SPECTRAL DISCRIMINATION OF ROCK TYPES IN THE ARAVALLI MOUNTAIN RANGES OF RAJASTHAN (INDIA) USING LANDSAT THEMATIC MAPPER DATA

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ABSTRACT

Spectral discrimination of the rock types performed through automated digital classification of the visible and NIR satellite data is a complicated task leading to a great deal of misclassification among them (rock types). The misclassification is attributed to the identical spectral signatures of the rock types in the visible and NIR spectral ranges. In order to understand the misclassification among the rock types as obtained through the digital classification of the multispectral satellite data and further to select the appropriate spectral bands that would provide better discrimination among the rock types, it is pertinent to perform spectral discrimination of the rock types on the individual bands as well as by considering the various band pairs of the multispectral data. One of the most efficient and straightforward statistical techniques for determining the spectral discrimination between any two categories (rock types) by considering any two spectral bands is the two-dimensional discriminant function analysis as proposed by Davis (1986). This technique is based on the determination of a discriminant function from the pooled variance-covariance matrix of the training signatures of the rock types derived from the different band pairs of the multispectral satellite data. In this paper, this technique has been employed with a view to determining the degree of discrimination among the rock types occurring in the Aravalli mountain ranges in Rajasthan, India using the Landsat thematic mapper data. The dominant rock types consist of quartzites, granites and phyllites. The results obtained from the analysis are found to be very much useful in explaining the misclassification of the rock types obtained from the multispectral classification technique and in selecting the appropriate spectral bands that would provide the better discrimination of the rock types.

1. INTRODUCTION

Digital mapping of the rock types using the digital satellite data is performed taking into consideration primarily the spectral signatures exhibited by them in the different spectral bands of the sensors of the satellite. The extent to which the different rock types occurring in an area can be discriminated among each other is characteristically determined by the degree of discrimination of the spectral signatures of the rock types portrayed in the different spectral bands.

Several techniques of classification of the satellite data exist in literature (Jensen, 1986), which have been employed frequently by various researchers for different applications to varying extent of success (Rowan, 1975; Rowan et al, 1987; Segal et al, 1989). In the context of lithological discrimination, however, digital classification of the satellite data in the visible and NIR spectral ranges has proved to be relatively unsuccessful leading to a great deal of misclassification among the various rock types (Patel, 1992). The misclassification among the various rock types has been attributed to their identical spectral signatures which results due to their similar chemical and mineralogical compositions i.e. Al, Si and O (aluminosilicates) on their surficial exposures on the earth caused by weathering. The misclassification among the rock types is further increased by the occurrence of the varying types and density of vegetation cover on them. The task of lithological discrimination becomes more complicated in the mountainous terrains due to the prevalence of varying illumination conditions induced by the topography which results in the occurrence of both illuminated and shadowed portions of the individual rock types. It becomes therefore imperative to determine the degree of discrimination among the various rock types on the basis of their spectral signatures recorded in the different spectral bands occurring in the visible and NIR ranges of the sensors of the satellite and subsequently, characteristically determine the factors responsible for the misclassification in terms of the mineralogical compositions and field occurrences of the rock types. One of the most effective yet quite straightforward statistical techniques of performing the spectral discrimination between any two categories (i.e. rock types) on a two-dimensional scatter plot is the two-dimensional discriminant function analysis proposed by Davis (1986). In the present study, this technique has been applied on a subscene of Landsat 5 thematic mapper (TM) data (P148 – R043 of Jan31, 1998) comprising the six bands of the visible NIR and MIR ranges pertaining to the Aravalli mountain ranges in Rajasthan state of India keeping in view the following objectives.

a. To determine the degree of discrimination of the dominant rock types occurring in the study area, that is, granite, phyllite and quartrite in the selected band pairs.
b. To select the optimum bands those provide the minimum misclassification among the rock types.

