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off

Date: September 23, 1976

Project Title: Analysis of LANDSAT Data over Southwest Georgia and Southwest Alabama

Project No: A-1874

Project Director: Mr. N. L. Faust

Sponsor: NASA, George C. Marshall Space Flight Center, Alabama 35812

Agreement Period: From 6/25/76 Until 12/25/76 (Contr. Period)

Type Agreement: Contract No. NAS8-31990

Amount: \$18,000 NASA + \$900 GTT Contribution

Reports Required: Informal Letter Report; Final Report.

Sponsor Contact Person (s):

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Defense Priority Rating: None

Assigned to: Electromagnetics Laboratory (School/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY
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Date: March 14, 1978

Project Title: Analysis of LANDSAT Data over Southwest Georgia and Southwest Alabama

Project No: A-1874

Project Director: Mr. N. L. Faust

Sponsor: NASA, George C. Marshall Space Flight Center, AL 35812

Effective Termination Date: 11/30/77

Clearance of Accounting Charges: by 11/30/77

Grant/Contract Closeout Actions Remaining:

- ☒ Final Invoice and Closing Documents
- ☐ Final Fiscal Report
- ☐ Final Report of Inventions
- ☒ Govt. Property Inventory & Related Certificate
- ☐ Classified Material Certificate
- ☐ Other _____

Actions have already
been requested

Assigned to: Electromagnetics Laboratory (School/Laboratory)

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A-1874

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STUDY: ANALYSIS OF LANDSAT DATA

FINAL TECHNICAL REPORT /

by

N. L. Faust
Engineering Experiment Station

and

G. W. Spann
Metrics, Inc.

December, 1977

Prepared for

National Aeronautics & Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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(Project A-1874)

Prepared by

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DATA ANALYSIS

In the past the cotton production has not been estimated very accurately until some months after the harvest. This project was to determine the ability of Landsat to detect and measure the area of soybean and cotton fields during growth to allow better crop forecasting. EES analyzed Landsat data for Limestone, Lawrence, and Madison Counties in north central Alabama (Figure 1.) Four dates were selected in hope that comparisons would be made of the cotton acreage estimates as a function of the stage of growth for cotton. The only dates for cloud free scenes were April 5, 1975 (scene 1986-15365), May 11, 1975 (scene 5022-15350), July 13, 1975 (scene 2172-15433), and October 20, 1975 (scene 5184-15253). Ground truth data were also provided by NASA/MSFC in the form of aerial photographs and topographic maps with crop types marked for specific areas.

In June 1977 EES implemented a color infrared simulation of Landsat data on the ERDAS system. Using this technique Landsat data for all four dates have been displayed to determine how much vegetation information is available for cropland for each date. April Landsat data were examined to locate fields, since planting was in process or had just occurred for cotton and soybeans. Figure 2 shows an enhanced image of a production area in Lawrence County. This was verified in the color infrared data for April and also for May (Figure 3). The crops had not yet achieved a sufficient ground cover to change the signature from that of bare soil. October data were also analyzed using the color infrared method (Figure 4). The conclusion drawn from comparing the color infrared data to the ground truth photographs was that almost all cropland had been harvested by the October date, even though there were a few fields which exhibited a tone suggestive of crops. In the interest of being able to estimate cotton and soybean acreage, however, it should be noted that by October most of the crops would have been harvested; thus an acreage estimation for October would have little value.

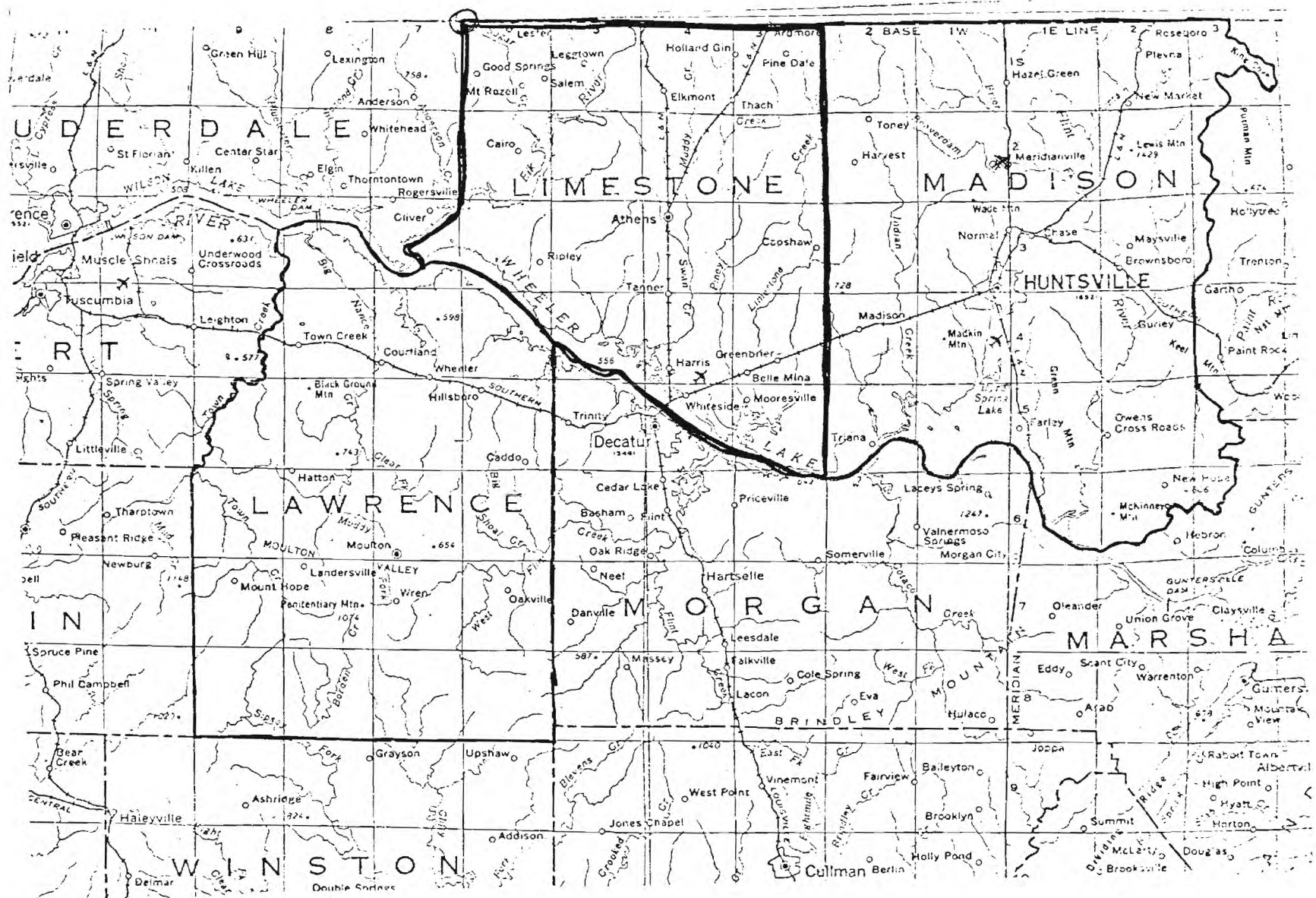


Figure 1. Limestone, Madison, and Lawrence Counties, Alabama.

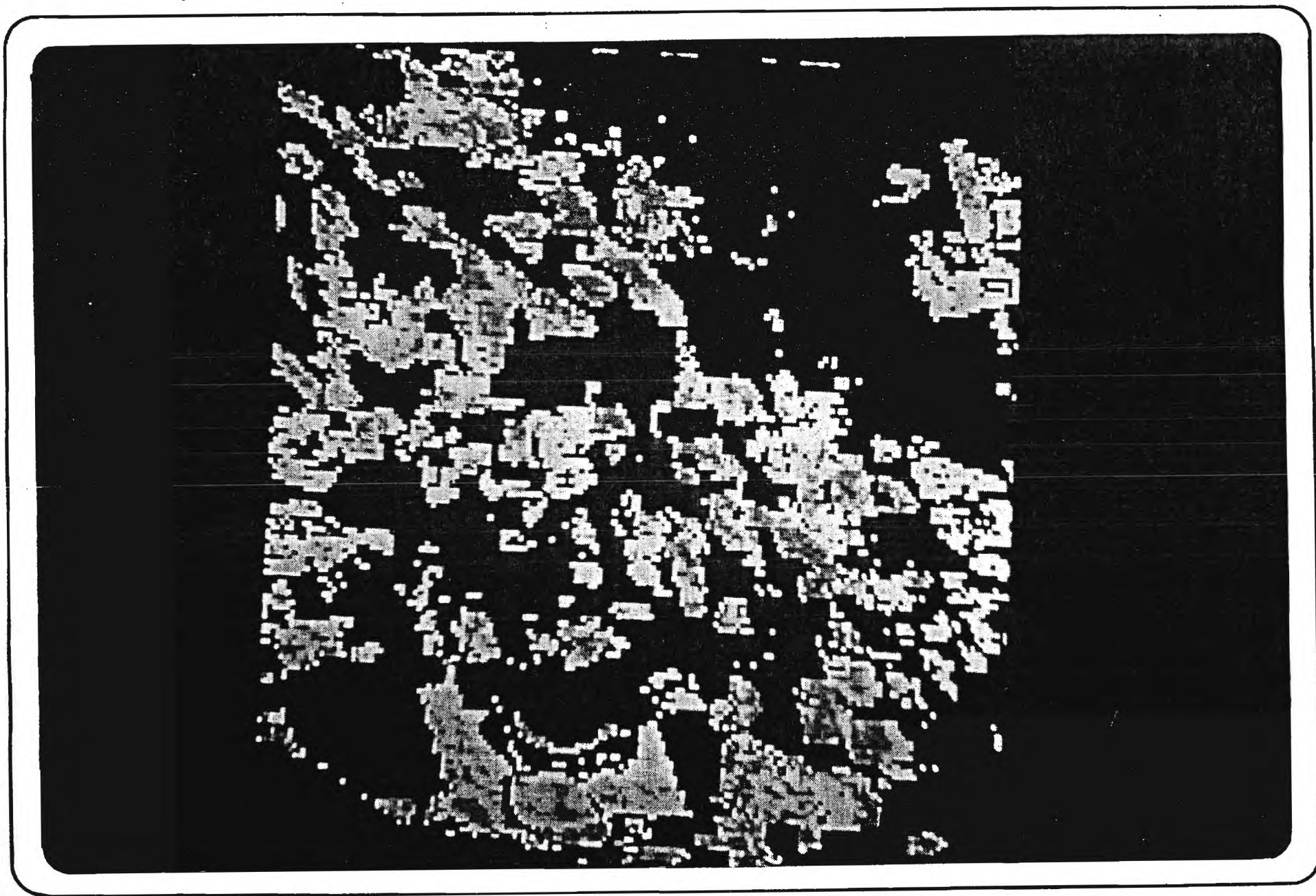


Figure 2. Enhanced Landsat Data, Lawrence County, Alabama.



Figure 3. Color Infrared Image of May Landsat Data for Limestone Co. Alabama.

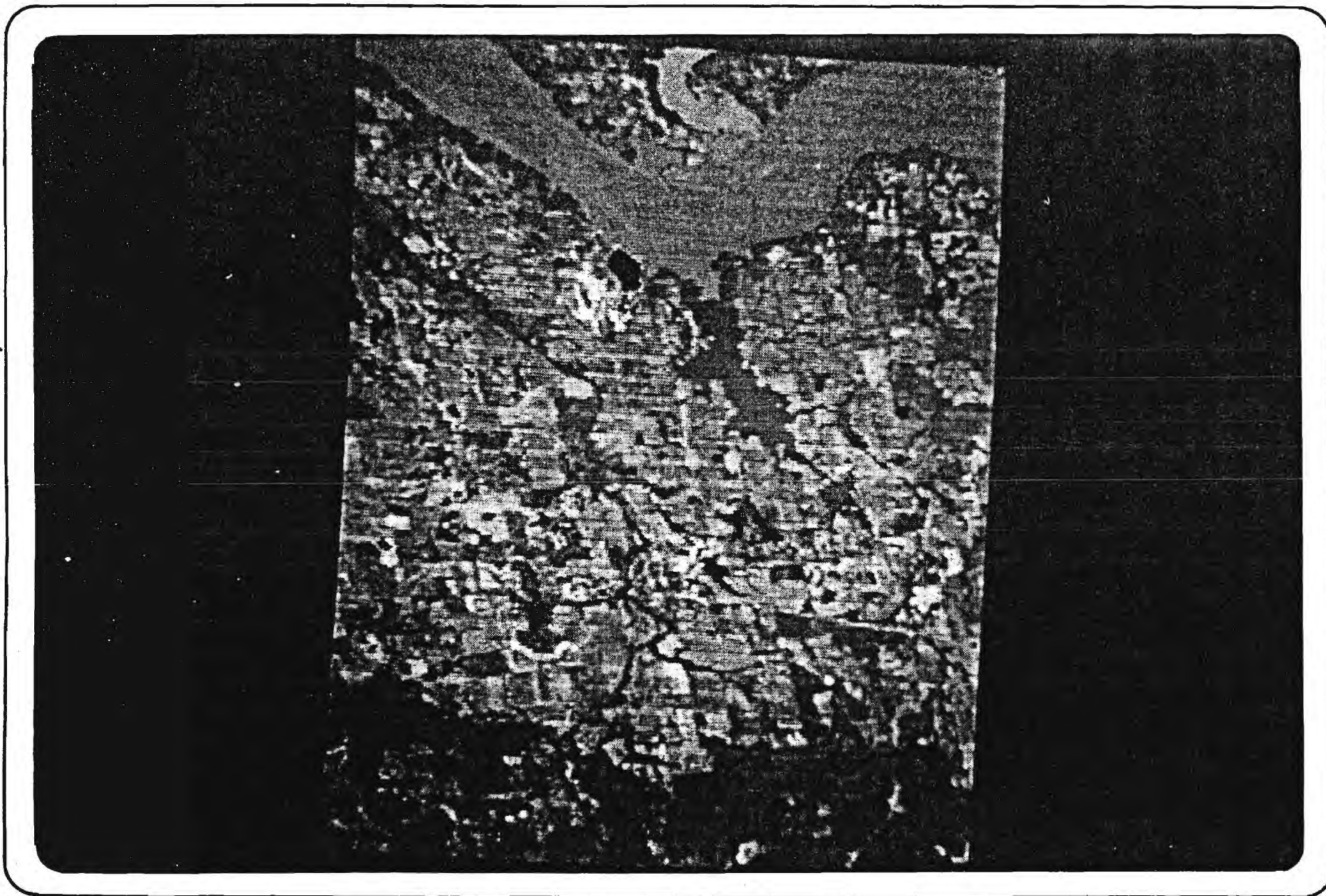


Figure 4. Color Infrared Image of October Landsat Data for Lawrence Co. Alabama.

Even though the April and May data could be used to provide areas of plowed land that would probably be put into some crop, they could not be used for crop discrimination. Because of these observations, it was decided that the effort involved in developing software for multitemporal analysis using eight or twelve channels of superimposed Landsat data was not warranted by the returns expected from the data available for the 1975 growing season.

After viewing the color infrared versions of the Landsat data it was decided that the July data by itself would be the only Landsat data for which potential positive results could be expected in crop discrimination. Using the color infrared images on the ERDAS system (Figure 5), a small subset of test signatures were taken for both soybeans and cotton in training fields in Limestone and Lawrence Counties for which ground truth was available for large fields.

Two large soybean fields were located north of the Tennessee River with slightly different tones on the color infrared image. Signatures for these two fields (Soybean No. 1 and Soybean No. 2) were taken as well as that for one cotton field (Cotton No. 1) (Figure 6a, b). In the Courtland area south of the river two different signatures (Cotton No. 2 and Cotton No. 3) (Figure 7) were taken for large fields noted on the ground truth as cotton. The color infrared image shows obvious tonal differences in the training areas for cotton and soybean fields as indicated on the ground truth information; thus for these test signatures it could be expected that a classification could distinguish between the crops in July. An empirical method for determining if categories will tend to be confused with one another is the plotting of the normal distributions for each test classification in two dimensions for all combinations of channels. For each channel the statistical distribution of normal data is represented by a bell type curve. When one channel's data is plotted against another's it is an ellipse. Two dimensional plots of the class signatures for the two soybean fields and the three cotton fields are shown in Figure 8 and Figure 9 for all

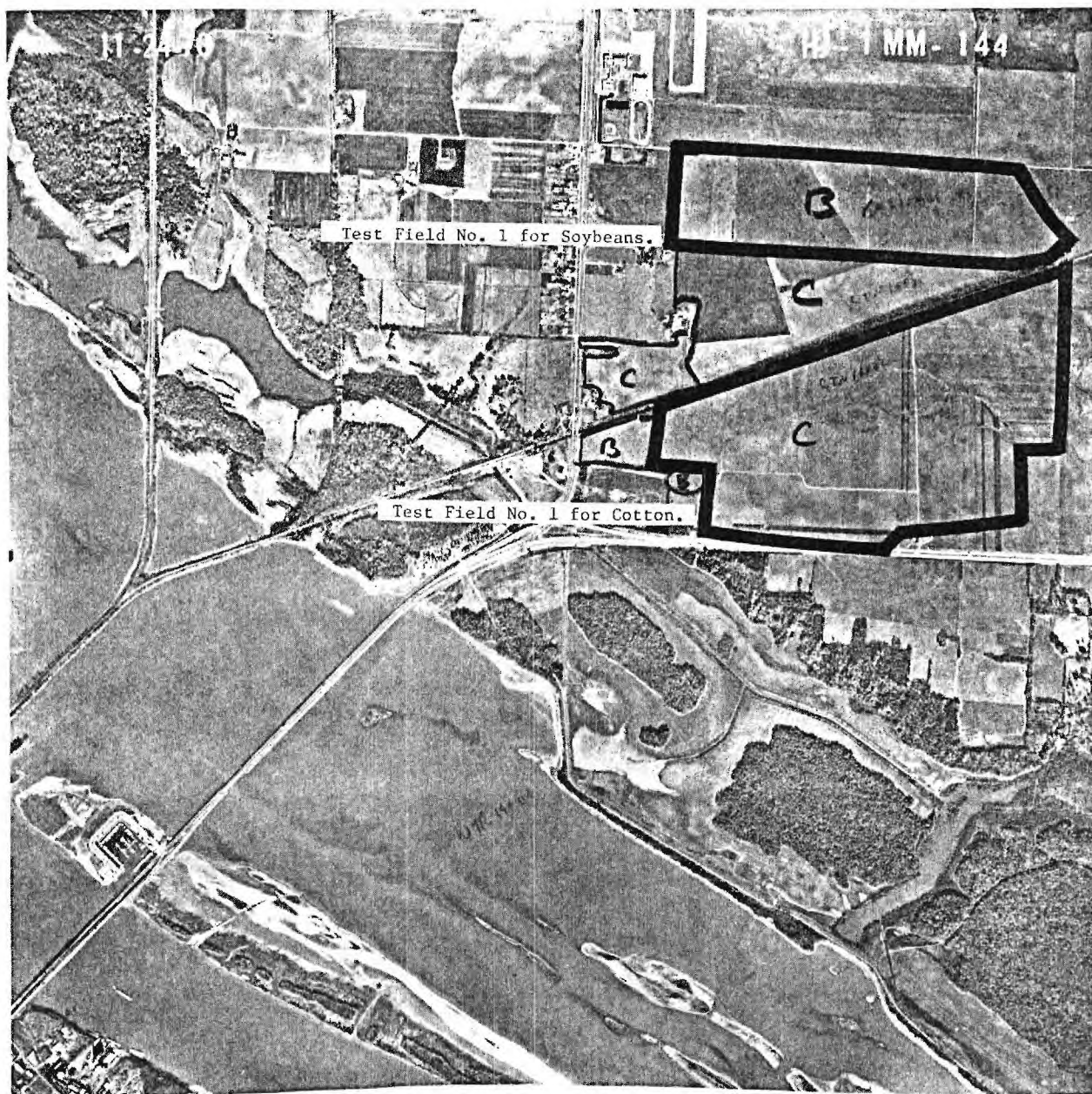


Figure 6(a). Soybean No. 1 Training Field and Cotton No. 1 Training Field in Limestone Co. Ala.

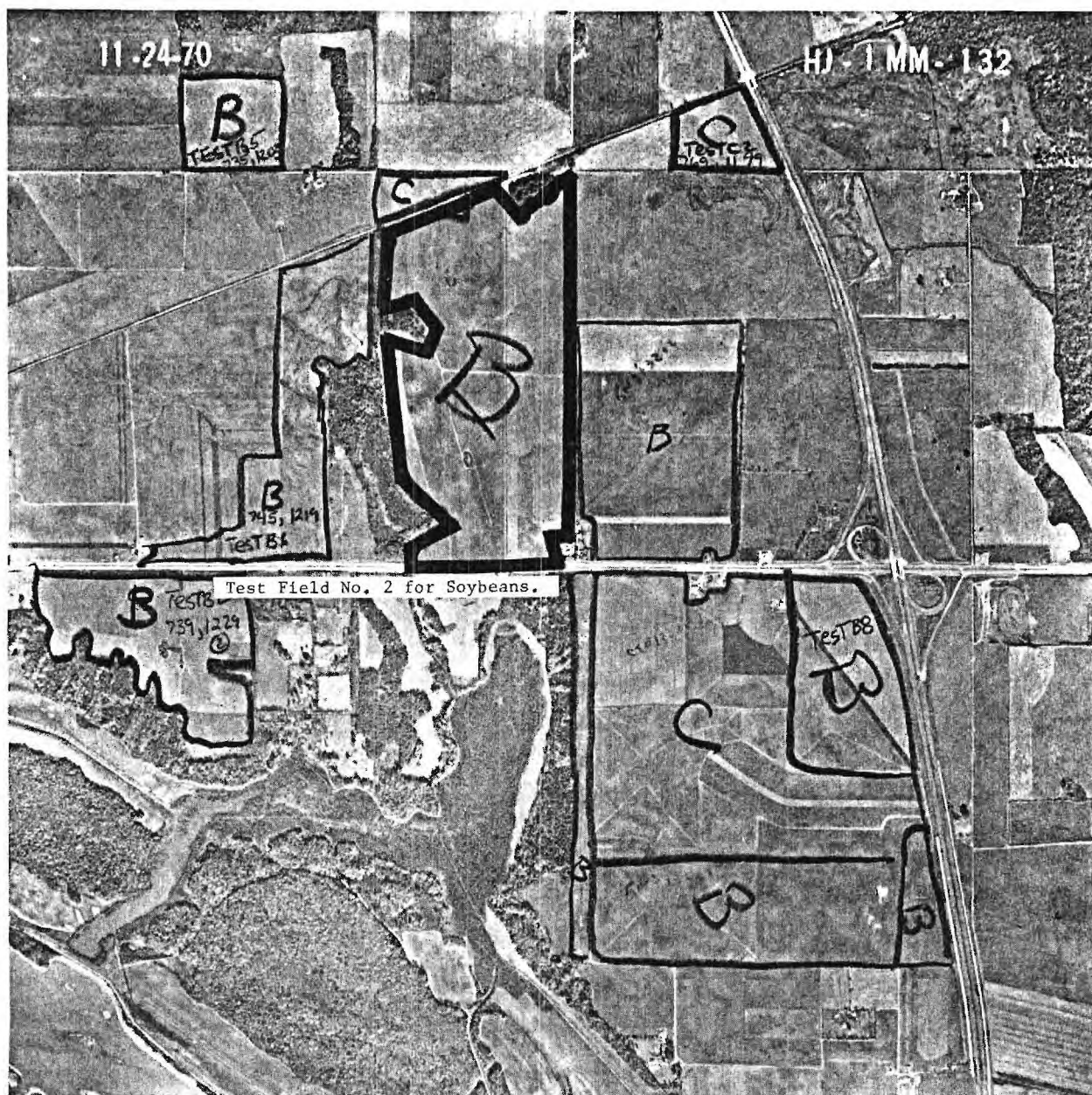


Figure 6(b). Soybean No. 2 Training Field in Limestone Co. Ala.

