

AD A117076

APPLICATIONS OF TEXTURE ANALYSIS FOR ROCK TYPES DISCRIMINATION

Final
~~SECRET~~ Technical Report

SHIN-YI HSU, Ph.D.
Susquehanna Resources and Environment, Inc.
305 Main Street
Johnson City, New York 13850

DTIC
ELECTE
JUL 19 1982
S F D

Approved for public release;
distribution unlimited.

Sponsored by:

Advanced Research Projects Agency (DOD)
ARPA Order No. 4288

Monitored by AFOSR Under Contract No. F 49620-81-C-0087
Bolling Air Force Base, D.C. 20332

DTIC FILE COPY

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFOSR-TR- 82 - 0549	2. GOVT ACCESSION NO. AD A117076	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Applications of Texture Analysis for Rock Types Discrimination		5. TYPE OF REPORT & PERIOD COVERED ~~Annual~~ Report Final 6 July 81 - 5 April 82
6. AUTHOR(s) Shin-yi Hsu, Ph.D.		7. PERFORMING ORG. REPORT NUMBER
8. PERFORMING ORGANIZATION NAME AND ADDRESS Susquehanna Resources and Environment, Inc. 305 Main Street Johnson City, New York 13790		9. CONTRACT OR GRANT NUMBER(s) Contract F49620-81-C-0087
10. CONTROLLING OFFICE NAME AND ADDRESS Air Force Office of Scientific Research Bolling Air Force Base Washington, D.C. 20332		11. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 2309A1
12. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. REPORT DATE June, 1982
		14. NUMBER OF PAGES 50
		15. SECURITY CLASS. (of this report) Unclassified
		16. DECLASSIFICATION/DOWNGRADING SCHEDULE
17. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited		
18. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
19. SUPPLEMENTARY NOTES		
20. KEY WORDS (Continue on reverse side if necessary and identify by block number) Rock types discrimination Region growing LANDSAT data Granite Supervised classification Band ratioing Texture analysis Clustering analysis Nuclear monitoring		
21. ABSTRACT (Continue on reverse side if necessary and identify by block number) → Aimed at developing image processing methods for rock types analysis with LANDSAT data, numerous experiments were conducted using supervised and unsupervised classification techniques under the general concept of texture analysis with LANDSAT digital data covering two geological quads of Nevada. The results indicate that the supervised classification method is		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

> very effective in the extraction of granite regions when (1) data were in ratio format, (2) feature variables included both tone and texture information, and (3) the classifier is capable of handling non-normally distributed data. Classification errors occurred when there exists pixels of non-granite category whose spectral and textural properties are statistically similar to that of granite pixels. Two cases of errors can be noted: Type 1 pixels located at the periphery of the granite regions, and Type 2 pixels located far away from the core of the granite areas.

To reduce the error rate, an unsupervised classification method based on the concept of region growing and texture clustering analysis was employed to segment the scene in multiple stages and thus depict edge patterns by the scene content and a gradual mathematical generalization process. Identification of the granite regions becomes a labeling process using the training sets information. Since the Regions algorithm is based on an additional constraint on spatial contiguity, the above-mentioned two types of errors can be effectively reduced because sharp edges exist between the granite and non-granite pixels in the study area.

> The final decision regarding the delineation of the granite regions is based on the intersection of two classification maps using a simple map overlay analysis. The result yields a correct classification rate of about 95 percent based on a visual comparison between the composite classification map and the ground truth information given in the U.S.G.S. geological map of the study area. <

To improve the developed techniques for lithological analysis, it is recommended that additional experiments be conducted using other regions in the United States centering around the following tasks:

- (1) developing algorithms for merging supervised and unsupervised classification methods;
- (2) finetuning the Region algorithm by adding subroutines to output digital information of each segmented region;
- (3) developing a color prediction model for rock types identification using the texture and tone information in the color domain with a color monitor; and
- (4) developing change detection methods for monitoring purposes based on the extension of the above three methods.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Aval and/or	
Dist	Special
A	



Macl
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

PREFACE

This research was sponsored by the Advanced Research Projects Agency under the monitorship of Mr. William Best of Air Force Office of Scientific Research. Dr. Shin-yi Hsu is the principal investigator. Research scientists of the project include Dr. Timothy Masters and Ms. Jane Huang of Susquehanna Resources and Environment, Inc.

Mr. Jack Rachlin and his associates at U.S. Geological Survey provided technical assistance and advice throughout the effort. Lt. Colonel James Smith of AFOSR also served as technical evaluator and adviser.

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH (AFSC)
NOTICE OF TRANSMITTAL TO DTIC
This technical report has been reviewed and is
approved for public release IAW AFR 190-12.
Distribution is unlimited.
MATTHEW J. KERPER
Chief, Technical Information Division

TABLE OF CONTENTS

Executive Summary	i
Section A: Introduction	1
Section B: A Brief Review of Relevant Literature	2
Section C: The Tasks, Data Analysis and Results	3
1. Tasks to be Accomplished	3
a. Preliminary Testing on the Proposed Methodologies	3
b. Tasks Determined for the Phase-I Effort	4
2. The Data Sets	5
a. The Original Data Set from the LANDSAT Tape	5
b. Derived Data Sets to be Analyzed	6
3. Image Processing and Data Analysis Methodologies Utilized	6
a. Extraction of texture-tone information of the training sets and the entire data set	6
b. Analysis of the Training Sets	7
c. Discriminant Analysis of the Training Sets	7
d. Supervised Classification Methods	8
e. Scene Segmentation with Unsupervised Training/Classification Method	8
f. Comparative Analysis with the Results from Supervised and Unsupervised Classification Method	8
g. Analysis of Factors Influencing the Classification Results	9
4. Experiments Conducted and Research Results	9
a. Generation of Texture-tone Variables for Data Analysis by Supervised Classification Methods	9
b. Analyses of the Training Sets	9
c. Classification Analyses with a Supervised Training Approach	15
d. Feature Extraction with an Unsupervised Training Approach	17
e. Classification Analysis by a Combination of Supervised and Unsupervised Training Approaches	22
Section D: Image Processing Techniques Towards Identification of Rock Types	23
1. Integration of Supervised and Unsupervised Classification Methods	23
2. Fine-Tuning of the Region Algorithm	24
a. Dynamic Edge Patterns as Indication of Rock Types	24
b. Display Texture and Tone Information of Each Segmented Region	24
c. Generalization by a Color Prediction Model	24
References Cited	26

Executive Summary

It has been determined in the literature on seismology and geophysics that the recorded seismic wave energy from nuclear explosions is highly dependent upon the actual yield of the explosion and its interaction with the environments in which the detonation occurs. These environmental factors can be characterized by the depth of explosion below the surface, the degree of coupling between the charge and the adjacent medium, and the lithological nature of the test sites. Therefore, the analysis of rock type at the test sites is the first step in nuclear monitoring.

The LANDSAT data have been determined effective for terrain analysis. The choice of the LANDSAT imagery for rock types analysis at the nuclear test sites is also based upon the fact that it can provide world-wide coverage with repetitive observations for monitoring purposes. The goal of this study is to test the feasibility of utilizing LANDSAT's digital, multi-spectral reformation for rock types discrimination at the nuclear test sites, based on the texture-tone analysis algorithms of the image processing systems at Susquehanna Resources and Environment, Inc.

The experiments were based on two subframes of LANDSAT MSS data, covering two geological quadrangles of Nevada. Whereas Site 1 (Antler Peak Quad) was used mainly for methodological development, Site 2 (Duffer Peak Quad) was designed as an analog test site to foreign areas for performing the task of extracting the granite regions.

The task was accomplished by using two separate but complimentary image processing techniques. The first technique, a supervised classification, was designed to extract granite regions using four ratio bands (4/7, 4/6, 5/7, and 6/7) based upon four manually selected, but automatically pre-processed training sets. The non-granite regions were extracted as well

using the reject category of the classification model. The second method, an unsupervised classification procedure based on the concepts of region growing and texture analysis, was designed to delineate granite regions using one ratio band (4/7 is most effective) by growing the granite regions from the cores of the training sets to the edges bordering non-granite areas.

The final granite regions were defined by the intersection of two granite images produced by two different image analysis techniques. The result indicates that a very high level of correct classification rate--95 percent or better--has been achieved, based on an overlay analysis using the classification result against the geologic map produced by the U.S. Geological Survey.

Though the defined task of extracting granite regions has been successfully accomplished, it is necessary to test the developed image processing and analysis techniques using additional U.S. test sites before they are applied to foreign regions. The reasons are (1) fine tuning of the methods are required to handle diverse patterns of lithological associations, and (2) the LANDSAT imagery can be exploited further for detecting environmental and man-made changes before and after nuclear explosions.

Applications of Texture Analysis for Rock Types Discrimination

Section A: Introduction

Ever since the Soviet Union's detonation of its first nuclear device prototypes, both the realities of an arms race and the requirement to maintain scientific/technological advantages have forced the United States to expend significant resources in monitoring of foreign nuclear tests. Sophisticated technologies that have evolved about the framework of seismology and geophysics have made significant contributions in satisfying the national requirement to detect, locate, identify and yield-quantify world-wide nuclear detonations. Yet, there is room for improvement using non-seismic methods, particularly in the area of yield estimation. To this end, this study is intended to develop image processing and analysis methodologies for the discrimination and identification of rock types at nuclear test sites. The rationale of this approach is based on the fact that the recorded seismic wave energy resulted from nuclear explosion depends on the following environmental/lithological factors:

- (1) the actual yield of the explosion;
- (2) depth of the explosion below the surface;
- (3) the degree of physical coupling between the charge and the adjacent medium; and
- (4) the geological nature of the median in which the detonation occurs.

Indeed, rock types analysis is the first step in yield estimation.

To accomplish the goal of rock types discriminated at the nuclear test sites, LANDSAT's multispectral data were used. The choice of the LANDSAT imagery is based on the fact that it is capable of providing a world-wide and repetitive coverages and thus a basis for monitoring nuclear test

activities. The thrust of this study is to exploit the digital information of LANDSAT data in the context of texture-tone analysis for such purposes.

To test the feasibility of the SR&E's image processing system for lithological analysis, two test sites in Nevada were utilized, the Antler Peak Quadrangle, Nevada at the scale of 1:62,500 (ANA1) and the Duffer Peak Quadrangle, Nevada at 1:48,000 (ANA2) as analogs to foreign nuclear test sites. Specifically, the first site (ANA1) was used as a testbed for methodological development; whereas the second site (ANA2) was designed as an analog area for extracting granite regions.

To classify granite versus non-granite regions, two complementary image analysis techniques were employed. First, a supervised classification analysis was conducted to delineate granite areas based on manually selected, but digitally pre-processed training sets, and to reject non-granite regions based on a pre-set statistical model/probability level for identifying pixels which are significantly different from the training sets. Second, an unsupervised clustering analysis based on SR&E's Region Growing Texture Clustering algorithm was performed to extract granite areas by region growing from the cores of the granite training sets. The final definition of granite regions is based on the intersection of these two sets of "granite maps."

Section B: A Brief Review of Relevant Literature

Prior to 1972 and the launch of LANDSAT, pioneer work on reflective properties of minerals was accomplished by Hunt and Salisbury at the USAF Cambridge Research Laboratories (1970, 1973). Their study and explanation of reflective/transmission properties of both minerals and rocks in the visible and near-infrared regions serves as a basis for semi-automatic rock discrimination to techniques that exploit the spectral (tone) parameters of multispectral imagery. Rather than being a simple empirical result, it turns out

that minerals and rocks spectral characteristics are a direct function of the physics and theory associated with crystal-field theory (Burns, 1970), as evidenced from theoretical and laboratory analyses of the rocks and minerals of the moon (McCord, 1968; further McCord, et al, 1972).

Since then, scientists at the U.S. Geological Survey, Jet Propulsion Laboratory and NASA/Goddard Space Flight Center, have attempted to exploit LANDSAT MSS data for rock types analysis as evidenced from Goetz, et al (1973), Goetz, et al (1975), Vincent, et al (1975), Rown, et al (1976), Rown, et al (1977), Abrams, et al (1977), and Podwysocki, et al (1977). Recent work by other researchers including Lyon (1977), Lyon, et al (1978), Hunt (1977), and Siegrist et al (1980), also emphasized digital processing of LANDSAT and other types of multispectral scanner data for optimal combination of spectral channels for rock discrimination.

While the majority of the work cited above emphasized rock types analysis and identification with color enhancement techniques with LANDSAT images, our study is devoted exclusively to extracting rock types using the digital information of the LANDSAT MSS data in the context of texture analysis, which has been largely neglected by previous researchers.

Section C: The Tasks, Data Analysis and Results

1. Tasks to be Accomplished

a. Preliminary Testing on the Proposed Methodologies

At the beginning of our research, the task was loosely defined as discrimination of rock types with LANDSAT data using our texture analysis algorithms.

