VARIATION OF SOIL PROPERTIES WITHIN THE SOIL MAPPING UNIT: A STATISTICAL STUDY

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LIST OF ABBREVIATIONS

Color:	hue	- hue
	Val	- value
	Chrom	- chroma
Mottling:	Msize	- mottles size
	Mcont	- mottles contrast
	Mabund	- mottles abundance
Roots:	Rmed	- medium roots
	Rqunat	- roots quantity
Structure:	Clas	- structure class
	Gras	- structure grade
	Type	- structure type
Coating type:	Claycoat	- clay coating
	Oxicoat	- oxide coating
	Orgcoat	- organic matter coating
Consistence:	Dry	- dry consistence
	Moist	- moist consistence
	Stk	- wet consistence
	Plct	- wet consistence
Pore orientation:	Ranpor	- random pores
	Oblipor	- oblique pores
	Verpor	- vertical pores
	Horpor	- horizontal pores

Thickness - indicates the thickness of each horizon.

DDARKL - indicates the thickness of the dark layer in the profile starting from the surface.

DBURL - indicates the depth at which the lithological discontinuity was recognized in the profile.

DROOZ - indicates the thickness of the zone which is contained by 90% of the plant roots.

DCROTV - indicates the maximum depth at which the krotovina activity was recognized in the profile.

DCONCR - indicates the minimum depth at which concretions were located in the profile.

DMOT - indicates the minimum depth at which the mottles were located in the profile.

DBWBOD - indicates the minimum depth at which white and black bodies were located in the profile.

DCLAYFLM - indicates the minimum depth at which the clay films were recognized in the profile.

DSLKSID - indicates the minimum depth at which slikensides were observed in the profile.

DPRESFAC - indicates the minimum depth at which pressure faces were recognized in the profile

DSTRK - indicates maximum depth at which streaking features were observed in the profile.

DRANG - indicates drainage class.

PERM - indicates permeability class.

K - potassium

H - hydrogen

CEC - cation exchange capacity

$CaCO_3$ - calcium carbonate

OM - organic matter

Na - sodium

Ca - calcium

Mg	- magnesium
fs	- fine sand
vfs	- very fine sand
bst	- base saturation
RZD	- root zone

CHAPTER I

INTRODUCTION

The research reported in this dissertation is divided into seven chapters. Each one is a manuscript prepared for publication in the Agronomy Journals after minor modifications. The second chapter deals with analysis of variance. The third chapter deals with regression analysis, while the fourth and the fifth deal with the canonical correlation. The sixth and seventh deal with factor analysis, while the eighth deals with numerical taxonomy. Appendix A includes simple statistics for both areas.

Soil is a three dimensional body that results from the integrated effect of many external and internal factors. Any change in one or more of these factors causes changes in the make up of the soil body.

The systematic examination of soil is necessary for better agricultural and non-agricultural uses. This is usually done in the field by delineating similar soil together on soil maps. These delineations are called the mapping units. Dissimilar soil within the mapping units are called soil inclusions. The percentage of the soil inclusions vary depending on the precision of the mapping. The quantitative characterization of these units gives some insight on how soil properties vary within the soil mapping units. This helps to provide a better definition of the soil mapping units for better mapping.

The objective of this research is to study the variation of soil properties within the mapping unit. A total of 18 and 23 soil pedons from two areas were described and sampled for this study. This objective is approached through different statistical analysis on the 41 soil pedons as follows: 1) variation of the soil properties within the different mapping units (analysis variance); 2) the relationships between chemical properties, chemical and morphological properties, and morphological and morphological properties (regression and canonical correlation); 3) the study of the magnitude of the variation of each soil property within the different soil horizons (principal component, factor analysis); 4) mathematical classification (numerical taxonomy).

CHAPTER II

SIMPLE STATISTICS

Abstract

The objective of this study was to investigate the variability of different soil properties within the soil mapping unit. Two areas were selected in which the variation of soil-forming factors were minimized. A total of 18 and 23 profiles were sampled from the first and second areas, respectively. Laboratory data were obtained using the Slipped-Block design to adjust for the variation arising from conducting the analyses at different times. The experiment was executed two times and the adjusted mean values were used in the statistical analysis. The means, standard deviation, maximum and minimum values of the mean (α=.9), and the coefficient of variation (C.V.%) were calculated from the adjusted data. The number of samples required to estimate the true mean where the STD of the estimate is 10% of the mean is also reported.

Most of the soil properties showed high C.V.% values within the area as a unit and for the individual series within each area. There was a strong tendency for the C.V.% values of the chemical properties to decrease when both areas were delineated to different soil mapping units. This tendency was not observed among the C.V.% values for the morphological properties. High C.V.% values were indicative of the high variability among different soil properties even for areas where

variation of the soil-forming factors were kept constant or minimum over a short distance. Also, based on this study, it is concluded that a more accurate characterization of the soil mapping units will require more samples than usually taken by the soil surveyor.

Field Work Investigations

Soil is a heterogenous system. The heterogeneity arises from the many factors that affect the soil body. These factors are parent material, climate, topography, organisms, and time. In the selected areas of this study, these factors were reasonably constant. The land use in area one was pasture. The second area was part of the O.S.U. Agronomy Experiment Station. The topography of Area One was mainly the summit position, and was flat linear in Area Two. The slope ranged from .3 to 3.5% and from .5 to 1% in Area One and Two, respectively.

A total of 18 profiles were described and sampled in the first area and 23 profiles in the second area. To ensure unbiased random site selection, the outside boundary of each area was drawn on a transparent paper (Figure 2.1), then the center of each area was marked and several radial lines, branching from the center toward the boundary, were drawn. Starting from the central point, the sites were located on each line. The distance between each location was approximately 60 feet. More than one mapping unit occurred inside each area. The sites were located without any reference to the boundaries of the different mapping units. This provided different numbers of sites in each mapping unit.

The depth of the sampling was to the bedrock in Area One and to 92 inches in Area Two. Complete morphological description was attempted

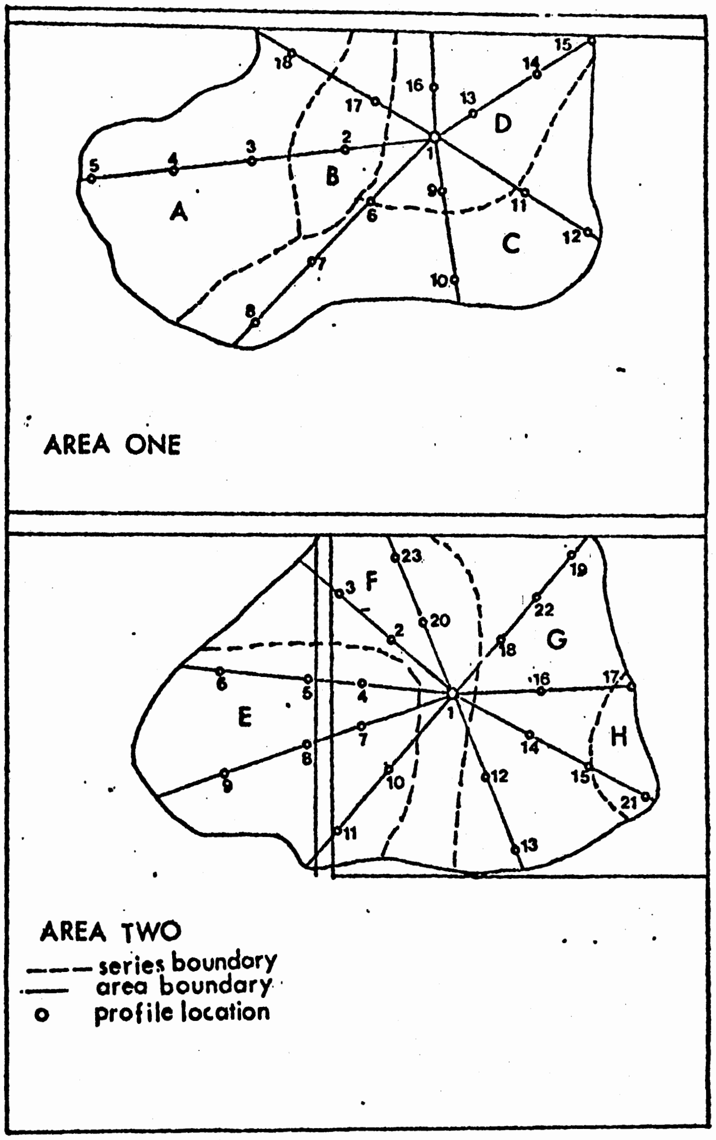


Figure 2.1. Locations of the Sampling Sites and the Field Design.

according to a coded system designed by the author. Horizons that occurred below the line of lithological discontinuity were designated as buried horizons.

Two types of parent material were recognized: Permian Formation in the first area, and Old Alluvium in the second area.

Laboratory Statistical Design

The Slipped-Block design was used to ensure removing the variations arising from conducting the chemical tests at different times (Timon, 67). Figure 2.2 shows the design layout. The samples of each area were given serial numbers and, by random process, the 12 samples were assigned to each block with one sample repeated in the next block as an overlap as required by the design. All the tests were conducted using 12 samples at the same time. Each area was randomized and blocked separately. The experiment was repeated two times for each area.

Chemical Analysis

Particle size fractionation was determined as described by Grossman (29) and as suggested by Baktar (4). Calcium carbonate was removed by soaking the soil in sodium acetate for two weeks. Organic matter was removed by heating the soil with 31% hydrogen peroxide. Sodium acetate and overnight shaking were employed to ensure maximum dispersion. Clay was measured by the hydrometer method (Day, 221). The very fine sand was separated and measured and the rest of the sand fractions were reported as fine sand. Silt was obtained by subtraction after adjusting for $CaCO_3$. Organic carbon was determined by the potassium dicromate procedure of Schollenberger (62). Cation exchange

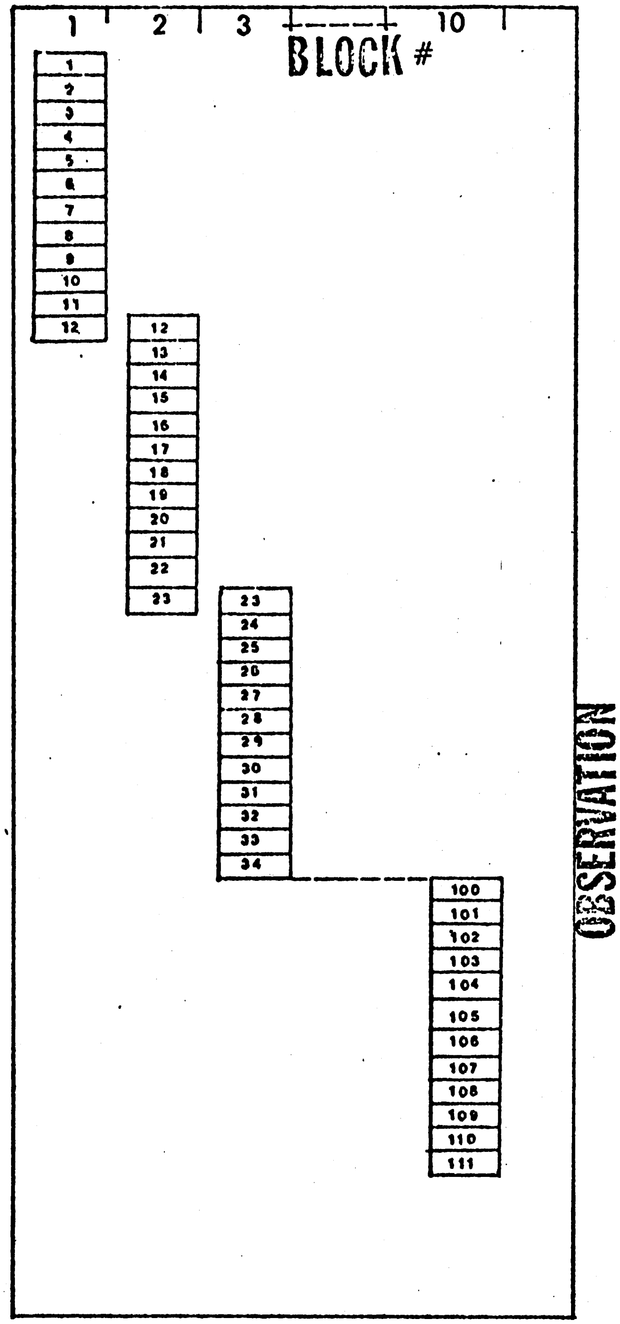


Figure 2.2. Layout of the Slipped-Block Statistical Design.

capacity was determined by saturating the soil with sodium acetate pH 8.2 (Bower, 19). Exchangeable hydrogen determination was according to Peech (50). Base saturation was calculated by dividing the sum of the NH_4OAC extractable bases by the CEC. The pH was measured with a Beckman pH meter on a 1:1 soil to water suspension. Calcium carbonate was determined by acid neutralization (Richards, 55).

Statistical Analysis

The adjusted means values for all the measurements were obtained by removing the effect of time-to-time from the row data according to the statistical design. The following statistics were computed for each variable using the adjusted data: mean, standard deviation, minimum and maximum values, coefficient of variation, and the number of samples required to estimate the true mean with standard deviation equal to 10% of the mean. The following formula was used to compute the numbers of samples required to estimate the means for each variable using the adjusted data:

$$S\bar{x}^2/n = P\bar{X}^2 \qquad (2.1)$$

$$100\sqrt{S\bar{x}^2/\bar{X}^2} = 100P\sqrt{n} \qquad (2.2)$$

$$\sqrt{n} = C.V./100P \qquad (2.3)$$

$$n = (C.V./100 \cdot P)^2 \qquad (2.4)$$

C.V. = Coefficient of Variation

P = .1

n = number of samples required to estimate the true mean where the standard deviation is equal to 10% of the mean.

The above analysis was conducted on Ap horizon (designated as Ap zone), B horizons (designated as subsurface zone), and Cr horizons (designated as parent material zone). Also, the above analysis was conducted on a layer equivalent to the zone occupied by 90% of the plant roots.

The depth of the root zone was defined as follows:

$$\text{Depth of root zone} = A_1 Ap + C_1 B_1 + D_1 B_2 \qquad (2.5)$$

where A_1, C_1, and D_1 are the thicknesses of each horizon (Ap or B_1 or B_2) contained in the root zone. Either C_1 or D_1 could be zero. The weighted averages were calculated depending on the depth. Furthermore, the analysis was reported for each area as an independent unit and for different series within each area.

Results and Discussion

Area One, Ap Zone

Area One included four series designated as series A, B, C, and D. The number of profiles was described randomly for each series as indicated on AOV Table 2.1. The results are discussed for each zone within the area as an independent unit and within each series. A complete list of the computation is found in Appendix A.

C.V. is a measurement of the relative variability. The number of the samples required to estimate the mean is a function of the C.V.%. Thus the C.V.% and the required number of samples were used to indicate the extent of variability among different soil properties throughout the discussion.

Among the chemical properties for the whole area, K(C.V.% 74.5), Na(289.2), and $CaCO_3$(59.7) showed maximum variation. The number of samples required to estimate the mean were 56, 836, and 36 samples, respectively. C.V.% for the rest of the chemical properties ranged from 8 for pH to 37.7 for calcium (Table 2.1). Comparing the same variables within each series, the C.V. dropped sharply for all properties except for Na in series C (219.6) and series D (190). The C.V. for K decreased only in series A. The rest of the measurements showed moderately low to low C.V.%, but varied widely above 10%. However, a strong tendency in the reduction of the C.V. was observed for some properties like the CEC, OM, and clay. These properties are considered very important for management practices and soil classification.

TABLE 2.1

COEFFICIENT OF VARIATION FOR THE
SURFACE ZONE, AREA ONE

Property	Series				Overall Area
	A	B	C	D	
K	18.6	66.6	66.4	20.6	74.5
Na	57.2	2.5	219.6	190.0	289.2
$CaCO_3$	94.0	39.0	39.4	53.2	59.7

Area One, Subsurface Zone

Among the measured chemical properties for the whole area, C.V.% for Mg (25.9) and H (95) were the highest, followed by calcium (74), potassium (65), and CEC (57). The C.V.% for $CaCO_3$ (10.9) and base saturation (29.9) were the lowest. Comparing with different series, C.V.% for H, pH, Ca, Mg, VFS, and CEC decreased significantly by series mapping. The C.V.% for clay remained relatively low, but increased dramatically in series D (41.7). The C.V.% for Na increased sharply for all series (Table 2.2). It was noticeable that the C.V.% for the sodium in the subsurface was higher than in the Ap zone when computed for different series, but the result was reversed when the C.V.% was computed for the whole area.

TABLE 2.2

COEFFICIENT OF VARIATION FOR THE SUBSURFACE ZONE, AREA ONE

Property	Series				Overall Area
	A	B	C	D	
Mg	39.6	9.0	30.1	25.5	125.9
H	25.9	20.0	68.5	46.0	95.0
Ca	59.1	34.0	90.0	56.0	74.9
CEC	39.7	5.0	16.5	13.9	57.4
BST	47.5	30.8	69.7	41.7	29.9
Na	156.5	70.3	250.0	79.8	63.9
$CaCO_3$	63.2	56.2	51.7	67.4	10.6
K	83.3	106.0	110.2	35.2	65.0

Area One, Parent Material

The C.V.% for potassium (262.8), $CaCO_3$ (189.8), sodium (95.2), and calcium (84.5), followed by hydrogen (79.6), OM (64), base saturation (59), and very fine sand (58.7) were the highest among the chemical properties. The C.V.% for pH (10.3) was the lowest (Table 2.3).

TABLE 2.3

COEFFICIENT OF VARIATION FOR THE PARENT MATERIAL, AREA ONE

Property	Series				Overall Area
	A	B	C	D	
K	177.6	60.0	107.5	405.7	262.8
$CaCO_3$	61.3	0.0	68.2	159.6	189.8
Na	159.1	6.6	54.4	86.3	95.2
Ca	74.8	89.3	72.3	73.7	84.5
H	56.1	125.7	67.2	85.4	79.5
OM	54.1	58.4	76.0	69.3	64.1
BST	24.0	55.8	41.5	47.1	59.0
VFS	18.3	102.6	61.9	40.0	58.7

Based on series analysis, C.V.% for potassium decreased sharply in all series except in series D where it increased to 405.7. $CaCO_3$ also decreased for all series. Sodium did not show any significant change except in series C (54.4). The C.V.% for calcium did not show any noticeable improvement in any of the four series. Also, the C.V.%

for clay, fine sand, very fine sand, and silt did not show any significant changes in all series in comparison with the analysis for the whole area.

Area One, Root Zone

Analysis of the data for the root zone of the entire area was not much different from its Ap counterpart. However, the C.V.% for various variables in the root zone were lower than those for the subsoil except for sodium which was high in the surface.

Area One, Morphological Data

The morphological data for the entire area (Table 2.4) exhibited high C.V.% values. Some very important criteria like depth of clay film (81%), depth of mottling (126%), and slickensides (134%) were high. The high C.V.% for the depth of the buried layer (175.4) might indicate the type of the truncated horizon. Except for the drainage, all the morphological properties exceeded the value of 10% which is accepted by many workers. Furthermore, based on the individual series analysis, there was no decisive declination or inclination trend in C.V.% for various properties. Generally, delineation of series based on chemical properties, especially those properties useful in soil classification, though the C.V.% was still high, was better than if the delineation would have been based on morphological properties. The samples required to estimate the true mean of the morphological properties were high and impractical to undertake in the field. High proportion of soil inclusions in some series might have contributed to the big increase in the C.V.% for some of these morphological properties.

TABLE 2.4

COEFFICIENT OF VARIATION FOR THE MORPHOLOGICAL PROPERTIES, AREA ONE

Property	Series				Overall Area
	A	B	C	D	
D. clay film	73.6	9.4	72.1	110.7	81.2
D. mottling	58.8	141.4	155.0	161.7	126.5
D. slickensides	200.00	---	161.0	62.3	134.4
D. pressure faces	200.0	---	161.4	65.3	130.0

Area Two, Ap Zone

Area two included four series designated as series E, F, G, and H. The computed statistics were reported in the same way as for Area One.

Among the chemical properties (for the entire area), the C.V.% was highest for $CaCO_3$ (98.3), followed by Na (47.1), clay (44.6), and calcium (30.7). The C.V.% for the rest of the chemical properties ranged from 9.8% for pH to 26% for Mg (Table 2.5). Based on individual series, the C.V.% for $CaCO_3$ did not decrease (in comparison with the entire area) dramatically except in series E (50.7). It remained the same or increased dramatically for other series. C.V.% for clay decreased sharply only in series H (14.3). C.V.% for Na increased to 21.5% in series G, 29% in series H and to 58.3% and 54.5% in series F and E respectively. However, it decreased significantly for calcium in series

H (9.9) and for series E (11.2). Also it increased to 46.3 for Mg in series F. The rest of the properties exhibited slight changed from one series to another.

TABLE 2.5

COEFFICIENT OF VARIATION FOR THE
SURFACE ZONE, AREA TWO

Property	Series				Overall Area
	E	F	G	H	
$CaCO_3$	75.8	150.9	89.4	215.3	98.3
Na	58.3	54.5	21.5	29.6	47.1
Clay	42.0	38.5	42.2	14.3	44.6
Ca	11.2	35.1	38.4	9.9	30.7
H	16.9	26.2	28.9	15.0	23.6
Mg	14.4	46.3	16.1	14.2	26.1

Area Two, Subsurface Zone

Based on the entire area, the C.V.% for sodium was the highest, followed by $CaCO_3$ (36.9), OM (24.5), and fine sand (29). The C.V.% for the rest of the data was below 20%. Based on individual series, the C.V.% for all the chemical properties remained the same or decreased significantly, except for Na in series E (100.6) (Table 2.6). It was observed that the C.V.% values were noticeably lower for the subsurface zone than the Ap zone. This was true for the entire area and for the individual series.

TABLE 2.6

COEFFICIENT OF VARIATION FOR THE SUBSURFACE, AREA TWO

Property	Series				Overall Area
	E	F	G	H	
Na	100.6	16.5	21.5	5.6	51.2
$CaCO_3$	50.3	26.2	89.4	19.5	36.9
OM	29.3	14.4	11.4	14.2	24.5
FS	18.4	12.8	22.5	8.6	29.0

Area Two, Root Zone

Except for the sodium (80.7), which was higher than its counterpart in the Ap or subsurface zones, the C.V.% for the rest of the data were either averages or slightly different from Ap or subsurface values (see Appendix A).

Area Two, Morphological Properties

The soil properties (using the area as a unit) associated with amount and type of clay, such as depth of slickensides (155.9), depth of pressure faces (253.8), and depth of maximum streaking (50.4) showed highest C.V.% values (Table 2.7). The C.V.% for the depth of mottling (56.5), depth of white and black bodies (49.4), and depth of krotovina (52.1) were next highest in C.V. values to the depth of slickensides and pressure faces.

TABLE 2.7

COEFFICIENT OF VARIATION FOR THE MORPHOLOGICAL PROPERTIES, AREA TWO

Property	Series				Overall Area
	E	F	G	H	
D. Slickensides	0.0	223.6	69.6	173.2	155.9
D. Pressure Face	0.0	46.9	232.6	134.2	253.8
D. Streaking	28.5	0.0	44.1	0.0	50.1
D. Mottling	33.5	34.4	87.5	65.5	56.5
D. Black/White Bodies	51.6	0.0	0.0	24.0	49.4
D. Krotovina	48.1	28.3	69.4	15.0	52.1

All these properties are related directly or indirectly to the soil-water relationships. This might suggest that soil moisture distribution may be the reason for this pattern. Noticeably, the slope of this area averaged .5%, and the general inclination of the topography was from north to south. Based on individual series analysis, the C.V.%

for the depth of pressure face decreased sharply in series F (46.9), and to (<.01) in series E, but remained very high in series G and H. Streaking decreased sharply in all series of the second area. C.V.% for the black and white bodies decreased sharply in all series except for series E (51.6). The C.V.% for the depth of mottling did not change except in series F (< .01). The absence of the sharp decline in the C.V.% for the morphological properties within each individual series in comparison with the C.V.% for the entire area was very obvious.

Conclusions

1. The C.V.'s% for the chemical and morphological properties were found to be very high whether computed for the entire area or for each individual series within that area.

2. In both studied areas, the chemical properties of the subsurface (subsoil) showed less variation than the Ap zone (surface zone). The variation of chemical properties were lowest in the parent material of Area One.

3. The C.V.'s% for the chemical properties showed a substantial decrease when the area was delineated by the different mapping units. This trend was not noticeable among the morphological properties.

4. Based on the computer number of samples required to estimate the true mean (P = .9), it would be impractical, or uneconomical, to fully characterize the variability in the mapping units. This would be difficult to achieve, especially for the morphological characterization which showed higher variations.

5. Both areas where this investigation was conducted occupied small areas. In both areas, the variations of the soil-forming factors were reasonably constant. However, morphological properties showed high C.V.% values within the different series. This indicated that soil morphological properties can be highly variable even within a very short distance.

CHAPTER III

REGRESSION ANALYSIS

Abstract

The objective of this study was to investigate the relationships between 14 soil properties. The properties examined were fine sand, very fine sand, silt, clay, pH, hydrogen, organic matter, sodium, calcium, magnesium, potassium, cation exchange capacity, calcium carbonate, and base saturation. Two areas were selected. The first area was on Permian Formation, and the second was on Old Alluvium. Conditions minimizing the diversity of factors that enhances wide differences in soil genesis were maintained. A total of 18 and 23 profiles were described and sampled from the first and second area respectively and using a random transect. Chemical measurements were obtained utilizing the Slipped-Block design to remove the variation arising from conducting the analyses at different times. The whole experiment was repeated twice. Adjusted means were used in the statistical analysis. Multiple regression analyses were conducted. A stepwise regression procedure was used to select the appropriate regression equations. Standardized partial regression coefficients were also estimated. Pairwise correlations between the 14 soil properties were also computed. Regression analysis indicated the existence of multiple relationships between soil

properties rather than a simple one. Correlation coefficients did not seem to provide information on the true relationships between different soil properties, especially when relative importance of different properties in relation to each other are considered.

Introduction

Quantitative relationships between soil properties have not been investigated in great detail. Correlations and simple or multiple regression have been used in some cases. Few researchers reported such work. Protz (52) used regression analysis in studying relationships between landform parameters and soil properties. He also used it in studying the soil variability across selected landscapes in Iowa. Wilding (70) used regression to study the relationship between cation exchange capacity, organic matter, and various clay fractions. Hallsworth (31), Helling (33), Williams (32), Makeague (43), and Karmanov (38) also reported similar work.

In studying the relationships between soil properties, two factors have not been fully considered. The first factor is that soils develop under a diverse number of factors. These factors may include geology, climate, vegetation, topography, time, and organisms, including human activity. Thus if specific generalizations about the relationship between different soil properties using multiple regression have to be made, the diversity of the conditions or the factors that contribute to, or give rise to a wide range of soil genesis, should be minimized. The second factor is that, in most cases, multiple correlation governs the relations between soil properties. Thus if building models for prediction purposes is the researcher's main interest, a wide range of conditions and huge amount of data are necessary, even if the model is intended for a small area. On the other hand, if the investigator is interested in studying the relative contributions of certain variables in explaining the variations of a particular soil property, the traditional multiple regression may not provide the answer.

The objective of this study was to evaluate the relationships between 14 different soil properties. Namely, fine sand (fs), very fine sand (vfs), silt, clay, pH, hydrogen (H), cation exchange capacity (CEC), sodium (Na), potassium (K), organic matter (OM), calcium (Ca), magnesium (Mg), calcium carbonate ($CaCO_3$), and base saturation (BST). Emphasis was given to the relative contribution of individual soil properties in explaining the variation of a particular property using the selected regression equation which resulted from the stepwise procedure.

Results and Discussion

Regression analysis was conducted for each genetical horizon separately (Ap zone, subsurface zone, Cr or parent material zone), and for all horizons treated together (this will be referred to as all sample analysis). The above analysis was done for each area. Thirteen variables were used as independent variables and one as a dependent variable at each step. A stepwise regression was conducted to select the appropriate regression equations. The criterion used for choosing the number of variables in the regression equations was by maximization of the R-square (R^2). When the maximum R^2 was reached, the variable contributed to an increase of 2 to 3 percent or less in R^2 and the variable was deleted from the equation. Then the regular regression analysis was conducted on the selected equations and the standardized partial regression coefficients were estimated (Draper, 23). The usual statistics were computed.

Tables 3.3, 3.4, 3.5, 3.6, and 3.7 show the pairwise correlation between the 14 soil properties and Tables 3.1 and 3.2 show the regression equations for each dependent variable, multiple correlation, R^2, F for the regression equation, and the significance of the F test. The regression equations were reported at the two significant levels. The odd number indicated the equation was significant at probability of .5% and the even number was significant at probability of 1%. Equations 1 and 2 represent all samples, equations 3 and 4 represent the surface zone, equations 5 and 6 represent the subsurface zone and equations 7 and 8 represent the Cr zone. If no equation was given for the even number, then it was the same for the odd number. The partial regression coefficient was interpreted as the relative contribution of that variable in explaining the variation of the dependent variable. For the purpose of clarity, some equations were discussed. The rest of the equations would be interpreted in the same manner. The number that appears between two brackets following the measurements represents the standardized partial regression coefficient as reported in the different regression equations.

All samples regression equation for CEC in Area One indicated that 87% of the variation of CEC could be explained by Ca, Mg, clay, and BST. BST (-.69) was slightly higher than Ca (.55), Mg (.55), and clay content (.23) seemed to be the least significant.

However, for Area Two, (all samples) regression equations indicated that BST (.6), Ca (.68), and Mg (.68) explained the largest portion, 95% of the CEC variation. Clay contribution appeared to be negligible.

TABLE 3.1

REGRESSION ANALYSIS FOR AREA ONE

		r	R^2	F	prob > F
1	CEC = .55 Ca + .55 Mg + .23 clay - .69 bst	.93	.87	123.4	0.0001
3	CEC = .83 Ca + .60 Mg + .31 K - 1.39 bst	.98	.97	90.1	0.0001
5	CEC = .49 Mg + .34 H - .23 K + .11 silt + .54 clay	.96	.93	31.9	0.0001
6	CEC = - .32 K + .18 silt + .80 clay	.94	.88	34.8	0.0001
7	CEC = .01 clay + .10 Mg - 1.6 bst + 1.34 Ca + .56 Na	.88	.78	8.35	0.0017
8	CEC = .33 Mg + .39 clay	.54	.29	3.1	0.0741
1	Na = 1.02 bst + .51 CEC + .32 clay - .73 Ca - .31 K	.84	.70	23.3	0.0001
3	Na = .38 H + .51 pH + .43 Ca - .18 k	.94	.89	26.7	0.0001
4	Na = .49 H + .59 pH + .42 Ca	.93	.87	30.6	0.0001
5	Na = .29 H - 1.10 Ca + .75 clay + 1.81 bst	.95	.90	28.8	0.0001
7	Na = .59 H - .62K + .73 pH + .64 silt + .38 CEC	.86	.74	6.7	0.0038
1	OM = .62 H + .48 silt - .21 clay	.85	.72	64.6	0.0001
3	OM = - .35 pH - .26 vfs	.50	.25	2.45	0.1187
5	OM = .41 H + .39 Na - .49 Mg + .30 silt - .52 bst	.96	.93	34.5	0.0001
6	OM = .80 H + .52 pH - .91 Mg + .42 silt + .31 clay	.98	.95	41.7	0.0001
7	OM = .36 Ca - .40 silt + .39 vfs - .90 pH	.84	.71	7.8	0.0023
8	OM = - .20 silt + .52 vfs - .86 pH	.80	.64	8.2	0.0024
1	pH = .31 Mg - .21 Ca - .67 H - .32 K	.86	.72	55.	0.0001
3	pH = .32 clay + .20 vfs + .70 Na - .70 H	.91	.83	16.3	0.0001
4	pH = .22 clay + .82 Na - .75 H	.90	.81	20.	0.0001
5	pH = .67 CEC + 1.31 bst - .34 vfs - .33 silt - .16 K - .51 H	.97	.94	20.2	0.0001
6	pH = - .73 H - .30 K	.89	.80	37.1	0.0001
7	pH = - .84 H - .37 OM - .34 Ca - .51 silt + .47 bst	.95	.91	25.0	0.0001
8	pH = - .73 H - .46 OM - .55 silt - .27 bst	.94	.89	26.5	0.0001
1	K = .04 OM - .15 pH - .32 Na + .44 silt + .08 clay	.70	.49	14.1	0.0001
2	K = .54 silt - .39 Na	.68	.46	33.7	0.0001
3	K = .20 silt - .25 $CaCO_3$ - .30 H - .62 vfs	.88	.77	10.9	0.0007
5	K = .87 clay - 1.01 CEC - .23 silt - .47 pH	.79	.63	5.7	0.0075
6	K = -.59 pH - .22 vfs	.64	.41	5.3	0.0184
7	K = -.62 Na + .74 silt - .30 $CaCO_3$ + .22 CEC	.85	.73	8.7	0.0015

TABLE 3.1 (Continued)

1	Ca = .74 bst + .51 CEC	.93	.86	244.2	0.0001
3	Ca = .99 bst - .56 CEC - .23 Mg - .19 pH - .13 K	.99	.97	70.9	0.0001
5	Ca = .88 bst + .41 CEC - .22 pH	.98	.96	117.4	0.0001
7	Ca = 1.04 bst + .48 CEC - .34	.96	.92	55.5	0.0001
1	Mg = .18 pH + .37 bst + .72 CEC	.91	.82	117.7	0.0001
3	Mg = 1.92 bst + 1.43 CEC - .86 Na - 1.09 Ca - .37 K	.97	.94	36.4	0.0001
5	Mg = .67 CEC + .20 silt - .19 Ca - .70 OM	.98	.95	63.0	0.0001
6	Mg = .66 CEC - .54 OM	.96	.93	92.6	0.0001
7	Mg = .46 Ca + .54 Na + .31 K + .23 vfs	.83	.69	7.3	0.0029
8	Mg = .63 Ca + .38 Na	.78	.61	11.8	0.0011
1	Fs = -.40 vfs - .63 silt - .71 clay	.99	.99	999999.9	0.0001
3	Fs = -.20 vfs - .72 silt - .73 clay	.99	.99	958642.3	0.0001
4	Fs = - .63 silt - .67 clay	.99	.97	275.3	0.0001
5	Fs = - .52 silt - .90 clay - .38 vfs	1	1.0	999999.9	0.0001
6	Fs = - .58 silt - .38 clay + .66 vfs	.99	.99	94964.7	0.0001
1	vfs = - 2.5 fs - 1.58 silt - 1.77 clay - .002 bst	.99	.99	269376	0.0001
3	vfs = .49 pH - .64 K - .54 clay - .20 bst	.89	.80	13.3	0.0003
4	vfs = .40 pH - .60 K - .50 clay	.88	.77	15.8	0.0002
5	vfs - - 1.39 silt - 2.66 fs - 2.39 clay	.99	.99	999999.9	0.0001
6	vfs = - .70 silt + .23 bst	.71	.51	7.9	0.0047
9	vfs = - .88 silt - 1.52 fs - .58 clay	.99	.99	58906.2	0.0001
1	Silt = 0.001 OM - 1.58 fs - .63 vfs - 1.12 clay	.99	.99	652132.5	0.0001
3	Silt =-1.39 fs - .28 vfs - 1.02 clay	.99	.99	496832.1	0.0001
5	Silt = .72 vfs - 1.91 fs - 1.73 clay	1	1.0	999999.9	0.0001
7	Silt = - 1.14 vfs - 1.73 fs - .66 clay	.99	.99	45300.9	0.0001
1	Clay = 0.001 CEC - 1.4 fs - .56 vfs - .89 silt	.99	.99	822799.9	0.0001
3	Clay = 1.41 fs - .88 silt	.97	.94	125.3	0.0001
5	Clay = - 1.11 fs - .58 silt - .42 vfs	1	1.0	999999.9	0.0001
7	Clay = - 2.64 fs - 1.52 silt - 1.73 vfs	.99	.99	19593.0	0.0001

TABLE 3.1 (Continued)

1	Bst = .19 pH + .88 Ca + .22 Na - .51 CEC	.99	.90	168.4	0.0001
3	Bst = .22 K + .62 Ca + .46 Na + .39 Mg - .67 CEC	.99	.99	189.4	0.0001
5	Bst = .25 pH + 1.02 Ca + .17 vfs - .30 CEC	.99	.98	148.9	0.0001
7	Bst = .88 Ca + .34 Na - .45 CEC	.96	.93	66.6	0.0001
1	$CaCO_3$ = .42 bst - .36 vfs - .40 fs - .32 H - .35 Mg	.63	.40	10.1	0.0001
3	$CaCO_3$ = .33 Mg + .33 clay - .38 K	.66	.44	3.7	0.3840
4	$CaCO_3$ = .28 bst + .53 clay - .30 K	.67	.45	3.8	0.0349
5	$CaCO_3$ = .42 Mg + .42 Ca	.79	.63	12.9	0.0008
7	$CaCO_3$ = .60 Ca - .64 vfs - .41 K - .51 fs	.79	.62	5.3	0.0093
8	$CaCO_3$ = .77 Ca - .34 vfs	.69	.48	7.0	.0071
1	H = .44 OM - .51 pH - .20 bst - .26 K	.88	.78	67.9	0.0001
3	H = .92 Na - .86 pH - .03 Ca	.87	.75	14.1	0.0003
4	H = .89 Na - .86 pH	.87	.75	22.6	0.0001
5	H = .81 OM - .70 pH + .43 Mg - .36 silt - .20 K	.98	.95	44.8	0.0001
7	H = -.23 OM - .68 pH - .44 Ca - .47 silt + .38 bst	.95	.91	24.2	0.0001
8	H = -.59 pH - .31 Ca - .30 silt	.93	.87	30.1	0.0001

TABLE 3.2

REGRESSION ANALYSIS FOR AREA TWO

	Regression Equations	r	R^2	F	Prob > F
1	CEC = .68 Ca + .68 Mg + .07 clay - 0.6 bst	.98	.95	511.4	.0001
3	CEC = 0.001 $CaCO_3$ + .93 Ca + .48 Mg - .79 bst	.99	.99	796.3	.0001
4	CEC = .98 Ca - .23 $CaCO_3$	.94	.88	72.45	.0001
5	CEC = 1.02 Ca + .03 K - .13 H + .29 Na + .49 Mg - .03 fs - .98 bst	.99	.99	222.6	.0001
6	CEC = .31 K + .43 pH - .69 fs	.88	.78	22.7	.0001
1	Na = .08 pH - .23 K - .05 Ca - .63 Mg - .07 clay + 1.87 bst + 2.03 CEC	.88	.78	52.7	.0001
2	Na = .48 pH + .42 Mg - .15 clay	.74	.55	45.	.0001
3	Na = -.87 Mg - .28 K + .40 silt - .19 Om	.85	.73	12.27	.0001
5	Na = - 1.13 Mg + .04 silt + .02 pH + .19 $CaCO_3$ - 2.44 Ca + 2.15 bst + 2.37 CEC	.97	.94	32.7	.0001
6	Na = 0.32 Silt + .28 $CaCO_3$ + .62 pH	.84	.70	115.0	.0001
1	K = .45 fs - .02 vfs + .5 OM + 2.77 CEC + 2.35 bst - 2.53 Ca - 64 Na - 1.11 Mg	.74	.54	15.0	.0001
3	K = .32 H + 1.35 pH + .19 fs - .74 bst	.73	.53	5.2	.0058
4	K = .40 H + .32 OM + 1.25 pH - .52 bst	.78	.60	6.62	.0022
5	K = 1.23 H + .75 pH - .43 clay	.76	.57	8.3	.0013
6	K = .67 H	.82	.67	17.2	.0007
1	H = .22 OM - 0.99 pH + .27 clay + .28 CEC	.93	.86	169.6	.0001
3	H = .74 pH + .15 $CaCO_3$ - .46 Ca - .16 vfs - .29 silt + .5 CEC	.93	.87	17.7	.0001
4	H = - 1.0 pH + .36 CEC - .21 Silt	.91	.83	30.5	.0001
5	H = - .55 pH + .28 OM + .44 Ca + .19K - .55 bst	.96	.93	54.4	.0001
1	OM = .28 K + .55 H + .17 Ca - .27 fs - .51 CEC	.78	.61	33.7	.0001
3	OM = .52 K - .39 Na - .35 fs - .20 clay	.65	.42	3.3	.0353
4	OM = .42 K - .27 Na	.53	.28	4.0	.0341
5	OM = - .25 K + .28 Na + .34 bst - .61 $CaCO_3$ - .66 silt + .74 H	.85	.72	6.7	.0014
6	OM = .36 H - .32 $CaCO_3$ - .50 silt	.80	.64	11.3	.0003
1	pH = .28 CEC + .25 clay - .74 H	.94	.89	299.5	.0001
3	pH = .20 bst - .22 K - .40 H + .36 Ca	.96	.92	53.8	.0001
4	pH = .13 $CaCO_3$ + .30 K - .52 H + .41 Ca	.96	.93	56.2	.0001
5	pH = - .72 H - .48 silt - .15 clay + .51 CEC	.95	.90	39.0	.0001
6	pH = - .71 H - .36 silt + .43 CEC	.94	.89	53.0	.0001

TABLE 3.2 (Continued)