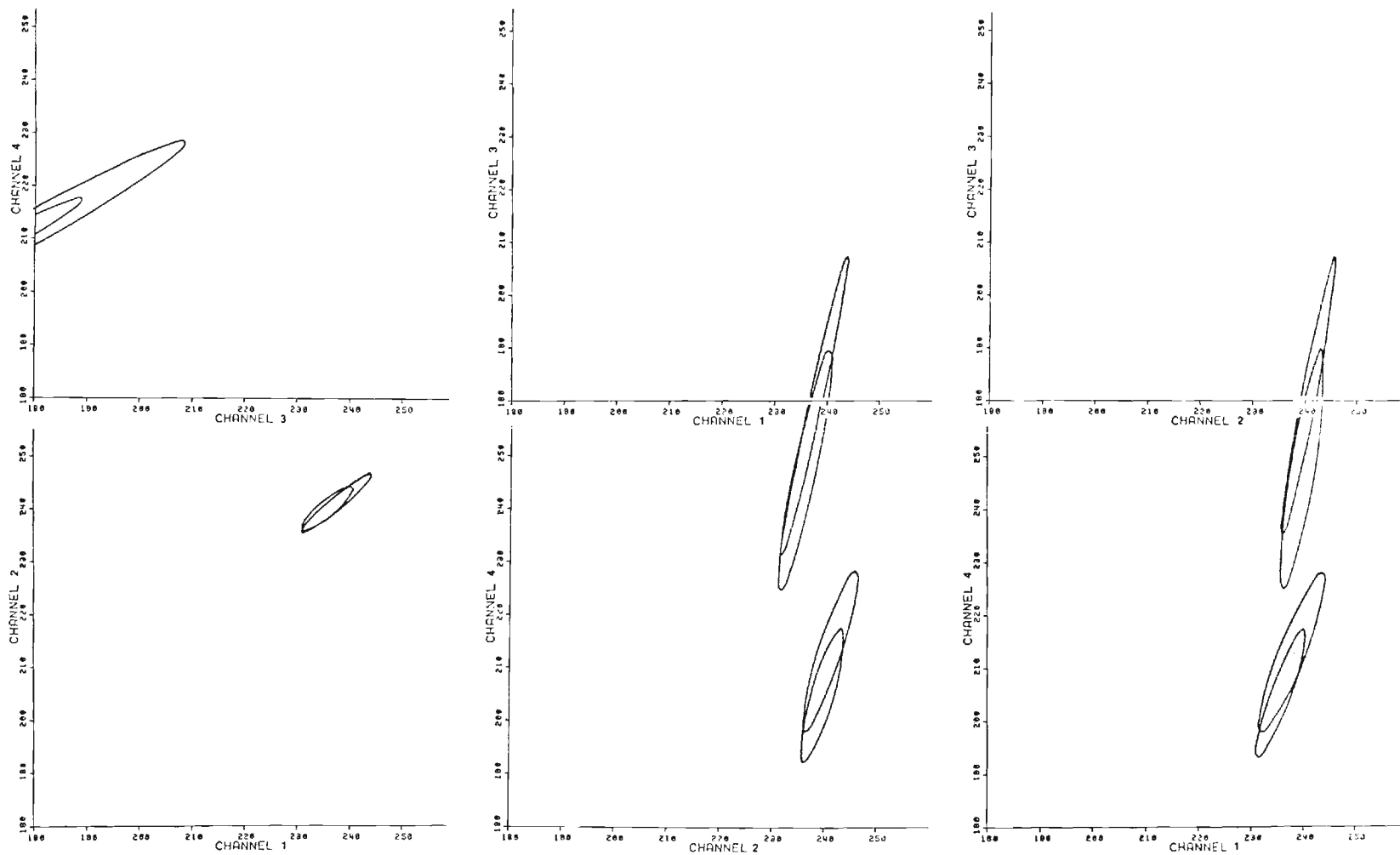


Figure 8. Two Dimensional Signature Ellipses for Soybean Test Signatures in Limestone Co.

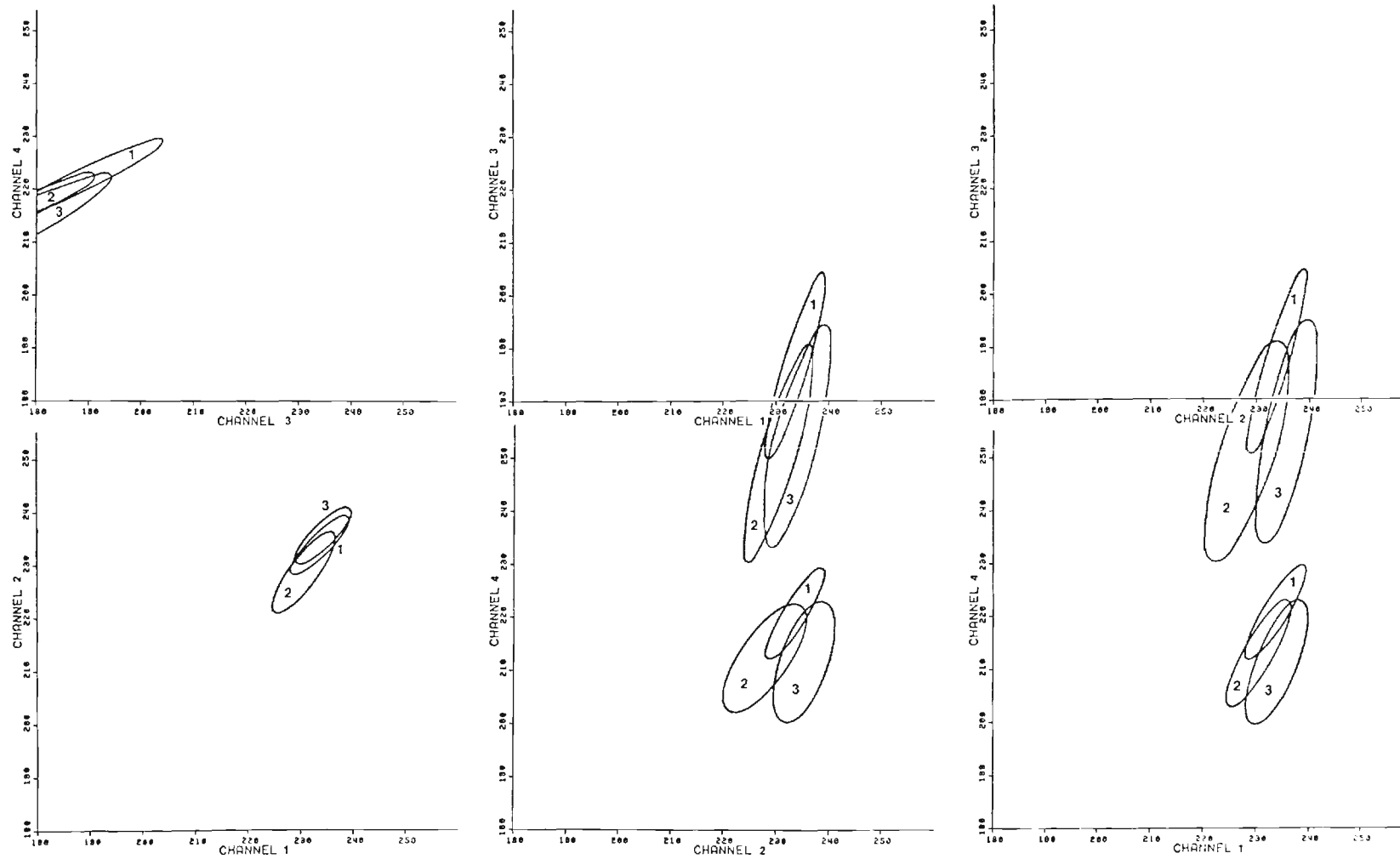


Figure 9. Two Dimensional Signature Ellipses for Cotton Test Signatures in Limestone Co.

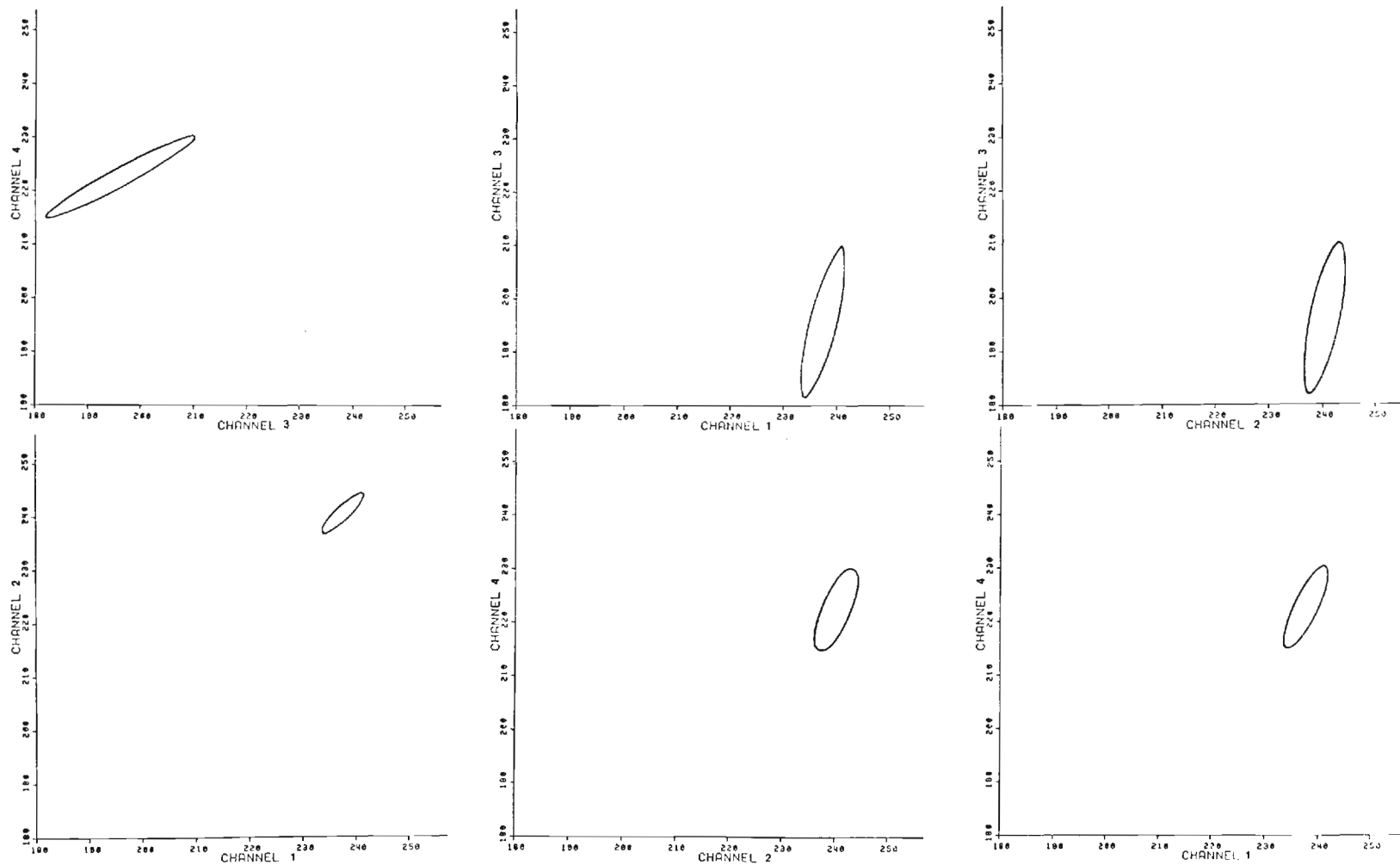


Figure 10. Two Dimensional Signature Ellipses for Forest.

combinations of channels. These plots show the mean and the 3 sigma normal distribution ellipses that contain the data values described by the training fields. Note that the signatures for each of the training fields vary for each crop, depicting possibly a difference in planting date or crop management practice. Nevertheless, by overlaying the ellipses for cotton and soybean for the test fields, it can be seen that there is very little overlap in these signatures for cotton and soybean for July data. Thus it can be assumed that these categories may be differentiated. Figure 10 shows the two dimensional distribution for forest. By overlaying Figure 10 on Figures 8 and 9 it can be seen that forest also can be differentiated from these signatures for soybeans and cotton in July.

As a test of this differentiation, a linear classification was used on the ERDAS system to classify the area from which the training fields were selected. Figure 11 shows the areas classified as Soybean No. 1 in pink with the rest of the scene in the color infrared mode. Figure 12 shows the areas classified as Soybean No. 2, and Figure 13 shows the combination of both soybean classes. Figure 14 shows the areas in pink that were classified as Cotton No. 1. Figure 15 shows the area south of the river classified as Cotton No. 2 in pink and Figure 16 shows the area classified as either Cotton No. 2 or Cotton No. 3 in pink.

During this test classification, however, it also became obvious that not all the ground truth fields were being classified as either cotton or soybeans using the linear classifier. Looking back at the color infrared depiction of Landsat data, it was found that there were some fields coded as cotton or soybeans in the ground truth data that had significantly different colors than the other test fields. Some of these fields (Figure 5) were coded as either soybeans or cotton but showed a brownish white color in the color infrared data indicating that the fields were bare in the July data. This discrepancy could be caused by either very early planting and early harvest of the fields, very late planting of the fields, poor growing conditions, or errors

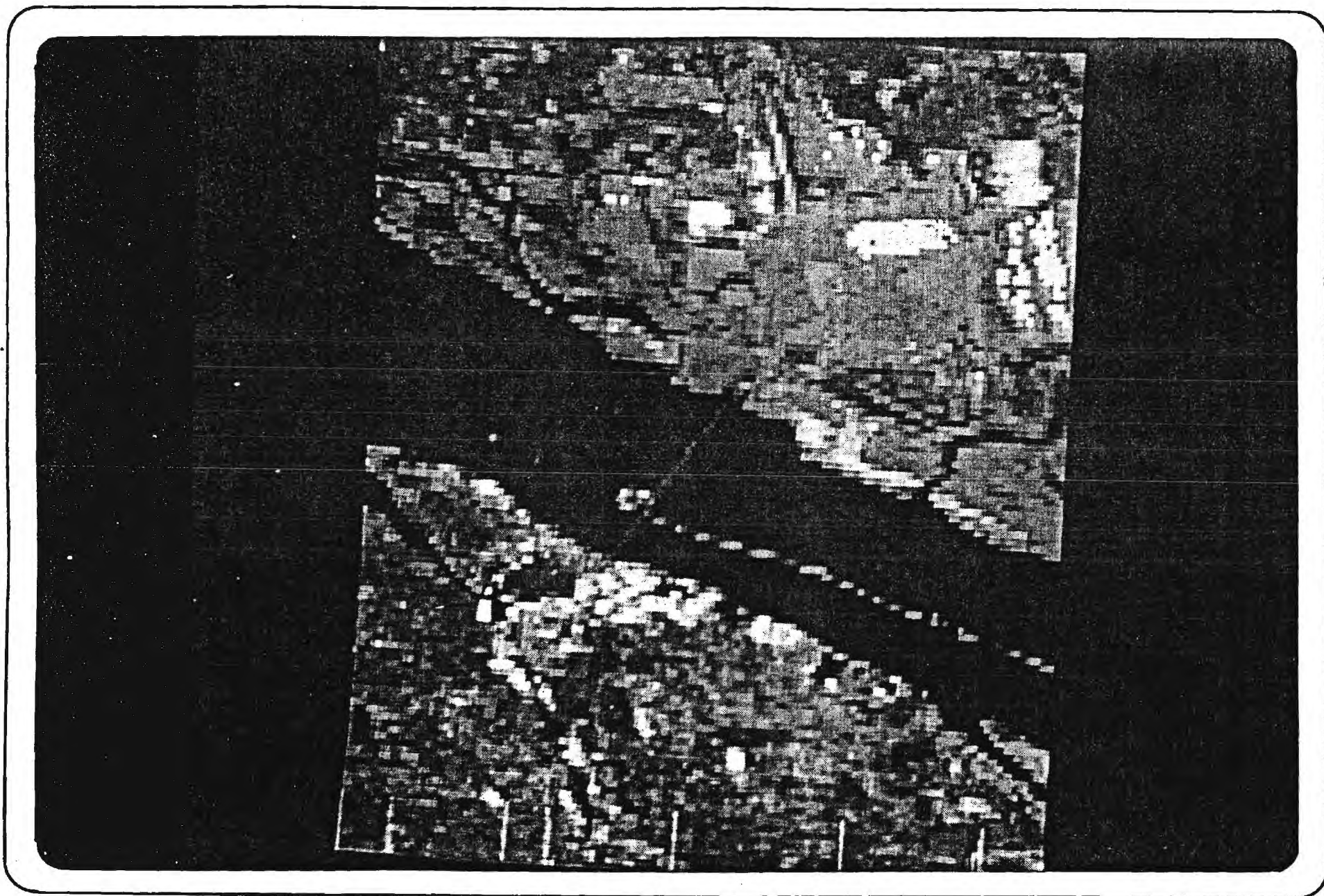


Figure 11. Test Classification for Soybean Signature No. 1.



Figure 12. Test Classification with Soybean Signature No. 2.



Figure 13. Test Classification with Soybean Signatures No. 1 and No. 2.

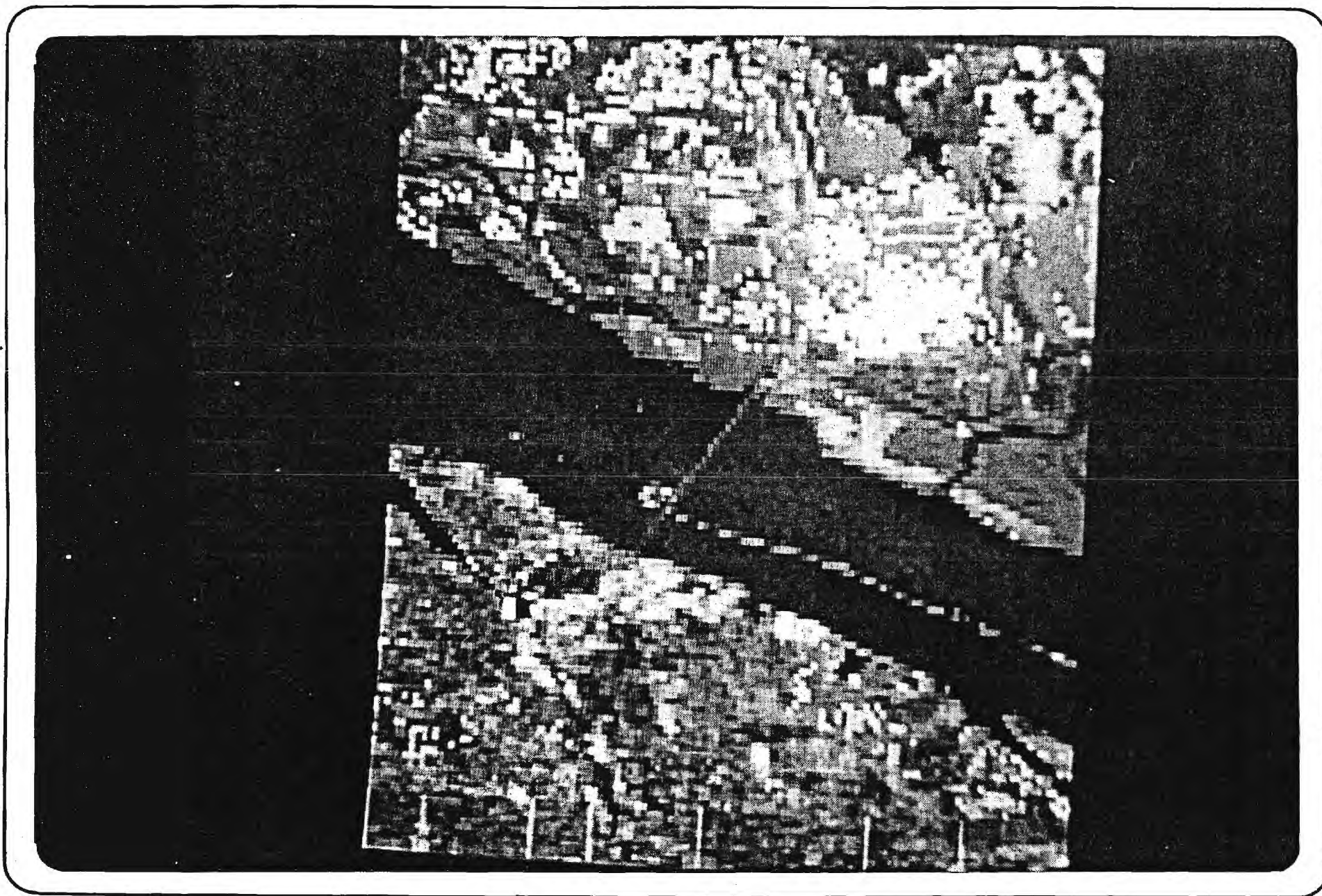


Figure 14. Test Classification With Cotton Signature No. 1.

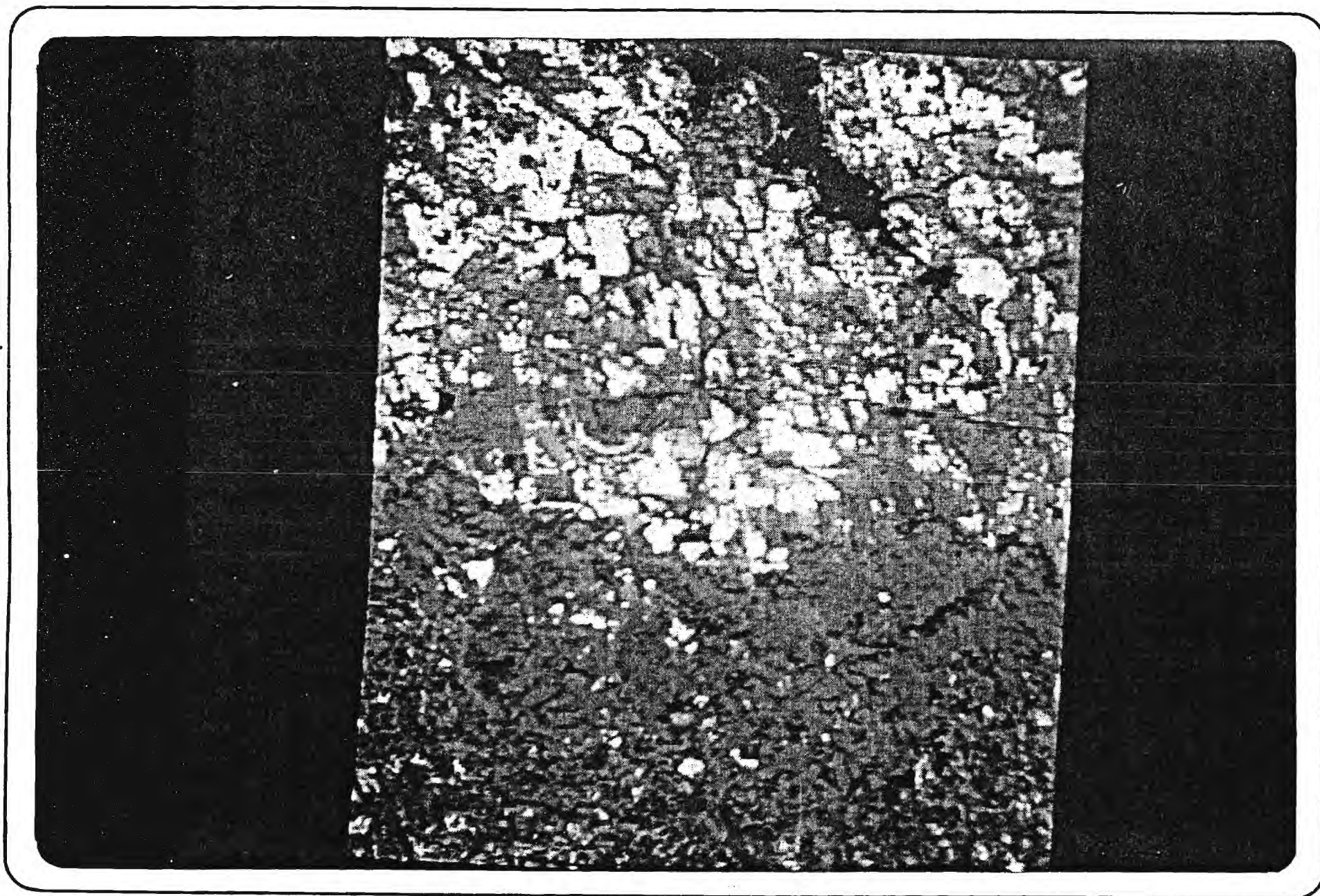


Figure 15. Test Classification with Cotton Signature No. 2.