Using more than 20 training sets evenly distributed over the entire Site 1 (Antler Peak Quad.), it was determined that (1) our texture algorithm is capable of separating these training sets with

a correct classification rate of over 95 percent even though many of the training sets belong to the same major rock types--sedimentary, igneous and metamorphic; and (2) while the three major rock types are well separated, in terms of statistical means of texture-tone variables, the range of these measurements from training sets within the same major rock-type is not small for all training sets, meaning that local variations exist in major rock types.

In the mapping analysis, it was determined that our region-growing texture clustering algorithm is apparently effective in delineating surface material which may be relatable to the bedrock information with LANDSAT data without compression. It is not effective when the LANDSAT data are compressed by a factor of three.

b. Tasks Determined for the Phase-I Effort

From a discussion session among Mr. Best of AFOSR, Col. Lowrey of DARPA, Mr. Rachlin and his colleagues of U.S. Geological Survey, and Dr. Hsu, it was determined that the tasks of our effort should be aimed at answering the following three questions:

1. How well can we map the granite areas versus non-granite regions using our supervised and unsupervised classification methods in the context of texture analysis?
2. What are the factors affecting the classification results--slope, drainage pattern, data used, methodologies utilized?
3. What are the potential contribution of image processing techniques and methodologies towards the discrimination and even identification of rock types using LANDSAT data?

For data analysis, a study area within Duffer Peak Quadrangle, Nevada was selected by Mr. Dempsie of U.S. Geological Survey. Furthermore, based on the geologic map, 22 training sets were selected manually to cover four

major rock types: (1) granite, (2) metamorphic, (3) volcanic, and (4) unconsolidated.

2. The Data Sets

a. The Original Data Set from the LANDSAT Tape

Corresponding to the study area selected by Mr. Dempsie of U.S.G.S., a digital set composed of (256 x 256) pixels of LANDSAT MSS data was determined using visual analysis. The Northwest corner of the data set is located at (row 1268, column 1987).

In addition, the training sets with their locations within the (256 x 256) frame have also been determined as follows:

1. Group 1: Granite

G1: (15,124), (15,144), (27,144), (27,124)
 G2: (56, 38), (56, 55), (71, 55), (71,38)
 G3: (130,133), (130,147), (142,147), (142,133)
 G4: (132,7), (132,19), (146,19), (146,7)
 G5: (170,137), (170,150), (181,150), (181,137)

2. Group 2: Metamorphic

B1: (75,158), (75,172), (85,172), (85,158)
 B2: (115,163), (115,182), (129,182), (129,163)
 B3: (150,175), (150,189), (166,189), (166,175)
 B4: (95,89), (95,106), (105,106), (105,89)

3. Group 3: Volcanic

H1: (213,144), (213,159), (221,159), (221,144)
 H2: (215,174), (215,190), (223,190), (223,174)
 H3: (241,186), (241,197), (248,197), (248,186)
 H4: (217,13), (217,25), (228,25), (228,13)
 F1: (188,81), (188,93); (197,93), (197,81)

F2: (228,106), (228,117), (235,117), (235,106)

F3: (213,124), (213,134), (222,134), (222,124)

T1: (234,68), (234,80), (243,80), (243,68)

T2: (246,100), (246,112), (254,112), (254,100)

4. Group 4: Unconsolidated

Q₀1: (132,51), (132,64), (139,64), (139,51)

Q_f1: (51,196), (51,207), (61,207), (61,196)

Q_f2: (150,212), (150,223), (158,223), (158,212)

Q1: (56,237), (56,249), (65,249), (65,237)

b. Derived Data Sets to be Analyzed

To remove the shadow effect of the original LANDSAT data, and to extract information from four MSS bands simultaneously, the following data sets are generated.

- (1) First, second and third components from the four MSS bands;
- (2) Six ratio bands from the four MSS bands: 4/5, 5/6, 6/7, 4/6, 4/7, and 5/7.
- (3) The first component map from 4 selected ratio bands.

Therefore, ten derived image data sets are available for analysis in addition to the original four MSS bands. The location of the training sets with respect to these derived data sets remain the same.

3. Image Processing and Data Analysis Methodologies Utilized

To analyze the relationship between the selected training sets, and to classify the granite areas versus non-granite regions, the following analytical techniques are utilized.

a. Extraction of texture-tone information of the training sets and the entire data set.

Using the texture-tone extraction algorithm, 23 texture-tone-

ratio variables have been generated for any given pixel from four multi-spectral bands using (3 x 3) moving grid. They are composed of 4 tone variables, 12 texture variables (3 from each band), 1 linear feature variable, and final 6 ratio variables.

For data analysis, the analyst is able to select a portion of the 23 variables.

b. Analysis of the Training Sets

Based upon the selected variables from 23-variable system, typically we use three variables, the training sets will be analyzed and edited so that each training set will meet the following two criteria:

- (1) single mode; if two modes exist in one training set, the set will be split into subsets;
- (2) extreme outliers are to be removed based on a statistical confidence level.

c. Discriminant Analysis of the Training Sets

After the training sets are edited or preprocessed, they will be analyzed in terms of how close they are between pairs of training sets using the means of selected tone-texture variables. The distance is generally measured by statistical distance called Mahalanobis D^2 with or without a log-determinant term.

While the D^2 distance is indicative of the degree of similarity and dissimilarity between two training sets, the analyst usually uses a confusion matrix--classification result using only the training sets--to examine how well these training sets are separated. The analyst will then decide whether he should proceed with a classification analysis of the entire test set. In general, if dissimilar training sets are confused, a classification analysis should not be conducted.

d. Supervised Classification Methods

As mentioned earlier, a supervised classification analysis can be made only when the training sets are well separated. To achieve this goal, the following steps can be taken:

- (1) purify the training sets as in (b);
- (2) change the location of the training sets;
- (3) increase the power of the feature extractor by using
 - (i) more texture-tone variables, and (ii) using different spectral-band combinations; and
- (4) increase the power of the classifier by using a non-Gaussian model if the data are essentially non-multivariate normal.

In the analysis, we have done all these image processing techniques except step (2), changing the location of the training sets.

e. Scene Segmentation with Unsupervised Training/Classification Method

This analysis is intended to extract the granite regions first based on segmentation concept using a region-growing texture clustering algorithm. Once the entire test area is segmented into numerous subregions according to different levels of thresholding (generalization), we are able to extract the granite regions according to the location of the training sets.

Since this algorithm is based on local statistics or edge information instead of global separation employed by the supervised classification method, it should be used as a complementary classification method instead of a replacement of the supervised method.

f. Comparative Analysis with the Results from Supervised and Unsupervised Classification Method

g. Analysis of Factors Influencing the Classification Results

In this analysis we will concentrate our effort on two broad categories: (1) classification results influenced by terrain factors, surfacial material, slope, drainage, etc., and (2) classification results influenced by the data sets and techniques, feature extractors, and classifiers, used in the analysis.

4. Experiments Conducted and Research Results

The description of this section regarding data analysis corresponds to the methodologies discussed in the previous section.

a. Generation of Texture-tone Variables for Data Analysis by Supervised Classification Methods

Using the original LANDSAT MSS data and derived ratio bands, these data sets containing 23 texture-tone variables for each pixels were generated:

- (1) Data Set 1 is composed of MSS Bands 4, 5, 6, and 7;
- (2) Data Set 2 is composed of 4 ratio bands: 4/5, 5/6, 6/7 and 4/7; and
- (3) Data Set 3 is composed of 4 ratio bands: 4/7, 4/6, 5/7 and 6/7.

b. Analyses of the Training Sets

The training sets selected manually by Mr. Dempsie of U.S. Geological Survey were analyzed for two distinctive purposes:

- (1) All 22 training sets were analyzed to detect the confusion pattern between the granite sets and the non-granite sets; and
- (2) Four granite sets of the original five granite sets were pre-processed for serving as calibration samples for classification analysis.

The analysis starts with preprocessing of the training sets aimed at detecting whether bi-modal distribution and outliers exists in each set.

Indeed, it was determined that in the original MSS data sets B2, B3, B4, T1 and Q₀1 are bi-modal, and thus each was split into two subsets, resulting in 28 training sets, instead of 22 sets in original design. Furthermore, outliers are edited and eliminated using a predetermined distribution scheme. Table 1 summarizes the training sets information, original and after pre-processing, whereas Appendix 1 gives the sample statistics of the texture-tone variables for each training set.

Using the statistics given in Appendix 1, an analysis was conducted to reveal the confusion pattern between the granite training sets (set 1 through set 5) and the rest. The results are given in Table 2, and it indicates that (1) granite set 1 is highly confused with non-granite sets, and (2) granite set 2 through set 5 are highly correlated among themselves, but are not confused with non-granite sets (set 6 through set 28). For instance, the percentage of correct classification of G1 into G1 through G5 is only 61.7, whereas the figures for G2, G3, G4 and G5 are 100, 86.1, 99.5 and 99.4, respectively. It was therefore determined that training set G1 should be eliminated from the design sets in the final classification analysis aimed at delineating granite versus non-granite regions.

The same analyses were also applied to the training sets with ratio data, instead of the original MSS data. Whereas Appendix 2 gives the texture-tone statistics of each training set, Table 3 summarizes the result of pre-processing; from the original 22 sets, 25 sets are obtained, instead of 28 as in the case of the original MSS data. This means that the ratio data are more homogeneous than the raw MSS data because the LANDSAT's shadow effect has been removed by the ratioing process.

In terms of confusion pattern between granite sets versus non-granite sets, no significant difference exists between the raw MSS data and the ratio data, as indicated in Table 4; namely, granite set 1 is totally confused

with other non-granite sets, granite set 2 through granite set 5 are similar among themselves, but quite different from other non-granite rocks.

Raw Data

Table 1: Preprocessing of the Training Sets with Original MSS Data
(Band 4 and Band 7)

Original		Training Set Size		New Set ID
Training at ID #	Code	(1) # of Points	(2) after Preprocessing	New Training Set ID #
1	Granite G1	273	269	1
2	G2	288	278	2
3	G3	195	190	3
4	G4	195	187	4
5	G5	168	164	5
6	Metamorphic B1	165	162	6
7	B2	300	141	7
8	B3	165	154	8
9	B4	198	95	9
10	Volcanic H1	144	70	10
11	H2	153	91	11
12	H3	96	92	12
13	H4	156	143	13
14	F1	130	150	14
15	F2	96	96	15
16	F3	110	93	16
17	T1	130	63	17
18	T2	117	126	18
19	Unconsolidated Qf1	132	94	19
20	Qf2	108	108	20
21	Q1	130	64	21
22	Qo1	112	51	22
			111	23
			131	24
			105	25
			130	26
			58	27
			50	28

Table 2: Confusion Matrix: Percent of Correct Classification
With the Raw Data

[illegible][illegible]

Table 3: Preprocessing of Training Sets with Ratio Data

Training Set ID #	Code	# of Points	After pre-processing	New ID #
1 Granite	G1	273	258	1
2	G2	288	278	2
3	G3	195	186	3
4	G4	195	178	4
5	G5	168	162	5
6 Metamorphic	B1	165	165	6
7	B2	300	183 111	7 8
8	B3	165	74 83	9 10
9	B4	198	196	11
10 Volcanic	H1	144	143	12
11	H2	153	150	13
12	H3	96	93	14
13	H4	156	154	15
14	F1	130	127	16
15	F2	96	93	17
16	F3	110	108	18
17	T1	130	127	19
18	T2	117	115	20
19 Unconsolidated Q _f 1		132	130	21
20	Q _f 2	108	105	22
21	Q1	130	63 57	23 24
22	Q _o 1	112	111	25

In terms of the confusion pattern among these 4 granite sets, it was determined that they are related only to a certain degree since the correct classification rate with the four sets reach at a high level of 75 percent (Table 5). This means significant local variation of granite exists in the study area.

Table 5. Confusion Matrix of the Granite Training Sets

	G2	G3	G4	G4
G2	211	0	63	5
G3	0	164	2	20
G4	62	2	113	2
G5	12	31	19	102

Correct Classifier = 73.02%

c. Classification Analyses with a Supervised Training Approach

The goals of this analyses are first to generate classification maps of granite versus non-granite regions using different data sets, different feature variables and different classifiers, and second to compare these classification results against the ground truth information including terrain information and bedrock geologic map.

For the study, numerous experiments have been conducted; the following table indicates the experiments derived from combinations of different data sets with different methodologies.

Table 6. Experiments of Supervised Classification

Data Sets	Data Sets		
	Data Set 1 (4 original MSS)	Data Set 2 (4 ratio bands: 4/5,4/5,5/7,4/7)	Data Set 3 (4 ratio bands: 4/7,4/6,5/7,6/7)
Methodology			
1. Gaussian Classifier with 7 texture-tone variables	Exp 1 with 5 granite sets Exp 2 with 5 granite sets plus 5 automatically selected new sets	Exp 1 with 4 granite sets Exp 2 with 4 granite sets plus 2 automatically selected new sets	Exp 1 with 4 granite sets
2. Gaussian Classifier with 16 texture variables		Exp 1 with 4 granite sets	
3. Non-Gaussian classifiers with 7 texture-tone variables		Exp 1 with 4 granite sets	Exp 1 with 4 granite sets

From these experiments, it can be concluded that:

- (1) For rock type analysis, Data Set 3 composed of these 4 ratio bands: 4/6, 4/7, 5/7, 6/7 is most effective. Data Set 1 with the 4 original 4 LANDSAT MSS bands is least effective. Figure 1, a decision map, indicates that the vast majority of granite areas are correctly identified, except
 - (a) the granite area, within which the training set G1 (which was not used in the analysis is located, is largely classified as non-granite, and
 - (b) one "metamorphic rock" area as labeled in the geologic map was largely classified as "granite."