2. STUDY AREA

The study area is bounded by latitudes N25 01' 16" and N25 09' 53" and longitudes E73 28' 23" and E73 39' 20" and occurs in Udaipur and Pali districts of Rajasthan state (India). The study area in general is characterized by low rainfall, which has led to the development of less vegetation cover in areas not affected by weathering.

Among the three dominant rock types present in the study area, granititic rocks are highly weathered and aare covered by a dense vegetation cover. Phyllites and schists are less weathered and have a thin vegetation cover. Quartzites are hard and resistant to weathering and therefore, have no vegetation cover on them. Quartzites have ridge like exposures in the field.

3. METHODOLOGY

The objective of discriminant function analysis is to determine a linear discriminant function from the pooled variance-covariance matrix of the training signatures of the rock types that separates the means of the rock types as much as possible making the variance as small as possible (Davis, 1986). This is illustrated in Figure 1 in which it is seen that an adequate separation between groups A and B cannot be made using either variable X or X2. However, it is possible to find an orientation on which if the data are projected, will separate the two groups the most while inflating each the least. This line is called the discriminant function line, ab. A line passing at right angles to the discriminant function line, through a point, Ro, that is, the discriminant index , midway between Ra and Rb , that is , the projections of the respective means of groups A and B on the discriminant function line clearly divides the elliptical plots of groups A and B on the scatter diagram. This line, cd, is called the line of division (Patel, 1992).

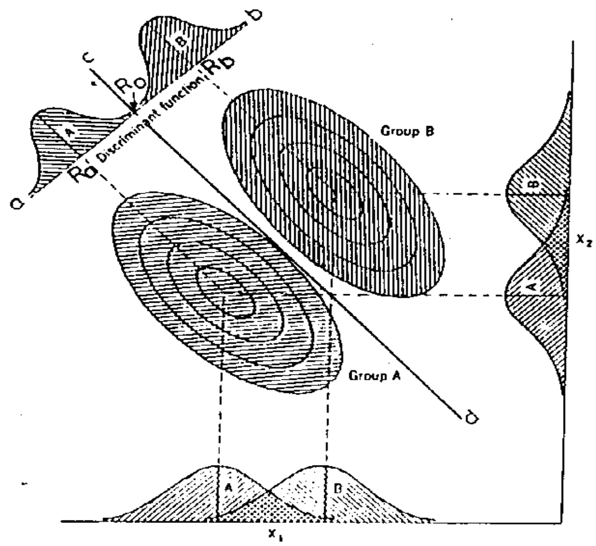

Figure 1. Scatter Diagram for Discriminant Function Analysis (from Davis, 1986)
(refer to text for detailed explanation)

In computational form, the discriminant function can be determined by solving the following equation.

[S^2p]. [ë]= [D] (1)

where [S^2p] is a mxm matrix of pooled variances and covariances of the m variables (bands), **ës** are coefficients of the linear discriminant function, D is the column vector of **m** differences and **m** is the number of variables. The slope of the discriminant function line may be determined from the ratio of ë1 and ë2, that is, ë1/ ë2.

Both the lines, that is, the line of division and the discriminant function line may be plotted on the scatter diagram of the two rock types. The discrimination potential of the discriminant function analysis can be estimated on the basis of the number of samples of any particular rock type being classified as the same rock type. On the scatter diagram, the classification accuracy of a rock type is determined by the percentage of samples or training pixels of this rock type lying on that side of the line of division where the rock type in question is represented by the maximum number of its training samples.

Scatter diagrams for the three pairs of rock types, that is, phyllites-granites, quartzites-granites, and quartzites-phyllites were plotted in six different band pairs of the thematic mapper data, that is, 1-5, 1-7, 3-4, 3-7, 4-7, and 5-7 in order to account for the distribution of the training signatures of the rock types in the visible vs. NIR, visible vs. MIR, NIR vs. MIR, and MIR vs. MIR spectral bands. The degree of discrimination between the rock types in each band pair was determined following the technique as explained above in their respective scatter diagrams. For the sake of understanding, scatter diagrams for the rock type pairs, that is, phyllites-granites, quartzites-granites, and quartzites-phyllites plotted in TM band pairs 3-7, 3-4 and 3-7 are shown in Figures 2, 3, and 4 respectively.