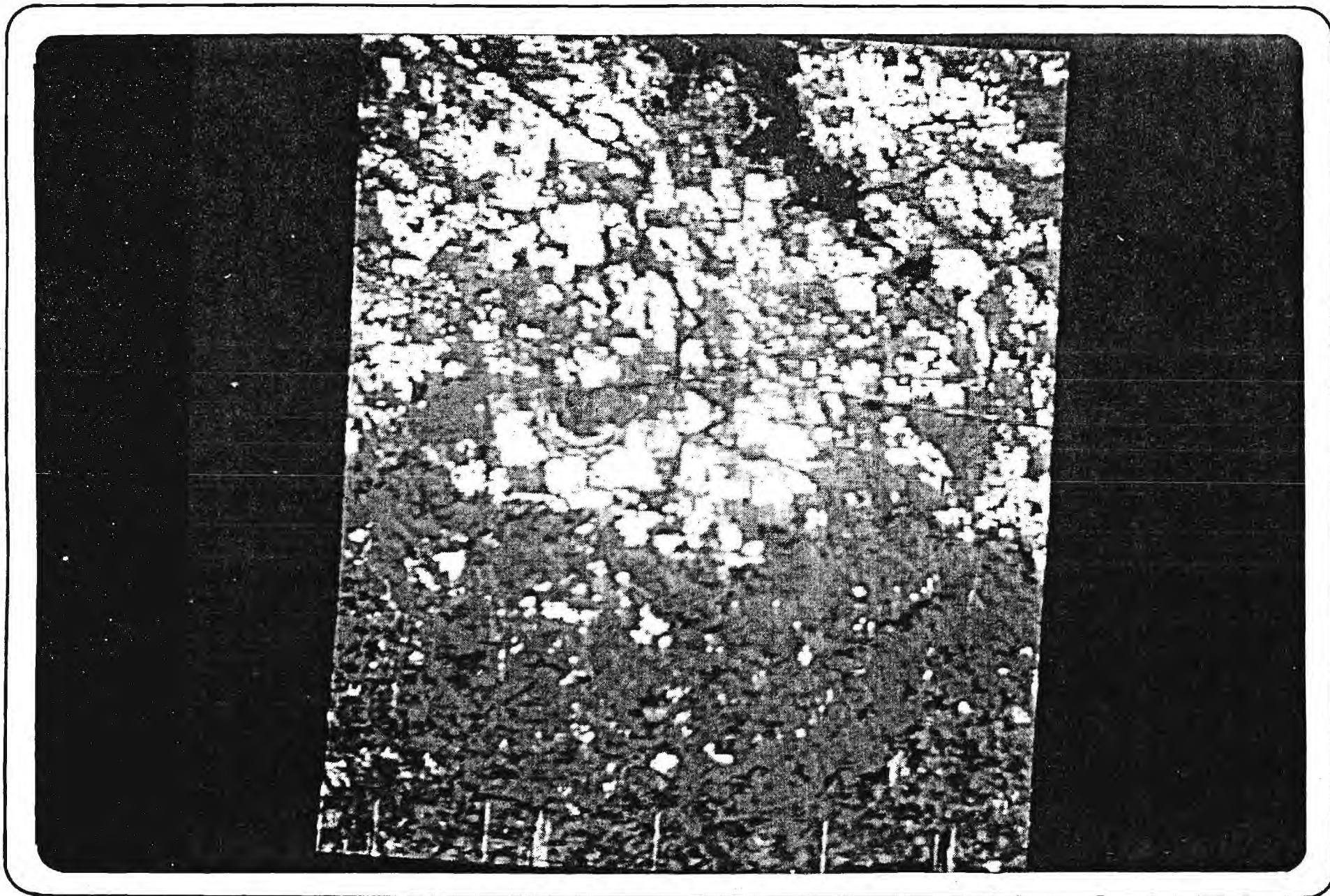


Figure 16. Test Classification with Cotton Signatures No. 1 and No. 2.

in ground truth data. Other fields exhibited a mottled appearance which could be caused by irregular soil moisture patterns possibly due to low areas within fields and time of planting and/or poor growth of the crops.

Since ground truth data are normally assumed to be correct in remote sensing studies, training samples were gathered for the ground truth fields not adequately represented by the cotton or soybean signatures gathered in the test exercise described above. On the near infrared representation, these fields varied from the bright red similar to the test signatures to the light brown signifying a lack of vegetation. Even though no ground truth was available, interpretation of the color infrared Landsat data also enabled us to take signatures for bare land and grass land. Fifty seven fields were used as training fields for cotton, soybeans, urban, water, and forest. Since two dimensional plots of this many distributions would be confusing, plots of the envelope of all ellipses for cotton, soybeans, and forest are given in figures 17, 18 and 19. By overlaying these signatures it can be seen that the overlap between cotton, soybeans, and forest is considerable. Thus, in a classification using these signatures, there are likely to be significant misclassification errors between cotton, soybeans, and forest. No ground truth was available for corn or crops other than cotton and soybeans in the four county area so no signature ellipses could be compiled and no classification could be achieved. Thus, it is suspected that there could be some misclassification of corn and other fields as either cotton or soybeans.

These results tend to support the findings of LACIE that multi-temporal data gathered several times during the growing season is needed for adequate crop discrimination. To test this hypothesis a classification of Limestone, Madison, and Lawrence counties was carried out using the fifty-seven signatures and a maximum likelihood decision rule. The results of the classification were then aggregated by the categories 1) cotton - red, 2) soybeans - green, 3) urban - white, 4) forest - dark green, 5) other - purple and 6) water - blue. The classified

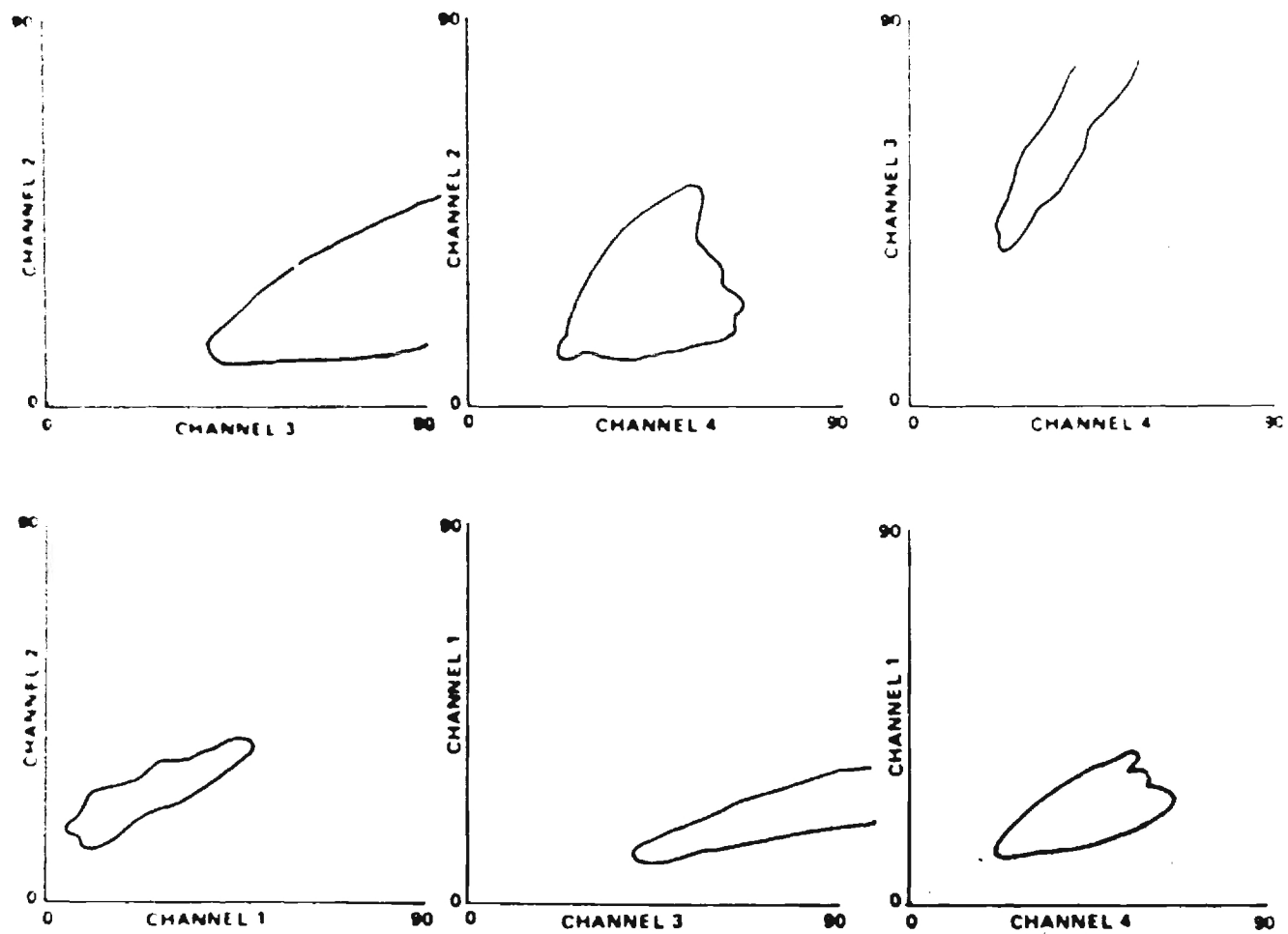


Figure 17. SIGNATURE ELLIPSE ENVELOPES FOR COTTON USING ALL SIGNATURES.

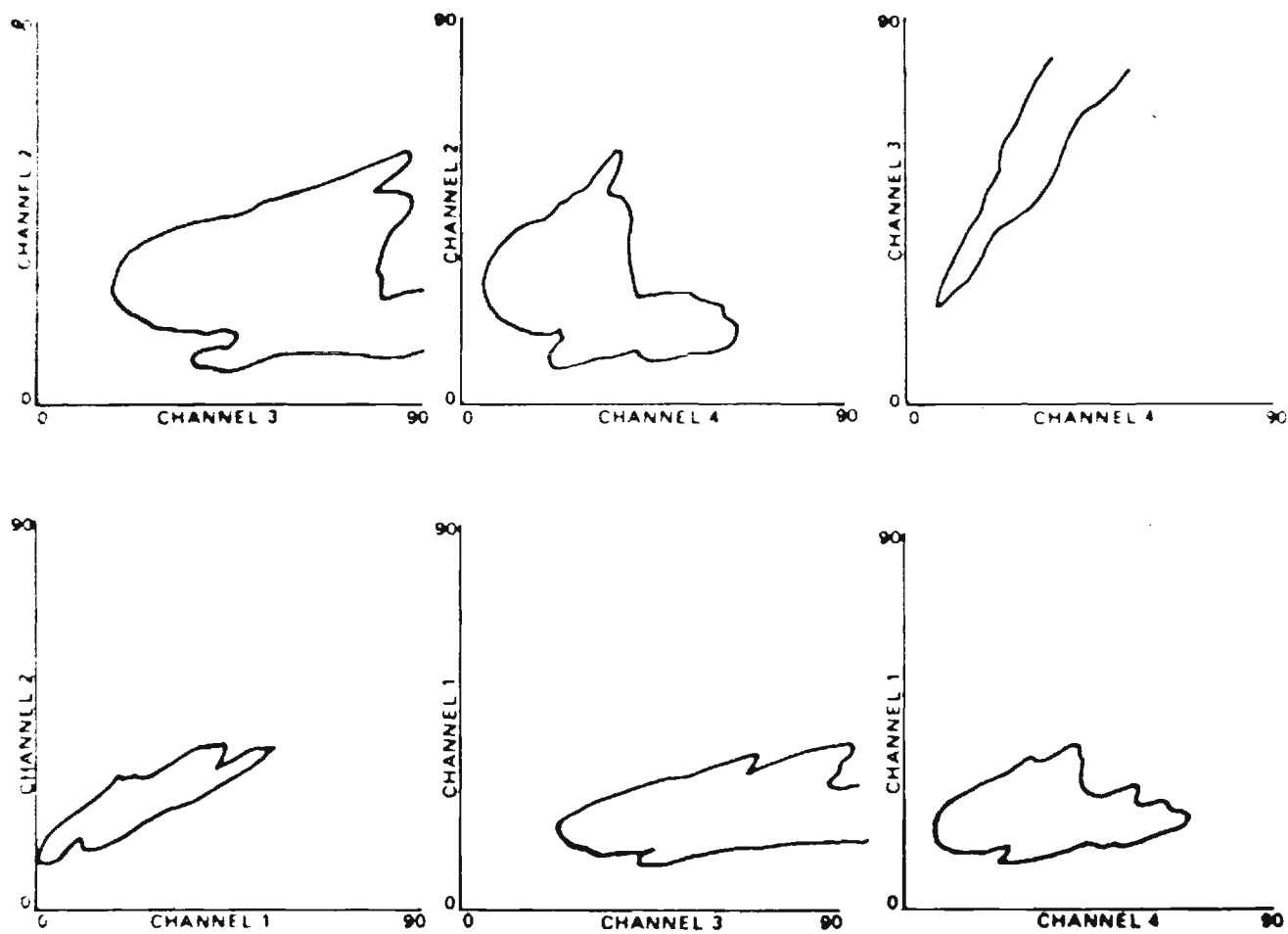


Figure 18. SIGNATURE ELLIPSE ENVELOPES FOR SOYBEANS USING ALL SIGNATURES.

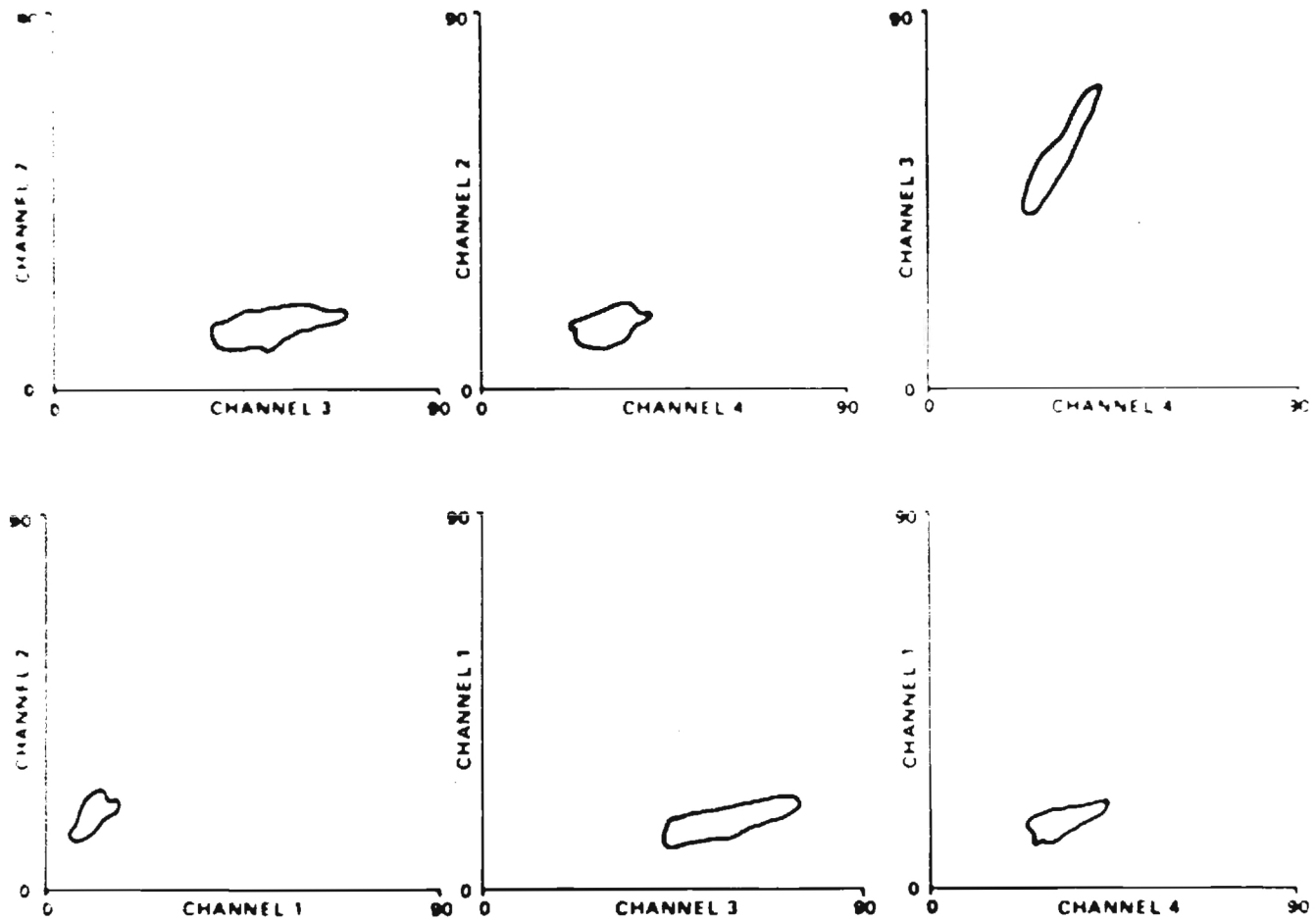


Figure 19. SIGNATURE ELLIPSE ENVELOPES FOR FOREST.

maps are presented in Figures 20a, 21 and 22. Table 1 gives the acreage estimates for each category. Figure 20b is a blowup of Figure 20.

Classification accuracy was calculated by taking twelve test fields not used as training fields and evaluating the percent error within the field. Table 2 and 3 give the classification results for the four cotton test fields and eight soybean test fields distributed throughout the three county region.

The average classification accuracy for all cotton fields was found to be 71% and the average accuracy for soybeans was 56%. These statistics emphasize the general difficulty in separating cotton and soybeans when only one time period of data is used and the class signature variation is very large. Weather conditions or early or late planting could cause the signatures to vary from that of bare land to that of a crop with complete canopy closure. On the other hand, accuracies of 90% and 94% were recorded for cotton and soybean test fields with a strong near infrared signature showing canopy closure and vigorous growth. It would seem then that differentiation between cotton and soybeans could be made for fields in a vigorous stage of growth with canopy closure while fields that have not yet reached canopy closure due to any number of reasons can not be accurately differentiated using data from one time period.

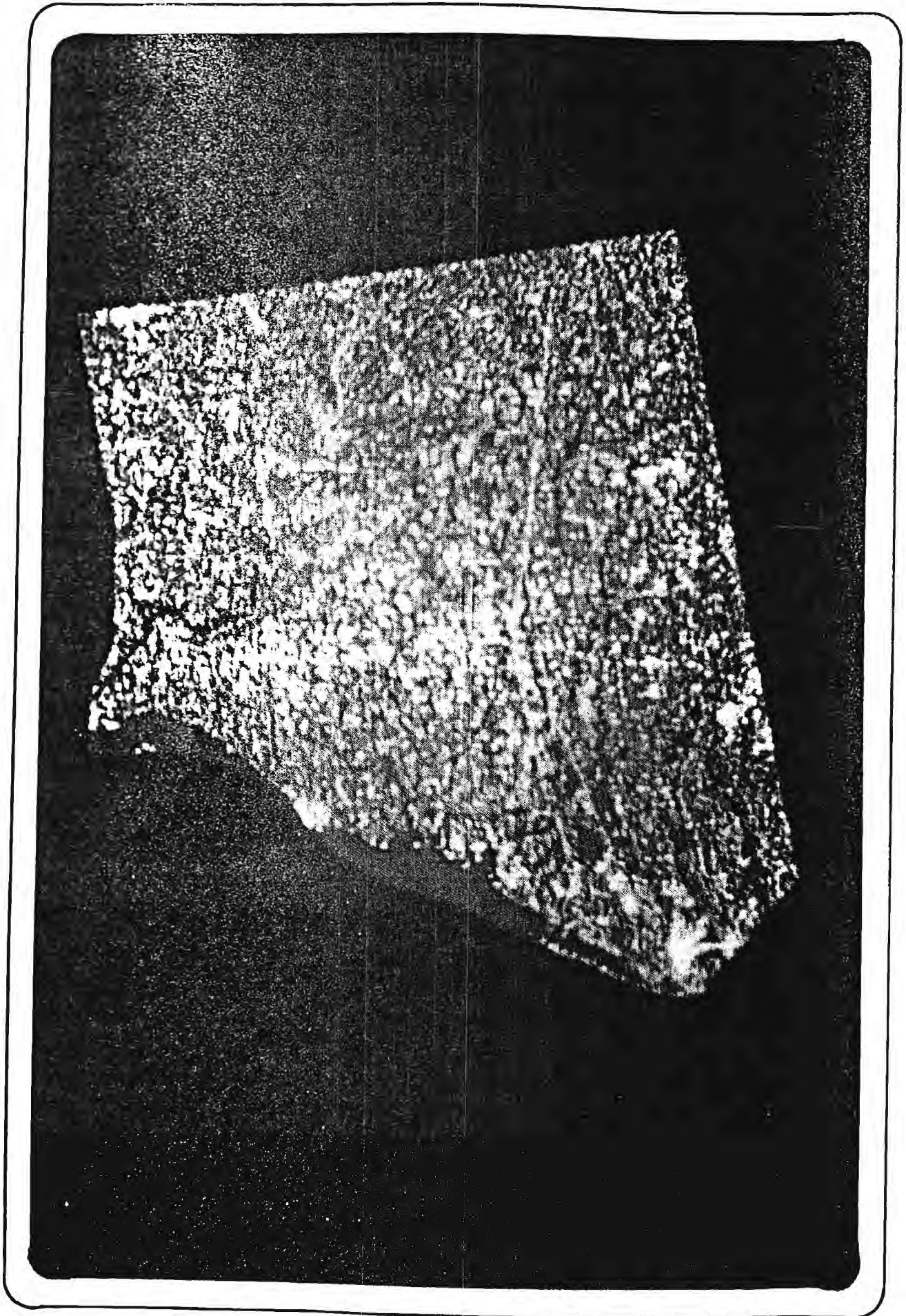


Figure 20(a). Limestone County Classified.