These two regions will be investigated further using our unsupervised segmentation algorithm in the next section.

- (2) Regarding the classifiers, our Non-Gaussian classifier with 7 texture-tone variables is superior to the Gaussian classifier no matter whether it utilizes 7 or 16 texture-tone variables.

- (3) There is little difference between 7-variable Gaussian classifier and 16-variable Gaussian classifier in terms of the confusion matrix using the training sets data.
- (4) In terms of correct classification of the granite versus non-granite regions (areal distribution), both our Gaussian and non-Gaussian classifiers achieved a level of over 90 percent hit-rate. The Non-Gaussian Classifier is slightly better than the Gaussian Classifier in these experiments.

d. Feature Extraction with an Unsupervised Training Approach

(1) Experimental Design

The goal of these analyses is to extract homogeneous regions in the study area from various LANDSAT ratio bands using our region-growing texture clustering analysis algorithm. Identification of the granite regions becomes a labeling process using training sets information and other related statistical and terrain characteristics data. It is our intention to use the results from this unsupervised classification method to investigate the areas of misclassification by the supervised classifier.

From the four LANDSAT MSS bands, it is possible to derive six ratio bands: $4/5$, $4/6$, $4/7$, $5/6$, $4/7$, and $6/7$. In our earlier experiments, it was determined that these ratio bands are not effective for segmenting regions of the study area: $4/5$, $5/6$ and $6/7$. Hence, our experiments for rock-type/surface material analyses utilized information from these three ratio bands: $4/7$, $5/7$, and $4/6$. These three ratio bands in fact characterize the contrast between the visible and the infrared spectrum.

To extract rock-type/surface material regions, the following experiments were conducted using our unsupervised classification

("Region") algorithm:

Experiment	Data Set	Thresholding Parameter	No. of Passes
1	A2R47F3	(2,2) through (2,5)	5
2	A2R47F3	(3,3) through (3,6)	4
3	A2R47F3L	(2,2) through (2,6)	5
4	A2R57F3	(3,3) through (3,7)	5
5	A2R57F3L	(2,2) through (2,5)	4
6	A2R46F3	(2,2) through (2,7)	7
7	A2R46F3L	(2,2) through (2,4)	3

For the data set ID, A2 means Analog Area 2 of the study areas; R47 means ratio between Band 4 and Band 7; and F3 means the third data file (Analog 2) and L in the data set name identifies the fact that the data set is derived from double log ratio mode.

Regarding the thresholding parameters, the first parameter stands for the first stage cutoff regarding the difference between adjacent (pairs) pixels or clusters; whereas the second parameter refers to the second stage cutoff for grouping clusters in terms of a weighted geometric distance computed from a tone and a texture variable.

Since we design the algorithm to perform a dynamic cueing task, the analytical results can be printed (output) at any given stage of clustering process according to the second stage cut-off parameter specified by the analyst. Furthermore, the statistics for each region of a given pass can be extracted and displayed.

(2) The Results of the Analyses

By examining the results from these experiments, it can be concluded that:

(a) General conclusions:

- (i) In general, the "Region" algorithm is able to extract spatially contiguous, homogeneous regions of rock-type/surface material regions as defined by

the contrast between visible and infrared spectrum of the LANDSAT data;

- (ii) The performance of a given ratio band is not uniform over the entire study area, meaning that it may take two or more ratio bands to extract all of the "distinctive" regions in the study area.
 - (iii) Our "dynamic cueing" approach is able to reveal the strength and weakness of the contract lines or zones between two adjacent rock-type/surface-material regions. This means that the existence of "contact lines or zones" is both spectral/spatial information dependence, and thresholding parameter dependence as well.
 - (iv) In the area where the supervised training classifier failed to identify the granite and non-granite regions, the unsupervised, region-growing algorithm is capable of identifying them as distinctive regions.
 - (v) Combining the results from the supervised and the unsupervised classification approaches, we believe that the correct classification rate of granite versus non-granite region is about 95 percent.
 - (vi) Therefore, it can be concluded that our two classification algorithms are indeed complementary for extracting distinctive rock-type/surface-material regions.
- (b) Conclusions from individual experiments:
- (i) Results from Log Ratio of Band 4 and B7 (Figure 2).
The base map of Figure 2 is the Pass 3 results of

the unsupervised classification with log ratio of Band 4 and Band 7. Using the location of the training sets G1 through G5, the major granite areas are identified and colored in light red, whereas the bedrock regions of granite are shaded in green. In general, there is a high degree of agreement between the segmented regions and the bedrock boundaries. Particularly, by comparing Figure 2 against Figure 1, we are able to derive that (1) the rejected granite G1 area can be delineated by the Region algorithm, and (2) the confused area in Figure 1 between G2 and G3 can be discriminated as well. Similar to the supervised classifier, the Region algorithm failed to distinguish the bedrock granite from the surfacial granite in the area near training set G4. As will be noted later, this boundary is detected in the analysis with the data set of log ratio of Band 4/Band 6.

- (ii) Results from Log Ratio of Band 4 and Band 7 with a Larger First Stage Cutoff. This experiment was intended to reveal the effect of using a larger first stage cutoff parameter as compared to the above experiment. The results indicate that with a larger cutoff the algorithm failed to detect the boundary between granite versus non-granite in the area where training set G1 is located; the rest of the results remains essentially the same.
- (iii) Results from Double Log Ratio of Band 4 and Band 7 (Figure 4). This experiment shows the effect of

using a double log transformation of the data set Band 4/Band 7. By comparing the result against Figure 2, it can be noted that this double transformation in fact has less discrimination power as evidenced from the fact that there is boundary shift in the area near training sets G2 and G5.

- (iv) Results from Log Ratio of Band 4 and Band 6. In this experiment, we replaced Band 7 with Band 6 of the LANDSAT infrared spectra and kept Band 4 as a constant. The result shows that (1) log ratio of Band 4 and Band 6 is able to detect the boundary between bedrock granite and surfacial granite as evidenced from the area near the location of G4, but (2) it failed to detect the granite versus non-granite boundaries in the areas where G1 and G4 are located. In general, it appears that the spectral data from ratio of Band 4/Band 6 contain a component which is affected by the drainage pattern of the area.

- (v) Results from Log Ratio of Band 5 and Band 7.

This experiment shows the effect regarding a change in the visible band in the analysis, and the results indicate that the ratio of Band 5 and Band 7 is less effective for rock type analysis as compared to B4/B7. It appears that the B5/B7 data set contains a component which is highly affected by the drainage patterns of the area.

- (vi) Results from Double Log Ratio of Band 5 and 7.

In general this experiment indicates that in certain

regions the double log transformation of ratio data of B5/B7 may be more sensitive than the single log transformation as evidenced from the segmentation results in the area where training set G1 is located.

e. Classification Analysis by a Combination of Supervised and Unsupervised Training Approaches

From the results given in Sections c and d, we have used a multiple map overlay analysis to delineate the final granite regions as given in Figure 3 with the following conclusions:

- (1) In the areas where training sets information exists, there is a remarkable correspondence between Figure 1 and Figure 2;
- (2) From a manual editing process, we can place the granite G1 area from Figure 2 onto Figure 1;
- (3) The areas of misclassification in Figure 1--
 - i. region between G2 and G3, and
 - ii. pixels located outside the boundaries of labeled granite regions of G1, G2, G3, G4 and G5 in the northeast, southeast and southwest quadrangles--
 can be removed from Figure 1.
- (4) Since there is no information regarding ground truth in the area between the location of G1 and G2, we will use the result as given in Figure 1 for granite identification; and
- (5) Comparing the results as described above in reference to Figure 3, it can be concluded that an extremely high level of correct classification of granite and non-granite has been achieved. It should be noted that we are able to edit this map further using additional ground truth information and the segmentation results given by other ratio bands.

Section D: Image Processing Techniques Towards Identification of Rock Types

1. Integration of Supervised and Unsupervised Classification Methods.

As indicated in Section C, the task of identifying rock types can be achieved provided that ground truth information of the training areas is known. The task can be achieved by using either a supervised or unsupervised classification technique as shown in Figure 1 and Figure 2, respectively.

To obtain a better result, the intersection of these two classification maps (Figure 3) was used as the final decision rule for defining the granite regions. The advantages of Figure 3 over Figure 1 and Figure 2 are several:

- (1) It avoids random errors in the decision map of the supervised classification methods, particularly those located far away from cores of the training sets;
- (2) It has information for labeling segmented regions from the unsupervised classification method; and
- (3) the intersection of two decision maps in fact, strengthens the probability of correct classification.

In this report, the "intersection" of two classification methods was done by use of an overlay analysis of two decision maps.

Theoretically, a new algorithm should be developed to perform the task of merging two image processing methods centered around:

- (1) Classifying the results of the region algorithm using the training sets information, and
- (2) Extracting distinctive regions using multiple ratio bands, and classifying them according to the training sets information.

It is believed that certain techniques of artificial intelligence are useful to this effort.

2. Fine-tuning of the Region Algorithm.

a. Dynamic edge patterns as indication of rock types

For this technical report, the region algorithm was utilized to segment terrain/rock types in multiple stages, and to reveal the evolutionary patterns of the edges, such as lineaments or contact zones between two lithological types, at the study area.

An improvement of the region algorithm can be made by adding a subroutine aimed at testing whether edges within a larger region are noise or real boundaries. If they are determined as noise, they can be removed, and vice versa. This capability will provide the analyst with a sounder basis for the regionalization of terrain and lithological types.

b. Display Texture and Tone Information of each Segmented Region

To provide more information for the analyst to make decisions regarding identification of rock types, another subroutine can be added to output the texture, tone and size information of the segmented regions under investigation. Using such information, the analyst may be able to identify the terrain and rock types by means of a comparative analysis provided that certain texture-tone characteristics of training areas are known.

In practice, the analyst would use both edge pattern and quantitative texture-tone information for rock types discrimination and identification.

c. Generalization by a Color Prediction Model

Conventionally color monitors are used as a device for generating color composite from multi-channel data by means of a coding process using three color primaries, red-green-blue or yellow-cyan-magenta.

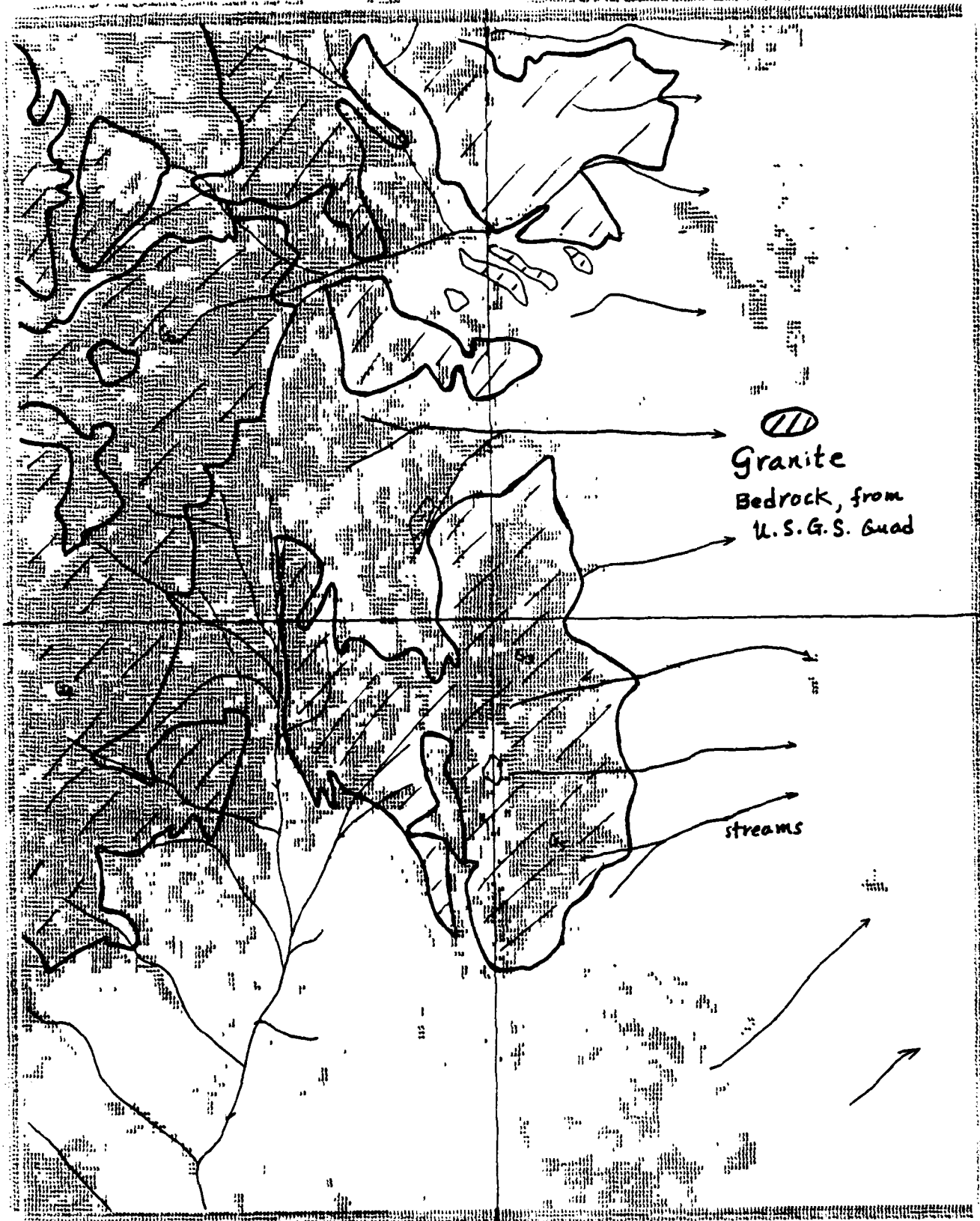
With known quantitative texture and tone information, specific

colors can be generated for a given rock type by means of the color theory. For instance, if there are two parameters (1 tone and 1 texture) for each region, a specific color for that region can be made by assigning the tone information to Red domain and the texture information to Blue versus Green domain. If three parameters are available, 1 tone and 2 textures, the specific color code for that region can be generated by assigning tone to Red, texture 1 to Green, and texture 2 to Blue.