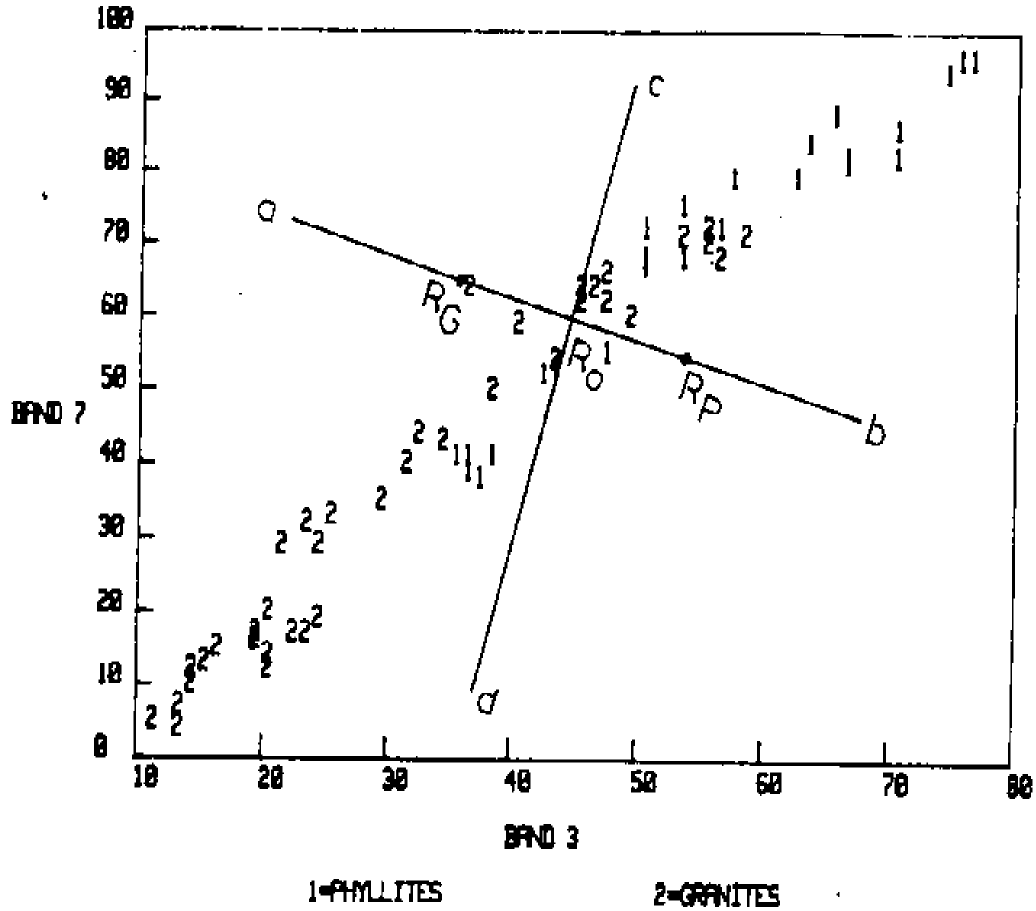

Figure 2. Scatter Diagram for Discriminant Function Analysis of Phyllites versus Granites
(ab is the discriminant function line, cd is the line of division)