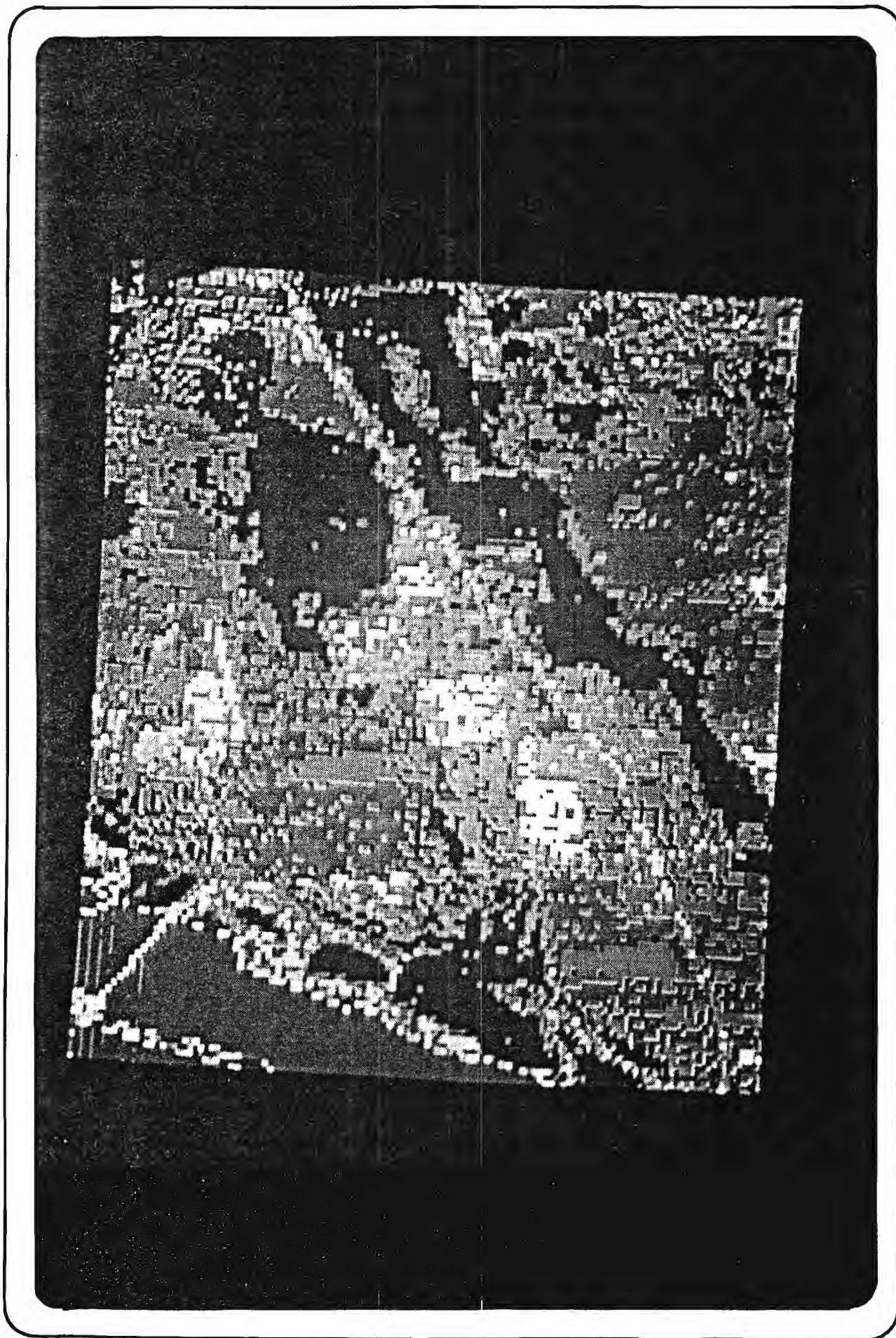


Figure 20(b). Blow-up of Part of Limestone Co.

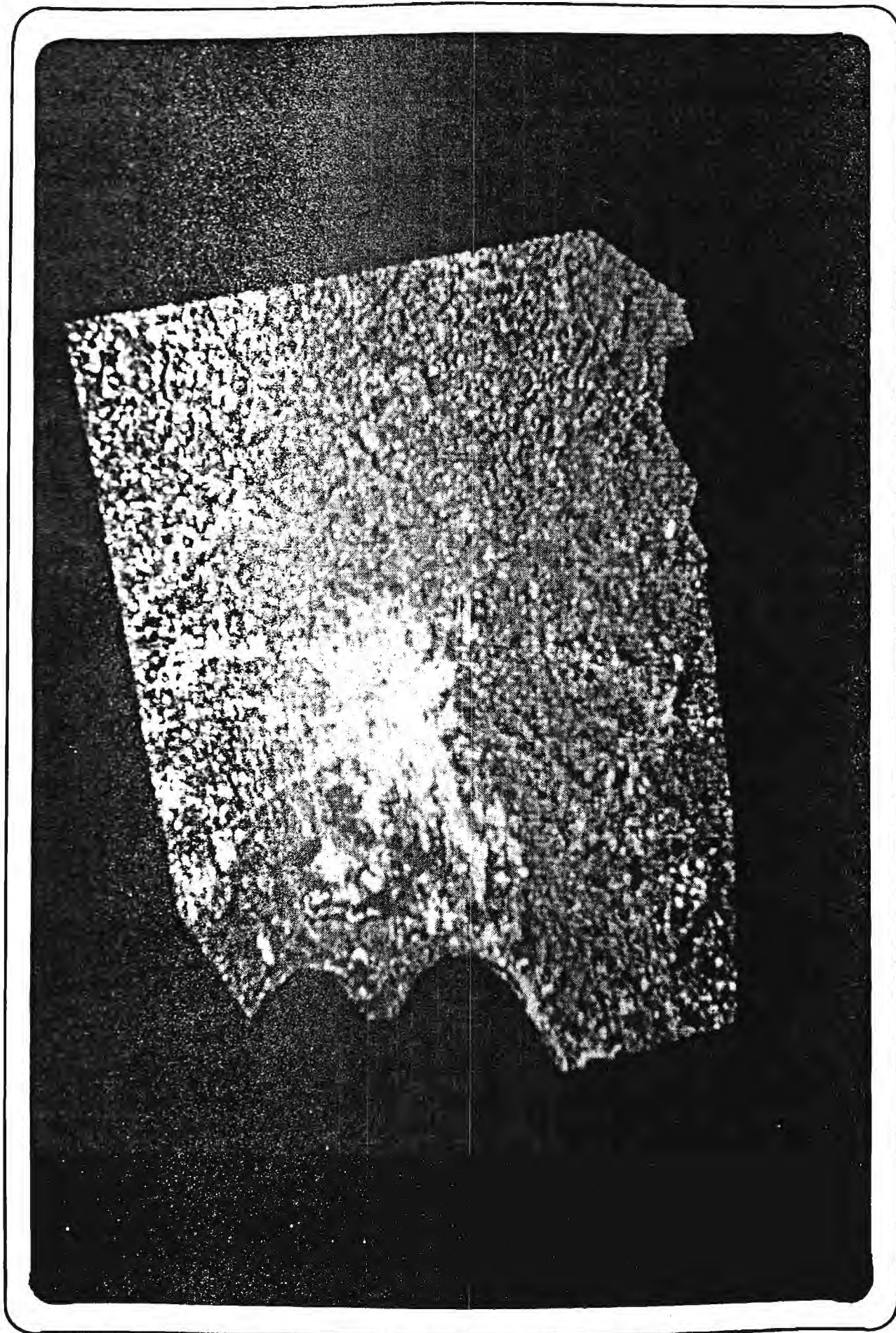


Figure 21. Madison County Classified.

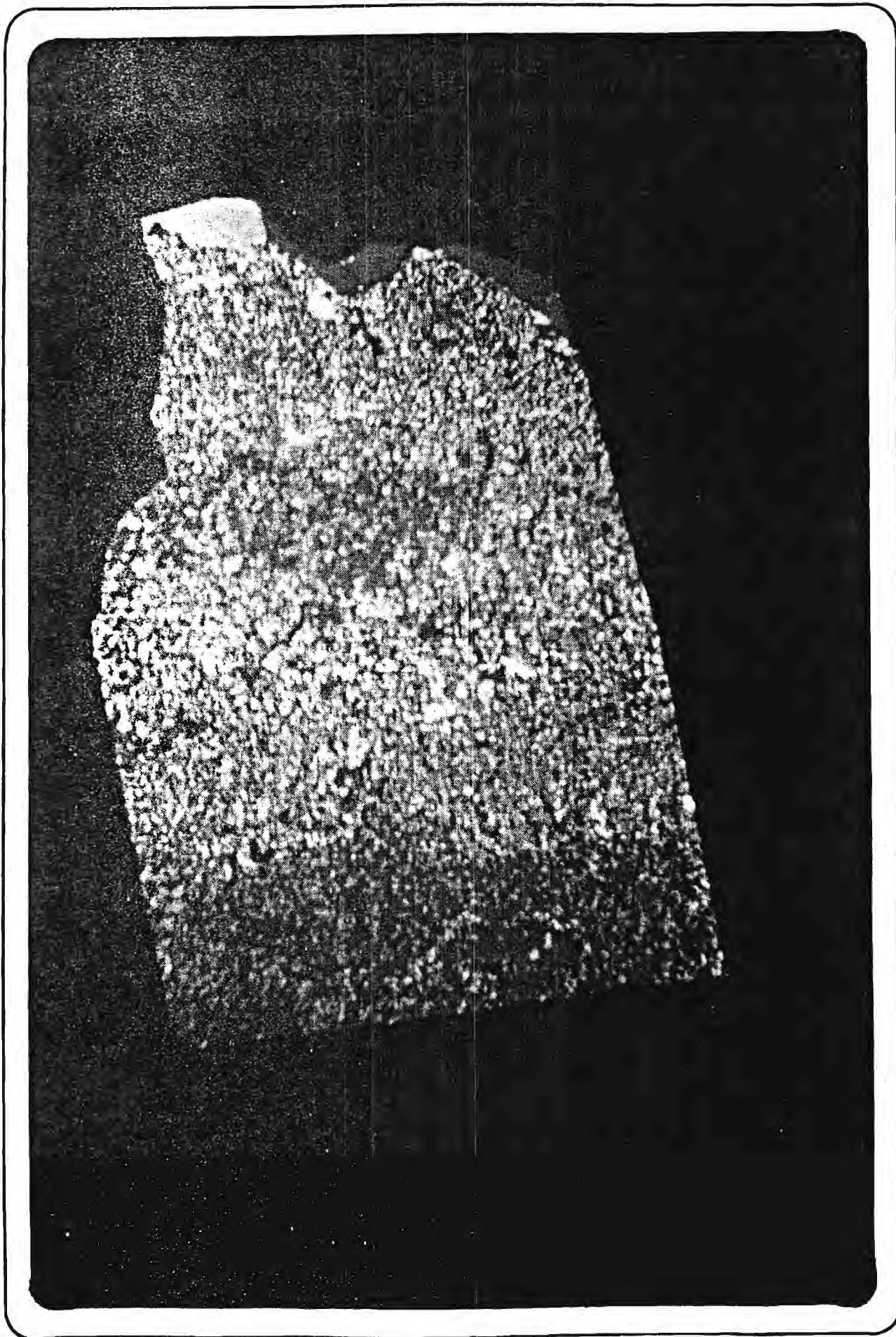


Figure 22. Lawrence County Classified.

COST ESTIMATE FOR COTTON ACREAGE ESTIMATION

In view of the results of this study and of previous LACIE results, it seems that a multitemporal classification scheme is necessary for accurate crop discrimination between cotton and soybeans. For such a technique to be usable, raw Landsat data will need to be registered to raw Landsat data or rectified to a particular co-ordinate system for several time periods. At present, Georgia Tech EES has not yet incorporated a multitemporal capability into the software library; however, techniques for providing this capability are currently in development.

EES does currently have the capability for the rectification of raw Landsat data and relative estimates of the costs for this technique versus rectification of classified data, have been calculated. A cost factor of 2.5 is indicated by preliminary testing.

If a standard maximum likelihood formulation is used for classification, the cost will vary linearly with the number of channels of data. Thus, if data from 3 time periods are combined into a 12 channel data set it may be expected that the cost of classification will triple over that required for four channels. The cost of normal maximum likelihood classification for land cover using the Georgia Tech computer has been computed at approximately one dollar per square mile including training field selection, statistical calculations, and polygon aggregation. At this rate for 4 channel classification, and assuming \$.50 per square mile per date for raw data rectification, the total estimated cost for multitemporal data analysis would be approximately \$4.50 per square mile.

CONCLUSION

The optimum test of such an hypothesis would be a multitemporal classification using data for the current or previous growing season. If detailed information can be gathered throughout a growing season and if Landsat data can be acquired in a timely manner, crop acreage estimation may be a valuable asset to the agriculture industry in America.

Table 1. CLASSIFICATION SUMMARY

	<u>LAWRENCE COUNTY</u>		<u>LIMESTONE COUNTY</u>		<u>MADISON COUNTY</u>	
	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT
COTTON	53,569	12.1	56,390	13.1	70,206	14.8
SOYBEANS	47,666	10.8	63,866	14.8	73,783	15.5
URBAN	4,117	0.9	8,777	2.0	12,853	2.7
FOREST	161,938	36.8	91,174	21.1	142,232	29.9
WATER	9,775	2.2	21,157	4.9	1,340	0.3
OTHER	163,415	37.2	189,826	44.1	175,424	36.8
TOTAL	440,460		431,190		475,838	

Table 2. TEST FIELD RESULTS FOR COTTON

<u>FIELD NO.</u>	<u>COTTON</u>	<u>SOYBEANS</u>	<u>BARE</u>	<u>FOREST</u>	<u>TOTAL PIXELS</u>	<u>ACCURACY (%)</u>
1	16	1	3	0	25	64
2	22	3	1	0	26	85
3	175	84	6	0	265	66
<u>4</u>	<u>46</u>	<u>2</u>	<u>3</u>	<u>0</u>	<u>51</u>	<u>90</u>
TOTAL	259	90	18	0	367	71

Table 3. TEST FIELD RESULTS FOR SOYBEANS

<u>FIELD NO.</u>	<u>COTTON</u>	<u>SOYBEANS</u>	<u>BARE</u>	<u>FOREST</u>	<u>TOTAL PIXELS</u>	<u>ACCURACY (%)</u>
1	0	26	38	0	64	41
2	38	19	0	0	57	33
3	32	18	0	0	50	36
4	26	11	9	0	46	24
5	30	32	0	1	63	51
6	6	95	0	0	101	94
7	0	54	17	0	71	76
<u>8</u>	<u>14</u>	<u>24</u>	<u>7</u>	<u>0</u>	<u>45</u>	<u>53</u>
TOTAL	146	279	71	1	497	56

REFERENCES

1. The Large Area Crop Inventory Experiment (LACIE), NASA Earth Resources Survey Symposium, Houston, Texas, June 1975.
2. Resource Sensing from Space: Prospects for Developing Countries, National Academy of Sciences, Washington, D. C. 1977.
3. Landsat Follow-On: A Report by the Applications Survey Groups, NASA TM-33-803, December 15, 1976.
4. Earth Resources Survey Benefit - Cost Study: Economic, Environmental, and Social Costs and Benefits of Future Earth Resources Survey Systems, Earth Satellite Corporation and Booz-Allen Applied Research Corporation, Washington, D. C.
5. The Economic Value of Remote Sensing by Satellite: An ERTS Overview and the Value of Continuity of Service, ECON Incorporated, Princeton, N. J. 1974.
6. Earth Resources Information Systems, Report prepared by the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U. S. House of Representatives, Washington, D. C. November 1977.
7. Earth Resources Information Satellite System Act of 1976 - Senate Bill S.3759, 94th Congress, Washington, D.C. August 1976.

APPENDIX A

THE ERDAS SYSTEM

The Georgia Tech Earth Resources Data Analysis System (ERDAS) was designed and constructed by EES to allow true interactive digital processing of all types of remote sensing data (Figure A-1). ERDAS consists of a set of 4 modules: 1) minicomputer subsystem, 2) input medium, 3) hardcopy output medium, and 4) display subsystem.

The minicomputer subsystem consists of a NOVA-2/10 minicomputer with 64000 bytes of core memory and a dual Diablo disk system with 5.0 megabytes of storage for programs or data.

The input medium for the ERDAS system is a set of two nine track dual density (phase encoded/NRZI selectable) magnetic tape drives and controller -- each drive with a capacity for 10 1/2 inch reels of tape.

The hardcopy output medium is a twenty inch electrostatic dot matrix printer/plotter. Scaled maps of Earth Resources data can be made using this medium. A CROMALIN^(R) photographic process may then be used to generate a color coded output hardcopy product. Color products may also be obtained through a service offered by a commercial producer of film writers.

The display subsystem consists of a high quality video monitor that is interfaced to the minicomputer for complete user interaction in the choice of training samples for earth resources classification.

Elements of the subsystem are:

1. Color monitor
2. Trackball cursor
3. Self contained refresh memory
 - a. one image 512 x 512 elements by 8 bits or
 - b. three image 256 x 256 elements by 8 bits

ERDAS is a completely software oriented system. Training statistics can be calculated instantaneously for cursor located fields. A histogram may then be displayed to check homogeneity of training fields.

Classification may be performed on stored data sets or data sets read in from the system's magnetic tape drives. This system is inherently interactive, and ratioing of MSS bands, level slicing, classification, and change detection software will provide display data to be fed to the color monitor.

The EES ERDAS System may be used in either of two general modes. In Mode 1 an image may be displayed on the display screen with a resolution of 512 by 512 elements with data values ranging from 0 - black to 255 - white. These data values may be color coded via a pseudo color memory to produce a false color display of the image. The user may select sixty-four display colors from a possible variety of 4096 colors (4 bits for each color gun). The colors are arranged in the pseudo color memory such that data values 0 - 3 are assigned to the first color values, 4 - 7 are assigned to the next, etc. A pseudo color scale that is often used varies from dark blue to green, yellow, orange, and red with different shades and combinations of these colors filling out the chart. This method is often used in displaying an image in as nearly a natural color state as possible (Figure A-2).

In addition to the pseudo color capability of the ERDAS System, it also has the capability of passing the original data values through a function memory before the data are displayed. As with the pseudo color memory, this function may be selected by the user. For example, if a linear function memory with a slope of one is to be used, a value "0" would be coded as a zero, a 10 as a 10, and so on. After the value of 127 is coded to a 254, all subsequent values would be coded as 255. The function memory may be envisioned by a two dimensional grid with the bottom axis as the original data value and the vertical axis as the coded data value. The two examples given above are shown in Figure A-3. A logarithmic example is also given in Figure A-4. This capability allows the dynamic density stretching or compression of any image by linear or nonlinear functions. In all cases the data in the image memory remains the same as the original image. The function only operates on the image that is displayed on the television screen.

The second mode of the ERDAS System has a resolution of only 256 by 256 elements on the television screen but three Landsat or other images may be displayed at the same time. As before, each image contains data values between 0 and 255, but in this case each image may be assigned specifically to one color gun of the television (Figure A-5). For Landsat data, normally three of the four channels of Landsat data are assigned to individual color guns. If channel one and channel two (visible bands) of Landsat data are applied to the red gun, a simulated near infrared image is displayed on the screen. This type of picture incorporates three channels of Landsat data at one time and results in a very similar color scheme to that of color infrared aerial photography. This technique has been most effective in the location of training fields for Landsat classification (Figure A-6) and as an aid in interpretation of the raw Landsat image.

All of the function memory and pseudo color memory operations discussed above may be performed in this mode also for each of the three images. For example, three different functions may be applied to the three images and the result shown as an enhanced color infrared display.

The remote sensing data at EES are processed by one or more picture processing computer programs. Basic analysis modules available are"

1. Supervised Classification (Maximum Likelihood)
2. Linear Supervised Classification
3. Sequential Unsupervised Classification (Clustering)
4. Non-Sequential Clustering (ISODATA)
5. Histogram Generation
6. Level Slicing
7. Registration and Rectification
8. Factor Analysis
9. Grey Scale Display
10. FFT (Fast Fourier Transform)
11. Change Detection
12. Polygon Training Field
13. Polygon Classification
14. Edge Enhancement
15. Ratioing

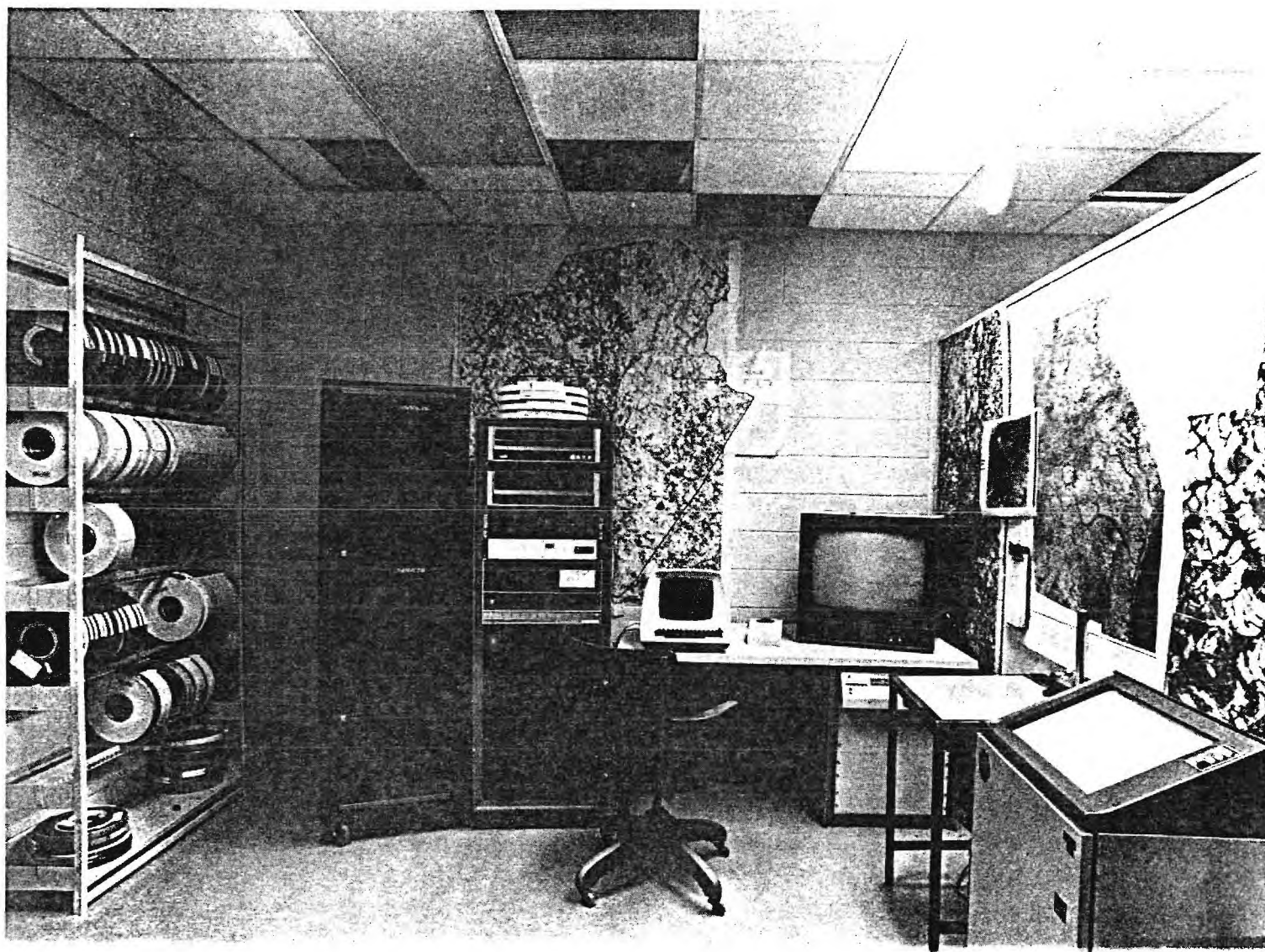


Figure A-1. ERDAS System

ONE LANDSAT
SPECTRAL
CHANNEL

IMAGE
GREY
SCALE
VALUES
0-255

RESCALE
DATA
VALUES

FUNCTION
MEMORY

0-255
GREY
SCALE
IMAGE

COLORCODE
DATA VALUES

PSEUDO
COLOR
MEMORY
64 COLORS

64
COLOR
IMAGE

FIGURE 2. Color Video Display - Mode 1

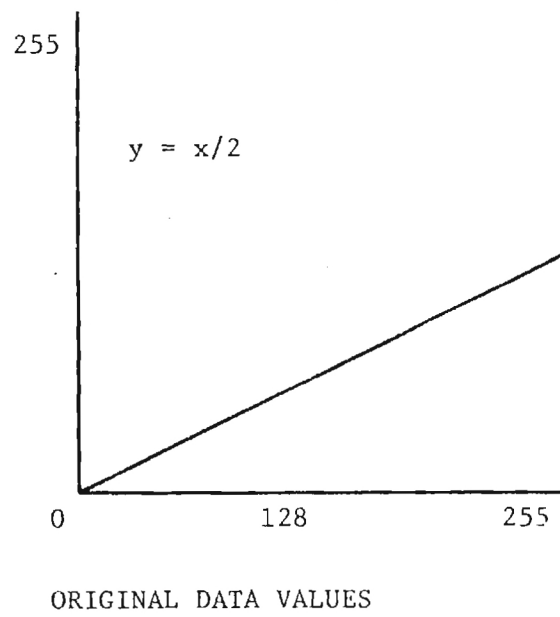
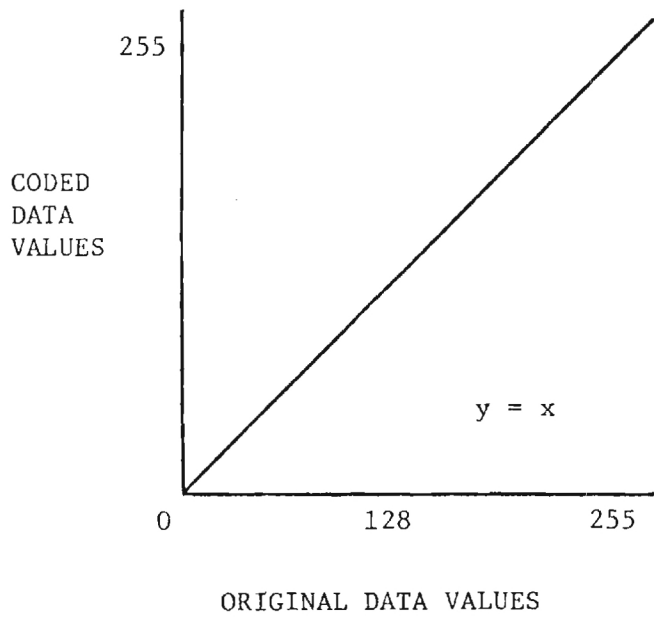