For the two-parameter system, different color/tensity codes can be generated if one allows the tone parameter to control intensity levels and texture to control colors. In an 8-bit color monitor system, for instance, one can allow the tone parameter to display 16 intensity levels, and the texture variable to give 16 different colors. The combination of such intensity and color codes should allow the researcher to predict and identify certain rock types using given texture and tone information from either ground truth or laboratory analysis, or a combination of both.

Figure 1

Classification Map of Granite Regions, Supervised Method, Non-quantization, Ratio Bands: 4/6, 4/7, 5/9, 6/7.



Training sets

	Training set 1
	Training set 2
	Training set 3
	Training set 4

01	0000	000000
02	0000	000000
03	0000	000000
04	0000	000000
05	0000	000000

Figure 2:

Dynamic Regions of Granite by Unsupervised Classification Method
Based on Logratio of Band 4 / Band 7

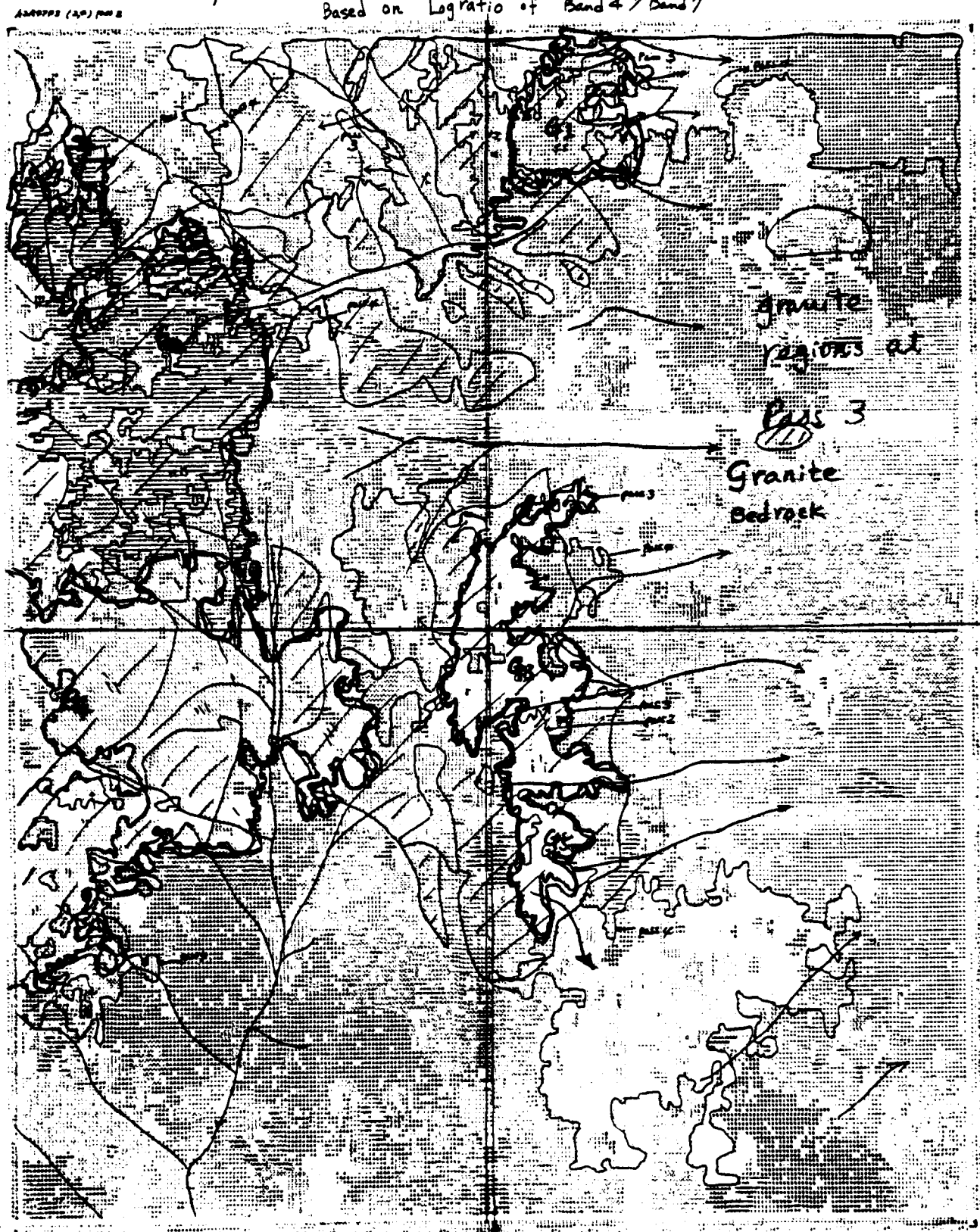


Figure 3: Decision map from Overlay of Figure 1 and Figure 2

Classification Map of Granite Regions, Supervised Method, Non-Gaussian, Ratio Bands: 4/6, 4/7, 5/7, 6/7.

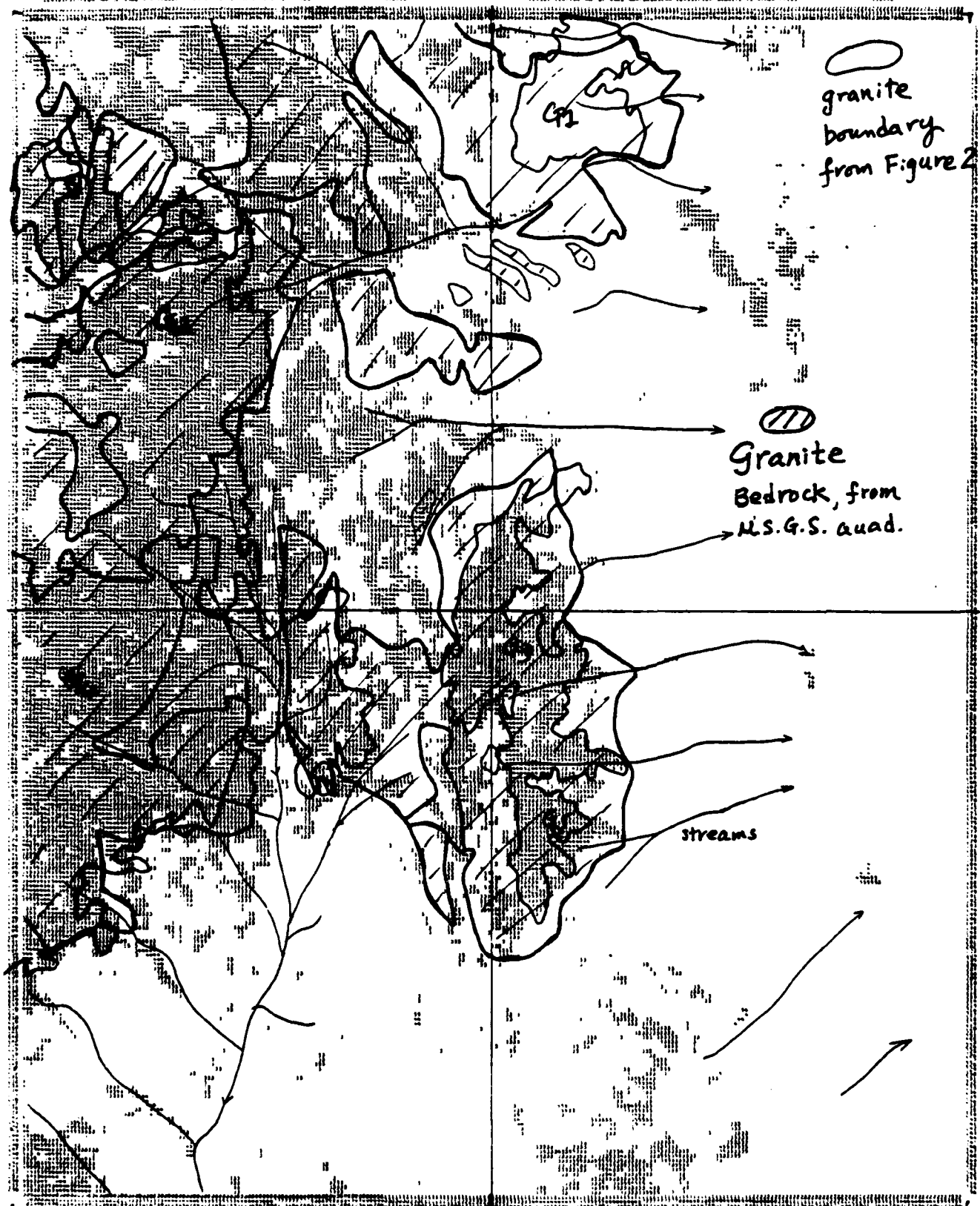
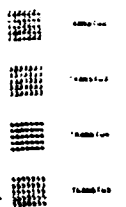


Figure 1
Decision
from T. Seto



TOTAL CLASSIFICATION

00	00000	00000
01	00000	00000
02	00000	00000
03	00000	00000
04	00000	00000

References Cited

- Abrams, M.J., R.P. Ashley, L.C. Rowan, A.F. Goetz, and A.B. Kahle, 1977. Use of Imaging in the 0.46-2.36 μ m Spectral Region for Alteration Mapping in the Cuprite Mining District, Nevada, USGS Open File Report 77-585.
- Burns, R.G., Mineralogical Applications of Crystal Field Theory, Cambridge: Cambridge University Press, 1970.
- Goetz, A.F.H., and Billingsley, F.C. "Digital Image Enhancement Techniques Used in Some ERTS Applications." Contributions to Geology, Vol. 12, No. 2 (edited by R.B. Parker), Laramie, Wyoming: University of Wyoming, 1973.
- Goetz, A.F.H., Billingsley, F.C., Gillespie, A.R., Abrams, M.J., Squires, R.L., Shoemaker, E.M., Lucchitta, I., and D.P. Elston, Application of ERTS Images and Image Processing to Regional Geologic Problems and Geologic Mapping in Northern Arizona. NASA Technical Report 32-1597, JPL, Pasadena, California: California Institute of Technology, 1975.
- Goetz, A.F., B.S. Siegal, and L.C. Rowan, 1975. Quantitative Spectral Techniques and Computer Image Processing as Applied to Lithologic Mapping, Proc. of 1975 IEEE Conference on Decision and Control, pp. 412-413.
- Hunt, G.R., 1977. Spectral Signatures of Particulate-Minerals in the Visible and Near-Infrared, Geophysics, 42 (3), pp. 501-513.
- Hunt, G.R., and J.W. Salisbury, 1970. Visible and Near-Infrared Spectra of Minerals and Rocks--I. Silicate Minerals, Modern Geology, Vol. 1, pp. 283-300.
- Hunt, G.R., J.W. Salisbury, and C.J. Lenhoff, 1971. Visible and Near-Infrared Spectra of Minerals and Rocks--IV. Sulphides and Sulphates, Modern Geology, Vol. 3, pp. 1-14.
- _____, 1973. Visible and Near-Infrared Spectra of Minerals and Rocks--VI. Additional Silicates, Modern Geology, Vol. 4, pp. 85-106.
- McCord, T.B., "Color Differences on the Lunar Surface," Ph.D. Thesis, California Institute of Technology, pp. 1-30, 1968.
- McCord, T.B., and J.A. Westphal, "Two Dimensional Silicon Vidicon Astronomical Photometer," Applied Optics, Vol. 11, No. 3, pp. 522-526, 1972.
- McCord, T.B., J.B. Adams, and R.L. Huguenin, 1976. Reflection Spectroscopy: A Technique for Remotely Sensed Surface Mineralogy and Composition, M.I.T. Remote Sensing Laboratory Publication #147.
- Podwysocki, M.H., F.J. Gunther, and H.W. Blodget, 1977. Discrimination of Rock and Soil Types by Digital Analysis of Landsat Data, NASA X-923-77-17.