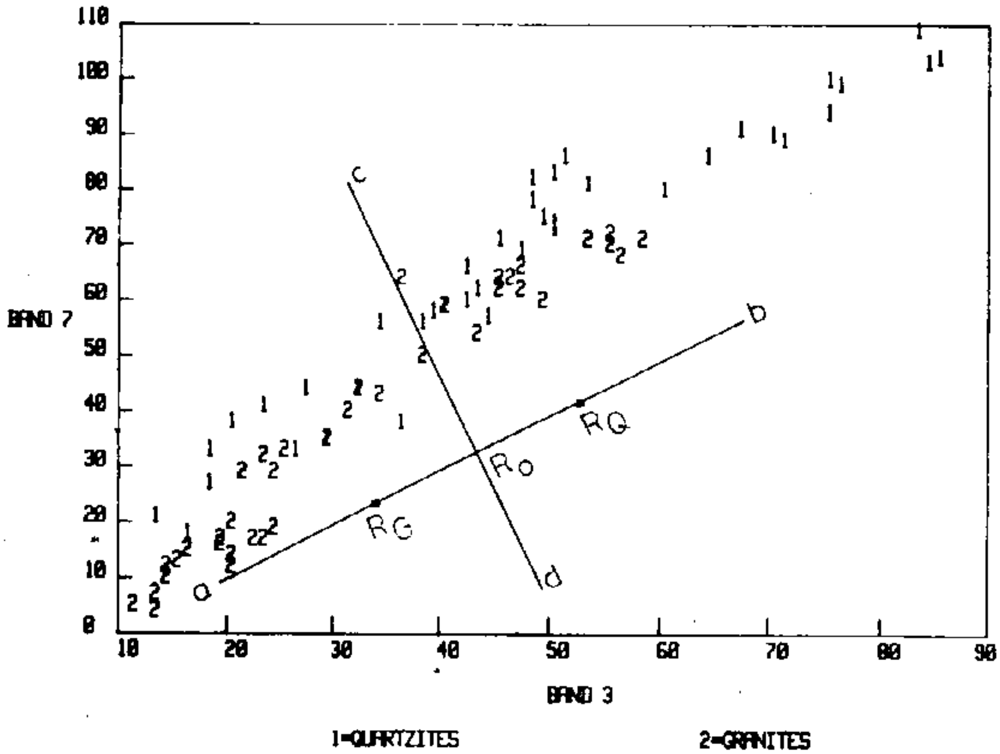

Figure 3 Scatter Diagram for Discriminant Function Analysis of Quartzites versus Granites
(ab is the discriminant function line, cd is the line of division)