FIGURE 3. Linear Function Memory Example

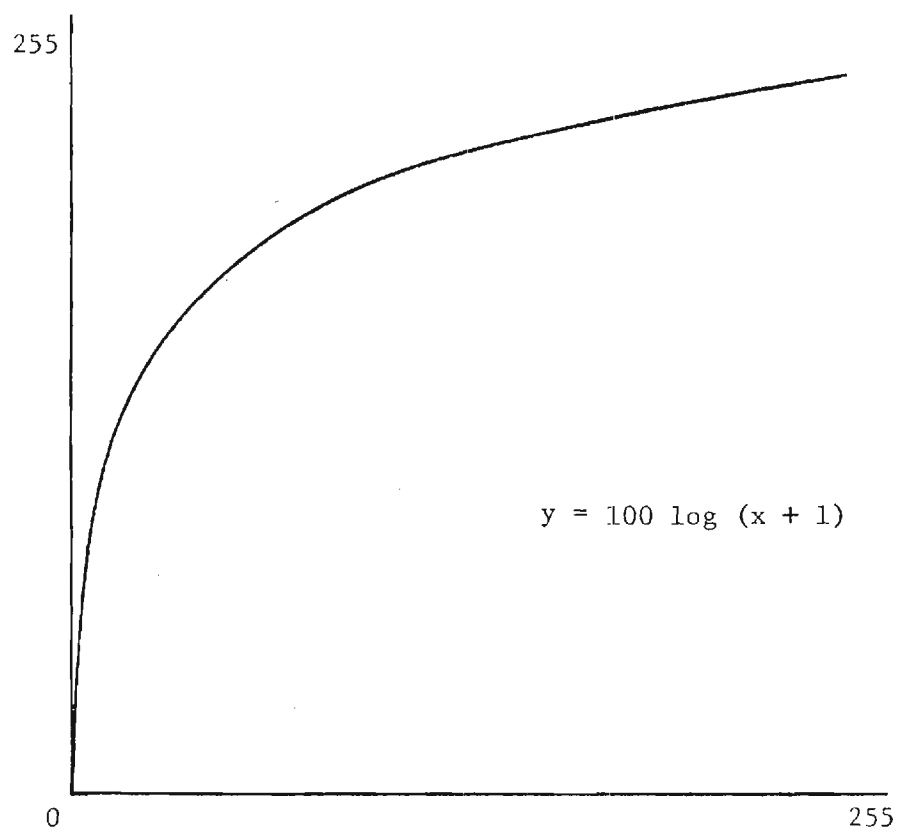


FIGURE 4. Logarithmic Function Memory

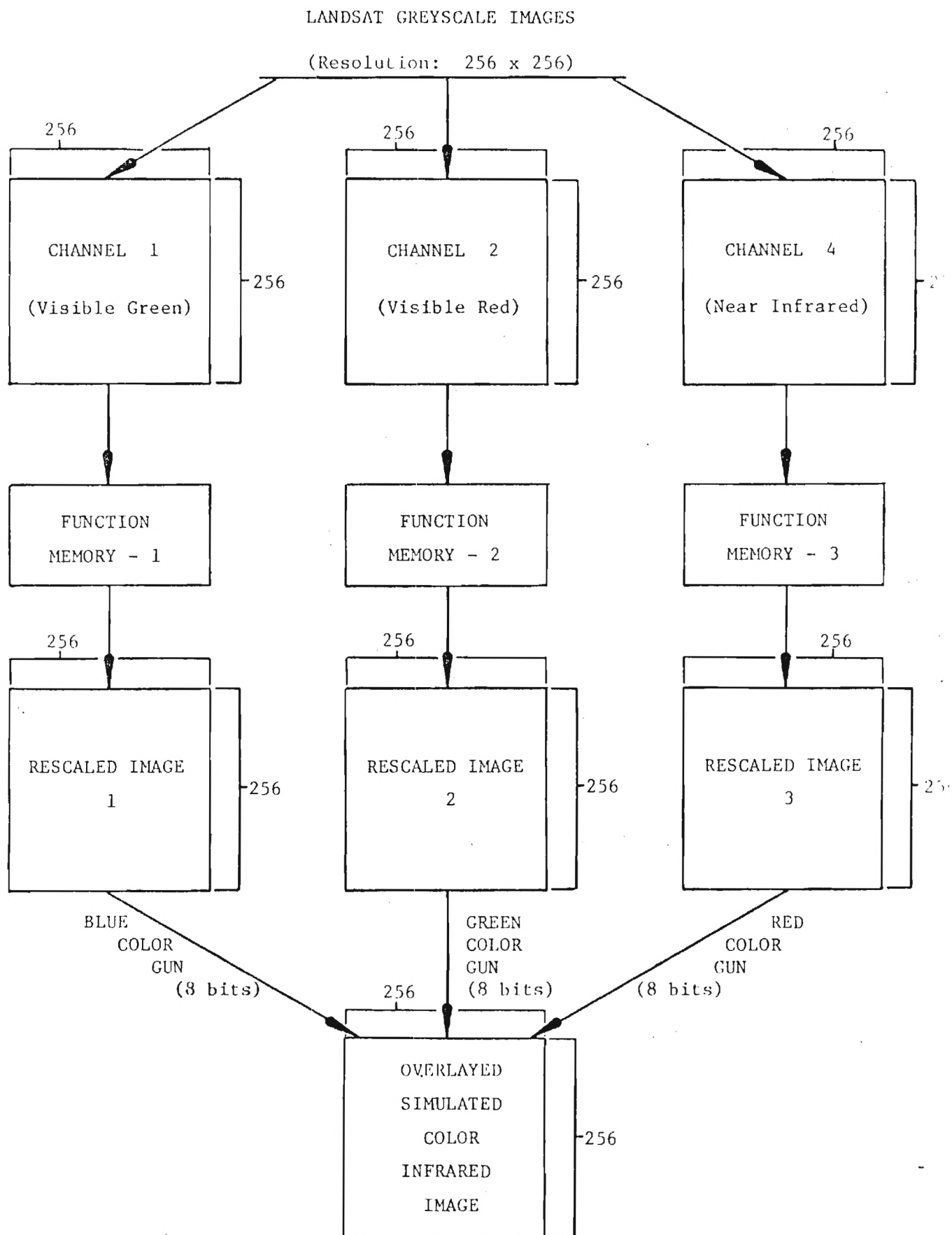


Figure 5: Block diagram of Mode 2 of the Color Video Display.

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and

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INTRODUCTION

Study of geology in the southeastern United States is a complex field due to a variety of geologic provinces ranging from intensely metamorphosed rock to sedimentary rock. Much is left to be done to adequately describe these complex structural relationships and mechanisms for their formation. For many years remote sensing in the form of aerial photographs has been used in geological interpretation, and techniques for visual interpretation are fairly well advanced. Recently, with the advent of photography and multispectral scanner data from space platforms, the use of remote sensing for geology has accelerated due to the almost orthogonal perspective and large area coverage of satellite data such as Landsat. In fact, the mineral and petroleum exploration industries are by far the major purchasers of Landsat data.

Example projects using Landsat data for delineation of geologic boundaries abound in remote sensing literature; however, most of the successes of geologic rock type recognition have occurred in arid regions of the world with little if any vegetated cover. Computer processing of Landsat data has extended the accuracy of rock type recognition in arid areas but there are few examples of even computer processed Landsat data where direct rock type recognition has occurred in vegetated regions such as the Southeast. Because of this vegetative cover of major rock formations, indirect means must be used for geologic interpretation.

Investigations were conducted during this study to determine the usefulness of digital Landsat data for several geologic applications in Georgia and Alabama. First, geobotanical relationships were investigated along a fault zone in middle Georgia. Secondly, the ability of digital Landsat to identify potential sink hole areas in south Georgia was tested. Lastly, a study of the ability of Landsat data for locating strip mines was performed.

GEOBOTANICAL INDICATORS

EES has applied computer processing techniques and pattern recognition algorithms to the definition of areas where possible geobotanical relationships might exist in the Southeast. These methods locate vegeta-

tive trends which may be related to the underlying geology. In past efforts¹ supported by NASA/MSFC, EES has been able to identify vegetation groups in digital Landsat data which corresponded directly to a geologic trend. The Brevard shear zone heading northeast through the Atlanta area is characterized by shallow acidic soils derived from the cataclastic rocks forming the Brevard schist even though the parent rock types along the fault zone vary considerably. This soil type was found to support only the heartiest of trees in the area, the loblolly pine. Two areas along the Brevard zone were investigated for vegetative indicators of geology. The first area was south of Atlanta near Douglasville, Georgia. In this area the Chattahoochee River follows the Brevard zone which is topographically expressed as a series of parallel ridge lines trending northeast. A land cover classification of the area overlaid by soil maps at the same scale indicated that an elongated vegetation group, loblolly pine, corresponded directly to the Louisa Fine sandy loam soil which was derived from the cataclastic rocks of the Brevard zone.

The second area, north of Atlanta, was located near Lake Lanier which was formed by damming the Chattahoochee River. A land cover classification of this area also revealed that the loblolly pine vegetative group was elongated and generally followed the trace of the Brevard zone. Thus by the recognition of trends in the loblolly pine by digital pattern recognition, a delineation of the Brevard shear zone was also accomplished. These vegetative patterns are called geobotanical indicators for geological trends.

Another area in which geobotanical indicators have proved useful is in north Georgia near Lake Chatuge. In this area a clustering of Landsat data was used to indirectly delineate regions underlain by an ultrabasic rock type. A large area to the east of Lake Chatuge has rock exposures or soils derived from dunite. These areas are generally characterized by thin or nonexistent vegetative cover whereas most of the surrounding area is densely forested. Different clusters were

successfully correlated to rock exposures and thinly vegetated regions that corresponded to a geologic map of the dunite.

As an extension of this work, two areas were selected in Georgia as test sites for further geobotanical indicators. The first site is near Columbus, Georgia and is the region containing two fault zones -- the Goat Rock fault and the Bartletts Ferry fault. The second area is around Albany, Georgia in which lime sinks or sink holes are common. This is an area of karst topography underlain by the Ocala Limestone.

Site No. 1 has been under study by Arden and Westra of Georgia Southwestern College using photographic interpretation of Landsat and high altitude color and color infrared aerial images. Detailed visual interpretation of these photographs and previously gathered ground truth information indicated that differences in vegetative species were not present across the change in geologic structure. The study then focused on attempting to identify any differences in vegetative reflectance due to stress related to geology. Aerial photographic data were also taken during several time periods and analyzed to try to identify differences in the onset of greening of the vegetation that might be related to the geology. The initiation of the greening period fluctuates substantially from year to year and area to area. The only way to detect differences in the onset of greening would be to have aerial data taken at the exact time of greening; unfortunately the data analyzed did not correspond to the greening period and thus did not provide the desired contrast across the fault zone. The study also involved a field survey of the area to determine if any vegetative stress across the fault zones would be identifiable by ground investigation. The results of both the ground survey and photographic interpretation were largely inconclusive due to critical timing factors.

Initially, EES used the ERDAS system (Appendix A) to look at each channel of Landsat data over the test area in black and white and using a pseudo-color enhancement technique. Next each image was subjected to a variety of enhancement techniques including density stretching by

either linear or logarithmic means between a selected high and low value, color coding and a derivative edge enhancement. In addition, the ERDAS capability of combining three Landsat channels into a simulated color infrared picture was also used. Figure 1 shows an enhanced image of the Bartletts Ferry. Figure 2 shows a color infrared simulation of the same area. Columbus, Georgia is the white area at lower left of the figure. The ability to display three of the four Landsat channels in a color infrared picture dramatically increases the usefulness of Landsat data for detecting geobotanical relationships where the tree species varies across a geologic contact. Using winter data an obvious differentiation is evident between coniferous and deciduous trees and some differentiation can be made within coniferous species. Since the geobotanical relationships previously discovered along the Brevard zone in Georgia primarily related to linear homogeneous patches of loblolly pine within a general mixed hardwood pine environment, this ability could be very valuable in locating potential geobotanical relationships. This region is near the Goat Rock -- Bartletts Ferry fault zone as indicated in Figure 3. A sinuous north-eastward topographic trend, Pine Mountain, is also evident in the area. The Pine Mountain trend is shown to have pure hardwood forest stands versus the mixed character of the general area. The trend is the topographic expression of an outcrop of the Hollis Quartzite. Since no species differentiation was present across the Goat Rock -- Bartletts Ferry fault zone and since the resolution and the timing of the Landsat data were inappropriate for detection of the onset of greening, no geobotanical expression of the fault zone was found in this study.

SINK HOLE DETECTION

In the Albany, Georgia area there is an extensive problem with sink holes due to the underlying geology of the region. There are documented examples of entire buildings being destroyed by sink hole formation beneath their foundations. Roads and airport runways are also subject to collapse if sink holes form beneath them. In an area such as this, it is necessary to have an indication of the subsurface and its propensity

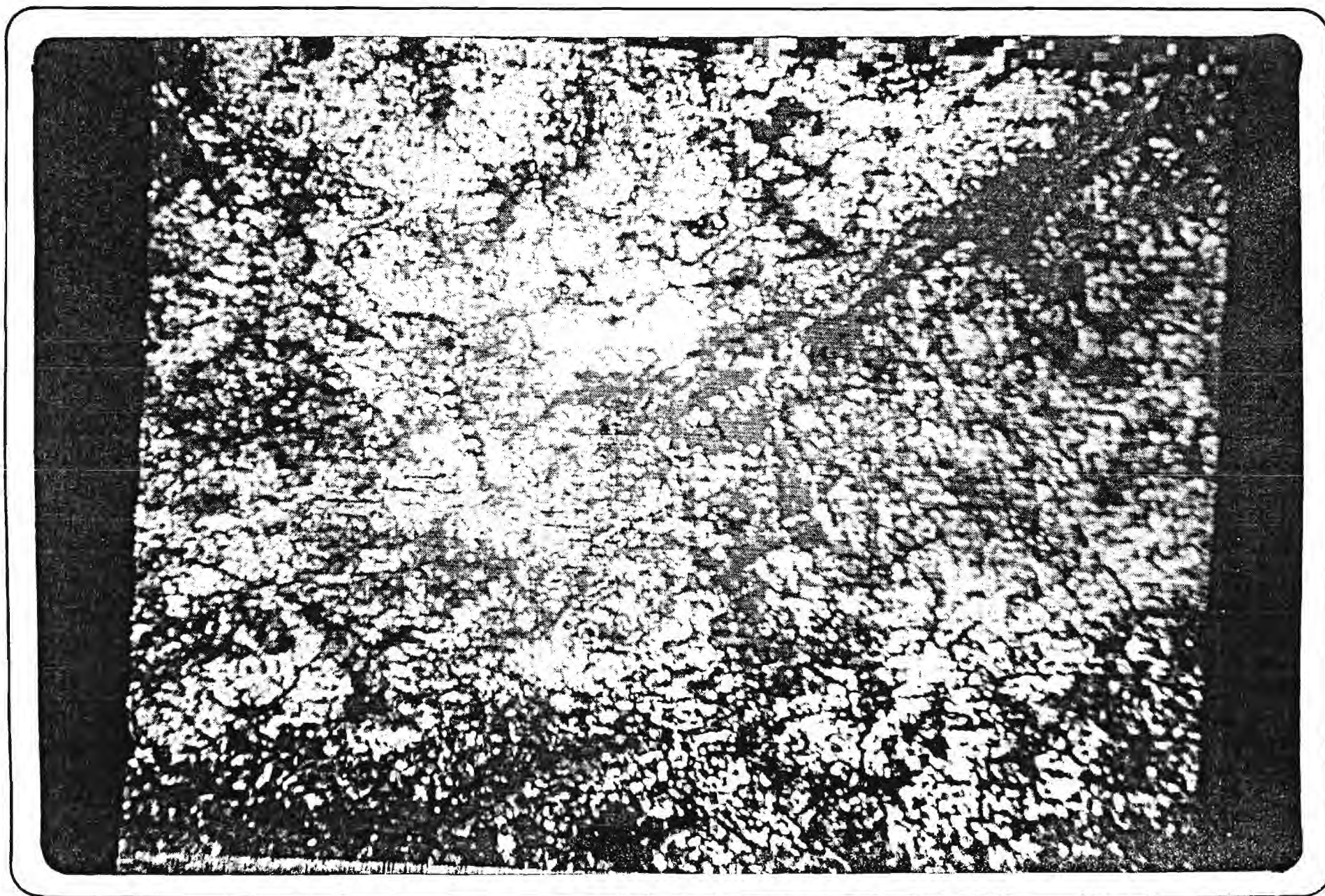


Figure 1. Enhanced Landsat Data of Bartletts Ferry Area.

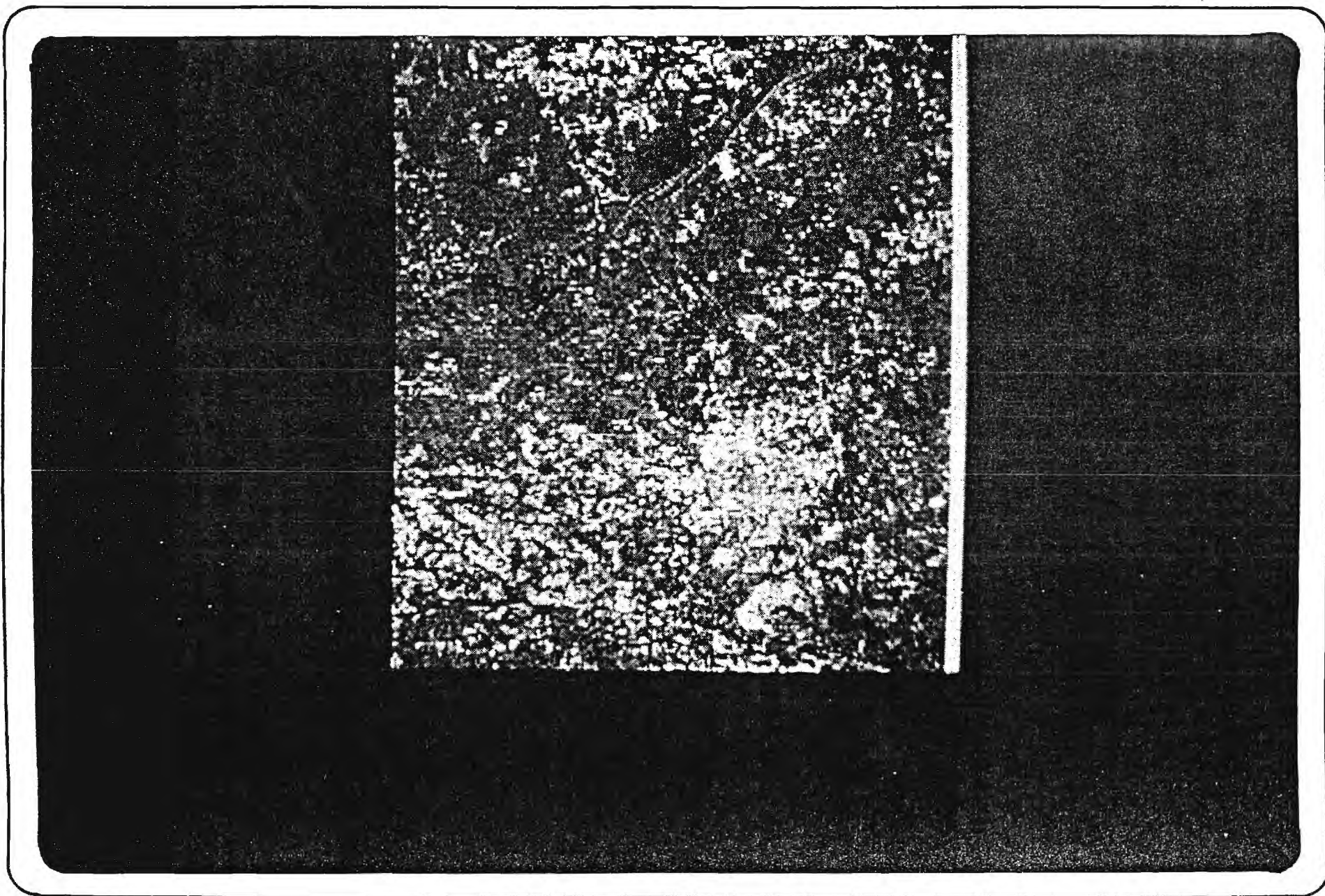
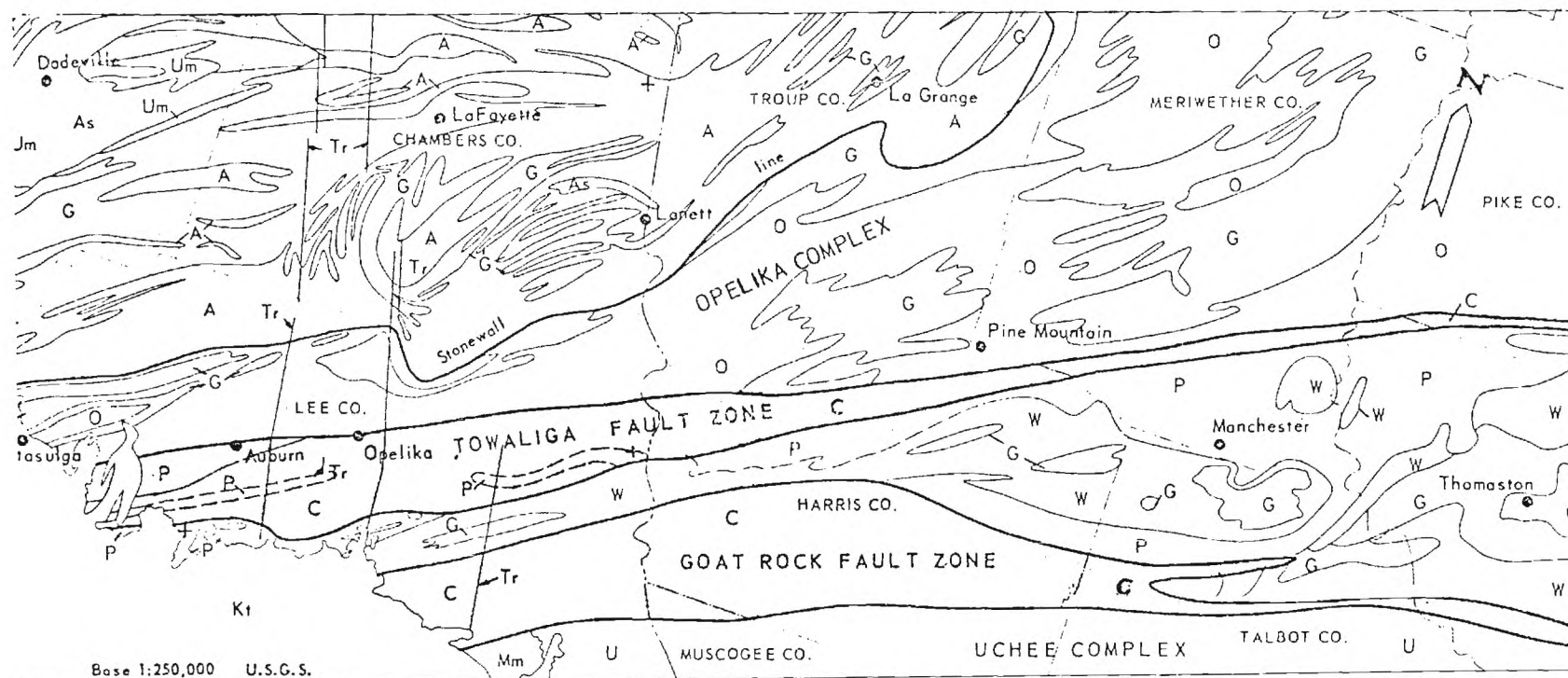


Figure 2. Color Infrared version of Landsat Data.



