greater the apparent density of vegetation (whether upland forests or wooded swamplands) the lower the amount of land devoted to agriculture. In addition, however, the density of agriculture apparently is positively correlated with the number and frequency of small central places.

As indicated above, there is a general dearth of large central communities in the study region. Thus, from the standpoint of the proposed

Tennessee-Tombigbee Waterway, the area will function as a "pass-through" region. Barges may serve to move agricultural commodities out of the area, but initial costs of constructing terminal facilities--warehouses and docks--and, later, terminal costs for loading (and unloading) shipped commodities may be prohibitively high. The latter factor would be especially true for hauling agricultural commodities over short distances, e.g., to Mobile, AL, or Knoxville, TN. Based on the data gathered, a single barge terminal in the vicinity of Tupelo-Aberdeen, MS, along the Tennessee-Tombigbee Waterway would appear to be most advantageous because of the central location within the core of the agricultural region.

## First-Order Regions

Surface configuration.--Because of the obvious generalized traits of small-scale physiographic regions and associated drainage conditions, such features are obviously discernable from space-derived imagery of the LANDSAT type. Surface configuration and drainage has a significant linkage with other features of the physical environment--soil, vegetation, and land use, among others.

In the study area the surface configuration displayed by the Black Belt complex--a cuesta lowland--and the surrounding hill lands has a dramatic impact on the appearance of the photomorphic units of the area (Figure 28). Obviously, surface configurations are directly apparent on the ground. Even with stereo vision, however, the photographic characteristics associated with elevation (such as relief, slope forms, and related morphological traits) would be rather subdued. But the linkage traits would most definitely appear. Among others, the linkage between first-order surface configuration and land survey traits becomes apparent. In that the study area has a township-and-range pattern throughout (except for the Tennessee section), it should display textural traits which are separated in the general vicinity of the Tombigbee River. To the east of this line, the surface configuration of low and open hills will decidely differentiate this region from the western area. Also, in the eastern region it is expected that a few rectangular plots will be apparent where surveys are associated with low-density population regions and large forest areas, the latter situation probably being associated with large land holdings. Drainage densities in the eastern division are finer than in the western area because of the surface configuration as already noted (Figure 31). From field work it is evident that the low-lying Black Belt area has drainage problems, especially flooding, during times of heavy rains. An obvious general difference in the study area is the relatively coarser drainage pattern in the Black Belt. The lower and flatter Black Belt topography also gives rise to a greater intensity of agricultural land use.

The Tennessee valley region in the northern part of the study area displays a pattern similar to that of the Black Belt. The Tennessee valley section, however, is separated by a narrow low-open hill section which shows a drainage pattern similar to that to the south. Another pattern similar to that found east of the Tombigbee River is also found in the southwest portion of the study area. Here again, the cuesta-ridge pattern should be displayed in a two-prong situation with respect to photomorphic units (see Figure 28). The relief in the latter situation is not great (100-300 feet/30.5-91.4 meters) compared with the area to the east of the Tombigbee River (300-500 feet/91.4-152.4 meters). This low relief exercises less control of the drainage network than the hill lands to the east of the Tombigbee River.

Vegetation and cropland.--Related to the spatial landscape patterns of the first-order factors of surface configuration and land survey system are the large-area traits associated with vegetation and general cropland situations. In most cases the correlation between natural vegetation and cropland is negative (-0.7666), as would be expected. That is, as woodland increases cropland decreases, and vice versa, for the various counties in the study region.

The spatial relationship here is strongly related to and associated with surface configuration and drainage density. The counties to the east of the Tombigbee River display topographic patterns which are "rougher" than those found to the west of the river, thus less land is available for cropland use (or pasture) and more is available for retention as woodland. Some 17.1 percent of all land in the study area is in woodlands on farms, or stated in another way, more than one-third (35.5%) of the land on farms is in woodlands. The mean of the county percentages and standard deviations from the mean indicate that the higher proportion of woodland is located east of the Tombigbee River (Table 9). Exceptions seem to be related to high rural non-farm density counties (Tables 4 and 9). The correlation between rural population densities and woodland, however, is, in general, low (-.4511) for the area as a whole.

# TABLE 9

## PROPORTION OF LAND IN FARMS
## IN CROPLAND, IN WOODLAND - 1970

| STATE<br>County | Cropland<br>(Percent) | Woodland<br>(Percent) |
|---|---|---|
| TENNESSEE | | |
| Hardin | 21 | 40 |
| McNairy | 24 | 39 |
| Wayne | 8 | 60 |
| ALABAMA | | |
| Colbert | 28 | 27 |
| Fayette | 15 | 51 |
| Franklin | 16 | 42 |
| Greene | 16 | 40 |
| Hale | 26 | 26 |
| Lamar | 17 | 50 |
| Lauderdale | 22 | 26 |
| Marengo | 14 | 40 |
| Marion | 13 | 49 |
| Pickens | 22 | 45 |
| Sumter | 12 | 35 |
| Tuscaloosa | 15 | 47 |
| MISSISSIPPI | | |
| Alcorn | 22 | 30 |
| Chickasaw | 30 | 22 |

## TABLE 9 (Cont.)

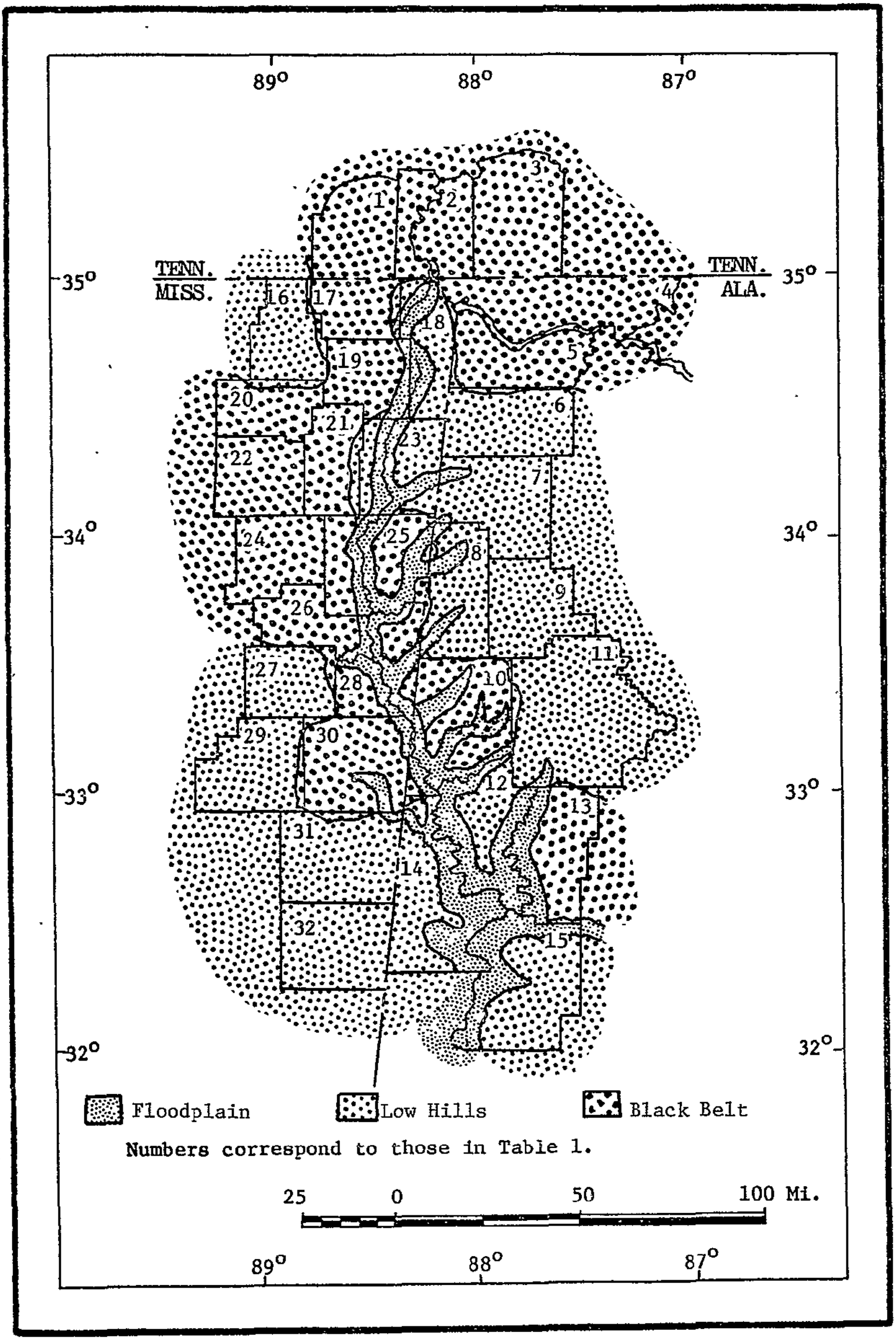
## PROPORTION OF LAND IN FARMS
## IN CROPLAND, IN WOODLAND - 1970

| STATE<br>County | Cropland<br>(Percent) | Woodland<br>(Percent) |
|---|---|---|
| MS (Cont.) | | |
| Clay | 24 | 23 |
| Itawamba | 18 | 44 |
| Kemper | 12 | 37 |
| Lauderdale | 8 | 46 |
| Lee | 37 | 17 |
| Lowndes | 29 | 28 |
| Monroe | 31 | 30 |
| Noxubee | 27 | 24 |
| Oktibbeha | 17 | 27 |
| Pontotoc | 26 | 28 |
| Prentiss | 29 | 35 |
| Tippah | 17 | 42 |
| Tishomingo | 17 | 46 |
| Union | 29 | 31 |
| Winston | 12 | 39 |

Black Belt, Low Hills (Tombigbee Flood Plain) Photomorphic Pattern.--At the first-order level it is expected that a two-region pattern situation is characteristic of the study area based on the spatial traits considered Some variations of tonal traits are to be expected. For purposes of convenience these patterns are called (1) the Black Belt pattern, and (2) the Low Hills section (Figure 34). Between and among these two patterns is a minor pattern representing the floodplains of the Tombigbee River and its tributaries.

As would be expected the Black Belt pattern is largely associated with the Black Belt physiographic region. However, in addition to this location, the Black Belt pattern is also found in association with the Tennessee valley area. Specifically, this photomorphic pattern is located in Lauderdale, Hale, Pickens and Colbert Counties in Alabama; Hardin and McNairy Counties in Tennessee; and Alcorn, Prentiss, Union, Pontotoc, Lee, Chickasaw, Monroe, Clay, Lowndes and Noxubee Counties, in Mississippi. Because of the domination of cultivated croplands and relatively low relief in these areas, and by virtue of the low proportion of land in woodland vegetation, the dominant spatial signature is expected to be rectangular or near-rectangular, producing a block-like configuration. Tonal patterns are expected to vary (and are associated with second- and third-orders of classification) within the Black Belt pattern largely because of differences in cropland and pasture signatures. Specifically, the central areas within the state of Mississippi should reveal patterns which show grassland traits while the other regions, especially the areas in the Tennessee valley region, will tend to appear as cropland. From

Figure 34: FIRST-ORDER PATTERNS



Numbers correspond to those in Table 1.

a temporal standpoint, the grassland tonal properties will remain more constant between summer and winter, while the cropland signatures will show a wide variation between the seasons.

The factors responsible for variation of the photomorphic regions within the Black Belt have little impact on the variations of central places within the other two major regions as indicated in Table 10. In those counties within the Black Belt pattern area, there are 72 central places as revealed by the Census. There are 64 central places in the Low Hills section; a difference of less than six percent. As indicated by Table 10 the mean number of central places differs by less than .5; also indicating that the factors responsible for first-order photomorphic qualities have little influence on the number of central places. The difference between the number of people living in urban areas in the Black Belt and the number of people living in urban areas in the Low Hills section is a little greater than two percent (2.25). This, again, seems to indicate that factor differences responsible for photomorphic variation between the two areas is not responsible for change in the size and arrangement of central places in the study area. Of course, the larger size of the Low Hills area as compared with the Black Belt section provides for a greater distance between central places.

From a photomorphic point-of-reference it is expected that at the first-order level of classification, the tonal differences between the traits for urban and rural areas cause spatial variation within the two first-order classes. The urban areas remain rather consistent in their tonal appearances for any short temporal period (less than a year).

## TABLE 10

## NUMBERS, FREQUENCIES, AND AVERAGES OF CENTRAL PLACES IN THE STUDY AREA, BLACK BELT COUNTIES, AND LOW HILLS SECTIONS

Number of Central Places in Study Area = 136
$\overline{X}$ per County = 4.25
Standard Deviation = 2.13

Number of Central Places in Black Belt = 72
$\overline{X}$ per County = 4.50
Standard Deviation = 1.97

Number of Central Places in Low Hills = 64
$\overline{X}$ per County = 4.00
Standard Deviation = 2.31

In contrast, rural factors change for various reasons, but especially because of agricultural cropland changes. These conditions produce changes in the photographic contrast ratios between and among the various seasons of the year. Thus, the first-order categories for the detection of such things as the urban-rural boundary are expected to vary according to season of the year, the neighboring dominant type of land cover, and the spectral band within which the photomorphic complex is viewed. In the case of the latter factor, it is expected that the poorest overall division will take place in the blue-green range (.54 microns) and the best will occur in the red range (.68 microns).

Because urban areas in the Black Belt area reflect traits which are similar to pasture areas, it is expected that small central places will not produce any type of significant pattern differences.

The amount of land devoted to pasture use (excluding woodland pasture) in the Black Belt region is basically the same as that for the Low Hills area (15.0 percent for the former, and 16.1 percent for the latter). Here again, as mentioned above, the difference between the two areas is largely in terms of the amount of land devoted to cropland and woodlands. In the counties within the Black Belt, 27.3 percent of the area is devoted to cropland; while for the study area as a whole, only 20.4 percent is given over to cropland use. Therefore, as expected, the proportional amount of land in woods on farms is less in the Black Belt area (29.5%) than in the study area as a whole (36.4%) or the Low Hills section.

It was concluded, therefore, that the signatures for these two areas will, in part, be the result of assemblages of woodland/cropland/pasture associations. The Black Belt region ought to display a signature which is the result of cropland/woodland/pasture, while the Low Hills section should yield a signature which reflects a woodland/pasture/cropland relationship, in respective order of areal importance. The tonal differences within these two areas is of little importance from the standpoint of first-order classification. The tonal differences at the spatial boundaries of the two areas should be distinctive and clearly discernible.

The Low Hills section within the study area displays a pattern having less block-like appearance than that of the Black Belt area. From published maps of the area, it is expected that road patterns and networks will display arrangements which have been conditioned by dominant surface configurations. A built-in bias realized by the investigators having viewed the northern section of Alabama on a previous occasion is that large forestry establishments have "cut-out" segments of that area here referred to as the Low Hills section and which follow the township-and-range survey lines. Vegetative regrowth in these areas produces a pattern which is, in turn, block-like in appearance.

In contrast to the Black Belt area, the vegetation of the Low Hills section should display a stronger contrast range between the urban and surrounding rural areas. A possible exception should occur where the large and small central places have great amounts of tree-cover. If such situations exist in the study area it will be nearly impossible to differentiate the rural-urban fringe, but the central portion of urban sites should be discernible. Indications are that the largest urban place in the study area, Tuscaloosa, AL, has large amounts of vegetative cover which would tend to generate a rural appearance within the central portions of the city, but not in the Central Business District and adjacent areas.

Traits which add to the overall spatial patterns of both the Black Belt and Low Hills sections are a combination of drainage, vegetation and soils. Here again, the tonal factors reflecting these traits are associated with second-order classification. Nevertheless, some of the first-order characteristics are due, in part, to the drainage, soil, and vegetation factors. Particular significant is that the floodplain areas which, from a hydrologic point-of-view, are excessively wet and poorly drained, consist of soils classified as entisols (alluvial), and are covered by southern hardwoods (see Figure 34). The tonal traits of this complex should vary between major seasonal periods bringing out distinctive spatial boundaries. Most important, it is believed, is the floodplain complex of the Tombigbee River. The major trait which this floodplain contributes to the photomorphic construct of the study area is that of serving as a boundary zone between the two major first-order regions.

In summary, with respect to the first-order categorization of expected photomorphic regions in the study area based on library data, two major and different regions are identified in terms of spatial traits--the Black Belt and Low Hill sections, separated by a floodplain. The internal spatial traits of these regions are mainly responsible for the differentiation of these areas and therefore counties are included totally within or without either section. Tonal factors obviously play a role in the process of boundary differentiation.

Second-Order Categorization.--As mentioned earlier, the categorization of the photomorphic units from library materials at second-order level largely involves various types of population data. Herewith, four major categories of data were investigated: total population; rural population; urban population; and rural population densities.

The total population of the study area in 1970 was 884,395, with a mean population per county of 27,637.34. One standard deviation for county population data is 22,090.02, a very high figure which is indicative of extreme differences in population among the counties in the study area.

Forty-three percent of the population is classified as urban (381,198). The mean urban population per county was 13,614.21. One standard deviation for county population exceeds the mean (17,913.73). Obviously several counties have high urban population and dominate the general population distribution (see Figure 35). Of greatest significance are Tuscaloosa County, AL, followed by Lauderdale County, AL, and Lauderdale County, MS. Of lesser importance are Lowndes, Oktibbeha, and Lee Counties, MS, and Colbert County, AL. Each of these counties has one or more large urban centers; the largest place being the city of Tuscaloosa, AL. All of the other twenty-five counties have less than the mean number of people, and are therefore classified as rural.

Compared to the total population distribution, the urban component obviously accounts for the deviation from the norm when the two sets of county data are compared. Only two rural counties have higher than normal population. These are Prentiss and Monroe Counties, MS, (Figure 36).

It is suggested that a set of visual signatures exist which are representative of urban areas, and that a set of signatures exist as well for areas of high rural population. An analysis of the rural population data leads to the conclusion that the counties with the largest urban population

Figure 35: TOTAL POPULATION, 1970

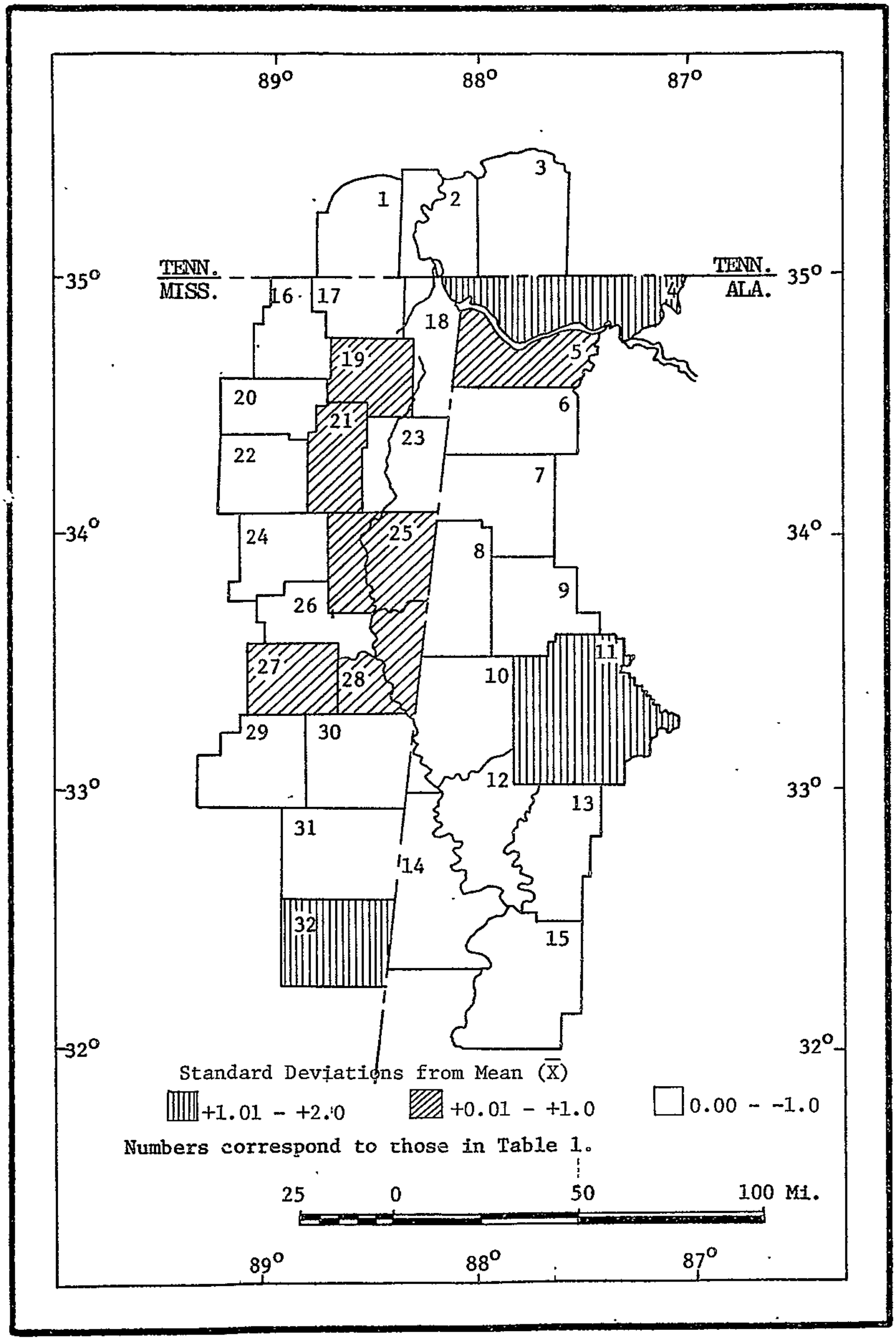
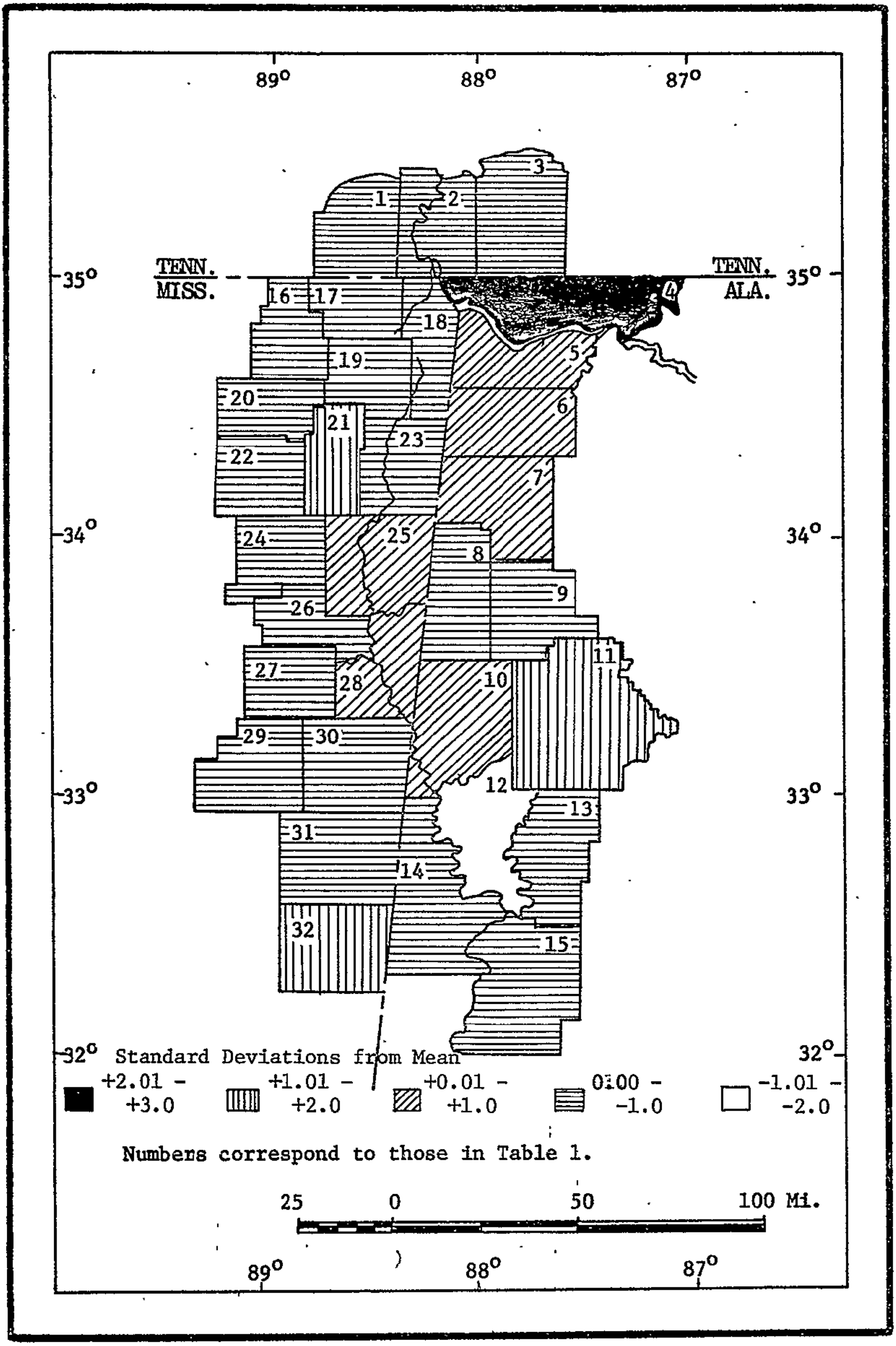


Figure 36: RURAL POPULATION, 1970



also have the largest rural population. This, in turn, suggests that a significant proportion of the rural population is rural non-farm (See Table 4), and/or that a significant proportion of the rural population contributes to the various urban labor forces.

Although the characteristics for the spatial signatures for all American cities are basically the same, and, while it can be expected that signatures for urban places in the study area will also be the same as those in any other area; it is not known exactly what can be expected of signatures of the rural-urban fringe zone. From topographic maps and field work, however, it is surmised that areas in the vicinity of urban places which display low-relief, but some slope (for drainage), will be devoted to crop agricultural uses, and that lands with extremely high slopes which are also near urban places will be devoted to forest and/or pasture. Areas which have "middle" characteristics will probably be in rural non-farm or small "baby" farm uses.

Thus it is suspected that at least three types of signatures can be witnessed in the vicinity of the urban places: (1) a speckled pattern of various tonal and/or textural densities which describes the mixture of residential, crop, forest, and pasture uses, (2) a uniform, light to medium tonal pattern of pasture grasses, especially on lands made available to dairy cattle, depending on the underlying color of the soil and the grass density characteristics, and (3) dark to medium uniform patterns for the forest.

With respect to the variety of population characteristics which could have tonal and/or textural photomorphic expression, several combinations of conditions were seen ao exist in the study area. The criteria used to identify the groupings were as follows: (1) population of the individual county in relation to the mean of the population and standard deviations from the mean for the study area; (2) urban population of the individual county in relation to the mean for the study area and the standard deviations from the mean; (3) rural population of the individual counties, in relation to the mean and standard deviations from the mean for all counties; (4) rural non-farm population in relation to the mean for all the counties and the standard deviations from the mean; and (5) average rural densities in relation to the mean for the study area and standard deviations from the mean (see Table 11).

Those counties which were deemed significant were those which expressed a standard deviation of one or more from the mean, either below or above. Following this procedure, seven groups of counties were identified on the basis of population characteristics. The county groupings and their characteristic were as follows: (see Figure 37 also.)

(1) Winston, Tishomingo, Pontotoc, Noxubee and Kemper Counties, MA. Identifying traits: very low rural non-farm population (in addition, Kemper County rural population density is low.)

(2) Lee County, MS. Identifying traits: high rural population, and very high rural population density.