1	Clay = - .95 silt - .42 fs - .22 vfs	.99	.99	7937.3	.0001
3	Clay = - 1.02 silt - .26 fs	.99	.98	491.9	.0001
5	Clay = - .90 silt - .68 fs	.99	.98	629.2	.0001
1	Bst = 1.07 Ca + .30 Na + .54 Mg - 1.11 CEC	.98	.95	546.0	.0001
3	Bst = 1.10 Ca + .56 Mg - 1.19 CEC + .10 pH + .03 H + .01 $CaCO_3$	.99	.99	359.5	.0001
4	Bst = 1.18 Ca + .57 Mg - 1.23 CEC	.99	.99	713.3	.0001
1	Fs = .02 K - .48 vfs - 2.19 silt - 2.29 clay	.99	.97	1057.1	.0001
2	Fs = - .49 vfs - 2.2 silt - 2.31 clay	.88	.78	1410.2	.0001
3	Fs = - .65 vfs - 4.51 silt - 4.10 clay + .08 Na - .10 Ca + .11 OM	.99	.99	177.2	.0001
4	Fs = - .27 OM + .41 Ca - .60 Na	.58	.34	3.2	.0449
5	Fs = 0.001 K - .45 vfs - 1.88 silt - 1.92 clay + .0001 CEC	.99	.99	999999.9	.0001
6	Fs = - .45 vfs - 1.88 silt - 1.92 clay	.99	.99	999999.9	.0001
2	Vfs = - .008 CEC - 3.77 silt - 1.60 fs - 3.9 clay	.96	.92	304.7	.0001
3	Vfs = 0.11 OM - 6.67 silt - 1.54 fs - 6.12 clay	.98	.95	85.9	.0001
5	Vfs = - 4.22 silt - 2.24 fs - 4.31 clay	.99	.99	478603.5	.0001
1	Silt = - .44 fs - .23 vfs - 1.04 clay	.99	.99	7247.8	.0001
3	Silt = - .26 fs - .96 clay	.99	.98	525.0	.0001
5	Silt = -.53 fs - 1.02 clay - .24 vfs	.99	.99	999999.9	.0001
6	Silt = - .75 fs - 1.09 clay	.99	.98	520.9	.0001
1	$CaCO_3$ = .32 Ca + .40 clay + .34 bst	.82	.68	76.2	.0001
3	$CaCO_3$ = 1.30 bst + .71 H + .24 vfs + .26 Na - .30 Ca	.78	.83	5.7	.0032
4	$CaCO_3$ = 1.1 bst + + .74 H + .20 vfs	.76	.57	8.4	.0012
5	$CaCO_3$ = - .46 H - .22 OM - .39 pH + .23 Ca + .25 Na + .71 clay	.92	.85	15.4	.0001
6	$CaCO_3$ = - .51 H - .26 OM - .26 pH + .22 Ca + .71 clay	.91	.83	16.7	.0001
1	Ca = .99 CEC + .87 bst - .44 Mg - .26 Na	.98	.96	680.8	.0001
3	Ca = 1.01 CEC + .86 bst - .49 Mg - .02 pH	.99	.99	729.5	.0001
4	Ca = 1.03 CEC + .84 bst - .47 Mg	.99	.99	101.1	.0001
5	Ca = .98 CEC + .91 bst - .48 Mg - .33 Na	.99	.99	466.4	.0001

TABLE 3.2 (Continued)

1	Mg = 1.18 CEC + .71 bst - .69 Ca	.99	.91	370.6	.0001
3	Mg = 1.79 CEC + 1.32 bst - 1.49 Ca - .08 fs + .03 $CaCO_3$	.99	.98	190.2	.0001
4	Mg = 1.82 CEC + 1.38 bst - 1.54 Ca - 0.08 fs	.99	.98	245.6	.0001
5	Mg = 1.75 CEC + 1.62 bst - 1.82 Ca - .001 fs - .12 vfs - .57 Na - .06 pH	.98	.97	63.1	.0001
6	Mg = .59 CEC - .59 OM + .15 silt	.97	.94	76.6	.0001

TABLE 3.3

CORRELATION COEFFICIENT FOR CHEMICAL PROPERTIES, AP ZONE, AREA ONE

	THICK	K	H	CEC	OM	PH	CACO3	CA	NA	MG	FS	VFS	SILT
THICK	1.00000 0.0000	0.04966 0.8448	-0.20483 0.4149	-0.10749 0.6712	-0.09382 0.7112	0.25536 0.3064	-0.33455 0.1748	-0.10553 0.6769	0.01131 0.9645	-0.15518 0.5386	0.09700 0.7018	0.46602 0.0513	0.19196 0.4454
K	0.04966 0.6448	1.00000 0.0000	-0.36548 0.1358	0.12884 0.6104	0.19176 0.4459	-0.18891 0.4528	-0.30957 0.2113	-0.31393 0.2046	-0.55280 0.0173	0.10435 0.6803	-0.37681 0.1232	-0.74221 0.0004	0.60479 0.0078
H	-0.20483 0.4149	-0.36548 0.1358	1.00000 0.0000	0.11740 0.6427	0.22451 0.3704	-0.39979 0.1002	-0.00080 0.9975	0.48646 0.0406	0.45745 0.0563	0.08191 0.7466	0.18525 0.4618	0.05075 0.8415	-0.16517 0.5125
CEC	-0.10749 0.6712	0.12884 0.6104	0.11740 0.6427	1.00000 0.0000	-0.21029 0.4023	0.32724 0.1850	0.32382 0.1899	0.40304 0.0972	0.40922 0.0917	0.77848 0.0001	-0.47191 0.0480	-0.24033 0.3367	0.07263 0.7746
OM	-0.09382 0.7112	0.19176 0.4459	0.22451 0.3704	-0.21029 0.4023	1.00000 0.0000	-0.43011 0.0748	0.01479 0.9536	-0.07966 0.7534	-0.28424 0.2530	-0.22916 0.3603	0.04312 0.8651	-0.36611 0.1351	0.06207 0.8067
PH	0.25536 0.3064	-0.18891 0.4528	-0.39979 0.1002	0.32724 0.1850	-0.43011 0.0748	1.00000 0.0000	0.39018 0.1094	0.27862 0.2629	0.51009 0.0306	0.45081 0.0604	-0.18607 0.4598	0.30283 0.2219	-0.26398 0.2898
CACO3	-0.33455 0.1748	-0.30957 0.2113	-0.00080 0.9975	0.32382 0.1899	0.01479 0.9536	0.39018 0.1094	1.00000 0.0000	0.39747 0.1024	0.47876 0.0444	0.48799 0.0399	-0.21373 0.3944	0.02825 0.9114	-0.20301 0.4191
CA	-0.10553 0.6769	-0.31393 0.2046	0.48646 0.0406	0.40304 0.0972	-0.07966 0.7534	0.27862 0.2629	0.39747 0.1024	1.00000 0.0000	0.82067 0.0001	0.63254 0.0048	0.17581 0.4853	0.09091 0.7198	-0.38681 0.1128
NA	0.01131 0.9645	-0.55280 0.0173	0.45745 0.0563	0.40922 0.0917	-0.28424 0.2530	0.51009 0.0306	0.47876 0.0444	0.82067 0.0001	1.00000 0.0000	0.52916 0.0239	0.15471 0.5399	0.38309 0.1166	-0.46994 0.0390
MG	-0.15518 0.5366	0.10435 0.6803	0.08191 0.7466	0.77848 0.0001	-0.22916 0.3603	0.45081 0.0604	0.48799 0.0399	0.63254 0.0048	0.52916 0.0239	1.00000 0.0000	-0.40294 0.0973	-0.24268 0.3319	0.00925 0.9709
FS	0.09700 0.7018	-0.37681 0.1232	0.18525 0.4618	-0.47191 0.0480	0.04312 0.8651	-0.18607 0.4598	-0.21373 0.3944	0.17581 0.4853	0.15471 0.5399	-0.40294 0.0973	1.00000 0.0000	0.44485 0.0643	-0.73610 0.0005
VFS	0.46602 0.0513	-0.74221 0.0004	0.05075 0.8415	-0.24033 0.3367	-0.36611 0.1351	0.30283 0.2219	0.02825 0.9114	0.09091 0.7198	0.38309 0.1166	-0.24268 0.3319	0.44485 0.0643	1.00000 0.0000	-0.48898 0.0395
SILT	0.19196 0.4454	0.60479 0.0078	-0.16517 0.5125	0.07263 0.7746	0.06207 0.8067	-0.26398 0.2898	-0.20301 0.4191	-0.38681 0.1128	-0.46994 0.0390	0.00925 0.9709	-0.73610 0.0005	-0.48898 0.0395	1.00000 0.0000
CLAY	-0.45075 0.0605	0.12323 0.6261	-0.10319 0.6837	0.63800 0.0044	-0.01943 0.9390	0.42957 0.0752	0.48405 0.0418	0.11564 0.6477	0.16541 0.5119	0.60736 0.0075	-0.76422 0.0002	-0.40199 0.0982	0.15671 0.5346
BST	0.01915 0.9399	-0.27189 0.2751	0.34658 0.1588	0.09816 0.6984	-0.08957 0.7238	0.36323 0.1385	0.34646 0.1590	0.89981 0.0001	0.77406 0.0002	0.52368 0.0257	0.27779 0.2644	0.16945 0.5015	-0.39629 0.1035

TABLE 3.4

CORRELATION COEFFICIENT FOR CHEMICAL PROPERTIES, SUBSOIL ZONE, AREA ONE

	K	H	OM	PH	CACO3	CA	NA	MG	FS	VFS	SILT	CLAY	BST
K	1.00000 0.0000	0.41042 0.0907	0.54620 0.0190	-0.60264 0.0081	-0.32306 0.1910	-0.43224 0.0732	-0.47738 0.0451	-0.46447 0.0521	0.05644 0.8240	-0.25277 0.3115	0.13490 0.5936	-0.03530 0.8894	-0.52972 0.0238
H	0.41042 0.0907	1.00000 0.0000	0.88057 0.0001	-0.85228 0.0001	-0.52343 0.0258	-0.57632 0.0123	-0.57975 0.0117	-0.63843 0.0044	0.16062 0.5243	0.05838 0.8180	-0.00752 0.9764	-0.19781 0.4314	-0.75103 0.0003
OM	0.54620 0.0190	0.68057 0.0001	1.00000 0.0000	-0.78248 0.0001	-0.51555 0.0285	-0.68390 0.0017	-0.60801 0.0074	-0.71861 0.0008	0.16588 0.5107	-0.06796 0.7887	0.14539 0.5649	-0.23958 0.3383	-0.80767 0.0001
PH	-0.60264 0.0081	-0.85228 0.0001	-0.78248 0.0001	1.00000 0.0000	0.49504 0.0367	0.47995 0.0438	0.60006 0.0085	0.67334 0.0022	-0.14407 0.5684	0.05415 0.8310	-0.17975 0.4754	0.24110 0.3352	0.64607 0.0038
CACO3	-0.32306 0.1910	-0.52343 0.0258	-0.51555 0.0285	0.49504 0.0367	1.00000 0.0000	0.75534 0.0003	0.68195 0.0018	0.75576 0.0003	-0.62285 0.0058	-0.28297 0.2552	0.28889 0.2450	0.64013 0.0042	0.63782 0.0044
CA	-0.43224 0.0732	-0.57632 0.0123	-0.68390 0.0017	0.47995 0.0438	0.75534 0.0003	1.00000 0.0000	0.81056 0.0001	0.80741 0.0001	-0.67020 0.0023	-0.12920 0.6094	0.31519 0.2027	0.61322 0.0068	0.89840 0.0001
NA	-0.47738 0.0451	-0.57975 0.0117	-0.60801 0.0074	0.60006 0.0085	0.68195 0.0018	0.81056 0.0001	1.00000 0.0000	0.74518 0.0004	-0.64774 0.0037	0.12383 0.6245	0.11929 0.6373	0.59640 0.0090	0.83878 0.0001
MG	-0.46447 0.0521	-0.63843 0.0044	-0.71861 0.0008	0.67334 0.0022	0.75576 0.0003	0.80741 0.0001	0.74518 0.0004	1.00000 0.0000	-0.71231 0.0009	-0.28732 0.2477	0.31468 0.2034	0.72604 0.0006	0.68738 0.0016
FS	0.05644 0.8240	0.16062 0.5243	0.16588 0.5107	-0.14407 0.5684	-0.62285 0.0058	-0.67020 0.0023	-0.64774 0.0037	-0.71231 0.0009	1.00000 0.0000	0.36966 0.1311	-0.58319 0.0111	-0.92327 0.0001	-0.40048 0.0996
VFS	-0.25277 0.3115	0.05838 0.8180	-0.06796 0.7887	0.05415 0.8310	-0.28297 0.2552	-0.12920 0.6094	0.12383 0.6245	-0.28732 0.2477	0.36966 0.1311	1.00000 0.0000	-0.67935 0.0019	-0.43242 0.0731	0.17125 0.4969
SILT	0.13490 0.5936	-0.00752 0.9764	0.14539 0.5649	-0.17975 0.4754	0.28889 0.2450	0.31519 0.2027	0.11929 0.6373	0.31468 0.2034	-0.58319 0.0111	-0.67935 0.0019	1.00000 0.0000	0.34935 0.1553	0.08489 0.7377
CLAY	-0.03530 0.8894	-0.19781 0.4314	-0.23958 0.3383	0.24110 0.3352	0.64013 0.0042	0.61322 0.0068	0.59640 0.0090	0.72604 0.0006	-0.92327 0.0001	-0.43242 0.0731	0.34935 0.1553	1.00000 0.0000	0.32281 0.1914
BST	-0.52972 0.0238	-0.75103 0.0003	-0.80767 0.0001	0.64607 0.0038	0.63782 0.0044	0.89840 0.0001	0.83878 0.0001	0.68738 0.0016	-0.40048 0.0996	0.17125 0.4969	0.08489 0.7377	0.32281 0.1914	1.00000 0.0000
CEC	-0.31942 0.1963	-0.17515 0.4870	-0.26499 0.2879	0.32393 0.1897	0.61760 0.0063	0.68501 0.0017	0.62278 0.0058	0.80687 0.0001	-0.87263 0.0001	-0.37197 0.1285	0.42093 0.0819	0.87725 0.0001	0.39866 0.1013

TABLE 3.5

CORRELATION COEFFICIENT FOR CHEMICAL PROPERTIES, CR ZONE, AREA ONE

	K	H	OM	PH	CACO3	CA	NA	MG	FS	VFS	SILT	CLAY	BST
K	1.00000 0.0000	-0.17481 0.4878	-0.06545 0.7964	-0.17871 0.4780	-0.06512 0.7974	0.13817 0.5845	-0.51983 0.0270	0.05776 0.8199	-0.31444 0.2038	-0.15372 0.5425	0.51963 0.0271	0.31055 0.2098	-0.00762 0.9761
H	-0.17481 0.4878	1.00000 0.0000	0.42083 0.0820	-0.77946 0.0001	-0.42059 0.0822	-0.71740 0.0008	-0.32344 0.1905	-0.68594 0.0017	0.75905 0.0003	-0.51571 0.0285	-0.60156 0.0083	-0.19247 0.4442	-0.70955 0.0010
OM	-0.06545 0.7964	0.42083 0.0820	1.00000 0.0000	-0.62125 0.0059	-0.17652 0.4835	-0.05362 0.8326	-0.45921 0.0552	-0.29516 0.2344	0.23103 0.3563	0.05241 0.8364	-0.37634 0.1237	-0.12661 0.6166	-0.23478 0.3484
PH	-0.17871 0.4780	-0.77946 0.0001	-0.62125 0.0059	1.00000 0.0000	0.28823 0.2461	0.40293 0.0973	0.53794 0.0213	0.51435 0.0290	-0.47751 0.0451	0.53898 0.0210	0.21165 0.3992	0.00008 0.9997	0.58024 0.0116
CACO3	-0.06512 0.7974	-0.42059 0.0822	-0.17652 0.4835	0.28823 0.2461	1.00000 0.0000	0.62214 0.0058	0.21755 0.3858	0.35279 0.1510	-0.40997 0.0911	-0.02230 0.9300	0.47944 0.0441	0.38103 0.1188	0.53083 0.0234
CA	0.13817 0.5845	-0.71740 0.0008	-0.05362 0.8326	0.40293 0.0973	0.62214 0.0058	1.00000 0.0000	0.16803 0.5051	0.68909 0.0016	-0.68338 0.0018	0.41674 0.0837	0.55484 0.0169	0.23233 0.3536	0.84984 0.0001
NA	-0.51983 0.0270	-0.32344 0.1905	-0.45921 0.0552	0.53794 0.0213	0.21755 0.3858	0.16803 0.5051	1.00000 0.0000	_0.48067 0.0435	-0.15623 0.5359	0.11401 0.6524	0.12909 0.6097	0.01569 0.9507	0.33595 0.1729
MG	0.05776 0.8199	-0.68594 0.0017	-0.29516 0.2344	0.51435 0.0290	0.35279 0.1510	0.68909 0.0016	0.48067 0.0435	1.00000 0.0000	-0.60053 0.0084	0.43317 0.0725	0.47780 0.0449	0.10804 0.6696	0.62557 0.0055
FS	-0.31444 0.2038	0.75905 0.0003	0.23103 0.3563	-0.47751 0.0451	-0.40997 0.0911	-0.68338 0.0018	-0.15623 0.5359	-0.60053 0.0084	1.00000 0.0000	-0.59574 0.0091	-0.74237 0.0004	-0.47519 0.0463	-0.60512 0.0078
VFS	-0.15372 0.5425	-0.51571 0.0285	0.05241 0.8364	0.53898 0.0210	-0.02230 0.9300	0.41674 0.0837	0.11401 0.6524	0.43317 0.0725	-0.59574 0.0091	1.00000 0.0000	0.02447 0.9232	-0.20014 0.4259	0.46027 0.0546
SILT	0.51963 0.0271	-0.60156 0.0083	-0.37634 0.1237	0.21165 0.3992	0.47944 0.0441	0.55484 0.0169	0.12909 0.6097	0.47780 0.0449	-0.74237 0.0004	0.02447 0.9232	1.00000 0.0000	0.39470 0.1050	0.56406 0.0148
CLAY	0.31055 0.2098	-0.19247 0.4442	-0.12661 0.6166	0.00008 0.9997	0.38103 0.1188	0.23233 0.3536	0.01569 0.9507	0.10804 0.6696	-0.47519 0.0463	-0.20014 0.4259	0.39470 0.1050	1.00000 0.0000	-0.06175 0.8077
BST	-0.00762 0.9761	-0.70955 0.0010	-0.23478 0.3484	0.58024 0.0116	0.53083 0.0234	0.84984 0.0001	0.33595 0.1729	0.62557 0.0055	-0.60512 0.0078	0.46027 0.0546	0.56406 0.0148	-0.06175 0.8077	1.00000 0.0000
CEC	0.00030 0.9991	-0.17157 0.4960	-0.08467 0.7384	0.05380 0.8321	0.08150 0.7478	0.19520 0.4376	0.33427 0.1752	0.37478 0.1254	-0.12811 0.6124	-0.06854 0.7870	0.02140 0.9328	0.42708 0.0771	-0.16273 0.5168

TABLE 3.6

CORRELATION COEFFICIENT FOR CHEMICAL PROPERTIES, AP ZONE, AREA TWO

	K	H	OM	PH	CACO3	CA	NA	MG	FS	VFS	SILT	CLAY	BST
K	1.00000 0.0000	-0.27439 0.2051	0.45751 0.0282	0.53658 0.0083	-0.10199 0.6433	0.43619 0.0374	-0.15107 0.4914	0.30973 0.1504	0.30166 0.1618	-0.15585 0.4777	-0.12327 0.5752	0.08803 0.6896	0.21544 0.3235
H	-0.27439 0.2051	1.00000 0.0000	-0.12907 0.5572	-0.81136 0.0001	-0.09297 0.6731	-0.52969 0.0093	0.12818 0.5600	-0.02571 0.9073	-0.19887 0.3630	-0.12732 0.5627	0.06432 0.7706	0.00855 0.9691	-0.73850 0.0001
OM	0.45751 0.0282	-0.12907 0.5572	1.00000 0.0000	0.13486 0.5395	-0.26570 0.2204	0.04444 0.8404	-0.34093 0.1114	-0.09517 0.6658	-0.04353 0.8436	0.07819 0.7229	0.16081 0.4636	-0.15944 0.4674	-0.04191 0.8494
PH	0.53658 0.0083	-0.81136 0.0001	0.13486 0.5395	1.00000 0.0000	0.31304 0.1458	0.83390 0.0001	0.00315 0.9886	0.41656 0.0480	0.28937 0.1805	0.01694 0.9389	-0.35977 0.0918	0.30835 0.1523	0.83425 0.0001
CACO3	-0.10199 0.6433	-0.09297 0.6731	-0.26570 0.2204	0.31304 0.1458	1.00000 0.0000	0.38819 0.0672	0.18300 0.4033	0.30538 0.1565	0.10879 0.6212	0.15023 0.4939	-0.55274 0.0062	0.54464 0.0072	0.55570 0.0059
CA	0.43619 0.0374	-0.52969 0.0093	0.04444 0.8404	0.83390 0.0001	0.38819 0.0672	1.00000 0.0000	0.28972 0.1799	0.72736 0.0001	0.22974 0.2916	-0.10194 0.6435	-0.48229 0.0198	0.47431 0.0222	0.77573 0.0001
NA	-0.15107 0.4914	0.12818 0.5600	-0.34093 0.1114	0.00315 0.9886	0.18300 0.4033	0.28972 0.1799	1.00000 0.0000	0.66691 0.0005	-0.38650 0.0685	-0.32024 0.1363	0.10465 0.6346	0.03390 0.8779	-0.00590 0.9787
MG	0.30973 0.1504	-0.02571 0.9073	-0.09517 0.6658	0.41656 0.0480	0.30538 0.1565	0.72736 0.0001	0.66691 0.0005	1.00000 0.0000	-0.17081 0.4358	-0.28571 0.1863	-0.34075 0.1116	0.46039 0.0271	0.31205 0.1472
FS	0.30166 0.1618	-0.19887 0.3630	-0.04353 0.8436	0.28937 0.1805	0.10879 0.6212	0.22974 0.2916	-0.38650 0.0685	-0.17081 0.4358	1.00000 0.0000	0.18215 0.4055	-0.24894 0.2520	-0.01010 0.9635	0.29827 0.1669
VFS	-0.15585 0.4777	-0.12732 0.5627	0.07819 0.7229	0.01694 0.9389	0.15023 0.4939	-0.10194 0.6435	-0.32024 0.1363	-0.28571 0.1863	0.18215 0.4055	1.00000 0.0000	-0.42210 0.0448	0.26066 0.2296	0.04025 0.8553
SILT	-0.12327 0.5752	0.06432 0.7706	0.16081 0.4636	-0.35977 0.0918	-0.55274 0.0062	-0.48229 0.0198	0.10465 0.6346	-0.34075 0.1116	-0.24894 0.2520	-0.42210 0.0448	1.00000 0.0000	-0.95626 0.0001	-0.45129 0.0306
CLAY	0.08803 0.6896	0.00855 0.9691	-0.15944 0.4674	0.30835 0.1523	0.54464 0.0072	0.47431 0.0222	0.03390 0.8779	0.46039 0.0271	-0.01010 0.9635	0.26066 0.2296	-0.95626 0.0001	1.00000 0.0000	0.39559 0.0617
BST	0.21544 0.3235	-0.73850 0.0001	-0.04191 0.8494	0.83425 0.0001	0.55570 0.0059	0.77573 0.0001	-0.00590 0.9787	0.31205 0.1472	0.29827 0.1669	0.04025 0.8553	-0.45129 0.0306	0.39559 0.0617	1.00000 0.0000
CEC	0.41516 0.0488	0.07734 0.7258	0.03439 0.8762	0.32813 0.1264	0.07221 0.7434	0.66946 0.0005	0.58543 0.0034	0.91202 0.0001	-0.08271 0.7075	-0.28921 0.1807	-0.24619 0.2575	0.33801 0.1147	0.08487 0.7002

TABLE 3.7

CORRELATION COEFFICIENT FOR CHEMICAL PROPERTIES, SUBSOIL ZONE, AREA TWO

	K	H	OM	PH	CACO3	CA	NA	MG	FS	VFS	SILT	CLAY	BST
K	1.00000 0.0000	0.67126 0.0005	0.32885 0.1255	-0.41708 0.0477	-0.51229 0.0124	-0.29128 0.1775	-0.46669 0.0248	-0.31561 0.1424	0.37291 0.0797	0.11360 0.6058	-0.10500 0.6335	-0.11747 0.5935	-0.51619 0.0117
H	0.67126 0.0005	1.00000 0.0000	0.66620 0.0005	-0.77607 0.0001	-0.60562 0.0022	-0.40029 0.0584	-0.73473 0.0001	-0.56091 0.0054	0.39688 0.0608	0.22012 0.3129	-0.22106 0.3107	-0.04093 0.8529	-0.65977 0.0006
OM	0.32885 0.1255	0.66620 0.0005	1.00000 0.0000	-0.40966 0.0522	-0.44879 0.0317	-0.41170 0.0509	-0.52062 0.0109	-0.47622 0.0216	0.38485 0.0698	0.46445 0.0256	-0.51597 0.0117	0.19763 0.3660	-0.50143 0.0148
PH	-0.41708 0.0477	-0.77607 0.0001	-0.40966 0.0522	1.00000 0.0000	0.68408 0.0003	0.41647 0.0481	0.75776 0.0001	0.66345 0.0006	-0.49877 0.0154	-0.22773 0.2960	-0.17437 0.4262	0.48343 0.0194	0.39308 0.0635
CACO3	-0.51229 0.0124	-0.60562 0.0022	-0.44879 0.0317	0.68408 0.0003	1.00000 0.0000	0.62378 0.0015	0.64511 0.0009	0.61493 0.0018	-0.66093 0.0006	-0.39416 0.0627	-0.18525 0.3974	0.61725 0.0017	0.54337 0.0074
CA	-0.29128 0.1775	-0.40029 0.0584	-0.41170 0.0509	0.41647 0.0481	0.62378 0.0015	1.00000 0.0000	0.36043 0.0911	0.51943 0.0111	-0.68647 0.0003	-0.76921 0.0001	0.26876 0.2150	0.27265 0.2081	0.79497 0.0001
NA	-0.46669 0.0248	-0.73473 0.0001	-0.52062 0.0109	0.75776 0.0001	0.64511 0.0009	0.36043 0.0911	1.00000 0.0000	0.65723 0.0007	-0.57229 0.0043	-0.35786 0.0936	0.16008 0.4656	0.22397 0.3043	0.38565 0.0692
MG	-0.31561 0.1424	-0.56091 0.0054	-0.47622 0.0216	0.66345 0.0006	0.61493 0.0018	0.51943 0.0111	0.65723 0.0007	1.00000 0.0000	-0.76551 0.0001	-0.61804 0.0017	0.14247 0.5167	0.40247 0.0569	0.53373 0.0087
FS	0.37291 0.0797	0.39688 0.0608	0.38485 0.0698	-0.49877 0.0154	-0.66093 0.0006	-0.68647 0.0003	-0.57229 0.0043	-0.76551 0.0001	1.00000 0.0000	0.77670 0.0001	-0.23976 0.2705	-0.46598 0.0250	-0.51438 0.0120
VFS	0.11360 .6058	0.22012 0.3129	0.46445 0.0256	-0.22773 0.2960	-0.39416 0.0627	-0.76921 0.0001	-0.35786 0.0936	-0.61804 0.0017	0.77670 0.0001	1.00000 0.0000	-0.50337 0.0143	-0.14315 0.5147	-0.60743 0.0021
SILT	-0.10500 0.6335	-0.22106 0.3107	-0.51597 0.0117	-0.17437 0.4262	-0.18525 0.3974	0.26876 0.2150	0.16008 0.4656	0.14247 0.5167	-0.23976 0.2705	-0.50337 0.0143	1.00000 0.0000	-0.73863 0.0001	0.37768 0.0756
CLAY	-0.11747 0.5935	-0.04093 0.8529	0.19763 0.3660	0.48343 0.0194	0.61725 0.0017	0.27265 0.2081	0.22397 0.3043	0.40247 0.0569	-0.46598 0.0250	-0.14315 0.5147	-0.73863 0.0001	1.00000 0.0000	0.03863 0.8611
BST	-0.51619 0.0117	-0.65977 0.0006	-0.50143 0.0148	0.39308 0.0635	0.54337 0.0074	0.79497 0.0001	0.38565 0.0692	0.53373 0.0087	-0.51438 0.0120	-0.60743 0.0021	0.37768 0.0756	0.03863 0.8611	1.00000 0.0000
CEC	-0.13063 0.5524	-0.33858 0.1140	-0.36484 0.0869	0.64632 0.0009	0.63041 0.0013	0.65038 0.0008	0.66917 0.0005	0.74690 0.0001	-0.78910 0.0001	-0.62925 0.0013	0.07153 0.7457	0.48691 0.0185	0.27584 0.2027

In the Ap zone (surface zone, Area One), BST contribution was still the highest (-1.39) followed by Ca (.83), and Mg (.6). Clay did not appear in the regression equation and was replaced instead by K (.26). However, for the same zone (Area Two), Ca contribution was the highest (.93) followed by BST (-.79), and Mg (.48). $CaCO_3$ contribution at the 5% significance level was negligible. The regression equation explained 99% of the CEC variations. Furthermore, at the .1 probability level, only Ca (.91) and $CaCO_3$ (-.23) seemed to be important and explained 88% of the CEC variations.

In the subsurface zone (Area One), clay seemed to contribute most to the variation in CEC. Its contribution was four times higher than silt and three times higher than potassium; while in Area Two, FS (.69) was twice as important as K (.32) and one and one half times higher than pH (0.43). Clay did not seem to be important in the explaining CEC variation in the subsurface of Area Two. This might be due to the stratified nature of the clay minerals in this area.

Clay (.39) and Mg (.33) explained 29% of the variation of CEC in the Cr zone (Area One) at the 1% significance level. At the 5% significance level, clay (.01) contribution seemed to be the least important. OM was not found to be associated with the CEC in any zone of any area. All samples regression (Area One) indicated that BST (1.02), CEC (.51), clay (.32), and Ca (-.73) explained 70% of the variation of Na, while in Area Two, pH (.48), Mg (.42), and clay (-.15) explained 55% of the Na variation at the 1% significance level. In Area One, H (.49), pH (.59), and Ca explained 87% of the variation of Na in the Ap zone, while CEC (2.37), BST (2.15), Mg (-1.13), Ca (2.44), and $CaCO_3$ (.19) explained 94% of the variation of Na in Area Two (r=.97).

In the subsurface (Area One) multiple correlations were .95. BST (1.81), Ca (-1.1), clay (.75), and H (.29) explained 90% of the variation of Na, while 70% of the Na variation in the subsurface (Area Two) was explained by pH (.62), $CaCO_3$ (.28), and silt (.32) (r=.84). Furthermore, in the Cr zone (Area One) 74% of the Na variation was explained by silt (.64), pH (.73), K (-.62), H (.59), and CEC (.38).

Regression equations for fine sand, very fine sand, silt, and clay confirmed previous knowledge about the relationship between these properties. In most cases, 99% of the variations of one of these variables were explained by the other two. However, in a few cases this rule did not apply. In the subsurface (Area Two), Ca (.41), Na (.60), and OM (.29) accounted for 34% of the FS variation at 1% significance level. Also, in the Ap zone (Area One), very fine sand was only explained by K (-.60), clay (.50), and pH (.4) at .1 probability level. Very fine sand was not correlated with silt in either the surface or the subsurface, or with the clay in the surface of Area One, or in the surface or subsurface of Area Two.

Further study of the regression equations revealed the extremely high correlation between these soil properties. Multiple correlation coefficients varied from .80 to .90 in most cases. However, in a few cases, R^2 was noticed to be relatively low. For example, R^2 for OM in the surface zone was .42 (Area Two), and .25 (Area One). This relatively low correlation between organic matter and soil properties suggests that external factors exert more impact on the OM of the surface zone. This relation was reversed in the subsurface of both areas. Also, Na and K in the surface of both areas did not have high multiple correlations with different soil properties (.46 to .54). Multiple correlations for $CaCO_3$ were .40 for the surface zone of both areas.

The trend of low R^2 values of the regression equation for some variables in the surface zone of both areas could be due to a strong association with climate, as in the case of OM, or with factors that govern the mobility of the leaching intensity, as in the case of Na, K, and $CaCO_3$. No explanation could be advanced for the low correlation obtained for the very fine sand in the surface (Area One , P = .1) or the fine sand in the subsurface (Area Two, P = .1).

Regression equations also revealed that except for sand, silt, and clay, no one soil property can be predicted by less than two properties. Furthermore, the regression equations indicated that, in most cases, the number and kind of variables important in explaining the variation of a particular soil property will depend totally, except for sand, silt, and clay, on the genetic horizon under consideration. If these horizons were treated together, different equations or relationships might result.

Correlation Coefficient As a Prediction Criterion

Tables 3.3, 3.4, 3.5, 3.6, and 3.7 show the pairwise correlation between 14 soil properties. A close examination of these correlations revealed high correlation between many soil properties. The correlation coefficient is interpreted as the trend followed by one variable if another variable correlated with it varies. Thus, in soil there might exist conditions where high correlations might be obtained, but as was shown before, the variation in one variable cannot be explained only by one single variable.

For example, examining the matrix of the pairwise correlations (Table 3.3) for the Ap zone (Area Two) showed the correlation between Ca and Na to be .82 and .63 between Ca and Mg, but Na with the high correlation with Ca did not appear in the regression equation for Ca. In Area Two (subsurface zone) (Table 3.6) correlation between Ca and pH was .83; Ca and Na, .3; Ca and silt, -.48; and .47 for Ca and clay. None except sodium (with low pairwise correlation with Ca) appeared in the regression equation. In the subsurface zone (Area One) (Table 3.2), correlation between Ca and OM was -.68, .75 with $CaCO_3$, .81 with Na, .81 with Mg, -.67 with FS, and .61 with clay, but none of these variables appeared in the regression equation for Ca. This pattern dominated the relationships between the different variables and their respective regression equations. Exception to this, was the regression equations for the organic matter in the surface zone only, and for the sodium in the surface zone of Area One. This might suggest that high pairwise correlation may exist between soil properties, but it does not mean that the correlation can be informative since multiple correlations govern the relationships between all the soil properties investigated in this study.

Conclusions

1. The multiple regression model seemed to fit the relationships of different soil properties very well. Simple regression was not found to exist between these properties.

2. The pairwise correlation coefficient did not seem to be a proper tool to be used as an indicator to explain the relationship between

two soil properties. This is true since multiple relationships govern the relationships between these properties.

3. Regression analysis indicated that the number and kind of variables that appeared in the regression equations and the R-squared values, depended totally on the genetic horizon considered. If the different genetic horizons were treated together, completely different equations may result.

4. Eventhough the two areas seemed to be composed of soil that developed under conditons that would stimulate a narrow range of genetic processes, no general pattern could be established for each area. Each property should be considered separately. This might suggest that a regression model with a high prediction capability to cover a wide range of conditions may not be feasible. However, soil separates seemed to yield to such a model provided that mineralogical and weatherability of the sand fractions were known.

CHAPTER IV

CANONICAL CORRELATION

Abstract

For many years, soil scientists implied the existence of certain relationships between chemical and morphological properties with little pursuit in this area. One problem they faced was how to establish any relationships between discrete multistate morphological and continuous chemical properties, or how to make inference about a specific state of the morphological properties.

In this investigation, the technique of canonical correlation is introduced as a statistical tool in studying the relationships between morphological and chemical properties. The canonical correlation was conducted on different genetic zone: 1) surface zone (includes all Ap-designated horizons); 2) subsurface zone (includes all B-designated horizons); 3) P.M. zone (includes all Cr-designated horizons); and 4) all samples (includes all of the samples).

Mathematical relationships established using this technique showed that significant relationships do exist between chemical and morphological properties. These relationships also differ from one zone to another. This investigation also demonstrated that this technique can be used to test the suitability of different soil properties as diagnostic criteria in the system of soil classification. In many cases,

superiority of some soil properties was indicated. Moreover, the conclusion reached about the suitability of some properties as diagnostic criteria was in harmony with the way these criteria are used in the current system.

Furthermore, since this procedure can be carried for different genetic zones, selection of better criteria for the lower categories of the system can be carried out with minimum subjectivity. The statistical test to support the significance of the groups produced from using such criteria are also available. In addition to this, canonical correlation could be an excellent tool in isolating factors responsible for explaining certain soil patterns. One potential area is land capability classification or land use planning.

Introduction

Morphological properties of soil are discrete multistate variables. If causes and effects that result in the variation of the different soil morphological properties are to be studied, then the level of the chemical properties or the state of the morphological properties must be attached to the conclusion about the variations of these properties.

For example, if the hue is to be related to the chemical properties of the soil, it would be of great importance to know how the value and the chroma would relate to the same properties at the same time. Usually regression analysis treat all the variables as continuous variables, and it is concerned only with univariates as the dependent variables. Inference about discrete (multistate dependent) variables, such as structure (grade, class, type), or concretions (type, abundance) or pores orientation may not be possible. Therefore, a new approach is adopted here to treat the discrete morphological properties as multistate dependent variables and to study their relationships with the chemical properties.

The technique suggested here was introduced by Hotelling (36) and was improved to be used by high speed computers. A detailed description of the mathematics involved can be found in many statistical texts, but a simplified summary of the concept involved is presented here.

Let us assume that a group of observations were recorded on certain sampling units. These units can be soil horizons, or soil profiles. The observations can be a group of morphological or chemical properties. The vectors of these observations can be mathematically represented as follows:

Set one	Set two	
$X_{11}, X_{12} \ldots\ldots\ldots X_{p1}$	$Y_{11}, Y_{21} \ldots\ldots\ldots Y_{q1}$	Observation 1
$X_{12}, X_{22} \ldots\ldots\ldots X_{p2}$	$Y_{21}, Y_{22} \ldots\ldots\ldots Y_{q2}$	Observation 2
.		.
.		.
.		.
.		.
$X_{1N}, X_{2N} \ldots\ldots\ldots X_{pN}$	$Y_{1N}, Y_{2N} \ldots\ldots\ldots Y_{qN}$	N

Where $(X_1, X_2, \ldots\ldots\ldots X_p)$ is a group of variables (morphological properties, for example) recorded on a unit (set one) and we desire to study their relationship with $Y_1, Y_2, \ldots\ldots\ldots Y_q$, which is another set of variables (set two, chemical properties) recorded on the same unit. N is the number of the units (horizons or profiles).

The correlation matrix for the whole data can be represented as follows:

$$R = \begin{bmatrix} Rxx & Rxy \\ Ryx & Ryy \end{bmatrix}. \qquad (4.1)$$

Rxx, Ryy are correlations among variables of set one and set two respectively. Rxy and Ryx are the correlations between the variables of set one and the variables of set two.

Two assumptions are made about R:

1. R is a full rank p + q.

2. Since R is a correlation matrix, it is implicitly assumed that the relationships between X's and Y's are linear. Also Ryx contains at least one none zero element.

The objective now is to find a new coordinate system in space of each set of variables in such a way that the new system displays, unambiguously, the system of correlations between the variables of the two sets. More precisely, find the linear combination of the variables in each set that has maximum correlation. These linear combinations are the first coordinates of the new system. Then the second linear combination in each set is found in such a way that the correlation between them is maximum and is uncorrelated with the first linear combinations. This procedure is continued until the new coordinate system is completely specified.

The following procedure explains the mathematical construction of the two new coordinate systems. Assume the variance-covariance matrix of the whole data can be represented as follows:

$$A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}. \tag{4.2}$$

$$\text{Where } A_{11} = \text{Var } (X) \tag{4.3}$$

$$A_{22} = \text{Var } (Y) \tag{4.4}$$

$$A_{12}, A_{21} = \text{Cov } (X,Y). \tag{4.5}$$

Consider an arbitrary linear combination: $\underset{\sim}{U} = \underset{\sim}{a}'X$ and $\underset{\sim}{V} = \underset{\sim}{c}'Y$, we ask for the linear functions U and V which have maximum correlations. Correlations between U and X, and V and Y are not changed by the linear operators a and c. Therefore, we can normalize a and c without affecting the correlations. To construct the U's and the V's of maximum correlations where U_i and V_i are uncorrelated with U_j and V_j, the following restrictions are imposed:

$$\text{Var } (\underset{\sim}{U}) = \text{Var } (\underset{\sim}{a}'X) = \underset{\sim}{a}'A_{11}\underset{\sim}{a} = 1 \tag{4.6}$$

$$\text{Var } (\underset{\sim}{V}) = \text{Var } (\underset{\sim}{c}'Y) = \underset{\sim}{c}'A_{22}\underset{\sim}{c} \tag{4.7}$$

$$E\ (\underset{\sim}{U}) = E\ (\underset{\sim}{a}'X) = 0 \tag{4.8}$$

$$E\ (\underset{\sim}{V}) = E\ (\underset{\sim}{c}'Y) = 0. \tag{4.9}$$

Thus the correlation between $\underset{\sim}{U}$ and $\underset{\sim}{V}$ is:

$$\text{Corr } (\underset{\sim}{U},\underset{\sim}{V}) = \frac{\text{Cov } (\underset{\sim}{U},\underset{\sim}{V})}{(\text{Var } (\underset{\sim}{U}).\ \text{Var } (\underset{\sim}{V}))^{\frac{1}{2}}} \tag{4.10}$$

$$\text{Cov } (\underset{\sim}{U},\underset{\sim}{V}) = \text{Cov } (\underset{\sim}{a}'X,\ \underset{\sim}{c}'Y = \underset{\sim}{a}'A_{12}\underset{\sim}{c}\ . \tag{4.11}$$

Therefore, A_{12} should not be the null matrix.

The problem now is to find a and c to maximize Cor ($\underset{\sim}{a}$'X, $\underset{\sim}{c}$'Y) subjected to:

$$\underset{\sim}{c}'A_{22}\,\underset{\sim}{c} = 1, \text{ and } \underset{\sim}{a}'A_{11}\,\underset{\sim}{a} = 1. \tag{4.12}$$

By using the Lagrange multiplier technique, it can be shown that a and c can be found from solving the following system of equations (Anderson, 1; Morrison, 46)

$$\begin{bmatrix} -\lambda A_{11} & A_{12} \\ A_{21} & -\lambda A_{22} \end{bmatrix} \begin{bmatrix} \underset{\sim}{a} \\ \underset{\sim}{c} \end{bmatrix} = 0. \tag{4.13}$$

In order to have non-trivial solutions to the above system, the determinant of the above matrix is set equal to zero. This leads to finding λ, which can be proved to be equal to

$$\lambda = \underset{\sim}{a}'A_{12}\underset{\sim}{c}. \tag{4.14}$$

Therefore, λ is the correlation between $\underset{\sim}{U}$ - $\underset{\sim}{a}$'X and $\underset{\sim}{V}$ = $\underset{\sim}{c}$'Y when $\underset{\sim}{a}$ and $\underset{\sim}{c}$ satisfy the system for some value of λ.