- Rowan, L.C., Wetlaufer, P.H., Goetz, A.H., Billingsley, F.C., and J.H. Stewart, "Discrimination of Rock Types and Detection of Hydrothermally Altered Areas in South-Central Nevada by the Use of Computer Enhanced ERTS Images," U.S. Geological Survey Professional Paper 883, U.S. Government Printing Office, Washington, 1976.
- Rowan, L.C., Goetz, A.H., and R. Ashley, "Discrimination of Hydrothermally Altered and Unaltered Rocks in Visible and Near Infrared Multispectral Images," Geophysics, Vol. 42, No. 3 (April, 1977), pp. 522-535.
- Siegrist, A.W. and C.C. Schnetzler, "Optimal Spectral Bands for Rock Discrimination," Photogrammetric Engineering and Remote Sensing, Vol. 46, No. 9 (September, 1980), pp. 1207-1215.
- Vincent, R.K., L.C. Rowan, J. Gillespie, and C. Knapp, 1975. Thermal-Infrared Spectro and Chemical Analysis of Twenty-six Igneous Rock Samples, Remote Sensing of the Environment, 4, pp. 199-209.

Addendum

- Hsu, Shin-yi, "The Mahalanobis Classifier with the Generalized Inverse Approach for Automated Analysis of Imagery Texture Data," Computer Graphics and Image Processing, 9 (1979), pp. 117-134.
- _____. "Texture Tone Feature Extraction and Analysis," Rome Air Development Center, Air Force Systems Command, Griffiss Air Force Base, Rome, New York, 1977. (RADCR-77-279).
- Lyon, R.J., 1977. Mineral Exploration Applications of Digitally Processed Landsat Imagery, USGS Professional Paper 1015.
- Lyon, R.J., A. Prelat, H. Sheffer, and M. Inglis, 1978. Separation of 11-Terrain Classes at the Navajo Mine, Framington, NM, Using Hierarchical (Pairwise) Discriminant Analysis on Landsat CCT Data, Stanford Remote Sensing Laboratory Technical Report 77-12.

APPENDIX 1

Texture and Tone Variables of the Training Sets with
the Original LANDSAT MSS Data

STATISTICAL ANALYSIS SYSTEM DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SFT = 1

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
RRIGHT4	269	7275.44600000	27.04626766	10.613336356	3.2781577
RRIGHT5	269	7116.44100000	26.45000000	10.613336356	3.2781577
RRIGHT6	269	10653.99500000	39.60592917	28.51131077	5.3403783
RRIGHT7	269	10653.99500000	39.60592917	28.51131077	5.3403783
MLNCON4	269	7116.44100000	26.45000000	10.613336356	3.2781577
MLNCON5	269	7116.44100000	26.45000000	10.613336356	3.2781577
MLNCON6	269	7116.44100000	26.45000000	10.613336356	3.2781577
MLNCON7	269	7116.44100000	26.45000000	10.613336356	3.2781577
MDEVN4	269	7116.44100000	26.45000000	10.613336356	3.2781577
MDEVN5	269	7116.44100000	26.45000000	10.613336356	3.2781577
MDEVN6	269	7116.44100000	26.45000000	10.613336356	3.2781577
MDEVN7	269	7116.44100000	26.45000000	10.613336356	3.2781577

SFT = 2

RRIGHT4	278	6884.66900000	24.76499281	24.625032162	4.962336351
RRIGHT5	278	9550.32700000	34.35369424	61.18083864	7.82777820
RRIGHT6	278	12416.22500000	44.66267986	61.18083864	7.82777820
RRIGHT7	278	11812.55200000	42.49119424	41.01921470	6.098956164
MLNCON4	278	709.58100000	2.55244964	1.09061455	1.04590852
MLNCON5	278	1095.32900000	3.95441727	2.09061455	1.46397851
MLNCON6	278	1162.82900000	4.18283813	2.09061455	1.46397851
MLNCON7	278	965.07700000	3.47058849	2.09061455	1.46397851
MDEVN4	278	671.82700000	2.41664388	1.11257230	1.05458855
MDEVN5	278	1049.18700000	3.77405396	2.61258830	1.6166475
MDEVN6	278	1076.09900000	3.87085971	2.61258830	1.6166475
MDEVN7	278	903.25700000	3.24912590	2.40167631	1.54973427

SET = 3

RRIGHT4	190	5390.77700000	28.37251053	181.64973	4.2339911
RRIGHT5	190	7647.77700000	40.25145789	172.211862	7.26100032
RRIGHT6	190	8691.66800000	45.74762105	172.211862	7.26100032
RRIGHT7	190	7609.99900000	40.05262632	172.211862	7.26100032
MLNCON4	190	275.83700000	1.45177368	0.66831013	1.2841860
MLNCON5	190	450.32900000	2.37015263	1.26200635	1.1149310
MLNCON6	190	522.75100000	2.75132195	1.34906622	1.16439039
MLNCON7	190	438.49900000	2.311315263	1.1117910	1.089338140
MDEVN4	190	282.07900000	1.48462632	0.79813033	1.28193202
MDEVN5	190	448.65900000	2.36136816	1.64334970	1.28193202
MDEVN6	190	513.43100000	2.70226842	1.81731244	1.34807731
MDEVN7	190	453.64800000	2.38762105	1.6335	1.28086921

SET = 4

RRIGHT4	187	4712.66400000	25.20141176	796.9193	5.8861630
RRIGHT5	187	6446.55200000	34.47154011	936.18136	5.9258110
RRIGHT6	187	8259.22000000	44.15277004	1593.1304	5.9258110
RRIGHT7	187	7792.22000000	41.6866845	1593.1304	5.9258110
MLNCON4	187	478.58500000	2.5582289	0.10110996	1.02501508
MLNCON5	187	688.08200000	3.6790428	0.62472330	1.25327
MLNCON6	187	759.83500000	4.0632877	0.9574810	1.308809662
MLNCON7	187	760.49800000	4.0632877	0.9574810	1.308809662
MDEVN4	187	445.65500000	2.39318182	1.6697021	1.19336989
MDEVN5	187	655.06100000	3.50300000	1.49073021	1.19336989
MDEVN6	187	711.68000000	3.8077540	1.7568778	1.19336989
MDEVN7	187	710.83400000	3.80125134	1.7568778	1.19336989

STATISTICAL ANALYSIS SYSTEM

16:14 WEDNESDAY, JANUARY 6, 1982

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 5

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	164	449.55200000	27.41469512	5.10719661	2.26003686
BRIGHT5	164	423.53600000	25.82561037	5.10719661	2.26003686
BRIGHT6	164	423.53600000	25.82561037	5.10719661	2.26003686
BRIGHT7	164	423.53600000	25.82561037	5.10719661	2.26003686
MINCON4	164	355.21500000	21.65914646	6.56289390	2.56016081
MINCON5	164	232.66000000	1.41867013	6.56289390	2.56016081
MINCON6	164	349.41000000	2.13059146	0.66595515	0.81606035
MINCON7	164	307.42000000	1.87448780	0.48637724	0.69590031
MOEVN4	164	307.42000000	1.87448780	0.48637724	0.69590031
MOEVN5	164	217.45100000	1.32592073	0.25172126	0.50171831
MOEVN6	164	326.24500000	1.98929878	0.67358810	0.82072413
MOEVN7	164	324.04300000	1.97587195	0.58334838	0.76377247
MOEVN7	164	290.17000000	1.76932927	0.57967684	0.76136511

SET = 6

BRIGHT4	162	4638.99930000	28.63579630	2.46844277	1.57112787
BRIGHT5	162	637.00200000	39.30248148	6.02707590	2.45501037
BRIGHT6	162	637.00200000	39.30248148	6.02707590	2.45501037
BRIGHT7	162	637.00200000	39.30248148	6.02707590	2.45501037
MINCON4	162	515.17200000	31.83167284	10.64225787	3.26119266
MINCON5	162	338.96700000	2.07529912	10.64225787	3.26119266
MINCON6	162	381.16000000	2.36522222	0.54813357	0.74018227
MINCON7	162	431.20000000	2.68643211	0.69143657	0.83152665
MOEVN4	162	431.20000000	2.68643211	0.69143657	0.83152665
MOEVN5	162	223.08700000	1.37708035	0.33461366	0.57845801
MOEVN6	162	342.26700000	2.11275926	0.86120043	0.91716739
MOEVN7	162	410.62000000	2.53470988	0.86707270	0.93116739
MOEVN7	162	381.65100000	2.35587037	0.89797816	0.94761710

SET = 7

BRIGHT4	141	3810.77500000	27.02677305	4.14628981	2.03624404
BRIGHT5	141	5377.22100000	38.13631915	10.37580806	3.22115011
BRIGHT6	141	5681.77500000	40.29627660	10.37580806	3.22115011
BRIGHT7	141	4407.10000000	31.25680564	5.69515541	2.38645209
MINCON4	141	288.00000000	2.04326222	0.46235743	0.68175079
MINCON5	141	383.66100000	2.72100000	0.97381716	0.98707042
MINCON6	141	453.25000000	3.22145519	0.97381716	0.98707042
MINCON7	141	360.92100000	2.55972222	0.72327779	0.85084383
MOEVN4	141	360.92100000	2.55972222	0.72327779	0.85084383
MOEVN5	141	370.92000000	2.64948227	0.40071126	0.63295332
MOEVN6	141	371.92000000	2.64948227	0.40071126	0.63295332
MOEVN7	141	421.13700000	3.01586325	1.00583393	1.00287150
MOEVN7	141	326.22000000	2.31361702	0.76483080	0.87454605

SET = 8

BRIGHT4	154	3378.40000000	22.01792208	11.26555696	3.36867113
BRIGHT5	154	4599.99000000	30.07011688	18.85196089	4.34402133
BRIGHT6	154	4929.99000000	32.01298352	22.12045537	4.67515668
BRIGHT7	154	3856.89000000	25.04477274	32.12809403	5.68151230
MINCON4	154	370.41000000	2.40525974	2.84557749	0.53185191
MINCON5	154	581.08700000	3.77329221	2.45557499	0.49170913
MINCON6	154	625.08500000	4.05899351	2.61054394	0.51527178
MINCON7	154	551.25200000	3.57955844	2.05133505	0.45124825
MOEVN4	154	365.55200000	2.37371429	2.08943032	0.45124825
MOEVN5	154	571.33000000	3.70997403	2.89160454	0.53597534
MOEVN6	154	604.34300000	3.92431169	2.81861394	0.53597534
MOEVN7	154	528.69400000	3.43307192	2.12433994	0.45751158

16:14 WEDNESDAY, JANUARY 6, 1982

STATISTICAL ANALYSIS SYSTEM DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SFT = 9

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	95	2447.77400000	25.76604211	1.46768568	1.20148078
BRIGHT5	95	3168.22500000	33.34973684	1.12392383	1.06074465
BRIGHT6	95	3211.10800000	33.80113684	3.28584895	1.81269108
BRIGHT7	95	2409.22400000	25.36025263	3.48917211	1.86293258
MINCON4	95	1322.24000000	1.39209474	0.20312924	0.45069861
MINCON5	95	196.16900000	2.06493684	0.48636444	0.69741985
MINCON6	95	173.00200000	1.82107368	0.45968388	0.67744981
MINCON7	95	174.75100000	1.83948421	0.40720534	0.63812643
MEVN4	95	111.70100000	1.17580000	0.11114574	0.33338527
MEVN5	95	171.33400000	1.80351579	0.50060515	0.70733455
MEVN6	95	154.07500000	1.62184211	0.38167073	0.61779504
MEVN7	95	158.41700000	1.66154737	0.33673900	0.58029216

SET = 10

BRIGHT4	70	1523.44500000	21.76350000	5.89092156	2.42712207
BRIGHT5	70	1924.33700000	27.49052857	12.80131130	3.57892027
BRIGHT6	70	2055.33400000	29.34162857	12.81891676	3.58035149
BRIGHT7	70	1550.77600000	22.15394286	10.52061666	3.24355001
MINCON4	70	175.74900000	2.51070000	0.39977604	0.63227845
MINCON5	70	240.33100000	3.43330000	1.39326288	1.09236573
MINCON6	70	275.16800000	3.93097143	1.36786414	1.16097551
MINCON7	70	233.08000000	3.32971429	1.87502221	1.36931450
MEVN4	70	165.00900000	2.35744143	0.55206990	0.74300060
MEVN5	70	236.42000000	3.37742857	1.33128152	1.15381174
MEVN6	70	252.98900000	3.61412857	1.36960310	1.17303043
MEVN7	70	203.28300000	2.90118571	1.65304317	1.28370726