(3) Lowndes County, MS. Identifying traits: high rural population density.

(4) Lauderdale County, MS, & Tuscaloosa County, AL. Identifying traits: high total population, high urban population and high non-farm population.

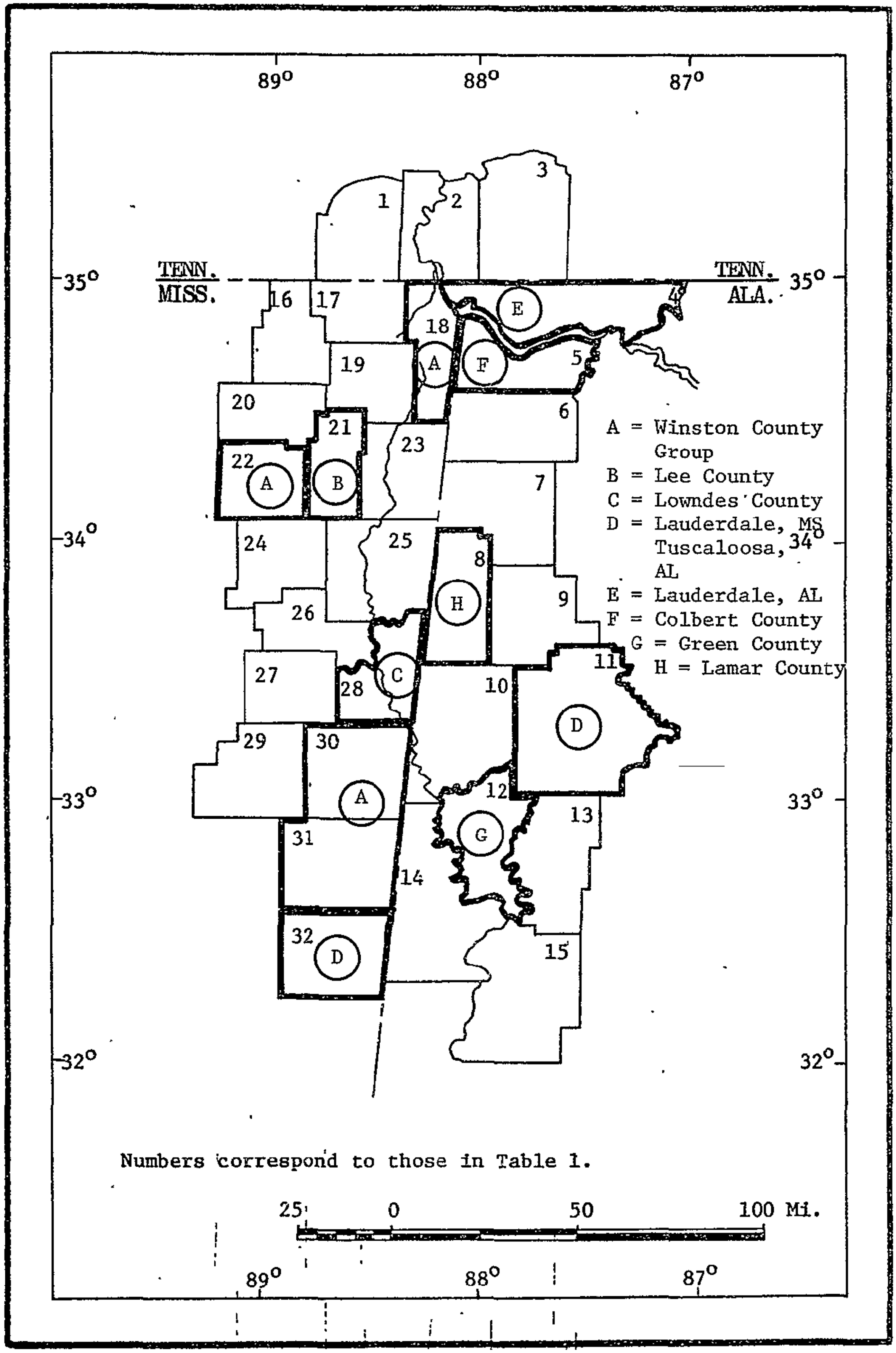
## TABLE 11

## POPULATION TRAITS IN TERMS OF DEVIATIONS FROM THE STUDY AREA NORMS

| | Pop. Total | Pop. Urban | Pop. Rural | Rural Non-Farm Pop. | Rural Density |
|---|---|---|---|---|---|
| TENNESSEE | | | | | |
| Hardin | N | N | N | N | N |
| McNairy | N | N | N | N | N |
| Wayne | N | N | N | N | N |
| ALABAMA | | | | | |
| Colbert | N | N | N | H | N |
| Fayette | N | N | N | N | N |
| Franklin | N | N | N | N | N |
| Greene | N | N | L | N | L |
| Hale | N | N | N | N | N |
| Lamar | N | N | N | N | N |
| Lauderdale | H | H | VH | N | H |
| Marengo | N | N | N | N | L |
| Marion | N | N | N | N | N |
| Pickens | N | N | N | N | N |
| Sumter | N | N | N | N | N |
| Tuscaloosa | H | VH | H | H | H |
| MISSISSIPPI | | | | | |
| Alcorn | N | N | N | N | N |
| Chickasaw | N | N | N | N | N |
| Clay | N | N | N | N | N |
| Itawamba | N | N | N | N | N |
| Kemper | N | N | N | VL | L |
| Lauderdale | H | H | H | L | N |
| Lee | N | N | H | N | VH |
| Lowndes | N | N | N | N | H |
| Monroe | N | N | N | N | N |
| Noxubee | N | N | N | VL | N |
| Oktibbeha | N | N | N | N | N |
| Pontotoc | N | N | N | VL | N |
| Prentiss | N | N | N | N | N |
| Tippan | N | N | N | VL | N |
| Tishomingo | N | N | N | VL | N |
| Union | N | N | N | N | N |
| Winston | N | N | N | VL | N |

LEGEND: (N) = Normal (within one S.D. of $\overline{X}$); (H) = more than + one S.D. of $\overline{X}$, but less than + two S.D.; (VH) = more than + two S.D. of X; (L) = less than − one S.D. of $\overline{X}$; VL more than − two S.D. of $\overline{X}$.

Figure 37: SECOND-ORDER PATTERNS



Numbers correspond to those in Table 1.

(5) Lauderdale County, AL. Identifying traits: high total population, high urban population, very high rural population, very high rural population density, and low rural non-farm population.

(6) Colbert County, AL. Identifying traits: high rural non-farm population.

(7) Greene County, AL. Identifying traits: low rural population and low rural population density.

(8) Lamar County, AL. Identifying traits: high rural non-farm population.

Third-Order Categorization.--The third-order categorization of photomorphic traits is believed to be related directly to land use traits or to surrogates of land use. These factors are both tonal and textural, and exist within the broader tonal and textural traits of the first- and second-orders. From a temporal standpoint, third-order traits are not very stable; changing annually, seasonally, and perhaps even daily. "Ground-truth" procedures, therefore, are difficult and in some cases downright guesses must be made as to what has existed, presently exists, or will exist in the future. For example, using such library sources as the National Atlas or the Census as major sources of data, one is confined to reviewing LANDSAT-type imagery from the time of the last Census or the time when cartographic work was completed for the National Atlas. In addition, a major failing of the Atlas and the Census is that the data categories do not necessarily conform to all of the traits of the landscape. Needless to say, however, these are still the best sources available.

Third-order categorization is temporally modulated with respect to detecting photomorphic traits. That is, land use traits, especially crop types, will change reflectivity according to their growth patterns. Bare row crop fields with high reflection characteristics should be common in the late fall, winter and early spring. If, however, cover crops are used, then darker traits will be characteristic, especially during this same fall to spring period of time. The high proportion of hay crops in most of the counties in combination with row crops--cotton, corn, and soybeans should produce medium density tonal patterns. If the fields are left without cover crops, then soil traits become the dominant factor in determining reflective patterns. Floodplain soils would generally show as dark (whether wet or dry) as compared to most of the upland soils. Most of the fields with upland soils would tend to reflect in the orange and red range (.6 -.7 microns) and would, therefore, tend to be darker during wet season and lighter in the summer. Lands being prepared for cotton would need to be plowed in the late fall, winter or early spring because of the long growing season required. In that the study region is near the margins of the cotton growing season, these lands would have to be prepared quite early. In contrast, corn and soybean lands could be prepared as late as May or June and still yield a crop return. Obviously farmers in the study area have a number of alternative crop selection decisions which they can make from growing season to growing season and within individual growing seasons. These decisions would depend on such physical traits as frost occurrances, precipitation and soil moisture traits, as well as market price factors. With respect to the latter, for example, the increased market price for soybeans since the middle of the 1960's is strongly reflected in the patterns of cropland use.

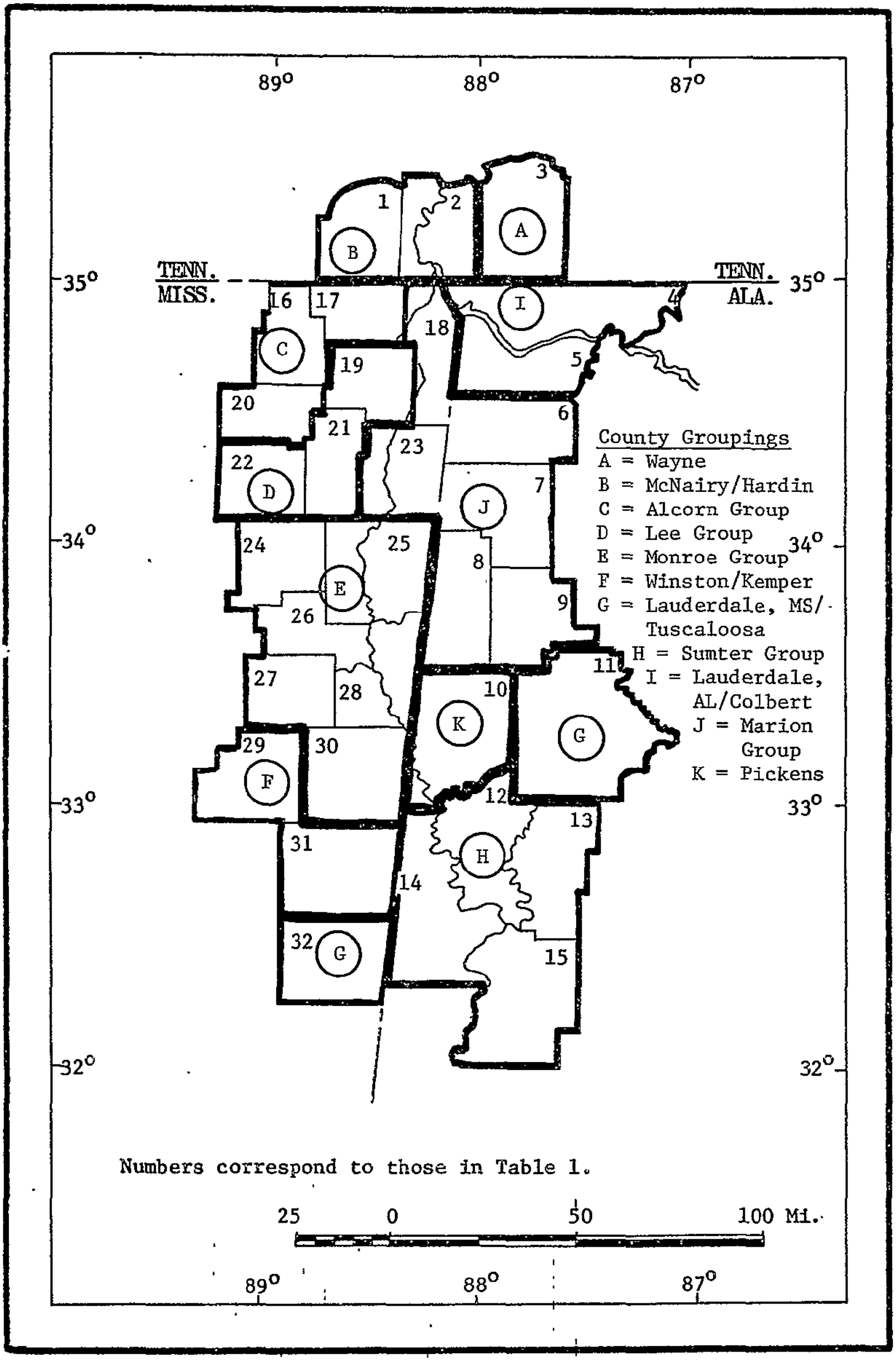
The approach taken to determine the thirdorder categorization of the study area was to individually examine counties in the study area and predict their photomorphic patterns based on combinations and proportions of major land uses and specific crops, proportion of lands in farms and farm sizes. The third-order patterns thus derived are as shown in Figure 38.

Wayne County, TN.--Most of the sales of agricultural products is gained from raising livestock, particularly hogs, and smaller than normal amounts of land are in farms (37.0%) in Wayne County, TN. The majority of county land is in forest, and would tend to show a darker tone in the blue-green range in the summer months. Because these are largely deciduous trees, however, the pattern would be lighter in the winter. The average rural population density is low (16.7 people per square mile/10.4 per square kilometer, less than the 26.16 /sq. mile or 16.2/sq. kilometer mean for the study area) and the average-size farm is 206.6 acres/83.6 hectares (which is near the 186.72 acre/75.6 hectare average for the study area).

Woodlands constitute the majority of land on farms and croplands are the second major land use. Hay and field corn are the major crops; a situation which agrees with the fact that the major agricultural pursuit is swine raising. The income gained from agriculture is one of the lowest in the study area, a fact which also correlates with the low average value of farms for the study area.

It is postulated that the photomorphic appearance of this county will consist of irregular and small spots of cropland surrounded by woods. The density of cropland probably increases toward the Tennessee River and

Figure 38: THIRD-ORDER PATTERNS



Numbers correspond to those in Table 1.

toward the major central places situated outside the county (i.e., the Quad-cities of Florence, Sheffield, Tuscumbia and Muscle Shoals, AL).

From field observations it has been noted that croplands are located on the interfluvial land and that river bottoms are narrow with steep slopes flanking the floodplains. The drainage density of the higher-order streams in Wayne County, TN, is rather fine. This would account for some great amounts of riparian vegetation of denser reflective traits. Concomitantly the road network is coarse, a fact corresponding to the low rural population density.

McNairy and Hardin Counties, TN.--Hardin and McNairy Counties in Tennessee are similar in: (1) crop-combinations; (2) proportion of farms in crops and woodlands; and (3) income gained from agricultural pursuits. They significantly differ in the proportion of the total land devoted to farms (45.1 percent for Hardin County and 59.3 percent for McNairy County). These differences possibly result from the fact that Hardin County is traversed by the Tennessee River and a significant proportion of the area is covered by TVA reservoir (Pickwick Dam), while McNairy County is largely located on uplands associated with the Tennessee River drainage divide.

In contrast to Wayne County, both Hardin and McNairy Counties have average size farms which are smaller than the mean for the study area (156.6 and 146.1 acres, or 63.4 and 59.1 hectares, respectively).

The field patterns should show some degree of rectangularity, even though these counties are located in Tennessee where the township-and-range survey system was not used. A "private" rectangular survey system, however, was employed in the Jackson Purchase section of Tennessee to which these two counties belong. This survey system is displayed to some degree by the road network.

In many ways the crops and their reflective patterns in these two counties represent a transitional zone. Cropland and woods are the dominant land uses and the specific crops are, in order of importance: soybeans, field corn, with hay and cotton occupying alternating positions in the two counties. These crops can be (and should be) rotated among the various fields. Thus, the tonal characteristics should vary within the counties and perhaps between (and among) adjacent counties from year to year.

Similarities exist between these counties in densities of population. Hardin county has a rural population density of 21.5 people per square mile (13.4/sq. kilometer), while McNairy registers 26.1 persons per square mile (16.2/sq. kilometer).

There is an obvious "trend surface" which slopes away from the northeastern section of the study area (centered on Wayne County, TN) toward the west and south. This trend surface is strongly expressed by the proportion of land in farms. In most cases "other" land uses are large forest tracts in private ownership.

Tishomingo, and Itawamba Counties, MS, and Marion, Lamar, and Fayette Counties, AL.--For lack of better terms, the investigators classified counties with similar probable appearances by the name of one of the counties. In terms of crop types, emphasis of agricultural programs, densities of population, and proportions of major land use, the above-named counties in the study area can be simply classified as Marion county type. They are similar to many characteristics of Wayne County, TN.

Of particular significance is the fact that these counties are all within the headwater sections of the Tombigbee and Tennessee watersheds and the proportion of land in farms is significantly low, ranging from 31.0 percent to 42.0 percent with the mean proportion being 35.32 percent.

Crop-combinations in these counties vary from those of Wayne County, TN, with cotton, corn, hay and soybeans dominating the fields in all of the counties. Woodland on farms occupies the highest proportion of lands, with croplands second in areal extent. As in Wayne county, however, the major sales are gained from livestock in all counties of the group, and crops are second in some of the mentioned counties (Lamar, Tishomingo, and Fayette). Incomes from farming are low for all counties except Marion (below the mean for the study area). The farm sizes among the counties are also very similar, ranging between average sizes of 115.9 acres/46.9 hectares and 134.5 acres/54.4 hectares, except for Fayette County, in which the average size farm is 180.3 acres/73.0 hectares.

Because of the low proportion of land in farms, and the high proportion of land in forest on the farms, it is predicted that the spatial patterns of tonal variation of this county-grouping will consist of a general matrix of reflective traits from the forest cover (which would consist of mix of southern floodplain hardwoods and upland hardwoods and conifers). Within the general tonal matrix, spotted open-field areas should be pronounced. These fields would, in general, be small, reflecting the small size of farms and the variety of crops characterizing the area. Because of the dominance of the Low Hills physiographic traits, the low-order drainage, and "winding" and "twisting" pattern of the road network, it is expected that the spatial distribution of the fields will be very irregular.

Alcorn, Tippah, Union Counties, MS.--These counties (the Alcorn county group) are similar in their general land use traits and specific crop-combinations. They are also similar in the proportion of land devoted to farms and the ranking of the sale of agricultural commodities. The average sizes of farms are extremely similar, 141.3, 136.1, and 128.3 acres, or 57.2, 55.1, and 51.9 hectares, respectively. Livestock first, crops second, is the order of significance for sale of agricultural commodities; and soybeans, field corn, hay and cotton are crops of importance according to the Thomas-Weaver approach for determining crop-combinations (see Table 8). Expectedly, therefore, a "speckled" pattern of rectangular farms would be characteristic of the area.

Croplands, followed by woodlands are the general land use patterns, and between 58 and 64 percent of the county areas are devoted to farm lands.

Farm incomes vary among the counties of this group. Respectively, they are $2,821, $1,821, and $2,481; a fact which seems to be related to the association with medium-sized central places (Corinth in Alcorn County, and New Albany in Union County). That is, farm incomes can be increased by people living close to larger cities and, perhaps, having second (part-time) employment in urban occupations.

The counties belonging to the Alcorn group should be very similar in photomorphic appearance to McNairy and Hardin Counties in Tennessee. Farm sizes, however, are larger in the latter group which could indicate large-sized fields, This fact again tends to confirm the earlier suggestion of a "trend surface."

Lee County, MS, Group.--The Lee County group of counties significantly represents way the association of "core agricultural counties" of the study area. The counties involved are Prentiss, Pontotoc, and Lee.

In all of these counties a high proportion of land is in farms (the highest in the total study area). Soybean and cotton dominate crop-combinations. Hay is also significant in the crop-combination for Pontotoc county. Cropland and woodland dominate the general areal patterns of Prentiss and Pontotoc counties. Cropland, followed by pasture, is the general land use characteristic of Lee County; but woodland is of little or no significance in this county. These factors should account for a "speckled" photomorphic tonal pattern. Here again, the sale of livestock is most significant; and crops are second in importance. But the sale of crops (and/or livestock) and farmers median incomes show little correlation.

Rectangular patterns and medium-size fields seem to be indicated by the Census and map analysis as being characteristic of the area and, thus, the variation of tones should have a fairly regular geometric appearance. The fact that two crops (three crops in Pontotoc County) dominate the agricultural scene may indicate that fields are larger than the size of the farms may otherwise indicate. The average size farms of Prentiss, Lee and Pontotoc Counties are 149.2, 163.8 and 131.3 acres or 60.4, 66.3, and 53.1 hectares, respectively.

Monroe County, MS, Group.--Some of the crop-combination characteristics associated with Prentiss, Lee, and Pontotoc Counties are also found in the Monroe County group. Average farm size is significantly different, however.

The Monroe County group consists of Chickasaw, Lowndes, Noxubee, Oktibbeba, Clay, and Monroe Counties. The average size of farm ranges from a low of 194.1 acres/78.5 hectares (Lowndes) to a high of 290.1 acres/117.4 hectares (Noxubee). These are the largest average-size farms in the study area, indicating that field sizes are large. Soybeans, hay and cotton are the predominant crop-combinations, and the major land use structure is based on cropland/woodland/pasture. Some variations of these crop-combinations and land use traits do exist. For example, in Clay and Oktibbeha Counties, soybeans and hay form the crop-combinations, and croplands and woodlands are the major land uses in Monroe County. Land in farms in these counties in relation to the total land area is less than in the Lee County group--(59.3 percent for the former and 68.5 percent for the latter). Nevertheless, both county groups are significantly high for this factor.

The tonal and textural patterns of the Monroe County and Lee County groups are expected to be quite similar. A possible difference could exist between the two areas because of variations in farm sizes, but this factor may be compensated for by the fact that few crop types are characteristic of the Lee County group. It is therefore possible that photomorphically (and geographically) the Lee-Monroe County groups form a single landscape unit. This landscape pattern should have regular, "blocklike" geometric characteristics with variations of tonal densities resulting from the reflective spectral traits of the different crop types. Cover crops should be responsible for winter reflective scenes, and summer scenes should also be fairly uniform in tonal traits. The greater differentiation among tonal densities would occur in the spring and fall, because of different growth patterns and harvesting schedules among the various fields.

Winston and Kemper Counties, MS.--Both Winston and Kemper Counties form a distinctive type in terms of crop-combinations, major land uses, and proportion of land devoted to farms. Hay, corn and cotton, in that order, are the major crop-combinations. Soybeans also play a role in the crop-combination identification in Kemper County, but not in Winston County. Cropland/woodland/pasture form the land use combinations, occuring in that order for the two counties.

In contrast to the surrounding counties, the proportion of land in farms is different for both Winston and Kemper Counties, being 46.0 percent and 41.3 percent, respectively. The average farm size for Kemper County (200.5 acres/81.1 hectares) is significantly larger than Winston county (138.5 acres/56.0 hectares). This disparity should be visible as a significant difference in field sizes between the two areas.

One characteristic which is common to both of these counties is that the farm incomes are low. Kemper County had the distinction of having the lowest farm income for the study area: $971. Farm income in Winston County was almost twice that of Kemper--$1,648, but both counties were below the average for the study area--$2,497.34. The low income derived from agriculture could be reflected in the tonal and textural traits of the photomorphic pattern in these counties. Particularly this could be a result of lower use of fertilizers and insecticides and other capital investments which could improve the income return for farmers. It should be noted, however, that the correlation between farm expenses and farm incomes for the counties in the study area was very low--.2729. This quite probably is the result of the very different agricultural pursuits in the different counties. Nevertheless, total farm expenses for

Kemper County were the lowest in the study area in 1970--$1,925,465. Farm expenses in Winston County were higher--$3,678,629, but rather well below the mean for the study region as a whole--$4,949,795.

Lauderdale County, MS, and Tuscaloosa County, AL.--Lauderdale and Tuscaloosa Counties are widely separated from each other in the study area (Figure 1). Both counties, however, are highly urbanized (second-order classification) and have similar crop-combination traits and gross land-use characteristics. Both of these factors are undoubtedly related to urban influences. Woodland/cropland forms the major land use traits of Tuscaloosa County and woodland/cropland/pasture identifies Lauderdale County. Hay is the only crop which identifies Lauderdale County, while a cotton-hay crop-combination identifies Tuscaloosa County. Both counties have low proportions of land devoted to farms, 34.7 percent for Lauderdale County and 20.5 percent for Tuscaloosa County. The latter is the lowest proportion for the entire study region.

The average farm sizes are 168.4 acres/68.1 hectares for Lauderdale County and 203.3 acres/82.3 hectares for Tuscaloosa County. Sale from farm products is low for both counties, and Lauderdale is the lowest in the study region. Yet, farm incomes for these two counties are about average. In Tusculoosa County, for example, the median earnings of farm laborers is higher than the median earnings for farmers; a reverse-type situation from that of all other counties in the study region. This can be explained in part by the presence of a greater number of "prestige" farms and rural non-farm places.

Sumter, Greene, Hale, and Marengo Counties, AL.--The Sumter County group counties all display similar types of crop-combinations (see Table 8), but in different orders of proportion. Further, they all display similar traits with respect to major land use classes, but, again, in different orders of proportion (see Table 7). Proportion of land in farms, however, are very similar--the mean being approximately 53 percent.

Soybeans, cotton, hay and field corn are the major crop-combinations in the area, and woodland/cropland/pasture are the land use combinations. Sale of livestock represents the major source of return for farmers, but sales of crops are also significant.

The mean farm size for the Sumter County group is 281 acres/113.7 hectares, and the standard deviation is less than 15 acres/61.1 hectares. This suggests not only similar size holdings, but also similar traits in terms of field sizes and patterns. Median farm incomes are generally low, the average of median incomes being $1,696 for the four counties. The Sumter County average, however, is significantly higher than the others ($2,818). Factors other than those indicated by the Census probably explain this disparity.

A significant areal portion of the Sumter County group is in low-lying floodplains (see Figure 11). Thus it is surprising that the proportion of land in farms is as high as it is. Expectedly, the lands in the vicinity of the Tombigbee River are in forest cover while the lands some distance away are in crops and pasture. Large fields in a rectangular geometric pattern should be characteristic of the area and a variety of tonal patterns should occur. The tones should be denser than those found in surrounding counties, however, due to dark soil color (vertisols) and/or denser color resulting from the field crops.

Pickens County, AL.--Pickens County, in many ways, is a transitional county in terms of its landscape traits. Soybeans, cotton, hay, and corn are the typical crop-combinations. This is similar to the county group to the south (the Sumter County group). Pickens County has 36 percent of its land in farms; similar to the county group to the north (the Marion County group). Livestock and crops account for the sale of agricultural products. This is similar to most counties in the study region. But pastures and cropland are the dominant land uses; a combination order which is different from any other county area in the study region. The average farm size of Pickens County is 230.4 acres/93.2 hectares, an "in-between" size category among the surrounding counties. Expectedly, therefore, "in-between" size fields should form the spatial pattern in the area. Farmers median income is also "transitional," being $2,472; more than the Sumter County group and less than the Marion County group. The photomorphic patterns should thus be "transitional" between the adjacent county grouping.

Lauderdale and Colbert Counties, AL.--Lauderdale and Colbert Counties, AL, are somewhat similar to Lauderdale County, MS, and Tuscaloosa County, AL, in that they are all highly urbanized in comparison to the other counties. Part-time farms and part-retirement farms form a significant proportion of all farms in the area (more than fifty percent of the farms in all of the mentioned counties are classified as such). Rural non-farm holdings are also high in these counties (91). Eighty-seven percent of Colbert and Lauderdale County rural population is classified as rural non-farm. Farm median income levels in Lauderdale and Colbert Counties reflects the strong urban influence. They are $3,200 and $5,238, respectively. The median income of Colbert County is the highest in the study area.