Since we want to maximize the correlation between $\underset{\sim}{U}$ = $\underset{\sim}{a}$'X and $\underset{\sim}{V}$ = $\underset{\sim}{c}$'Y, we take $\lambda = \lambda_1$, which is the largest eigenvalue for the augmented matrix of the above system. Thus $\underset{\sim}{U}_1$ = $\underset{\sim}{a}_1$'X and $\underset{\sim}{V}_1$ = $\underset{\sim}{c}_1$'Y (where $\underset{\sim}{U}_1\underset{\sim}{a}_1$, $\underset{\sim}{V}_1$,$\underset{\sim}{c}_1$ satisfy the value $\lambda = \lambda_1$) are the normalized linear combinations of X and Y respectively, with maximum correlation.

The second maximum correlation is obtained from $\underset{\sim}{U}_2$ = $\underset{\sim}{a}_2$'X and $\underset{\sim}{V}_2$ = $\underset{\sim}{c}_2$'Y such as $\underset{\sim}{U}_1$, and $\underset{\sim}{V}_1$ are uncorrelated with $\underset{\sim}{U}_2$ and $\underset{\sim}{V}_2$. Therefore, the new complete coordinate system can be summarized as follows:

$$\underset{\sim}{U}_1 = \underset{\sim}{a}_1'X,\ \ \underset{\sim}{V}_1 = \underset{\sim}{c}_1'Y_1, \ldots\ldots, \underset{\sim}{U}_p = \underset{\sim}{a}_p'X,\ \ \underset{\sim}{V}_p = \underset{\sim}{c}_p'Y. \tag{4.15}$$

with corresponding correlations $\lambda = \lambda_1, \lambda_2, \ldots. \lambda_p$, where λ_1 is the maximum value of the eigenvalue among all possible λ_i. The practical interpretations of these relationships will be undertaken in the discussion section using real data.

The objective of this study was to relate specific morphological properties at any state with the chemical properties.

Materials and Methods

Two areas were selected for this study. A total of 18 and 23 profiles were sampled from Area One and Two respectively. Descriptions of the two areas, field design, laboratory measurements, and laboratory statistical design were given in previous chapters. The coding system for the morphological properties was established prior to the field work and is given on the attached description sheets. The horizontal bold number represents the number of the horizon. The vertical number represents the code for each morphological property written on the same line. The code values for the texture increase as the clay content of the texture abstract increases accordingly. The code values for the soil texture were equally spaced. The Munsell color, as recorded in the field, was not changed since hue, chroma, and value were equally spaced. High value for the hue will refer to 10YR, and low hue will refer to 2.5YR. The codes for all other morphological properties were equally spaced.

Analyses were conducted on different genetic horizons (Ap horizons will be referred to as the surface zone; the B horizons will be referred to as the subsurface zone; and the Cr horizons will be referred to as the parent material zone). The same analysis was also conducted on all on all horizons treated together (this zone will be referred to as all-sample analysis).

Results and Discussion

Correlations less than (.5) in absolute value were not considered important. The choice of this value was arbitrary and subjective. However, a threshold correlation value could be determined by the following formula:

$$\frac{|r| \sqrt{n-2}}{\sqrt{1-r^2}} \leq t_{a/2,\ n-2} \qquad (4.15)$$

n is the sample size and $t_{a/2,\ n-2}$ is the tabulated t with n-2 degree of freedom, a is the desired probability level, and r is the correlation coefficient which needs to be determined. The following correlation classes were established for the absolute value of r: .5 - .59 = low or very low; .6 - .70 = moderate; .7 - .8 = moderately high; .8 - .9 = high; .9 - 1 = very high.

In some cases, a class transitional between two classes was used to fit the many class levels for the original variables, especially for the morphological properties. The above classes were established for the correlations between the properties and the canonical variables, not for the correlations between the canonical variates themselves.

Association Analyses for Color, Area One

The first canonical correlation (corr (U_1,V_1)) was .87 (Table 4.1). This can be interpreted as follows: U_1 is highly correlated with V_1. Thus, high hue code value (.78), moderately low value code (-.6), and

TABLE 4.1

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES FOR AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.40171373	38.01821269	0.86567626	149.76020	39	0.0001
2	0.70532925	94.41835593	0.59418561	49.42898	24	0.0017
3	0.35646513	83.43941021	0.46722455	17.85549	11	0.0846

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.797339	-0.601289	-0.869248
VAR # 2	0.547254	0.656709	-0.199639
VAR # 3	0.254487	-0.440398	0.452275

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CFC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	0.658656	0.379577	0.200358	-0.244356	-0.214572	0.886423	-0.192749	-0.108462	0.584091	-0.265549
	MG	NA	BST							
	-0.088953	-0.452170	-0.516618							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	-0.095210	-0.021271	-0.265286	-0.097209	0.235559	-0.258028	0.255456	-0.324116	-0.168510	-0.213025
	MG	NA	BST							
	0.015931	-0.344390	-0.134253							

very low chroma code (-.87) are highly associated with moderate amount of hydrogen (.68), very high organic matter content, moderate silt, and base saturation. The number between the brackets indicates the level of the original data as correlated with the other properties. The canonical correlation is a measure of how strong the two canonical sets were correlated (Figure 4.1).

In terms of the original data, this can be reworded as follows: 10YR hue, value of 3-4, and chroma of 1-2 are highly associated with a moderate content of hydrogen, a very high content of organic matter, moderate silt, and low base saturation.

The level of low, moderate, or high for the chemical properties refers to the standardized adjusted means of that particular property. For example, organic content ranged from .01% to 2%. Thus very high organic content refers to the 2%, while very low refers to the .01%. Therefore, the classification of high or low refers to the particular level in the area where the soil was sampled. The figures given here (Figure 4.1) represent the sample values of U_1 and V_1 as calculated from the data, $\underset{\sim}{U}_1 = \underset{\sim}{a}_1'X$, and $\underset{\sim}{V}_1 = \underset{\sim}{c}_1'Y$, that satisfy the value of L_1.

Later in the following section, the construction of the graphs will be investigated in more detail and will be used as a tool to select some of the properties that would be suitable as a diagnostic criterion in the mathematical classification.

The canonical correlation for the surface zone (area one) indicated that no significant correlation existed (above the .5) between any of the variables, even U_1,V_1 were strongly correlated (.99) (Table 4.2, Figures 4.2 and 4.3).

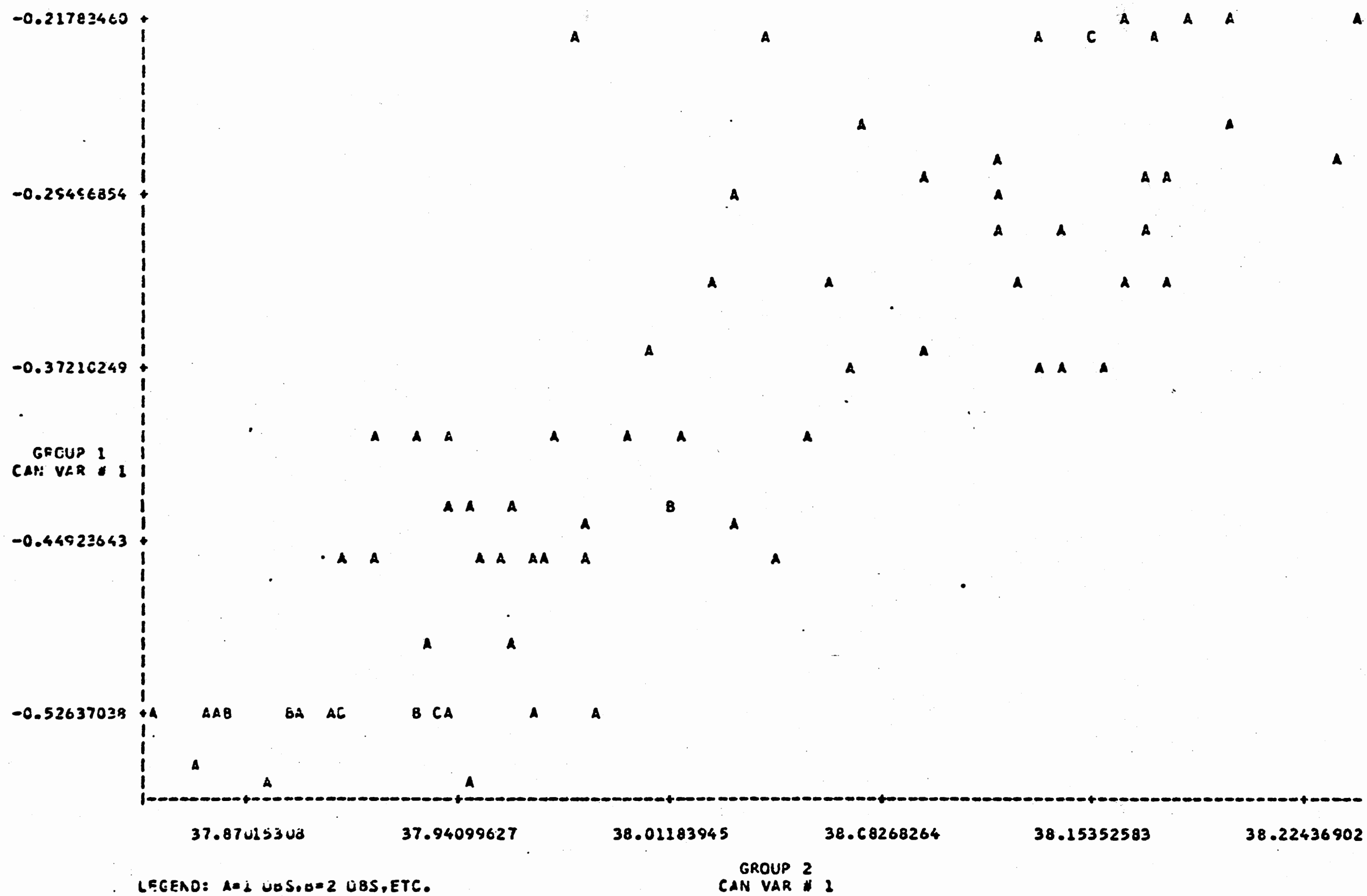


Figure 4.1. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples (Area One).

TABLE 4.2

CANONICAL CORRELATION ANALYSIS FOR SURFACE ZONE FOR AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.59497209	1433.61201620	0.99797864	84.70811	39	0.0001
2	-1.17173128	2188.38504244	0.94164274	32.34554	24	0.1184
3	1.21393938	-539.17314817	0.84075867	11.65799	11	0.3899

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.497463	0.700611	-0.375375
VAR # 2	0.550817	-0.706800	-0.800389
VAR # 3	0.670169	-0.097868	0.467409

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA	MG	NA	BST
VAR # 1	-0.010405	0.092313	0.140112	-0.099431	-0.043389	-0.337717	-0.262451	-0.077484	0.213322	0.388467	0.350569	0.091068	0.050993
VAR # 2	0.286619	-0.133343	-0.133496	0.011827	0.065683	0.214154	0.190507	-0.299208	0.160012	-0.163280	-0.082413	-0.047409	0.014804

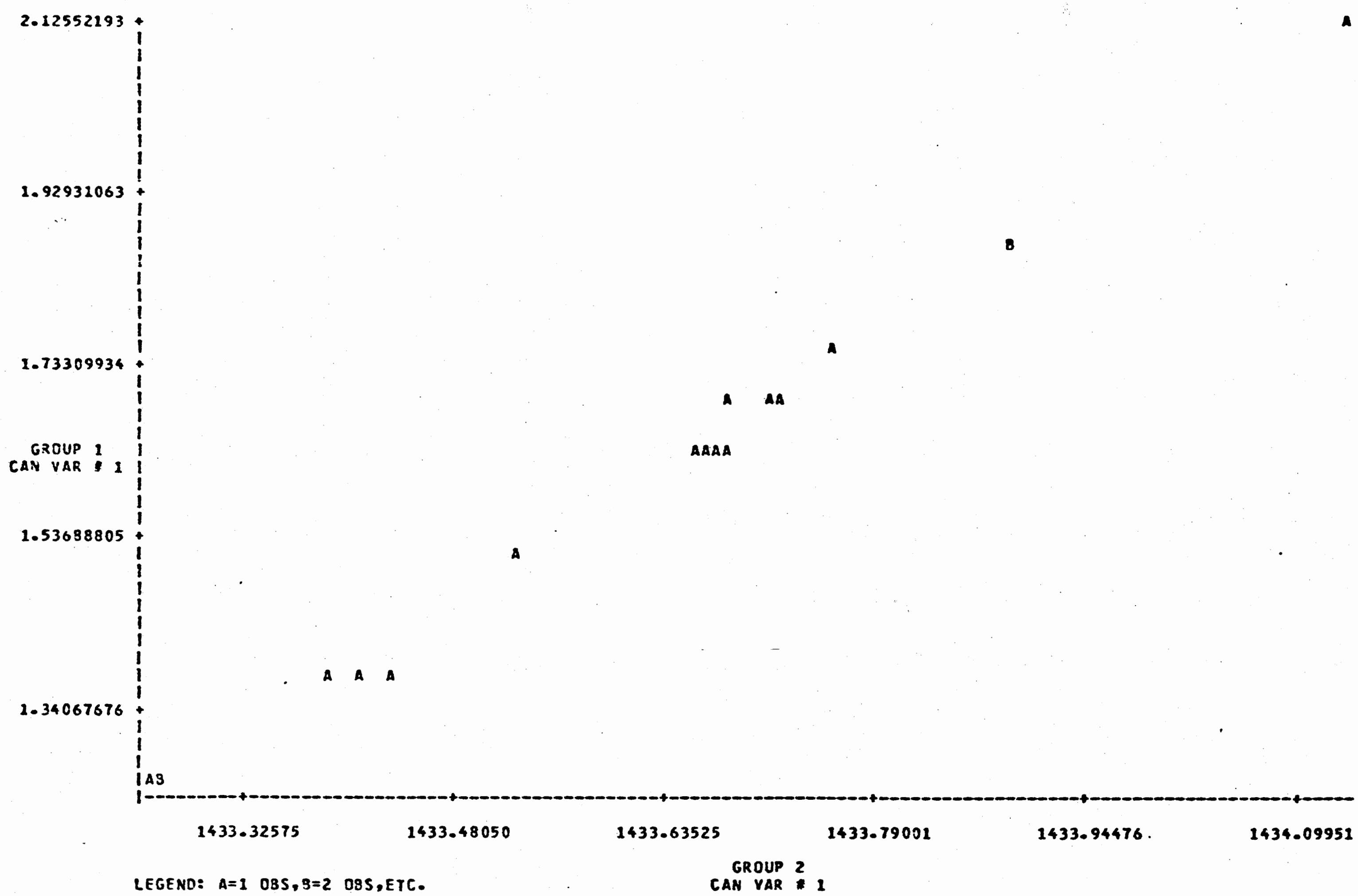


Figure 4.2. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Surface Zone, Area One.

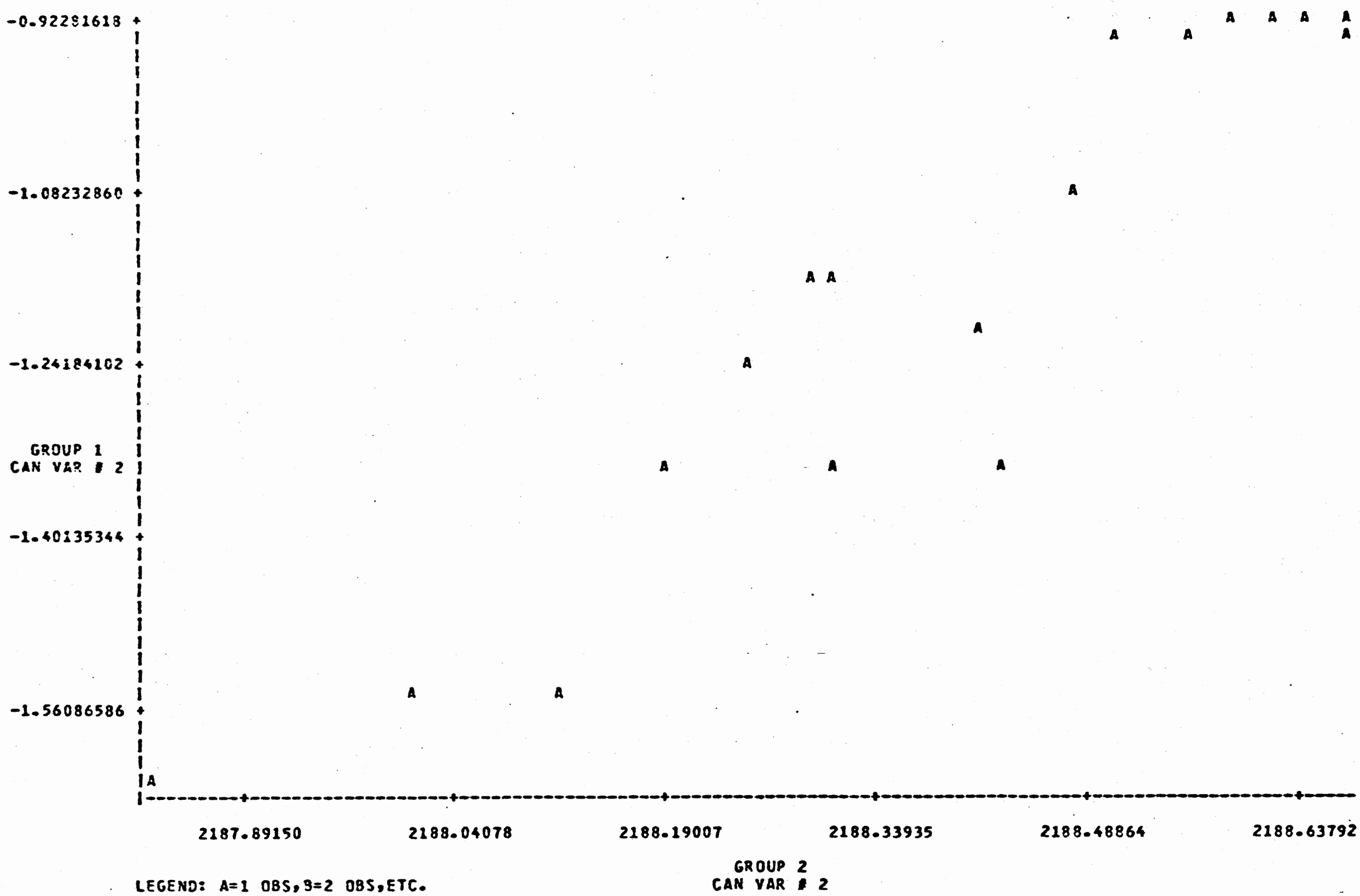


Figure 4.3. Plot of the Compounds in the Plan of the Second Pair of Canonical Variables for the Surface Zone, Area One.

The first canonical correlation for the same set of variables in the subsurface (area one) was .83. This was interpreted as follows: moderate to high hue (.77), moderate to low value (-.64), and very low chroma (-.89) is highly associated with a high content of organic matter. In other words, hue of 7.5YR or 5YR, value of 3-4, and 1-2 chroma (-89) are highly associated with a high content of organic matter (Figure 4.4). The second canonical variate was not significant (Table 4.3).

The canonical correlation for the first canonical variate (parent material zone - area one) was .99%, prob > χ = .03 and indicated that 7.5 YR hue is associated with a low cation exchange capacity (CEC) (.51) and low clay content (Figure 4.5, Table 4.4).

Association Analyses for Color, Area Two

Canonical correlation for the first canonical variable (all samples was .92). This was interpreted as follows: very high hue code (.91), moderately low value code (-.66), and very low chroma code is highly associated with a moderate content of hydrogen (.66), and very high organic matter content (Table 4.5, Figure 4.6). In terms of original data, 10YR, 3-4 value, and 1-2 chroma, is highly associated with a moderate amount of hydrogen and very high organic matter contents. The second canonical variate was not significant.

As it was for the first area, canonical correlation for the first canonical variate was (.98) but no significant correlations (above .5) were exhibited between the morphological and chemical properties (Table 4.6, Figure 4.7). However, canonical correlation between the first two variates for the subsurface was .90, and was highly significant.(prob > Chi-SQ = .0001) (Figure 4.8). It was interpreted as follows: 10YR hue,

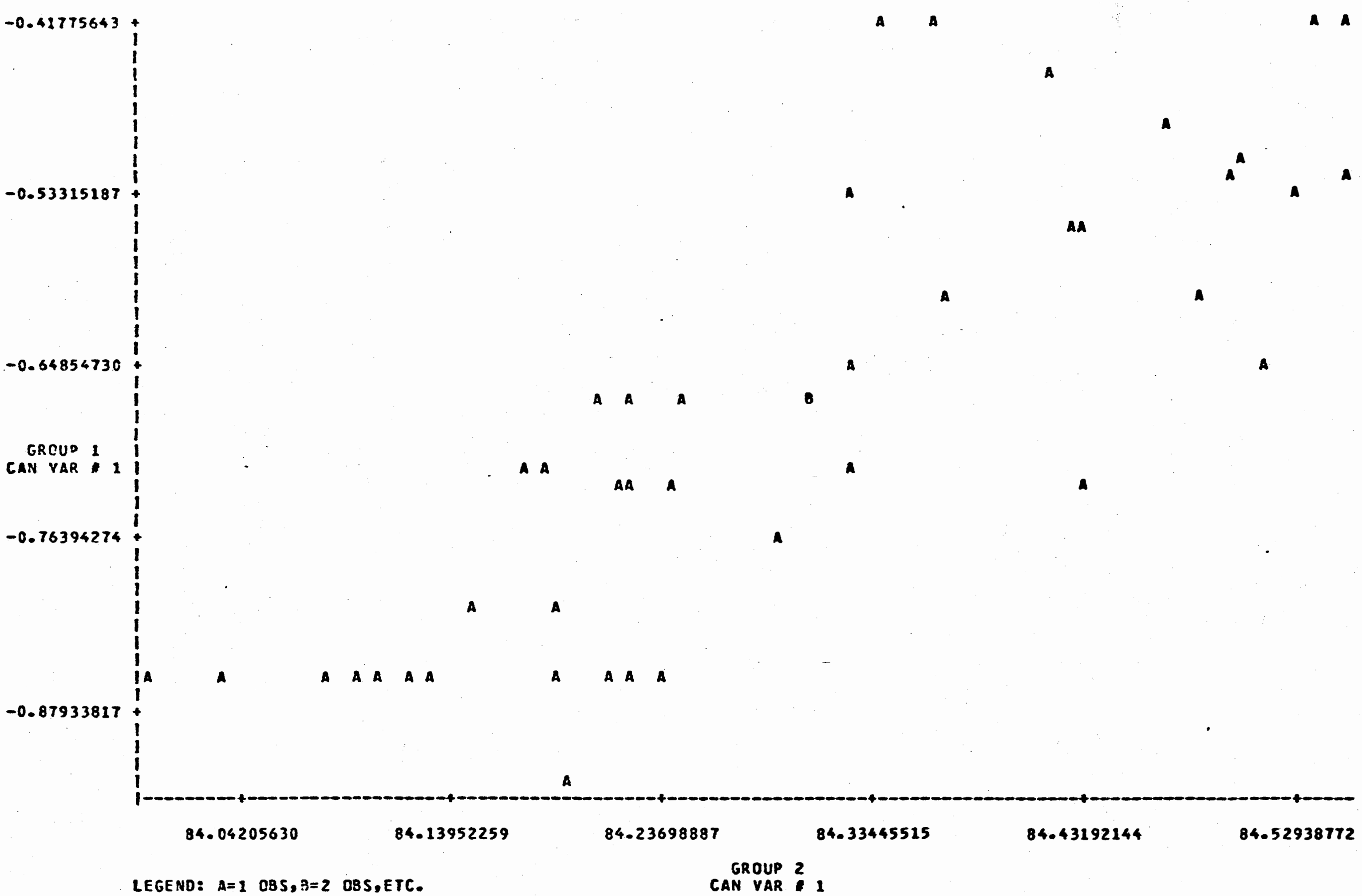


Figure 4.4. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area One.

TABLE 4.3

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.63274141	84.29478074	0.82703544	65.68357	39	0.0048
2	1.04720310	-34.12170473	0.65687451	24.78850	24	0.4173
3	0.64400058	120.96789066	0.35356595	4.74072	11	0.9428

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.772619	-0.642627	-0.839034
VAR # 2	0.577640	0.711351	-0.275387
VAR # 3	0.263424	-0.284625	0.365760

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	0.484323	0.110878	0.159435	-0.242293	-0.008336	0.807341	-0.158159	-0.187566	0.352700	-0.328416
	MG	NA	BST							
	-0.147724	-0.451614	-0.483754							
CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.014366	0.021538	-0.331878	-0.112684	0.442609	-0.340369	-0.052527	-0.506155	-0.081836	-0.369075
	MG	NA	BST							
	-0.114339	-0.399396	-0.251324							

TABLE 4.4

CANONICAL CORRELATION ANALYSIS FOR THE P. M. ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.10141319	166.37932644	0.97773601	56.74966	39	0.0329
2	2.29117486	-242.01380318	0.90612296	27.08276	24	0.3004
3	1.75832260	-208.89940149	0.82280321	10.73613	11	0.4660

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.876522	-0.131622	0.361765
VAR # 2	0.085238	0.886746	-0.338849
VAR # 3	-0.473755	-0.443123	0.868509

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.074602	0.087888	0.501668	0.058542	-0.186532	0.110295	0.037636	0.512683	-0.052559	0.253861
	MG	NA	BST							
	0.454925	-0.077102	-0.275830							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.047802	-0.040700	-0.305109	0.069095	-0.198204	-0.315159	0.195751	0.263263	-0.055278	-0.176484
	MG	NA	BST							
	-0.189688	-0.147935	0.095891							

TABLE 4.5

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.17255993	0.18566818	0.91170705	223.93953	39	0.0001
2	0.40267441	1.35159758	0.43501369	38.02375	24	0.0345
3	0.73431602	-0.55669445	0.37788910	16.10180	11	0.1368

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.904264	-0.658098	-0.984247
VAR # 2	0.108655	0.725236	-0.114267
VAR # 3	0.412917	0.196719	0.134912

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	0.659675	0.176958	-0.257485	-0.144055	-0.301899	0.949915	-0.241183	-0.212052	0.405656	-0.106752
	MG	NA	BST							
	-0.257968	-0.420456	-0.433598							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	-0.061580	0.073955	-0.245953	-0.095713	0.244874	0.002707	0.410220	-0.276668	0.094370	0.266648
	MG	NA	BST							
	-0.144299	-0.278085	-0.190728							

TABLE 4.6

CANONICAL CORRELATION ANALYSIS FOR THE SURFACE ZONE, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	4.13063303	-47.94909915	0.97854222	60.32696	39	0.0158
2	1.79429903	12.58360057	0.77800738	17.67630	24	0.8188
3	-0.82403908	17.29148092	0.56210254	5.12646	11	0.9249

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.806937	0.084398	0.100156
VAR # 2	-0.278205	0.830124	0.861920
VAR # 3	0.521013	-0.551155	0.497053

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.206288	-0.283957	0.101225	0.085410	-0.325118	-0.443849	-0.088534	0.114533	-0.047003	0.172270
	MG	NA	BST							
	0.113099	0.186975	0.167135							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.360375	-0.196264	-0.104581	0.564212	0.176559	-0.494216	0.350515	0.469976	-0.524430	-0.109531
	MG	NA	BST							
	-0.006804	-0.226655	-0.199132							

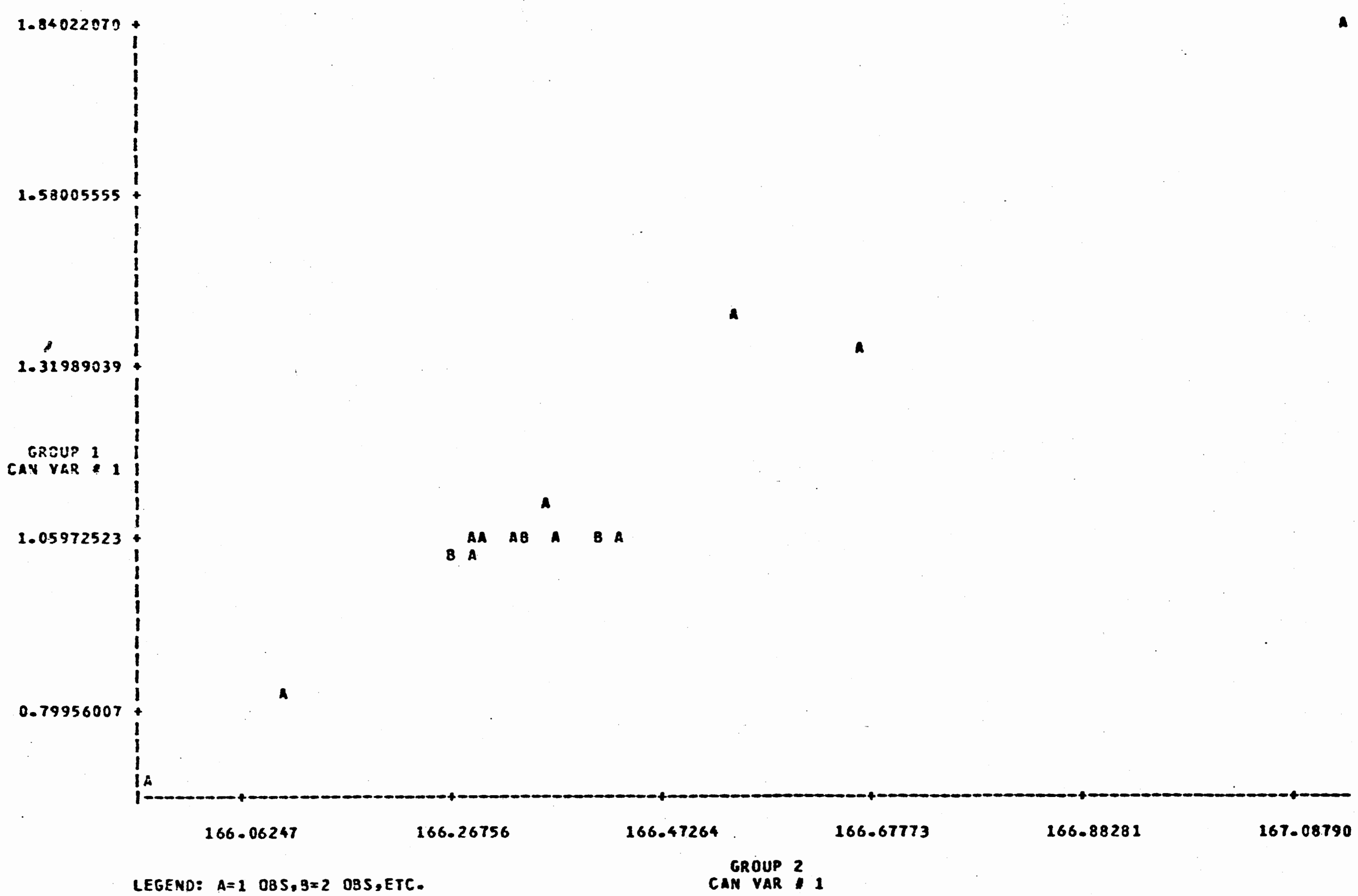


Figure 4.5. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the P. M. Zone, Area One.

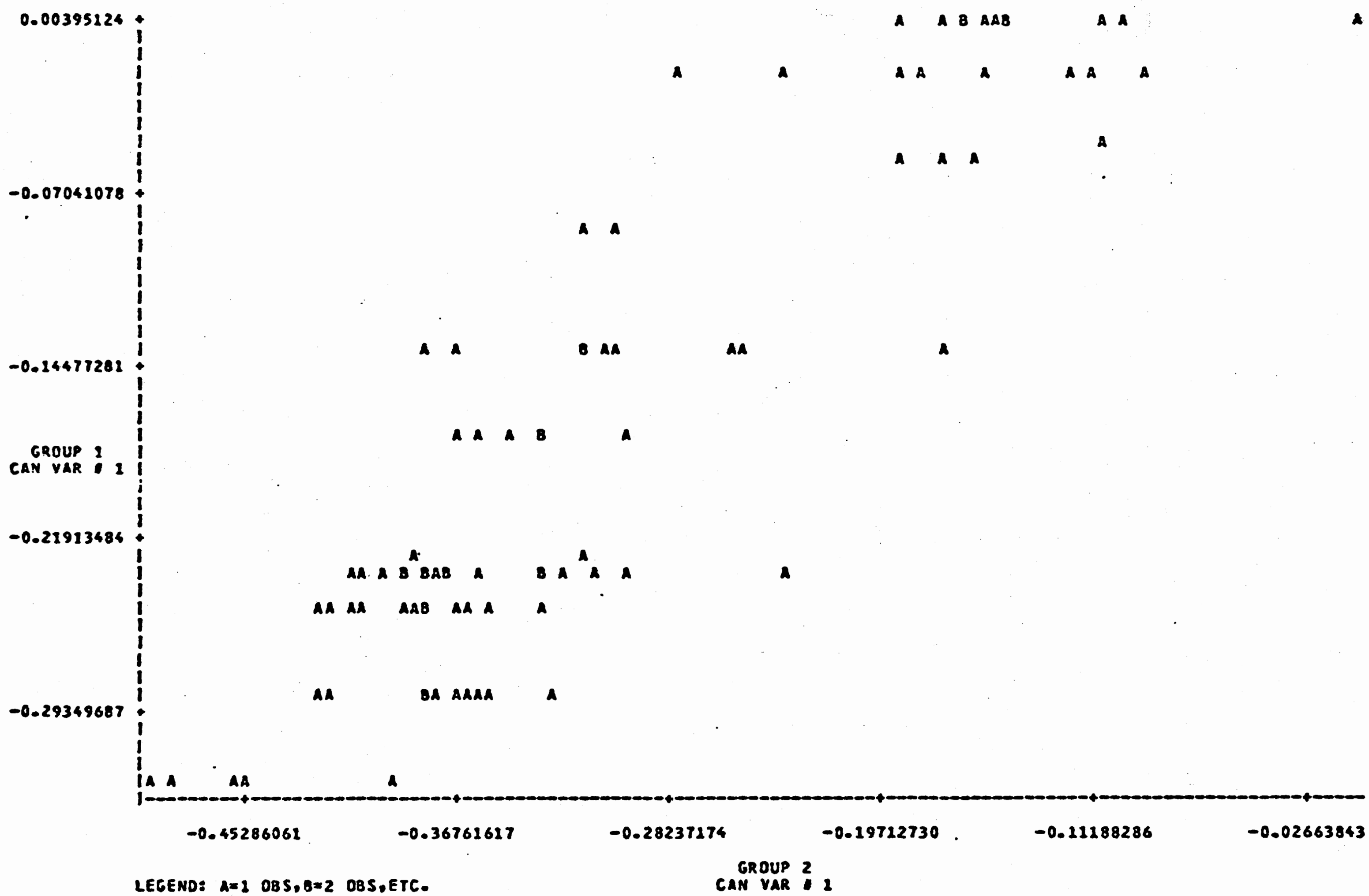


Figure 4.6. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

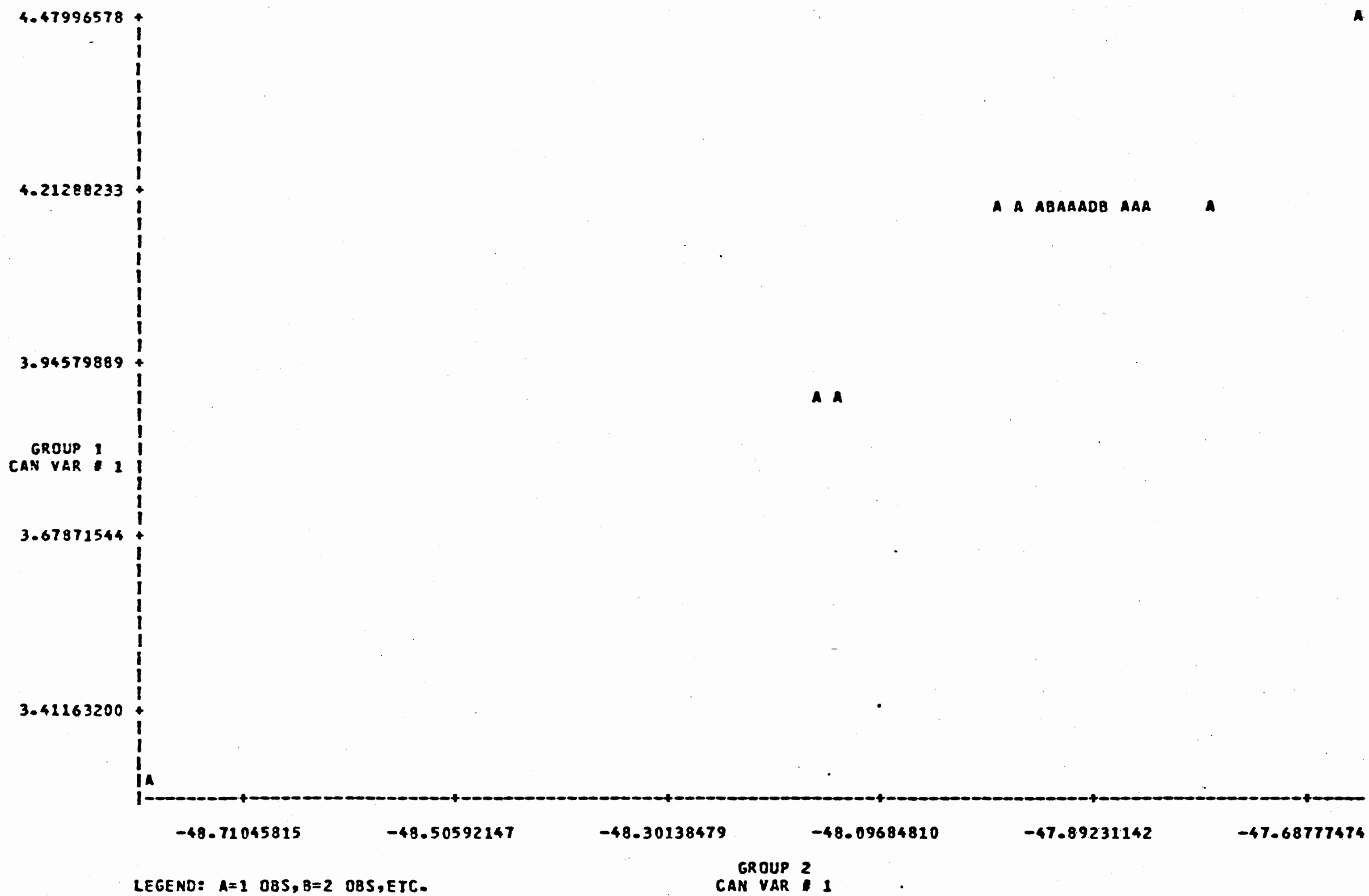


Figure 4.7. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Surface Zone, Area Two.

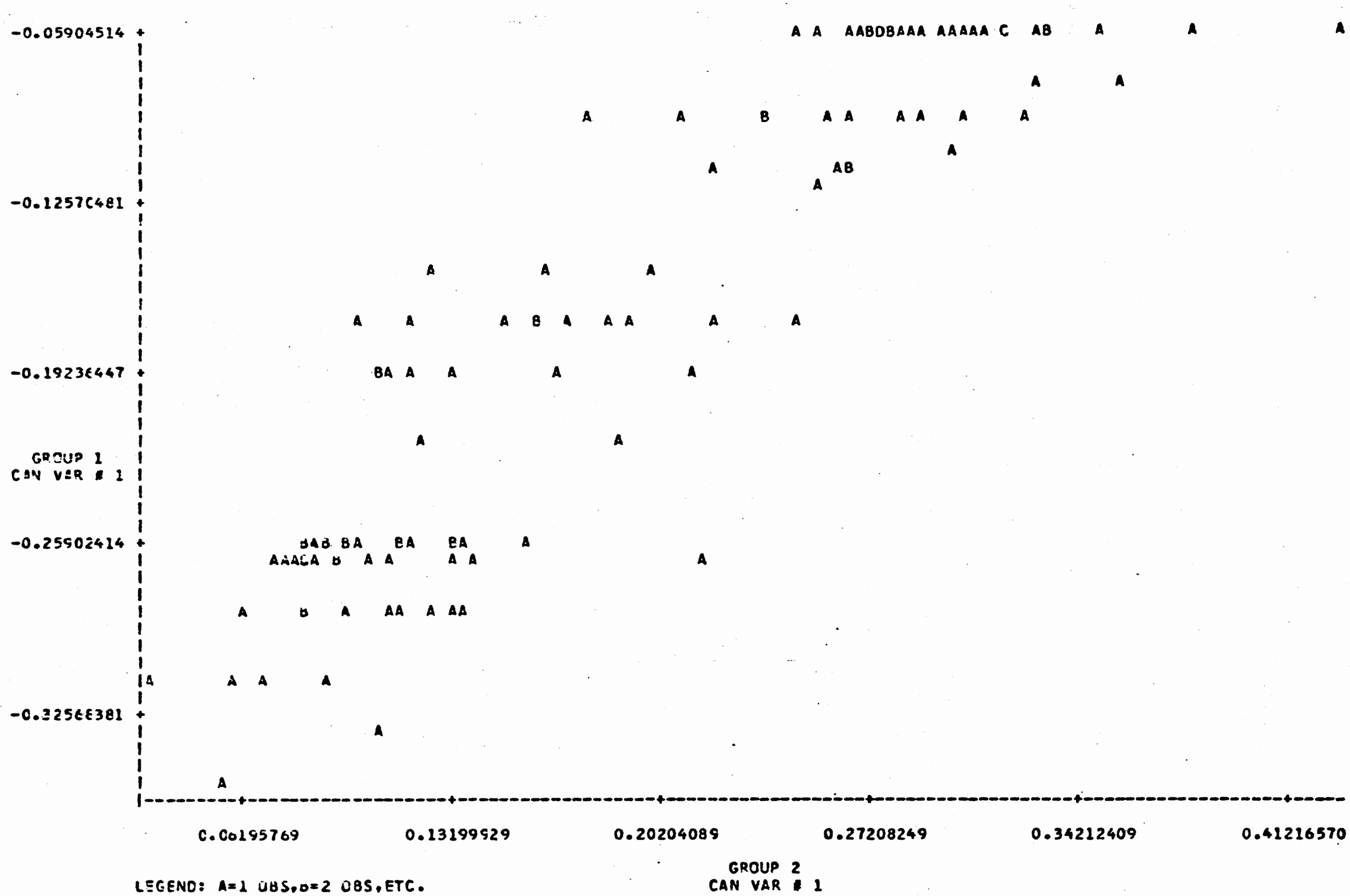


Figure 4.8. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area Two.