SET = 11

BRIGHT4	91	1756.88900000	19.28449451	1.21079574	1.10036169
BRIGHT5	91	2277.22700000	24.99450353	1.32014703	1.14971507
BRIGHT6	91	2558.88700000	28.11963736	6.97802924	2.64157782
BRIGHT7	91	2086.66500000	22.90840679	9.12385531	3.02057205
MINCON4	91	98.66300000	1.08420879	0.14188017	0.37666989
MINCON5	91	141.83200000	1.55859341	0.29958862	0.54346884
MINCON6	91	208.83200000	2.29485714	0.66608283	0.81613898
MINCON7	91	231.16800000	2.54030769	0.74157706	0.86114869
MEVN4	91	91.53200000	1.00584615	0.15315360	0.39134844
MEVN5	91	137.16000000	1.50725275	0.40260077	0.63450829
MEVN6	91	191.90400000	2.10883516	0.67421056	0.82110326
MEVN7	91	220.04700000	2.41809890	1.04746260	1.02345620

SET = 12

BRIGHT4	92	2117.22100000	23.01327174	3.37468295	1.80845101
BRIGHT5	92	2806.44300000	30.48307609	8.44973252	2.90676804
BRIGHT6	92	3208.77900000	34.88455435	8.16117326	2.85376971
BRIGHT7	92	2778.44100000	30.20445523	6.46117326	2.53739273
MINCON4	92	115.91600000	1.26047826	0.08863231	0.29176973
MINCON5	92	158.74900000	1.71773361	0.08863231	0.29176973
MINCON6	92	199.50700000	2.16952291	0.27095948	0.51733689
MINCON7	92	199.22700000	2.16952291	0.67472322	0.81613898
MEVN4	92	108.72900000	1.18478269	0.09472322	0.30736176
MEVN5	92	152.72900000	1.65270932	0.4416880	0.73161798
MEVN6	92	192.71100000	2.09468178	0.93036611	0.91124097
MEVN7	92	188.78500000	2.05701087	0.78983056	0.88872412

16:14 WEDNESDAY, JANUARY 6, 1982

STATISTICAL ANALYSIS SYSTEM

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SFT = 13

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	143	3103.32700000	21.70158741	5.68157364	2.38309518
BRIGHT5	143	4048.77800000	28.3112287	5.22444396	2.28372742
BRIGHT6	143	4491.31500000	31.33639043	5.22444396	2.28372742
BRIGHT7	143	3693.22000000	25.8259902	5.22444396	2.28372742
M1NCON4	143	192.24600000	1.34437762	0.00000000	0.00000000
M1NCON5	143	296.86600000	2.074966713	0.00000000	0.00000000
M1NCON6	143	293.82900000	2.0544825	0.00000000	0.00000000
M1NCON7	143	260.33500000	1.82052448	0.00000000	0.00000000
MDEVN4	143	177.08500000	1.23355664	0.00000000	0.00000000
MDEVN5	143	235.30700000	1.64550350	0.00000000	0.00000000
MDEVN6	143	270.32500000	1.89038462	0.00000000	0.00000000
MDEVN7	143	253.42500000	1.77220280	0.00000000	0.00000000

SET = 14

BRIGHT4	150	3773.32900000	25.15522667	5.59361374	2.36508218
BRIGHT5	150	5121.21700000	34.1444667	5.16023351	2.27270374
BRIGHT6	150	5591.33300000	37.2755333	5.16023351	2.27270374
BRIGHT7	150	4623.11040000	30.8026600	5.16023351	2.27270374
M1NCON4	150	223.58000000	1.49000000	0.00000000	0.00000000
M1NCON5	150	382.61700000	2.55077333	0.00000000	0.00000000
M1NCON6	150	334.08200000	2.22721333	0.00000000	0.00000000
M1NCON7	150	344.86900000	2.29612667	0.00000000	0.00000000
MDEVN4	150	361.23500000	2.40823333	0.00000000	0.00000000
MDEVN5	150	310.34300000	2.06895333	0.00000000	0.00000000

SET = 15

BRIGHT4	96	2514.67200000	26.19450000	3.94203699	1.98545637
BRIGHT5	96	3452.99400000	35.9686750	3.94203699	1.98545637
BRIGHT6	96	3850.89000000	40.11233750	3.94203699	1.98545637
BRIGHT7	96	3295.44400000	34.3375000	3.94203699	1.98545637
M1NCON4	96	113.74800000	1.18687500	0.00000000	0.00000000
M1NCON5	96	186.16700000	1.93937500	0.00000000	0.00000000
M1NCON6	96	212.83400000	2.21702083	0.00000000	0.00000000
M1NCON7	96	177.82700000	1.84206250	0.00000000	0.00000000
MDEVN4	96	109.82700000	1.14481250	0.00000000	0.00000000
MDEVN5	96	177.02100000	1.84512500	0.00000000	0.00000000
MDEVN6	96	196.37100000	2.04512500	0.00000000	0.00000000
MDEVN7	96	174.47800000	1.80706250	0.00000000	0.00000000

SET = 16

BRIGHT4	93	2393.88900000	25.74074194	7.60572758	2.75784836
BRIGHT5	93	3257.44400000	35.02627957	7.60572758	2.75784836
BRIGHT6	93	3497.31600000	37.6076344	7.60572758	2.75784836
BRIGHT7	93	2741.89100000	29.62899892	7.60572758	2.75784836
M1NCON4	93	181.25100000	1.9482693548	0.00000000	0.00000000
M1NCON5	93	263.66700000	2.85512903	0.00000000	0.00000000
M1NCON6	93	214.91800000	2.308274194	0.00000000	0.00000000
M1NCON7	93	283.99800000	3.054195699	0.00000000	0.00000000
MDEVN4	93	192.69200000	2.07195699	0.00000000	0.00000000
MDEVN5	93	226.54800000	2.435136982	0.00000000	0.00000000
MDEVN6	93	281.11330000	3.02293548	0.00000000	0.00000000

STATISTICAL ANALYSIS SYSTEM
DISCRIMINANT ANALYSIS SIMPLE STATISTICS

16:14 WEDNESDAY, JANUARY 6, 1982

SET = 17

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	63	1181.66400000	18.75657153	2.92230938	1.70977303
BRIGHT5	63	1133.77900000	24.34568254	9.22620354	3.03746663
BRIGHT6	63	1195.55200000	25.91352381	15.18471635	4.02702328
BRIGHT7	63	1195.88700000	19.04582540	15.82907811	3.97857740
MINCON4	63	105.50100000	1.67461905	0.47690714	0.69058464
MINCON5	63	159.25000000	2.52777778	0.70035601	0.83687156
MINCON6	63	191.25000000	3.03514229	1.21011621	1.10080009
MINCON7	63	14.91700000	2.37519048	1.04845922	1.02395019
MDDEVN4	63	106.22700000	1.68614286	0.63749929	0.79843348
MDDEVN5	63	155.22300000	2.47984113	1.15747979	1.07584323
MDDEVN6	63	189.43300000	3.00685714	2.0126603	1.41867756
MDDEVN7	63	187.80000000	2.98095238	2.02850901	1.42257538

SET = 18

BRIGHT4	126	2547.21400000	20.21601587	9.28669310	0.96368724
BRIGHT5	126	3411.00200000	27.01444444	2.38535074	1.54445807
BRIGHT6	126	2998.99800000	23.80157937	2.48698757	1.58734640
BRIGHT7	126	2998.99900000	23.80157937	2.06307111	1.44192450
MINCON4	126	131.42100000	1.04106386	0.41236302	0.64215498
MINCON5	126	182.83400000	1.45106386	0.39321726	0.62707038
MINCON6	126	250.67100000	1.98445238	0.62764096	0.79223795
MINCON7	126	199.24900000	1.58134127	0.18139189	0.4290127
MDDEVN4	126	126.18000000	1.00142857	0.46776344	0.68393233
MDDEVN5	126	176.81900000	1.40332540	0.54677552	0.73942243
MDDEVN6	126	226.88900000	1.8069841	0.46276803	0.68027055
MDDEVN7	126	179.00600000	1.42068254		

SET = 19

BRIGHT4	94	2362.89100000	25.13713830	5.8229597	1.7987897
BRIGHT5	94	3123.64400000	33.23672717	1.23607110	1.10899410
BRIGHT6	94	3123.64400000	33.23672717	2.06121584	1.43795277
BRIGHT7	94	2722.11400000	29.07455106	2.05441350	1.43795277
MINCON4	94	115.93400000	1.23072613	0.39271268	0.6269134
MINCON5	94	175.66600000	1.86878723	0.33434905	0.5782924
MINCON6	94	144.00000000	1.53191489	0.31200163	0.55857106
MINCON7	94	104.47000000	1.11138298	0.13780237	0.37121741
MDDEVN4	94	155.78100000	1.65724468	0.48340240	0.69271598
MDDEVN5	94	153.35600000	1.63144681	0.25012399	0.50012598
MDDEVN6	94	130.93900000	1.39296809	0.35564128	0.59635667

SET = 20

BRIGHT4	108	2742.89100000	25.39713889	2.2323068	1.49573750
BRIGHT5	108	3741.44400000	34.64300926	4.95930177	2.2323068
BRIGHT6	108	4099.11200000	37.95474014	4.95930177	2.2323068
BRIGHT7	108	3421.77600000	31.73866667	3.53664913	1.88093227
MINCON4	108	165.75100000	1.53880556	0.36494618	0.60757630
MINCON5	108	245.62100000	2.27224167	0.36494618	0.60757630
MINCON6	108	245.62100000	2.27224167	0.36494618	0.60757630
MINCON7	108	201.91500000	1.86958173	0.70323793	0.83969413
MDDEVN4	108	215.55000000	1.99584259	0.12249559	0.35366413
MDDEVN5	108	215.55000000	1.99584259	0.3244559	0.56969413
MDDEVN6	108	182.48100000	1.69667593	0.3244559	0.56969413
MDDEVN7	108	182.48100000	1.69667593	0.58568219	0.76529876

STATISTICAL ANALYSIS SYSTEM

16:14 WEDNESDAY, JANUARY 6, 1982

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 21

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	64	1515.001000000	23.67189062	1.49896667	1.2232311
BRIGHT5	64	2096.714000000	32.76217167	1.77261508	1.33163195
BRIGHT6	64	2241.558000000	35.02434375	2.461232299	1.57266448
BRIGHT7	64	1846.550000000	28.85234375	2.461232299	1.57266448
MLNCN4	64	77.334000000	1.19281875	0.06192567	0.25145658
MLNCN5	64	98.084000000	1.53250000	0.26158784	0.51145658
MLNCN6	64	115.333000000	1.78645312	0.38685914	0.62298002
MLNCN7	64	145.831000000	1.14485937	0.15378555	0.392211676
MDEVN4	64	68.494000000	1.07021875	0.06786878	0.25611634
MDEVN5	64	96.667000000	1.51042187	0.39201666	0.62298002
MDEVN6	64	107.263000000	1.67598437	0.50116186	0.70742786
MDEVN7	64	175.802000000	1.14440625	0.17703485	0.42075509

SET = 22

BRIGHT4	51	1429.226000000	28.02403922	1.48999337	1.20853805
BRIGHT5	51	2038.442000000	40.15529411	1.16011837	1.07145485
BRIGHT6	51	2212.777000000	43.38776471	1.72527974	1.31554852
BRIGHT7	51	1825.001000000	35.78276471	1.72527974	1.31554852
MLNCN4	51	82.583000000	1.61927647	0.05303480	0.23093557
MLNCN5	51	86.664000000	1.70007843	0.05303480	0.23093557
MLNCN6	51	100.414000000	1.96890196	0.30584909	0.55444379
MLNCN7	51	80.257000000	1.57354902	0.03847197	0.1919179
MDEVN4	51	48.570000000	0.95235294	0.09442195	0.30728155
MDEVN5	51	77.580000000	1.52117647	0.36898839	0.60744417
MDEVN6	51	93.333000000	1.83005882	0.29131438	0.53973548
MDEVN7	51	74.075000000	1.45245098	0.30775297	0.55444379

SET = 23

BRIGHT4	11	2494.776000000	22.67545946	1.70279572	1.3091215
BRIGHT5	11	3307.443000000	29.79678378	1.38912043	1.17611711
BRIGHT6	11	3591.779000000	32.65836937	1.40517681	1.17611711
BRIGHT7	11	2877.441000000	26.15836937	1.40517681	1.17611711
MLNCN4	11	1776.083000000	1.61363333	0.30965902	0.55444379
MLNCN5	11	227.030000000	2.06450505	1.10755115	1.04404379
MLNCN6	11	220.245000000	1.99448919	1.09128065	1.04404379
MLNCN7	11	220.166000000	1.99448919	1.09128065	1.04404379
MDEVN4	11	157.430000000	1.42828829	0.29752504	0.54404379
MDEVN5	11	201.803000000	1.83457273	0.29752504	0.54404379
MDEVN6	11	196.422000000	1.78565455	1.0041921	1.0041921
MDEVN7	11	186.348000000	1.69408108	1.13641175	1.05722108