In contrast to the southern urban counties (Lauderdale, MS, and Tuscaloosa, AL), the urbanized counties in the north focus on a variety of crop types and combinations. Cotton, soybeans, and hay are characteristic of both counties, and corn is part of the crop-combination in Lauderdale County, while wheat is part of the crop-combination of Colbert County. Colbert is the only county in the study region which grows wheat in an amount significant enough to appear in the identification of the county. Cropland and woodland make up the major land use combinations, and the proportion of land in farms varies for the two counties--58 percent for Lauderdale County and 47 percent for Colbert County. Both of these factors contrast with those of the southern urbanized counties. The average farm sizes are large in Colbert County (210 acres/85.0 hectares), and small in Lauderdale County (132 acres/53.4 hectares). Field sizes are, respectively, large and small in the two counties.

It is expected that the photomorphic patterns of both Colbert and Lauderdale Counties will be similar. From previous research carried out in this area (Peplies and Wilson, 1970) it is known that large fields (in agreement with the larger-size agricultural holdings) are characteristic of a major portion of Colbert County and smaller fields and smaller holdings are characteristic of Lauderdale County. Tonal traits will be strongly conditioned by seasonal crop and pasture growth patterns.

Summary and Conclusions Concerning the Ground Truth Based Description and Explanation of Photomorphic Patterns.--As indicated from previous research, physical factors have a strong impact on the landscape patterns associated with the study area. The hierarchical patterns of association forthe first-order traits with various physical properties, particularly physiography, drainage, and vegetation, are apparently logical and reasonable. The linkages between these factors and the broadest-type natural region should be easily visible, and should depict regions of similar planning problems in terms of high-order priorities. Problems at the first-order should include: soil erosion, flooding, reforestation and afforestation, and slope failure, among others. In general, these were verified by field observations.

Observations at the second-order of the proposed photomorphic hierarchy are associated directly with settlement patterns. In this case, population data from the Census serve as surrogates. The photomorphic expression of these settlement traits will be both tonal and textural and should be located within the first-order hierarchy. Second-order planning problems are obviously of a social and economic nature. For example, a potential problem for the urban counties in the near future will be the cost of transportation for the rural non-farm population to places of employment.

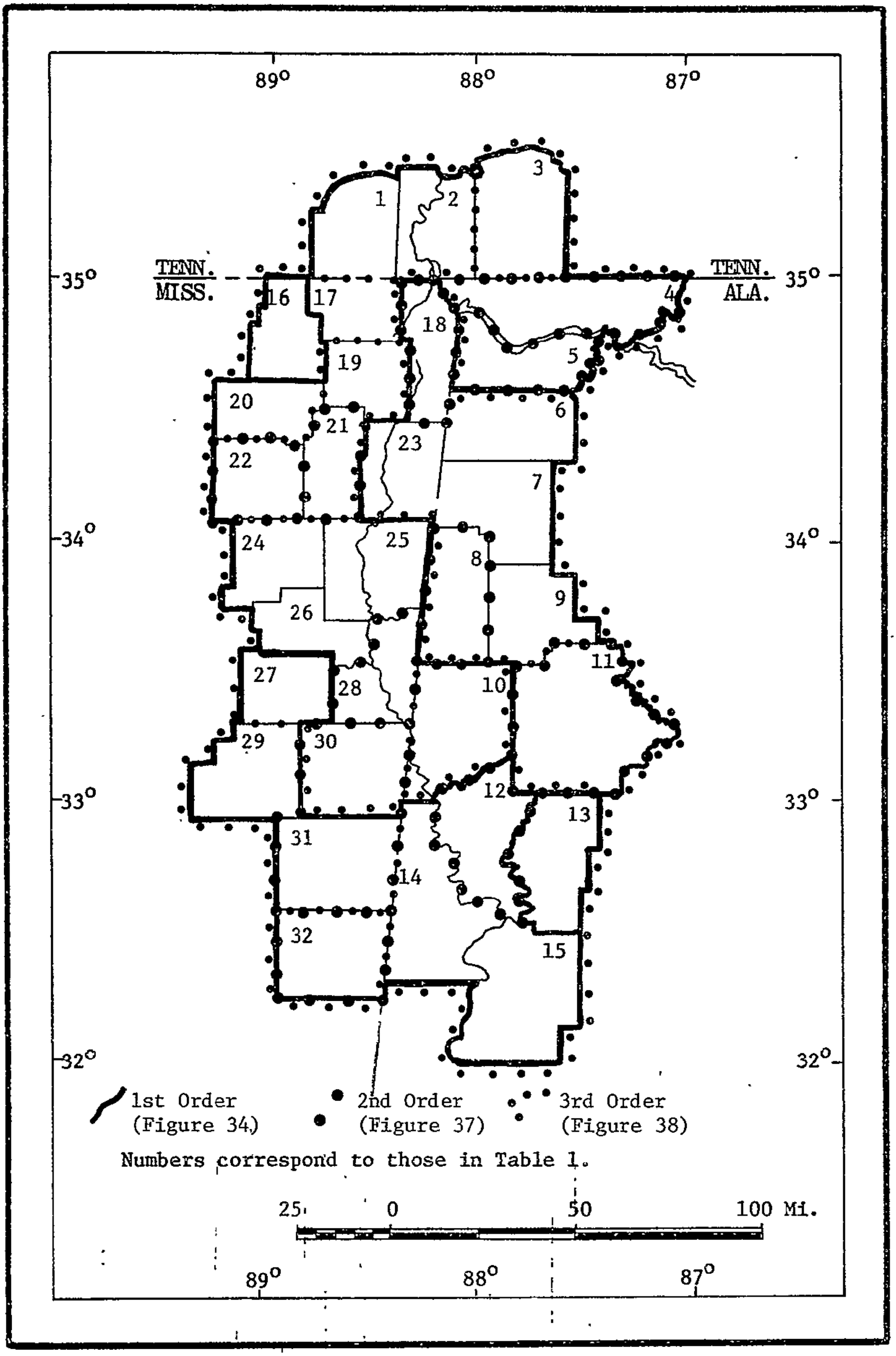
The third-order classification for the study area is largely concerned with economic resource allocations particularly land uses, crops, and livestock. In general, these are problems which are short-term, changing seasonally or yearly; whereas planning problems of the first- and second-orders have longer duration. Cultural traits of societal groups within the various third-order categories may have long-lasting impacts. A case-in-point may be that of Kemper County, MS, which suffers from low incomes and has a high proportion of its population (55 percent) below the poverty level. Here, changes may occur from year to year; but there is no certainty that those changes will up-grade the economic well-being of the population.

Based on the proposed hierarchy of levels of classification, it is reasonable to assume that the higher-level boundaries will mask over the lower-level boundaries. In fact, if several boundaries are located in close proximity to one another, they would have a tendency to reinforce each other. That is, a first-order boundary would tend to be more expressive if it superimposed a second-order or third-order boundary, because of changes in tonal and textural qualities of the lower-level boundaries. Thus, a map of boundary levels should show regional changes of different orders or, as suggested earlier, of a trend surface development. Such a map of the study area is presented in Figure 39. The boundaries are based on county lines and are in agreement with the data sources for second- and third-order classification. But even though first-order categories follow natural "lines," it is not unreasonable to find near-association with county lines. In addition, further justification for using county lines can be made in relation to the fact that decision-making processes tend to take place at that level which can have direct impact on the planning process.

## Summary and Conclusions

Introduction.--Component elements associated with photomorphic regions have different types of scalar and resolution traits. Within one photograph (or image) of a large area taken by high-altitude aircraft or spacecraft systems, the types of photomorphic phenomena that should be

Figure 39: COMPOSITE OF BOUNDARY LINES



Numbers correspond to those in Table 1.

detected will vary. To be sure, the variations would depend on (1) the size-format, (2) the limitations of the camera and/or image detecting system, and (3) the type of landscape which is being observed.

With respect to the latter factor, a landscape which consists solely of one type of substance (e.g., the ocean or a large snow-covered plain in Antarctica) would be very easy to describe and, perhaps, to explain. That phenomenon which is sampled at one location would be basically the same at all locations. Not many of such landscapes exist. Even though the ocean occupies three-fourths of the surface of earth it is still difficult not to detect surficial changes of some sort. Nevertheless, some areas tend to be more homogeneous than others. From an opposite point-of-reference, it may be said that some landscapes are more hetereogeneous than others. In effect, it can be restated that photomorphic regions are environmentally-modulated. Also, as already noted, photomorphic regions are temporally-modulated--daily, weekly, monthly, seasonally and so-forth. With respect to temporal modulation, some changes can be cyclical, (e.g., plant growth) and other changes can be progressive or developmental.

To some large degree both environmental (spatial) and temporal (time) modulation occur concomitantly, and can thus produce a variety of landscape types for different periods of time (Berry, 1964). In this sense, therefore, landscapes are four-dimensional.

The major concern with a four-dimensional landscape is scale. From any point-of-reference with respect to one-, two-, or three-dimensional traits, either singular or plural, the problems of scale are encountered. In most cases single-dimensional traits are topical; in a sense they are involved with object characteristics which occupy a point. Depending on the resolution of observation, however, single-dimensional traits may be points, lines, areas, or volumes. In a real sense all objects have a spatial component. If we conceive of scale as a continuum extending from the smallest object observable (via an electron microscope), through the one-to-one relationships of real life with which individuals are concerned, to the scales of observations revealed by high-powered telescopes; nothing is without the three-dimensional form. Further, everything which exists (or existed) empirically has a fourth dimension--time. In all cases, it seems highly probable that a scale factor with respect to the dimensions of reality depends as much on the observer as it does on whatever is being observed.

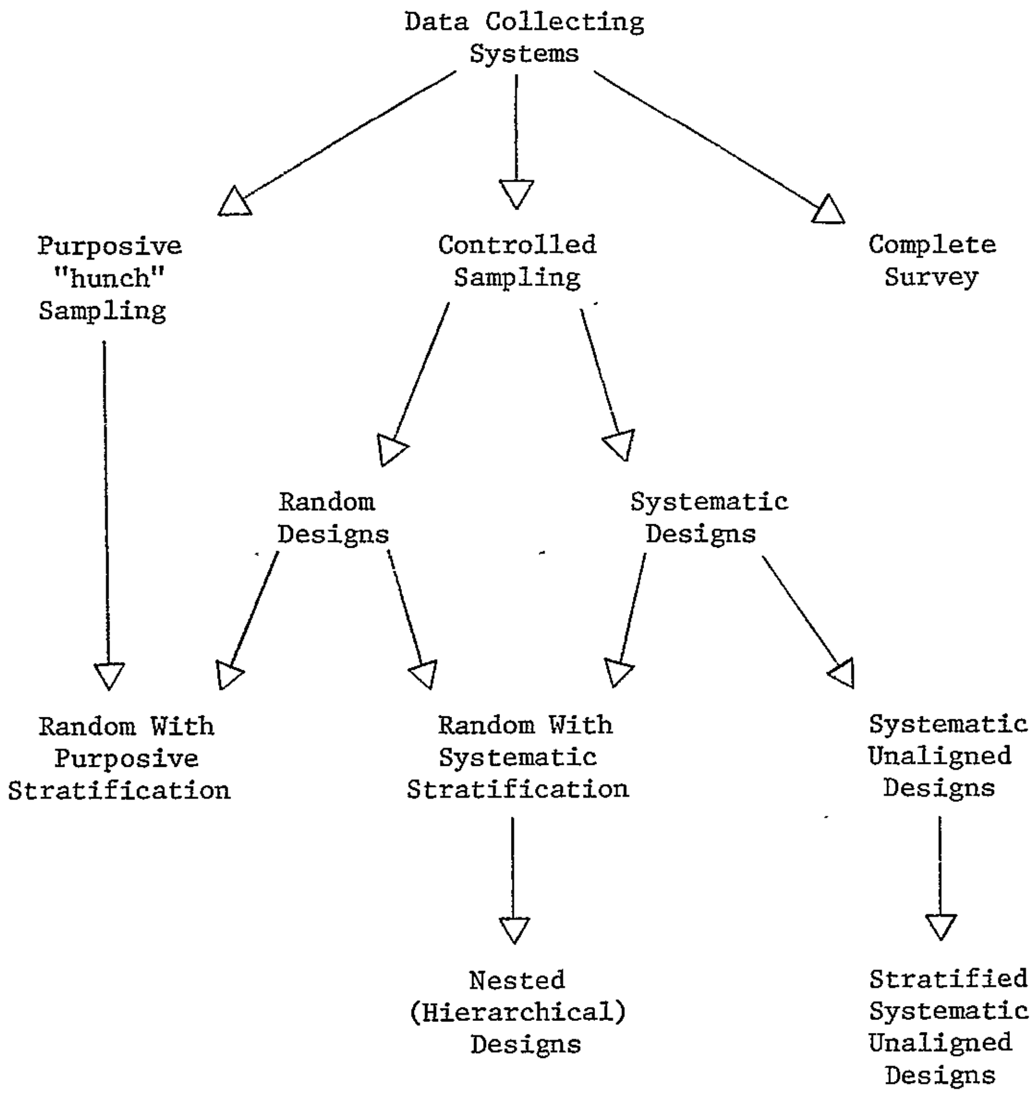
Haggett (1965) recognized three scalar problems which he referred to as (1) the scale-coverage problem, (2) the scale-linkage problem, and (3) the scale-standardization problem. All of these play a significant role in the task of identification of photomorphic landscapes.

With respect to the scale-coverage problem the tasks involved are largely the types of data acquisition systems (sampling systems) (see Figure 40), the sources of data which can be processed into information, and the improvements in data-collection over time. In a sense, this investigation was faced with all of these problems.

The complications are aggravated by the scale-linkage problem. As McCarty et.al. noted (1956):

> In geographic investigation it is apparent that conclusions derived from studies made at one scale should not be expected to apply to problems whose data are

Figure 40: MODEL OF SAMPLING SYSTEMS.



> expressed at other scales. Every change in scale will bring about the statement of a new problem, and there is no basis for assuming that associations existing at one scale will also exist at another.

Thus, in relation to this investigation of photomorphic units in the TennesseeTombigbee Waterway, the attempt to use Census data and field work within a limited and different timefinancial framework provides for some serious constraints. Only in relation to projecting forward (in the case of using the nearest (time) Census data), or projecting backwards (in the sense of doing field work after space photos have been made) in a logical manner can linkage probabilities be calculated. The question to be asked necessarily hinges on (1) what is expected to be seen, (2) what can possibly be witnessed given the parameters of the observing system, and (3) how data acquired in such a manner may correlate with ground-acquired data. Here again, Haggett has provided the guidelines, at least, for carrying through the verification of evidence associated with field investigation. He suggested (1) nested sampling and (2) filter (trend surface) mapping procedures.

Although sampling procedures, as such, were not herein attempted, a classification system based on logically derived "levels" of categorization was attempted. At each level some recognition was given to the hypothetical trend surface which may be regarded as a response to the operation of the whole complex of factors being considered.

Finally the scale-standardization problem has been a concern of this project from the point-of-reference that data, especially Census data, is associated with areas which vary widely in size and shape within the study region. The average-size county in the study region is 404,768 acres/163,803.8 hectares. The standard deviation was 126,306.48 acres/ 51,114.4 hectares; which is a sizable difference and can provide for difficulties in standardization of data.

Summary and Conclusions Concerning Hypotheses Investigated.--The process of verifying the hypothesis and the five sub-hypotheses of this investigation, of course, was only partially completed. Although a regionalization plan was developed based on a hierarchical structure of three levels, it needs to be empirically tested and criticized. It is obvious that the process of logical division with respect to the categories of sub-division needs to be carried out more completely. There is definitely a fourth-order of categorization, and perhaps a fifth-order. At this juncture, however, it is not certain where the sources of verifying and corroborative data are; it is obvious that they are not the traditional sources!

Boundary lines, both natural (physical) and cultural, are located within county political units. Except for population data, ground truth data are expensive to obtain. In addition, the process of testing "ground truth" via the use of the Census is time-dependent. That is, in most cases the Census is compiled once every ten years, sometimes every five years, or at different intervals for different Census types. For example, population data is compiled on a ten-year basis each "0" year; agriculture on a five-year basis with the data compiled each "4th" and "9th" year; and commerce and manufacturing data each five years with data compiled on the "3rd" and "8th" year. This situation obviously provides for problems of correlation.

Finally, the categories of Census data are definite and exacting, and while they can be highly descriptive of certain situations, they do not necessarily help to provide explanations of the causes of those situations. A case in point may be made with respect to the low income situations associated with Kemper County, MS. Several different types of statistical technique were employed in an attempt to achieve an explanation of just why farm income levels in Kemper County were almost three times less than the mean for the study area. None of the attempts proved satisfactory.

Only through the use of field work (which provides for inputs of the observers bias) and low-altitude (large-scale) air photographs will ground truth operations be totally satisfactory. Obviously field coverage of an area as large as the Tennessee-Tombigbee area through the use of field techniques and air photo interpretation would require many man-hours of work. (It is estimated that allowing two hours per square miles for complete coverage, it would take 40,480 man-hours, and at a cost of between \$3 and \$5 per hour would cost between \$121,440 and \$202,400.)

Obviously, some types of sampling procedure needs to be followed. Referring to Figure 40, it is considered possible by the investigators that a "random with systematized stratification" approach can be used if the photomorphic units are outlined and developed in advance.

# CHAPTER IV: CONCLUSIONS AND RECOMMENDATIONS

## Data/Information "User" Requirements

The data and informational needs of the regional planning/analysis user-community are both numerous and diverse. On the basis of the work conducted in relation to this investigation and elsewhere, it is apparent that remote sensing can supply some, but not all, of these needs. Certainly remote sensing serves as an effective technique for acquiring information about land and water resources. At least ten different dimensions of land alone are generally recognized as important input items for early (inventory) stages of the regional planning and analysis process. These are: (1) the current use (or activity); (2) the intensity of use; (3) the physical and/or cultural restrictions on use; (4) ownership; (5) the quality of land development taking place; (6) public services available; (7) natural or physical qualities; (8) financial value; (9) the location; and (10) the type of structure(s) (Peplies and Keuper, 1975). Some of these dimensions are mainly important in an urban context, while others have more widespread regional significance. In terms of identifying landscape characteristics and land-planning problems, items such as ownership, financial value, and cultural restrictions on use can hardly be determined satisfactorily via remote sensing procedures directly. Other dimensions of land can be only partially determined by remote sensing procedures. Very often, however, expediency may dictate that such a partial inventory, based upon remote sensing procedures, will have to suffice for the sake of timeliness, lower cost, and simple convenience.

Recent changes in the conduct of the planning process have stemmed, in part, from rather dramatic industrial and suburban residential growth which began shortly following World War II and which found planners in need of a means whereby they could focus attention on space allocation problems in regions of varying size and functional complexity. Shortly thereafter the concepts of "environment" and of the "quality of life" became areas of focus which ultimately stimulated a series of federal legislative measures including the National Environmental Policy Act of 1969, the Housing and Urban Development Act of 1970, and Amendments to the Water Pollution Control Act of 1972.

Such legislation was specifically aimed at the solution of problems having less to do with individual land parcels than with land use in the context of mutually interdependent environmental systems. Thus, the concept of land use regulation has been extended to include infinitely more complex details (large scale considerations) at the local level and infinitely more territory (small-scale considerations) (Keuper, et.al., 1973). Individual lots in neighborhood settings and the design and placement of structures on those lots are no longer the singular "issues" dealt with by planners. Complex systems of land use in regional ecological settings and the interrelationships between and among the natural/cultural environment and procedures for problem-solving have become the new issues.

In general, as one proceeds from local to national and multi-national planning contexts, the quantity of the data/information required increases, the spatial coverage increases, the size of individual regions of concern increases, the number of individual classes of phenomena (in terms of patterns to be dealt with) tends to decrease, and such classes of phenomena tend to be treated in terms of their homogeneity over larger areas (NRC, 1975b). Thus, one fundamental decision to be reached in selecting remote sensing systems and returns is the extent to which they are applicable to the data/information needs of the user-community of planners. In practice almost all levels of planning jurisdiction can employ information derived from large-scale remote-sensor imagery. A question of increasing significance, however, is the extent to which small-scale (and satellite) systems can satisfactorily address the needs of that same user community (NRC, 1975a) and, further, the extent to which additional technologies, either extant or as yet to be developed, are necessary to make the vitally important transition from a massive quantity of available data to a managable quantity of hard information suitable to the resolution of specific planning problems. As in all such studies addressing this problem, the question of the relationship between remote sensing and proxemic (proximal) sensing has been a major focus of this study.

Remote- versus Proximal-Sensing.--The process of "proximal-sensing" in which the sensor is in close proximity to, or even in contact with the feature or phenomenon about which information is sought is often necessary to augment acquisition by remote sensing procedures even where exclusive use of such remote sensing procedures would result in substantial time and cost savings (as noted above). As stated by Colwell (1975), the interplay between remote sensing and proximal sensing needs to be observed in terms of the following generalizations:

(1) In obtaining inventories of resources over any larger area:

(a) the resource manager (planner) almost always needs to rely primarily on remote sensing techniques;

(b) in obtaining such inventories, however, he needs to rely on proximal sensing techniques as secondary sources, (particularly where the "resource" in question is not a clearly visible discrete entity).

(2) In the performance of this inventory step, and to a far greater extent than in times past, the resource manager (planner) now frequently experiences the need for a second type of inventory, namely, one concerned, not with the resources of the earth *per se*, but with the attitudes of the people concerning resources and their management. (It is significant in this regard that, in order to cope with political pressures exerted by these same people, resource managers are finding themselves spending far more time than was heretofore the case both in briefing the public and in surveying public attitudes relative to resource management and planning problems.)

(3) In obtaining inventories of the attitudes of people:

(a) the resource manager needs to rely primarily on proximal sensing techniques;

(b) in obtaining such inventories, however, he needs to rely on remote sensing techniques as secondary sources (particularly such techniques as will enable him to "picture" each of the environmental situations existing where the people being inventoried live and which, thus, help to account for their correspondingly different attitudes.

What follows this inventory step is, of course, the most essential step to be taken by the planner in determining the planning action to be taken to attain a desired outcome. This step is analysis and, to the extent that the pertinent parameters involved can be quantified, this step can often be reduced to various mathematical computations. In such instances only two kinds of data input are ordinarily needed: (1) resource inventory data applicable to each of the areas that are to be planned and managed; and (2) benefit-cost data applicable to each of the management/planning measures which might be applied.

In this analysis step, however, just as in the inventory step, consideration must be given, not just to regions and their resources, but also to people and their attitudes. In fact, it is only by balancing these two categories of considerations that the resource manager/planner can hope to arrive at a determination as to which of the various alternative courses of action open might best be implemented.

Beyond the analysis there is a third step which Colwell (1975) has identified as the "operations" phase, or the extended time period over which the "plans" are implemented.

Sensing, both remote and proximal, can again be used to great advantage by the resource manager/planner in this third step as he seeks to make certain that, in implementing each management decision, he does the right thing in the right place at the right time. The term "monitoring" is commonly applied to this process. Monitoring is repetitive and as such, frequently acquires new inventory data about the region and its resources over both short- and long-term periods.

A major objective of regional planning and analysis is, of course, the solution of those problems which can best be identified and, subsequently, attacked on a region-wide basis. Recognizing this objective, a singular focus of this investigation has been to determine the extent to which remote sensing techniques, particularly photomorphic analysis, in conjunction with a well-coordinated ground truth (proximal sensing) investigation based upon readily-available census and/or other historical data, could, in fact, meet such a need. The conclusions, however tentative, reached by the investigators on the basis of the work described in previous chapters, are set forth immediately below.

## Conclusions and Recommendations Concerning the Comparability and Complementarity of the Photomorphic Regional Study Tasks and the Ground Truth Investigation

With respect to the extent to which the two principal tasks associated with this project (i.e., delimitation of photomorphic regions by subjective and automatic methods; and ground truth investigations of the study area) were capable of producing results which were comparable and complementary, in addition to conclusions stated earlier in this report the following major conclusions are offered by the investigators:

(1) Photomorphic regionalization does, indeed, hold promise as a process for the identification of landscape traits which are of interest to the regional resource manager/planner. That is, the basic photomorphic

process, whether implemented by human or machine, can be employed for purposes of identifying homogeneous spatial ingredients of small-scale planning and/or administrative areas.

(2) Problems associated with the photomorphic regionalizing process in its current state of development are very much of the type identified by other researchers and may be characterized by a relative inability for the process to clearly distinguish between what "is" (on the basis of precise tonal, textural, and signature traits) and what "might be" (on the basis of surrogate relationships not readily apparent at the scale of LANDSAT imagery.)

(3) In particular, boundary lines of photomorphic regions appear to be subject to both short- and long-term changes which are the result of both natural and cultural processes. Within the limits of human and machine photo-interpretation and pattern recognition capabilities, such boundary changes can be attributed to a wide range of possible direct and indirect causes which, without supplementary mid-altitude aerial imagery and/or expensive field reconnaissance, are not precisely identifiable at the scale of LANDSAT imagery. Colwell (1975) has strongly emphasized the capability of ERTS (LANDSAT) imagery as a basis for nationally- and even globally-uniform resource inventories, and with this conclusion the present investigators concur. Without substantial changes and improvements in resolution limits of such satellite imagery systems, however, it appears to be questionable whether or not the <u>data</u> made available can be directly and immediately connected to <u>information</u> useful to and usable by regional and local planning agencies (i.e., large-scale) without more conventional analyses as a continuous means of verification.

(4) In general, the tonal/textural photomorphic regions correspond (within reasonable limits) with the first-order areas delimited by the ground truth investigation. Further, although the extent to which time and fiscal limits imposed on the present study restricted detailed analysis of such, it is intuitively believed by the investigators that scale increases to a second-order of ground truth units seem to correspond to tonal variations within the photomorphic regions; and that further enlargement to a third-order (ground truth) bears a close relationship to textural variations in the photomorphic regions. The investigators are not yet willing to suggest a precise cause and effect relationship in this regard without further analysis, but this conclusion does appear to be of potentially high significance, particularly as it seems to bear out the findings of other researchers including Hawkins (1970), Lipkin (1970), and Rosenfeld and Lipkin (1970).

(5) The exact degree of correspondence between the photomorphic regions derived from LANDSAT imagery and the first-, second- and third-order regions derived by intensive analysis of ground truth (and other historical data) appears to be a function of boundary identification (in the case of photomorphic analysis) and boundary placement (in the case of ground truth analysis). Resolution of the apparent divergences between these two processes has long been a subject of concern among geographers and others concerned with boundary-type problems. The investigators can only conclude at this juncture that further work, perhaps along the lines suggested by Freeman (1970) and others, may prove beneficial.

(6) A further apparent divergence between the results obtained by the two parallel investigative tasks seems to stem, at least in part, from

the problem(s) that: (a) the photomorphic regional analyst is almost inevitably forced to admit that the regional boundaries he is identifying are based on a factor (or combination of factors) which are not precisely identifiable from the LANDSAT imagery (i.e., he "sees" something, but is not certain precisely what it is that he is "seeing"); and (b) the ground truth analyst is, likewise, inevitably forced to conclude that, while he can identify factors of convergence and divergence between and among various spatial units, he cannot proceed far beyond the stage of a "guess" when it comes to the task of portraying broad regional patterns (as seen from above the earth), because many of the things upon which he is forced to depend are not even visible (in the sense of direct images). Thus, the significance of Colwell's (1975) emphasis on the mutual interdependence of remote and proximal sensing is once more underscored heavily.