Kt	Cretaceous undifferentiated	O	Opelika Complex - undifferentiated	Mm	Moffits Mill Complex
G	Granite gneiss - undifferentiated	C	Cataclastic rocks - undifferentiated	Tr	Triassic(?) diabase dikes
A	Amphibolite - undifferentiated	P	Pine Mountain Group - undifferentiated	—	Microbreccia dikes
Um	Ultramafic rock - undifferentiated	W	Wacoochee Complex - undifferentiated	↗	Thrust faults
As	Agricola schist - gneiss	U	Uchee Complex - undifferentiated		

Figure 3. Generalized Geology and Location Map of Pine Mountain Area. (From Bentley and Nethery, 1970)

to form sink holes before buildings are erected and roads are laid. Albany has had some luck in dealing with the location of potential lime sink areas by using thermal imagery (8-14 micrometer wavelength) and color infrared photography to detect vegetation stress. Suspected sink hole zones were delineated and borings confirmed that 85% of the suspect sites were indeed potential sink holes⁴.

The basic reasoning for the use of color infrared data to detect potential sink holes is that as sink hole areas form the surface vegetation undergoes a stress condition that may often be detected by interpretation of color infrared photography. This stress often is of short duration and data may not be available at the appropriate time for detection.

Once potential sink areas are identified, expensive borings may be used for verification. Another technique in use by Arden and Westra is the examination of potential sink areas with a detailed field microgravity survey where topography information is well known. Analysis of the microgravity data has been demonstrated as an appropriate technique for detecting subsurface cavities which will eventually collapse to form sink holes. This combination of a visual remote sensing technique and a standard geophysical technique holds promise for economically evaluating sites for sink hole hazards.

The sink holes in the Dougherty Plain may range from 1 meter to 350 meters in diameter and thus may occupy up to as many as 20 Landsat pixels. The already mature sink holes are easy to detect on Landsat data, especially if the sink is water filled. Enhanced Landsat data (Figure 4) show some of the existing mature sink holes around the Albany area. Other suspect areas may be located in the enhanced imagery, but ground truth data were not available to accurately check these areas. The field surveys in Dougherty often concentrated on sink holes 10 meters or less in diameter (one fourteenth of one Landsat pixel) and thus, they could not be detected by Landsat. In general, Landsat data with the current resolution would probably not be useful in delineating potential sinks of less than 150 meters in diameter (approximately four pixels), but could provide information on those greater than that size. Also, the addition of thermal data to Landsat 3 and Landsat D will enhance this detection capability even though the



Figure 4. Enhanced Color Infrared Landsat Data (Albany, Georgia).

resolution of the thermal data is less than that for the other MSS bands. The RBV resolution of one quarter acre should allow the detection of potential sites much smaller in diameter than the current system will allow.

As earth resources satellite sensors acquire greater resolution, more information can be obtained that might allow the data to provide an effective first cut location for potential sink areas. An aircraft Multispectral Scanner (MSS) with its excellent spatial resolution might also contribute to the usefulness of remote sensors for detecting sink areas. The same problem of timeliness and availability of data, however, would hamper large scale efforts unless timely, regularly scheduled flights were available.

STRIP MINE LOCATION

Because of the new national energy policy coal is again emerging as one of our foremost sources of energy in the United States. As the United States cuts back on its demand for oil, more and more coal will have to be produced to supply residential and commercial power. As a control on the environmental effects of such a policy a mine reclamation law has been signed which will require mining operations to reclaim land that has been strip mined within a specified period of time.

For this part of this project, EES analyzed digital Landsat data in detail over the area bounded by Longitudes 87°07'30"W and 87°22'30"W and Latitudes 33°37'30"N and 33°52'33"N. The Landsat data covering this area were scenes 5184-15260 (October 20, 1975) and 1948-15273 (February 26, 1975) and were provided through NASA/MSFC by Goddard Space Flight Center.

Strip mining and shaft mining are the two most widely used methods of mining coal. Each method has its own drawbacks and benefits. Strip mining or surface mining is economical when a large coal seam or several moderate sized seams are found with little overburden. As the overburden increases it becomes non-economical to mine the coal. For this reason surface mines generally follow topographic contours in Alabama since the coal beds for the most part are gently dipping. Because of

the topographic following nature of surface mining, it has often been called contour stripping. As the overburden is stripped from the coal seam the spoil is dumped on land behind the stripped area or on land that has already been stripped. The mining technique generates a "high wall" which is the extent to which the overburden has been removed (Figure 5). Remote sensing data from aircraft and satellite can delineate the area of active strip mines - "i.e. the area from the high wall to the spoil dumps". From photographic data it is necessary to use a planimeter to measure the area of the strip mine, while digital data from Landsat and aircraft multispectral scanners allow accurate summation of stripped area automatically by using a simple classification scheme. Strip mines that are in varying degrees of reclamation may be identified until the strip mined area looks very similar to the surrounding terrain.

To demonstrate the capability of delineating strip mined areas from digital Landsat data, a candidate area was selected from the two Landsat images provided by NASA. This area is near Jasper, Alabama and contains an operational surface mine. Using the ERDAS system, EES was able to enhance each Landsat band of data and color code it so that the differentiation between the surface mine and the surrounding area was obvious. Figure 6 shows this differentiation vividly with the mined area in shades of green and the background forested areas in shades of blue. Notice the stripping pattern follows contour lines of the topography. Figure 7 shows a color-infrared composite of channels one, two, and four of the Landsat MSS for another stripmine south of Jasper. Using three bands of data brings out more detail in the strip mined area and in the background. An unsupervised clustering technique² or a maximum likelihood supervised technique may be used to extract the strip mined area from the background using all four Landsat bands.

In addition to the enhancement effort, digital topographic maps of the Warrior Basin area were obtained from the National Cartographic Information Service (NCIS). Figure 8 shows these data over the stripmine area with a grey scale related to elevation. Black is the lowest

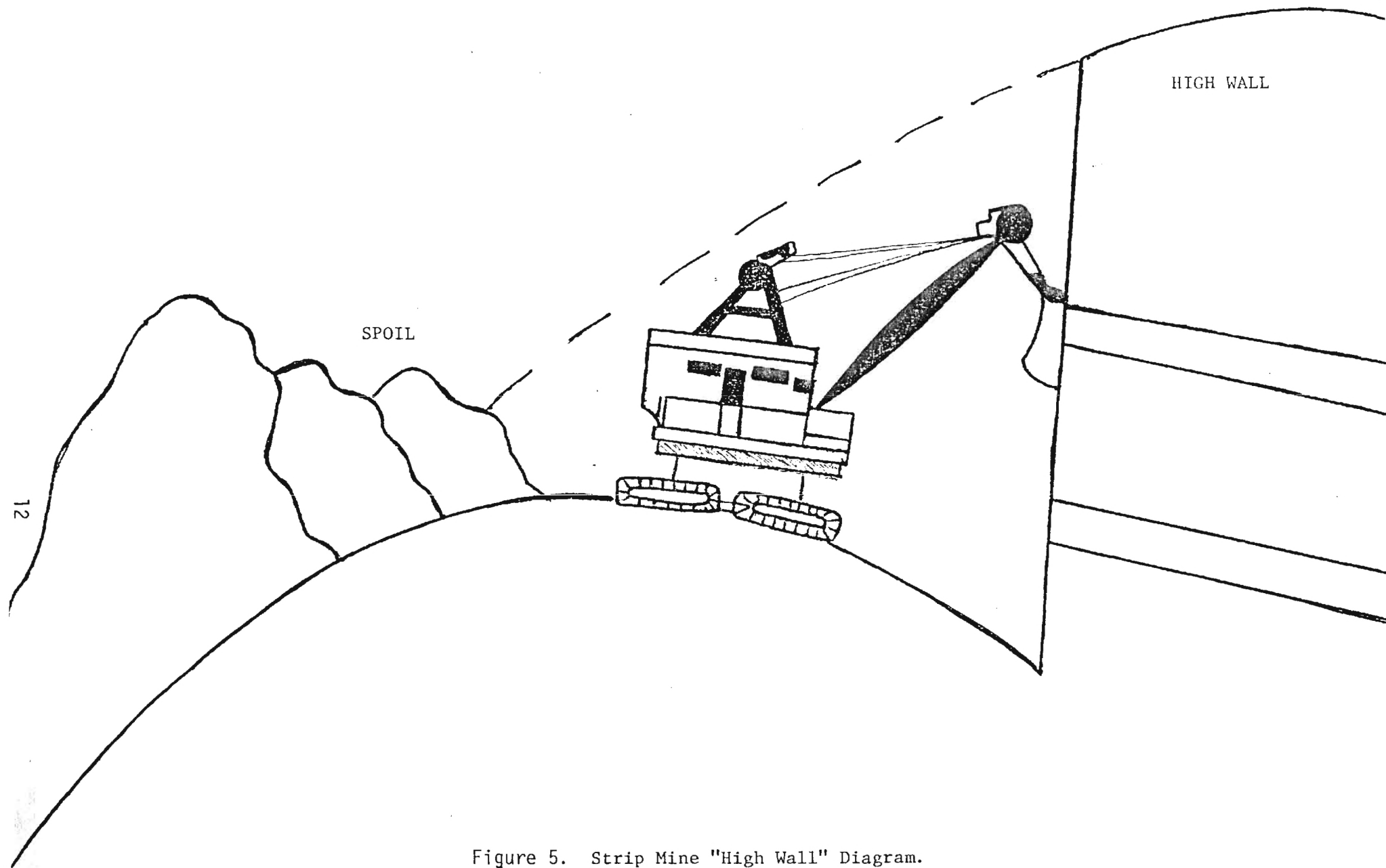


Figure 5. Strip Mine "High Wall" Diagram.

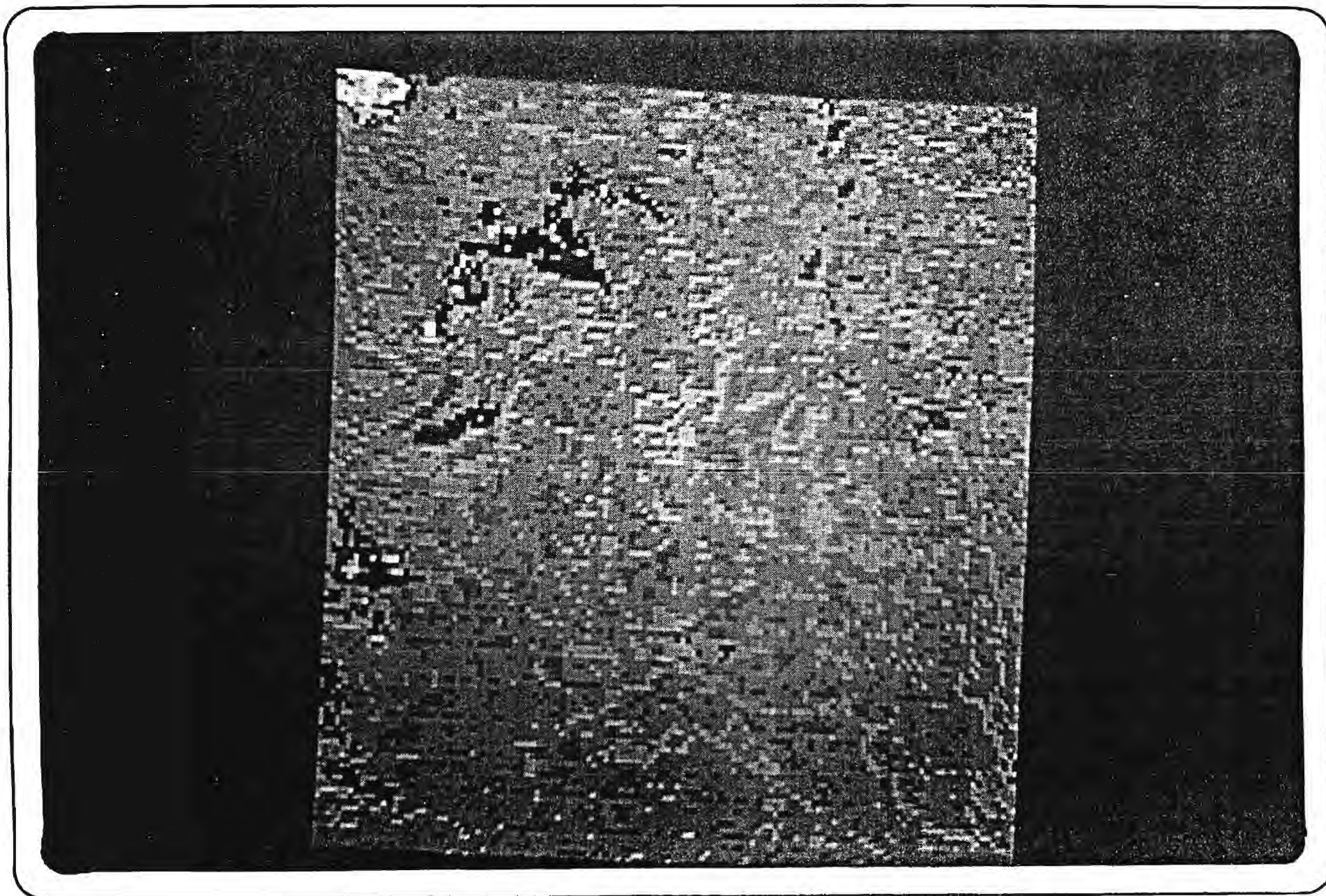


Figure 6. Enhanced Landsat Data for Strip Mine Location.

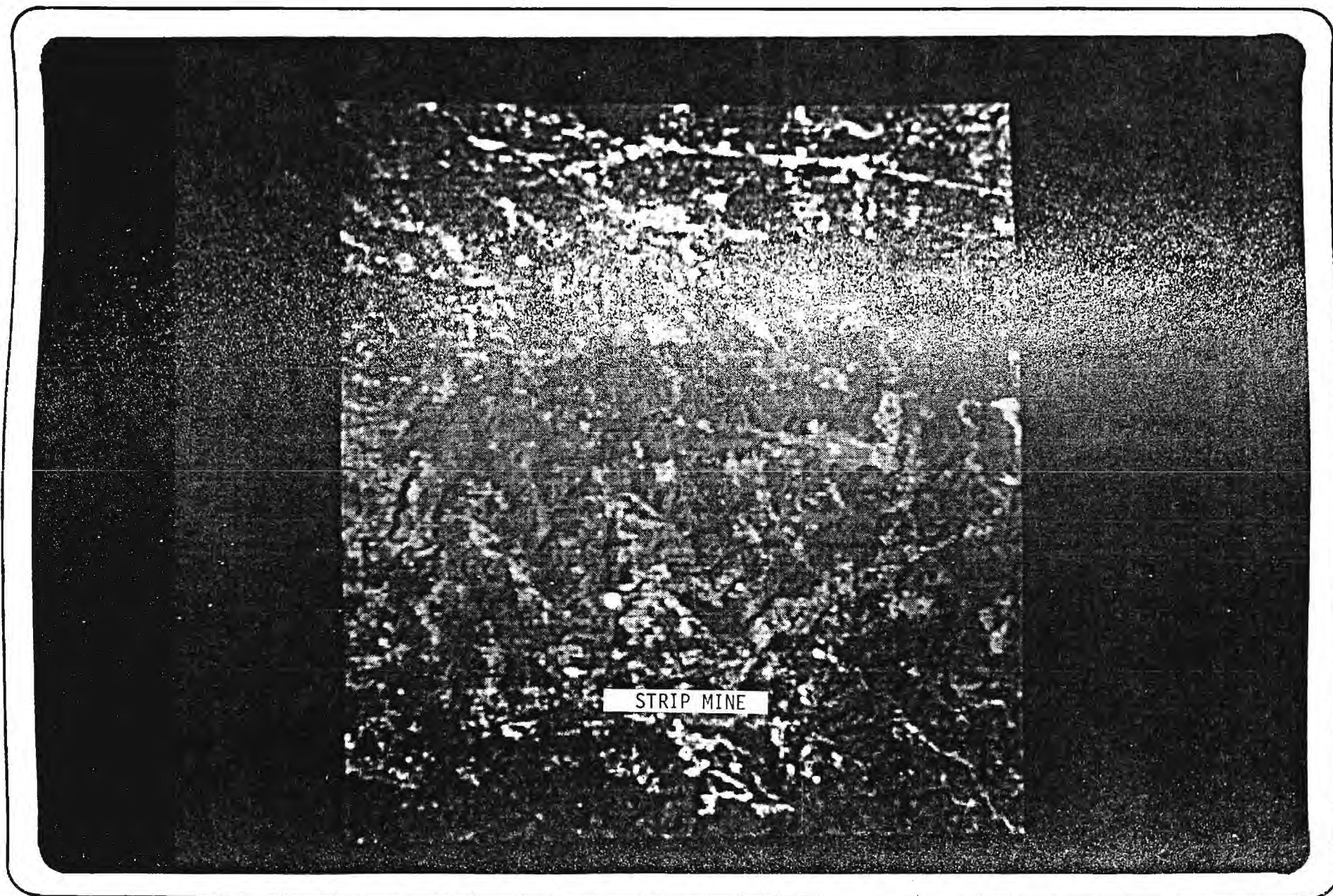


Figure 7. Color Infrared Landsat Data below Jasper, Alabama.

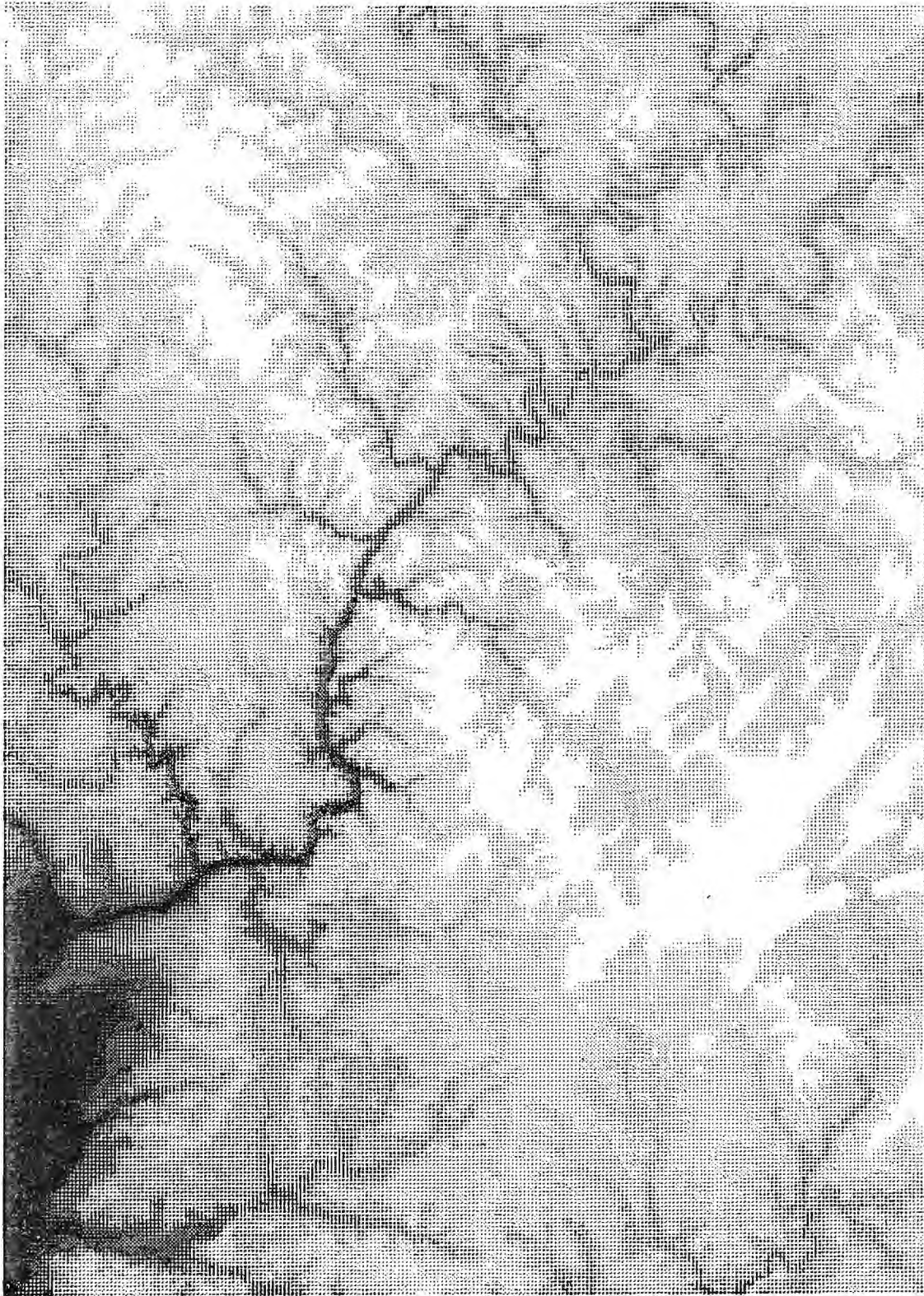


Figure 8. Digital Topography Map Over Warrior Basin, Alabama.

elevation present and white is the highest. Classified Landsat data for the study area were rectified to the Universal Transverse Mercator coordinate system and resampled to provide maps at a 1 to 24000 scale suitable for overlay on U. S. Geological Survey seven and one half minute quadrangle maps. In addition, the digital topographic data for the same area were also resampled to the same scale. The total stripped area in the study area was calculated to be approximately 15 km².