SET = 24

BRIGHT4	131	2621.557000000	20.02715267	7.47648070	2.73431549
BRIGHT5	131	3118.334000000	24.09415267	7.47648070	2.73431549
BRIGHT6	131	3776.666000000	28.82853344	27.47648070	5.26716858
BRIGHT7	131	5802.666000000	44.29853344	27.47648070	5.26716858
MLNCN4	131	180.423000000	1.37727481	50.39820949	7.06310322
MLNCN5	131	284.167000000	2.16921374	1.00487046	1.00487046
MLNCN6	131	319.580000000	2.44206397	1.00487046	1.00487046
MLNCN7	131	429.580000000	3.27923664	1.00487046	1.00487046
MDEVN4	131	171.612000000	1.31001527	1.00487046	1.00487046
MDEVN5	131	229.761000000	1.75395420	1.00487046	1.00487046
MDEVN6	131	297.761000000	2.272392366	1.00487046	1.00487046
MDEVN7	131	410.544000000	3.13392366	1.00487046	1.00487046

S T A T I S T I C A L A N A L Y S I S S Y S T E M
DISCRIMINANT ANALYSIS SIMPLE STATISTICS

16:14 WEDNESDAY, JANUARY 6, 1982

SET = 25

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	105	2739.77500000	26.09309524	2.64421292	1.62613435
BRIGHT5	105	3628.55300000	34.55747767	2.61951082	1.61826921
BRIGHT6	105	3848.90200000	36.64767810	14.10194587	3.75522871
BRIGHT7	105	2991.18000000	28.46914286	9.50658912	3.08221574
MINCN4	105	111.43900000	1.06533333	0.30521425	0.55246149
MINCN5	105	181.49700000	1.72884286	0.65758111	0.81694412
MINCN6	105	211.00200000	2.00942288	1.13930396	1.06738183
MINCN7	105	192.08200000	1.82935238	3.33132062	1.82519057
MDEVN4	105	101.09000000	0.96276190	0.24051649	0.49044810
MDEVN5	105	166.07500000	1.58166667	0.72150472	0.84944110
MDEVN6	105	193.78100000	1.84533333	1.19457510	1.09296619
MDEVN7	105	182.32000000	1.73680095	1.45553407	1.20690669

SET = 26

BRIGHT4	130	3483.66900000	26.79745385	2.76340032	0.87373069
BRIGHT5	130	4635.00100000	35.65322461	2.78700261	1.53193302
BRIGHT6	130	4877.89200000	37.52246615	2.78570094	1.66904446
BRIGHT7	130	3931.77500000	30.24642308	2.45514910	1.60745152
MINCN4	130	119.16500000	0.91652385	0.16598476	0.40743602
MINCN5	130	168.18700000	1.29372308	0.37334031	0.61091923
MINCN6	130	182.16200000	1.40124615	0.36073249	0.60771830
MINCN7	130	108.16500000	0.83197231	0.82464213	0.90715300
MDEVN4	130	148.89300000	1.14533077	0.09495523	0.34333350
MDEVN5	130	153.25900000	1.1822308	0.29523303	0.54191236
MDEVN7	130	131.68500000	1.01296154	0.29670905	0.54516861

SET = 27

BRIGHT4	58	1419.33300000	24.47125867	2.15950107	1.47458412
BRIGHT5	58	1980.22200000	34.30656897	2.19833033	1.47458412
BRIGHT6	58	2173.66500000	41.03831034	6.44792087	2.49558353
MINCN4	58	43.67000000	0.75232103	0.08113316	1.02848731
MINCN5	58	87.17100000	1.50155207	0.25470464	0.50639479
MINCN6	58	97.17100000	1.67446207	0.35927023	0.59929571
MINCN7	58	85.41000000	1.47222683	0.36867023	0.60771830
MDEVN4	58	38.49100000	0.66226833	0.08113316	0.25470464
MDEVN5	58	76.49100000	1.31894483	0.20246627	0.44966666
MDEVN6	58	85.98500000	1.49974138	0.30246627	0.54191236
MDEVN7	58	75.48300000	1.30173103	0.29565811	0.54191236

SET = 28

BRIGHT4	50	1192.00100000	23.84002000	3.09322703	1.4681387
BRIGHT5	50	1652.55700000	33.05114000	3.69502857	1.77396145
BRIGHT6	50	2006.89000000	40.13780000	6.49920810	2.52822652
MINCN4	50	1847.77500000	36.95550000	3.98918981	2.99729562
MINCN5	50	59.33000000	1.18668420	0.05968420	0.24430351
MINCN6	50	79.49900000	1.58998000	0.22104221	0.47015136
MINCN7	50	88.16500000	1.76330000	0.36638872	0.60771830
MDEVN4	50	78.13100000	1.56662000	0.2366742	0.49044810
MDEVN5	50	56.51600000	1.13032000	0.05238410	0.2366742
MDEVN6	50	76.67000000	1.53334000	0.30230517	0.54191236
MDEVN7	50	80.79100000	1.61582000	0.27017921	0.51977666
MDEVN7	50	70.34100000	1.40666000	0.28889645	0.53749088

APPENDIX 2

Texture and Tone Variables of the Training Sets with
Ratio Bands of LANDSAT Data

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 1

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	258	45579.53700000	172.78898062	3.81924701	1.95428939
BRIGHT5	258	60977.67000000	235.82244186	338.45636577	18.39726517
BRIGHT6	258	14113.85000000	54.70498062	56.20906558	7.49727054
BRIGHT7	258	137281.21900000	534.0008844	7.49230194	2.73720696
MINCCN4	258	788.08100000	3.04557752	0.9997022	0.9997022
MINCCN5	258	4244.66800000	16.45220155	655.93980442	25.61132180
MINCCN6	258	3317.16300000	12.85722093	16.62366157	4.07721247
MINCCN7	258	826.66000000	3.1993	0.95096933	0.97517657
MOEVN4	258	602.15600000	2.33390698	0.57400026	0.75524847
MOEVN5	258	3819.13800000	14.80293023	586.74690742	24.22285919
MOEVN6	258	2667.13800000	10.33774119	11.65871099	3.41648547
MOEVN7	258	710.96400000	2.75567442	1.00495719	1.00247553

SET = 2

BRIGHT4	278	47639.53300000	170.64587410	8.62712362	2.93719656
BRIGHT5	278	41260.66700000	220.36211141	96.53781932	9.72305007
BRIGHT6	278	13938.65100000	50.13903796	157.0374703	39.61620818
BRIGHT7	278	34807.95200000	125.20742006	14.1274762	4.02143557
MINCCN4	278	945.08500000	3.40196640	1.21512297	1.10423357
MINCCN5	278	2237.08500000	8.04706835	10.98785106	3.31479276
MINCCN6	278	13443.68000000	48.35856115	1507.30203903	38.82398793
MINCCN7	278	1025.58300000	3.68914748	1.85304922	1.36126750
MOEVN4	278	750.81200000	2.70076259	0.72887103	0.85373944
MOEVN5	278	1874.30600000	6.74210791	9.86474177	3.14081865
MOEVN6	278	12819.27600000	46.11250360	1514.33367058	38.91444039
MOEVN7	278	1881.83200000	6.75505755	1.86980393	1.36740774

SET = 3

BRIGHT4	186	31430.45000000	168.98091398	3.70226513	1.92441271
BRIGHT5	186	43765.65000000	235.29929370	76.07155522	8.72220499
BRIGHT6	186	6217.45000000	33.64220430	32.90095452	5.73593337
BRIGHT7	186	25176.33000000	135.35662903	7.10340693	1.76164891
MINCCN4	186	174.62000000	2.81988710	0.7505743	0.87009058
MINCCN5	186	265.24000000	1.425722581	0.70081373	0.83792019
MINCCN6	186	1407.24000000	7.56402584	10.4812990	3.23752018
MINCCN7	186	442.31000000	2.37812366	0.5822990	0.76705526
MOEVN4	186	473.38000000	2.54000000	0.50942684	0.71340819
MOEVN5	186	1713.77800000	9.21386022	182.47180732	13.50843467
MOEVN6	186	1495.35600000	8.03954839	5.94265597	2.43775614
MOEVN7	186	371.08000000	1.99505176	0.58207158	0.76293615

SET = 4

BRIGHT4	178	30523.00100000	171.47753371	7.82117591	2.79663654
BRIGHT5	178	39770.00700000	223.42269775	93.04077110	9.64598731
BRIGHT6	178	6455.55000000	36.26718539	920.52345612	30.34401247
BRIGHT7	178	22727.55000000	127.68286517	21.38572072	4.62446978
MINCCN4	178	582.00200000	3.27389326	1.19473701	1.093304026
MINCCN5	178	1247.00200000	7.00562921	15.72177554	3.96575057
MINCCN6	178	6038.00000000	33.92134481	1449.82269891	38.07651204
MINCCN7	178	655.08000000	3.68026404	0.65598891	0.817781204
MOEVN4	178	467.65700000	2.62728527	0.84267930	0.91797565
MOEVN5	178	1037.62700000	5.82933517	0.51354911	0.71607795
MOEVN6	178	5400.41000000	30.33955618	1221.40094774	34.97714894
MOEVN7	178	554.34100000	3.11427358	4.89871802	2.19970862

S T A T I S T I C A L A N A L Y S I S S Y S T E M 10:59 THURSDAY, JANUARY 7, 1982

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 5

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	162	27542.77500000	170.01712963	3.86506324	1.96572207
BRIGHT5	162	37638.99000000	232.33945383	40.02750002	6.32672903
BRIGHT6	162	5085.67000000	31.39302669	56.97669462	7.54842312
BRIGHT7	162	21586.46000000	133.24966667	7.41098747	2.75880182
MINCON4	162	10737.75000000	66.29243889	0.51212241	0.71562277
MINCON5	162	10737.75000000	66.29243889	15.51613396	3.93789697
MINCON6	162	1968.16700000	12.1725125	2.61926347	1.61838226
MINCON7	162	306.35700000	1.90155617	2.61816113	1.61838226
MDEVN4	162	391.97100000	2.42310247	0.30976781	0.55602861
MDEVN5	162	851.97100000	5.2598025	12.56279525	3.54408317
MDEVN6	162	1401.04200000	8.66075309	4.76828155	2.18363952
MDEVN7	162	417.23100000	2.57550000	2.45208628	1.56591368

SET = 6

BRIGHT4	165	28208.55300000	170.96092727	1.80743292	1.34440802
BRIGHT5	165	32566.00100000	197.36970303	2249.74192656	47.43144449
BRIGHT6	165	11322.00100000	68.61818788	10.59978220	3.26179321
BRIGHT7	165	24397.11200000	147.86128485	20.19660217	4.49406229
MINCON4	165	9402.41900000	56.98274545	0.76255423	0.87593049
MINCON5	165	1223.66000000	7.41098747	1699.93290812	41.23024264
MINCON6	165	2123.66000000	12.87070303	10.6092162	3.25713396
MINCON7	165	378.49000000	2.29322327	1.05818679	1.02868206
MDEVN4	165	9849.52000000	59.69407473	0.5037759	0.71082881
MDEVN5	165	1697.16300000	10.22521030	1931.77976758	43.9320092
MDEVN6	165	476.69400000	2.88905455	9.81756481	3.1322529
MDEVN7	165			1.35172914	1.16263867

SET = 7

BRIGHT4	183	30990.33800000	169.34610929	2.70056693	1.64334018
BRIGHT5	183	41781.67100000	228.31516208	620.65369516	24.91292225
BRIGHT6	183	11325.88400000	61.89007650	73.07104873	8.54816055
BRIGHT7	183	26454.77600000	144.56161749	5.7168461	2.39033149
MINCON4	183	575.99800000	3.14753005	0.57205004	0.75633390
MINCON5	183	5848.41500000	31.95855738	1337.97458389	36.57833490
MINCON6	183	2198.47500000	12.01504372	16.20466843	4.02550226
MINCON7	183	554.16800000	3.02824044	1.35239536	1.16292515
MDEVN4	183	439.99800000	2.40434973	0.35860279	0.59900149
MDEVN5	183	5427.99800000	29.66117486	1172.4526879	34.24109328
MDEVN6	183	1705.21100000	9.31809290	11.84418137	3.44153165
MDEVN7	183	449.33000000	2.45535519	1.08955971	1.04401136