(7) Another point of departure between the photomorphic regional analysis and the ground truth investigation is based upon a more traditional problem, that being the lack of direct correspondence between datum periods in the temporal plane. The ground truth investigation, of course, depended very heavily on 1970 Census data and on maps (and even aerial photographs) which simply do not provide a basis for direct comparison with 1973 and 1974 LANDSAT imagery. This may well mean that any apparent correspondence between regions, as identified according to the former and the latter data bases are coincidental at best. As suggested above, this problem is not new to any field of spatial analysis. In the case of the present study, however, its significance is perhaps greater by virtue of the introduction of yet another intangible over which the project

investigators have no control whatsoever. As Tobler (1968) states it: "Given that geographers have long been interested in the analysis of two-dimensional data one would expect that they might have developed techniques which are particularly valuable for the processing of such data." Such, however, is not yet the case!

(8) There is, indeed, a complimentary relationship between the photomorphic regional analysis and the ground truth investigation if the conclusions regarding correspondence between spatial arrays produced by the parallel investigations prove to be correct. That is, if further study shows that first-order ground truth regions are synonymous with photomorphic regions; and if scale-enlargement to second-order ground truth regions is reflected by tonal variations in photomorphic regions; and if further scale-enlargement to third-order ground truth regions is accounted for by textural changes in the photomorphic units; then, obviously, the ground truth work is reflecting the large-scale characteristics of the photomorphic regions which are, by definition, delimited at small-scale. The specific task to be addressed in any future work in regard to the user-community <u>must</u> focus on this relationship and seek to bridge the scale-gap in a manner not heretofore tackled by either geographers or by the planners themselves.

(9) The question of reconciling the apparent divergence between the two approaches which results from the still highly subjective nature of the photomorphic regionalizing process and the already much more objective ground "truthing" procedures has not been effectively dealt with in the present project, but must, inevitably, be faced and dealt with. It is extremely likely that such an end can be achieved as the

photomorphic process is further extended and given "on line" character, but any conclusion beyond this at the present juncture would be most blatant conjecture.

(10) Finally, the nature and problems associated with the methodological complexity of the coherent optical (Fourier transform) photomorphic regional identification and analysis process as herein experimented with will virtually obviate the direct transfer of such methodology to the regional resource management/planner user-community which, by and large, presently lacks the expertise, the technological instrumentation capability and, the fiscal resources necessary to immediately put into practice a set of procedures which are still so very tentative and highly theoretical. This does not, of course, imply that: (a) the theory cannot be put into practice in a not-quite-so-sophisticated mode; or (b) the planning community will not develop the expertise and support capabilities necessary for such a direct transfer. On the other hand, this conclusion does state most emphatically that, at present, the gap between the methodological theory and practical application in the planning community is so great as to prevent any firm assertion that this particular procedure will answer "these and those" specific questions and/or satisfy "thus and such" information requirements which will allow the planner to immediately address a precisely identifiable set of decision-making problems. The investigators are most singular-minded with respected to their continued belief that the photomorphic regional concept is an excellent and potentially highly effective planning tool. That belief, however, does very little to offset the bitter "taste" of being in a position wherein the only honest

C-3

conclusion must be that even though it was/is a very good idea, it was/is, nevertheless an idea whose time has not yet come!

## Conclusions and Recommendations Regarding Specific Planning Problems Associated with the Study Area

With respect to particular planning problems for resource allocations within the Tennessee-Tombigbee Waterway region, several conclusions based on the data and information assembled were reached. These were/are:

(1) Because of the high rural population, absence of large central places within the study region, heavy emphasis on agricultural or primary manufacturing industries (based on agricultural products), and the marginal character of the Tennessee-Tombigbee Waterway area with respect to major trade centers, some attempt needs to be directed to the development of a greater urban focus within the area. Particular concern needs to be given to the development of non-basic (locally-oriented) industries and the development of the residentiary sectors. Growth rates can be expected to continue to decline with continued emphasis given to the agricultural sector in the study region. If greater earnings are gained from manufacturing, particularly from secondary sources, then population growth should stabilize around the national earning levels (Berry, 1973). Berry has also noted that the greater the share of local earnings derived from the service sector (residentiary activities), the greater the population growth rates.

Presently, the Tennessee-Tombigbee Waterway area lacks promise of these conditions. If the economic structure of the area remains the same, socio-economic conditions are likely to become even more degraded in the future. To some large degree, the waterway will become a transit artery for goods moving <u>through</u> the region, or, at best, the waterway (and ancillary terminal facilities) will be "pick-up" points for goods moving out of the region (a basic industrial structure).

It is suggested here that several alternative planning actions need to be considered. One is to focus on concentrated urban development of one or two large central places, to develop an industrial base within these centers which would receive materials from outside the Tennessee-Tombigbee area to support the internal residentiary activities. Columbus or Aberdeen, MS, could become the focus of this type of urban development. A second alternative is to develop a "new town" structure within the area of the central core of the Tennessee-Tombigbee basin area. As with the first alternative, the new town should direct its attention to the development of the residentiary sector, as well as to maintaining the present export position for the region. Through careful planning, some of the large population now classified as rural non-farm should be encouraged to migrate into the new town (or into the central place mentioned above). It is recommended that barge facilities for outgoing and incoming goods be constructed in the region of Aberdeen-Tupelo, MS, because of its central location with respect to the agricultural core of the basin area. In close proximity to this area (if not in the same area) a new town should be constructed.

(2) One apparently underdeveloped resource of the area is the forestry industry. Earnings gained from the forest resource seem to be far less than potential should indicate. To be sure, some large forest products manufacturing is already associated with places like Meridian, MS, but greater attention could be given to this activity. A barrier at this time probably is the large number of rural holdings devoted to rural non-farm residence, part-time farming, or part-retirement activities. Here again, some focus of attention needs to be given to the development of a more urban-focused population. If urban opportunities exist--manufacturing, commerce, trade--then a natural in-migration to urban areas should take place.

(3) Although many recreational sites are located on the margins of the study area, there appears to be an absence of such sites in the core of the region, particularly along the Tombigbee River. It is somewhat apparent that recreation sites of various types could and should be planned in this area. In many ways these sites could be multi-functional. For example, flooding of low-lying lands could be lessened if large area flood retention dams were constructed in association with the waterway. These same sites could also be used as recreational areas at times when floods were not eminent.

(4) Finally, a future energy source exists in some of the low-lying areas which are presently poorly-drained or flooded during

most of the year. The conversion of these wet-land regions for the purposes of controlled biomass generation seems feasible. While research and development in this area is still in its infancy, some promising developments have been made. The southern sections of the waterway area seem to be appropriate for such developments.

In summary, the course for future physical, social, and economic development can be "hinged" to the construction of the waterway. With proper planning it is predictable that the waterway region could become another BEA, separated from Birmingham, Memphis, Huntsville, and possibly from Meridian. If such a situation developed, then greater economic goals could be reached with a new central trade center developing in the region. The worst type of situation, from both the regional planning and the economic health points-of-view, would be for the region to continue developing along its present path, i.e. strongly rural, traditional, and provincial. Even with the waterway this situation is possible.

## Recommendations for Further Research

Based in large measure on their conviction that the combination of the photomorphic regional concept and more traditional ground truth investigative methodologies (particularly as modified and re-directed according to procedures tested in this project) the investigators recommend that the following several areas be explored in future research which may arise out of this work and the various research efforts upon which it has been based and dependent:

(1) Further exploratory work to determine the best possible scale at which to derive photomorphic regional traits so as to maximize the comparability and complementarity relationships between remote and proximal sensing.

(2) Further experimentation to determine the degree to which resolution and other system limitations of the LANDSAT-derived imagery can be procedurally-reduced without further distortion of the photomorphic concept *per se*.

(3) Continued experimentation via coherent optical procedures to determine the interface between and among the various pattern recognition, mathematical modeling, and other theoretical studies forming the basis for this investigation.

(4) Continued experimentation with the Fourier transform and related optical procedures in direct conjunction with regional/spatial analysis in the regional planning context.

(5) Specific research aimed at solution of the change-of-scale problems mentioned in this report, particularly as they have a bearing on the question of the identification and analysis of temporal changes occuring within planning-type regions as depicted on LANDSAT and similar imagery.

(6) Specific research aimed at minimizing the difficulties anticipated in terms of direct transfer of photomorphic regionalizing technology(ies) to the planning user-community.

The investigators believe that these and other more specific tasks need to be undertaken in order that the remote sensing technique experimented with herein can be applied in order to directly contribute to the solution of human problems on the face of the earth.

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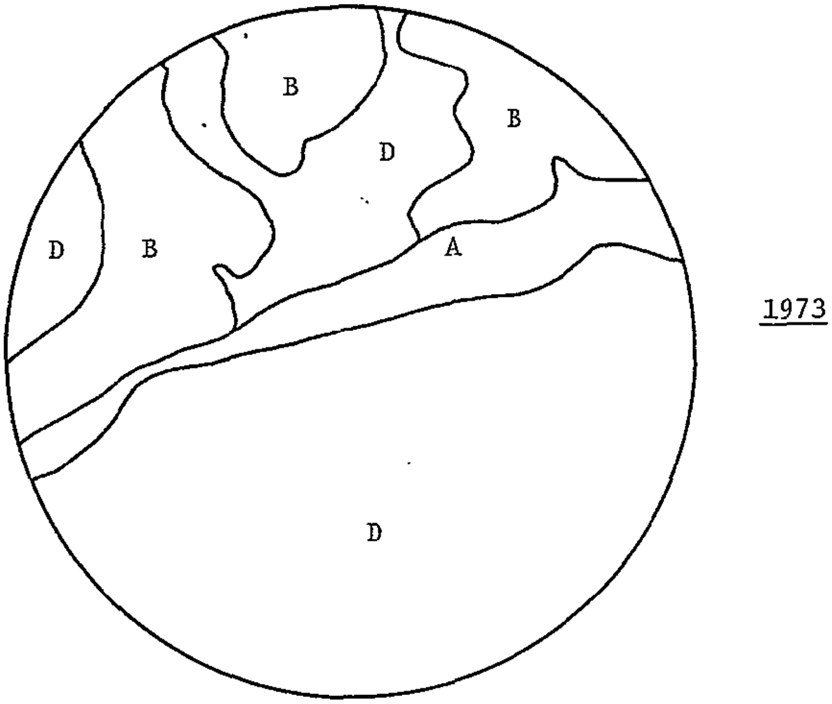
# APPENDIX A

## STUDY WINDOW

## TONAL CHARACTERISTICS,

## 1973 and 1974

TONAL CHARACTERISTICS OF STUDY WINDOW "A", 1973 and 1974.



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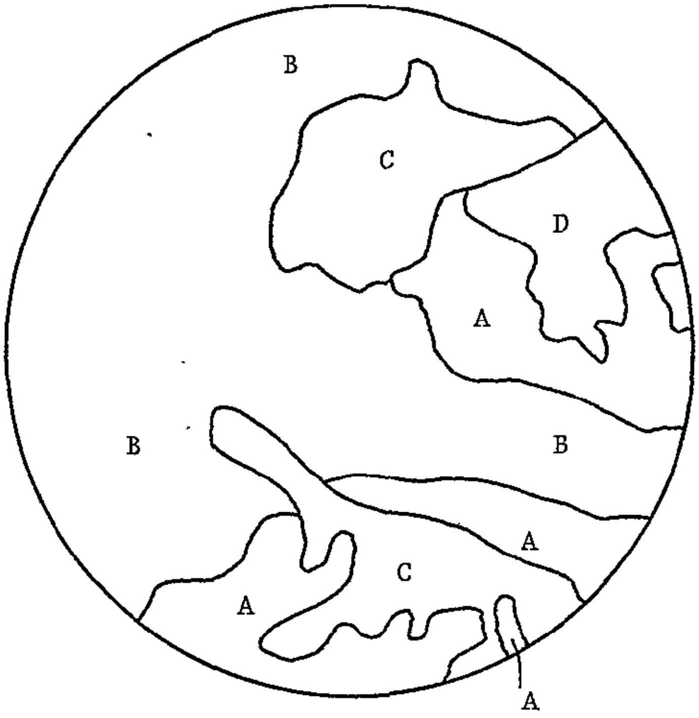

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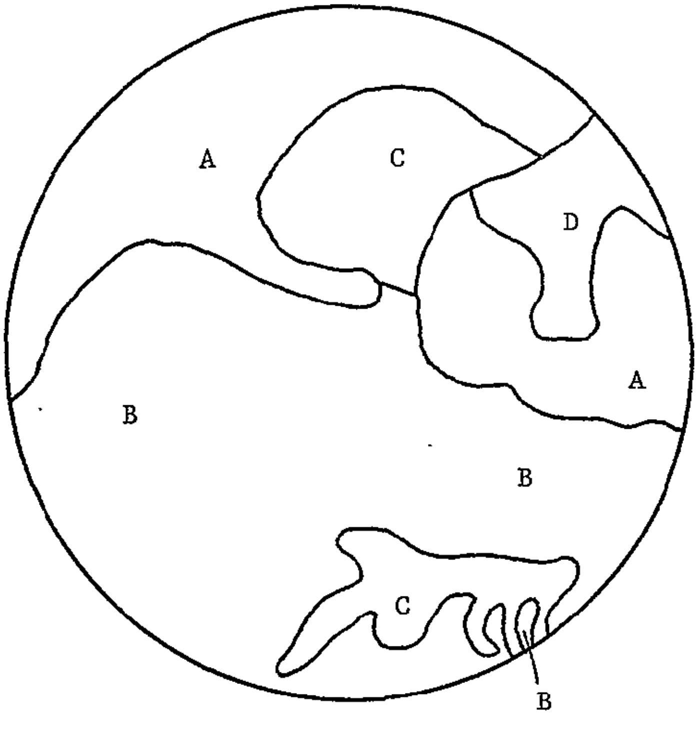
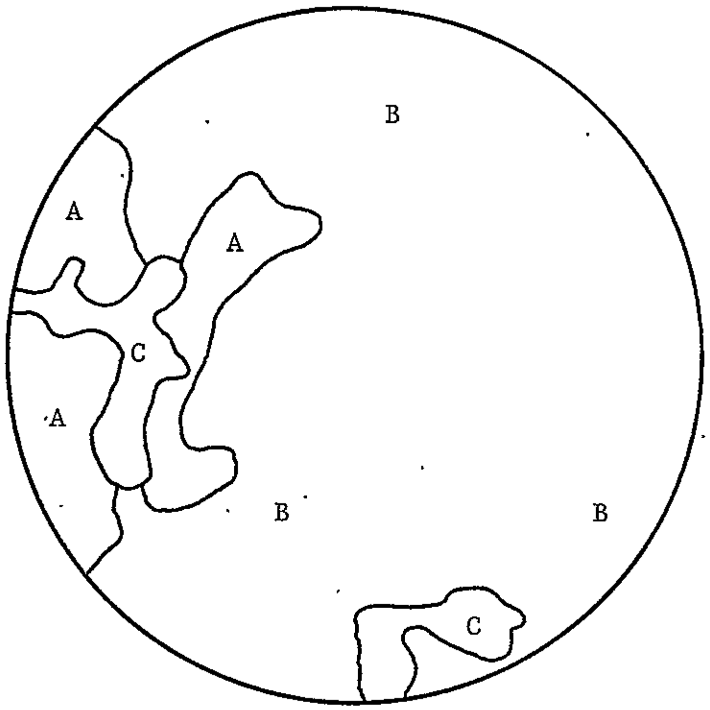


1974

TONAL CHARACTERISTICS OF STUDY WINDOW "C", 1973 and 1974.



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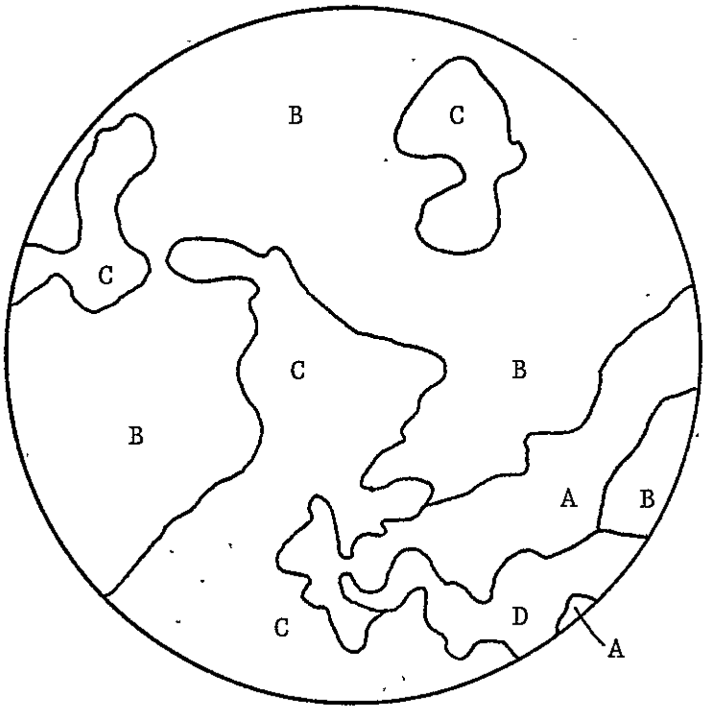

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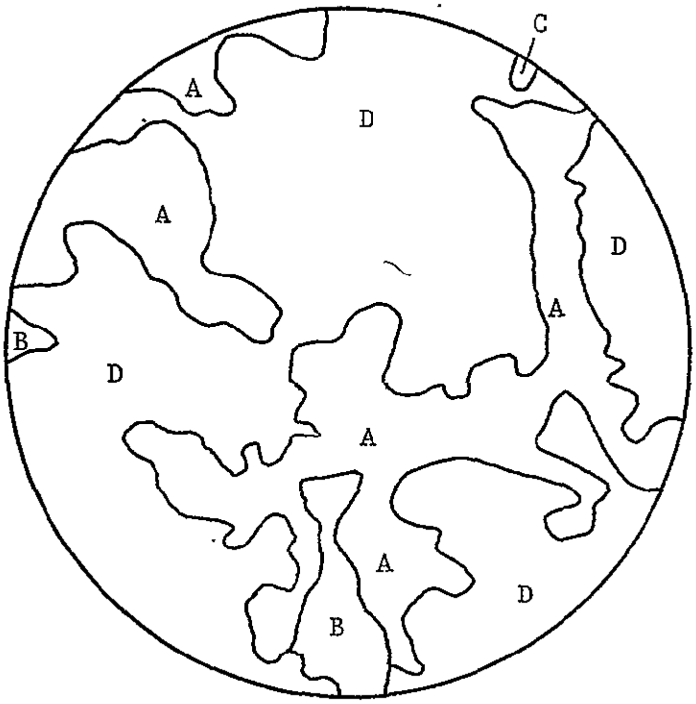
TONAL CHARACTERISTICS OF STUDY WINDOW "D", 1973 and 1974.



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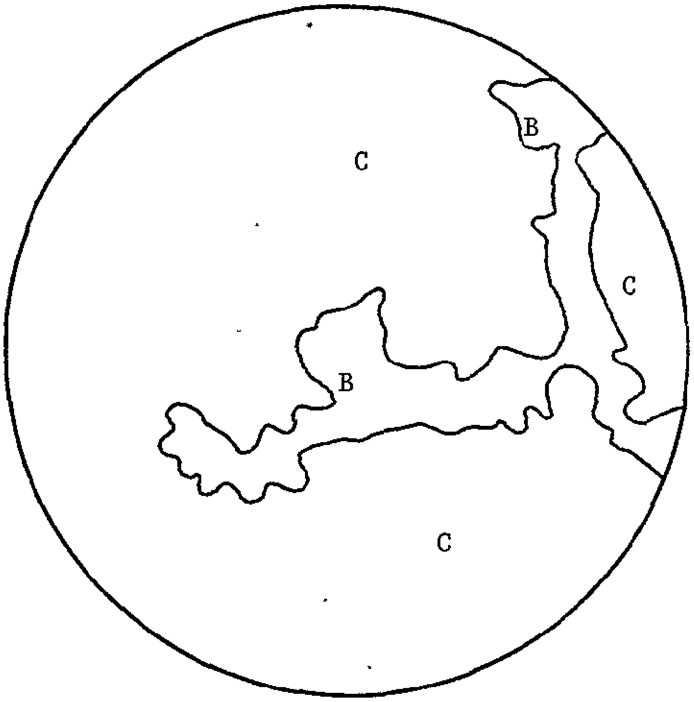


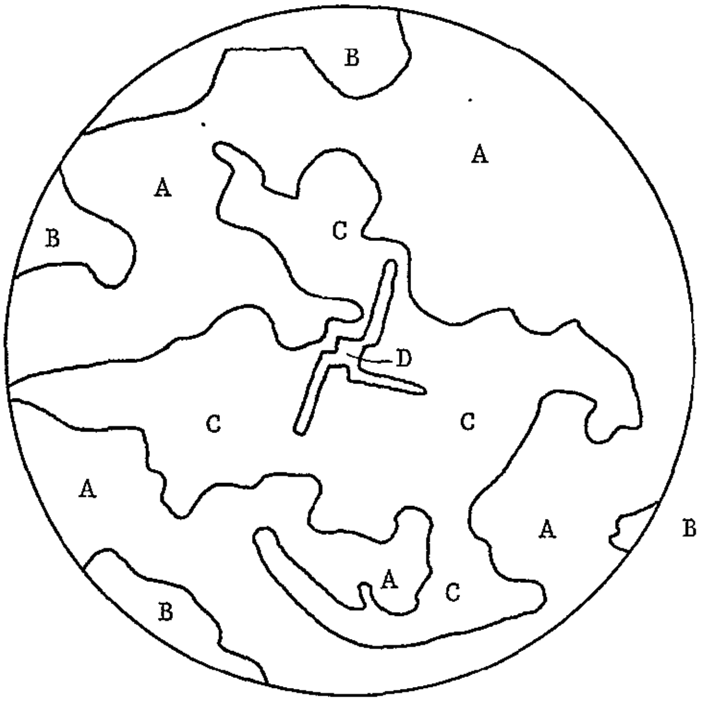
1974

STUDY WINDOW E

IS INCLUDED AS FIGURE 5 IN THE

REPORT TEXT

TONAL CHARACTERISTICS OF STUDY WINDOW "F", 1973 and 1974.



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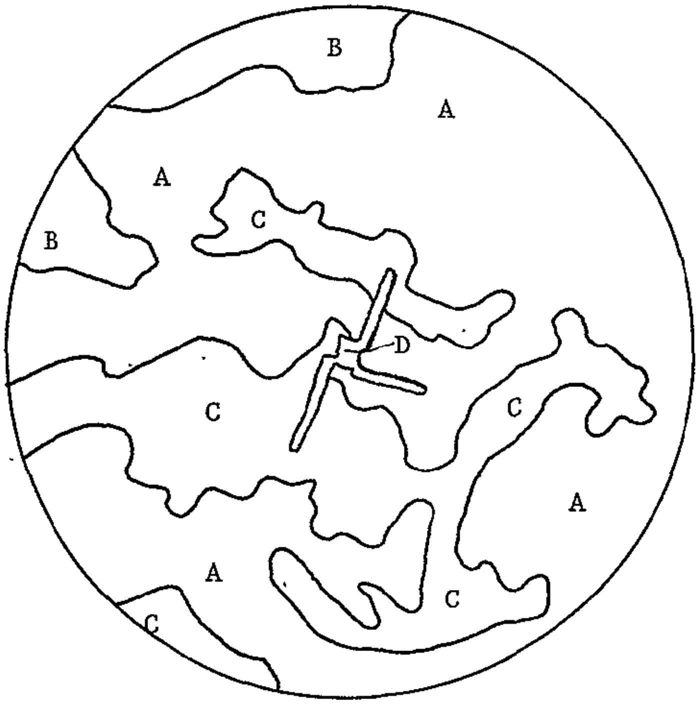

1974

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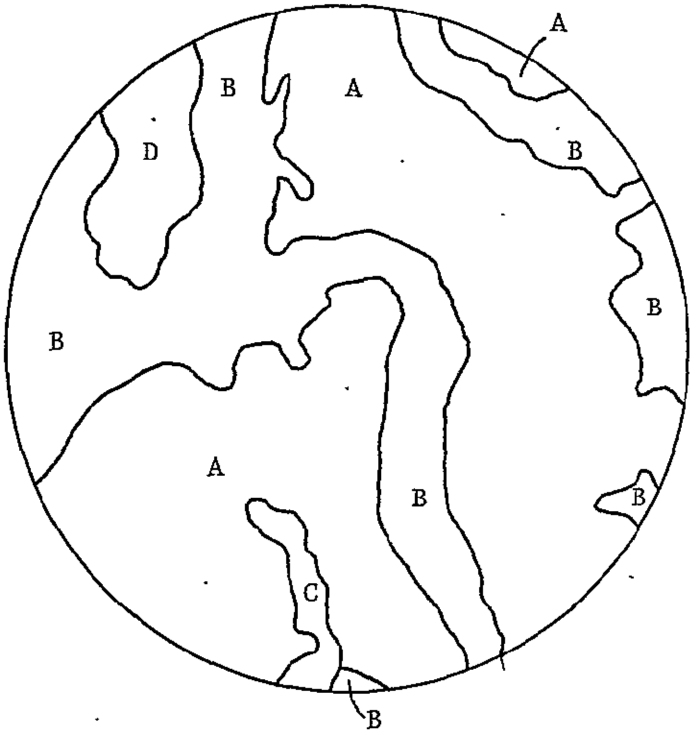

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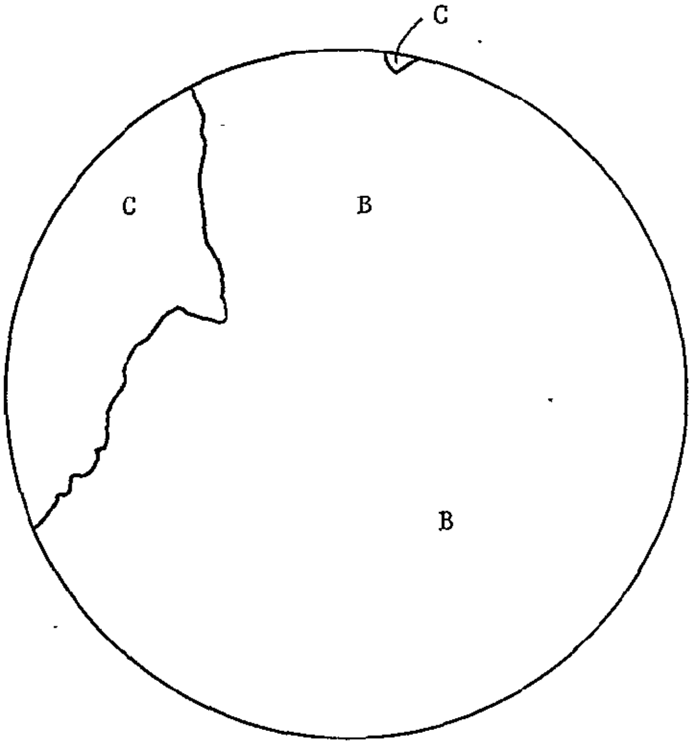
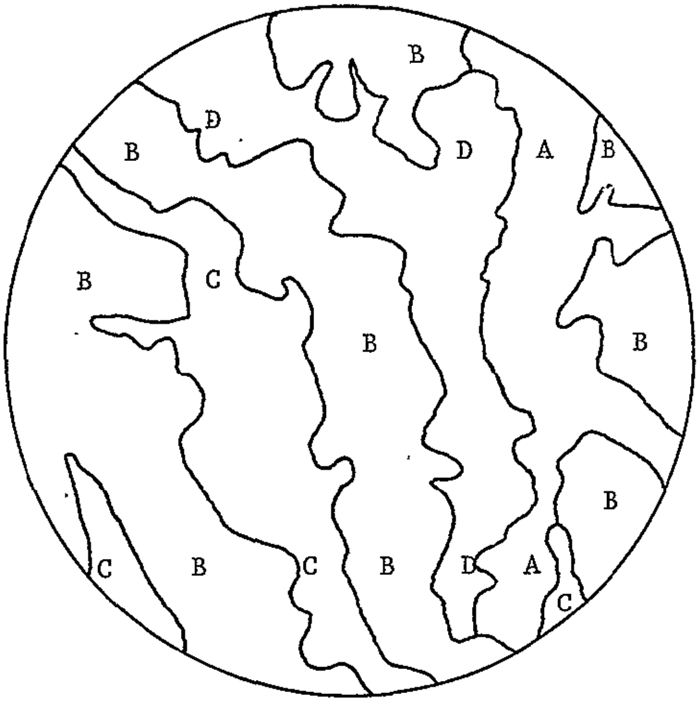


1974

TONAL CHARACTERISTICS OF STUDY WINDOW "H", 1973 and 1974.