A more detailed study of the effectiveness of using aircraft and satellite remote sensing data to assist in coal reserve calculations has been completed recently by the Alabama Geological Survey, NASA, and Georgia Tech. For this study aerial photography and Landsat data were used to estimate areas of strip mines. Digital topographic data and digitized drill hole data were used to model coal seams and calculate reserves. These data were compared to reserve calculations derived manually for the same area.

APPENDIX A

THE ERDAS SYSTEM

The Georgia Tech Earth Resources Data Analysis System (ERDAS) was designed and constructed by EES to allow true interactive digital processing of all types of remote sensing data (Figure A-1). ERDAS consists of a set of 4 modules: 1) minicomputer subsystem, 2) input medium, 3) hardcopy output medium, and 4) display subsystem.

The minicomputer subsystem consists of a NOVA-2/10 minicomputer with 64000 bytes of core memory and a dual Diablo disk system with 5.0 megabytes of storage for programs or data.

The input medium for the ERDAS system is a set of two nine track dual density (phase encoded/NRZI selectable) magnetic tape drives and controller -- each drive with a capacity for 10 1/2 inch reels of tape.

The hardcopy output medium is a twenty inch electrostatic dot matrix printer/plotter. Scaled maps of Earth Resources data can be made using this medium. A CROMALIN^(R) photographic process may then be used to generate a color coded output hardcopy product. Color products may also be obtained through a service offered by a commercial producer of film writers.

The display subsystem consists of a high quality video monitor that is interfaced to the minicomputer for complete user interaction in the choice of training samples for earth resources classification.

Elements of the subsystem are:

1. Color monitor
2. Trackball cursor
3. Self contained refresh memory
 - a. one image 512 x 512 elements by 8 bits or
 - b. three image 256 x 256 elements by 8 bits

ERDAS is a completely software oriented system. Training statistics can be calculated instantaneously for cursor located fields. A histogram may then be displayed to check homogeneity of training fields.

Classification may be performed on stored data sets or data sets read in from the system's magnetic tape drives. This system is inherently interactive, and ratioing of MSS bands, level slicing, classification, and change detection software will provide display data to be fed to the color monitor.

The EES ERDAS System may be used in either of two general modes. In Mode 1 an image may be displayed on the display screen with a resolution of 512 by 512 elements with data values ranging from 0 - black to 255 - white. These data values may be color coded via a pseudo color memory to produce a false color display of the image. The user may select sixty-four display colors from a possible variety of 4096 colors (4 bits for each color gun). The colors are arranged in the pseudo color memory such that data values 0 - 3 are assigned to the first color values, 4 - 7 are assigned to the next, etc. A pseudo color scale that is often used varies from dark blue to green, yellow, orange, and red with different shades and combinations of these colors filling out the chart. This method is often used in displaying an image in as nearly a natural color state as possible (Figure A-2).

In addition to the pseudo color capability of the ERDAS System, it also has the capability of passing the original data values through a function memory before the data are displayed. As with the pseudo color memory, this function may be selected by the user. For example, if a linear function memory with a slope of one is to be used, a value "0" would be coded as a zero, a 10 as a 10, and so on. After the value of 127 is coded to a 254, all subsequent values would be coded as 255. The function memory may be envisioned by a two dimensional grid with the bottom axis as the original data value and the vertical axis as the coded data value. The two examples given above are shown in Figure A-3. A logarithmic example is also given in Figure A-4. This capability allows the dynamic density stretching or compression of any image by linear or nonlinear functions. In all cases the data in the image memory remains the same as the original image. The function only operates on the image that is displayed on the television screen.

The second mode of the ERDAS System has a resolution of only 256 by 256 elements on the television screen but three Landsat or other images may be displayed at the same time. As before, each image contains data values between 0 and 255, but in this case each image may be assigned specifically to one color gun of the television (Figure A-5). For Landsat data, normally three of the four channels of Landsat data are assigned to individual color guns. If channel one and channel two (visible bands) of Landsat data are applied to the red gun, a simulated near infrared image is displayed on the screen. This type of picture incorporates three channels of Landsat data at one time and results in a very similar color scheme to that of color infrared aerial photography. This technique has been most effective in the location of training fields for Landsat classification (Figure A-6) and as an aid in interpretation of the raw Landsat image.

All of the function memory and pseudo color memory operations discussed above may be performed in this mode also for each of the three images. For example, three different functions may be applied to the three images and the result shown as an enhanced color infrared display.

The remote sensing data at EES are processed by one or more picture processing computer programs. Basic analysis modules available are"

1. Supervised Classification (Maximum Likelihood)
2. Linear Supervised Classification
3. Sequential Unsupervised Classification (Clustering)
4. Non-Sequential Clustering (ISODATA)
5. Histogram Generation
6. Level Slicing
7. Registration and Rectification
8. Factor Analysis
9. Grey Scale Display
10. FFT (Fast Fourier Transform)
11. Change Detection
12. Polygon Training Field
13. Polygon Classification
14. Edge Enhancement
15. Ratioing



Figure A-1. ERDAS System

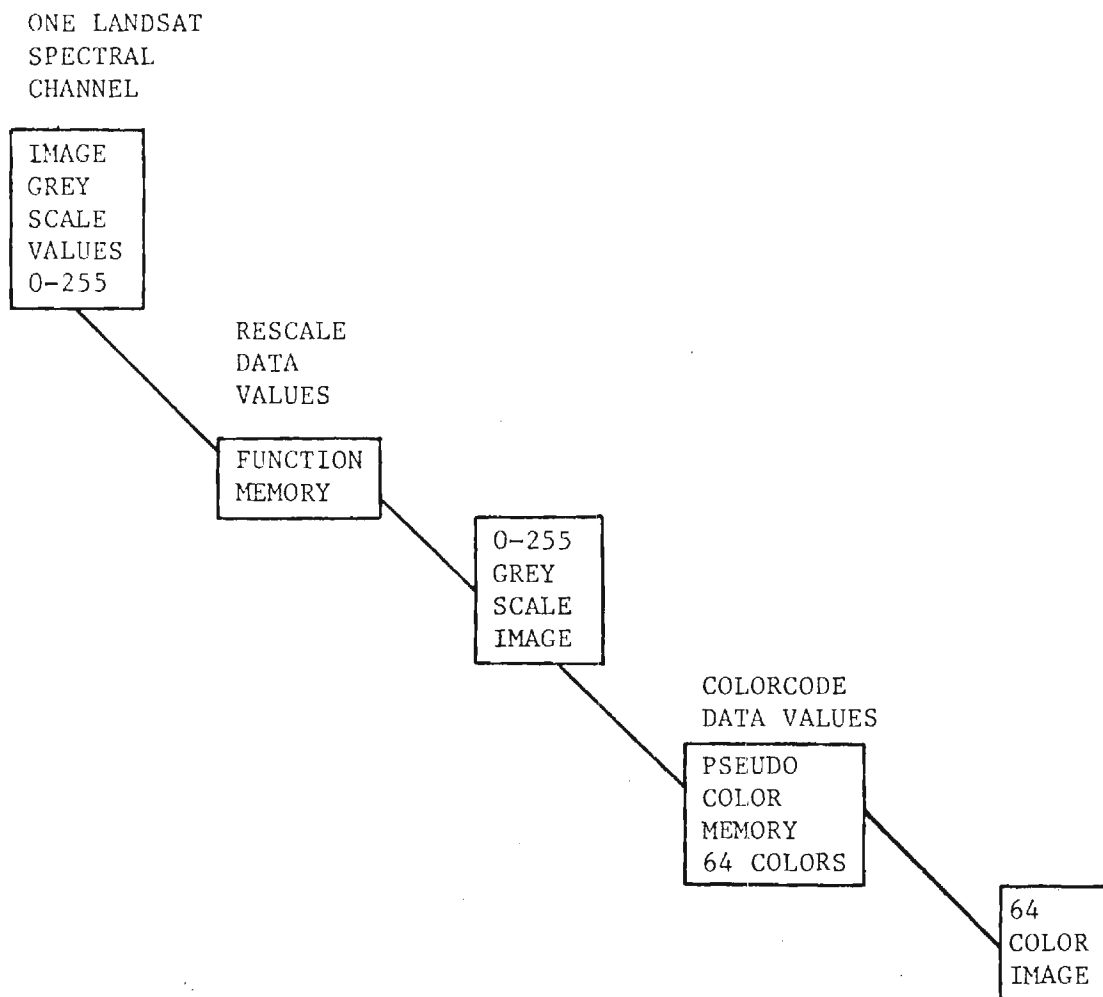


FIGURE 2. Color Video Display - Mode 1

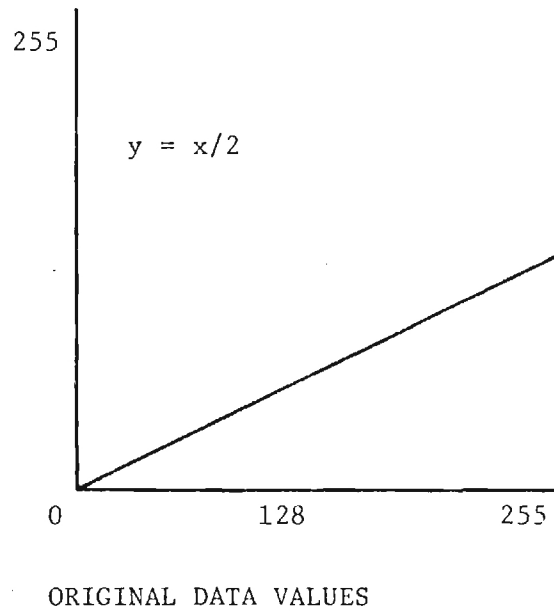
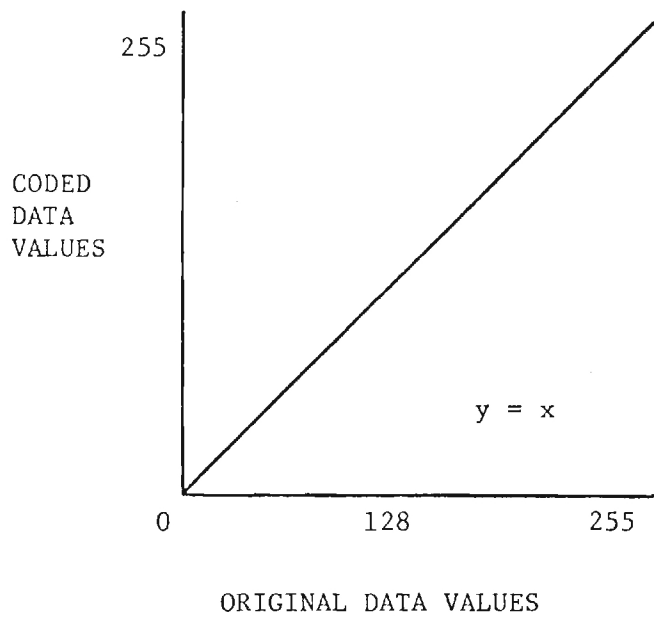


FIGURE 3. Linear Function Memory Example

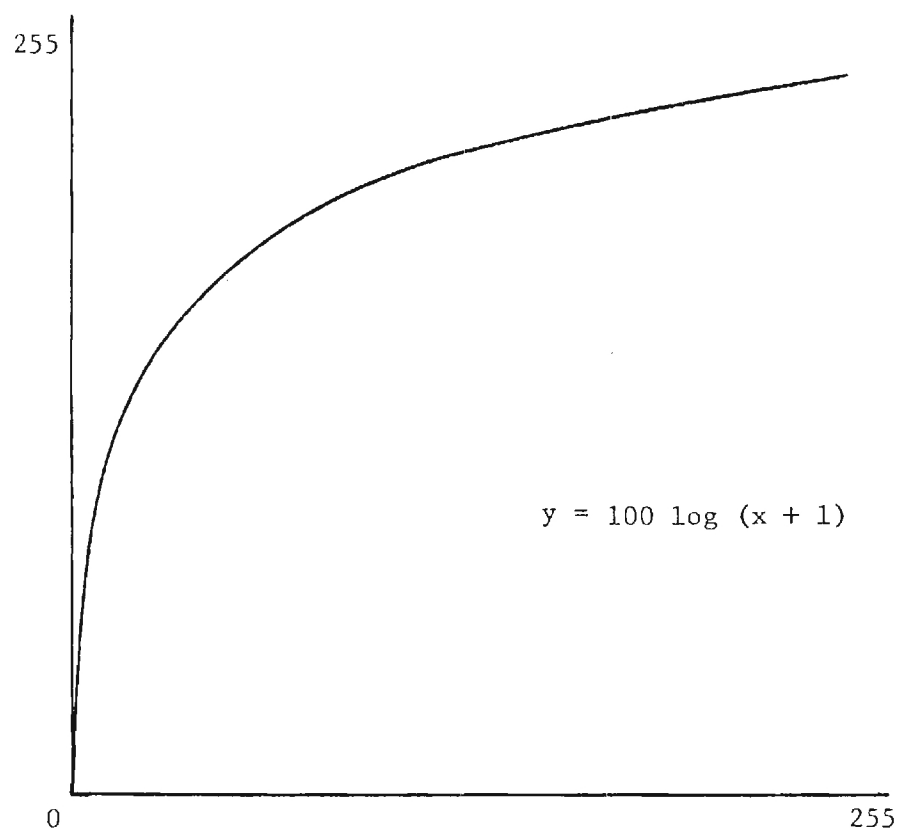


FIGURE 4. Logarithmic Function Memory

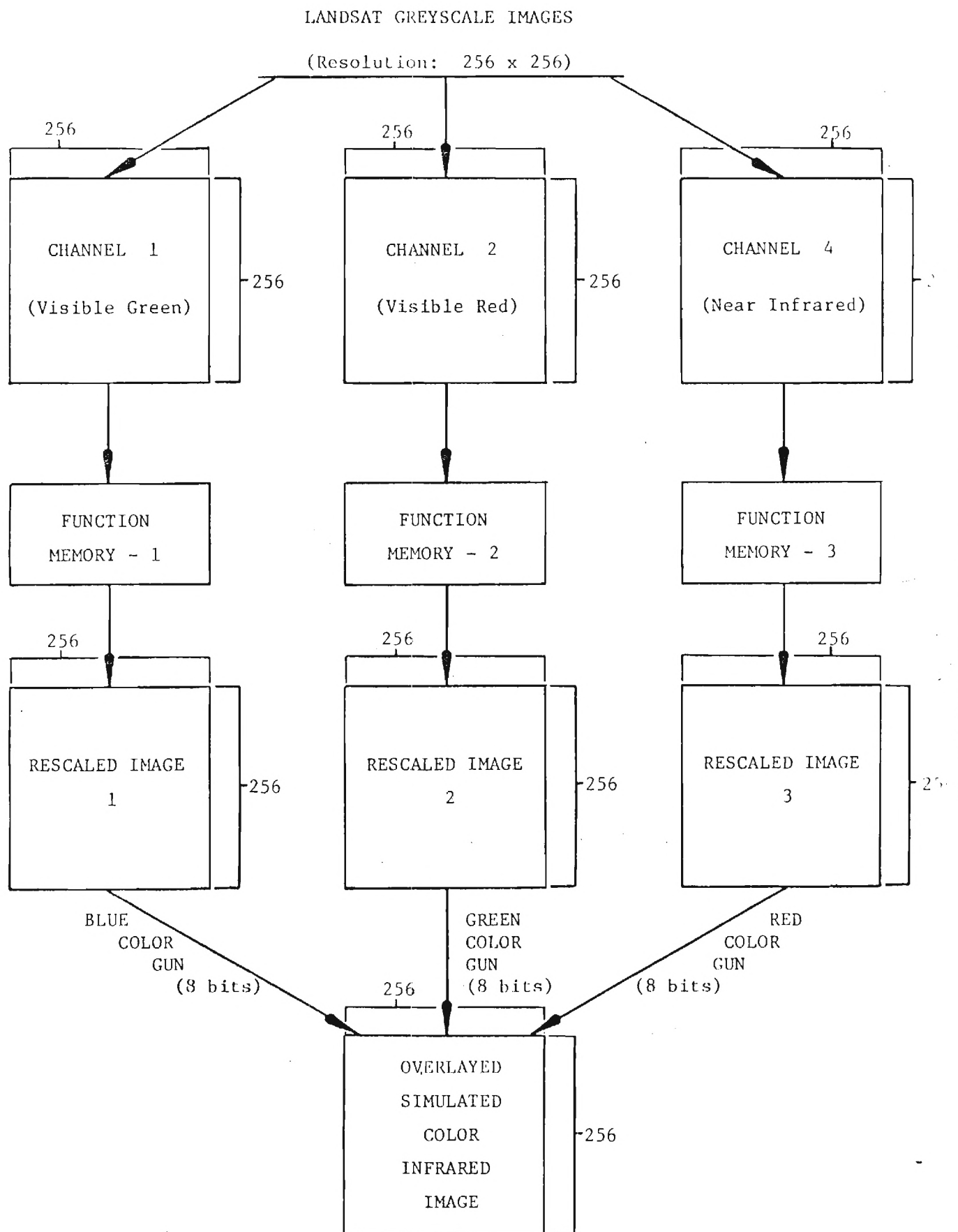


Figure 5: Block diagram of Mode 2 of the Color Video Display.

STUDY: ANALYSIS OF LANDSAT DATA

FINAL TECHNICAL REPORT

PART 3

by

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Translation of High Density Multispectral Data Tapes to Computer Compatible Tapes

This discussion concerns the hardware required for the conversion at Georgia Tech of high density (10000 bits per inch) magnetic tapes, obtained from a multispectral scanner, to computer compatible nine-track magnetic tapes having a standardized format. The computer compatible tapes will be formatted so that they may be read by computer installations having nine-track magnetic tape input facilities and standardized software support.

The information available on the DAEDALUS Multispectral Scanner indicates that the information from each of the scanner channels is direct recorded in biphase-level telemetry format on magnetic tape at a packing density of 10000 bits per inch - per track. The purpose of the electronic system discussed here is to obtain bit synchronization, decode the synchronization signals written on the tape by the multispectral scanner, recover the calibration and housekeeping data and then to recover the scanner data signals in such a fashion that they could be read into a minicomputer and formatted so that they may be read out to a magnetic tape recorder in nine-track computer compatible tape format. To do this requires that a tape transport and electronics capable of reading the recorded high density tapes be acquired and that the electronic interface between the high density tape recorder and a direct memory access channel to a minicomputer be constructed. A Nova 2 minicomputer with 32K of core memory and the nine-track digital recorders are operational in house.

A sizeable investment is required to procure an instrumentation tape recorder to handle the 10000 bits per inch biphase telemetry data. An Ampex FR-3000 Series magnetic tape recorder would require an investment of \$21,000 to \$22,000 for the basic tape drive mechanism plus \$125 per record amplifier and \$225 per reproduction amplifier per channel. Such tape machines can handle from 7 to 32 channels in certain manufacturer specified selections of head configurations. Since the DAEDALUS

Scanner has 12 channels, the number of tape channels needed would be 14, the next larger standard configuration of channels greater than 12. This is consistent with the scanner since it allows for a timing channel and an extra channel possibly for voice annotation. The number of channel reproduce amplifiers would be determined by the number of channels which need to be reproduced and converted. If the number of channels which need to be converted is greater than one, it would be desirable to have a reproduce amplifier for each of the channels required in order to eliminate the necessity of continually moving the reproduce amplifiers from one card position to another. Patch cord changing or switching could be done at the output of the reproduce amplifiers which should provide a more efficient and reliable system.

To read the high density data tape a PCM bit synchronizer for each channel is desirable. This allows the data tape to be read without the problems of errors caused by tape skew if a single channel of sync is used or if the data clock is derived from only one channel of data. After bit sync is acquired, the tape synchronization signal may then be acquired. The tape is formatted as shown in Figure 1. The first four 8-bit words are used for sync purposes. These words in the data stream are shifted bit-by-bit into four 8-bit serial to parallel converters. The outputs of these converters are fed to a series of "and" gates with the proper inverters inserted so that the final "and" gate output will be true when the proper four sync words are present in the four converters. Once sync is obtained, the data may then be decoded. Words 5 through 22 contain identification, calibration and housekeeping data. Words 23 through 740 contain data information. Words 741 to 750 contain end of frame marks. A provision is made in the electronic system for the delivery of data words to a D/A converter so that the data may be observed on an oscilloscope for quick-look purposes.

The electronic interface between the high density tape recorder and a minicomputer can be furnished by a system produced by Synaptic Systems, Ltd.* and designated TPS-2 tape playback synchronizer. This

*Synaptic Systems, Ltd. is the manufacturing division of MacDonald, Dettwiler and Associates, Ltd., 2182 West 12th Avenue, Vancouver, B.C.

device provides for bit synchronization, frame synchronization, and decoding of the data as well as digital to analog conversion of the data for quick look purposes.

To duplicate this TPS-2 tape playback synchronizer at this time would require an investment of \$9,300 if it were acquired from the original supplier. The unit would be self contained (including all necessary power supplies) and the front panel configuration would be the same as the unit at MSFC. However, the circuit boards contained in the unit would not be compatible with those in the old unit. This is believed to be largely due to the replacement of the bit synchronizer unit necessitated by the loss of the source of supply of the original unit.

Next the interface with the minicomputer needs to be considered. The tape playback synchronizer will operate at 600,000 - 300,000 - 150,000 and 75,000 bits per second which corresponds to tape playback speeds of 60, 30, 15 and 7.5 inches per second assuming that the data were recorded at 120 inches per second. At 60 inches per second tape speed and 600,000 bits per second from the synchronizer the output would consist of 75,000 - 8 bit words per second. Using the direct memory access channel available on the computer the data may be read into the computer at a rate of approximately 10^6 - 16 bit words per second. Utilization of the DMA channel on the computer allows the data to be transferred to memory directly without use of the computer interrupt system even though the transfers are one word at a time. To provide time for the initialization of the DMA channel, a count-down system from the data sync pulses could be used. Since the data are shifted bit-by-bit into the serial-to-parallel converters in the TPS-2 synchronizer the data words exist, for example, in the last converter at precise intervals of time. Counting down the bit clock after sync is recognized would allow a signal to be generated for DMA initialization before the time when a DMA interrupt is required. Thus, when the data word did exist in the last serial-to-parallel converter, it could be transferred directly to memory via the DMA channel. Times for data formatting and output of data could use the sync interval times and end of frame time

as well as time not used between DMA operation. The bit rate could be reduced until adequate time was available for these operations.