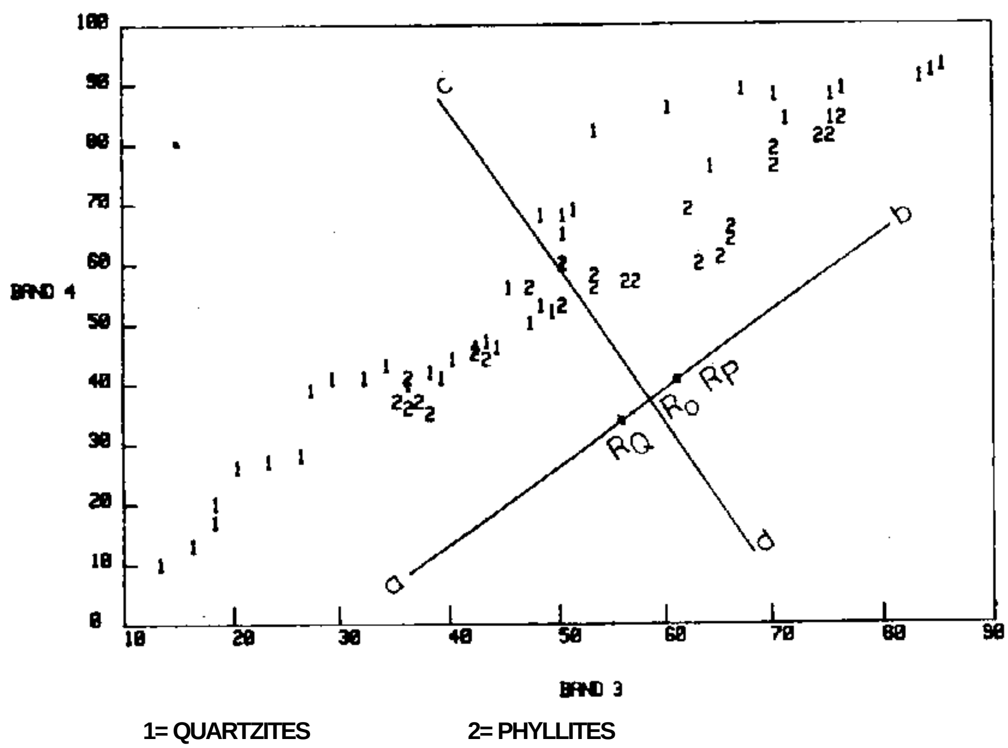

Figure 4 Scatter Diagram for Discriminant Function Analysis of Quartzites versus Phyllites
(ab is the discriminant function line, cd is the line of division)

4. RESULTS AND DISCUSSIONS

The degree of discrimination between the rock types in the six selected band pairs as determined from the discriminant function analysis is presented in Table 1.

Table 1 Results of the Discriminant Function Analysis for the Three Rock Type Pairs

(a) Phyllites-Granites		(b) Quartzites-Granites		(c) Quartzites-Phyllites	
Band Pairs	Average degree of intermixing (%)	Band Pairs	Average degree of intermixing (%)	Band Pairs	Average degree of intermixing (%)
1-5	26.5	1-5	33	1-5	55
1-7	26.25	1-7	33	1-7	44
3-4	29.25	3-4	32.5	3-4	36
3-7	25.75	3-7	27.5	3-7	43.5
4-7	30.5	4-7	38	4-7	42.5
5-7	23.75	5-7	35	5-7	41

The following criteria have been used in the computation of the degree of intermixing or misclassification between the rock types. When both the rock types dominate on the same side of the line of division, the average of their pixel percentages has been considered. However, when one rock type is dominant on one side and the other on the other side of the line of division, the average degree of intermixing is determined by first estimating the degree of misclassification of the less dominant rock type in the field of more dominant rock type and then averaging the sum of the degree of intermixing obtained for both the rock types.

From Table 1(a), it is observed that the average degree of intermixing between phyllites and granites in the six selected band pairs varies within a relatively small range, that is, between 23.75 and 30.5 percent. The band pairs viz. 5-7 and 3-7 exhibit 23.75 and 25.75 percentage of intermixing respectively. From this observation it may be inferred that TM bands 3,5 and 7 could provide better discrimination between phyllites and granites.

From Table 1(b), it is found that the average degree of intermixing between the quartzites and granites ranges between 27.5 to 38 percent; the band pairs viz. 3-7 and 3-4 showing the least values, that is , 27.5 and 32.5 percent respectively. This observation indicates that these two rock types could be better discriminated in TM bands 3,4, and 7.

The average degree of intermixing between the two rock types viz. quartzites and phyllites in the selected six bands pairs shows relatively a large range, that is, 36 to 55 percent (Table 1(c)). The band pairs 3-4 and 5-7 exhibit the minimum percentages of intermixing, that is, 36 and 41 percent respectively. This observation signifies that these two rock types can be better discriminated in TM bands 3, 4, 5 and 7.

Efforts have been made to explain the misclassification among the various rock types occurring in the study area on the basis of their laboratory-derived reflectance spectra, mineralogical composition and the vegetation cover developed on them. The study reveals good relationship between the misclassification observed among the rock types and the various controlling factors.

5. CONCLUSION

The present study demonstrates the capability of the two-dimensional discriminant function analysis for performing spectral discrimination between the various rock types in the different band pairs. The study reveals that the rock types present in the study area viz. granites, phyllites and quartzites can be better discriminated in TM bands combination of 3,4,5 and 7.

6. REFERENCES

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