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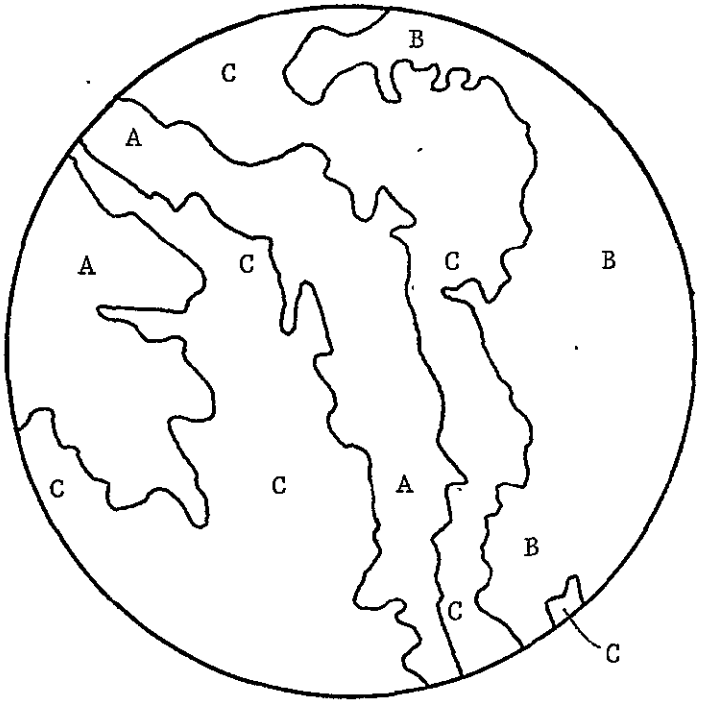

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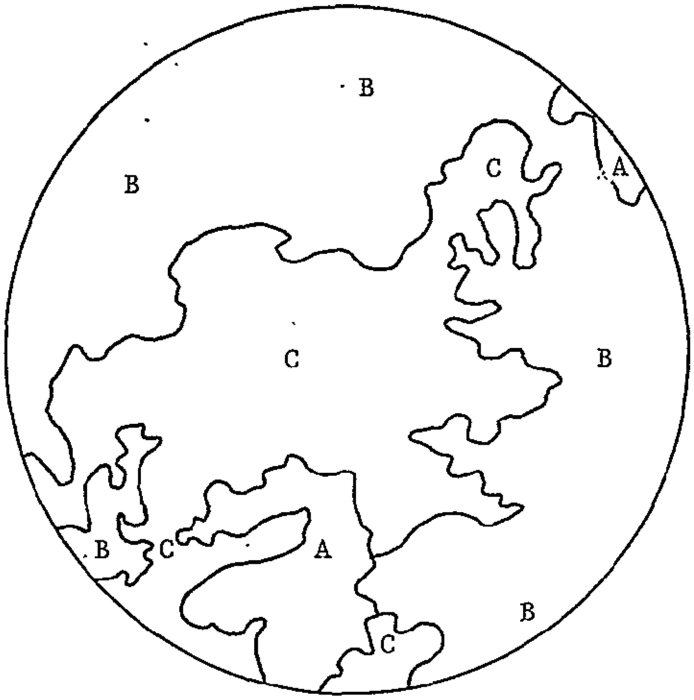
TONAL CHARACTERISTICS OF STUCY WINDOW "J", 1973 and 1974.



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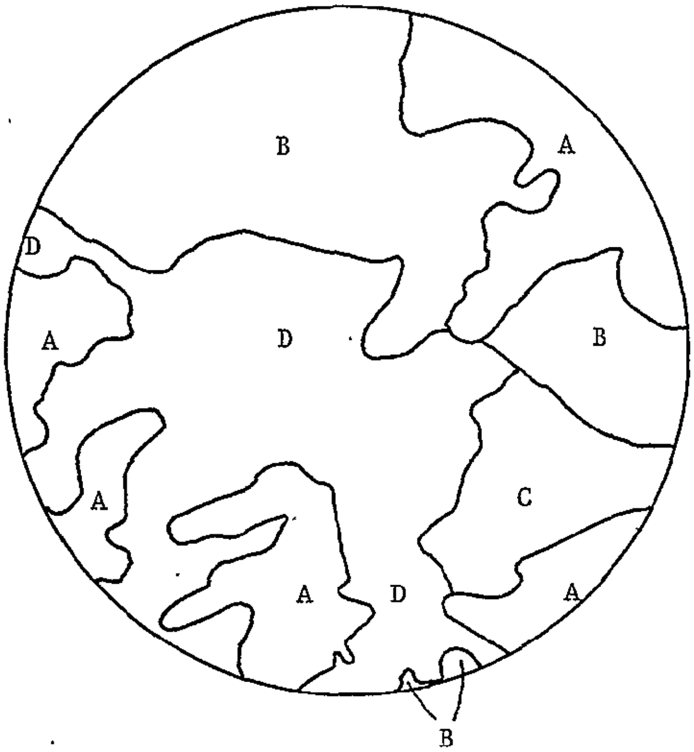

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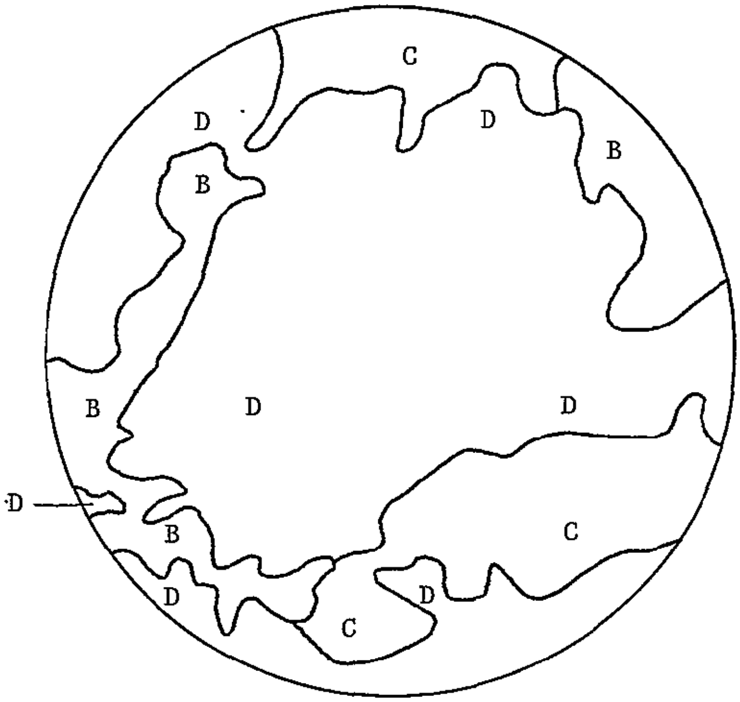
TONAL CHARACTERISTICS OF STUDY WINDOW "K", 1973 and 1974.



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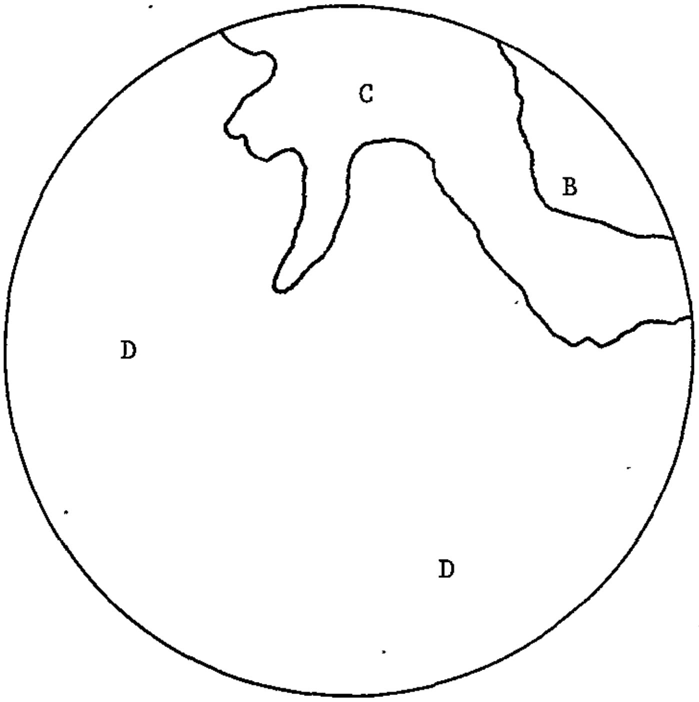
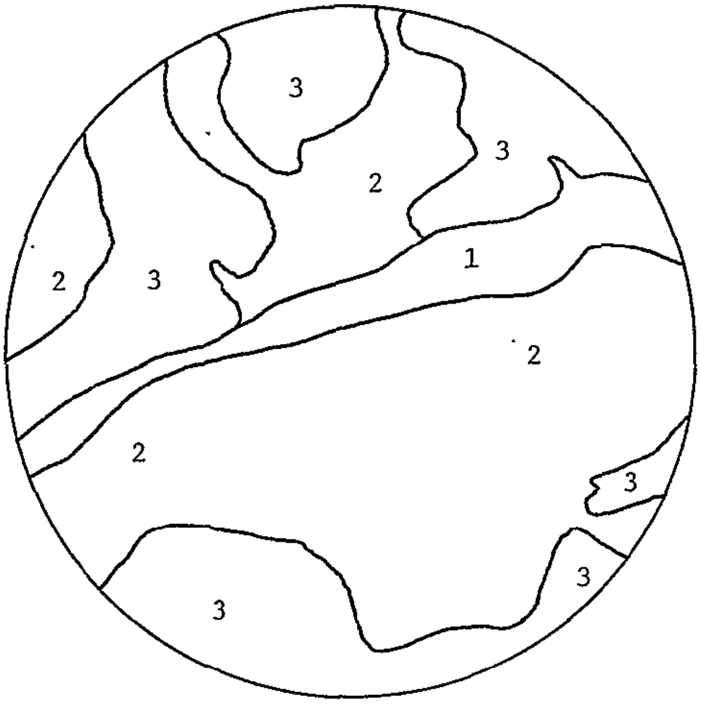


1974

# APPENDIX B

## STUDY WINDOW
## TEXTURAL CHARACTERISTICS,
## 1973 and 1974

TEXTURAL CHARACTERISTICS OF STUDY WINDOW "A", 1973 and 1974.



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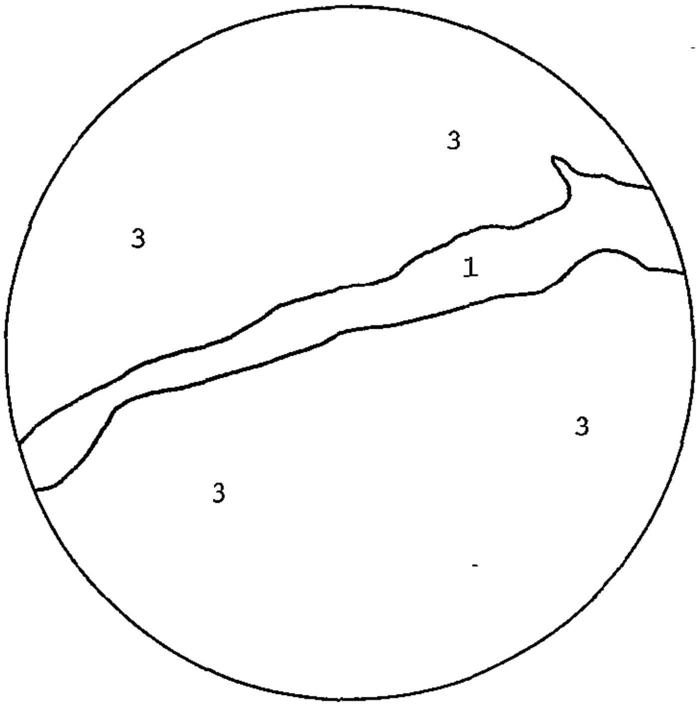
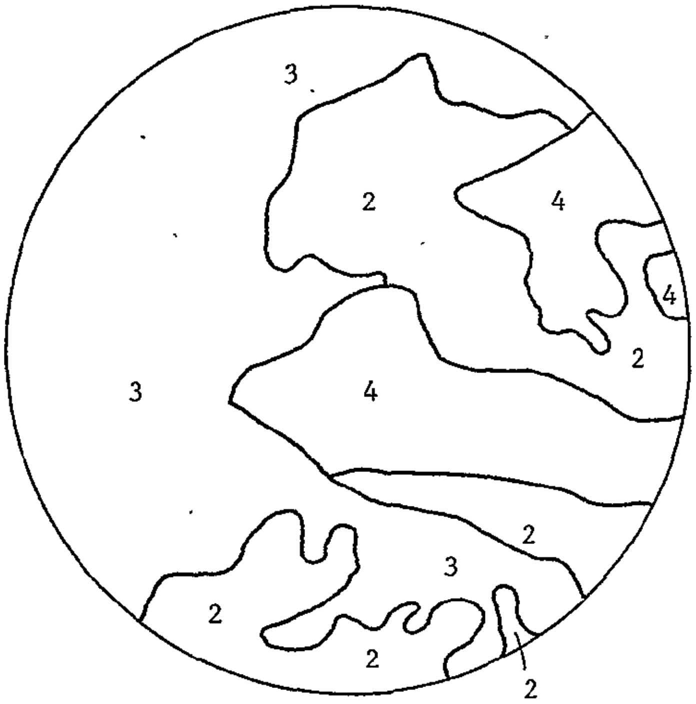


1974

TEXTURAL CHARACTERISTICS OF STUDY WINDOW "B", 1973 and 1974.



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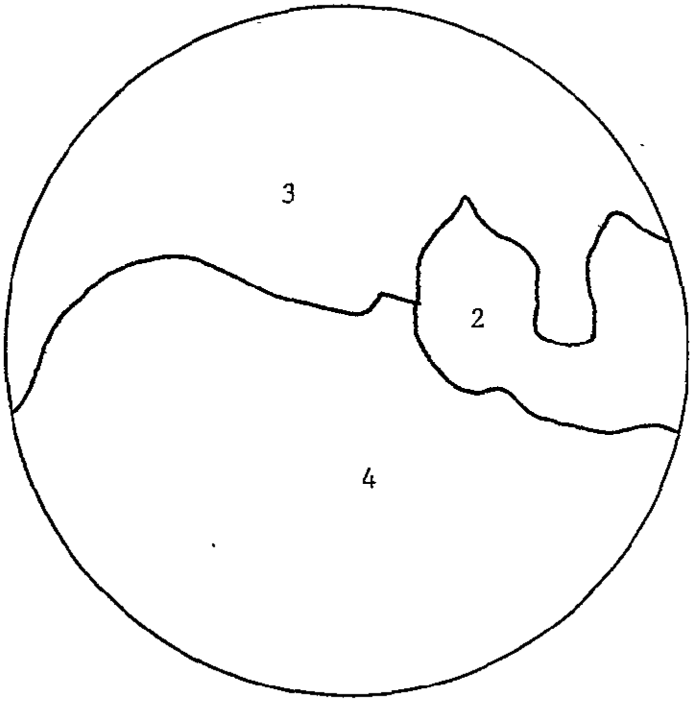
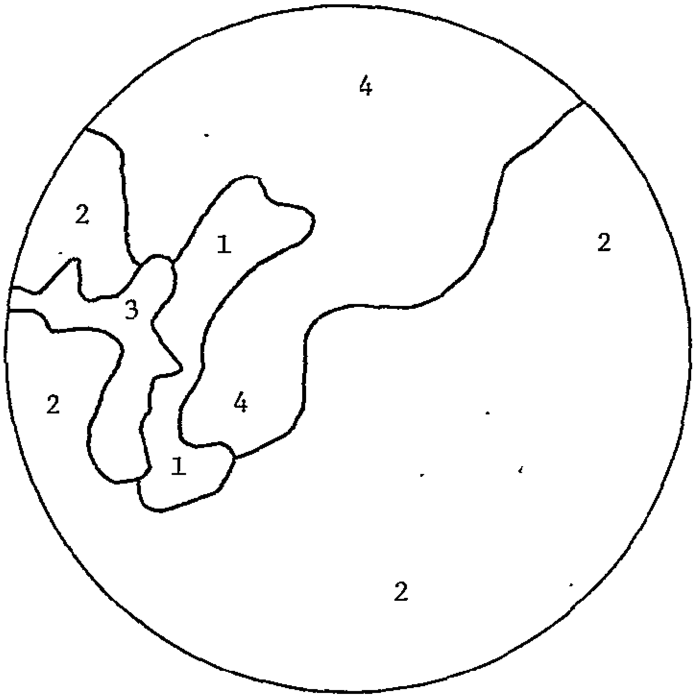


1974

TEXTURAL CHARACTERISTICS OF STUDY WINDOW "C", 1973 and 1974.



1973

1974

TEXTURAL CHARACTERISTICS OF STUDY WINDOW "D", 1973 and 1974.

1973

1974

STUDY WINDOW E

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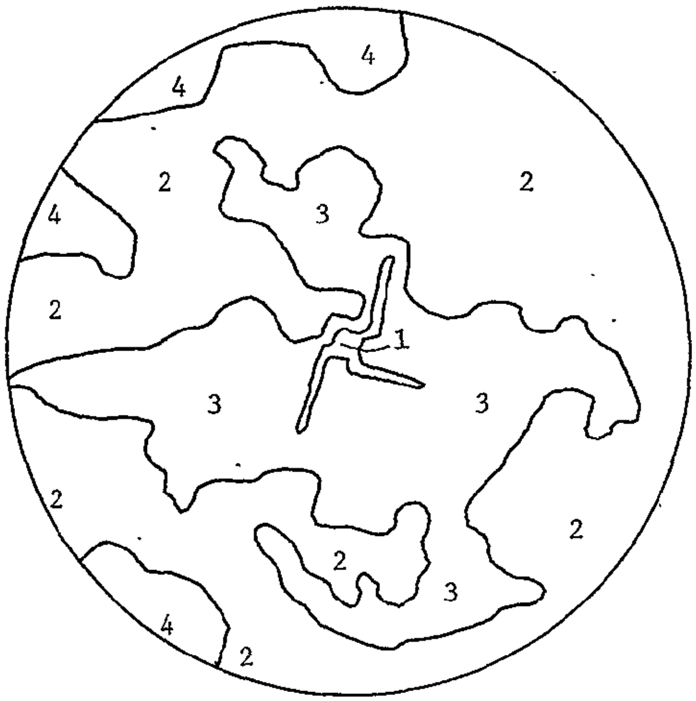
TEXTURAL CHARACTERISTICS OF STUDY WINDOW "F", 1973 and 1974.



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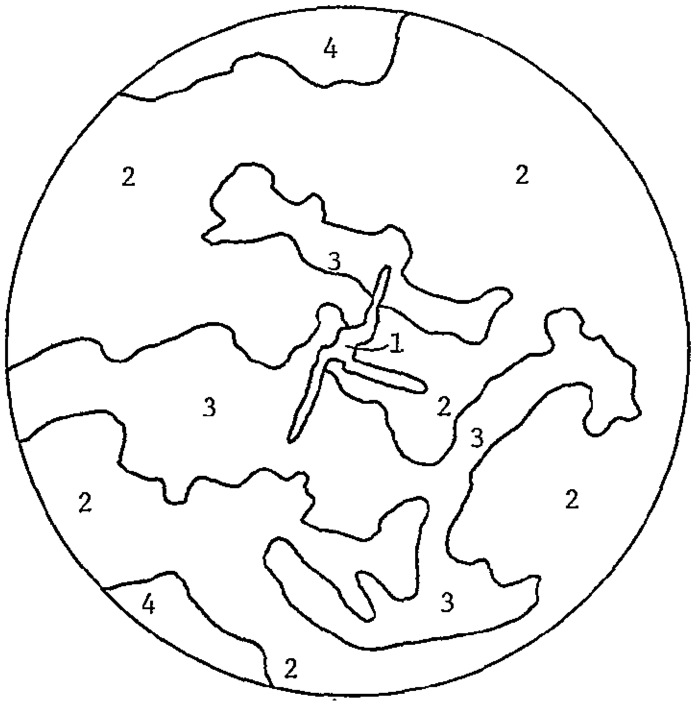

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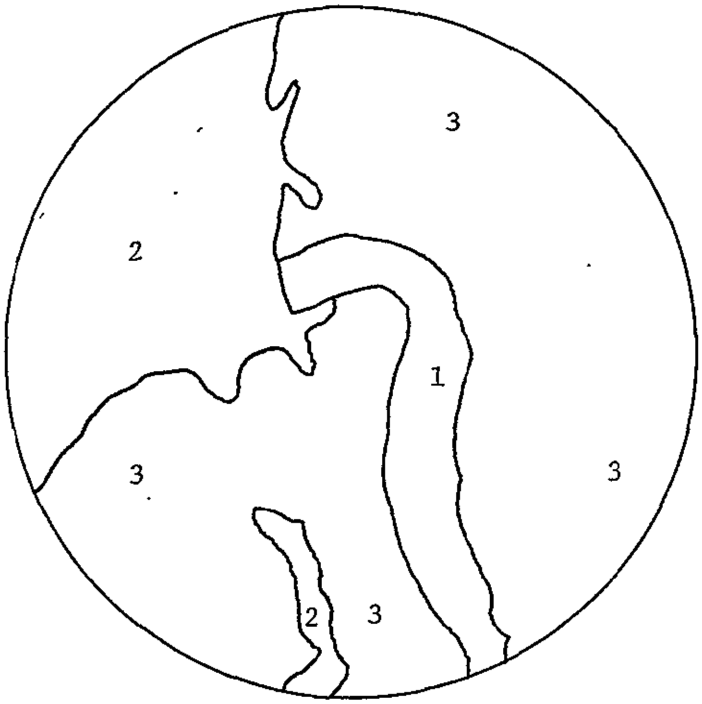

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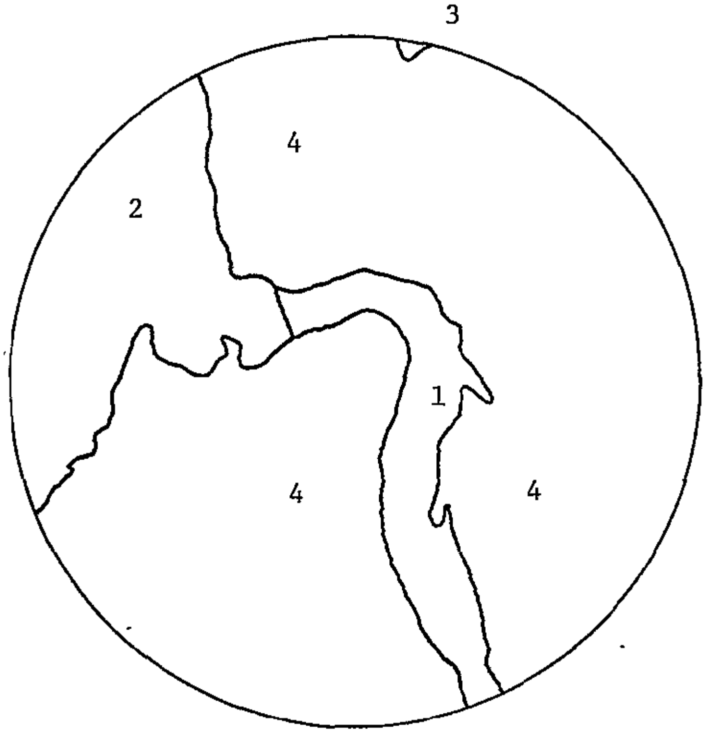
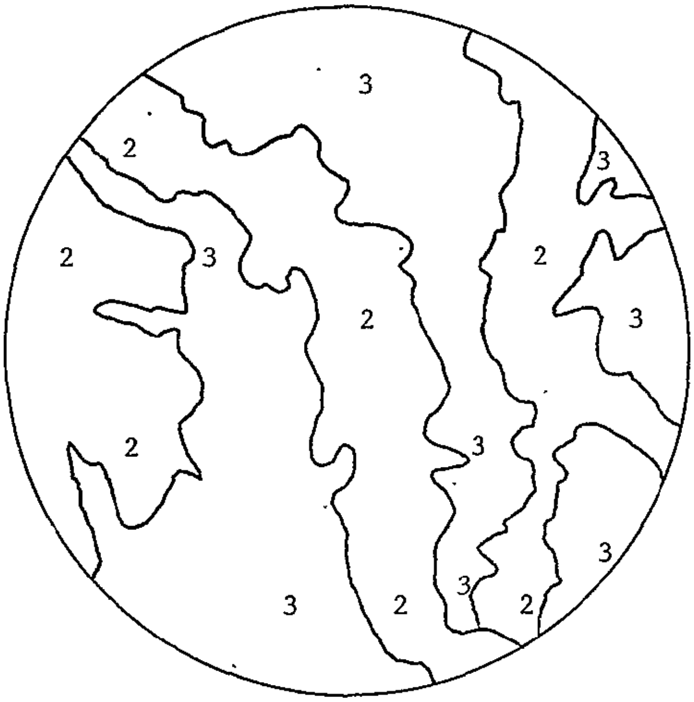


1974

TEXTURAL CHARACTERISTICS OF STUDY WINDOW "H", 1973 and 1974.