An estimate of \$1,000 should be adequate for the construction of the DMA sync countdown circuitry.

A dedicated DMA input board for the computer should also be provided. This can be acquired from MDB System, Inc.* It is designated NOVA/DCC-116 at a cost of \$535 plus a small cost for the input-output connector.

The exact technique used in the computer for handling the input output operation will depend on the design of the software for the system. Since the high data rate recorder will operate continuously at a selected speed, the data must be read in, processed, and disposed of by recording it on disc or the output recorder in such a way that no input data is lost.

A time period of six months would be necessary for the implementation of the conversion system at Georgia Tech including time for equipment procurement.

In summary, the total hardware cost for implementation of such a system (Figure 2) at Georgia Tech would be \$37,035 (Table 1). Personnel time for the six month period would amount to approximately \$9,500 including overhead and retirement or half time for one person.

*MDB Systems, Inc., 1995 North Batavia Street, Orange, CA 92665

TABLE 1. HARDWARE COST BREAKDOWN FOR CONVERSION OF DATELUS TAPES

1) Ampex FR3000 Series	\$22,000
2) 10,000 bpi Tape Recorder Record & Reproduction Amplifiers for 12 channels	4,200
3) TPS Tape Playback Synchronizer	9,300
4) DMA Sync Countdown Circuitry	1,000
5) DMA-Nova Interface	<u>535</u>
TOTAL	\$37,035

1.3 SMD-11 Output Format - TPS-2 Input FormatWORDINFORMATION

1, 2, 3, 4	Start of frame code: 01010110'10100101'10100110'10101111 MSB
5	Scanner Identification (programmable LSB)
6, 7, 8	Line Count (BCD)
9, 10, 11, 12	Thumbwheel Switch Settings (8 BCD)
13, 14	Calibration Source 1 (BCD)
15, 16	Calibration Source 2 (BCD)
17	Lamp Temp Cal (Binary or BCD)
18, 19, 20, 21	Ext Digital Data (Housekeeping Data)
22	Video Gain Setting*
23	Digitized BB1
24 to 739	Digitized Video (716 samples)
740	Digitized BB2
741 to 750	End of Frame Code (101010...)

NOTE: Words 1 to 21 and 741 to 750 are common to all channels.

* The following code is used for GAIN settings:

GAINWORD #22

10X	(MSB) 01000000 (LSB)
4X	00100000
2X	00010000
1X	00001000
0.5X	00000100

Figure 1. High Density Tape Format

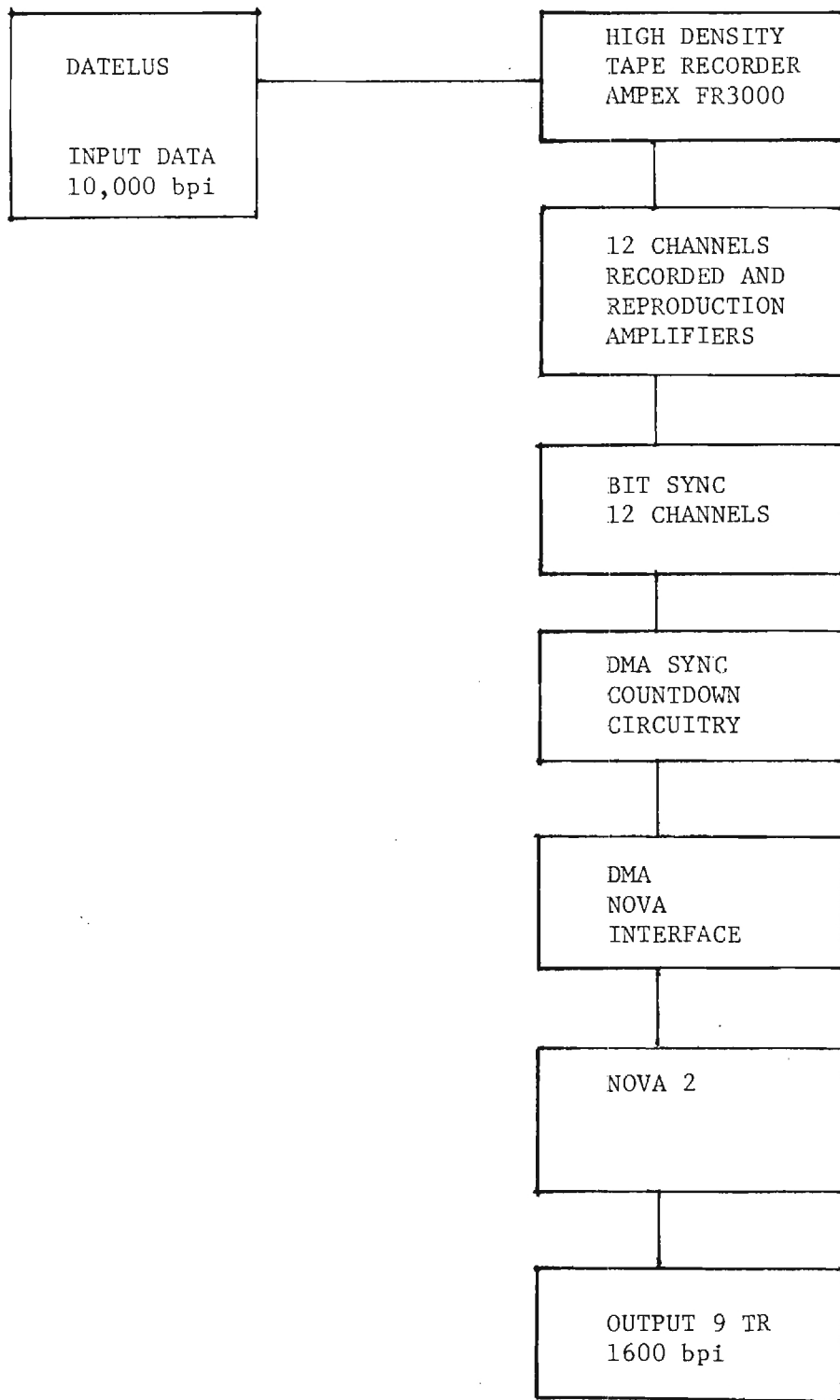


Figure 2. Data Conversion System.

APPENDIX A

THE ERDAS SYSTEM

The Georgia Tech Earth Resources Data Analysis System (ERDAS) was designed and constructed by EES to allow true interactive digital processing of all types of remote sensing data (Figure A-1). ERDAS consists of a set of 4 modules: 1) minicomputer subsystem, 2) input medium, 3) hardcopy output medium, and 4) display subsystem.

The minicomputer subsystem consists of a NOVA-2/10 minicomputer with 64000 bytes of core memory and a dual Diablo disk system with 5.0 megabytes of storage for programs or data.

The input medium for the ERDAS system is a set of two nine track dual density (phase encoded/NRZI selectable) magnetic tape drives and controller -- each drive with a capacity for 10 1/2 inch reels of tape.

The hardcopy output medium is a twenty inch electrostatic dot matrix printer/plotter. Scaled maps of Earth Resources data can be made using this medium. A CROMALIN^(R) photographic process may then be used to generate a color coded output hardcopy product. Color products may also be obtained through a service offered by a commercial producer of film writers.

The display subsystem consists of a high quality video monitor that is interfaced to the minicomputer for complete user interaction in the choice of training samples for earth resources classification.

Elements of the subsystem are:

1. Color monitor
2. Trackball cursor
3. Self contained refresh memory
 - a. one image 512 x 512 elements by 8 bits or
 - b. three image 256 x 256 elements by 8 bits

ERDAS is a completely software oriented system. Training statistics can be calculated instantaneously for cursor located fields. A histogram may then be displayed to check homogeneity of training fields.

Classification may be performed on stored data sets or data sets read in from the system's magnetic tape drives. This system is inherently interactive, and ratioing of MSS bands, level slicing, classification, and change detection software will provide display data to be fed to the color monitor.

The EES ERDAS System may be used in either of two general modes. In Mode 1 an image may be displayed on the display screen with a resolution of 512 by 512 elements with data values ranging from 0 - black to 255 - white. These data values may be color coded via a pseudo color memory to produce a false color display of the image. The user may select sixty-four display colors from a possible variety of 4096 colors (4 bits for each color gun). The colors are arranged in the pseudo color memory such that data values 0 - 3 are assigned to the first color values, 4 - 7 are assigned to the next, etc. A pseudo color scale that is often used varies from dark blue to green, yellow, orange, and red with different shades and combinations of these colors filling out the chart. This method is often used in displaying an image in as nearly a natural color state as possible (Figure A-2).

In addition to the pseudo color capability of the ERDAS System, it also has the capability of passing the original data values through a function memory before the data are displayed. As with the pseudo color memory, this function may be selected by the user. For example, if a linear function memory with a slope of one is to be used, a value "0" would be coded as a zero, a 10 as a 10, and so on. After the value of 127 is coded to a 254, all subsequent values would be coded as 255. The function memory may be envisioned by a two dimensional grid with the bottom axis as the original data value and the vertical axis as the coded data value. The two examples given above are shown in Figure A-3. A logarithmic example is also given in Figure A-4. This capability allows the dynamic density stretching or compression of any image by linear or nonlinear functions. In all cases the data in the image memory remains the same as the original image. The function only operates on the image that is displayed on the television screen.

The second mode of the ERDAS System has a resolution of only 256 by 256 elements on the television screen but three Landsat or other images may be displayed at the same time. As before, each image contains data values between 0 and 255, but in this case each image may be assigned specifically to one color gun of the television (Figure A-5). For Landsat data, normally three of the four channels of Landsat data are assigned to individual color guns. If channel one and channel two (visible bands) of Landsat data are applied to the red gun, a simulated near infrared image is displayed on the screen. This type of picture incorporates three channels of Landsat data at one time and results in a very similar color scheme to that of color infrared aerial photography. This technique has been most effective in the location of training fields for Landsat classification (Figure A-6) and as an aid in interpretation of the raw Landsat image.

All of the function memory and pseudo color memory operations discussed above may be performed in this mode also for each of the three images. For example, three different functions may be applied to the three images and the result shown as an enhanced color infrared display.

The remote sensing data at EES are processed by one or more picture processing computer programs. Basic analysis modules available are"

1. Supervised Classification (Maximum Likelihood)
2. Linear Supervised Classification
3. Sequential Unsupervised Classification (Clustering)
4. Non-Sequential Clustering (ISODATA)
5. Histogram Generation
6. Level Slicing
7. Registration and Rectification
8. Factor Analysis
9. Grey Scale Display
10. FFT (Fast Fourier Transform)
11. Change Detection
12. Polygon Training Field
13. Polygon Classification
14. Edge Enhancement
15. Ratioing

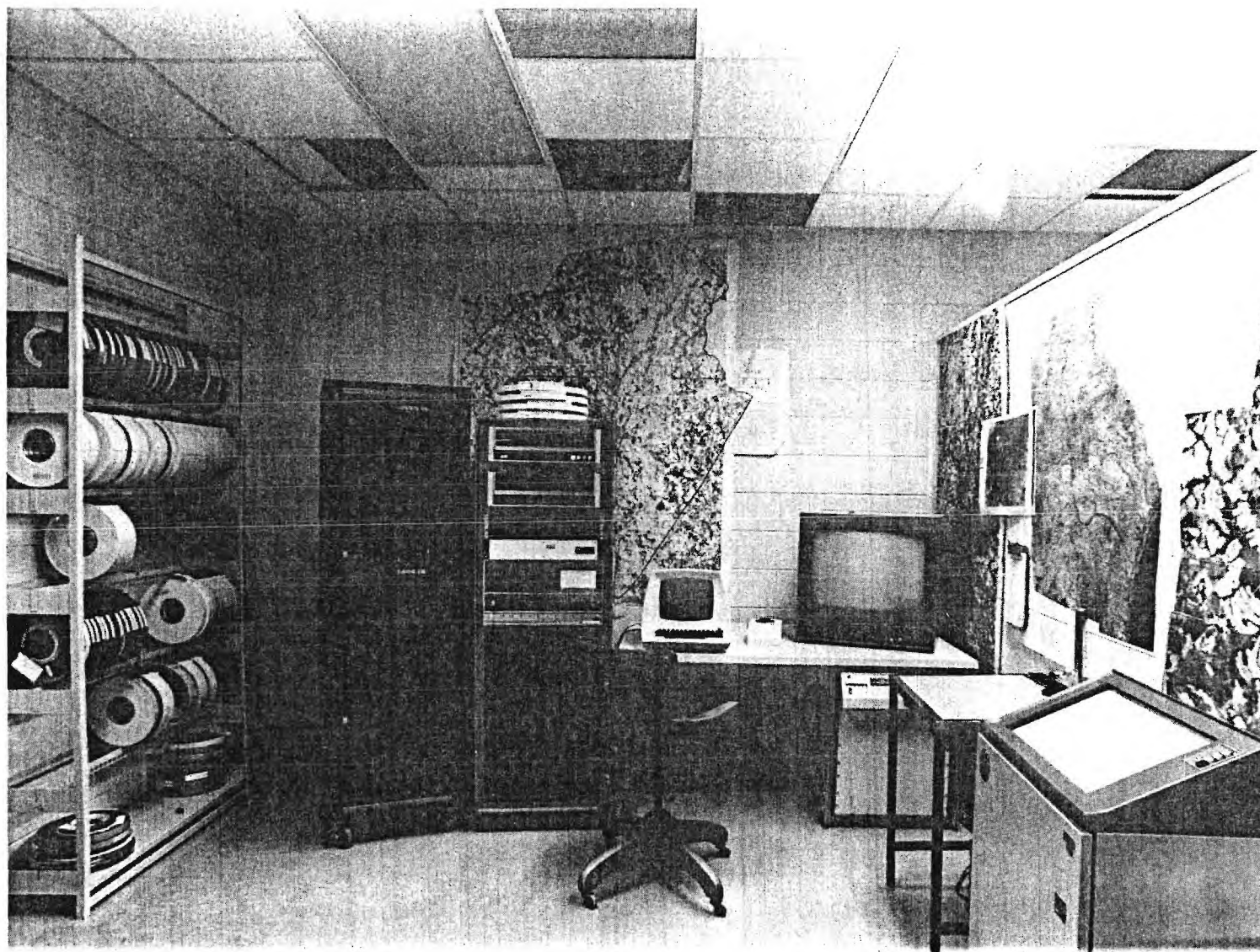


Figure A-1. ERDAS System

ONE LANDSAT
SPECTRAL
CHANNEL

IMAGE
GREY
SCALE
VALUES
0-255

RESCALE
DATA
VALUES

FUNCTION
MEMORY

0-255
GREY
SCALE
IMAGE

COLORCODE
DATA VALUES

PSEUDO
COLOR
MEMORY
64 COLORS

64
COLOR
IMAGE

FIGURE 2. Color Video Display - Mode 1

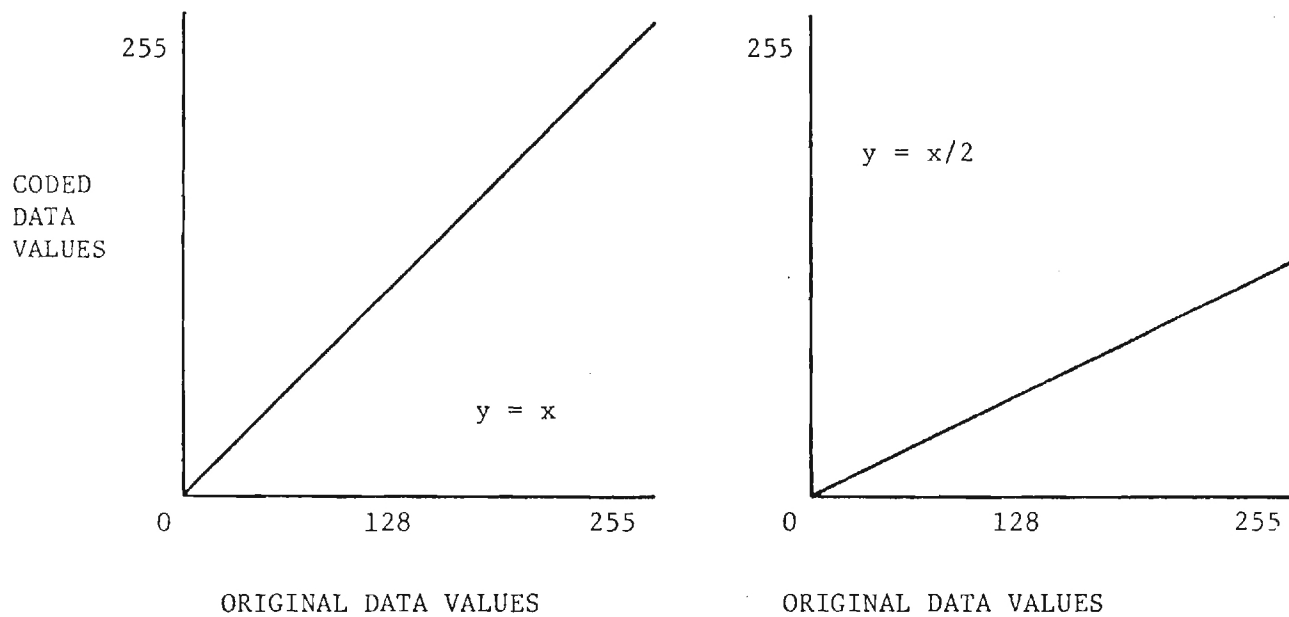


FIGURE 3. Linear Function Memory Example

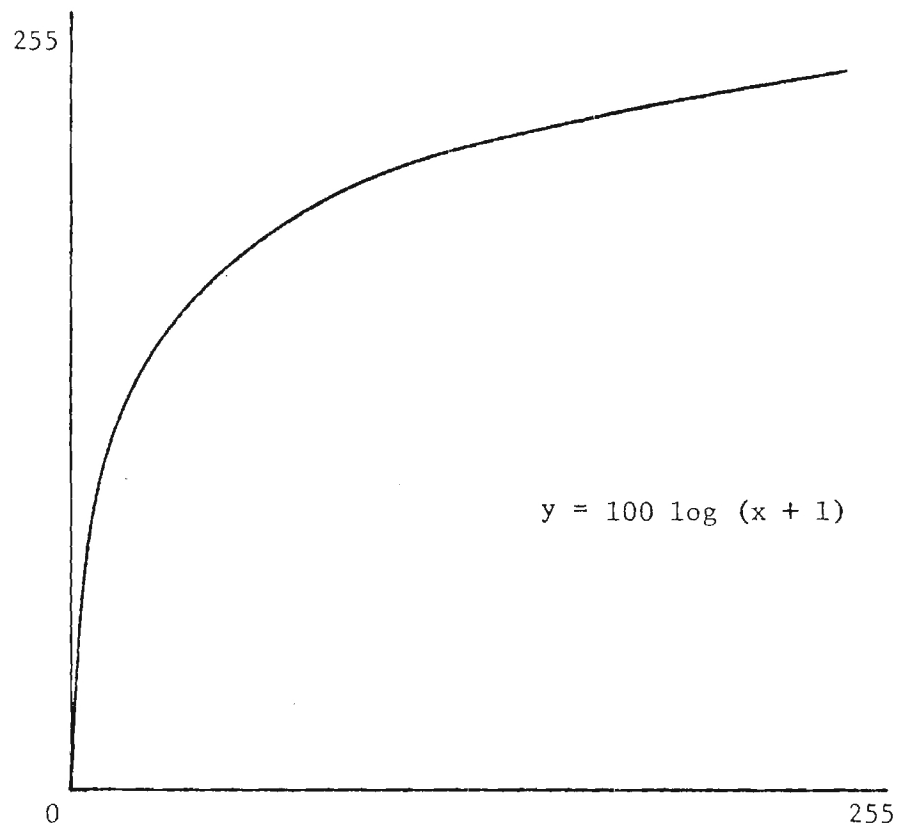


FIGURE 4. Logarithmic Function Memory

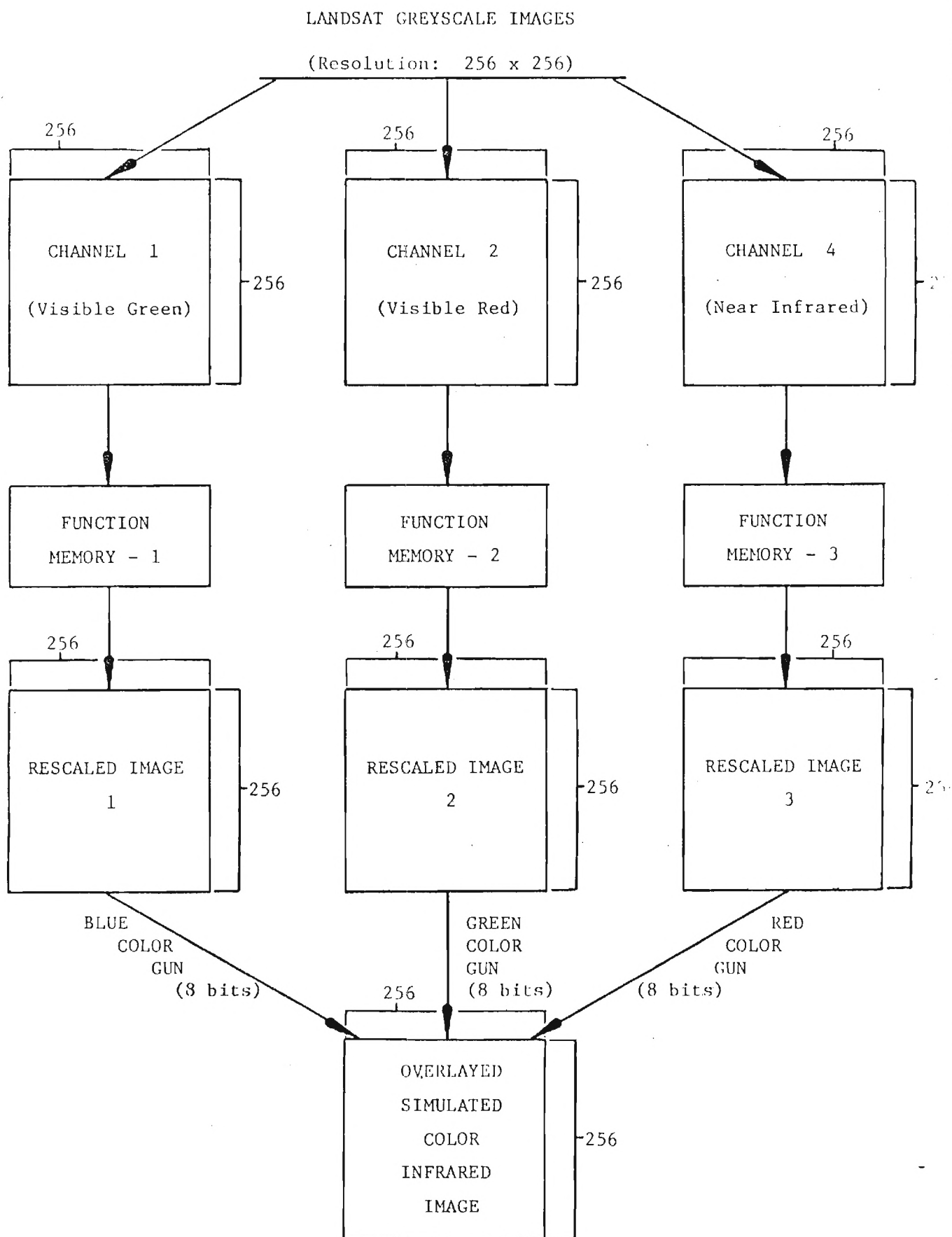


Figure 5: Block diagram of Mode 2 of the Color Video Display.