2-3 value, and chroma of 1 is highly (Table 4.7) associated with moderate amount of hydrogen (.6), low amount of fine sand, and a very high organic content. It was also interpreted as 2.5YR hue, 2-3 value, and 6-7 chroma being highly associated with moderately low hydrogen contents, very low organic contents, and a high content of fine sand.

From the above interpretations, it was observed that if all genetic horizons were treated together, organic matter would show very high associations with the color variables. The correlation was positive with the hue and negative with the chroma and the value. Moderate correlation was exhibited with moderate hydrogen content. No significant correlations were found between the color variables and the chemical properties for the surface zone in both areas. Furthermore, hydrogen seemed to be highly correlated with the color variables in area two, but not in area one (surface zones in both areas).

This pattern could possibly be tied with soil development as follows: Area two is composed of soils that exhibit an advanced stage of leaching and are highly developed. Hydrogen is highly correlated with the leaching intensity. From this, the extent of soil leaching, as indicated by the content of the exchangeable hydrogen content, can be associated with the color variables.

The absence of the significant associations between the color variables and the organic matter contents, in the surface zones of both areas, could probably be due to the existence of higher correlations between the color variables and certain types of organic compounds, especially those highly resistant to microbial activities. As it has been known for some time, the proportion of the highly resistant organic compounds in the subsoil exceed by many fold its proportion in the

TABLE 4.7

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE ZONE, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.17044363	-0.30495700	0.89874880	168.03002	39	0.0001
2	0.05055253	-2.91900509	0.52685981	40.23596	24	0.0202
3	0.94130998	1.17208534	0.41995394	15.03681	11	0.1801

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.926332	-0.575908	-0.946500
VAR # 2	0.020189	-0.528588	0.287683
VAR # 3	0.376168	0.623639	0.146210

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	0.606314	0.442621	0.354356	0.182589	-0.493845	0.910730	-0.554653	0.172606	0.165226	0.282839
	MG	NA	BST							
	0.325270	-0.236475	-0.322154							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.125481	-0.046684	0.407634	0.047680	-0.076276	-0.124690	-0.273046	0.404015	-0.326158	-0.275413
	MG	NA	BST							
	0.275036	0.257545	0.181761							

surface zones. No association was found to exist between organic content and color variables in this zone. Instead, moderate association was found between hue, clay, and cation exchange capacity. However, by definition, the Cr horizon is the zone of minimum organic matter accumulation in the profile.

Consistence, Area One

Canonical correlation for the first canonical variate (all samples) was .81 (Table 4.8). This was interpreted as follows: moderated dry code (.65), very high moist code (.96), very high sticky code (.90) is highly associated with moderately high CEC code (.72), moderate to low fine sand code (-.72), low, very fine sand code (-.63), high clay content (.82), and moderately low silt (-.62) (Figure 4.9). The second canonical variate was not significant. The interpretation of the above variate was as follows: hard, very firm to extremely firm with sticky and slightly plastic soil is highly associated with moderate CEC, high clay content, very low fine sand, low very fine sand, and low silt.

Canonical correlation for the first variables for the surface zone (area one) was .99 (Table 4.9). This indicated that low, dry code (.59) and moderate to high sticky soil is highly associated with low hydrogen content (.52) (Figures 4.10 and 4.11). In other words, loose to slightly hard and slightly sticky soil is highly associated with low hydrogen content. The second canonical variate was not significant.

Canonical correlation for the first variate (subsurface zone, area one) was .87 (Table 4.10). This was interpreted as moderate, dry code (.69), high moist code (.86), and low sticky code (.55) is highly associated with low, fine sand code (-.85), moderate to high clay content

TABLE 4.8

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.32287118	-33.53024981	0.81013046	122.98270	52	0.0001
2	0.11256052	30.74605331	0.49039072	46.08532	36	0.1209
3	0.23769590	154.84208762	0.47806673	26.28009	22	0.2395
4	0.07979305	43.25018137	0.31645558	7.59749	10	0.6693

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.659750	0.959422	0.898781	0.659956
VAR # 2	-0.309438	0.031057	0.003283	0.564519
VAR # 3	0.592406	-0.108385	0.167930	0.380475
VAR # 4	-0.343483	-0.258451	0.404947	0.317830

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	0.083615	0.157411	0.717947	0.373883	-0.724653	0.030344	-0.639950	0.823950	0.624222	0.479162
	MG	NA	BST							
	0.643146	0.463247	0.271668							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.573017	0.308558	-0.089304	-0.146945	-0.074923	0.687986	-0.254900	-0.247378	0.558647	-0.234230
	MG	NA	BST							
	-0.415435	-0.538250	-0.530657							

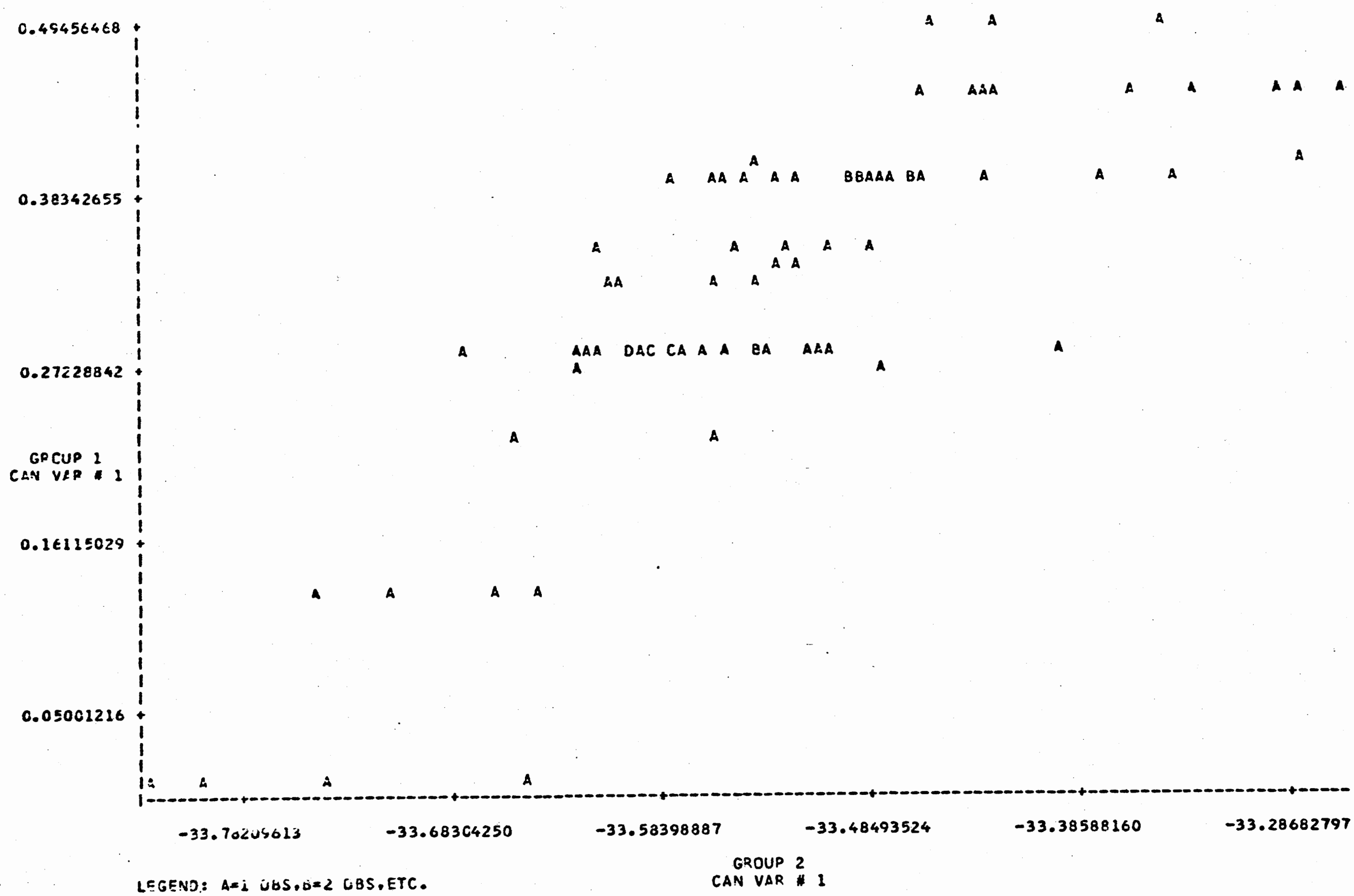


Figure 4.9. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area One.

TABLE 4.9

CANONICAL CORRELATION ANALYSIS FOR THE SURFACE ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.17086923	2525.99629289	0.99991390	156.14282	52	0.0001
2	-0.11789499	-196.60443172	0.99352590	78.14044	36	0.0001
3	3.95329796	-695.15647462	0.97305855	38.99007	22	0.0142
4	-1.26507961	752.20161547	0.86766439	12.57953	10	0.2475

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	-0.589986	0.461286	0.737017	0.323632
VAR # 2	0.658267	0.750892	0.265343	-0.452769
VAR # 3	0.450143	0.370761	0.424555	0.796769
VAR # 4	0.126386	-0.293110	0.454040	0.235418

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.524338	0.357453	0.089933	0.309318	-0.441287	-0.003089	-0.379719	0.444533	0.267122	-0.234902
	MG	NA	BST							
	0.146576	-0.212414	-0.192654							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.098409	0.003658	0.042236	-0.090974	-0.115920	-0.222294	-0.297033	0.390018	-0.151268	-0.042090
	MG	NA	BST							
	0.050710	-0.160085	-0.269194							

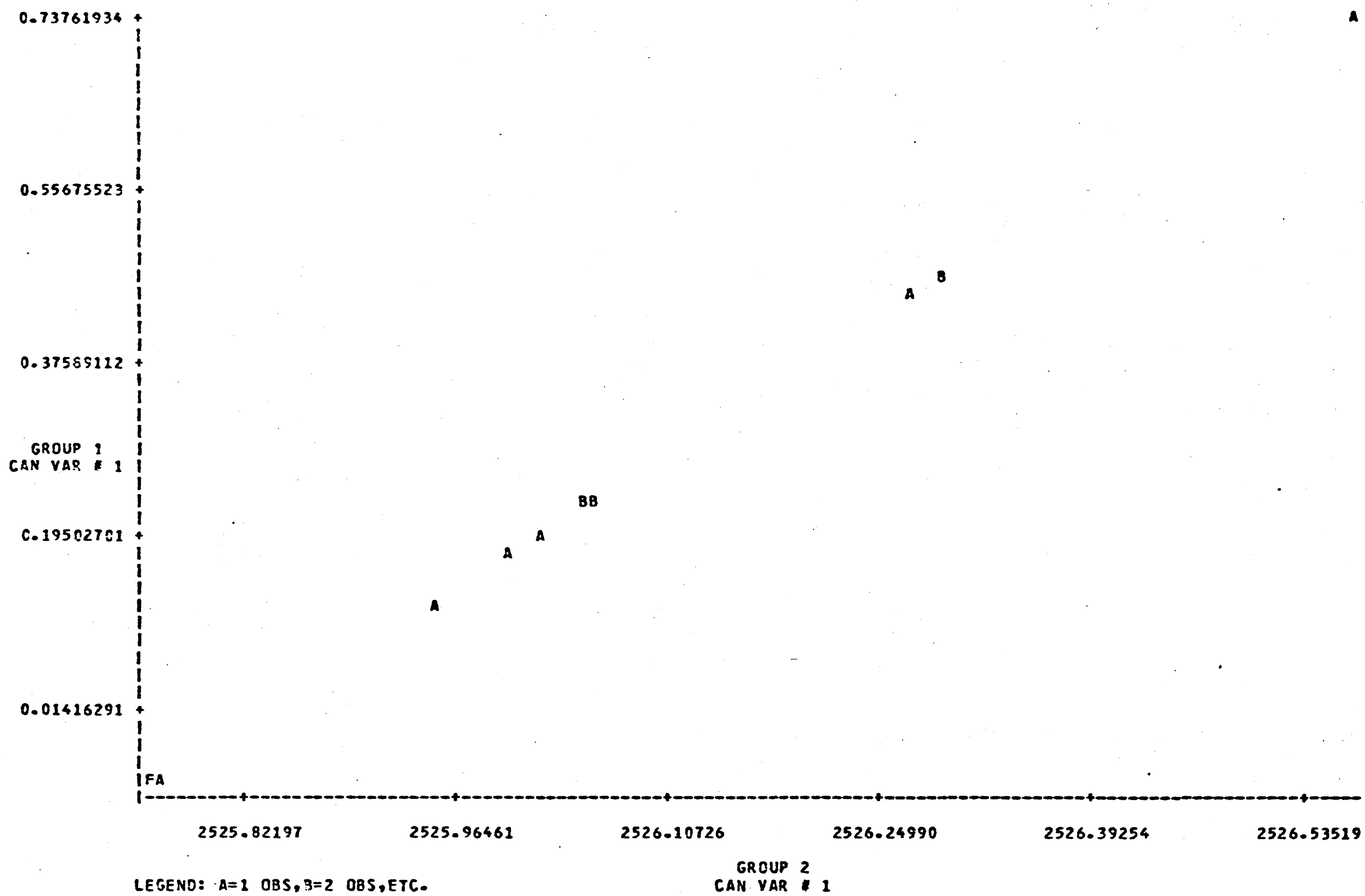


Figure 4.10. Plot of the Compounds in the Plan of the First Canonical Variables for the Surface Zone, Area One.

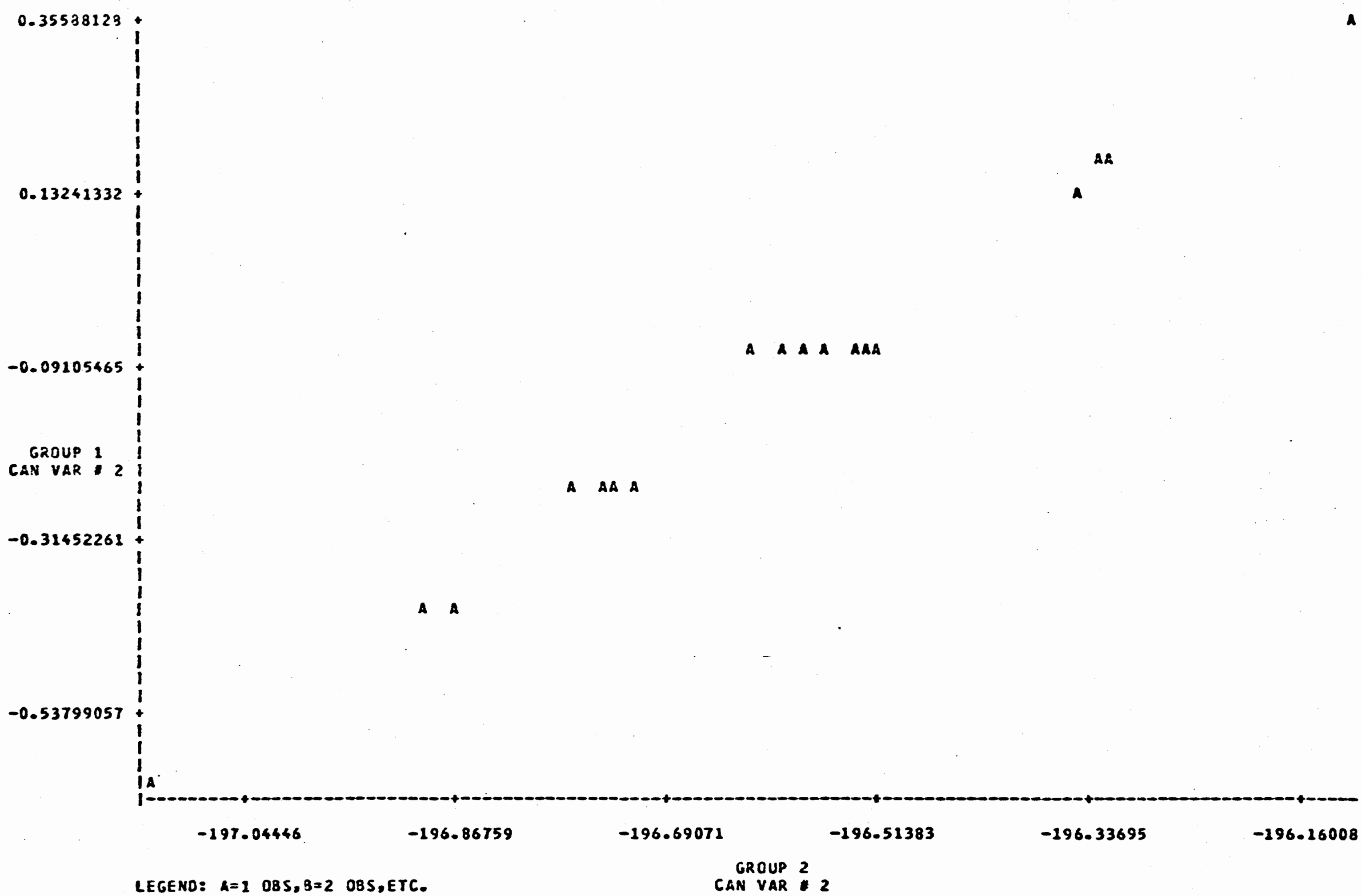


Figure 4.11. Plot of the Compounds in the Plan of the Second Pair of Canonical Variables for the Surface Zone, Area One.

TABLE 4.10

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.33453619	-39.96801807	0.87036124	105.51912	52	0.0001
2	1.26494010	307.71170551	0.79407600	55.92861	36	0.0182
3	-0.69645559	75.01131247	0.54498854	21.07708	22	0.5162
4	0.13051545	-185.15320635	0.47014100	8.74251	10	0.5576

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.695316	0.864695	0.552683	-0.086612
VAR # 2	0.230799	0.441510	0.351965	0.979152
VAR # 3	-0.675923	0.239302	-0.205375	-0.162470
VAR # 4	0.079974	0.010247	0.726969	0.085811

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.406440	0.145592	0.779072	0.291545	-0.852877	-0.165714	-0.146677	0.789884	0.547197	0.657111
	MG	NA	BST							
	0.800680	0.525643	0.348464							
CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	-0.029615	-0.179221	0.412119	0.172034	-0.132261	0.012347	-0.502828	0.326816	0.132825	0.185216
	MG	NA	BST							
	0.147030	0.144977	-0.038541							

(.79), low silt content (.54), moderate calcium code (.65), high magnesium content (.80), and low sodium content (.52). Thus, hard, very firm, slightly sticky is associated with moderate to high CEC values, low fine sand, low silt, moderate to high clay calcium content, but high magnesium and low sodium content (Figure 4.12).

The first canonical correlation for the Cr zone (Area one) was .96 (Table 4.11). This indicated that high moist (.78), and moderate stickiness (.65) is highly associated with low organic matter content (-.66), and moderate silt content (Figure 4.13) or friable to firm and slightly stick soil is highly associated with low organic matter and moderate silt content.

Consistence, Area Two

Canonical correlation for the first variate (all samples) was .91 (prob > CHI-SQ = .0001) (Table 4.12). This can be interpreted as very high dry value (.97), very high moist code (.88), moderate to high stickiness code (.78) and moderate to high plasticity code (.77) is highly associated with high CEC (.86), low $CaCO_3$, low clay; and moderately low organic matter content (-.77). In terms of the original data, extremely hard, very firm to extremely firm, slightly sticky and slightly plastic to plastic soil is highly associated with high CEC, low calcium carbonate, low clay, and moderately low organic contents (Figure 4.14). The second canonical variate was not statistically significant.

Soil properties of the first canonical variate for the surface zone (Area two) did not show any important correlation. Second canonical variate indicated that very high, dry code (.90), very high moist

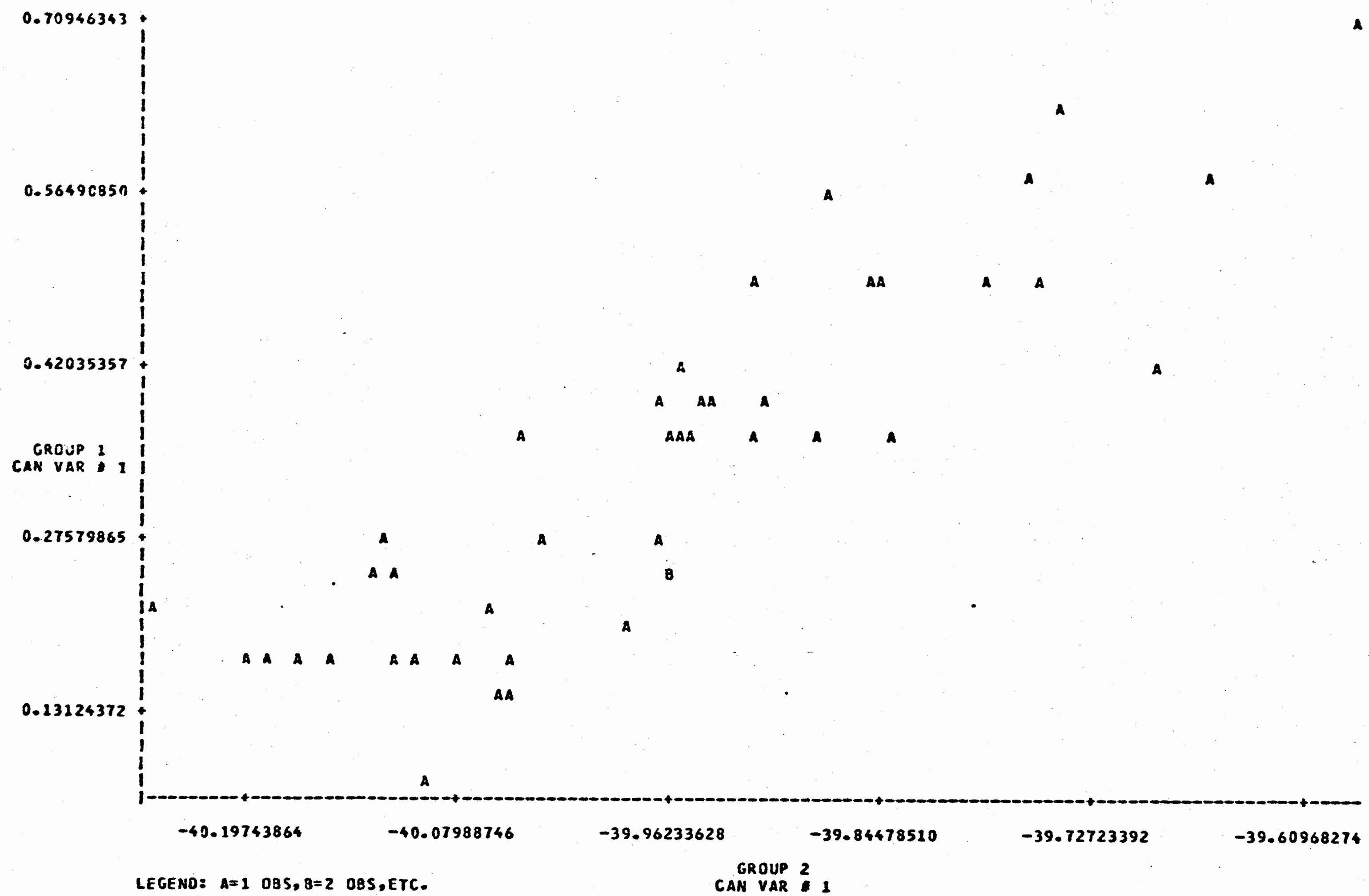


Figure 4.12. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area One.

TABLE 4.11

CANONICAL CORRELATION ANALYSIS FOR THE P. M. ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.12250458	11.34040473	0.97542318	60.37861	52	0.1987
2	-0.05097652	493.77207396	0.88989042	33.15209	36	0.6050
3	0.43335204	140.62598182	0.85395783	19.02425	22	0.6443
4	-0.00739906	-21.80867612	0.74426144	7.26542	10	0.7014

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.000859	0.781916	0.620328	0.497682
VAR # 2	-0.552482	-0.533772	-0.036723	0.421509
VAR # 3	0.599024	0.263242	0.764395	0.757840
VAR # 4	0.579597	0.185471	-0.171885	-0.017943

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.330839	0.009821	-0.256878	0.435708	-0.251683	-0.664950	-0.253756	0.143038	0.628094	0.085563
	MG	NA	BST							
	0.071028	0.345504	0.400883							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	-0.064084	0.155475	-0.125584	-0.122781	-0.096557	0.168411	0.179486	-0.252411	0.131492	0.076900
	MG	NA	BST							
	-0.264298	-0.377486	-0.296299							

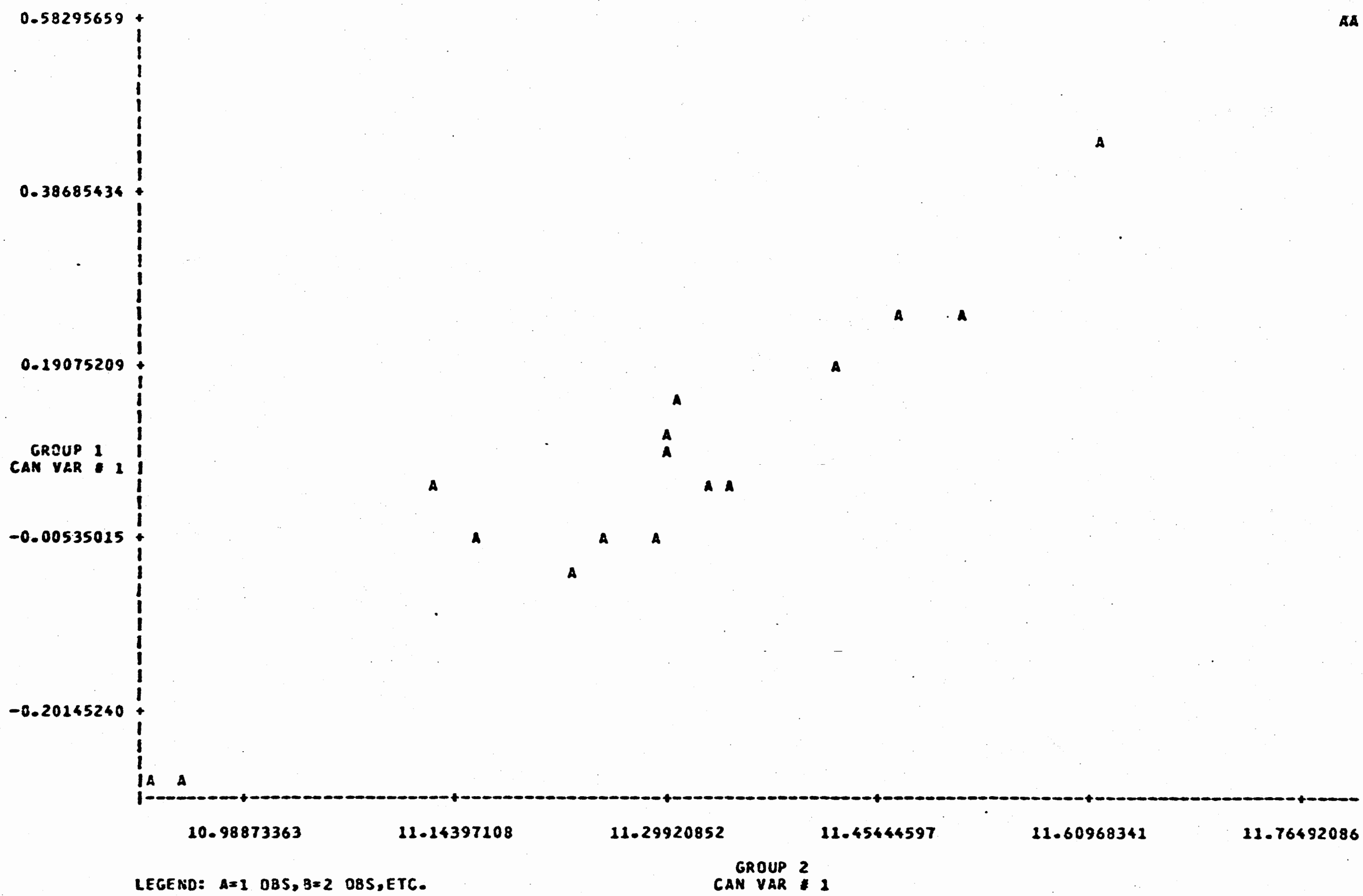


Figure 4.13. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the P. M. Zone, Area One.

TABLE 4.12

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.57381131	0.36468585	0.90652159	250.02862	52	0.0001
2	0.09057556	0.07246795	0.62140511	70.65520	36	0.0005
3	0.64314353	3.51303893	0.35121097	19.90368	22	0.5895
4	0.27373275	-2.27872545	0.24080259	6.21244	10	0.7982

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.973048	0.884981	0.783727	0.779660
VAR # 2	-0.172013	0.462963	-0.068860	-0.135985
VAR # 3	-0.152492	-0.040636	0.404641	0.534315
VAR # 4	-0.018332	-0.028668	-0.466151	0.296892

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.488264	-0.017904	0.857866	0.550325	-0.137018	-0.743590	-0.472034	0.543134	-0.398289	0.617089
	MG	NA	BST							
	0.837871	0.579102	0.503225							
CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.270607	-0.330878	0.185211	0.206793	-0.693237	0.209342	-0.307876	0.376884	-0.014066	0.423445
	MG	NA	BST							
	0.161883	-0.177747	-0.337144							

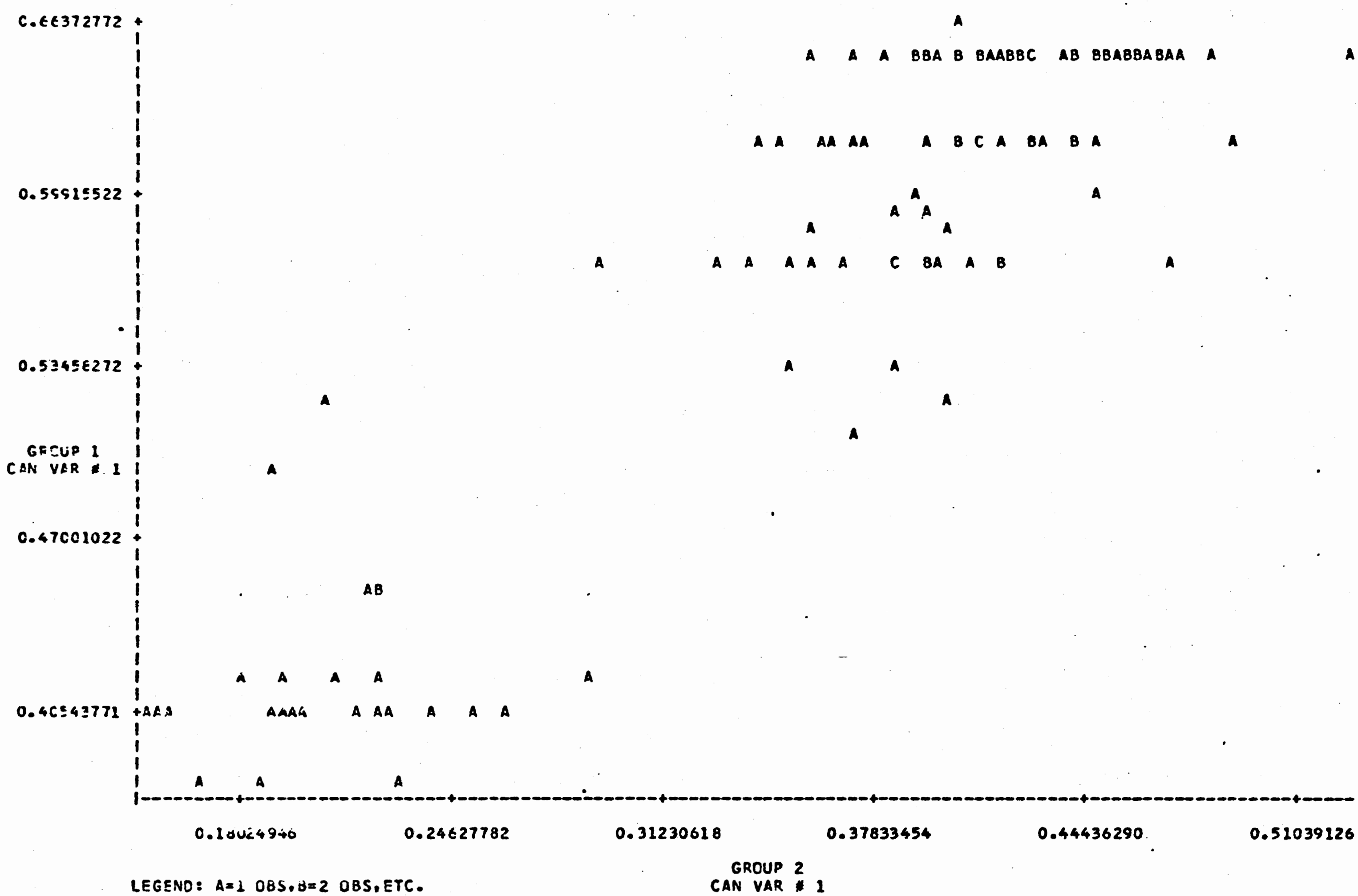


Figure 4.14. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

code (.95) and moderate plasticity code (.66) is highly associated (.99) with high CEC values (.79), high magnesium, or moderate sodium content (.69) (Table 4.13).

In referring to the original data, this indicated that very hard to extremely hard, extremely firm, and slightly plastic soil is highly associated with high CEC values, high magnesium, and moderate sodium content. Moderate to high association was indicated between consistence and chemical properties. First canonical correlation for the subsurface was .77. This was interpreted as moderate to high association exists between very hard (.83), friable to firm (.73), and slightly sticky (.71), and moderate CEC values; low, very fine sand content (.52), or calcium, sodium, and moderate magnesium content (Table 4.14, Figure 4.15).

It appears from the above interpretations that close association exists between consistence and clay content. Closer association was also exhibited with cation exchange capacity, which is a good criterion to indicate the type of clay mineral present. Moreover, the associations indicated between the sand fractions and soil consistence, which were negative in nature, support our knowledge about the relationships between these two properties. This confirmation might be considered as an indication of the validity of this mathematical approach of quantifying the relationships between soil morphological properties. Chemical properties like hydrogen, calcium, magnesium, and sodium also exhibited high association with the consistence. However, the degree of the associations obtained depended on the zone under consideration.

TABLE 4.13

CANONICAL CORRELATION ANALYSIS FOR THE SURFACE ZONE, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	2.64783006	-49.53941552	0.99997864	214.26188	52	0.0001
2	3.11970591	10.56464823	0.99336401	83.47273	36	0.0001
3	1.50785627	29.93716113	0.84483439	27.24222	22	0.2018
4	-1.20209745	10.70204502	0.75518629	10.98088	10	0.3588

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	-0.410873	0.038793	0.088222	-0.191636
VAR # 2	0.900581	0.997817	0.360956	0.669724
VAR # 3	-0.134179	-0.049744	0.461869	0.679934
VAR # 4	0.046185	0.019535	0.805360	-0.228986

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.111521	-0.467745	-0.157774	0.125871	-0.403353	-0.349001	-0.095772	-0.041844	0.112146	0.019891
	MG	NA	BST							
	-0.059543	0.169152	0.270885							

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	0.122483	0.423750	0.793801	0.084546	-0.408911	0.037319	-0.443035	0.190855	-0.010569	0.479927
	MG	NA	BST							
	0.829835	0.695354	0.260193							

TABLE 4.14

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE ZONE, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.50840436	4.21992803	0.77319352	133.23438	52	0.0001
2	0.44081475	3.79655887	0.59145484	63.09693	36	0.0035
3	0.33694574	3.96325511	0.50540044	29.94810	22	0.1194
4	0.83988234	-0.62046027	0.29951090	7.23712	10	0.7042

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.834790	0.735195	0.719398	0.487084
VAR # 2	0.070008	-0.648628	0.402153	0.293861
VAR # 3	-0.506573	0.192486	0.551517	0.143200
VAR # 4	-0.204022	-0.041452	-0.128720	0.809870

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 1	-0.211721	0.079010	0.699615	0.408262	-0.470545	-0.449994	-0.524381	0.283171	0.093698	0.505609
	MG	NA	BST							
	0.676438	0.511020	0.439203							
CANONICAL	H	K	CEC	CACO3	FS	OM	VFS	CLAY	SILT	CA
VAR # 2	-0.188116	-0.022817	-0.203617	-0.372268	0.368130	-0.344811	0.471103	-0.335289	0.085968	-0.560752
	MG	NA	BST							
	-0.286957	0.266001	0.385356							

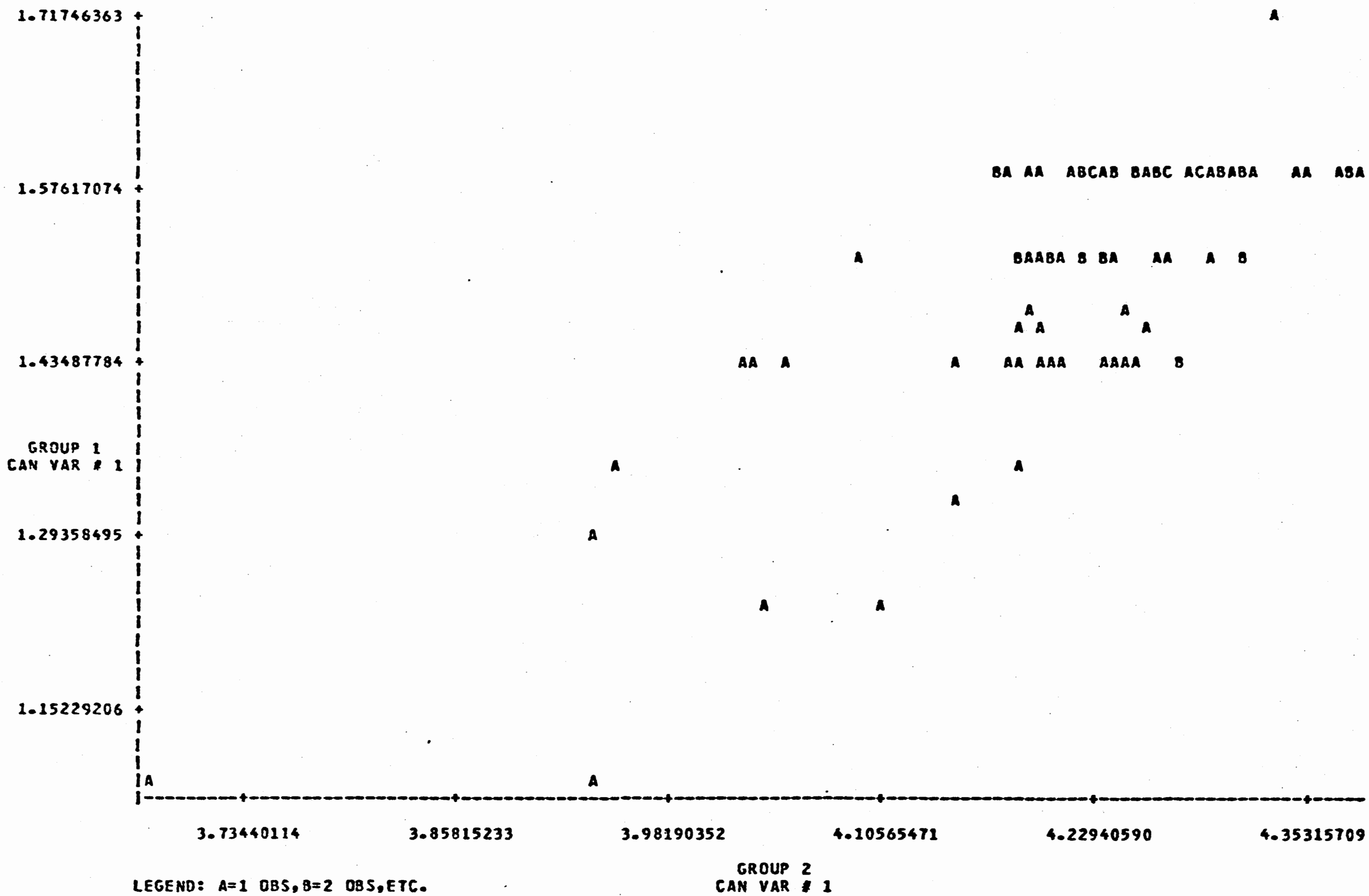


Figure 4.15. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area Two.

Pores, Area Two

Canonical correlation for first variate (all samples) was .85 (Table 4.15, Figure 4.16). This was interpreted as follows: high frequency of random pores (.97), and very low frequency of oblique pores is highly associated with very low CEC, moderate pH (.67) values, moderate organic content (.70), low clay content (-.52), or low calcium content (-.61). The second canonical variate was considered insignificant.

Structure, Area Two

First canonical variate (all samples) had .9 canonical correlation (Table 4.16). It indicated that very high grade code (.9), very low type code (-.95) is highly associated with moderately high CEC values, very low organic content (-.81), low clay content, moderate magnesium content (.70), and low sodium content (Figure 4.17). In reference to the original variables, very coarse, prismatic is highly associated with moderately high CEC, low organic matter, or magnesium, low clay, and sodium contents.

The second canonical variate had a canonical correlation of .59. It indicated that strong structure (.77) has a low association with low content of fine sand (-.56), or weak structure is associated with high fine sand. This conclusion is consistent with previous knowledge about the behavior of the sand fractions and structure.