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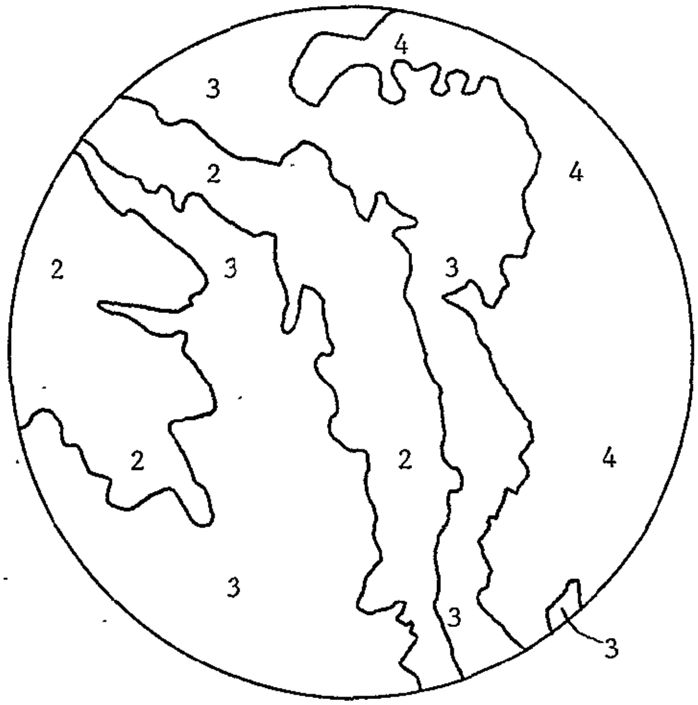

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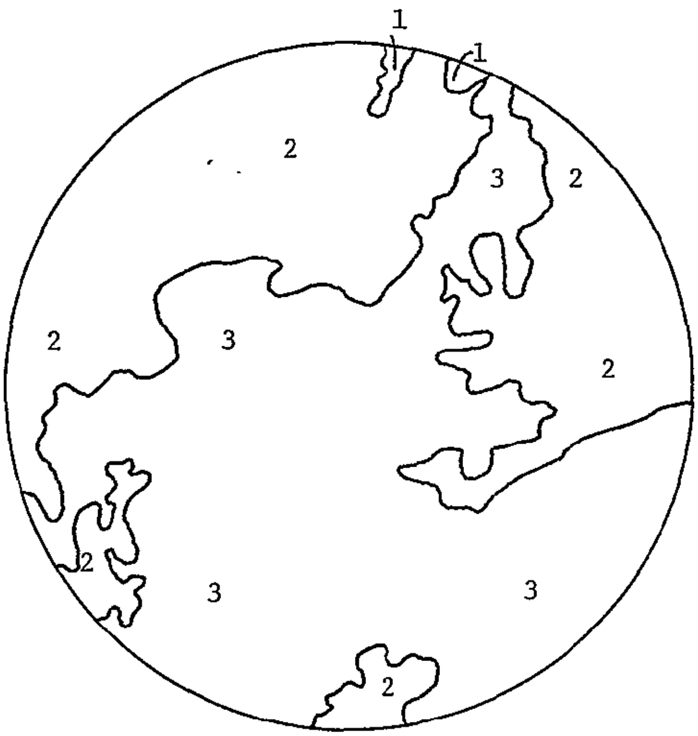
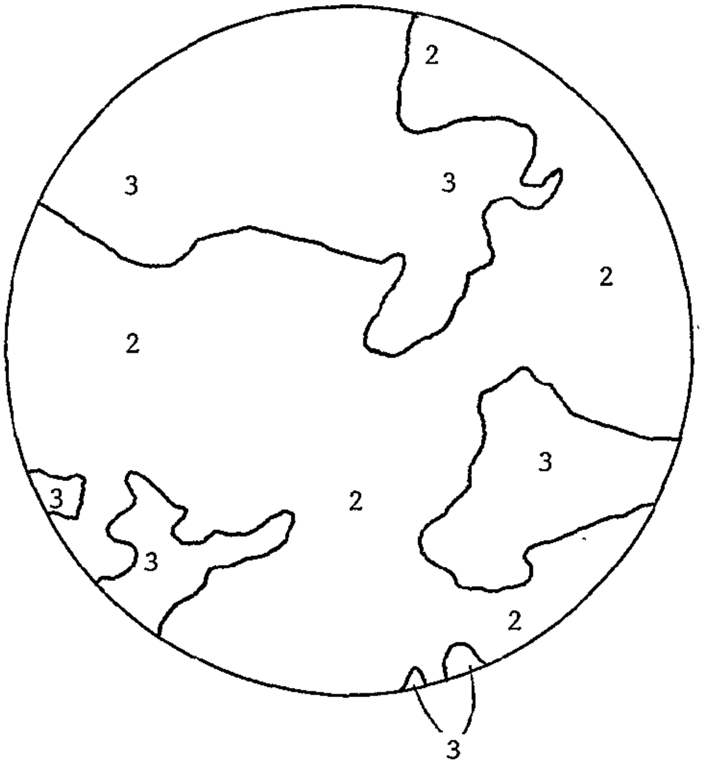
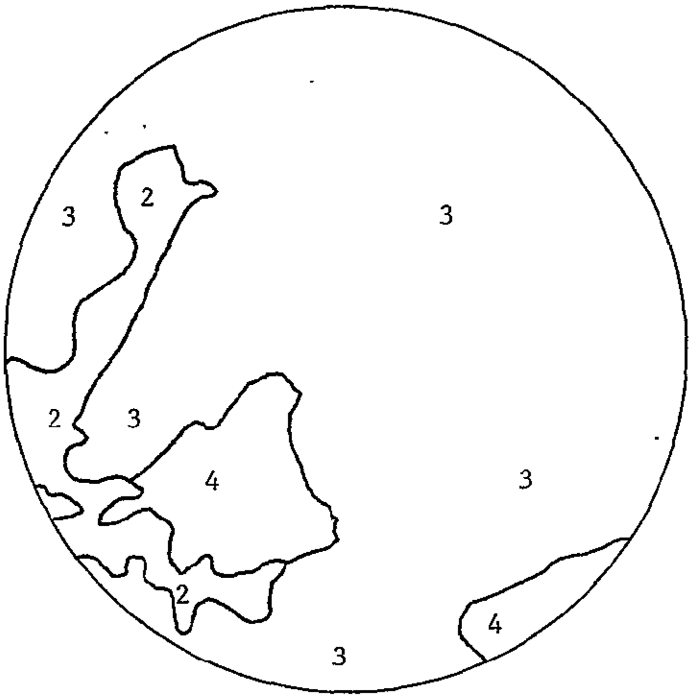


1973



1974

TEXTURAL CHARACTERISTICS OF STUDY WINDOW "K", 1973 and 1974.



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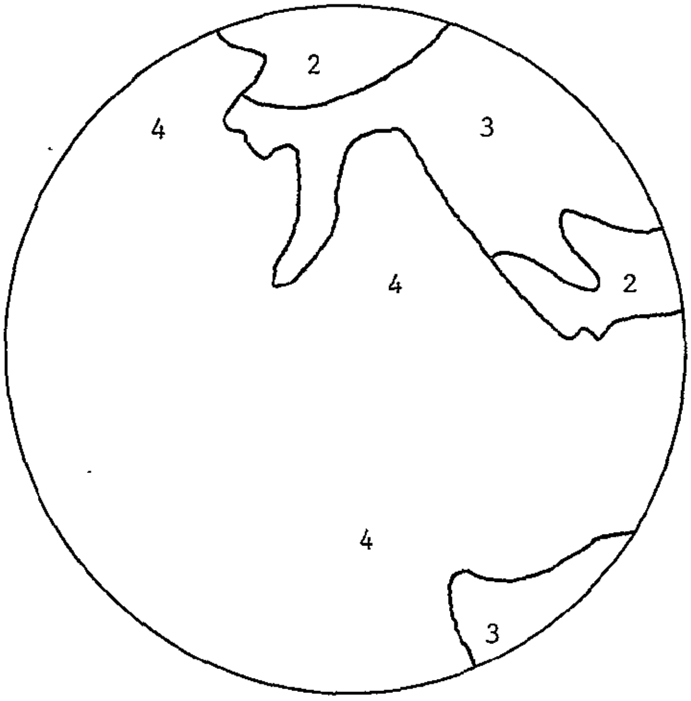


1974

# APPENDIX C

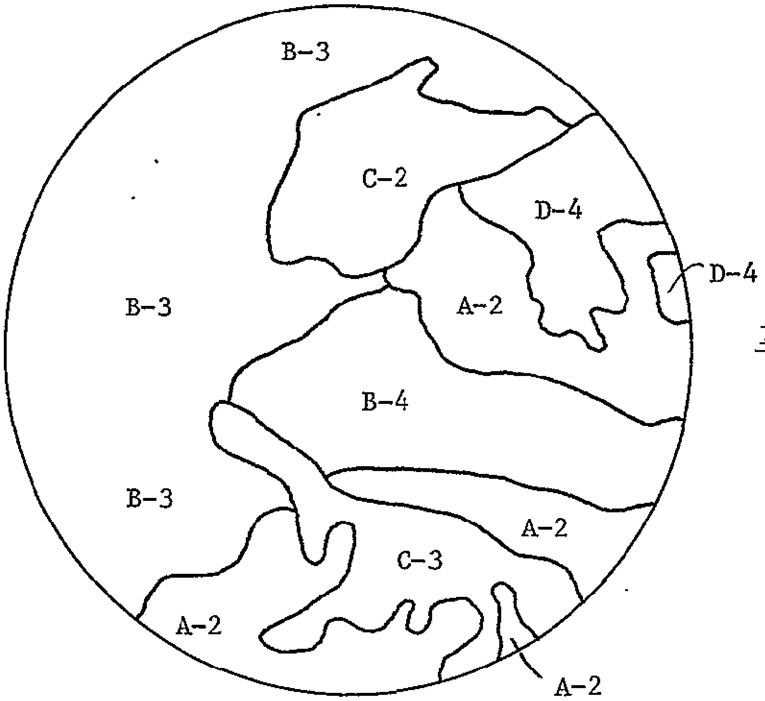
## STUDY WINDOW
## PHOTOMORPHIC REGIONS,
## 1973 and 1974

STUDY WINDOW A

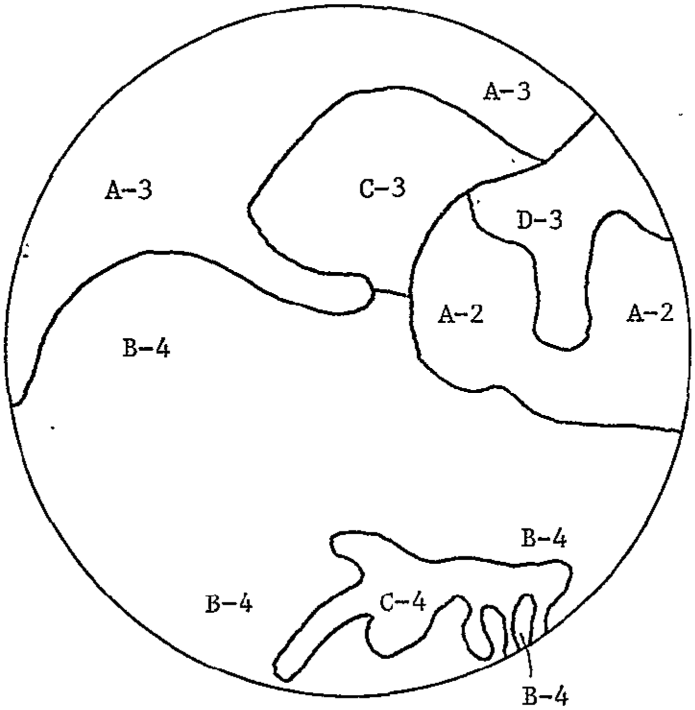
IS INCLUDED AS FIGURE 10 IN THE

REPORT TEXT

PHOTOMORPHIC REGIONS, STUDY WINDOW "B", 1973 and 1974.



1973



1974

STUDY WINDOW C

IS INCLUDED AS FIGURE 11 IN THE

REPORT TEXT

STUDY WINDOW D

IS INCLUDED AS FIGURE 12 IN THE

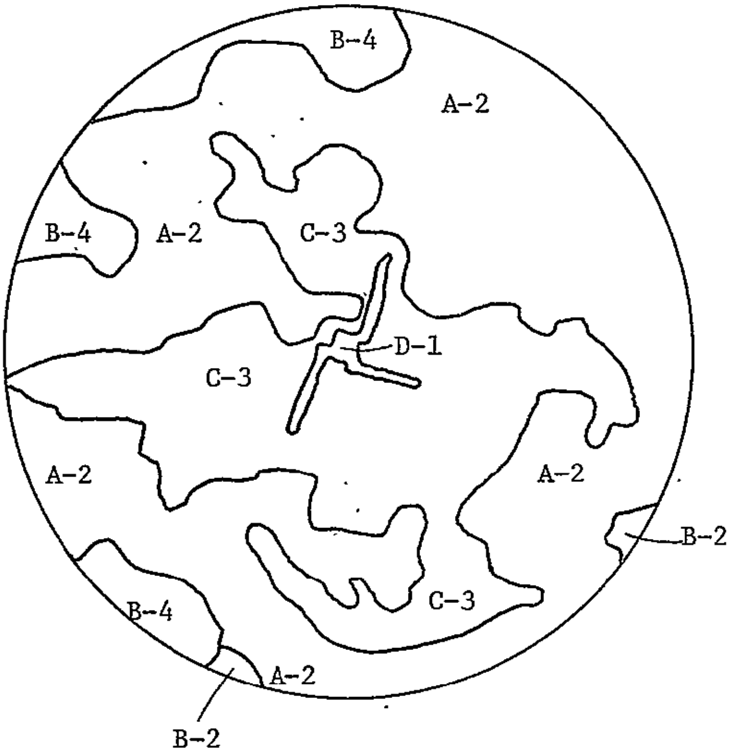
REPORT TEXT

STUDY WINDOW E

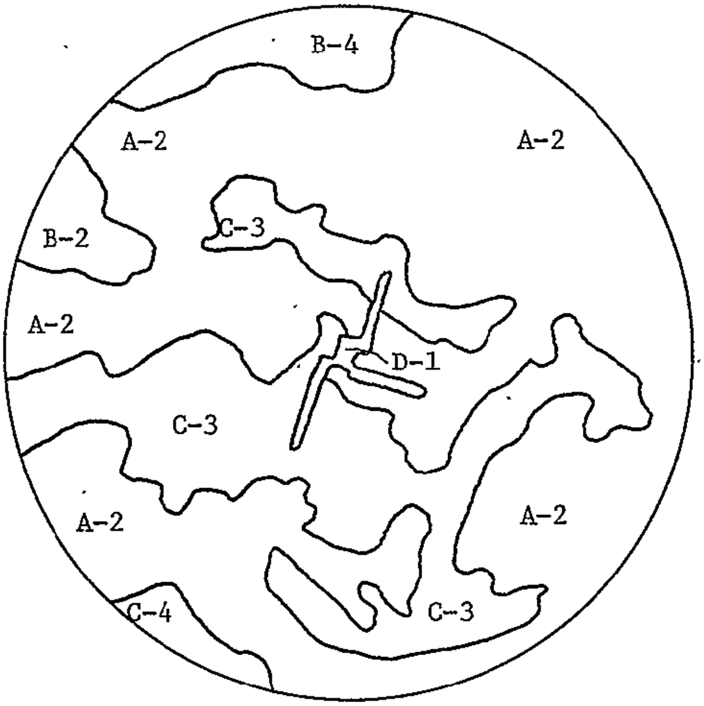
IS INCLUDED AS FIGURE 9 IN THE

REPORT TEXT

PHOTOMORPHIC REGIONS, STUDY WINDOW "F", 1973 and 1974.

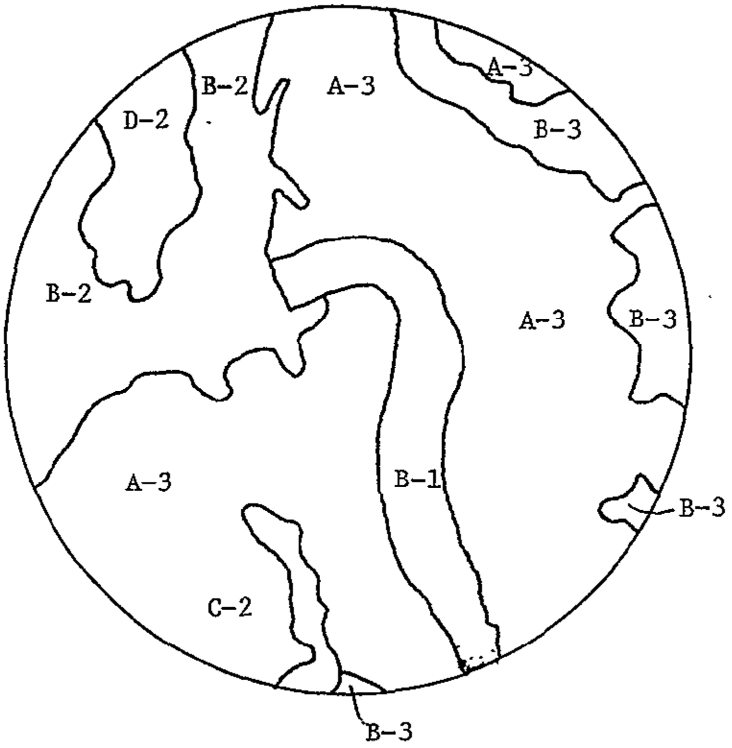


1973

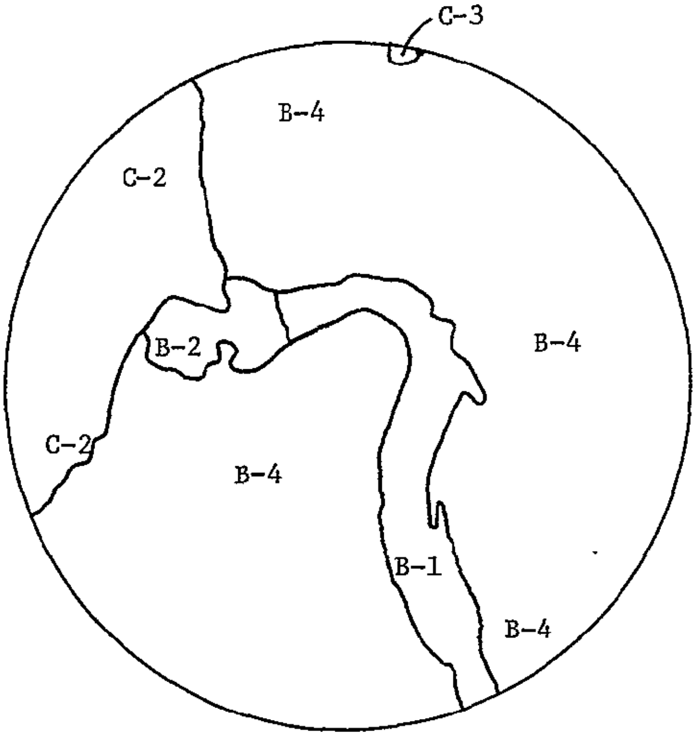


1974

PHOTOMORPHIC REGIONS, STUDY WINDOW "G", 1973 and 1974.

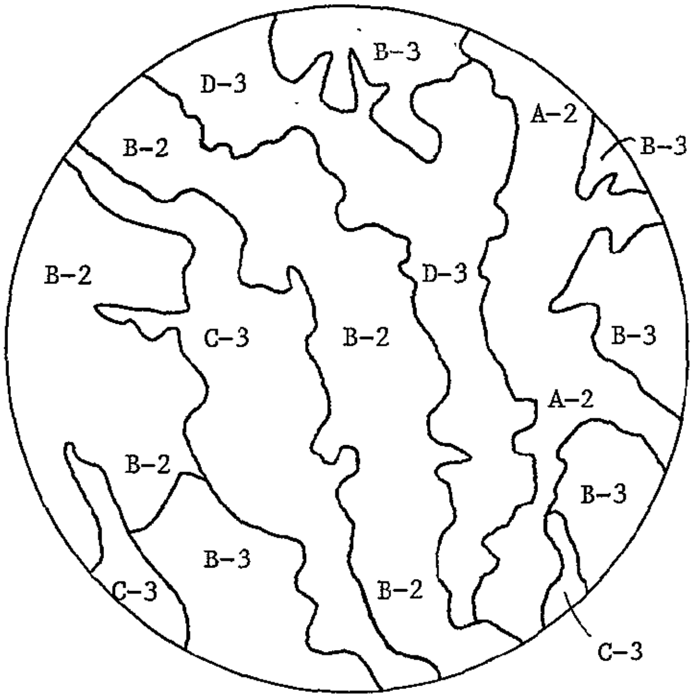


1973

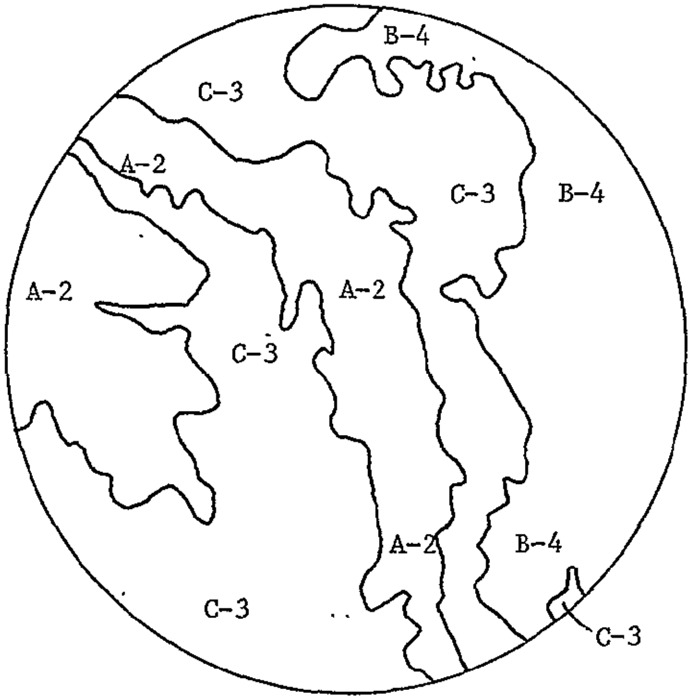


1974

PHOTOMORPHIC REGIONS, STUDY WINDOW "H", 1973 and 1974.

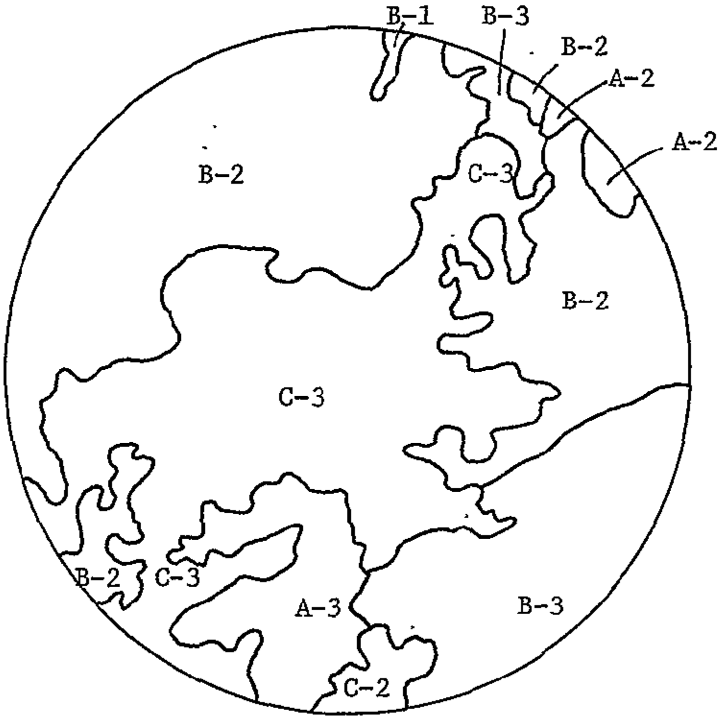


1973

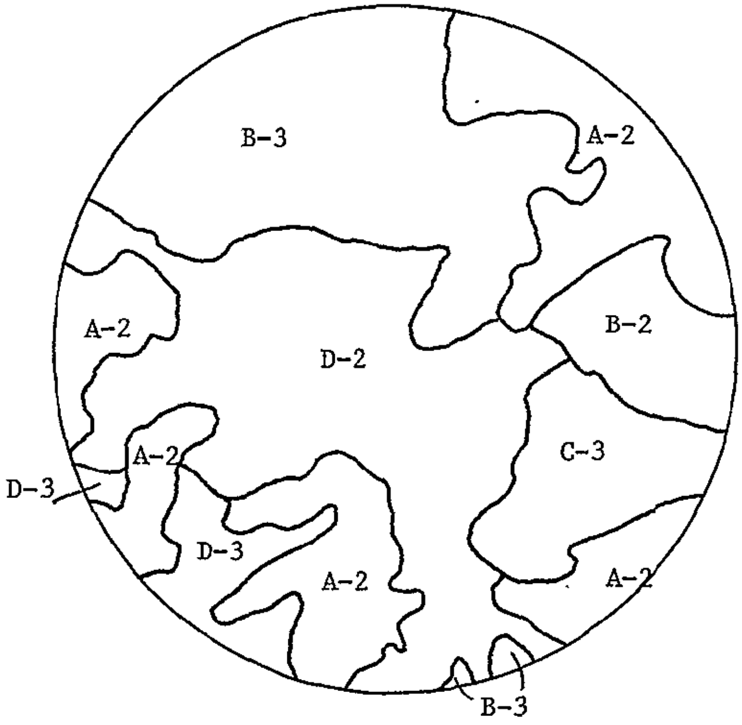


1974

PHOTOMORPHIC REGIONS, STUDY WINDOW "J", 1973 and 1974.