SET = 8

BRIGHT4	111	19141.44500000	172.47575045	6.60727874	2.57046375
BRIGHT5	111	24841.66700000	224.71718018	747.01701341	27.23704189
BRIGHT6	111	16449.88800000	148.35633818	747.01701341	27.23704189
BRIGHT7	111	17447.55600000	157.17100000	4.93399903	2.22216089
MINCON4	111	431.55000000	3.88514414	0.93844414	0.96813317
MINCON5	111	428.58100000	3.88514414	1472.72187926	37.7779146
MINCON6	111	1825.91700000	16.44970270	62.05959827	7.83001818
MINCON7	111	466.66600000	4.20419820	3.3496652	1.83001818
MDEVN4	111	362.31000000	3.26413515	0.69513021	0.83374469
MDEVN5	111	4030.53800000	36.31118828	0.75085026	36.52055581
MDEVN6	111	1423.22900000	12.82118828	33.28512867	5.76932654
MDEVN7	111	381.33000000	3.43540541	2.28986643	1.51322978

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 9

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	74	12864.22100000	173.84082432	0.91662187	0.95740371
BRIGHT5	74	15892.35000000	183.67872973	2134.18557894	46.19726664
BRIGHT6	74	15889.85000000	171.48506157	67.12115576	8.19274694
BRIGHT7	74	11184.37000000	152.49104054	6.93778511	2.62543957
MINCON4	74	11184.37000000	152.49104054	0.5291776	0.73259194
MINCON5	74	5657.08100000	76.44704054	1426.0821708	37.76350117
MINCON6	74	920.49000000	12.44475873	10.30909490	3.21090418
MINCON7	74	238.49000000	3.22227027	1.69337218	1.30129635
MDEVN4	74	142.00200000	1.92227027	0.20963927	0.45794466
MDEVN5	74	5843.00200000	78.95948649	1508.8430666	38.84388317
MDEVN6	74	771.72700000	10.42874324	11.64201482	3.4203969
MDEVN7	74	217.45400000	2.93856757	2.29687534	1.51554457

SET = 10

BRIGHT4	83	14690.33300000	176.99196386	3.66569172	1.91459962
BRIGHT5	83	15758.22400000	189.85812048	1767.0815233	42.03667624
BRIGHT6	83	16472.66700000	197.32128916	64.27092553	8.17991969
BRIGHT7	83	12187.88000000	155.09503614	10.25428716	3.20223159
MINCON4	83	12187.88000000	155.09503614	0.78887874	0.88649802
MINCON5	83	6456.83300000	77.79316867	1956.56655378	44.22303719
MINCON6	83	1512.24000000	18.21883133	56.6919448	7.52893453
MINCON7	83	380.63300000	4.58329440	3.4429101	1.85663746
MDEVN4	83	242.37000000	2.92007822	0.5766070	0.7603480
MDEVN5	83	6075.37000000	73.2009752	1635.0768679	40.31223391
MDEVN6	83	1181.06000000	14.22988355	39.84109179	6.35601583
MDEVN7	83	303.43300000	3.65581928	2.23831759	1.49610080

SET = 11

BRIGHT4	196	34090.55800000	173.93141837	4.92440674	2.22022673
BRIGHT5	196	45925.88500000	234.31577980	104.43362084	10.21927692
BRIGHT6	196	4876.00100000	24.28571939	167.40120145	12.93836164
BRIGHT7	196	27807.66700000	141.87585204	24.8188838	4.96183584
MINCON4	196	646.59400000	3.29899498	0.84040214	0.91817221
MINCON5	196	3007.83500000	15.34609694	470.29446624	21.68627368
MINCON6	196	3290.75000000	16.78696429	51.67080306	7.18824061
MINCON7	196	793.83300000	4.097020	1.94955659	1.40105553
MDEVN4	196	505.52000000	2.58110714	0.5482953	0.7401507
MDEVN5	196	2399.52000000	12.2427449	0.55967871	0.75789257
MDEVN6	196	2522.07000000	12.86771429	278.2826178	16.51876506
MDEVN7	196	687.24200000	3.50633673	1.8333655	1.35511496

SET = 12

BRIGHT4	143	2895.99800000	174.09788811	2.2258683	1.48747667
BRIGHT5	143	33177.14700000	232.0358842	432.7863341	20.80352454
BRIGHT6	143	6886.15000000	48.15697203	125.605193	11.21004246
BRIGHT7	143	20705.88000000	144.79641958	9.21013681	3.03482012
MINCON4	143	514.50000000	3.59615385	0.79776217	0.89317533
MINCON5	143	2388.16300000	16.66547452	882.5222477	29.70732611
MINCON6	143	2388.16300000	16.66547452	40.424966343	6.35806287
MINCON7	143	464.61600000	3.255116084	1.24486178	1.2466074
MDEVN4	143	404.61600000	2.82948252	0.51995180	0.72107643
MDEVN5	143	2111.74800000	14.76746853	0.74690460	27.65423846
MDEVN6	143	1729.35800000	12.09341259	764.7302399	4.90204284
MDEVN7	143	387.21000000	2.70776224	0.8722486	0.93766691

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 13

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	150	25742.44700000	171.61631333	3.99324643	1.99831089
BRIGHT5	150	32981.55000000	219.87633333	1081.21742584	32.8218312
BRIGHT6	150	7283.55000000	48.55703333	47.01131282	6.85649662
BRIGHT7	150	21382.10900000	142.54733333	10.41093989	3.22659881
MINCN4	150	481.24800000	3.20832000	0.89001344	0.94341584
MINCN5	150	4895.17100000	32.63447333	1343.92901872	36.65963745
MINCN6	150	1825.08500000	12.16723333	21.81504711	4.6706610
MINCN7	150	453.99700000	3.02664667	0.47420113	0.68701658
WDEVN4	150	378.55100000	2.52367333	0.47415529	0.68701658
WDEVN5	150	5086.63400000	33.91089333	1612.23786506	40.15268192
WDEVN6	150	1428.89100000	9.52594000	10.84053996	3.29249753
WDEVN7	150	386.51900000	2.57679333	1.03345119	1.01658801

SET = 14

BRIGHT4	93	15906.10800000	171.03341935	1.71596314	1.30984776
BRIGHT5	93	22140.72200000	238.0690323	1.76510959	1.32829210
BRIGHT6	93	24191.72200000	259.0451871	173.00017770	13.15276821
BRIGHT7	93	12234.93600000	132.0830215	9.36226842	3.05919129
MINCN4	93	249.93600000	2.6860880	1.05956389	1.03479719
MINCN5	93	1037.75100000	11.15861290	284.1755889	16.95750749
MINCN6	93	1727.83300000	18.6784946	352.26336380	18.78199574
MINCN7	93	261.59700000	2.81717204	0.58782784	0.76669932
WDEVN4	93	184.51900000	1.98407527	0.42334770	0.65065175
WDEVN5	93	844.29600000	9.07845161	174.22378053	13.19938561
WDEVN6	93	1460.36500000	15.70284946	315.06589165	17.75003554
WDEVN7	93	231.08600000	2.50630108	0.51471284	0.71743491

SET = 15

BRIGHT4	154	26623.10800000	172.87732468	9.03623665	3.00436959
BRIGHT5	154	33579.66700000	218.04978571	647.93398425	25.45433099
BRIGHT6	154	10855.10400000	70.48768831	244.86443398	15.64814475
BRIGHT7	154	22953.66600000	149.04977922	39.24432089	6.26373059
MINCN4	154	563.99800000	3.66227273	1.39344106	1.18044109
MINCN5	154	7127.99800000	46.2850130	1367.3311014	36.9766751
MINCN6	154	2464.75100000	16.00487662	71.33152227	8.4465961
MINCN7	154	699.66700000	4.5439271	3.0073274	1.7391839
WDEVN4	154	620.99000000	4.0265701	0.60735212	0.77691592
WDEVN5	154	678.71000000	4.39502192	1260.16555869	35.49881047
WDEVN6	154	1976.27100000	12.8322857	45.66160553	6.75733715
WDEVN7	154	590.56900000	3.83486364	3.04482494	1.74494268

SET = 16

BRIGHT4	127	21909.44300000	172.51529921	4.10469704	2.02600519
BRIGHT5	127	30460.00500000	239.84255906	93.32396847	9.66043314
BRIGHT6	127	7264.23100000	57.19866929	77.41346425	8.80417312
BRIGHT7	127	18347.66800000	144.46982677	5.17028662	2.27342642
MINCN4	127	400.00900000	3.14967717	1.36317122	1.16480301
MINCN5	127	1559.67000000	12.28086614	315.58822566	17.6483359
MINCN6	127	2366.15600000	18.63114961	180.07340442	13.42960334
MINCN7	127	398.66900000	3.13912598	0.4565762	0.67605259
WDEVN4	127	334.54200000	2.63448898	0.76491650	0.87424309
WDEVN5	127	1285.61700000	10.12288976	235.50717654	15.64418263
WDEVN6	127	1742.61700000	13.72119370	58.43368091	7.64418263
WDEVN7	127	330.00300000	2.59844882	0.60281973	0.83233793

DISCRIMINANT ANALYSIS SIMPLE STATISTICS

SET = 21

VARIABLE	N	SUM	MEAN	VARIANCE	STANDARD DEVIATION
BRIGHT4	130	23453.10700000	180.40851538	37.26942576	6.10323076
BRIGHT5	130	22725.21800000	174.80613866	171.08416055	13.0862088
BRIGHT6	130	13666.33100000	105.07910993	6417.89970723	81.73810581
BRIGHT7	130	14848.33100000	114.2096923	240.7773231	15.5397202
MINCON4	130	5845.50200000	44.9616923	45.42673443	6.70347835
MINCON5	130	2012.24700000	15.41882308	1773.17747938	42.10911397
MINCON6	130	6335.42000000	48.73400000	7.51128877	2.74066940
MINCON7	130	782.50100000	6.01923886	2.02289987	1.42226575
MEDEVN4	130	511.55100000	3.93500769	76.30632434	8.73534912
MEDEVN5	130	2004.07000000	15.41592308	1867.88914549	43.21908312
MEDEVN6	130	6327.43000000	48.61253846	10.42106784	3.22816788
MEDEVN7	130	776.26800000	5.97129231		

SET = 22

BRIGHT4	105	18193.22000000	173.26876190	3.83773876	1.93901474
BRIGHT5	105	22910.44400000	218.19470476	953.31363358	30.87577843
BRIGHT6	105	17031.55600000	162.96720000	92.39013041	9.61197849
BRIGHT7	105	15616.33500000	148.72700000	9.44318446	3.03117205
MINCON4	105	333.73790000	3.23790000	1.23116155	1.10947720
MINCON5	105	4783.75200000	45.56954286	1730.94944114	41.6648052
MINCON6	105	1521.83200000	14.50365379	1120.98302223	33.08100928
MINCON7	105	327.64000000	3.12522827	120.51905823	11.00244305
MEDEVN4	105	267.47900000	2.5471905	0.70997258	0.84260061
MEDEVN5	105	4644.26900000	44.22113313	0.06606571	0.25031715
MEDEVN6	105	1156.06900000	11.01018095	1620.08282940	40.64794431
MEDEVN7	105	304.91700000	2.90397143	9.39891166	3.06376445

SET = 23

BRIGHT4	63	10957.22500000	173.92420635	1.21068852	1.10030383
BRIGHT5	63	14806.11500000	235.01769841	394.44379370	19.86060910
BRIGHT6	63	3614.22100000	57.36858730	12.45506334	3.52917318
BRIGHT7	63	9309.77500000	147.77420635	0.54443397	0.73785769
MINCON4	63	154.75200000	2.45638095	0.74109634	0.86086952
MINCON5	63	1698.41700000	26.95900000	1554.78877822	39.43081002
MINCON6	63	1593.58100000	25.4192063	9.42122220	3.06940910
MINCON7	63	121.66200000	1.93722222	0.56221579	0.75981050
MEDEVN4	63	131.21200000	2.08279685	0.48461348	0.6934139
MEDEVN5	63	1423.01700000	22.61138095	0.2173101	0.4641419
MEDEVN6	63	469.53000000	7.4539683	4.35662918	2.0824445
MEDEVN7	63	104.74100000	1.66255556	0.40918803	0.63652810

SET = 24

BRIGHT4	57	9787.66400000	171.71340351	0.89151792	0.94420227
BRIGHT5	57	12786.67100000	224.32756140	616.79464961	24.83535081
BRIGHT6	57	2923.88800000	51.29628070	15.47724967	3.93350149
BRIGHT7	57	8267.02000000	145.03512281	1.60359982	1.26633322
MINCON4	57	158.66600000	2.78361404	0.7492963	0.86560362
MINCON5	57	2583.41600000	45.32308772	2124.41981287	46.09142884
MINCON6	57	587.00000000	10.29824561	5.66341262	2.37979256
MINCON7	57	131.58400000	2.30849123	0.56069533	0.74879592
MEDEVN4	57	122.00000000	2.14035088	0.41161470	0.64157205
MEDEVN5	57	2210.41900000	38.77928070	0.41161470	35.76500156
MEDEVN6	57	448.54400000	7.86919298	3.98973209	1.99743137
MEDEVN7	57	101.55700000	1.88696491	0.32702743	0.57186312