Coating, Area Two

First canonical variate (all samples) had .88 canonical correlation (Table 4.17). This indicated that high frequency of clay coating

TABLE 4.15

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.01007577	1.83584553	0.85472764	186.86069	56	0.0001
2	0.00307529	-0.09645464	0.50191883	51.13006	39	0.0923
3	0.49322313	-1.18876014	0.36363885	21.08932	24	0.6339
4	0.15045024	3.87012917	0.24505223	6.40968	11	0.8454

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HORPOR	VERPOR	RANPOR	OBLPOR
VAR # 1	-0.301593	-0.576232	0.971252	-0.862329
VAR # 2	0.209366	0.793949	-0.036302	-0.421314
VAR # 3	-0.133122	0.214019	0.176862	0.214396
VAR # 4	0.920590	-0.426956	-0.155151	0.181434

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 1	0.441148	0.066614	-0.735762	-0.390684	-0.672993	0.073634	0.703734	0.196211	-0.529311	0.492964
	CA	MG	NA	BST						
	-0.449870	-0.618309	-0.271866	-0.200483						

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 2	0.174507	0.434985	0.013731	0.014038	-0.023647	0.252654	0.505111	-0.050337	0.037753	-0.152990
	CA	MG	NA	BST						
	-0.164200	-0.048079	-0.219619	-0.281899						

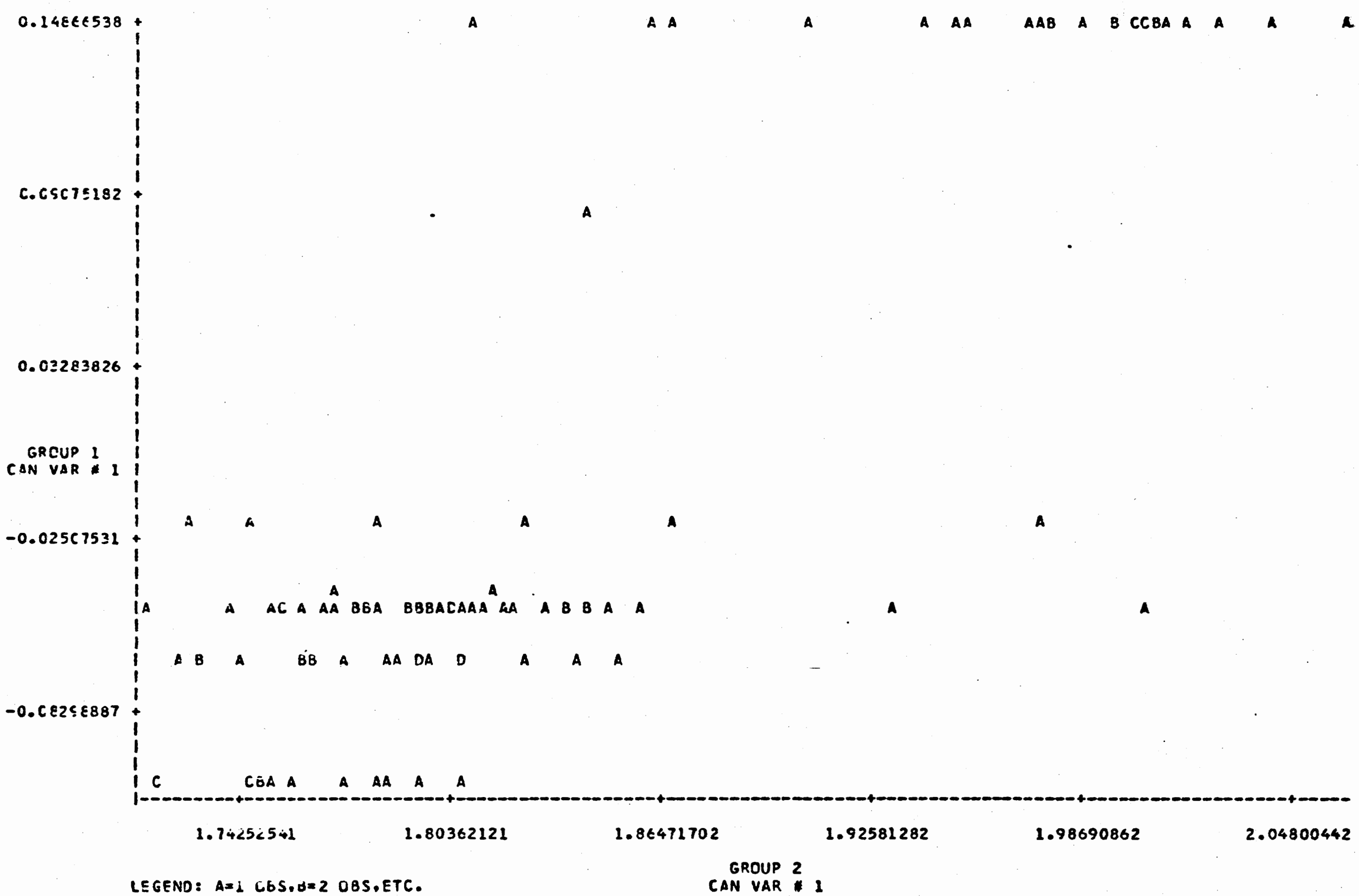


Figure 4.16. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

TABLE 4.16

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.26172924	0.19732326	0.90258196	235.07362	42	0.0001
2	-0.16806106	0.29474405	0.58846454	59.77829	26	0.0002
3	1.31837816	-2.87485345	0.37287118	15.56870	12	0.2112

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.901896	0.484243	-0.949170
VAR # 2	-0.300155	0.769496	-0.104841
VAR # 3	0.310631	0.415395	0.296790

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 1	-0.452052	-0.052650	0.751809	0.491464	0.662131	0.051997	-0.807696	-0.332072	0.506269	-0.474227
	CA	MG	NA	BST						
	0.489965	0.703055	0.544231	0.495089						
CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 2	0.052875	-0.422998	0.226109	0.207958	0.189626	-0.569216	0.053708	-0.401779	-0.046586	0.381553
	CA	MG	NA	BST						
	0.247157	0.081987	0.238938	0.185548						

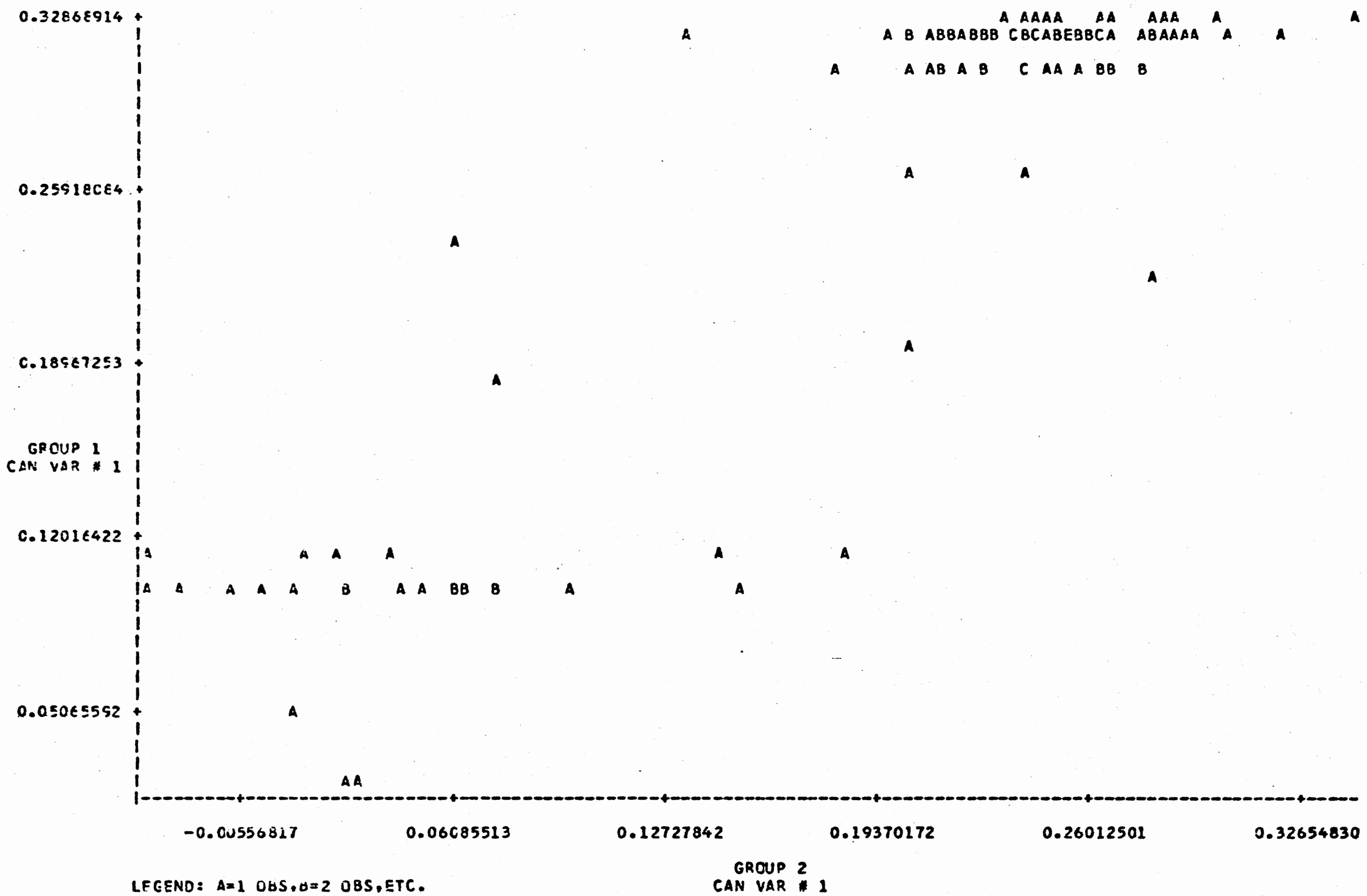


Figure 4.17. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

TABLE 4.17

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.18217646	0.22291230	0.88036328	249.26941	42	0.0001
2	-0.13334809	1.61325448	0.71666051	94.11904	26	0.0001
3	0.21129409	3.25599122	0.41022221	19.16326	12	0.0843

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAYCOAT	OXICOAT	OMCOAT
VAR # 1	0.869004	0.906949	0.031521
VAR # 2	-0.495486	0.419318	-0.348647
VAR # 3	-0.055578	0.040201	0.936724

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 1	-0.635824	-0.025562	0.562801	0.272712	0.712567	0.245923	-0.889648	-0.098106	0.325230	-0.427985
	CA	MG	NA	BST						
	0.329343	0.543724	0.454954	0.462753						

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 2	-0.115980	-0.224936	-0.626172	-0.476224	-0.251324	0.319272	-0.305983	0.493890	-0.588863	0.381104
	CA	MG	NA	BST						
	-0.558754	-0.626424	-0.175841	-0.045117						

(.80), and very high frequency of oxide coating (.91) is highly associated with low hydrogen content (-.63) and low CEC (.56) values, moderate pH (.71), very low organic matter, and low magnesium content. The high, but negative association between clay coating and organic matter content was probably due to the fact that clay coatings occurred mostly in the subsoil where organic matter content was low. This might suggest the weakness of the organic matter translocation in this area (Figure 4.18, and 4.19). The second canonical variate was not significant.

Mottling, Area Two

First canonical variate (all samples) was .76. It was interpreted as follows: very many (.97), medium to coarse (.9), distinct (.96) mottles is moderate to highly associated with moderate hydrogen content (-.6), low pH (.58), and very low content of organic matter (.93). This suggested that the clarity of observing the mottles increases with decreasing organic matter content, especially the contrast between the mottles and the soil matrix. The opposite is true when the organic matter increases. The highly negative association with the abundance and the size suggested that the mottlings are caused mostly by oxide coatings, not by the organic matter. This conclusion also supports the conclusion stated earlier that the organic matter translocation in this area is weak. This is true since clay coating, mottling, organic coating, and oxide coatings occur maximally in the subsoil (Table 4.18, Figure 4.20).

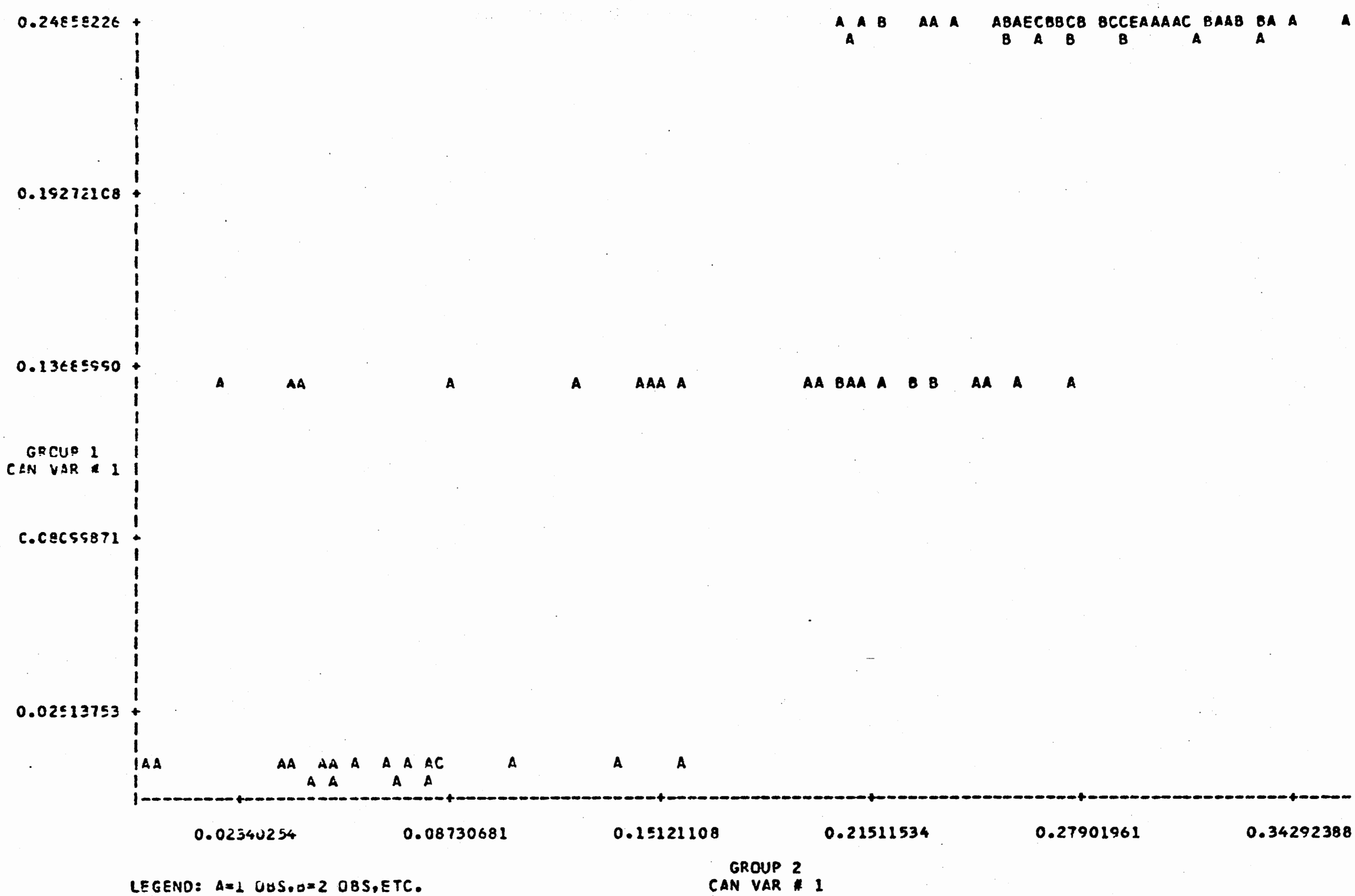


Figure 4.18. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

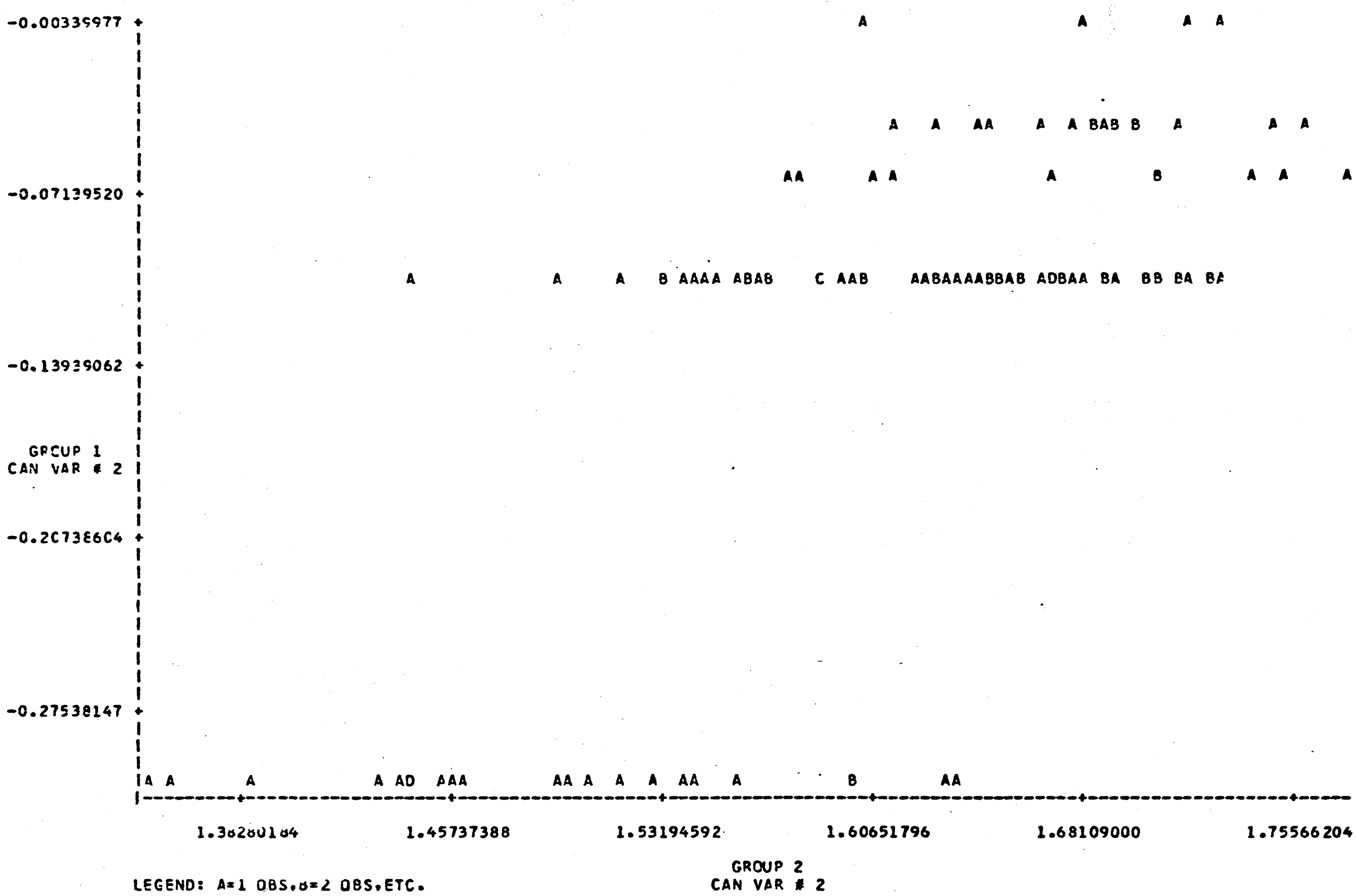


Figure 4.19. Plot of the Compounds in the Plan of the Second Pair of Canonical Variables for All Samples, Area Two.

TABLE 4.18

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.10820528	0.39223249	0.75565512	114.56625	42	0.0001
2	-0.00386908	-1.19928855	0.38198958	26.54766	26	0.4333
3	-0.00403757	2.55823697	0.30485102	10.14418	12	0.6042

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	MABAND	MSIZE	MCONT
VAR # 1	0.979311	0.908581	0.957831
VAR # 2	-0.083151	0.303193	0.181921
VAR # 3	-0.184486	-0.287322	0.222407

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 1	-0.609467	-0.055969	0.477670	0.204711	0.587530	0.173490	-0.930705	0.008724	0.174590	-0.256510
	CA	MG	NA	BST						
	0.405758	0.471171	0.393989	0.426879						

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 2	0.106840	0.580338	-0.301493	-0.050390	-0.145085	0.409924	0.080756	-0.119525	-0.108796	-0.039362
	CA	MG	NA	BST						
	0.005585	-0.230566	0.078789	0.247933						

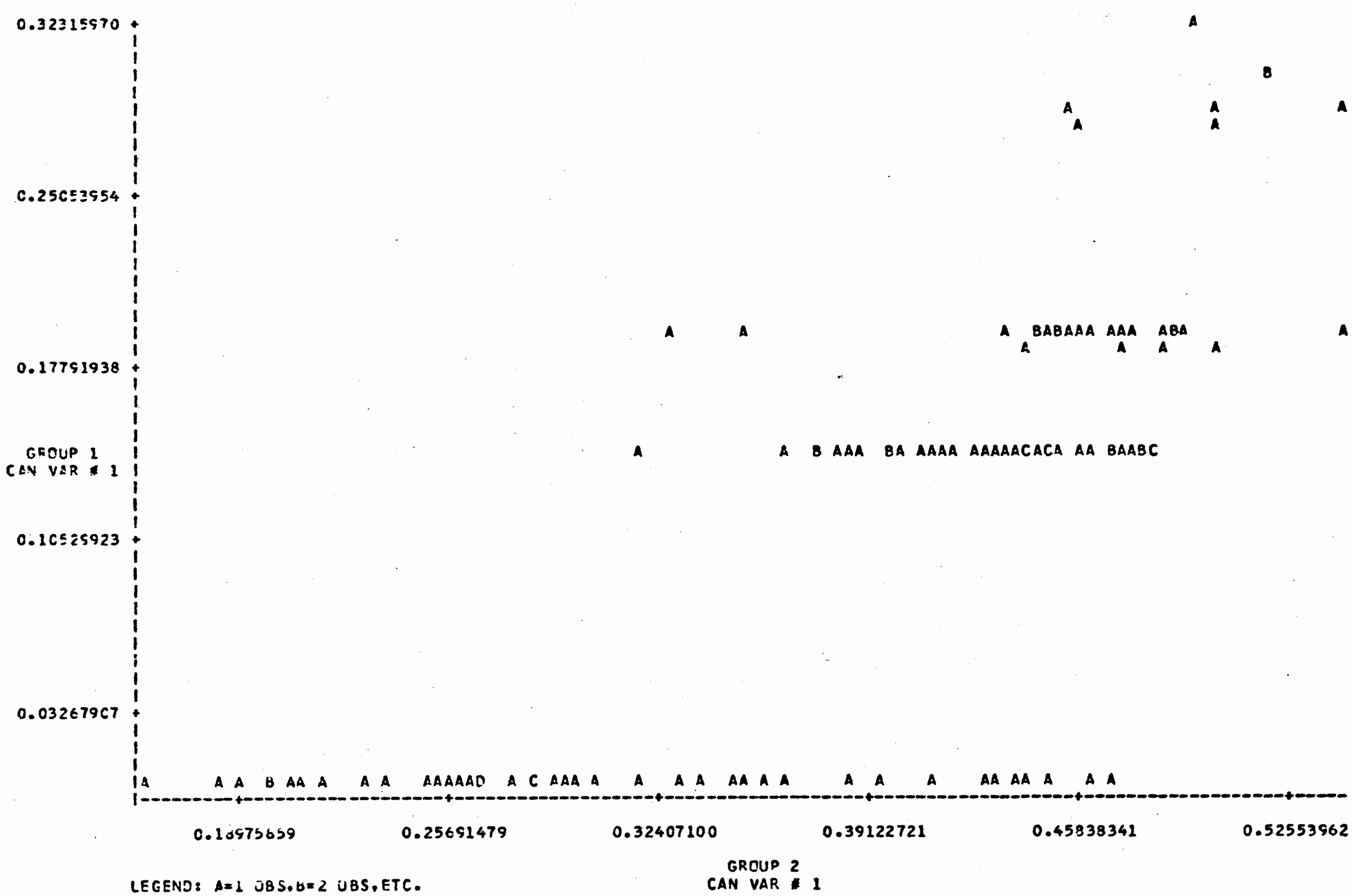


Figure 4.20. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

Concretions, Area Two

First canonical variate had canonical correlation of .74 (all samples) (Table 4.19). This was interpreted as follows: high concretions quantity (.90), large size (.92), with high frequency of white concretions is moderately associated with a low content of hydrogen (.77), calcium carbonate (.58), organic matter (.55), and calcium (.54), magnesium (.52), sodium and base saturation (.58) (Figure 4.21). Referring to the original data description, this can be stated as follows: many coarse, white concretions are moderately associated, but negatively with hydrogen, positively with low content of organic matter, calcium, magnesium, calcium carbonate, and base saturation. On the other hand, this also can be restated as follows: few, fine, white concretions are moderately associated, but negatively with hydrogen and positively with high content of calcium carbonate, calcium, magnesium, sodium, and base saturation. Table 4.20 shows the coding system.

Selection of Diagnostic Criterion

Previously, it was shown that

$$\underset{\sim}{U}_1 = \underset{\sim}{a}_1 X_1, \quad \underset{\sim}{V}_1 = \underset{\sim}{b}_1 X_2$$

$$\vdots$$

$$\underset{\sim}{U}_p = \underset{\sim}{a}_p X_1, \quad \underset{\sim}{V}_p = \underset{\sim}{b}_p X_2$$

where $\underset{\sim}{U}_1, \underset{\sim}{V}_1$ is a linear combination of X_1, which represents a group of measurements taken on one sample with p dimension, and X_2 is another group of measurements taken on the same sample with q dimensions, $p > q$.

TABLE 4.19

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.07203385	-0.91214861	0.74114464	151.47217	56	0.0001
2	-0.01647919	7.35857602	0.52048910	68.98856	39	0.0022
3	-0.31910623	-0.55040615	0.44990319	36.28706	24	0.0514
4	0.36587049	-0.95673499	0.34205944	12.87906	11	0.3009

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CONCUNT	CONSIZ	BCONCR	WCONCR
VAR # 1	0.904671	0.927212	0.146687	0.798289
VAR # 2	-0.045636	-0.370476	-0.033558	0.501993
VAR # 3	-0.339161	-0.040945	-0.649817	0.223228
VAR # 4	-0.253864	-0.036733	0.745046	0.246795

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 1	-0.770017	0.187723	0.419523	0.576866	0.774905	0.234153	-0.554751	-0.050971	0.094679	-0.206916
	CA	MG	NA	BST						
	0.549505	0.523524	0.510844	0.535238						
CANONICAL	H	K	CEC	CACO3	PH	FS	OM	VFS	CLAY	SILT
VAR # 2	0.004193	-0.216905	0.197362	0.416572	0.141352	-0.154488	-0.316257	-0.131675	0.247757	-0.108473
	CA	MG	NA	BST						
	0.144455	0.194770	0.472700	0.435717						

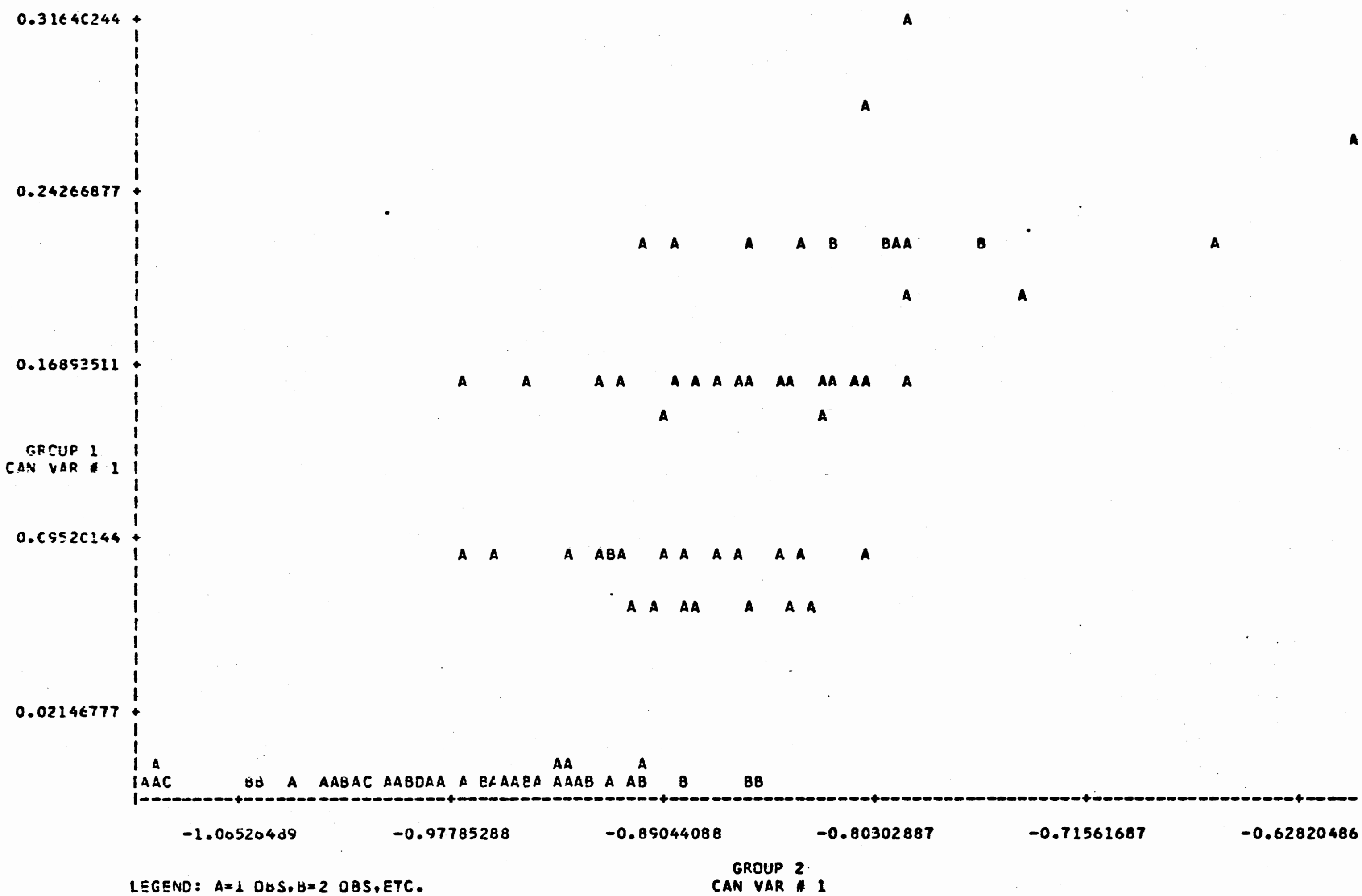


Figure 4.21. Plot of the Compounds in the First Pair of Canonical Variables for All Samples, Area Two.

TABLE 4.20

FIELD SHEET SHOWING THE CODING SYSTEM OF THE MORPHOLOGICAL PROPERTIES

				1	2	3	4	5	6	7	8	9
		HOR NO		1	2	3	4	5	6	7	8	9
		DESG										
BOUNDARY	DISTINCT.	AB	1									
		CL.	2									
		GR	3									
		DIF	4									
	TOPOG.	SM	1									
		WA	2									
		IRR	3									
		BR	4									
		DEPTH										
TEXTURE		S	1									
		LS	2									
		SL	3									
		L	4									
		SIL	5									
		SI	6									
		SCL	7									
		CL	8									
		SICL	9									
		SC	10									
		SIC	11									
		C	12									
CONSISTANCY	DRY	L	1									
		S	2									
		S.H	3									
		ΣH	4									
		V.H	5									
		E.H	6									
	MOIST	L	1									
		V.FR	2									
		FR	3									
		F	4									
		V.F	5									
		E.F	6									
	WET	N.S	1									
		SL.S	2									
		S	3									
		N.P	4									
		S.P	5									
		P	6									
COLOR		HUE										
		VALUE										
		CHROMA										
MOTTLING	ABUND.	FEW	1									
		COMM.	2									
		MANY	3									
		V.MANY	4									
	SIZE	F	1									
		MED.	2									
		COR.	3									
	CONTR.	FAINT	1									
		DIST.	2									
		PROM.	3									
COATING		CLAY	1									
		OXIDES	2									
		ORG.M.	3									

TABLE 4.20 (Continued)

CONCRETION	COLOR	BLACK	1
		WHITE	2
	QUAT	FEW	1
		COMM.	2
		MANY	3
	SIZE	FINE	1
		MED.	2
		COAR.	3
STRUCTURE	CLASS	V.F.	1
		F.	2
		MED.	3
		COAR.	4
		V.COAR.	5
	GRADE	STR.	1
		V.WEAK	2
		W.	3
		MOD.	4
		STROG	5
		V.STR.	6
	TYPE	PRISM.	1
		COLUM.	2
		SBK.	3
		ABK.	4
		GRAN.	5
		PLATT.	6
ROOT	SIZE	F.	1
		MED.	2
		COAR.	3
	QUANT	FEW	1
		COMM.	2
		MANY.	3
PORES	SIZE	V. F.	1
		F.	2
		MED.	3
		COAR.	4
	ORIENT	HOR.	1
		VER.	2
		RAND.	3
		OBLIQ.	4

AREA	
DATE	
LOCATION	
SLOPE	
D. DAR.L YER	
D. BUR. L	
D.90% ROOT	
D.CROTO.	
D.CONCR.	
D. MOTT.	
D. B.W. BOD.	
D. SLKSID.	
D. CL.FLM.	
D. PR.FACE	
D. STR.	
DRAINGE	
V. P.	1
P.	2
S.P.	3
MOD.W.	4
W.	5
S.EX.	6
EX.	7
PERMEAB.	
V. S.	1
S.	2
MED.	3
RAP.	4
P. SAMPLED	✓

X_1 represents the matrix of morphological properties, while X_2 represents the matrix of the chemical properties. $\underset{\sim}{U}_1$ and $\underset{\sim}{V}_1$ are vectors of compounds where N is the number of samples in the data.

The linear transformation could be visualized as scaling down a multidimensional hyperspace into a space whose points could be represented in Euclidian space. These points can be plotted in the plane of the first pair of the canonical variate with one coordinate representing the morphological properties and the other coordinate representing the chemical properties. The distance between the points in this plan can be used to investigate the presence of any clustering or grouping.

Since $\underset{\sim}{U}_i$ represents X_1 group of variables measured on i location and $\underset{\sim}{V}_i$ represents X_2 of variables measured on the same i location, therefore studying the clustering along both axes should reveal the superiority of each group of variables in producing a better-compacted grouping.

The unique identification of the different locations can be done either by a special computer program or from the original $\underset{\sim}{U}_i$,$\underset{\sim}{V}_i$ compounds. The moment the different groups are recognized along each axis, several statistical testing procedures are available to test the significance of the clustering. Wilk's criteria on student's t can be used to establish the number of the groups. While testing the equality of the means of the groups, computations of confidence intervals on the means could also be done. The compactness of each group can be indicated by the significance of Wilk's criteria on the width of the confidence intervals. The number of groups needed to be established can also be used to judge the superiority of diagnostic properties.

Sometimes a few locations will not graphically be assigned to any group. Discriminant analysis using Mahalinobis distance, or Fisher linear discriminant function could be used to assign these locations to the closest group. In the mean time, the Mahalinobian distance or the linear function can be used to judge whether these locations are inclusions or not, in this case, the exact percentage of the inclusions can be computed. Furthermore, by using this procedure, precise characterization of what would be considered as inclusions can be achieved.

Using this approach, and utilizing the profile or different genetic horizons as the main unit, the significance of each property as diagnostic criterion can be tested objectively. The property that produces the most compacted or most homogenous grouping would be favored to establish a new taxa. Moreover, the current diagnostic criteria used in the present taxonomy can be tested or redefined for possible improvements in the system. Another potential use of this procedure could be the establishment of a systematic objective way of improving any kind of artificial grouping, land capability classification, or any other interpretations which require finding the best criteria to achieve the most appropriate grouping at any scale.

The unique identification of the different locations was not possible at this time due to the extreme similarity between many locations. Thus the symbols seen on each figure represent the number of locations having the same values. However, the exact locations that constitute each point on the figure can be identified by inspecting the original canonical compounds. Nevertheless, it should be stressed again that statistical procedures adapted for computer analysis are available to test the significance of the established groups.

A brief discussion on each figure will be presented here. Preceding the discussion, a title will be given in the following order: Area, zone, variables that were used to construct $\underset{\sim}{U}_1$, variables that were used to construct $\underset{\sim}{V}_1$, and figure number.

<u>Area One, All Samples, Color (Group One) / Chemical Properties (Group Two), Figure 4.1.</u>

No distinctive clustering can be recognized along the axis that represents the chemical properties. Very weak clustering can be recognized along group one (color), but with extreme overlapping. No subdivision could be established if color or chemical properties were used as a diagnostic criteria. It should be noted that the failure of both the color and the chemical properties to produce any different grouping should not lead to discarding these properties as diagnostic criteria, but it should be taken as an indication to show that if one wants to compare these two groups of properties against each other, then both would fail to produce any grouping.

<u>Area One, Surface Zone, Color / Chemical Properties, Figure 4.2</u>

Two major groups with few points in the overlapping position can be recognized along both axes. The grouping was more compacted along the color axis. It is worthy to note here that this area is composed of two different soil orders in which the color is used as a diagnostic criteria to separate the two orders. This conclusion supports the validity of this mathematical approach. More than two groups can be recognized for the subsurface zone of the same area, but with many scattered points. The color of the subsurface is not diagnostic between Mollisols and Alfisols, orders which existed in this area (Figure 4.4).

Further evidence to support the validity of this approach is presented in Figure 4.5 (P. M. zone). Since by definition parent material is not soil, thus color should not have a diagnostic capability to discriminate non-soil, one-type parent material. That is why only one group was produced along both axes. Few points were far from the center of that group. These points could represent the locations where shale was interbedded with the sandstone of the Permian parent material.

Area Two, All Samples, Color/Chemical Properties, Figure 4.6

Three major groups with more than one subgroup can be recognized along the color axis with very little overlapping occurring between groups. No grouping existed along the chemical properties. If color has to be used as a diagnostic criteria, three major groups could be established with subgroup divisions based on color but not on chemical properties.

Area Two, Surface Zone, Color/Chemical Properties, Figure 4.7

Only one compacted group can be recognized along the color axis. This area is composed of only one soil order, namely Mollisols. This order is recognized by the presence of mollic epipedon. The production of only one group further substantiates the validity of this approach.

Area Two, Subsurface Zone, Color/Chemical Properties, Figure 4.8

Three major groups can be recognized along the color axis. Many subdivisions can also be established within the major groups. The significance of each subdivision should be tested statistically.

Two major groups can be recognized along the chemical properties with no clear boundaries. Each group could be divided to more than one subgroup on the color basis. The significance of the clustering along both axes should be tested statistically.

Area One, All Samples, Consistence/Chemical Properties, Figure 4.9

Several groups can be recognized along the consistence axis, but with few points unyielding to the clustering of the major groups. No clustering is recognized along the chemical properties. However, if confidence intervals were computed for the groups recognized along the color axis, a possible overlap between the groups may result.

Area One, Surface Zone, Consistence/Chemical Properties, Figures 4.10 and 4.11

Three groups, with no overlapping, are recognized along the consistence axis. The same number of groups are recognized along the chemistry axis. The superiority of clustering along the two axes should be established by statistical procedures. The same pattern is exhibited by the second canonical pair (Figure 4.11).

Area One, Subsurface Zone, Consistence/Chemical Properties, Figure 4.12

Three groups with possible overlap can be recognized along the consistence axis. Some points can be considered as inclusions. A very weak clustering pattern is exhibited along the chemistry axis. The superiority of the consistence in the subsurface zone as a diagnostic criteria over the chemical properties is clear and unquestionable.

Area One, P.M. Zone, Consistence/Chemical Properties, Figure 4.13

One uncompacted group with several scattered points can be recognized along the consistence axis. This pattern is consistent with the Cr horizon definition.

Area Two, All Samples, Consistence/Chemical Properties, Figure 4.14

Several groups are recognized along the consistence axis. Some points are located in an overlapping position or unyielding to the clustering. Two major groups, but not very dense, can be recognized along the chemistry axis. Two or more points can be considered in the overlapping position. The chemical properties would divide the data into two major groups and many subgroups. The superiority of the desired criteria will depend on the number of groups needed to be established and on the statistical tests.

Area Two, Surface Zone, Consistence/Chemical Properties

No clustering is produced. The points were so scattered that the computer failed to plot any point on the same scale. No conclusion can be advanced on the suitability of either property as a diagnostic criteria.

Area Two, Subsurface Zone, Consistence/Chemical Properties, Figure 4.15

Three major groups can be recognized along the consistence axis. Some overlapping exists between the groups and some points are far from the center of different groups. Three points can be regarded as inclusions. One major group can be recognized along the chemistry axis.

Therefore, in comparison with the consistence variables, the chemical properties possess very low discriminating capability.

Area Two, All Samples, Pores Orientation/Chemical Properties, Figure 4.16

Two major groups with clear overlap exist along the chemistry axis. The presence of the two groups should be tested statistically. Several groups, with one point unyielding to the classification, can be recognized along the pores axis. The groups are very compacted and the distance between some of the groups is not large. The overlapping should be established by the statistical procedures. However, stronger dissection is apt to be produced by pores.

Area Two, All Samples, Structure/Chemical Properties, Figure 4.17

Two major groups are produced along both axes. The clustering along the structure axis is more compacted, but with many points in the overlapping positions. Less points are unclassified along the chemistry axis and should be evaluated by the statistical methods. In this case, further subdivision along the consistence axis is possible.

Area Two, All Samples, Coating/Chemical Properties, Figures 4.18 and 4.19

Three major compacted groups are recognized along the coating axis and no points are unclassified. Two groups can be established along the chemistry axis, but with very wide range of variability and overlapping. The superiority of the coating as a diagnostic criteria over the chemical properties is clear. Using the second canonical pair, the coating is still superior to the chemical properties. As a matter of fact, no clustering is produced along the chemical properties axis.

Area Two, All Samples, Mottling/Chemical Properties, Figure 4.20

Four very compacted groups can be recognized along the mottling axis. No overlap or unclassified points are shown. The dissection between the different groups is sharp. No clustering is recognized along the chemistry axis. The superiority of the mottling as a diagnostic criteria over the chemical properties is clear and can be further evaluated by the statistical testing.

Area Two, All Samples, Concretions/Chemical Properties, Figure 4.21

Four major groups can be recognized along the concretions axis. Few unclassified and overlapping points can also be recognized along this axis. The groups are very compacted, but with possible subdivision within each group. No clustering can be recognized along the chemistry axis. The superiority of the concretions distribution over the chemical properties, as a discriminating criteria, is clear. Moreover, this conclusion can be further substantiated by the statistical testing.

Conclusions

Mathematical relationships established using the canonical correlation technique proved that strong associations do exist between the different morphological and the chemical properties. However, emphasis here is not placed on the many relationships examined in this study, but on the validity of the mathematical approach used as an effective tool capable of relating two sets of different variables. Moreover, inference about the relationship between the level of the chemical properties and the specific state of the morphological properties was possible by this technique. Since each level, or state of many of the morphological properties can be considered as the collective effect of many factors, further investigation utilizing this technique may prove to be an excellent tool in isolating the factors important in explaining certain patterns. One potential area is land use.