1973



1974

STUDY WINDOW K

IS INCLUDED AS FIGURE 13 IN THE

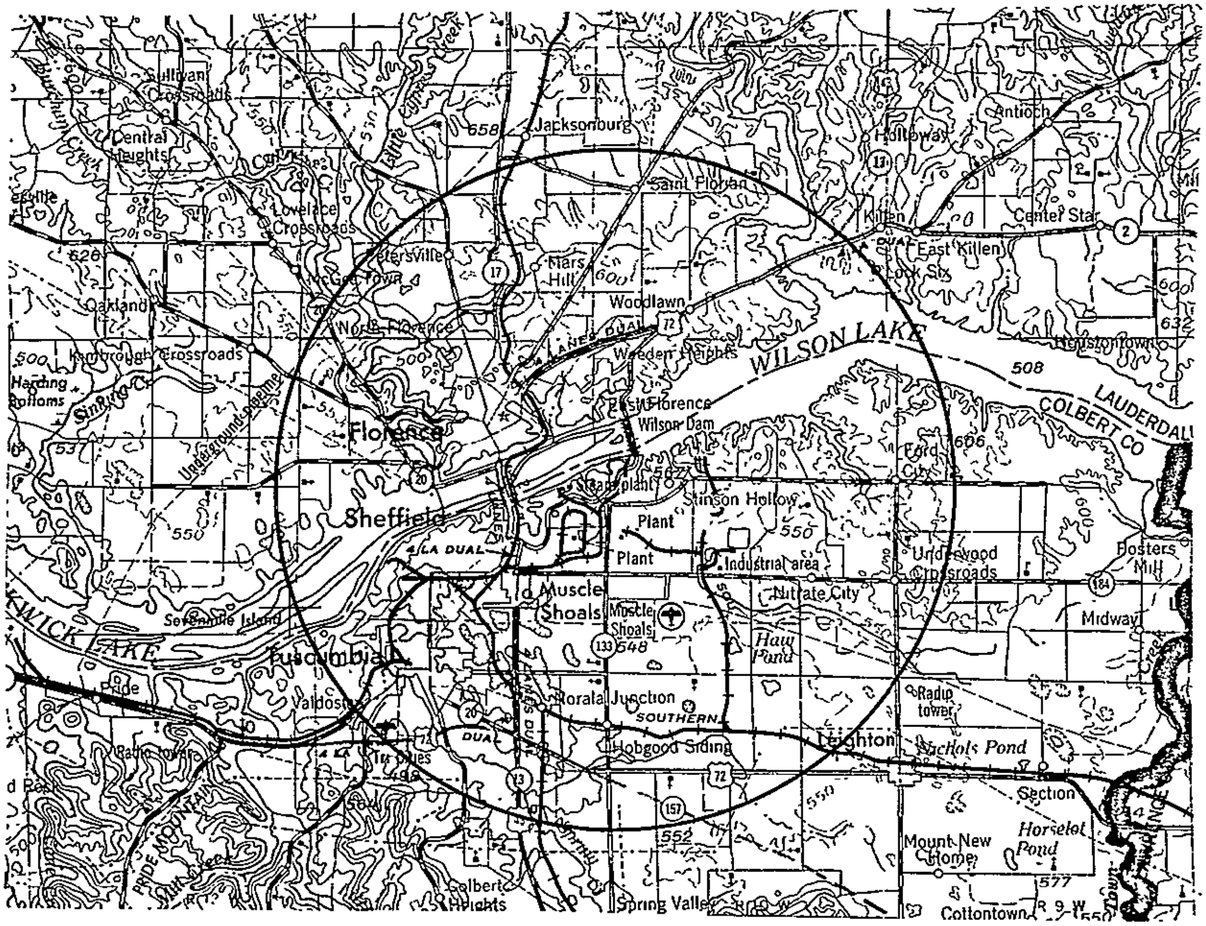
REPORT TEXT

# APPENDIX D

## STUDY WINDOW CHARACTERISTICS
## AS DERIVED FROM 1:250,000
## TOPOGRAPHIC SHEETS AS INDICATED

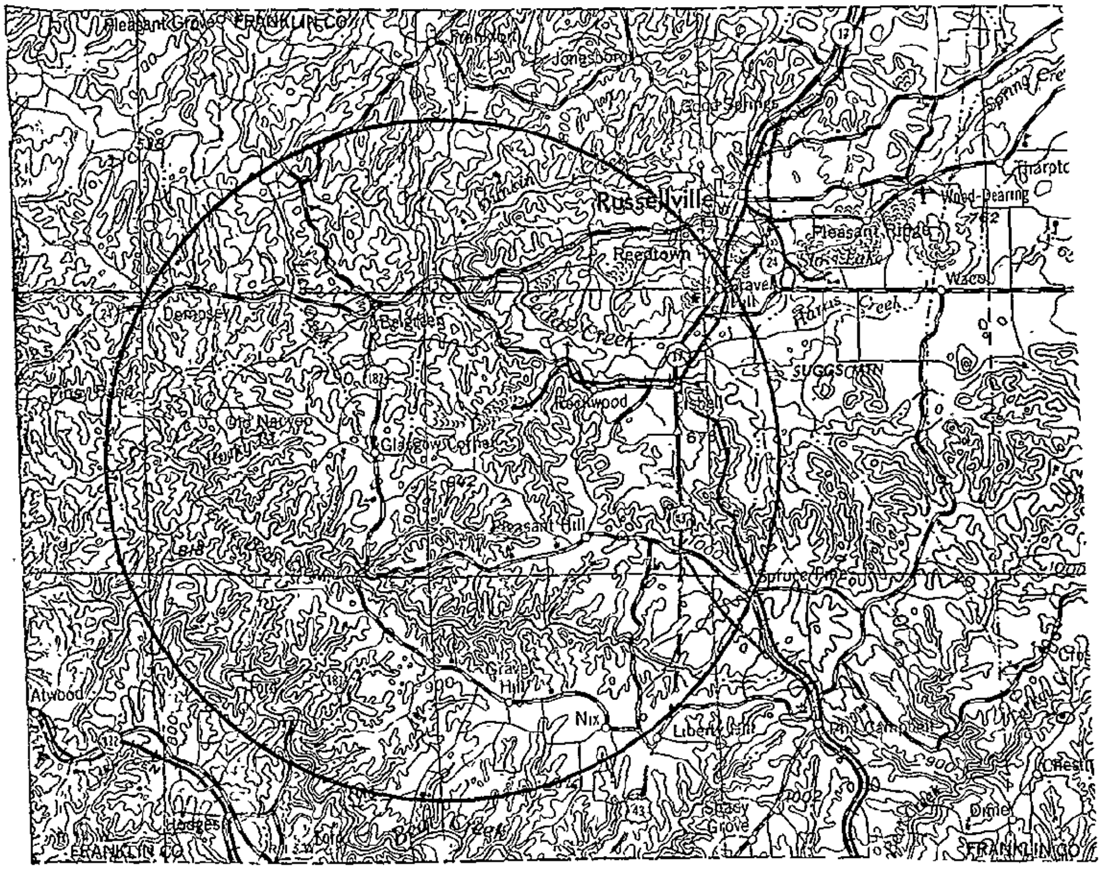
STUDY WINDOW "A"

SHEET NI 16-5 (Gadsden, AL)



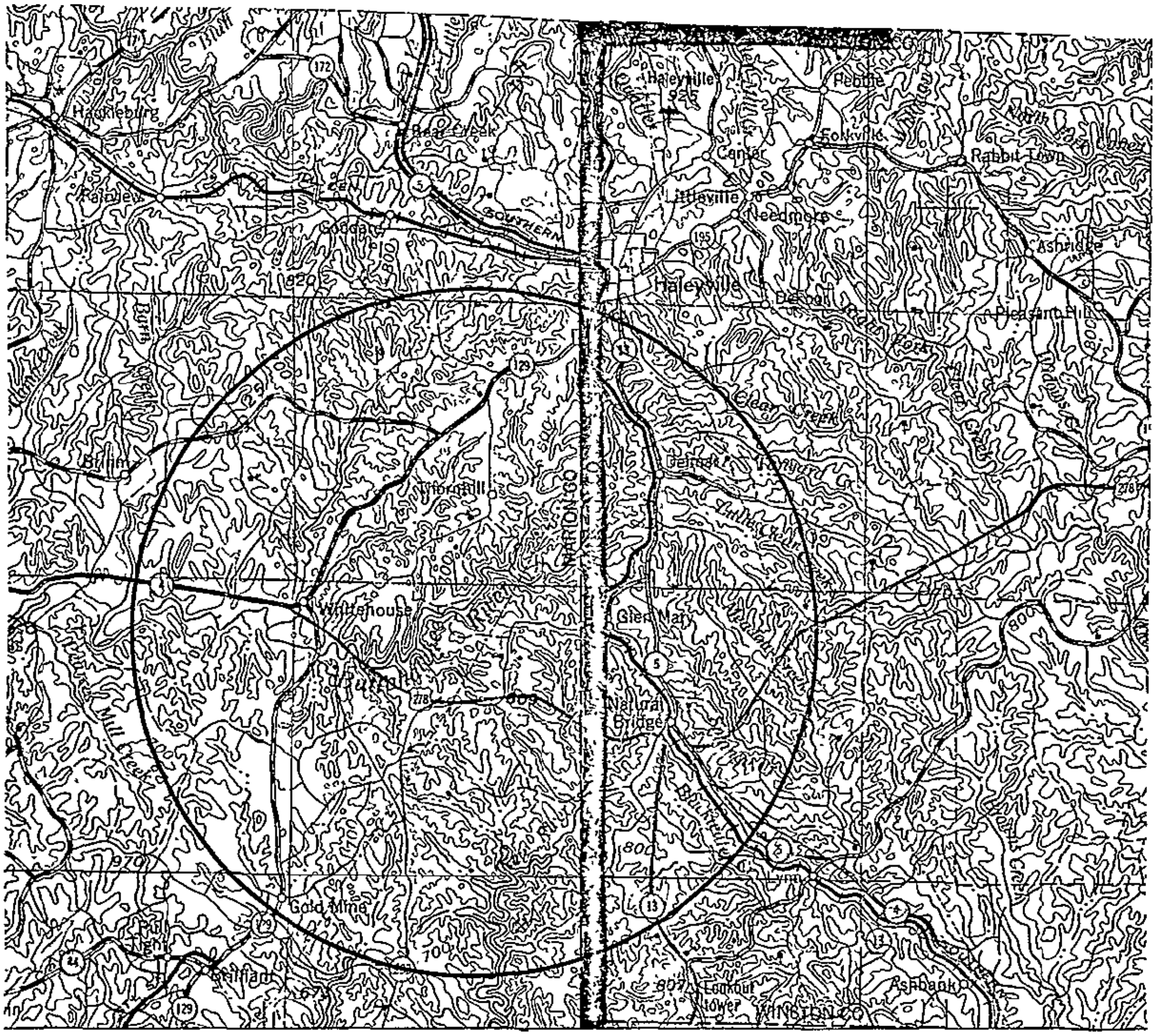
STUDY WINDOW "B"

SHEET NI 16-5 (Gadsden, AL)



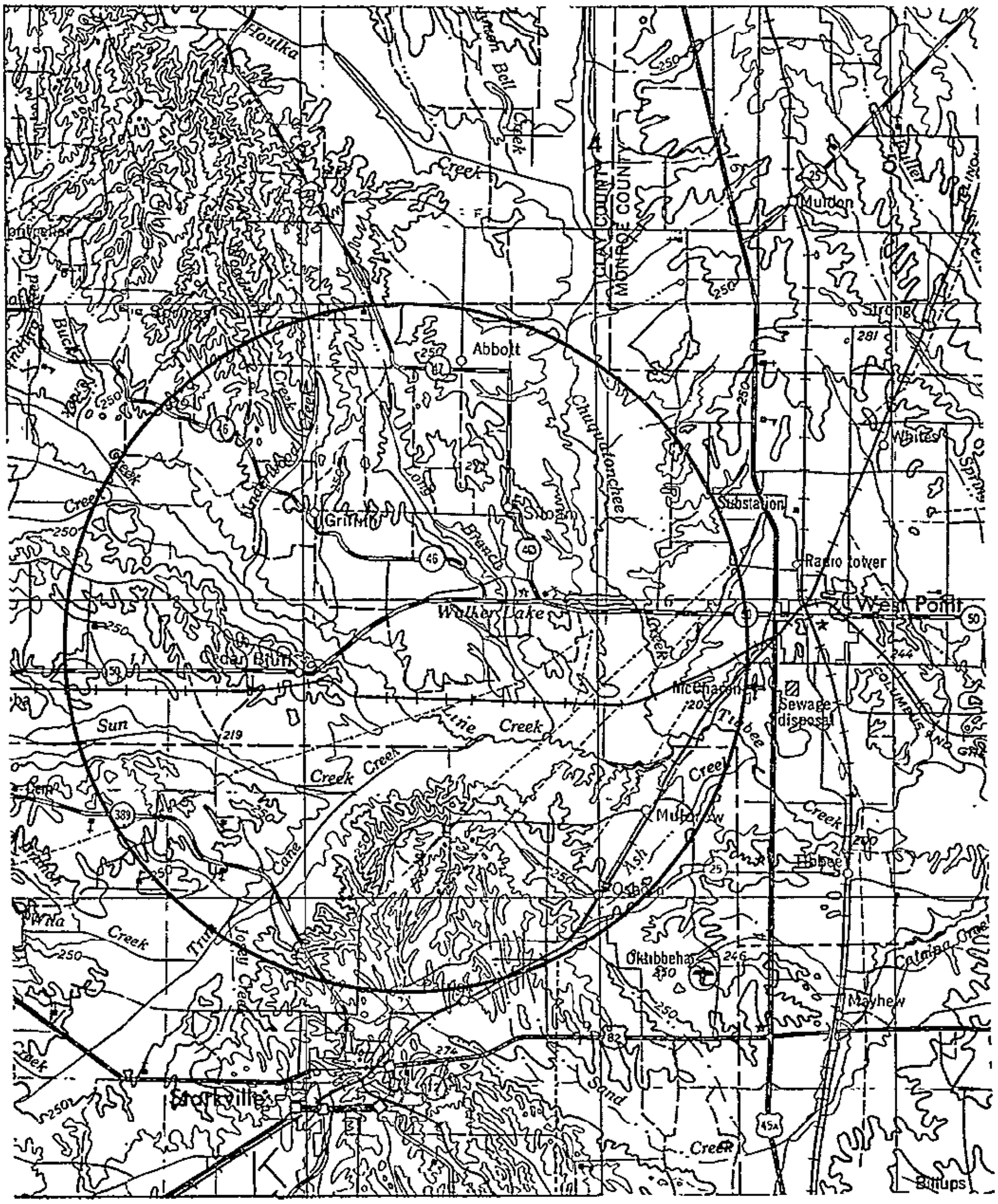
STUDY WINDOW "C"

SHEET NI 16-5 (Gadsden, AL)



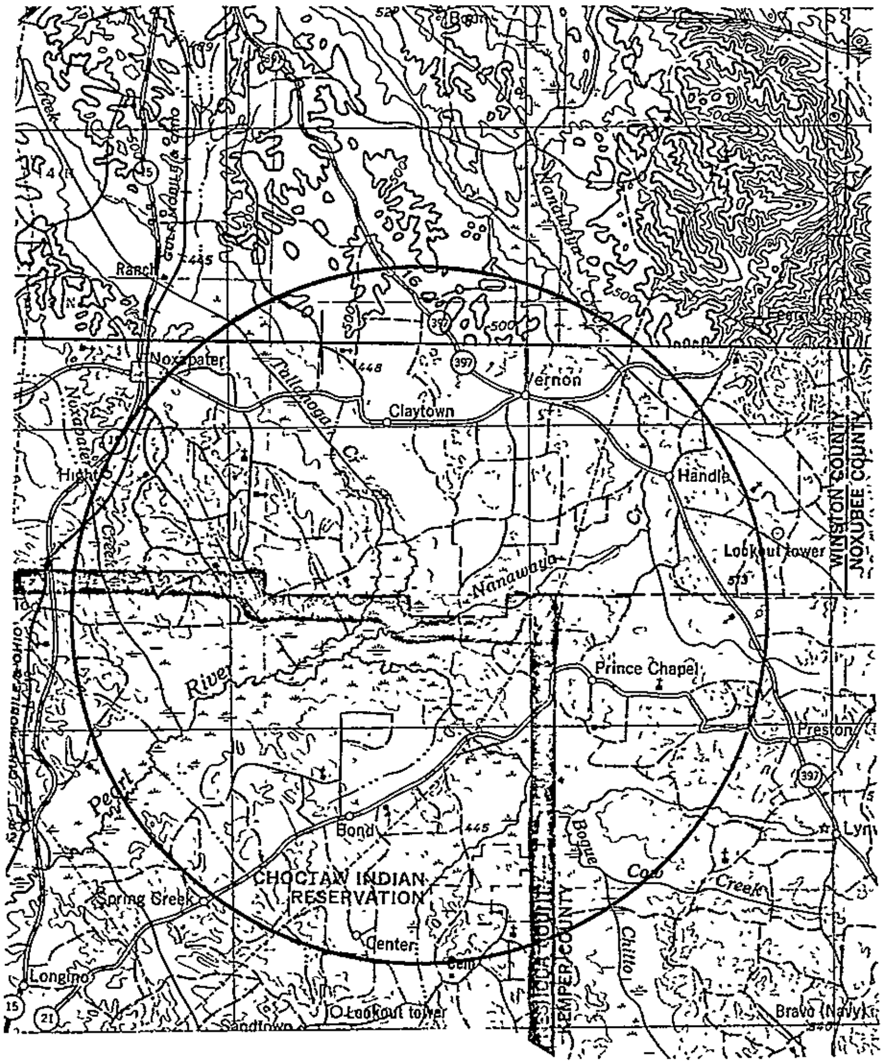
STUDY WINDOW "D"

SHEET NI 16-7 (West Point, MS-AL)



STUDY WINDOW "E"

SHEET NI 16-10 (Meridian, MS-AL)

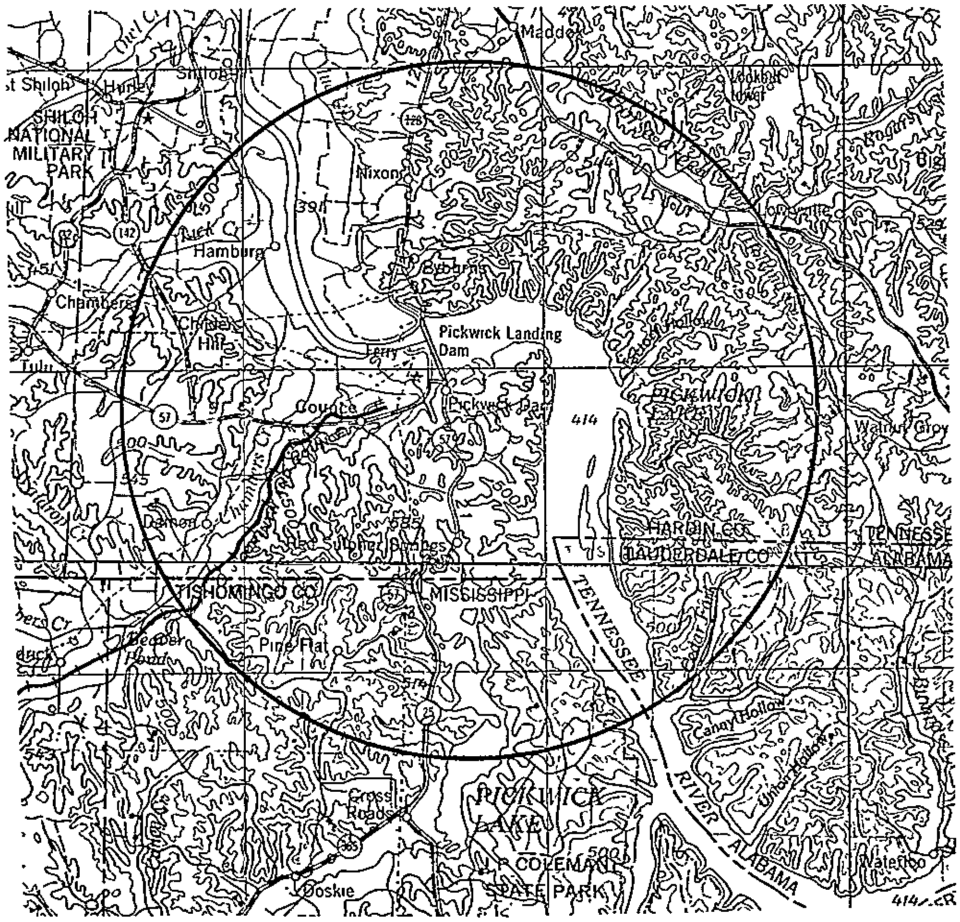


STUDY WINDOW "F"

SHEET NI 16-10 (Meridian, MS-AL)

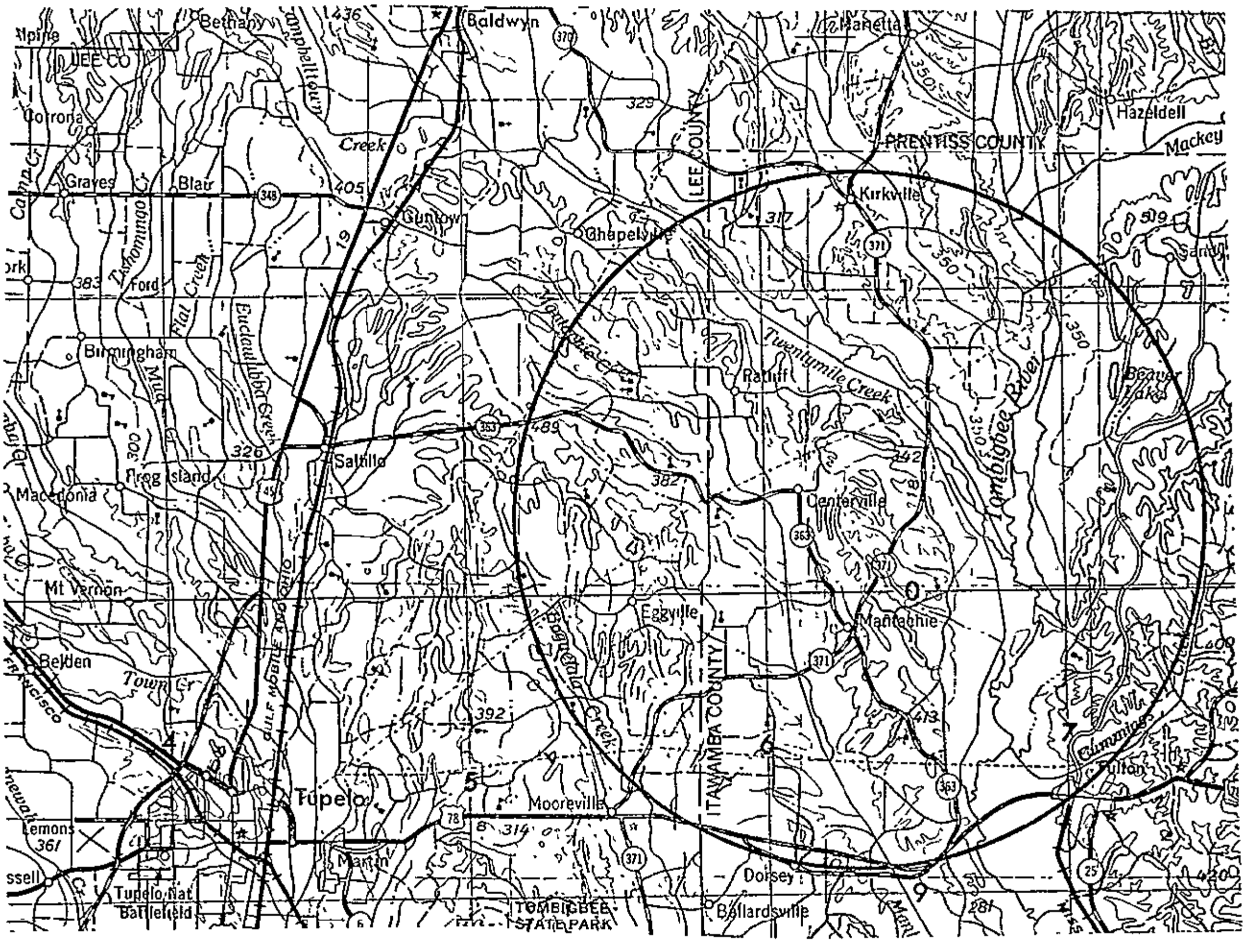
STUDY WINDOW "G"

SHEETS NI 16-1 (Blytheville, TN) and NI.16-4 (Tupelo, MS-AL)



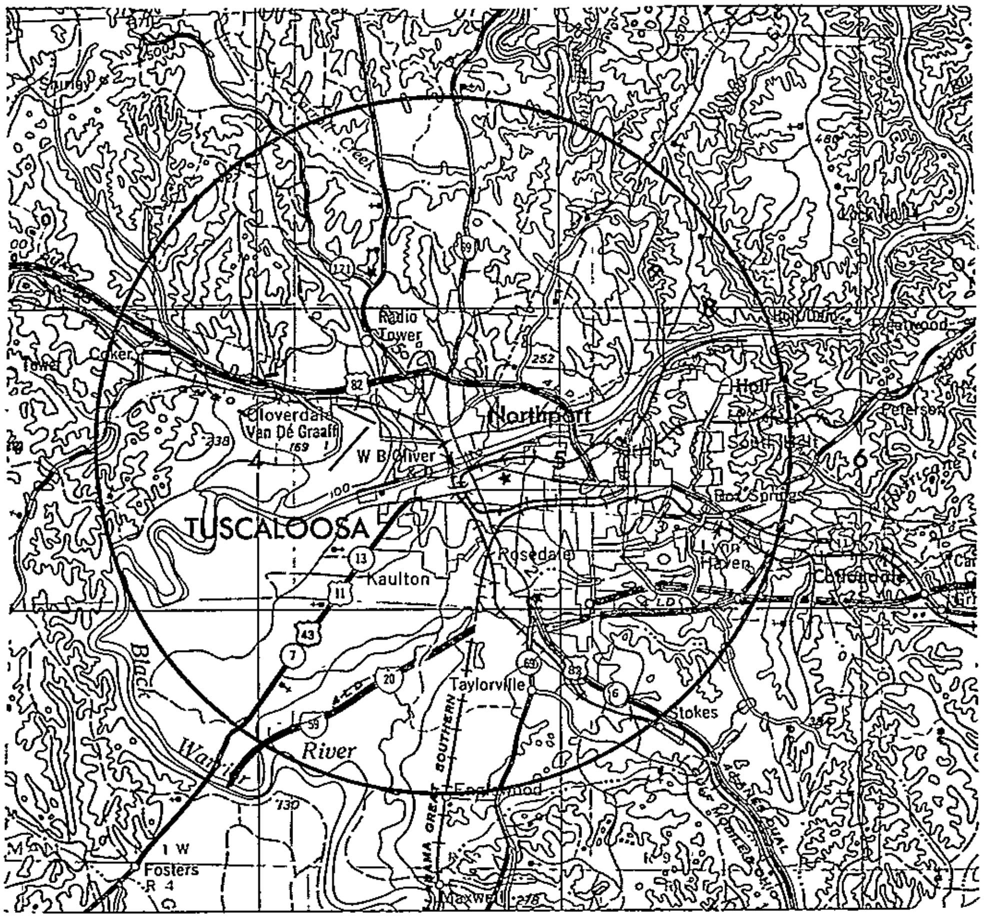
STUDY WINDOW "H"

SHEET NI 16-4 (Tupelo, MS-AL)



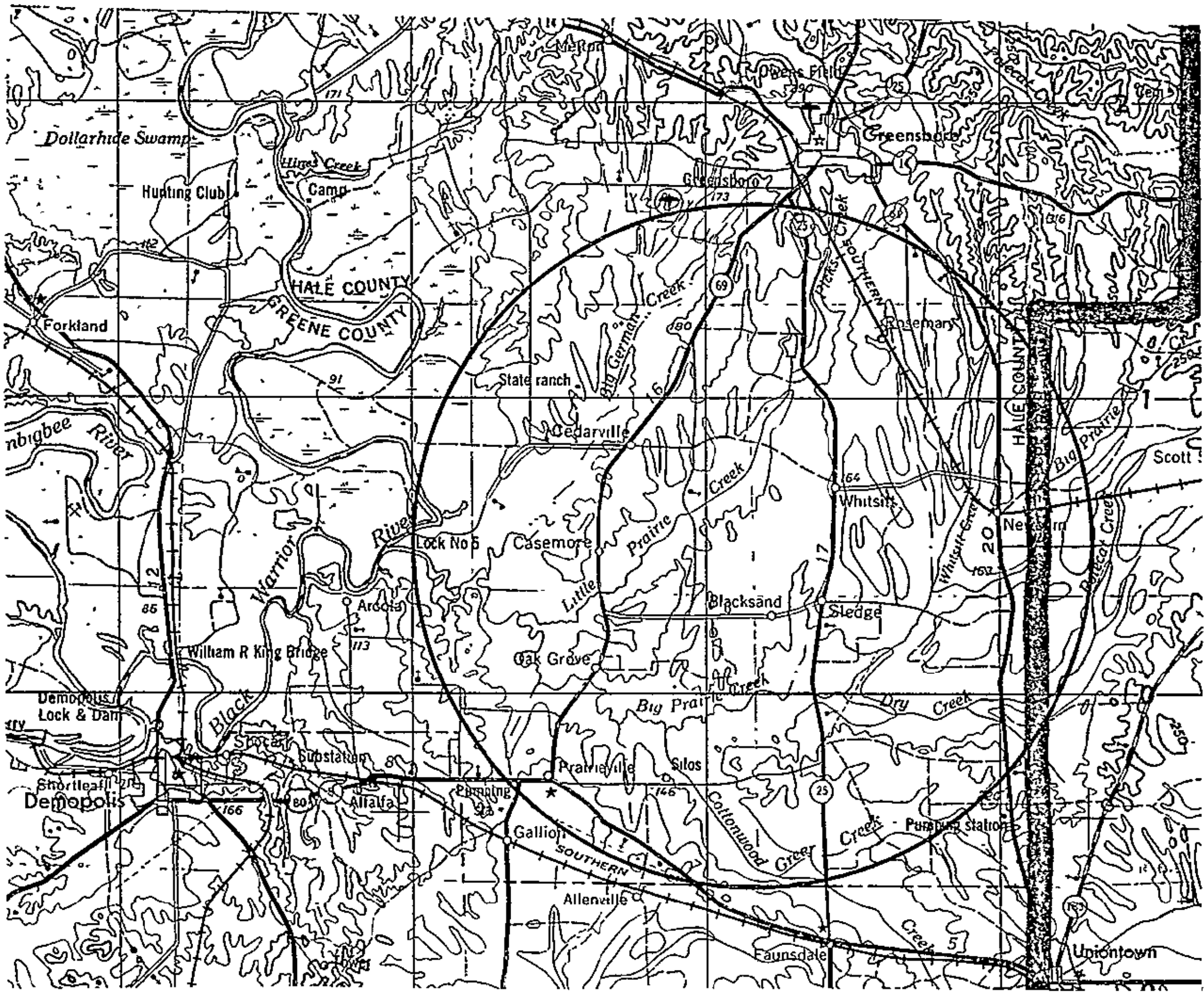
STUDY WINDOW "J"

SHEET NI 16-8 (Birmingham, AL)



STUDY WINDOW "K"

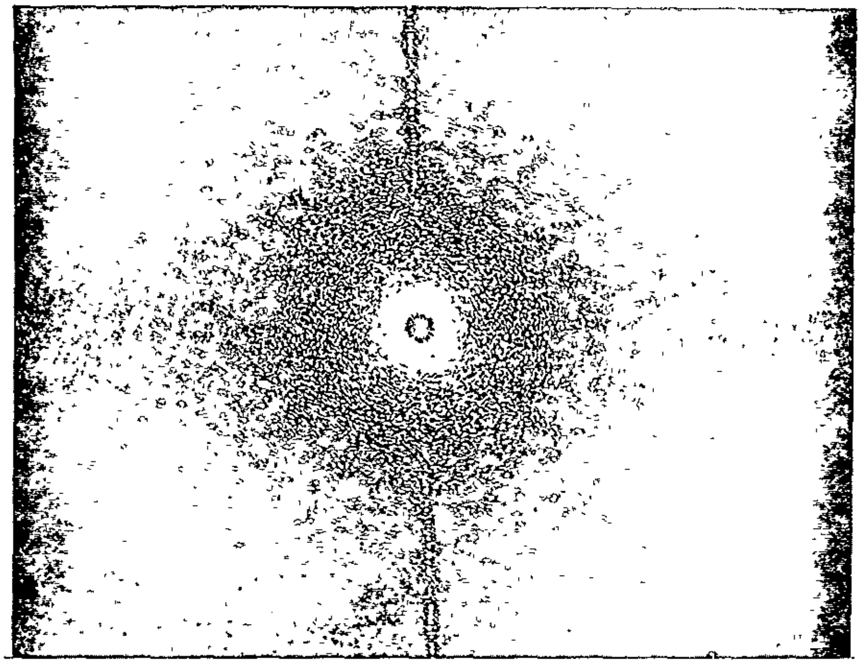
SHEET NI 16-11 (Montgomery, AL)



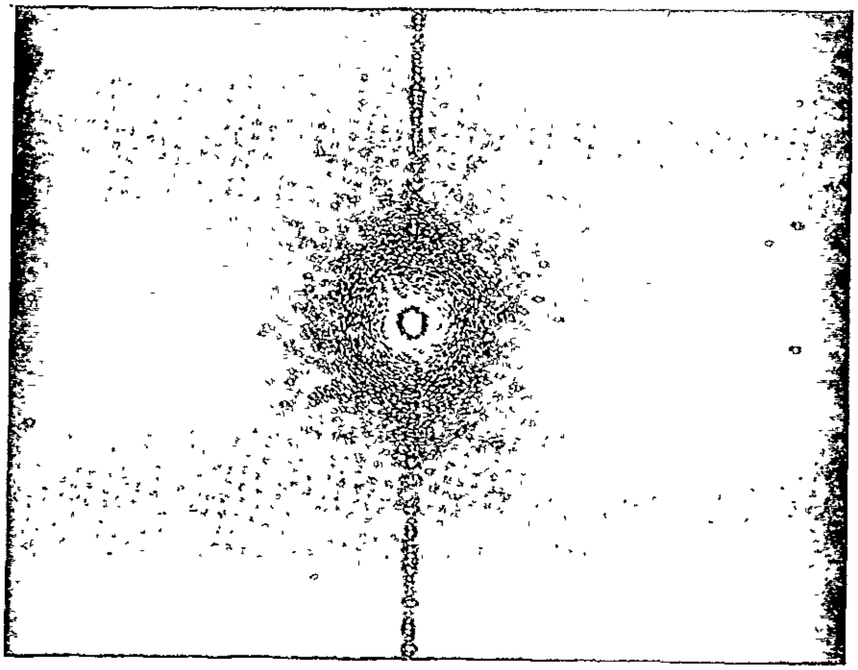
# APPENDIX E

## STUDY WINDOW
## POWER SPECTRA,
## 1973 and 1974

POWER SPECTRA FOR STUDY WINDOW A, 1973 & 1974

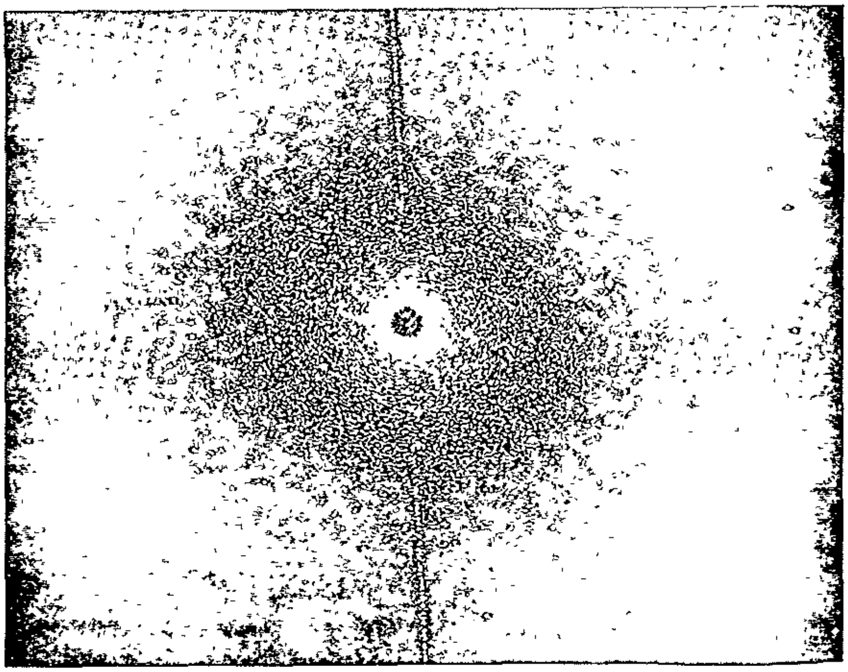


1973

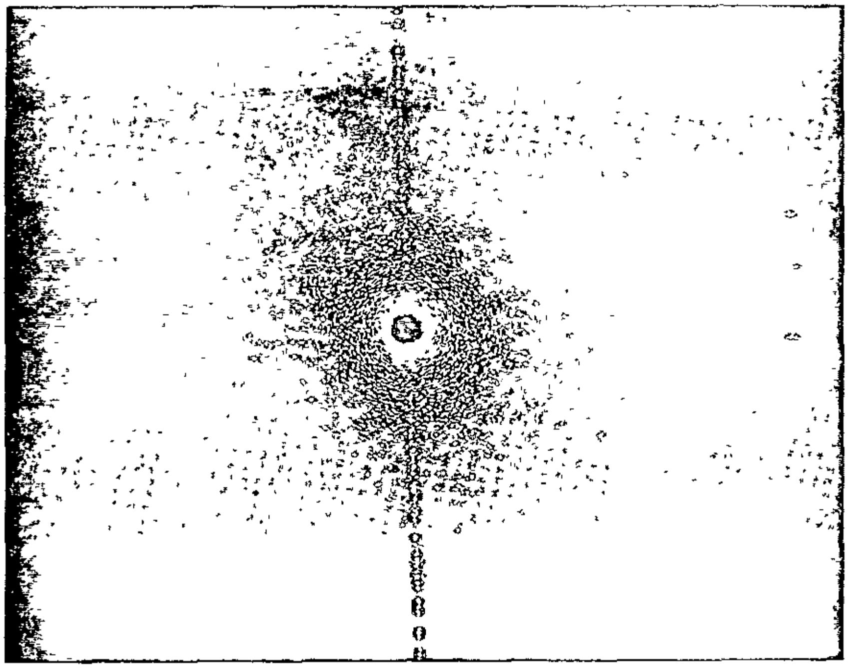


1974

POWER SPECTRA FOR STUDY WINDOW B, 1973 & 1974



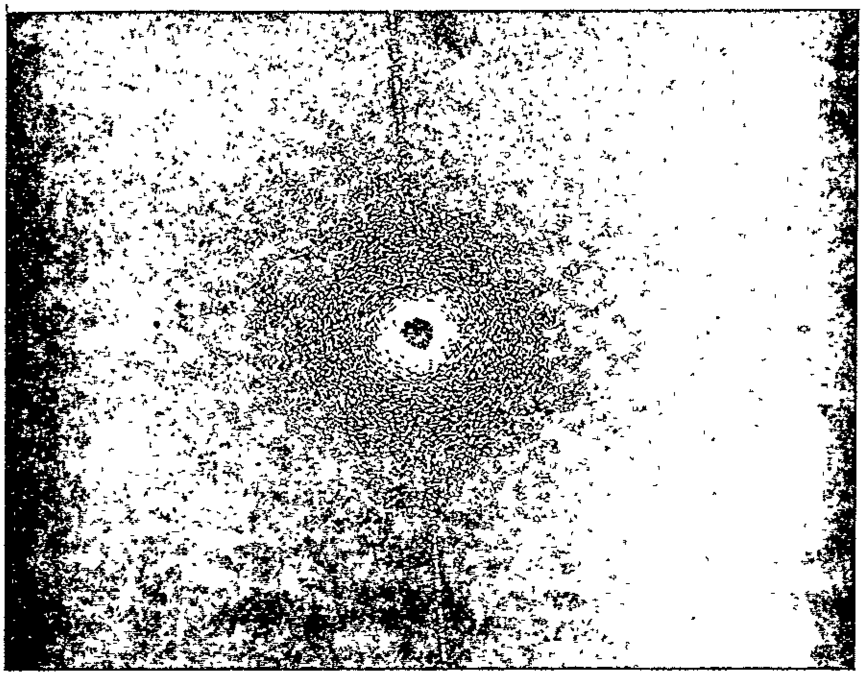
1973



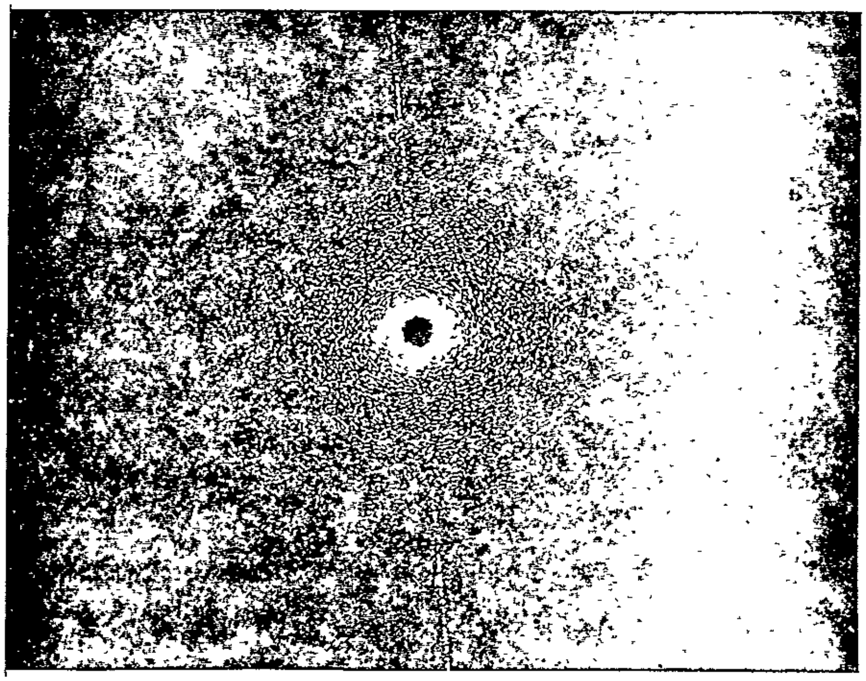
1974

ORIGINAL PAGE IS
OF POOR QUALITY

POWER SPECTRA FOR STUDY WINDOW C, 1973 & 1974



1973



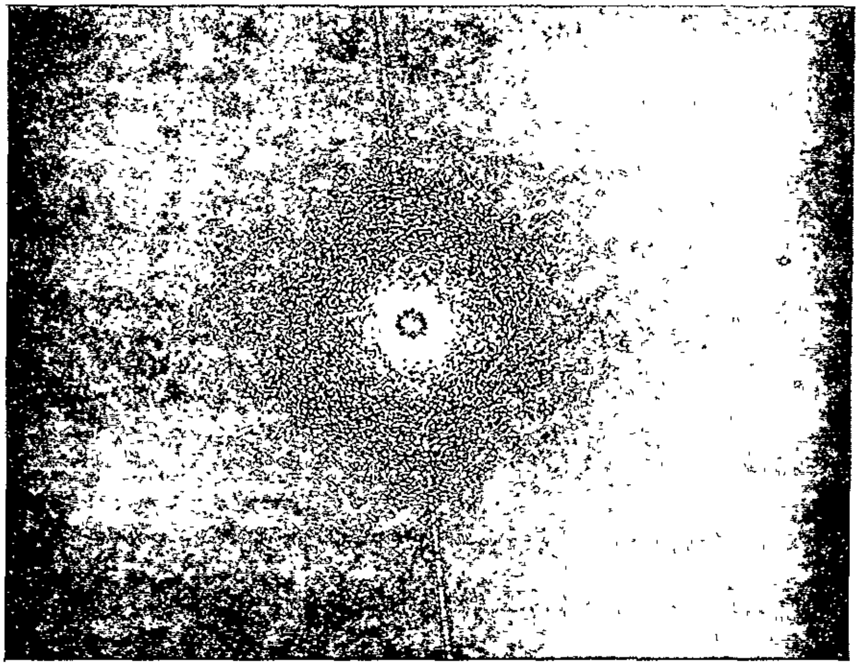
1974

STUDY WINDOW D

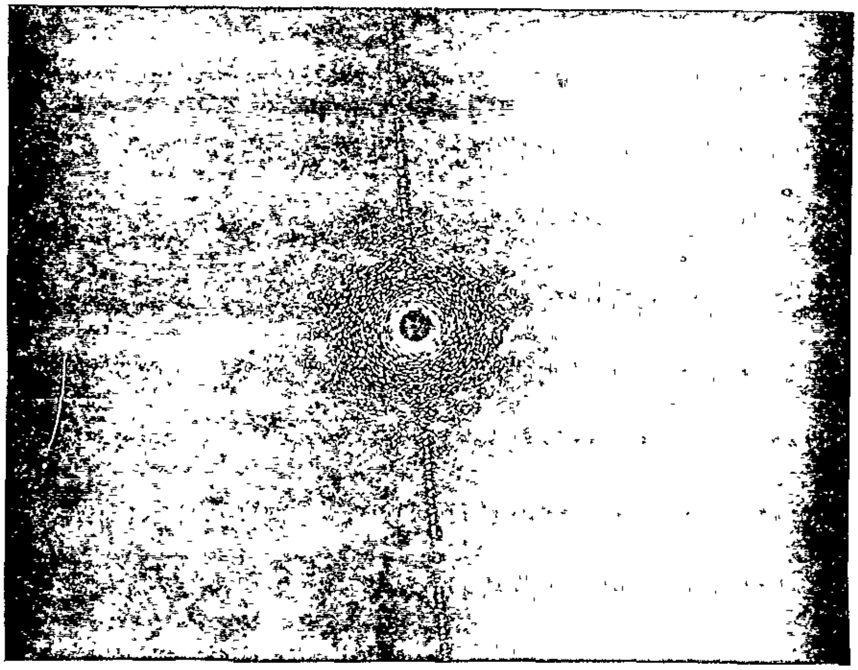
IS INCLUDED AS FIGURE 22 IN THE

REPORT TEXT

# POWER SPECTRA FOR STUDY WINDOW E, 1973 & 1974



1973



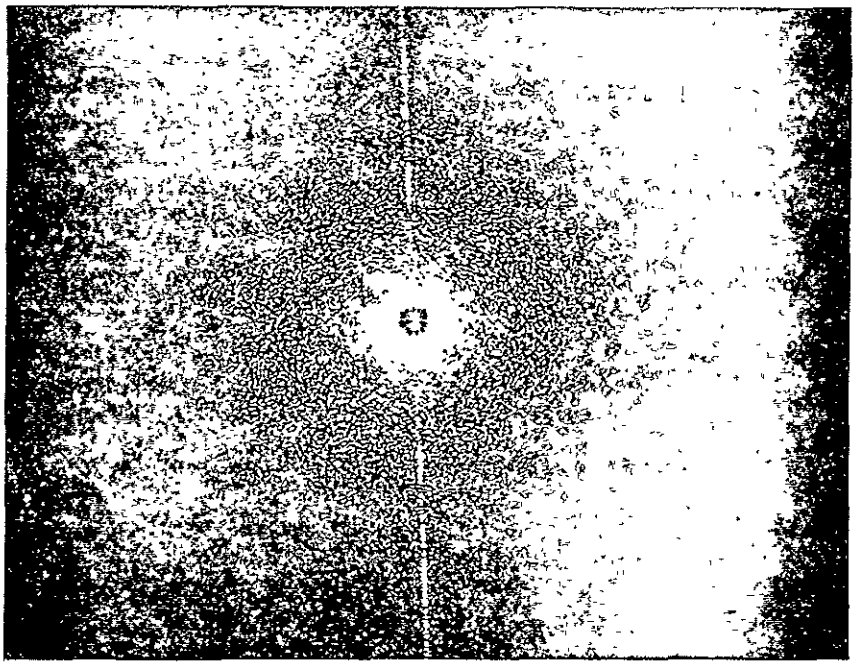
1974

STUDY WINDOW F

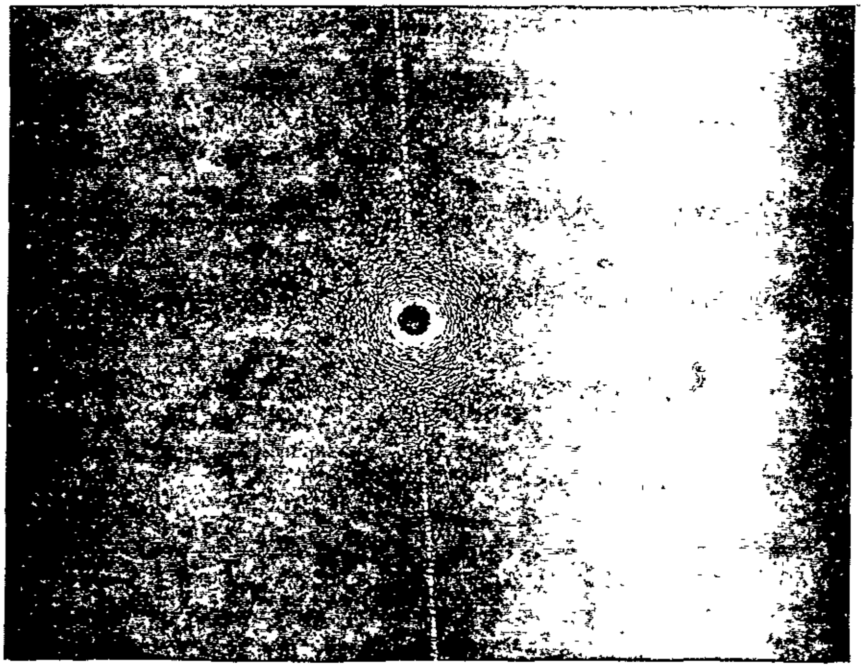
IS INCLUDED AS FIGURE 23 IN THE

REPORT TEXT

POWER SPECTRA FOR STUDY WINDOW G, 1973 & 1974

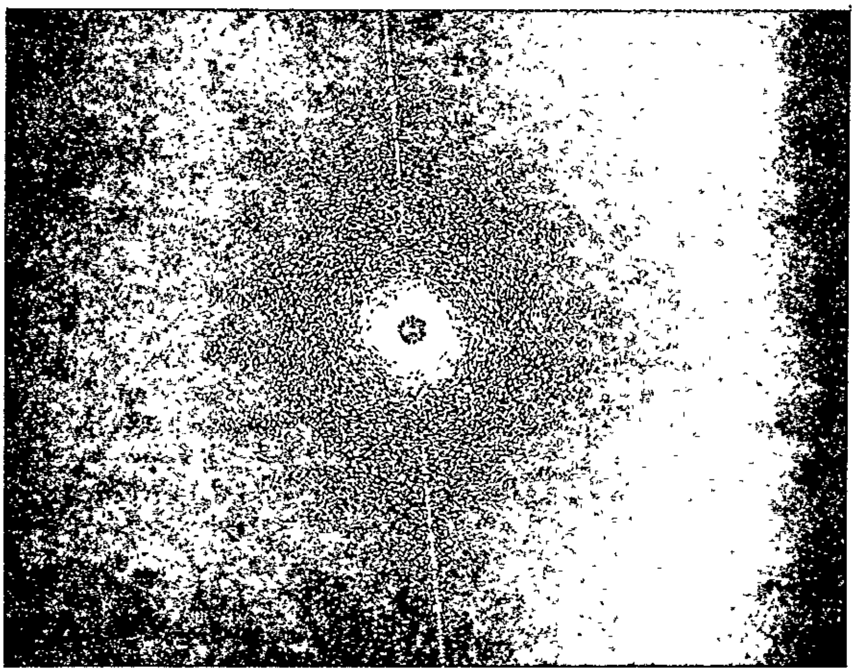


1973

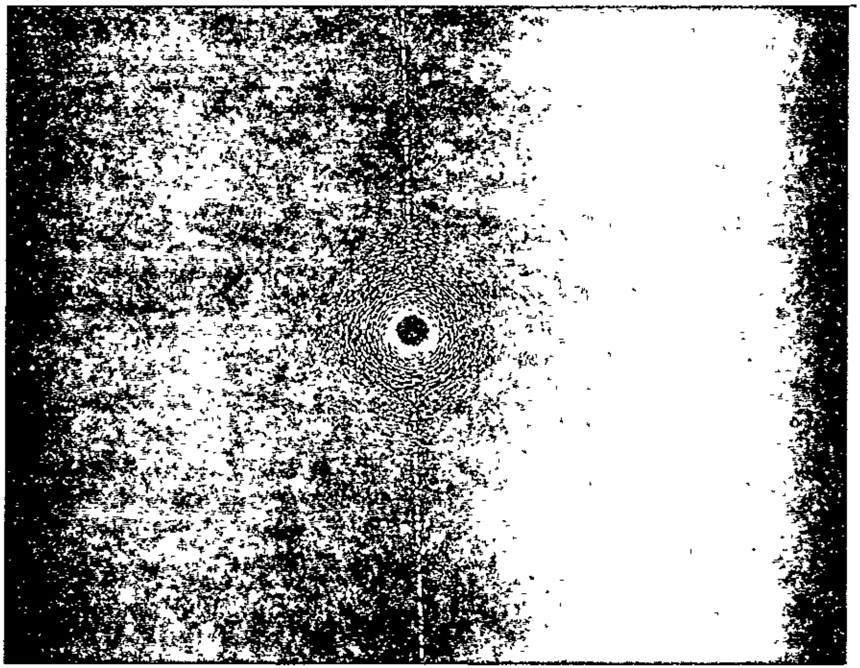


1974

POWER SPECTRA FOR STUDY WINDOW H, 1973 & 1974



1973

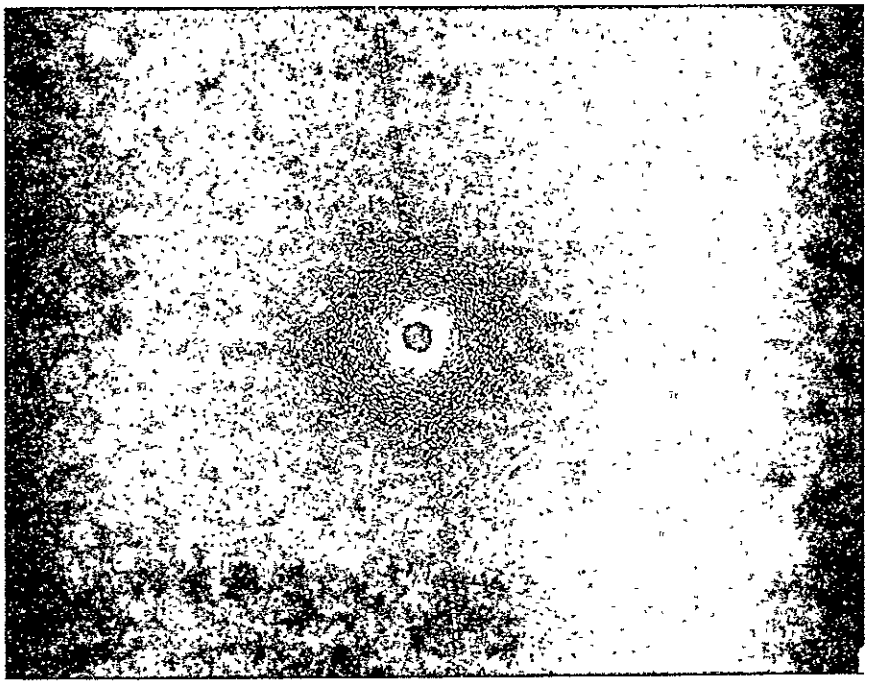


1974

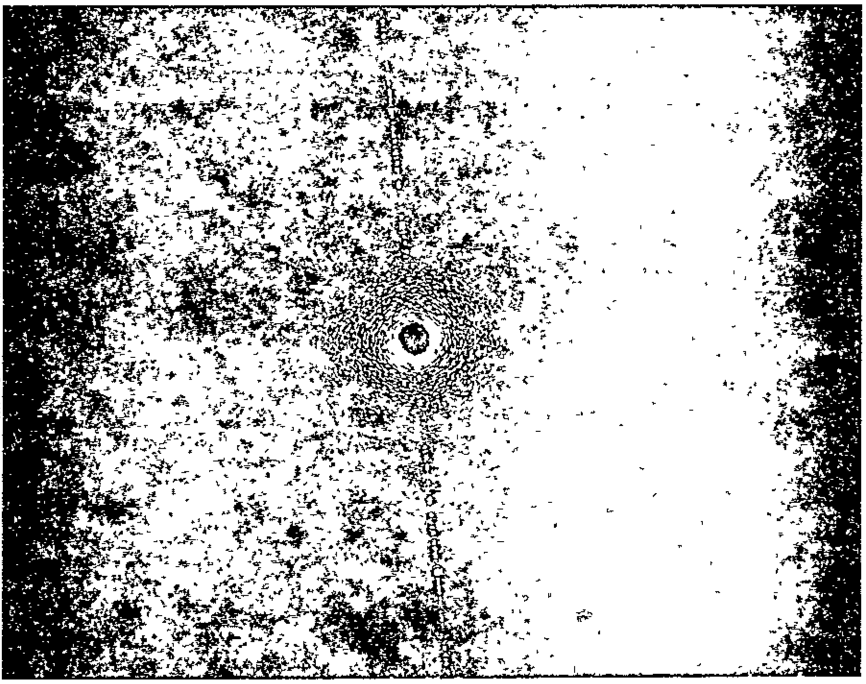
STUDY WINDOW J

IS INCLUDED AS FIGURE 24 IN THE

REPORT TEXT



1973



1974

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