This technique could also be used in an important aspect of the soil taxonomy, that is, the selection of the diagnostic criteria. The technique should not be regarded, at this stage, as a tool in creating taxonomical categories. Previous discussion proved that if supportive statistical tests were followed, suitability of different diagnostic criteria in the soil taxonomy can be evaluated objectively and the criteria selection for better taxonomy can be achieved. These diagnostic criteria can be evaluated for different horizons or for the profile as a whole. These results would be followed with maximum possible objectivity utilizing standard statistical techniques adapted to be executed by high-speed computers. This preliminary investigation indicated that the majority of the morphological properties were superior and capable of producing more compacted groupings than the chemical properties. In many cases, the conclusions reached through this technique showed to be compatible with the diagnostic definitions of some of the properties used in the current soil classification system.

CHAPTER V

CANONICAL CORRELATION

Abstract

The objective of this study was to investigate the relationships between different soil morphological properties. Descriptions of the study areas, field work design, number of profiles sampled, and laboratory statistical design were given in previous chapters.

Emphasis was given to the relationships between color, consistence, and other morphological properties. This was due to the significant roles played by the color variables and the consistence-related properties either in soil classification or soil development. Association analysis technique was used to investigate these relationships. Significant relationships were found to exist between the color variables and the other morphological properties.

Also significant and close associations were found between the soil structure and other properties like roots, pores orientation, and consistence.

Close examination of the graphs that represent the first canonical pair showed that canonical correlation can be used to test the suitability of different soil properties in producing more distinct grouping, if used as diagnostic criteria. Furthermore, the technique showed that some soil properties are superior as diagnostic properties within one

horizon and inferior in another. This might be helpful in selecting better criteria for the lower categories of the soil classification system. Moreover, testing the significance of the classification produced by this technique could be carried with minimum subjectivity.

Introduction

Quantitative relationships between soil morphological properties have not been fully investigated. One reason is that statistical techniques suitable for soil investigation require a high-speed computer which has been recently introduced to soil investigations.

Simple correlation coefficients (pairwise correlations) were used to indicate the possible relationship between two variables. If one has ten soil properties, it will take fifty simple correlation coefficients to show all possible relationships. These relationships, indicated by the fifty coefficients, may not be easily understood. Therefore, a technique, easy to interpret and understand, which expresses these relationships in that easy format, is needed. Furthermore, multiple relationships might exist between soil properties and simple pairwise correlations would not be a good tool. The canonical correlation technique was introduced by Hotelling (36). The technique was introduced to understand the possible relationships between two sets of variables.

For example, if one wishes to study the relation between the color variables (hue, value, chroma) and consistence variables (dry moist, stickiness, plasticity), we can represent the observations recorded on different horizons in a matrix format as follows:

Unit Number	hue	value	chroma .	dry	moist	stickiness	plastic.
1	X_{11}	X_{21}	X_{31} :	Y_{11}	Y_{21}	Y_{31}	Y_{41}
2	X_{12}	X_{22}	X_{32} :	Y_{21}	Y_{22}	Y_{32}	Y_{42}
.			:				
.			:				
.			:				
N	X_{1N}	X_{2N}	X_{3N} :	Y_{1N}	Y_{2N}	Y_{3N}	Y_{4N}

Let X be a matrix that represents the color data and Y to represent the consistence data, where X is NX3 and Y is NX4. The canonical correlation is concerned with a simple way to understand the relationship between the two groups. The technique linearly transfers these data to be displayed by a new axes that shows the relationship clearly. First, the data are transferred linearly to a new system. Let U_i = XA and V_i = YB where U_i, V_i are NX1 vectors, and A is 3X3, B is 4X4 matrices.

for i = 1, . . . N

$$\underset{\sim}{U}_i = \begin{bmatrix} U_1 \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ U_N \end{bmatrix} \begin{bmatrix} A_{11}X_{11} + A_{21}X_{21} + A_{31}X_{31} \\ \\ \\ \\ A_{11}X_{11} + A_{21}X_{21} + A_{31}X_{31} \end{bmatrix}$$

and

$$\underset{\sim}{V}_i = \begin{bmatrix} V_1 \\ \cdot \\ \cdot \\ \cdot \\ V_N \end{bmatrix} \begin{bmatrix} B_{11}Y_{11} + \cdots\cdots\cdots B_{41}Y_{41} \\ \\ \\ B_{11}Y_{11} + \cdots\cdots\cdots B_{41}Y_{41} \end{bmatrix}$$

If a and b were chosen such that U,V have maximum correlation, this correlation would be called the canonical correlation.

The degree of the association between the two sets is the value of the canonical roots (eigenvalues of the data matrix). The nature and the measure of this relation between the variables within each set is indicated by the variables in both sets having larger weights. If the canonical correlation between the two sets is unity, this means one of the sets would be predicted perfectly by the other set.

The number of the canonical variates that can be constructed is equal to the number of the variables in the smaller set, thus, in the above example, three canonical variates or axis can be compared. These canonical variates are uncorrelated by construction. Each canonical variate displays the maximum correlation with the first variate carrying the maximum correlation, followed by the second and the third. If we consider the set $U = XA$ alone, it can be treated as equivalent to the multiple regression. So is $V = XA$. Therefore, treating each set sépa-rately, the degree of the polynomial in each variable within the set can be determined under the restriction that increasing the degree of the polynomial improves the canonical correlation between U,V. Therefore, the degree of polynomial for either the color or the consistency can be determined and the relationship still can be expressed in a simple cor-relation. However, it should be noticed that even if quadratic of cubic terms are used in the model, the canonical correlation computation will be performed on these data as if they were original data, but these data express certain degrees of polynomial when they are inputed for calcula-tions.

The canonical variate, especially the first one, has another property besides displaying maximum correlation. That property is the maximum variance. This provides a measure of the variation explained in the regression model reached. This could be used as a tool to select the set of properties which show maximum variations.

The geometric interpretation of the canonical exes can be visualized as follows: in R-dimensional space (7 in our example) a sample of p + q = R(7) determines one hyperplane of p(3) and one of q(4) dimensions intersecting at the origin and contain a swarm of points representing the two sets. Linear transformations are developed for the first p coordinates axes and also for the q coordinates axes such that these two hyperplanes are as parallel as possible in a new dimensional space.

The objective of this study was to investigate the relationship between the different morphological properties of soil by the canonical correlation technique. Linear relationships were assumed, and no attempt was made to determine the degree of polynomial in each variable since producing prediction models was not the main goal of this investigation.

Results and Discussion

Selected samples of the association analysis (for different areas) were presented here since many relationships were established. The rest of the analysis will be reported somewhere else. Special attention was given to the detailed interpretation of the relationships between the soil color and other soil morphological properties. This was due to the significant role played by the color in the classification and development of the soil.

The canonical correlation for the first variate (all samples, Area Two) was .79 (Table 5.1). This can be interpreted as very high hue values (.92), low value value (-.68), and very low chroma value (-.97) is highly associated with low frequency of clay coating (-.68) and very low oxide coating frequency (-.98) (Figure 5.1). This can be interpreted in terms of the original data as hue of 10YR with value of 3 to 4 and chroma of 1 to 3 is highly associated with low frequency of clay coating on very low oxide coatings or hue of 2.5YR with value of 6 to 7 and chroma of 7 to 8 is highly moderate, high frequency of clay coatings and very high frequency of oxide coatings. However, for the Cr zone, (Area One) the first canonical variate had .7 canonical correlation (Table 5.2) (Prob > Chi SQ = .1467). This suggests that high hue value (.80) is moderately associated with high organic coating frequency (.84), or low to moderately low hue value is moderately associated with low frequency of organic coating. Another way of interpreting this pair is 5YR, 7.5YR hue is associated with high frequency of clay coating or hue of 2.5YR, 5YR hue is associated with low frequency of organic coating (Figure 2).

Canonical correlation for the first (all samples, Area Two) was .66 (Table 5.3). This can be interpreted as follows: high or very high hue values (.9), low value values (.7) and very low chroma code (.99) is moderately associated with very low class code (.96), low grade code (-.52), and high type code (.86). In referring to the original data, 7.5YR hue with 3 to 4 value and chroma of 1 to 2 is moderately associated with very coarse, weak, or moderate angular or subangular structure

TABLE 5.1

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.15876141	-0.11057781	0.77867316	104.33219	9	0.0001
2	0.72024002	0.23334007	0.13206257	2.25113	4	0.6929
3	0.45276422	0.17011798	0.05440146	0.32455	1	0.5762

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.915292	-0.681092	-0.971404
VAR # 2	0.320648	0.713907	-0.045029
VAR # 3	0.243774	-0.162834	0.233124

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CLAYCOAT	OXICOAT	OMCOAT
VAR # 1	-0.680820	-0.983873	0.168762
VAR # 2	0.012806	0.123968	0.943046
VAR # 3	0.732339	-0.123939	0.286678

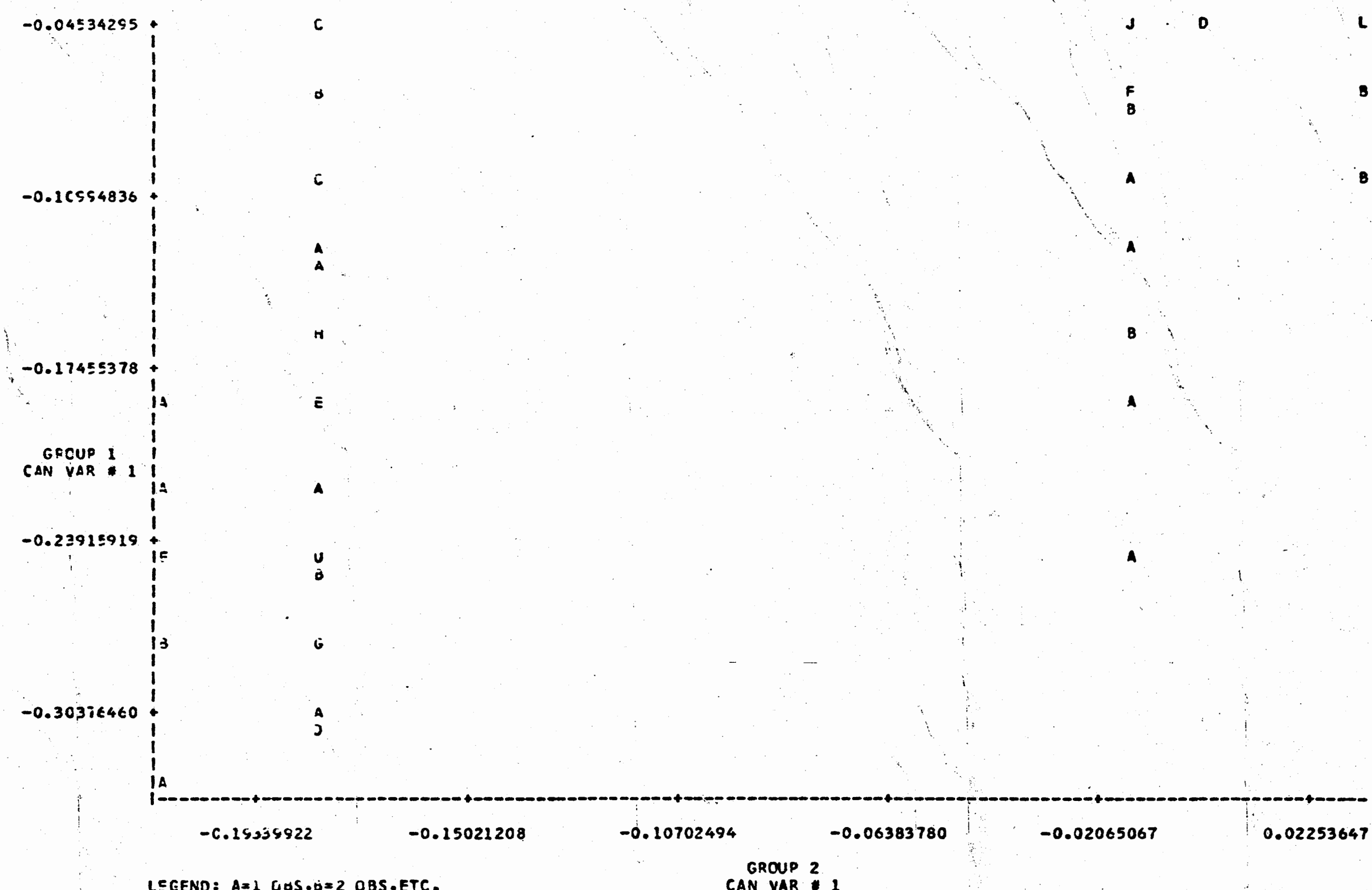


Figure 5.1. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

TABLE 5.2

CANONICAL CORRELATION ANALYSIS FOR THE P. M. ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-1.56424185	0.08822662	0.69686110	13.34707	9	0.1467
2	2.58391003	-0.00793972	0.42113876	3.70770	4	0.4484
3	0.65639012	-0.21939902	0.24223396	0.87680	1	0.3518

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.797537	0.029991	-0.424646
VAR # 2	0.602642	0.197907	0.394670
VAR # 3	0.027517	0.979762	-0.814808

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CLAYCOAT	OXICOAT	OMCOAT
VAR # 1	0.339569	0.177093	0.835626
VAR # 2	0.681964	-0.453954	-0.534874
VAR # 3	-0.647780	-0.873249	-0.125060

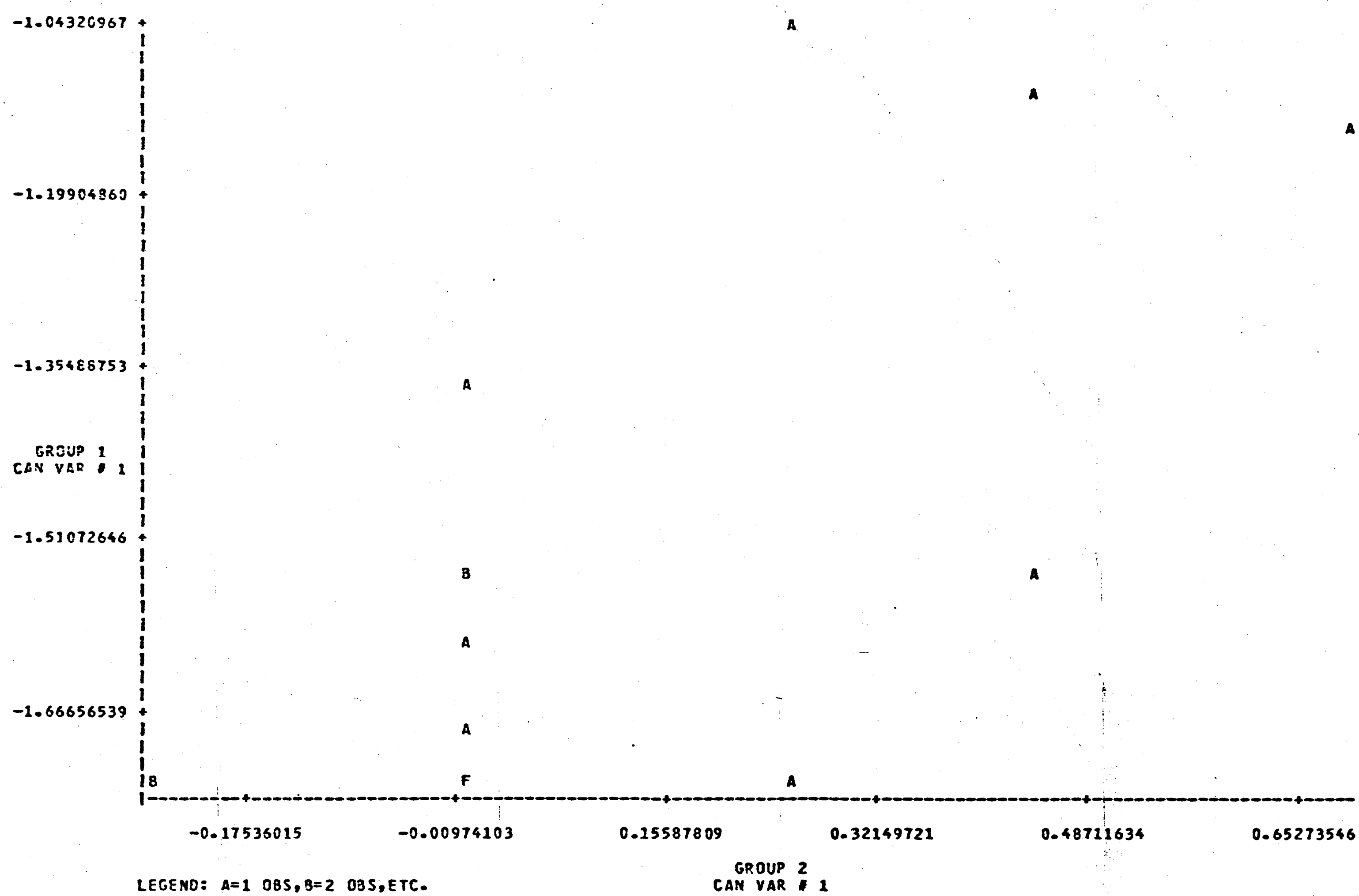


Figure 5.2. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the P. M. Zone, Area One.

TABLE 5.3

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.24986733	-0.53321151	0.65966889	71.42598	9	0.0001
2	-0.04646541	-1.05176111	0.26711581	8.87759	4	0.0634
3	0.61647465	-0.66659713	0.08381398	0.77193	1	0.3836

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.859959	-0.696142	-0.988173
VAR # 2	0.089813	-0.574718	0.151889
VAR # 3	0.502398	0.430216	-0.021059

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	-0.958913	-0.524166	0.862684
VAR # 2	-0.254754	0.260182	-0.467203
VAR # 3	0.124841	-0.810898	-0.193644

or 5 YR hue with value of 6 to 7 and chroma of 7 is moderately associated with fine moderate to strong subangular structure (Figure 5.3).

The first canonical variate had a correlation of .55 (Area One, all samples). It indicates that low hue values (.57), very high value code (.86), and moderate chroma code (.66) is associated with low class code (.62), or very low grade code (-.86), and low to very low type code (-.82) (Table 5.4, Figure 5.4). In terms of the original data, 5YR hue with 2 to 3 value and chroma of 6 to 7 is associated with medium weak or very weak subangular or prismatic structure, or 7.5 YR hue with 5 to 6 value and chroma of 2 to 3 is associated with coarse, strong to very strong angular or granular structure.

Color, Mottling, All Samples, Area Two, Figure 5.5, Table 5.5

First canonical variates had a correlation of .63 (all samples, Area Two) (Prob > CHI-SQ = .0001). This can be interpreted as follows: moderate hue value code (.69), very low value code (-.86), and very low chroma code (-.91) is moderately associated with very low mottling size code (-.96). In reference to the original variables, 5YR and 7.5YR hue with value of 2 to 3 and chroma of 1 to 2 is moderately associated with faint coarse mottles, or 2.5 YR and 5YR hue, value of 6 to 7 and chroma of 6 to 7 is associated with prominent fine mottles.

Color, Roots, All Samples, Area One, Table 5.6, Figure 5.6

First canonical variates had a correlation of .78 (prob > CHI-SQ = .0001). This was interpreted as follows: high hue values (.8), low value code (-.66), and very low chroma code (-.82) is highly associated with moderate frequency of medium roots (.92) and very high roots

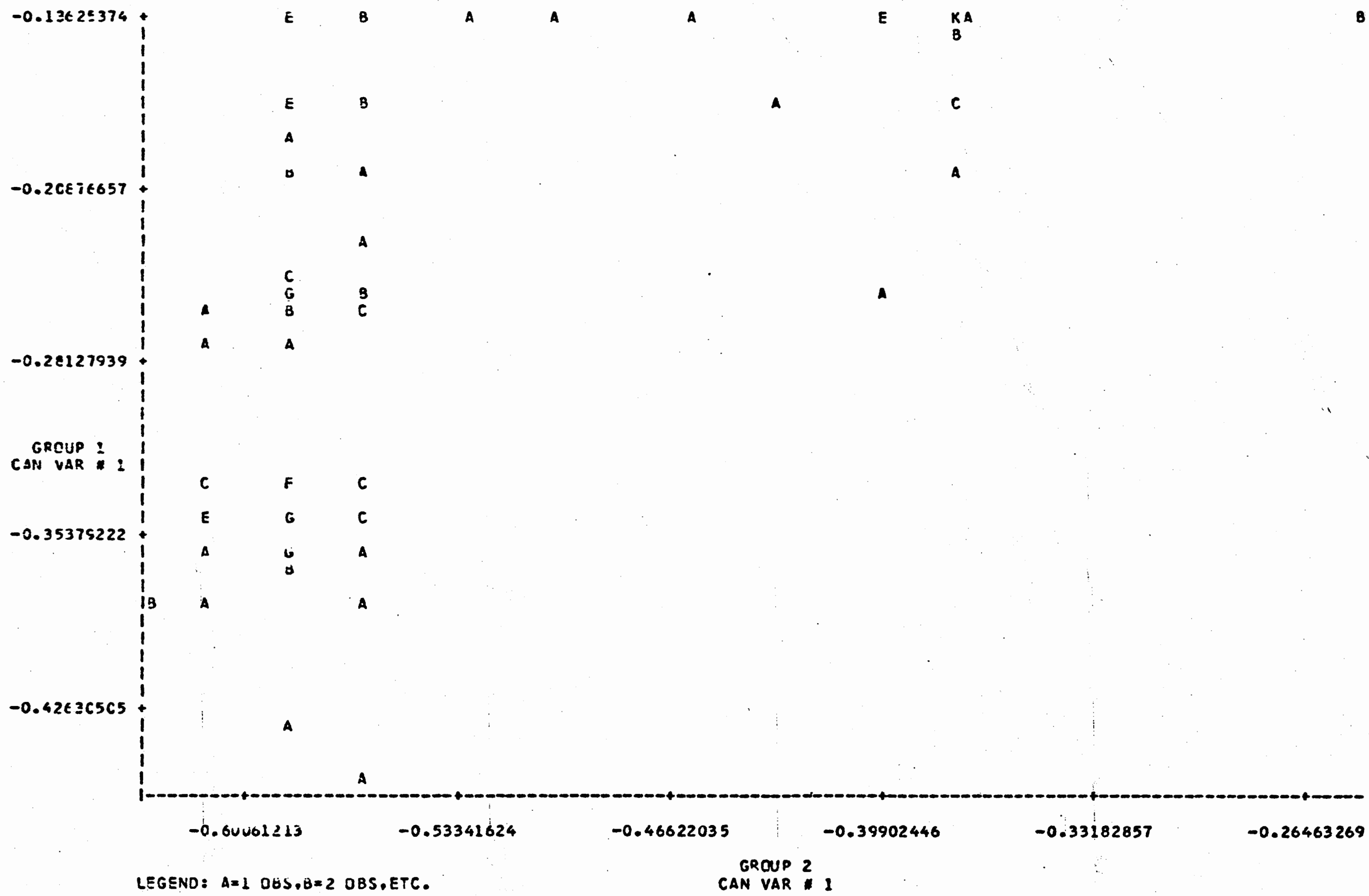


Figure 5.3. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

TABLE 5.4

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.59177804	-0.25677564	0.54925324	33.05327	9	0.0002
2	0.03292040	0.11717453	0.25523857	5.22484	4	0.2641
3	0.72310830	-0.07779376	0.00718400	0.00400	1	0.9054

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	-0.573455	0.862524	0.656460
VAR # 2	-0.337720	-0.466591	0.750437
VAR # 3	0.746388	0.138856	-0.076841

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	-0.620471	-0.856635	-0.828354
VAR # 2	-0.172892	0.165786	-0.554905
VAR # 3	-0.764934	-0.488220	0.076874

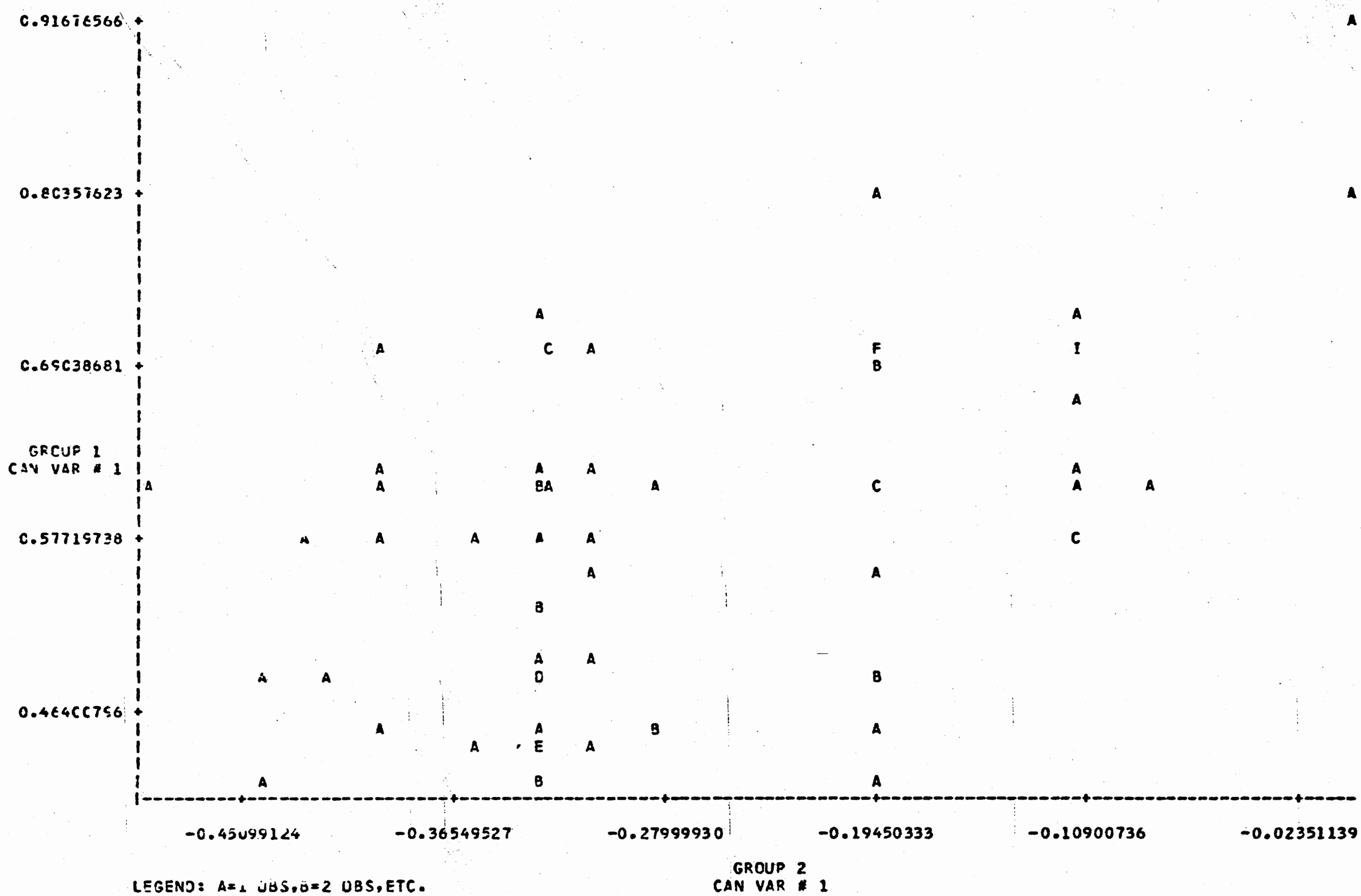


Figure 5.4. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area One.

TABLE 5.5

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.47532408	-0.10355606	0.62668849	63.64237	6	0.0001
2	0.26756362	-0.01035359	0.27689803	8.77484	2	0.0124

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.665870	-0.859454	-0.912262
VAR # 2	0.290733	0.511113	-0.373277

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	MSIZE	MCOUNT
VAR # 1	-0.972523	-0.956050
VAR # 2	0.232806	-0.293202

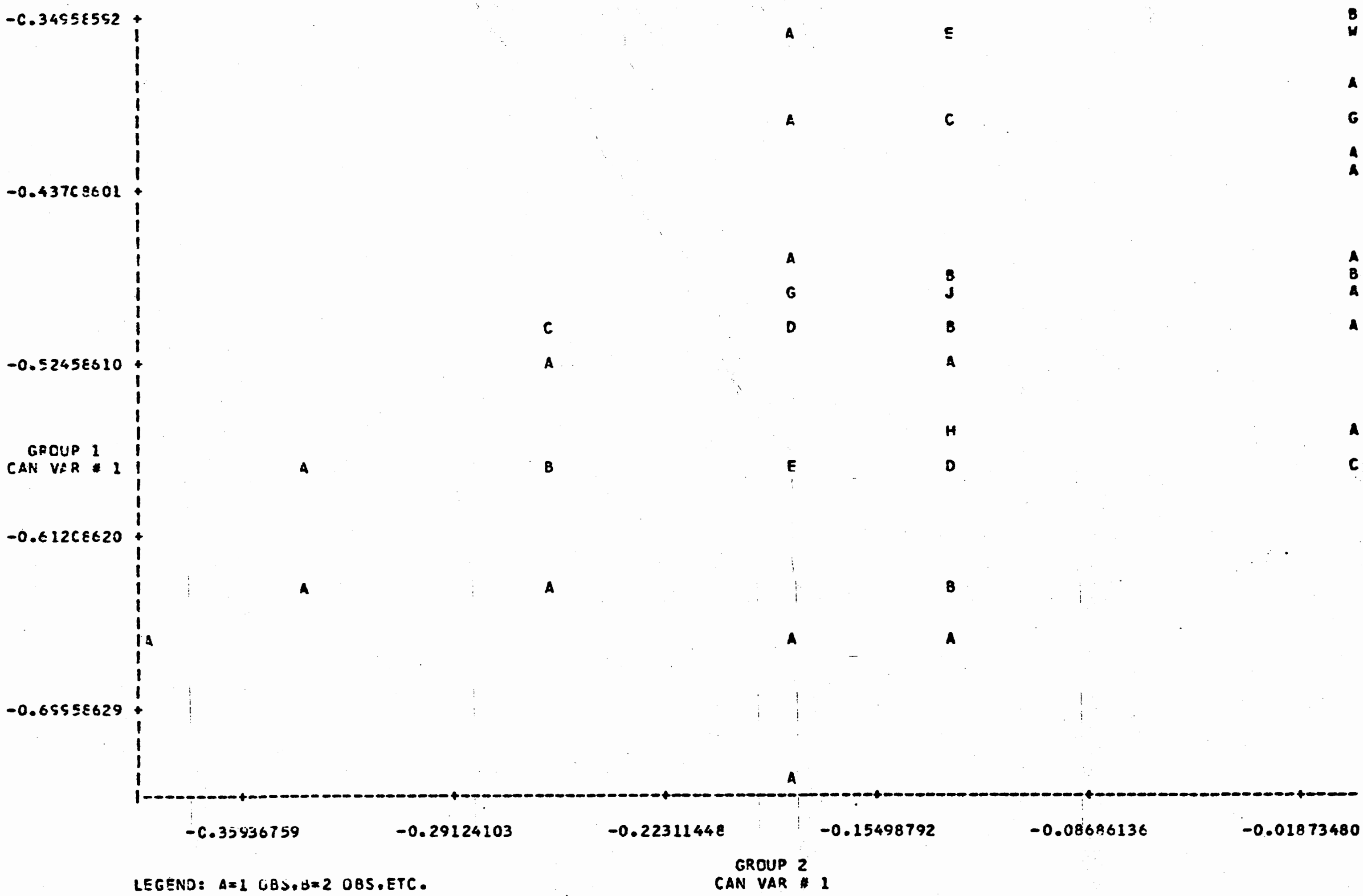


Figure 5.5. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area Two.

TABLE 5.6

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.38763187	0.18899431	0.77506807	82.14421	12	0.0001
2	0.42943663	-0.36162410	0.31171575	11.44907	6	0.0748
3	0.75439626	0.23485400	0.21309291	3.57833	2	0.1647

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.802147	-0.657620	-0.817767
VAR # 2	0.386036	0.755019	-0.471133
VAR # 3	0.455561	0.022320	0.330590

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	RFINE	RMED	RCORS	RQUNT
VAR # 1	0.256761	0.619115	-0.206325	0.963347
VAR # 2	-0.931966	0.359811	0.461841	-0.123819
VAR # 3	0.024133	-0.189797	0.856175	0.222864

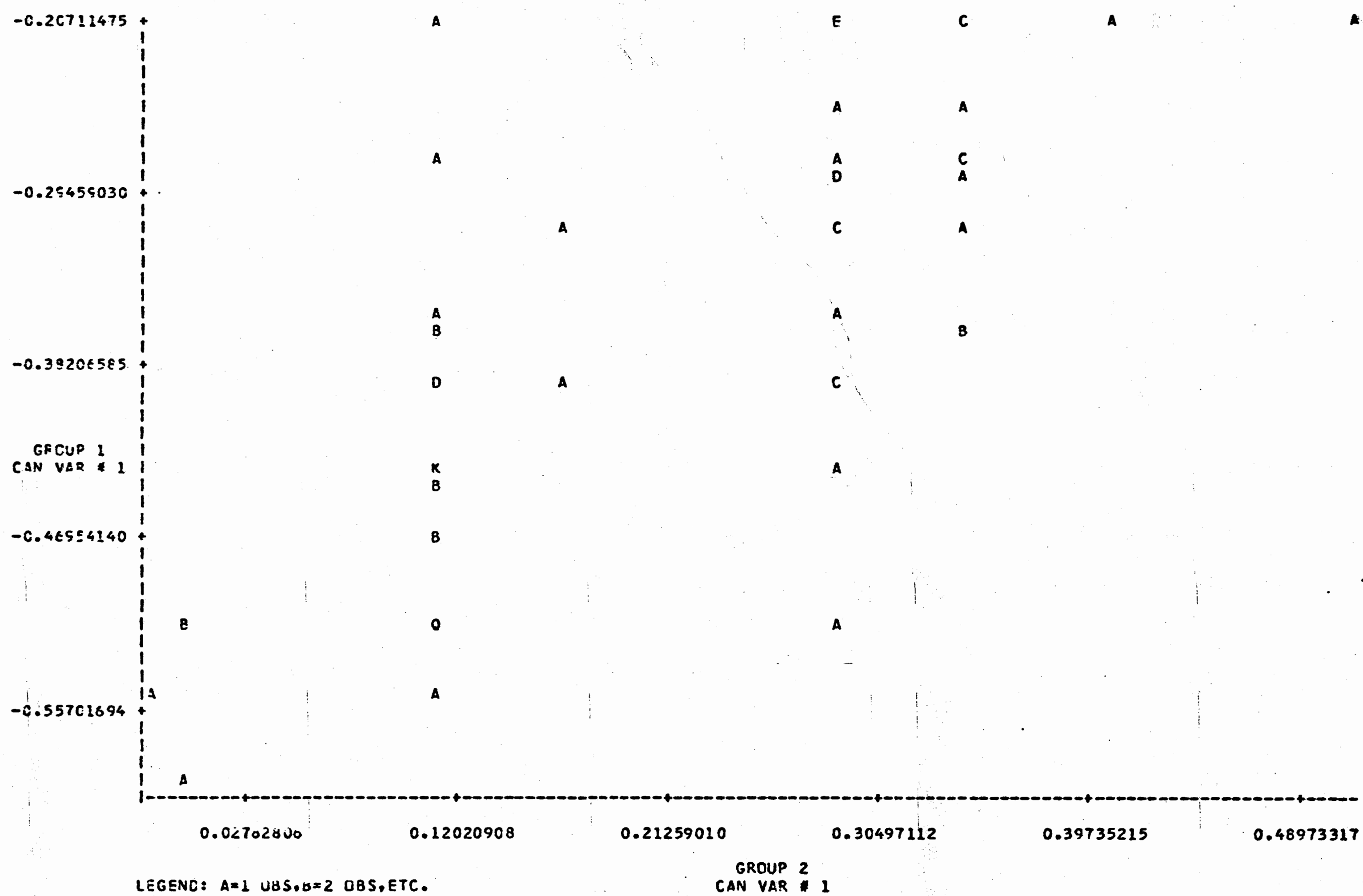


Figure 5.6. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area One.

quantity (.96). In terms of the original data, 7.5YR hue with values of 4 to 5 and chroma of 2 to 3 is highly associated with many medium roots, or 5YR with value of 5 to 7 and chroma of 6 to 7 is highly associated with few, fine roots.

Considering the same canonical variate for subsurface zone (Area One) (Table 5.7, Figure 5.7), canonical correlation for the first variate was .66 (prob > CHI-SQ = .0011). This was interpreted as follows: high hue value (.8), low value code (-.68) and very low chroma code (-.87) is moderately associated with low medium root frequency (.52) and very high root quantity (.89). In terms of the original variables, 7.5YR hue with value of 4 to 5 and chroma of 2 to 3 is moderately associated with many medium roots.

Structure, Pores Orientation, All Samples, Area Two, Table 5.8, Figure 5.8

The canonical correlation of the first variate was .80 (prob > CHI-SQ = .0001). This was interpreted as follows: very high class code (.92), low structure grade and very low type code (-.92) is highly associated with very low frequency of random pores code (-.99), and very high frequency of oblique pores (.89). In reference to the original variables, very coarse, weak prismatic structure is highly associated with oblique pores, while very fine to fine, strong granular structure is dominated by random pores. This conclusion may shed some light on the degree of permeability for different horizons if the pores orientation is known.

TABLE 5.7

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	-0.61213555	0.20622166	0.65559231	32.77825	12	0.0011
2	1.14098445	0.12971954	0.39174307	10.30744	6	0.1113
3	0.54880792	-0.80439340	0.29505924	3.64340	2	0.1593

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	HUE	VAL	CHRO
VAR # 1	0.803761	-0.636237	-0.874213
VAR # 2	0.575835	0.695795	-0.196849
VAR # 3	0.149605	-0.333275	0.443850

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	RFINE	RMED	RCORS	RQUNT
VAR # 1	-0.054607	0.523520	-0.358597	0.892014
VAR # 2	-0.742958	0.426008	0.873872	0.092475
VAR # 3	-0.555170	-0.502855	0.258979	0.187450

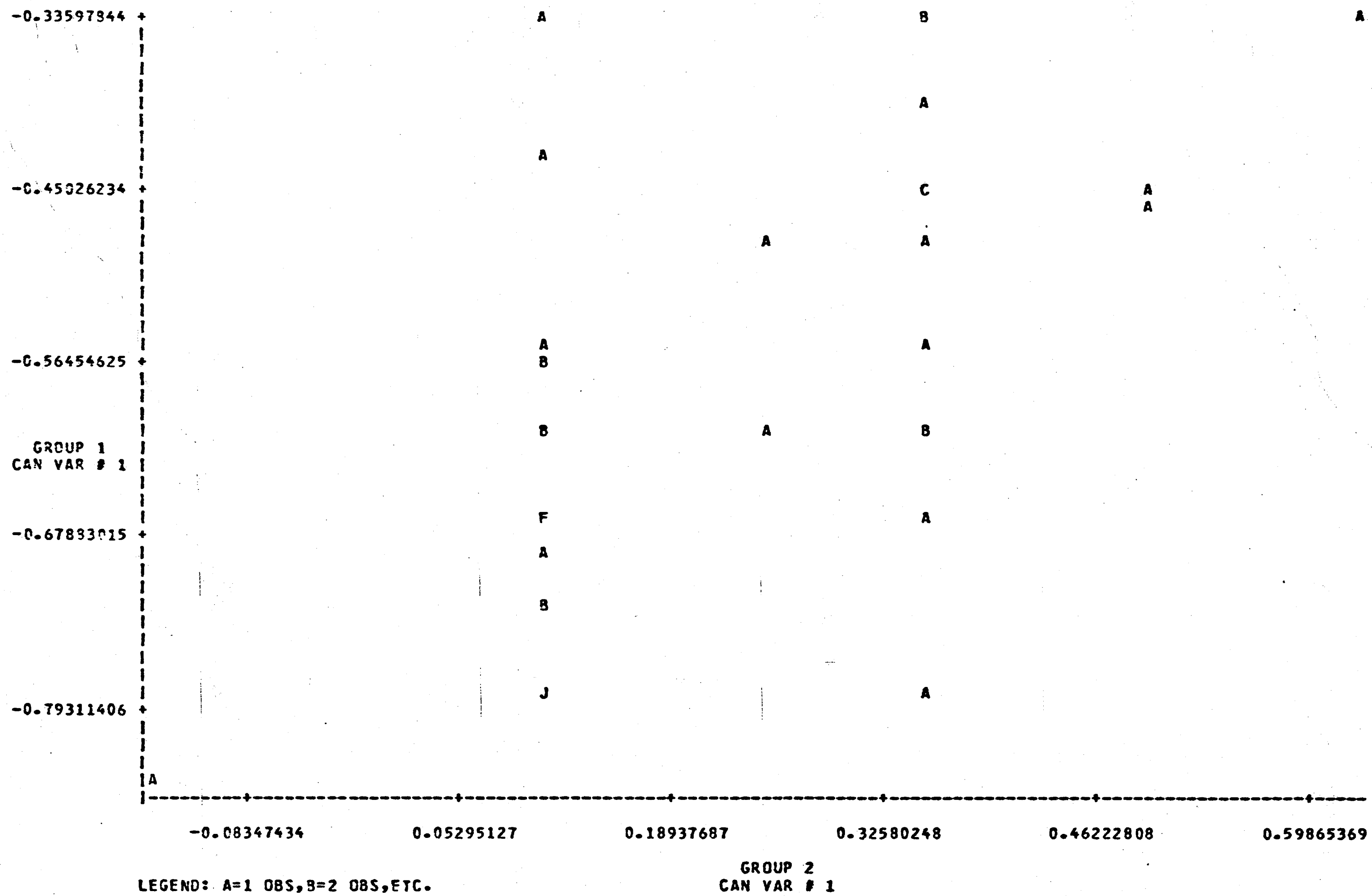


Figure 5.7. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area Two.

TABLE 5.8

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.50163872	-0.03003091	0.79739755	121.92035	12	0.0001
2	0.97557482	-0.47194399	0.29005492	11.81184	6	0.0657
3	0.86737470	0.15321151	0.14238797	2.23261	2	0.3280

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.920552	0.521903	-0.924202
VAR # 2	0.390101	-0.332000	0.314637
VAR # 3	-0.020123	0.785744	0.216459

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	HORPOR	VERPOR	RANPOR	OBLPOR
VAR # 1	0.410347	0.183746	-0.985425	0.891999
VAR # 2	-0.429723	0.230438	-0.056757	-0.335048
VAR # 3	-0.801737	0.222289	0.098204	0.233413

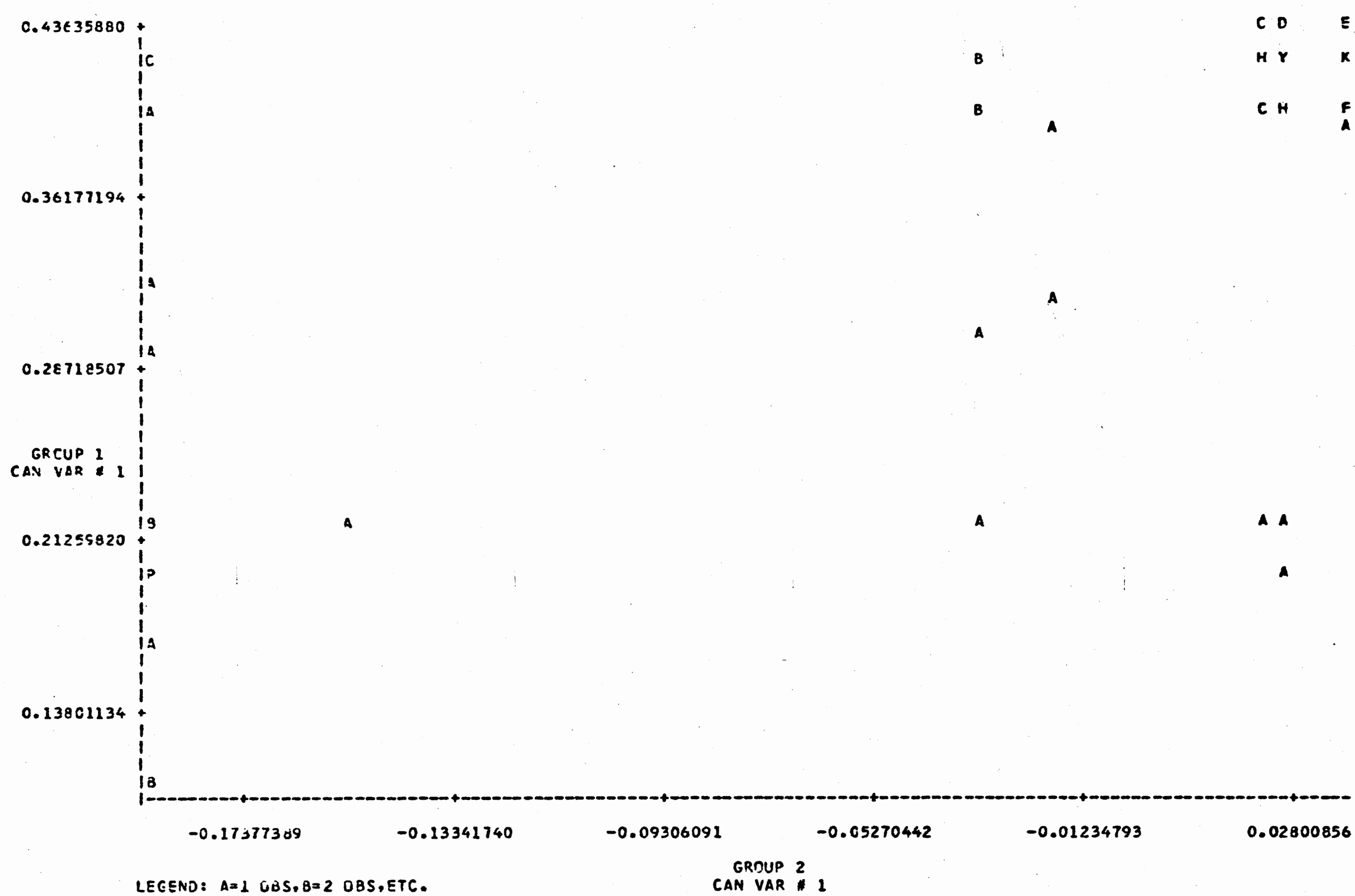


Figure 5.8. Plot of the Compounds in the Plan of the First of Canonical Variables for All Samples, Area Two.

Structure, Roots, All Samples, Area One, Table 5.9, Figure 5.9

The canonical correlation of first variate was .54 (prob > CHI-SQ = .0011). It indicated that moderate to high structure class code (.76) with high grade code (.82), and very high type code (.94) is associated with very high root quantity (.99). In terms of the original variables, strong, medium to coarse platy structure has low association with many roots, or very weak, medium prismatic structure has low association with few roots. It is very well known platy or strong prismatic structure impedes the growth of roots. This conclusion again supplies some evidence about the validity of this mathematical approach.

Structure, Consistence

The canonical correlation for the first variate was .63 (all samples, Area One) (prob > CHI-SQ = .0001).(Table 5.10, Figure 5.11). It was interpreted as follows: very high class code (.97), very high grade code (.97) and low type code is moderately associated with moderate dry code (.71), high moist code, high stickiness code (.85), and high plasticity. In terms of the original variables, moderate association is identified between very strong, coarse to very coarse angular or subangular structure and hard, firm, sticky and plastic soil materials. However, first correlation (all samples, Area Two) indicates that coarse or very coarse, weak to moderate prismatic structure is highly associated with very hard or extremely hard, firm to very firm, sticky and plastic soil materials.

The same canonical variate was interpreted as fine or very fine moderate granular or platy structure is highly associated with loose or

TABLE 5.9

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.21444311	0.31623298	0.53821425	32.98733	12	0.0010
2	-0.11916722	-0.32029010	0.26225228	6.65086	6	0.3542
3	0.15977733	0.09877164	0.12249637	1.16417	2	0.5643

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.758654	0.624681	0.938742
VAR # 2	-0.609532	-0.505186	0.316083
VAR # 3	-0.230032	0.252342	-0.137316

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	RFINE	RMED	RCORS	RCUNT
VAR # 1	0.438267	0.490182	-0.054882	0.989358
VAR # 2	-0.409967	0.441154	-0.553061	0.086818
VAR # 3	0.571444	-0.563708	-0.732627	0.022679

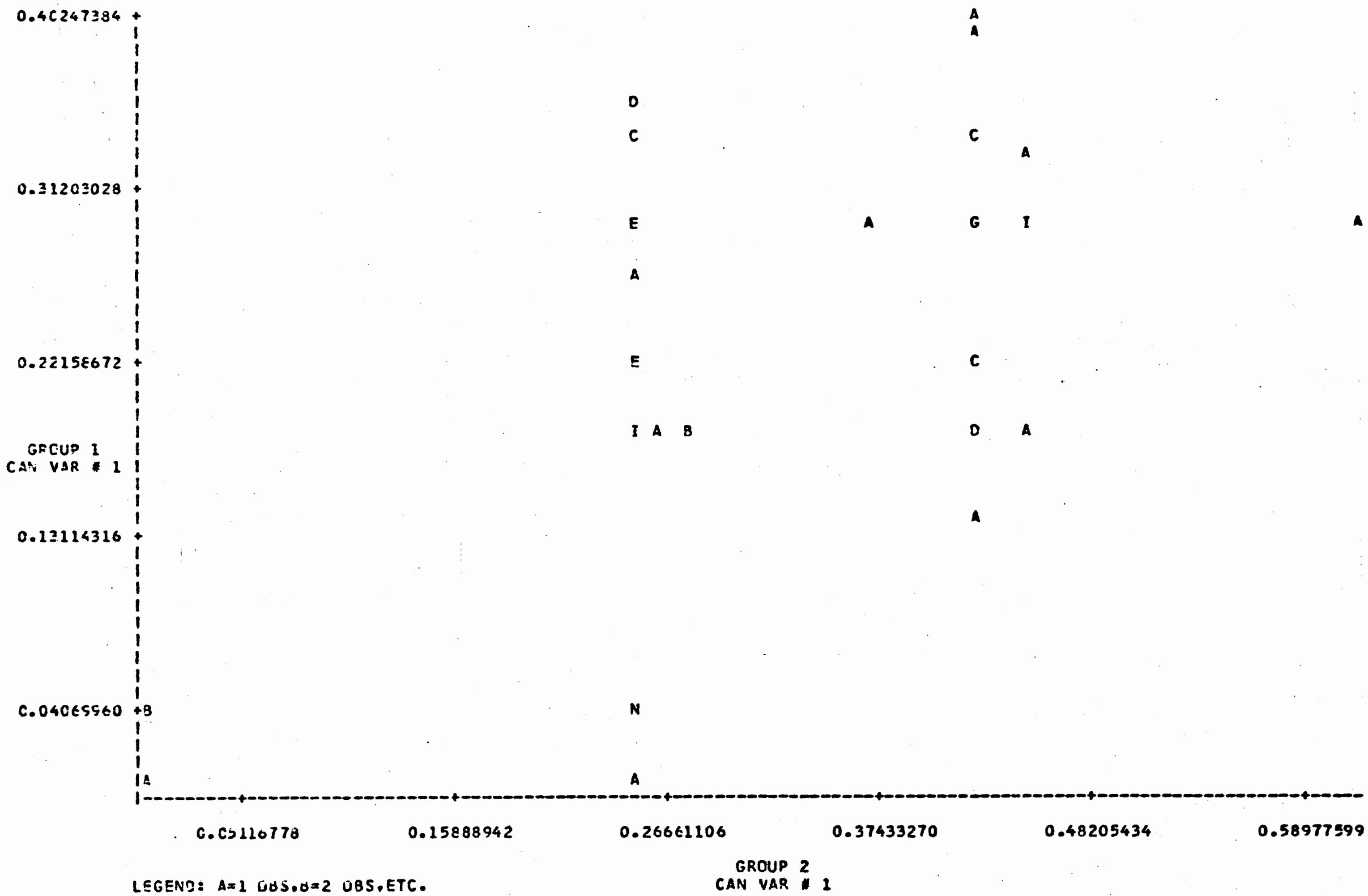


Figure 5.9. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area One.

TABLE 5.10

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.24625564	0.39005298	0.62911595	45.67761	12	0.0001
2	0.08827793	-0.10351036	0.24016808	4.86752	6	0.5626
3	0.12528236	-0.09933021	0.02610590	0.05522	2	0.9608

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.966914	0.967240	0.512103
VAR # 2	-0.101744	0.177143	0.743508
VAR # 3	-0.233934	0.181841	-0.430055

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.715808	0.866016	0.854674	0.857585
VAR # 2	-0.393142	0.159496	-0.347122	-0.027432
VAR # 3	0.487114	0.372643	-0.140871	-0.510102

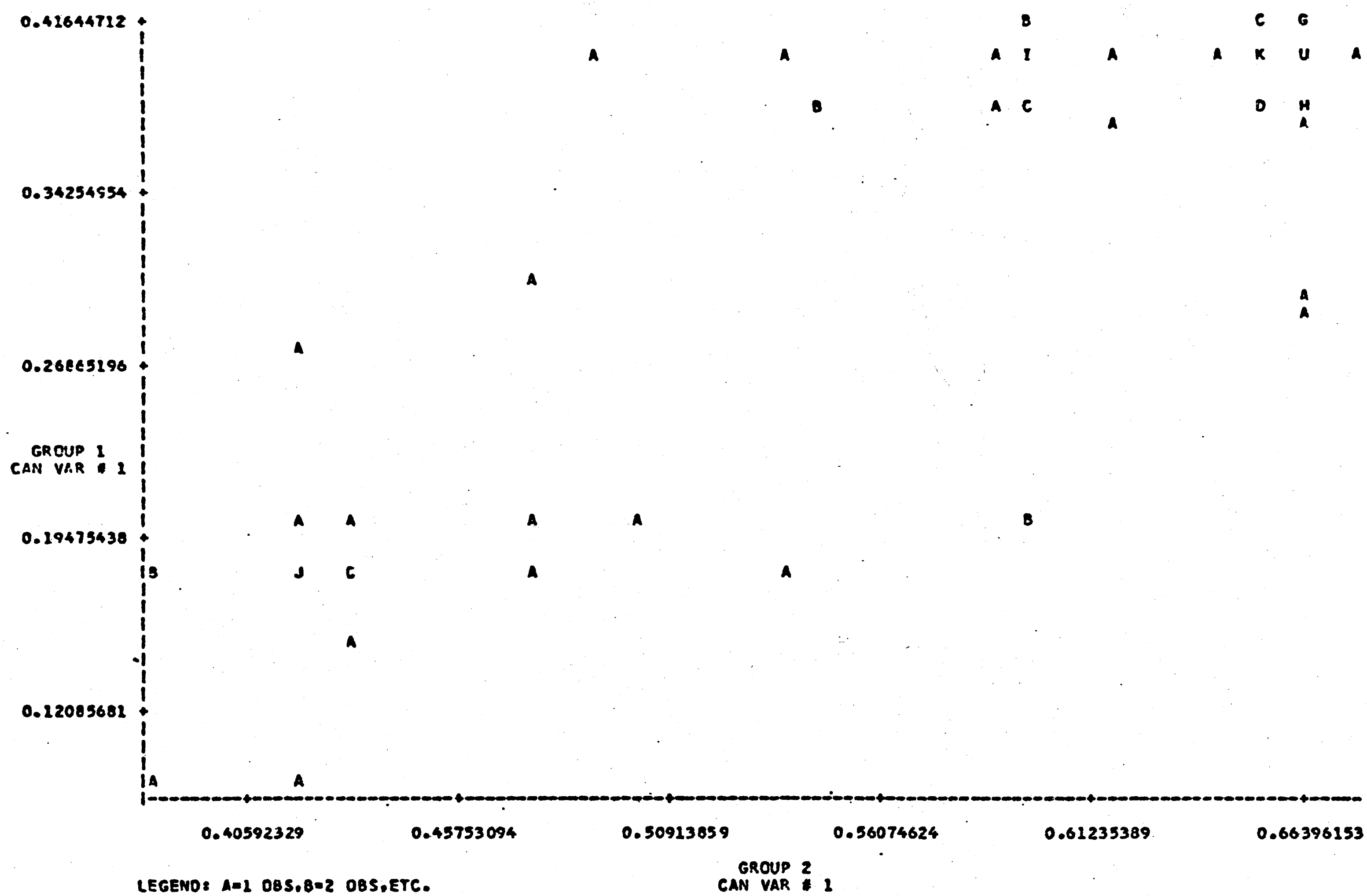


Figure 5.10. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area One.

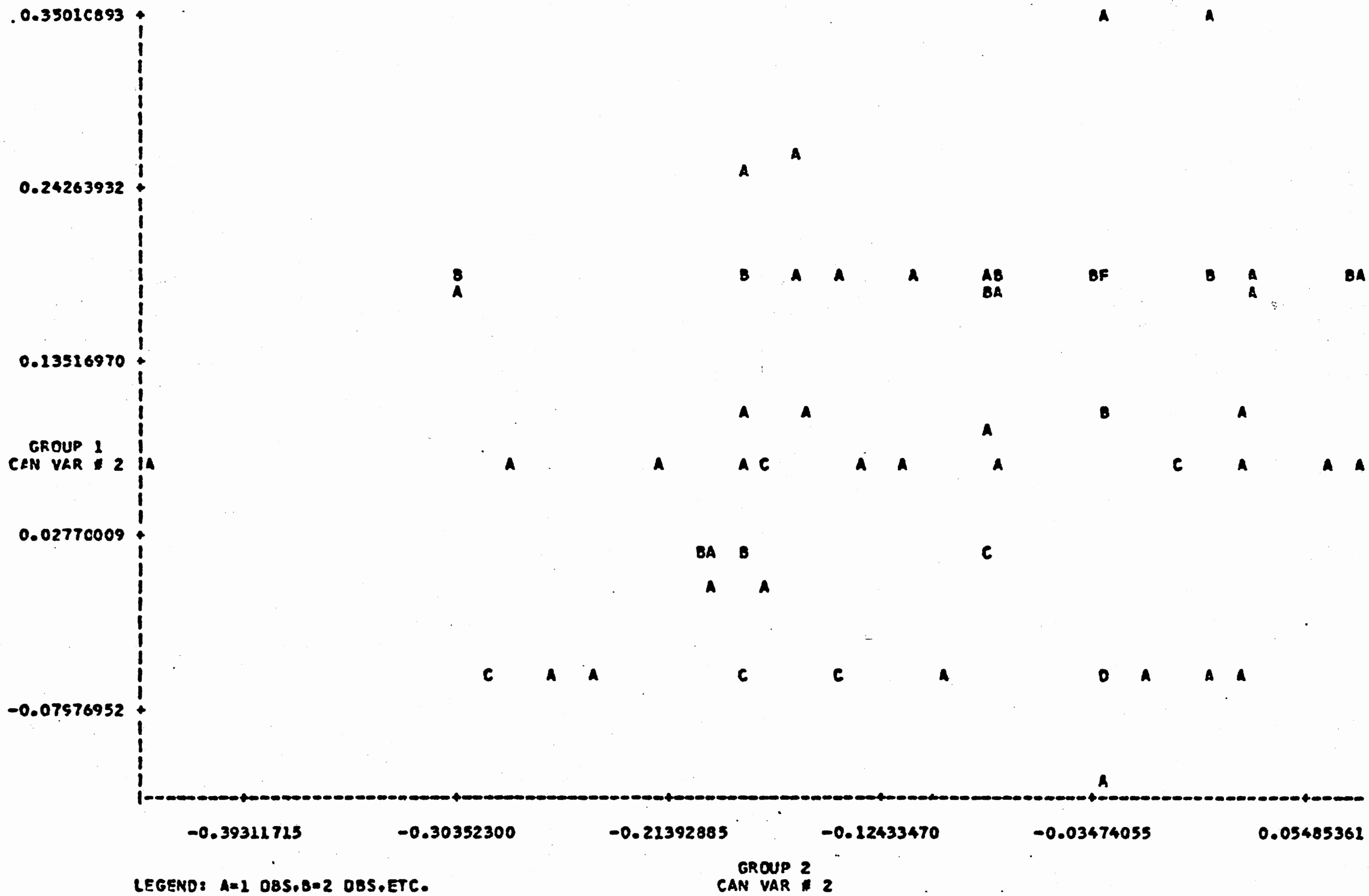


Figure 5.11. Plot of the Compounds in the Plan of the Second Pair of Canonical Variables for All Samples, Area One.

soft, slightly firm or firm, sticky, and plastic soil materials (Table 5.11, Figure 5.12).

Considering the subsurface zone (Area One), the first canonical variate suggested that weak to moderate angular or subangular structure is moderately associated with hard and friable or firm soil materials (Table 5.12, Figure 5.13). The canonical variate for the subsurface (Area Two) suggested that coarse, subangular or angular structure is associated with very hard, friable or firm, and sticky soil material (Table 5.13, Figure 5.14).

Selection of the Diagnostic Criteria

The comparison between morphological properties and their capabilities as a diagnostic criteria is investigated in this section. The mathematical and the statistical concept involved in this approach were outlined in Chapter Four. Preliminary results are reported here. No statistical tests are carried in this investigation.

Area Two, All Samples, Color/Coating, Figure 5.1

Four very-well compacted groups can be recognized along the coating axis. Only four points belong to a separate group. Subdivision could be carried along the color axis, but with excessive overlapping. The significance of the clustering along the color axis is not clear and should be established by the statistical procedures. The superiority of the coating over the color as a diagnostic criteria is clear.

TABLE 5.11

CANONICAL CORRELATION ANALYSIS FOR ALL SAMPLES, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	0.34241905	0.58945650	0.87807228	160.93921	12	0.0001
2	0.91349644	0.58000343	0.21006062	6.16071	6	0.4058
3	0.95047019	-0.61462744	0.11598923	1.42221	2	0.4956

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.919050	0.521195	-0.928530
VAR # 2	0.008951	0.777717	0.205358
VAR # 3	0.394040	-0.351443	0.309289

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.981384	0.844150	0.785948	0.807774
VAR # 2	-0.132958	-0.113752	0.554701	0.328483
VAR # 3	0.117309	0.075277	0.251104	-0.489308

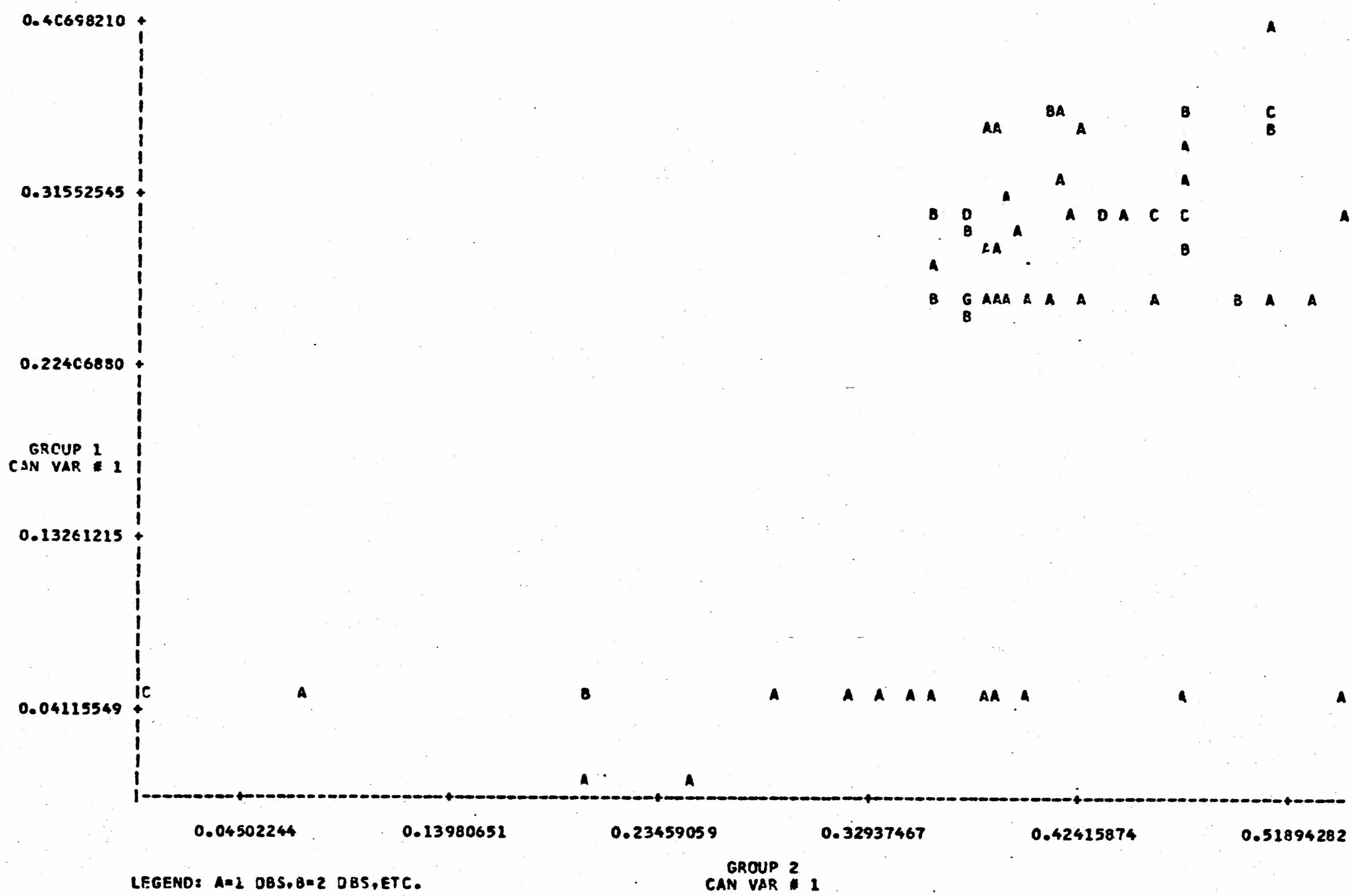


Figure 5.12. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for All Samples, Area One.

TABLE 5.12

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE ZONE, AREA ONE

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.29317599	0.22025221	0.59292610	27.85614	12	0.0059
2	0.99404984	0.16451238	0.34101831	8.36269	6	0.2117
3	-0.13574512	-1.21664589	0.24558473	2.79933	2	0.2454

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.252542	0.738324	0.522435
VAR # 2	0.941245	-0.182747	-0.335109
VAR # 3	-0.224234	-0.649215	0.784069

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.777537	0.517890	0.286167	-0.221597
VAR # 2	0.318604	-0.512491	0.353834	-0.025135
VAR # 3	-0.510224	-0.644245	-0.810790	-0.838477

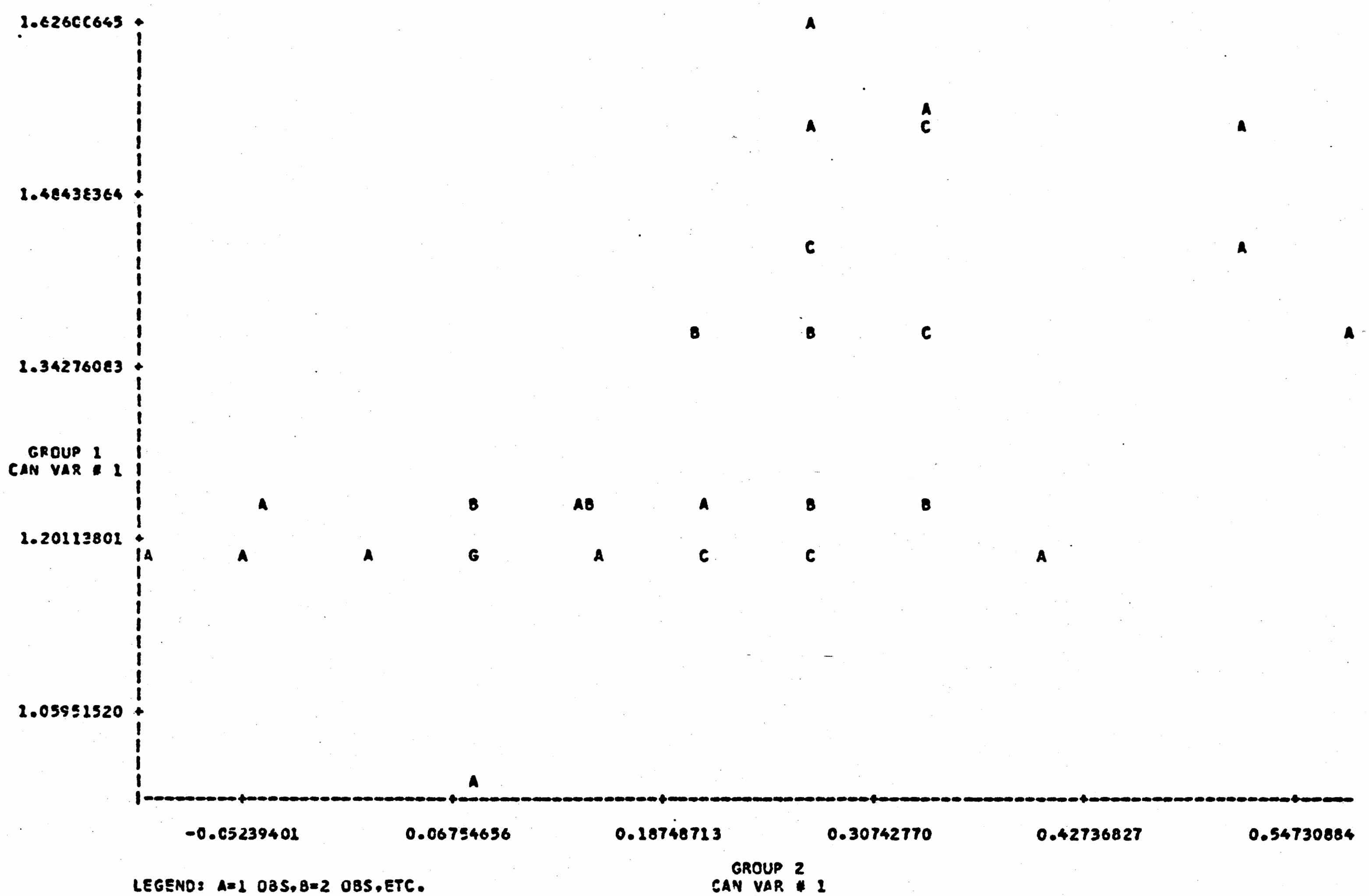


Figure 5.13. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area One.

TABLE 5.13

CANONICAL CORRELATION ANALYSIS FOR THE SUBSURFACE ZONE, AREA TWO

CANONICAL VARIABLE	MEAN OF GROUP 1 CANONICAL VARIABLE	MEAN OF GROUP 2 CANONICAL VARIABLE	CANONICAL CORRELATION	CHI-SQUARE	DF	PROB > CHI-SQ
1	1.14546939	1.38489253	0.52440995	31.03479	12	0.0020
2	0.61025831	-0.90117216	0.19096540	4.66428	6	0.5894
3	1.15354950	0.64302502	0.13978099	1.61803	2	0.4488

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 1 AND THE VARIABLES OF GROUP 1

CANONICAL	CLAS	GRAS	TYPS
VAR # 1	0.896749	0.184790	-0.618063
VAR # 2	0.428998	-0.642313	0.618433
VAR # 3	0.108632	0.743635	0.485323

CORRELATION COEFFICIENTS BETWEEN EACH CANONICAL VARIABLE OF GROUP 2 AND THE VARIABLES OF GROUP 2

CANONICAL	DRY	MOIST	STK	PLCT
VAR # 1	0.946425	0.542713	0.602631	0.445322
VAR # 2	0.182606	0.131683	0.069361	-0.845585
VAR # 3	-0.241057	-0.141664	0.772701	0.281296

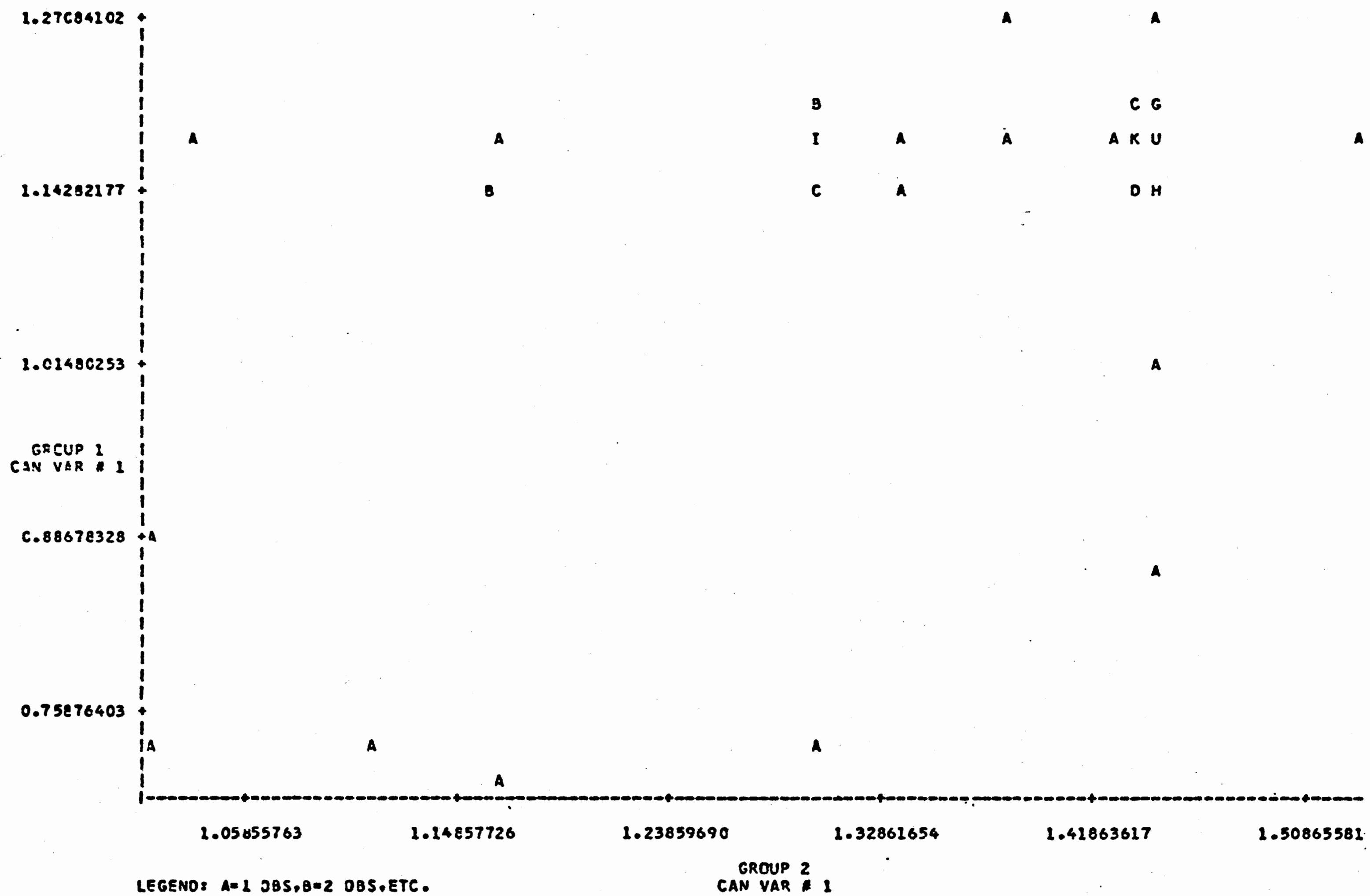


Figure 5.14. Plot of the Compounds in the Plan of the First Pair of Canonical Variables for the Subsurface Zone, Area Two.

Area One, P.M. Zone, Color/Coating, Figure 5.2

One major group can be recognized along the coating axis. No major grouping is recognized along the color axis. If the definition of the P.M. (the Cr horizon), to be consistent with this approach, no more than one major group should be formed. Because, eventhough genesis is not directly mentioned in the formation of the coating, they occur as a result of genetic processes. This process is not allowed in the P.M. zone. Some scattered points are present. These points could represent the locations where the shale interbeds with the sandstone in the Permian Formation.

Area Two, All Samples, Color/Structure, Figure 5.3

Four discrete, compacted groups can be established along the structure axis. About eight points are not assigned to any groups. Another four, less-compacted groups, with only two unclassified points, can be established along the color axis. The superiority of each grouping should be evaluated by the statistical procedures.

Area Two, All Samples, Color/Structure, Figure 5.4

Four compacted groups can be recognized along the structure axis with very little overlapping and unclassified points. Some clustering can be recognized along the color axis, but with overlapping and less dense clusters. The boundary of each group along the color axis should be established statistically. Tendency of the structure superiority can be anticipated at this point, but for a conclusive result, statistical tests should be employed.

Area Two, All Samples, Color/Mottles, Figure 5.5

Four discrete, compacted groups can be recognized along the mottles axis with three points forming a small separate group. No overlap exists between different groups. Four, but less compacted clusters with much overlapping can be established along the color axis.

If the soil is to be classified using the mottles as a diagnostic criteria, compacted and dissected groups can be easily established. A subdivision utilizing the mottles to subgroup would result in less overlap than if the subdivision would have been carried along the color axis. The capability of the mottles to produce more decisive grouping than the color is very clear and statistical evaluation would further support this conclusion.

Area One, All Samples, Color/Roots, Figure 5.6

Three compacted groups can be established along the roots axis with few unclassified points. Each roots group can be subdivided to several, less defined, overlapping subgroups. The limit on the suggroups should be established by statistical procedures. In this case, many points would be classified as inclusions.

Area One, Subsurface Zone, Color/Roots, Figure 5.7

Two major compacted groups can be recognized along the roots axis. few points did not belong to any of the major groups. If the color is used as a secondary criteria, many indistinctive subgroups with more unclassified points would result. In this case, many points would be regarded as soil inclusions. At this stage, the inclination is to consider the roots as a better criterion than the color unless statistically proven otherwise.

<u>Area Two, All Samples, Structure/Pores Orientation, Figure 5.8</u>

Three major groups can be established along both axes with subdivision possibilities within each group also along both axes. The compactness, or the confidence intervals on each group and the superiority of either property should be evaluated statistically.

<u>Area One, All Samples, Structure/Roots Distribution, Figure 5.9</u>

Two major groups can be recognized along the roots axis with few unclassified points. Three groups, but with more overlapping, can be produced along the structure axis. Subdivision for more dense subgroups is possible along both axes. There is strong tendency for the roots to produce more dissected groups than the structure. However, the subdivision should be evaluated statistically.

<u>Area One, All Samples, Structure/Consistence, Figure 5.10 and 5.11</u>

Several groups can be recognized along the consistence axis with several points occupying the overlapping position. Two major, more-compacted groups can be recognized along the structure axis, but with less unclassified points. Subdivision could be carried along both axes. Using the second canonical plan, the consistence exhibits very weak clustering capability. However, structure produces more groups with higher number of overlapping and unclassified points than in the case of the first canonical plan.

Area Two, All Samples, Structure/Consistence, Figure 5.12

Two major, dissected groups can be recognized along the structure axis. No overlapping or unclassified points are shown along this axis. No clustering is produced along the consistence axis. Some clustering patterns do exist, but with excessive overlapping. The presence of any groups or subgroups along this axis should be established by different statistical procedures. The superiority of the structure as a diagnostic criteria is very clear and can be further substantiated by the statistical evaluation.

Area One, Two, Subsurface Zones, Structure/Consistence, Figure 5.13 and 5.14

Three groups can be recognized along the structure axis with one unclassified point. Subdivision is possible also along this axis. Several, small groups, but with many unclassified points, can be established along the consistence axis. Major groups and subdivisions along this axis should be determined statistically, but it may depend on the number of the groups that need to be established. The same pattern also exists in Area Two (Figure 5.14). Two major groups are recognized along the structure axis with several small groups along the consistence axis. Many unclassified points are shown along both axes.

Conclusions

Relationships between many soil morphological properties were investigated using the canonical correlation technique. Significant associations were found to exist between different soil morphological properties. Inference about specific states of the soul properties was possible by this technique. This would help stimulate further investigations on the source of the variation, especially if hypotheses concerning these variations or the factors involved are to be formulated.

Many morphological properties are used as a diagnostic criteria in the present system of classification. Constructing different compounds that represent the soil properties and plotting these compounds in what is called the plan of the canonical variables showed to be a potential technique to test the suitability of different properties in producing different soil groups or subgroups. Testing the suitability of the different properties to be selected as a differentiating criteria was outlined.

However, it should be noted that this technique would not immediately produce taxonomical categories, but subsequent discriminant analyses should be used to test the significance of the classification groups or subgroups produced by the canonical variables. The use of this technique would also allow to assign, with a calculated probability (degree of affinity), the soil that would be considered as inclusions otherwise. Furthermore, percentage and precise characterization of soil conclusions would be possible. One of the most important features of this technique is that all the aforementioned computations can be done with maximum objectivity and utilizing statistical procedures.

CHAPTER VI

FACTOR ANALYSIS, AREA TWO

Abstract

A data set that consists of 109 horizons (23 locations) was used in this study. A total of 24 morphological and 14 chemical properties were used. The total data set was represented by a 109X38 matrix. The profiles were partitioned into the following zones and sets: 1) All samples (with three sets), 109X38, 109X24, and 109X14; 2) Surface zone (includes all horizons with Ap designation) represented by two sets, 23X14 and 23X14; 3) Subsurface zone (includes all horizons with B designation) represented by two sets, number of B'sX24 and number of B'sX14.

Principal component axes were computed for all the above zones using the different sets. Ten principal axes were retained for factor analysis. Characteristic roots, final communality estimates, the contributions of different factors to the common variance, and the correlation between the different rotated factors and the soil properties were also reported. An index to indicate the magnitude of the variation of different soil properties was formulated.

The factors' model was an effective tool in scanning the soil variations. The ten factors' model was sufficient for the morphological properties, while the six factors' model was more appropriate for the chemical properties. This indicated higher variability among

morphological than chemical properties. This was true regardless of the partitioning procedure. However, better understanding on the possible source of the variation among the different properties could result when the data are partitioned into subsets. Nevertheless, more compacted groups or clusters resulted when the data were not partitioned. In this case, the first three factors were the most important but with lower communality estimates than in the case of partitioned sets. The loading index indicated the importance of various soil properties within each horizon regarding the magnitude and the contribution to the total variation. However, as a general result, properties related to soil moisture were the most variable in the soils of this area.

Introduction

Mathematical classification is not the only way of expressing the relationships between continuous variables like soil. Alternatives to mathematical classification have been pursued by soil scientists. These alternatives include what is called ordination. Principal component and factor analysis are some of the techniques which have been used to study the relationships between soils, Cuanalo (18), Holland (31), and Arkley (2).

The principal component (PC) analysis is concerned with arranging soil individuals along a few axes chosen so as to preserve as much information as possible about the soil individuals being studied. The axes are derived mathematically and possess certain properties that can be used in studying the relationships between soil individuals. Physically, it could be said that the technique involves looking inside a single set of variables and attempting to assess the structure of these variables after they have been transformed to a system of independent variables.

A brief summary of the mathematical concepts involved is given here. For greater detail, many texts are available (Morrison, 46; Richards, 56; and Harman, 32). Suppose we have P measurements like color, organic matter, calcium, and potassium on as many as N observations. N can be either the number of soil profiles or the number of horizons. The original data can be represented in a matrix notation as follows:

$$X = \begin{bmatrix} X_{11} \cdots\cdots\cdots X_{p1} \\ \cdot \qquad\qquad \cdot \\ \cdot \qquad\qquad \cdot \\ \cdot \qquad\qquad \cdot \\ X_{1N} \cdots\cdots\cdots X_{pN} \end{bmatrix}. \tag{6.1}$$

Let us further assume that the covariance matrix Σ is of full rank and the characteristics roots $\lambda_1 > \ldots\ldots\ldots \lambda_p$ of Σ are all distinct. The set of the original P variables are used to generate new P variables $Y_1, Y_2 \ldots\ldots\ldots Y_p$ as follows:

$$\begin{aligned} Y_{11} &= a_{11}X_{11} + \ldots\ldots\ldots a_{p1}X_{p1} \\ &\vdots \\ Y_{1N} &= a_{1N}X_{1N} + \ldots\ldots\ldots a_{pN}X_{pN} \end{aligned} \tag{6.2}$$

or $Y = A'X$ where each column of A contains the coefficients for one principal component. Thus the Y_i's (principal axes) are linear combinations of the original data. The Y_i's are constructed such that the sample variance of $Y_i = a_i'X$ given by $S_{Y1}^2 = \tilde{a}'S\tilde{a}$ is greatest for all coefficient vectors normalized so that $\tilde{a}'\tilde{a} = 1$ where S is variance-covariance matrix. The problem is not to determine a_i subjected to the above constraint. Using the Lagrange Multiplier, it can be proved that the coefficient must satisfy the P-simultaneous linear equations

$$|S- \lambda I|\tilde{a}_i = 0. \tag{6.3}$$

If the solution to these equations were to be other than the null vector, the value of λ_i must be chosen so that the determinant

$$|S- \lambda_i I| = 0 \tag{6.4}$$

λ_i is thus the characteristics root of the covariance matrix and $\tilde{a}_i$ is its associated characteristic vector. Since $\tilde{a}_1\tilde{a}_1 = 1$, thus

$$\begin{aligned} 1 &= \tilde{a}_1'S\tilde{a}_1 \\ &= S_{Y1} \end{aligned} \tag{6.5}$$

where S_{Y1} is the variance of the first principal axis. Since the coefficient vector was chosen to maximize the variance, then λ_1 must be the greatest characteristic root of S. Therefore, the first principal axis possesses the property of explaining the largest amount of the variations of soil variables.

The second principal axis is the linear combination $Y_2 = a_2'X$, whose coefficients have been chosen subjected to the constraint, $\tilde{a}_2'\tilde{a}_2 = 1$, $\tilde{a}_1'\tilde{a}_2 = 0$, so that the variance of Y_2 is a maximum. From the above restrictions, it can be seen that the Y_2 is independent of Y_1, and next to Y_1, Y_2 has maximum variance. $Y_3 \ldots\ldots Y_p$ are constructed in the same way.

All of the original data are now transformed to a new system whose axes are orthogonal. Each axis accounts for a portion of the original variance. The following model expresses the whole system:

$$Y_{ij} = a_{1j}X_1 + a_{2j}S_2 + \ldots\ldots a_{pj}X_p \tag{6.6}$$

and the total system variance is $\lambda_1 + \lambda_2 \ldots\ldots + \lambda_p = \text{tr } S$, where λ_i's are the eigenvalues of S. The contribution of the jth component in explaining the variation of the system is

$$\frac{\lambda_i}{\text{tr } S} \text{ X } 100. \tag{6.7}$$

The moment correlation of the ith response and the ith component will then be

$$\frac{a_{ij}\sqrt{\lambda_j}}{S_i} . \tag{6.8}$$

If the components have been extracted from the correlation matrix rather than S, the sum of the characteristics roots will be

$$\text{tr } R = P \tag{6.9}$$

The proportion of the variance of the ith component to the total variance is

$$\frac{\lambda_i}{P} . \tag{6.10}$$

If the correlation matrix was used in the transformation, the new system is described as follows:

$$Y_{i1} = a_1 A_i, \ \ldots\ldots \ Y_{ir} = a_1 Z_i, \text{ where } Z_i = X_i - \bar{X} \qquad (6.11)$$

Principal Factor Analyses

Principal factor analyses was introduced by Spearman (64), and was developed to its present level by Gernett (26) and Thurstone (66). The technique aims to explain observed relations among numerous variables in terms of simpler relations. The simplification may be by producing a set of classification categories or creating a smaller number of hypothetical variables. Actually, factor analysis is a way of classifying manifestations of variables, but not immediately the producer of taxonomy of individuals. Two routes of factors computation have been followed (Cattel, 16): 1) the principal axes method; 2) the centroid method. In this study the principal axes method will be followed. Previously in the section of the principal component analysis, we already constructed the following model

$$Y_i = \sum_{j=1}^{p} a_{ij} X_j$$

$$j = 1, \ldots\ldots p \qquad (6.12)$$

or in matrix notation, $Y = A'X$. From this it follows that X can be regenerated from Y

$$\begin{bmatrix} X_1 \\ \vdots \\ X_p \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \cdots\cdots\cdots\cdots a_{N1} \\ & \\ a_{p1} & a_{2p} \cdots\cdots\cdots\cdots a_{Np} \end{bmatrix} \begin{bmatrix} Y_1 \\ \vdots \\ Y_N \end{bmatrix} \qquad (6.13)$$

$$\sigma_{ii} = \sum_{k=1}^{p} a_{ki}^{2} \, v(Y_k) \quad = \quad \sum_{k=1}^{p} a_{ki}^{2} \, \lambda_k . \tag{6.14}$$

Thus the mathematical model or the general linear representation of the data can be given in the following model:

$$\begin{bmatrix} X_1 \\ \cdot \\ \cdot \\ \cdot \\ X_p \end{bmatrix} = \begin{bmatrix} \lambda_{11}F_1 + \lambda_{12}F_2 + \ldots\ldots \lambda_{1m}F_m \\ \\ \\ \\ \lambda_{p1}F_1 + \lambda_{p2}F_2 + \ldots\ldots \lambda_{pm}F_m \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \cdot \\ \cdot \\ \cdot \\ \varepsilon_m \end{bmatrix} \tag{6.15}$$

or $X_p = \Lambda \underset{\sim}{F} + \underset{\sim}{\varepsilon}$ in matrix notation where Λ is a factor loading matrix, $\underset{\sim}{F}$ is a common primary latent factor, $\underset{\sim}{\varepsilon}$ is an error vector. The assumptions underlying the above model are: 1) the F's are independent, zero means unit variance; 2) the $\underset{\sim}{\varepsilon}$'s are independent, zero means variance ψ_i; and 3) the F's and the ε's are independent. As a consequence,

$$\sigma_{ii} = \sum_{j=1}^{m} \lambda_{ij}^{2} + \psi_i ,$$

$$\text{for } j = 1, \ldots\ldots, m,$$

$$i = 1, \ldots\ldots, p. \tag{6.16}$$

The first term $\sum_{j=1}^{m} \lambda_{ij}^2$ is called communality of the ith response (denoted h_i), while ψ_i is called specificity.

$$\sigma_{ij} = \sum_{k=1}^{m} \lambda_{ik} \, \lambda_{jk} ,$$

$$\text{for } i \neq j \tag{6.17}$$

which is in matrix notation

$$\Sigma = \Lambda\Lambda + \psi \tag{6.18}$$

From these relations it can be seen that the PC model regenerates the original data from the PC's, while the factor model partially regenerates the data from the common factors. Also, in the PC model, the σ_{ii}'s completely accounted for the PC's variance, but in the factor model, the σ_{ii}'s were split into two parts, the communality (that part of σ_{ii} attributed to the common factors), and the specificity (that part of σ_{ii} attributed to the error). Let

$$F_j = \frac{Y_j}{(\lambda_j)^{\frac{1}{2}}},$$

$$\text{for } j = 1,\ldots\ldots m, \tag{6.19}$$

and their corresponding loading $\lambda_{ij} = a_{ji}(\lambda_j)^{\frac{1}{2}}$. Also let

$$\varepsilon_i = \sum_{j=m+1}^{p} a_{ji} Y_j,$$

$$\text{for } j = 1,\ldots\ldots p. \tag{6.20}$$

Thus the factor model can be rewritten as follows:

$$X_i = \sum_{j=1}^{m} a_{ij} Y_j + \sum_{j=m+1}^{p} a_{ji} Y_j, \text{ or} \tag{6.21}$$

$$X_i = \sum_{j=i}^{m} a_{ij} (\lambda_j)^{\frac{1}{2}} \frac{Y_i}{(\lambda_j)^{\frac{1}{2}}} + \sum_{j=m+1}^{p} a_{ji} Y_j,$$

$$\text{for } j = 1, \ldots\ldots p. \tag{6.22}$$

As a consequence, the new model is

$$X_i = \sum_{j=1}^{m} \lambda_{ij} F_j + \varepsilon_i, \text{ where } \lambda_{ij} = a_{ij} = a_{ji}(\lambda_j)^{\frac{1}{2}} \tag{6.23}$$

$$\text{and } F_j = Y_j/(\lambda_j)^{\frac{1}{2}} \tag{6.24}$$

and the communality of the ith response is

$$\sum_{j=1}^{m} \lambda_{ij}{}^2 = \sum_{j=1}^{m} a_{ij}{}^2 \lambda_j, \text{ and } \psi = \Sigma a_{ji} \lambda_j^2. \tag{6.25}$$

In the PC model

$$\mathrm{corr}(X_i, Y_j) = \frac{(a_{jj} \cdot \lambda_j)^{\frac{1}{2}}}{S_{ii}} \tag{6.26}$$

while in the factor model,

$$\mathrm{corr}(S_i, F_j) = a_{ji} \cdot (\lambda_j)^{\frac{1}{2}} = \lambda_{ij}. \tag{6.27}$$

The factor loading are interpreted as the correlation between the response (standardized) and the latent factors.

Factor Rotation

It is well known that an orthogonal transformation of uncorrelated variables result in uncorrelated variables. Furthermore, if the coefficient producing the transformation are appropriately normalized, the variance of the original variables remain unchanged. Denote, by F, the mxn matrix of each of the m factor scores on the units, and let 0_{mxn} be any orthogonal matrix, such as, $0'0 = 00' = 0$. Thus the factor model becomes

$$X_{pxn} = \Lambda_{pxm} \cdot F_{mxn} + \varepsilon_{pxn}, \text{ or } X = 0'0F + \varepsilon \tag{6.28}$$

$$= C \cdot F^R + \varepsilon \tag{6.29}$$

Thus we have a new factor model in which the communalities and the specificities of the original model remain unchanged. The elements of C have the same interpretation as the elements of Λ.

$$C_{ij} = \mathrm{corr}(X_i, F_j^R). \tag{6.30}$$

Statistical Approach

Each area was treated as an independent unit and the series boundaries were ignored in this study. Three genetic zones were recognized. The surface zone (includes the Ap, and A12 horizons), the subsurface zone (includes all horizons whose field designations start with B), and all samples (all samples were treated alike without reference to the field designations). The last one will be referred to as "all samples analysis."

SAS (1976) was used in the computations. Principal axes were computed first. The largest portion of data variance was accounted by the first ten axes. Therefore they were retained for subsequent analysis. Eigenvalues and the contributions of each axis to the common variance were also computed. Ten axes were used to build the principal factors' model. The Varimax solution was employed for rotation of the factors.

The data set was partitioned into three sets, the chemical data set, the morphological data set, and all data combined together. Each of these sets was subjected to principal component analysis. This approach was followed in order to achieve the following objectives: 1) to study the sources of variation in each genetical zone in the soil profile and for the whole profile; and 2) a data reduction device was employed whereby sorting the different soil properties according to a certain weight determined by higher loading, the property association with the factor that accounts for a larger portion of the data variance will be discovered. Furthermore, it is hoped that this technique will yield an index to be used in selecting the most appropriate properties suitable for the cluster analysis.

Results and Discussion

A correlation of .4 or higher was declared significant in this study. This was an arbitrary and subjective choice.

Chemical Data, Surface Zone

Six axes accounted for 91.5% of the total variation. Twelve principal axes accounted for 100% of the variation. The first axis was correlated with pH, Ca, Mg, BST, CEC, clay, silt, and accounted for 34.9% of the total variance. No significant correlations were indicated between axes 8, 9, 10, and any of the soil properties (Table 6.1).

Ten principal axes were used to build the factors' model. The computed factors' model accounted for 99% of the total variance. Six factors accounted for 85% of the common variance (Table 6.2). Final communality estimates were above 97% for all soil properties. This indicates that the constructed model has a high capability in explaining the variation and regeneration of the original soil properties involved in the computation.

Table 6.2 shows the analysis of the rotated factor model. The coefficients listed under the heading "factor pattern" can be interpreted in two different ways. They are either the correlations between each factor and all the soil properties, or they are the loading

TABLE 6.1

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.45086	-0.12911	0.60085	0.47351	0.15335	-0.11030	-0.00749	0.38741	0.05910	0.06176
H	-0.50872	0.51219	-0.37754	0.45009	0.22561	-0.17065	0.14530	-0.05524	-0.01754	0.10820
CEC	0.59904	0.65339	0.21477	0.31075	0.08598	0.18369	0.02042	-0.07671	-0.12832	-0.06869
CACO3	0.55143	-0.03595	-0.54730	-0.22453	-0.01764	-0.33080	0.44632	0.14924	-0.09150	-0.06432
PH	0.64586	-0.30181	0.32774	-0.17528	-0.06714	0.04007	-0.06680	0.07826	-0.06548	-0.07952
OM	-0.02667	-0.26176	0.55088	0.50549	-0.45331	-0.14950	0.30059	-0.20932	0.08651	-0.03820
FS	0.23220	-0.54411	0.04107	0.11336	0.73970	0.15792	0.19460	-0.12883	0.06982	-0.03946
VFS	0.01647	-0.53211	-0.46459	0.23689	-0.28935	0.55444	0.18753	0.10433	-0.04962	0.06873
CLAY	0.65572	0.02466	-0.59412	0.33794	-0.12934	-0.13819	-0.23745	-0.01702	0.08542	-0.04579
SILT	-0.66424	0.18364	0.60619	-0.35300	-0.01488	0.01682	0.15296	0.02831	-0.08362	0.03324
CA	0.94793	0.06510	0.18786	-0.05598	0.02720	0.06622	0.01189	-0.18231	-0.03276	0.03320
MG	0.72205	0.64642	0.06778	0.10101	-0.01752	0.06679	0.03069	-0.01911	-0.08148	0.09242
NA	0.24133	0.82157	-0.01997	-0.31676	-0.05697	0.23873	0.18840	0.08355	0.24756	-0.03359
BST	0.80309	-0.36150	0.01968	-0.39202	-0.05340	-0.14346	0.01694	-0.10743	0.06555	0.17445

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.998296	0.982457	0.997083	0.999042	0.972011	0.999175	0.997506

VFS	CLAY	SILT	CA	MG	NA	BST
0.999744	0.999658	0.999805	0.981917	0.975264	0.999085	0.999694

	1	2	3	4	5	6	7
EIGENVALUES	4.889664	2.708132	2.238742	1.435149	0.947094	0.646554	0.505290
PORTION	0.349	0.193	0.160	0.103	0.068	0.046	0.036
CUM PORTION	0.349	0.543	0.703	0.805	0.873	0.919	0.955

	8	9	10	11	12	13	14
EIGENVALUES	0.311930	0.135335	0.082848	0.053148	0.044587	0.001232	0.000293
PORTION	0.022	0.010	0.006	0.004	0.003	0.000	0.000
CUM PORTION	0.977	0.987	0.993	0.997	1.000	1.000	1.000

TABLE 6.2

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE CHEMICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.24773	0.22444	0.05102	0.29918	0.19212	-0.09846	-0.09148	0.85899	-0.04008	-0.00168
H	-0.96514	0.10395	0.08535	-0.02978	-0.00673	-0.10836	0.06165	-0.06662	-0.03356	0.10411
CEC	0.02238	0.95473	0.16279	0.06070	0.01377	-0.11132	-0.06034	0.16980	-0.04259	-0.08959
CACO3	0.19567	0.09509	0.35913	-0.13246	0.03146	0.04627	0.89114	-0.08174	0.03317	0.00832
PH	0.88196	0.24574	0.16329	0.06917	0.12056	0.00308	0.10398	0.25929	-0.06776	-0.07166
CP	0.06348	-0.04462	-0.10492	0.96037	-0.04936	0.05862	-0.10293	0.20363	-0.04367	-0.00208
FS	0.17118	-0.11459	0.05529	-0.04582	0.95990	0.08059	0.03183	0.13794	-0.04421	0.00497
VFS	0.03199	-0.22850	0.24939	0.06358	0.08622	0.93007	0.03733	-0.07774	-0.01886	-0.00491
CLAY	0.10054	0.21096	0.94807	-0.05479	-0.06778	0.07922	0.17733	0.02379	-0.01724	0.00577
SILT	-0.14698	-0.12913	-0.91878	0.06615	-0.17056	-0.21839	-0.18097	-0.03997	0.03290	-0.01403
CA	0.86552	0.61499	0.29387	0.07879	0.18180	-0.08382	0.11984	0.06587	-0.03714	0.08976
MG	0.16069	0.90456	0.23649	-0.05468	-0.12689	-0.13049	0.12810	0.11575	0.01784	0.09508
NA	-0.04332	0.71205	-0.15841	-0.27208	-0.26583	-0.09098	0.14357	-0.15651	0.51673	0.00199
BST	0.85378	0.06406	0.26839	-0.01594	0.14203	-0.06766	0.31172	-0.02781	0.01060	0.26751

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.63311	0.51841	-0.46866	0.00277	0.13144	-0.00988	0.24724	0.17394	0.00057	0.04497
2	-0.41860	0.71422	0.09399	-0.19490	-0.36370	-0.31404	-0.00099	-0.08957	0.16999	-0.00495
3	-0.32633	-0.16362	-0.59032	-0.39562	-0.03838	0.29772	0.35653	-0.37782	0.02846	0.03111
4	-0.49129	0.15246	-0.42736	0.48824	0.14713	0.18736	-0.22984	0.41334	-0.17826	-0.04652
5	-0.20118	0.05795	0.07426	-0.44347	0.79609	-0.30030	-0.01337	0.16390	-0.05327	0.01275
6	0.08180	0.31516	0.19704	-0.21368	0.17000	0.73072	-0.43698	-0.14192	0.15657	-0.10507
7	-0.16276	0.16000	0.37500	0.38290	0.26237	0.26793	0.69139	-0.06010	0.18877	0.05266
8	-0.03601	-0.13586	0.10422	-0.38945	-0.28315	0.21740	0.23826	0.76035	0.16607	-0.16626
9	0.00203	-0.15476	-0.19786	0.13297	0.10170	-0.13354	-0.17537	0.03670	0.91119	0.16935
10	-0.03138	0.02078	0.07371	-0.09391	-0.07288	0.12854	-0.04757	0.13425	-0.13299	0.96152

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.075801	2.878203	2.250674	1.135712	1.157615	1.001809	1.046506	0.956745	0.284656	0.113017

(relative weight of each soil property on each factor). Furthermore, the summation of the squared values of these correlations is the portion of the variance explained by that factor.

For example, the first factor, by construction, explained as high as 22% of the total variation in the data. Hydrogen had a loading of (-.96), pH (.88), Ca (.89), and base saturation (.85). The rest of the soil properties did not show any significant (above .4) loading with this factor. This suggested that H, pH, Ca, and BST are the soil properties that contributed largely to the soil variation in the surface zone of this area. Thus, the first factor could be regarded as the factor explaining the intensity of leaching and acidity of the surface of the soil.

The second factor accounted for 20.6% of the total variance. It was highly correlated with CEC (.96), Mg (.90), and to a lesser degree with sodium (.71) and Ca (.62). This suggested that factor two is strongly tied with the exchangeable cations and soil capability of holding these cations.

The third factor explained 16.1% of the total variance and was highly associated with soil texture, namely, silt and clay. The fourth factor accounted for 8.1% of the total variance. It was highly correlated with one soil property, that is organic matter (.96). The loading of the rest of the soil properties on this factor were negligible. The fifth factor was correlated with fine sand (.95), while the sixth factor was correlated with very fine sand (.93). The seventh factor was correlated with calcium carbonate (.86). The ninth factor accounted for only 2% of the total variance and had a low correlation with sodium (.52). Factor ten explained only .8% of the total variance and did not show any significant correlation with the soil properties. Figure 6.1 shows the loading of the different locations on factor one and two. The symbols indicate the number of the locations having the same loading. For example, the number 9 indicates that nine different horizons (observations) had the loading values that were the same on factors one and two. These horizons belong to different soils since very few soils have more than one A1 horizon. Since more than one location (observation) had the same loading, the unique identification of the exact location was not possible. The graph showed the presence of several groups. This suggests that if the area is to be mapped on similarity between surface horizons, more than four groups or units would be established.

However, since very compacted (the presence of 12, 9, 8, and 7 observations having the same loading) clusters were observed, this suggests that mapping series with a narrow range of variation of chemical data might be possible. This was substantiated by the fact that six axes were able to explain 91% of the total variance, and it could be assumed that a reasonably homogeneous mapping unit could result.

Morphological Data, Surface Zone

Total variance was 21 (Table 6.3). Six and ten axes accounted for 76.1% and 92.4% of the total variance respectively. The morphological properties had significant correlations with ten principal axes. 92% of the variation of the chemical data was explained by six axes, while ten principal axes were needed to explain the same amount of variation in the morphological data. Final communality estimate, which is the portion of the variables variance explained by the factors' model, were

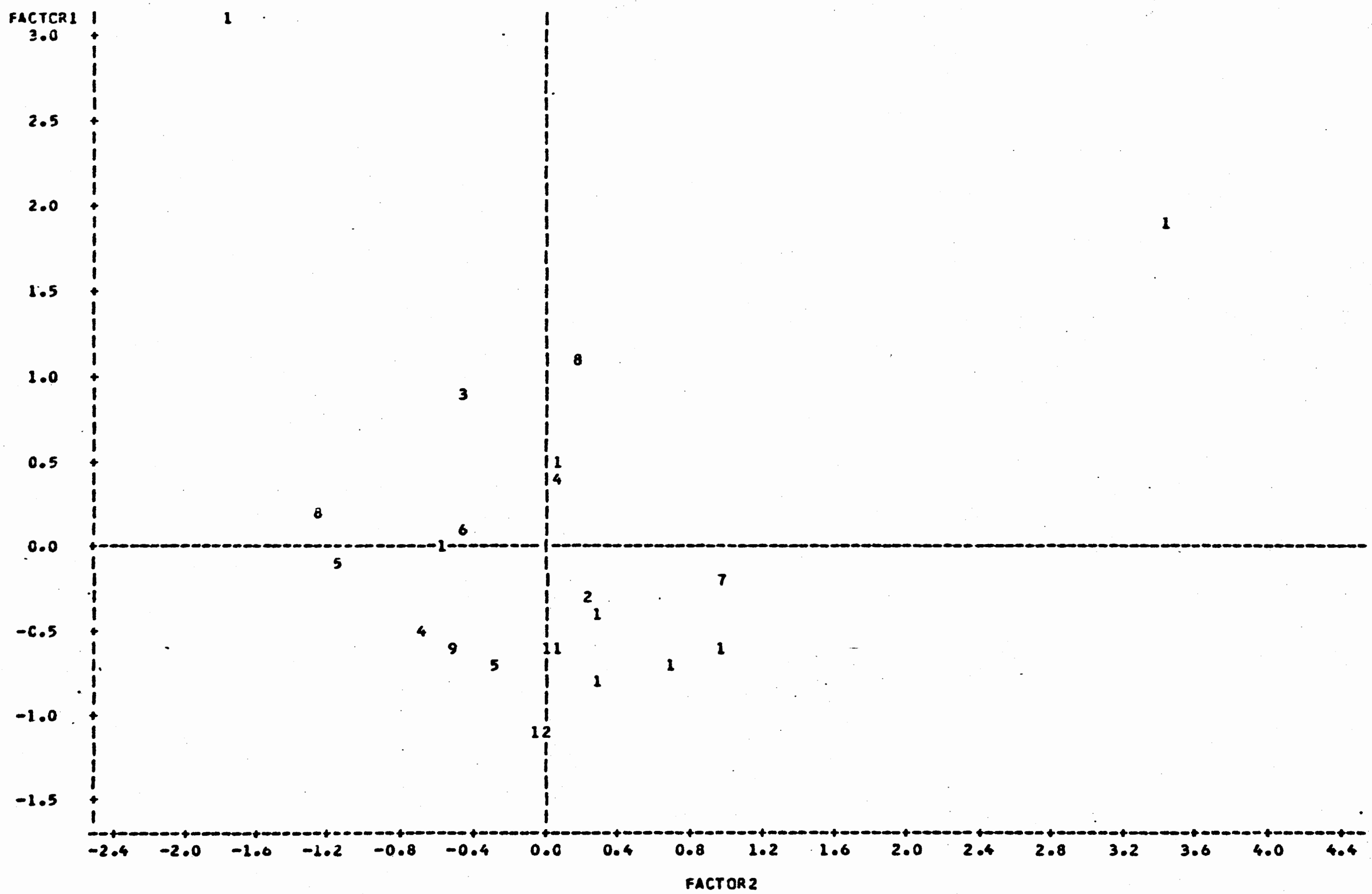


Figure 6.1. Loadings of Different Locations on Factors One and Two for Chemical Properties, Surface Zone.

TABLE 6.3

PRINCIPAL AXES, COMMUNALITY ESTIMATES FOR THE MORPHOLOGICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.38127	-0.52645	-0.35883	0.34530	-0.28192	0.03713	0.40181	-0.03778	-0.08430	-0.06843
THICK	-0.09490	0.08124	-0.18417	-0.73053	-0.34813	0.11871	0.24357	0.18796	0.23222	0.16530
TEXT	0.64160	-0.04260	0.22835	0.13816	0.25349	-0.47118	-0.11892	0.23446	-0.25007	-0.02959
DRY	0.87905	0.10444	-0.36722	0.01000	-0.01481	0.07064	-0.05086	-0.11300	0.03237	0.09455
MOIST	0.91277	0.08564	-0.21857	0.18004	-0.09035	-0.04791	0.07952	0.06295	0.09186	0.03467
STK	0.51921	-0.01810	0.54596	0.22336	0.18665	0.21308	0.03794	0.21764	0.13998	-0.16520
PLCT	0.69037	0.37211	0.18427	-0.26890	0.11325	-0.01128	-0.20063	0.18852	0.20322	0.09094
HUE	-0.00560	0.02027	0.53106	0.34957	-0.47690	-0.48799	0.23554	-0.00448	0.14455	0.01092
VAL	-0.05967	-0.14673	-0.08639	0.11866	0.79760	0.21846	-0.07858	0.39136	0.14836	0.01656
CHRO	-0.12142	-0.25745	0.04740	0.38411	0.48605	-0.18977	0.39715	-0.21330	0.28246	0.42953
CLAS	0.17316	0.27950	0.28488	-0.39025	0.39241	-0.21652	0.35781	-0.04582	-0.52340	0.14567
GRAS	0.60549	-0.01931	0.34464	0.15267	-0.26362	0.42471	0.19693	0.05381	-0.13745	-0.11256
TYPS	0.05272	-0.03603	0.52454	0.06639	-0.19173	0.68470	-0.00107	-0.01994	-0.15206	0.36394
RSIZE	-0.23170	0.88570	-0.13747	0.36308	-0.03524	0.05044	0.02884	0.03715	-0.02626	0.02608
ROUNT	0.19157	0.25374	0.25242	-0.09513	0.44206	0.22448	0.21790	-0.57912	0.17091	-0.32532
CONQUNT	-0.23170	0.88570	-0.13747	0.36308	-0.03524	0.05044	0.02884	0.03715	-0.02626	0.02608
CONSIZ	-0.23170	0.88570	-0.13747	0.36308	-0.03524	0.05044	0.02884	0.03715	-0.02626	0.02608
CONCOLOR	0.25819	0.43487	0.55428	-0.40052	-0.15698	-0.26543	-0.17349	-0.14932	0.20810	0.06036
COATYPE	0.64347	0.07974	-0.36658	-0.10881	0.05263	0.01663	-0.35199	-0.39770	-0.11969	0.15123
PORSIZE	0.16606	0.41459	-0.29669	-0.51833	0.10759	0.02006	0.51470	0.16946	0.02188	-0.10552
PORORIEN	0.91277	0.08564	-0.21857	0.18004	-0.09035	-0.04791	0.07952	0.06295	0.09186	0.03467

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	HUE	VAL	CHRO	CLAS
0.926025	0.894387	0.903497	0.950271	0.951057	0.793797	0.859650	0.948652	0.912142	0.962724	0.967717

GRAS	TYPS	RSIZE	ROUNT	CONQUNT	CONSIZ	CONCOLOR	COATYPE	PORSIZE	PORORIEN
0.832189	0.945187	0.996234	0.937563	0.996234	0.996234	0.917849	0.888934	0.874233	0.951057

	1	2	3	4	5	6	7	8	9	10	11
EIGENVALUES	4.875025	3.403050	2.194078	2.168396	1.927357	1.439700	1.142094	0.948101	0.730424	0.577408	0.512437
PORTION	0.232	0.162	0.104	0.103	0.092	0.069	0.054	0.045	0.035	0.027	0.024
CUM PORTION	0.232	0.394	0.499	0.602	0.694	0.762	0.817	0.862	0.897	0.924	0.948

	12	13	14	15	16	17	18	19	20	21
EIGENVALUES	0.354632	0.229890	0.181051	0.135954	0.102583	0.073662	0.004157	0.000000	0.000000	-0.000000
PORTION	0.017	0.011	0.009	0.006	0.005	0.004	0.000	0.000	0.000	-0.000
CUM PORTION	0.965	0.976	0.985	0.991	0.996	1.000	1.000	1.000	1.000	1.000

less than its chemical counterpart. It varied 79.4% for stickiness to 99% for the root size. This suggests that the degree of variability among the morphological properties is higher than for the chemical properties.

Six principal factors accounted for 67.2% of the variance of the total data (Table 6.4) and 85% of the chemical data. The first factor was responsible for 21.8% of the total variance. It is highly correlated with the consistence variables, namely, dry and moist, coating, and pores orientation, followed by texture, plasticity and the strength of the structure.

It seems that the first factor identifies the properties most important to soil moisture relationships. The second factor accounted for 15.2% of the variance. It is correlated with size of the roots and the concretions. The fourth factor is highly correlated with hue, value, and chroma, and to a lesser degree, with the type of concretions. The ninth factor is highly correlated with structure size. The tenth factor was correlated with chroma and accounted for 5.5% of the variance.

It seems that high correlations existed between morphological properties and different factors. However, 36.3% of the total variance was explained by the first two factors, while the rest of the variance was evenly shared by eight factors. This is a good indication of the high variability among soil morphological properties. This conclusion was supported by plotting the loading of different locations on different factors. The values of the loadings were so scattered that the computer plotter failed to plot them.

TABLE 6.4

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE
OF THE MORPHOLOGICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BAD	0.42818	-0.30190	-0.75470	0.21996	0.05943	0.02320	0.00351	-0.07171	-0.12059	0.09914
THICK	-0.06914	-0.13661	0.16461	0.05070	-0.17070	0.04652	0.87680	-0.14364	-0.06074	-0.12994
TEXT	0.49386	-0.17704	0.18446	0.05331	0.37555	-0.20399	-0.39533	-0.18265	0.46807	0.00052
DRY	0.96066	-0.03113	-0.01016	-0.08847	-0.07337	0.02546	0.05198	0.08086	0.00990	-0.05601
MOIST	0.94570	-0.00125	-0.06509	0.08611	0.20963	-0.00257	0.02405	-0.01377	0.01243	0.01345
STR	0.27813	-0.10470	0.16882	-0.02556	0.70375	0.31703	-0.20737	0.18696	0.04188	0.02896
PLCT	0.60204	0.03019	0.59944	-0.10194	0.27007	0.07151	0.14714	0.02695	0.12771	-0.09511
HUE	-0.10024	0.05627	0.08221	0.85794	0.32620	-0.00848	-0.16658	-0.14002	-0.01934	0.19599
VAL	-0.08802	-0.03747	-0.09876	-0.81213	0.35198	-0.09634	-0.11663	-0.01662	0.01710	0.30986
CHRO	-0.07308	-0.06147	-0.15214	-0.04469	0.01975	-0.05453	-0.15876	0.10672	0.05029	0.94126
CLAS	0.00651	0.01503	0.17755	-0.01590	0.00134	0.03951	0.13342	0.15554	0.94287	0.05573
GRAS	0.42640	-0.08040	-0.14422	0.20189	0.40686	0.58089	-0.01386	0.15928	0.06306	-0.22325
TYPS	-0.08677	-0.02314	0.07533	0.00698	0.06852	0.96146	-0.04541	0.00530	-0.01346	-0.00498
PSIZE	-0.02932	0.99462	0.05864	0.02457	-0.02511	-0.02131	0.00536	0.02249	0.00111	-0.02110
PCUNT	0.07189	0.05858	0.14984	-0.07539	0.08326	0.05280	-0.01470	0.92866	0.13372	0.10292
CONCUNT	-0.02932	0.99462	0.05864	0.02457	-0.02511	-0.02131	0.00536	0.02249	0.00111	-0.02110
CONSIZ	-0.02932	0.99462	0.05864	0.02457	-0.02511	-0.02131	0.00536	0.02249	0.00111	-0.02110
CONCOLOR	0.11390	0.02345	0.81250	0.40035	0.06965	0.05337	0.11201	0.16801	0.15354	-0.10847
COATYPE	0.75515	-0.08610	0.13758	-0.14756	-0.45485	-0.00831	-0.15151	0.14556	0.04375	-0.13251
PORSIZE	0.18273	0.19438	-0.02463	-0.12585	0.07073	-0.20187	0.76065	0.17710	0.35126	-0.08668
PERORIEN	0.94570	-0.00125	-0.06509	0.08611	0.20963	-0.00257	0.02405	-0.01377	0.01243	0.01345

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.91627	0.20800	0.08960	-0.04799	0.23492	-0.10804	-0.03309	0.09681	-0.15305	0.07809
2	-0.11210	0.86266	-0.36742	0.04403	0.00807	-0.02582	-0.17942	-0.15057	0.17286	-0.14436
3	-0.32587	0.16427	0.46301	-0.34755	0.45632	-0.43126	-0.25486	0.15511	-0.21455	-0.04904
4	-0.11018	0.40943	0.41386	0.12767	-0.24701	0.07123	0.63470	0.09197	-0.25709	0.29859
5	-0.05770	0.02556	0.11608	0.70367	0.15053	0.22482	-0.21294	0.30875	-0.34863	-0.38985
6	0.02346	0.07913	0.20372	-0.44997	-0.03492	0.73034	-0.17129	-0.25575	-0.28547	-0.19583
7	-0.05184	-0.05730	-0.50477	-0.28232	0.25131	-0.04552	0.52603	0.23086	-0.34123	-0.38452
8	-0.05711	-0.06827	-0.00399	0.28155	0.69804	0.05091	0.22814	-0.68324	-0.03683	0.14233
9	-0.06210	-0.03935	-0.33541	0.03063	-0.24037	-0.19185	-0.29715	-0.18043	-0.70587	0.40923
10	-0.12595	0.03916	-0.22141	-0.03358	0.40123	0.41375	-0.08466	0.47120	0.12448	0.59631

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
4.420277	3.186549	1.827530	1.731551	1.461670	1.474143	1.694589	1.127312	1.318915	1.163098

Subsurface Zone, Chemical Data

Total variance was 14 (Table 6.5). Six axes accounted for 91% of the total variance, while ten axes explained 98.6% of the total variance. No significant correlations were exhibited between the soil properties and the axes 7 to 10. Six of the ten factors accounted for 75.4% of the total variance (95% for the surface area zone). Final communality estimates were above 95% for all soil properties.

The first factor accounted for 14.4% of the total variance (22% for the surface zone). It is highly correlated with the sand fractions (Table 6.6). The second factor accounted for 14.8% (20.7% for the surface zone) and is highly correlated with hydrogen, pH, and to a lesser degree with sodium (.49). The third factor explained 14.4% of the variance and is highly correlated with clay (.92) and silt (-.95). Base saturation, calcium, and calcium carbonate had high loadings on the fourth factor which accounted for 17.4% of the total variance. The fifth factor identified potassium with high loading, while the sixth factor identified organic matter (.88) with the highest loading. No significant correlations were found with factors nine and ten.

It appeared that the factors in the subsurface zone had better physical interpretations than for the surface zone. Each factor explained a portion of the variance as special types of soil properties. For example, the first and third factors identified physical properties important for soil moisture relationships. The second and fourth factors identified properties important to the leaching pattern. The fifth factor was associated with potassium, while the sixth factor identified organic matter. The eighth factor was highly associated

TABLE 6.5

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES, SUBSURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.06223	0.66610	0.08315	-0.01629	0.65587	0.03828	0.25691	-0.18910	-0.08068	-0.07210
H	-0.24115	0.89293	-0.02189	-0.03346	-0.14074	-0.21189	0.08903	0.15757	0.10329	0.06281
CEC	0.78620	0.27405	0.13702	-0.39917	0.20370	-0.04624	-0.09623	0.13614	0.21685	-0.07464
CACO3	0.77249	0.00660	0.13843	0.44684	-0.10711	-0.15161	0.14443	0.25144	-0.16099	-0.16762
PH	0.56095	-0.65660	0.33867	-0.04660	0.04773	0.27735	-0.00147	-0.07672	0.08945	-0.04883
OM	-0.00014	0.78654	-0.06809	0.23820	-0.10050	0.52318	0.02893	0.14886	0.01957	0.09432
FS	-0.76013	-0.34483	0.06633	0.12307	0.41860	-0.13531	-0.01072	0.16774	0.04609	0.17424
VFS	-0.06526	-0.44657	0.34411	0.24355	0.23330	0.14047	-0.01312	0.20477	0.04403	-0.12915
CLAY	0.41931	0.32559	0.80358	0.07467	-0.19260	-0.06541	-0.03055	-0.13313	-0.02256	0.06151
SILT	0.07803	-0.07671	-0.96296	-0.20422	-0.03991	0.05722	0.04691	0.01502	-0.00719	-0.10022
CA	0.82908	0.04233	-0.22493	0.40461	0.15411	-0.08143	-0.04193	-0.02999	0.24606	0.00514
MG	0.80678	0.11607	-0.04016	-0.29195	0.28943	0.02899	-0.28232	0.14455	-0.22453	0.08827
NA	0.57478	-0.54413	0.08819	-0.41115	-0.07077	0.03265	0.38186	0.12290	0.00824	0.15085
BST	0.63446	-0.28996	-0.36153	0.57429	0.09098	-0.02617	0.00901	-0.08270	-0.03091	0.16012

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.999836	0.969157	0.995358	0.988172	0.958133	0.996109	0.970532

VFS	CLAY	SILT	CA	MG	NA	BST
0.954598	0.997467	0.998368	0.997080	0.994616	0.993096	0.989625

	1	2	3	4	5	6	7
EIGENVALUES	4.865030	3.191568	2.051209	1.288832	0.904469	0.476944	0.335665
PORTION	0.348	0.228	0.147	0.092	0.065	0.034	0.024
CUM PORTION	0.348	0.575	0.722	0.814	0.879	0.913	0.937

	8	9	10	11	12	13	14
EIGENVALUES	0.302143	0.215112	0.171174	0.124667	0.067954	0.002927	0.002306
PORTION	0.022	0.015	0.012	0.009	0.005	0.000	0.000
CUM PORTION	0.958	0.974	0.986	0.995	1.000	1.000	1.000

TABLE 6.6

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE
OF THE CHEMICAL PROPERTIES, SUBSURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.01659	-0.25180	0.10233	0.00235	0.92429	0.17058	-0.08034	0.18860	0.00893	-0.01265
H	0.16945	-0.87291	0.12479	-0.18610	0.18262	0.28114	-0.06626	0.00129	0.10700	-0.00565
CEC	0.37528	0.04042	0.17080	0.14806	0.18299	-0.00016	0.20110	0.79095	0.31929	0.01794
CACO3	0.22642	0.06283	0.29930	0.70795	-0.05178	0.02755	0.15881	0.19936	-0.00034	0.52324
PH	0.03447	0.83964	0.23363	0.21892	-0.14435	-0.10622	0.25501	0.19372	0.11893	0.02499
CM	0.18004	-0.35243	0.06471	0.02907	0.19217	0.88119	-0.14455	0.00806	-0.00036	0.00888
FS	-0.60948	-0.06436	-0.10525	-0.21947	0.03634	-0.20534	-0.05138	-0.26244	-0.08172	-0.17169
VFS	-0.30476	0.24151	0.11771	-0.25614	-0.07254	-0.02279	-0.12477	-0.35942	0.07695	0.11275
CLAY	0.31528	0.00054	0.92459	0.05783	0.06000	0.07096	0.03501	0.16131	0.02143	0.05924
SILT	0.26392	-0.05067	-0.95198	0.11124	-0.05997	-0.00728	0.03312	0.04902	-0.00766	-0.01722
CA	0.26463	0.09895	-0.00933	0.87699	0.08715	0.03460	0.00503	0.30959	0.20726	-0.02090
MG	0.28435	0.17337	0.00912	0.25413	0.11947	0.01063	0.07135	0.87483	-0.17484	0.06056
NA	0.16447	0.48504	-0.01573	0.08620	-0.13245	-0.22095	0.76265	0.25453	0.00986	0.05694
BST	0.09967	0.26070	-0.16565	0.92508	-0.05033	-0.01807	0.02715	0.03281	-0.15328	-0.01844

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.49673	-0.26656	0.13842	0.56934	0.02838	0.00072	0.22435	0.52119	0.05154	-0.11602
2	-0.32655	-0.67709	-0.16948	0.09036	-0.38310	-0.42626	0.20984	-0.15365	-0.04373	-0.00143
3	-0.16660	-0.17947	0.92570	-0.24519	0.04598	-0.03059	0.07013	0.03112	0.07056	-0.09135
4	-0.26474	0.05961	0.19266	0.72067	-0.02745	0.21909	-0.31790	-0.44274	-0.06384	-0.14130
5	-0.53191	-0.13360	-0.12438	0.12068	0.70656	-0.11781	-0.09009	0.36580	0.00907	0.11861
6	0.01257	-0.54116	-0.11841	-0.18424	0.05762	0.80643	-0.02606	-0.03570	-0.00383	0.05841
7	0.07057	0.05676	-0.05146	0.04305	0.42275	0.02831	0.73369	-0.46588	0.06783	-0.21871
8	-0.48092	0.28972	-0.08949	0.01707	-0.36255	0.27947	0.31209	0.38417	0.10212	-0.45992
9	-0.07955	0.06326	0.01218	0.12187	-0.11252	0.05299	0.09032	-0.04302	0.85780	0.46192
10	0.14955	-0.18130	-0.13336	-0.15062	0.15554	-0.15312	-0.38341	-0.07878	0.48521	-0.68412

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
2.022223	2.066265	2.017503	2.432924	1.037325	0.994900	0.770451	1.892027	0.237852	0.328674

with cation exchange capacity and magnesium which are important properties for clay mineralogical identification and soil development.

This pattern of speciality in explaining only certain types of soil properties helped in producing several groups, but with obvious overlapping when the loading of the locations on factor one and factor two were plotted by the computer (Figure 6.2).

Subsurface Zone, Morphological Data

Total variance was 23 (Table 6.7). Six principal axes accounted for 65.3% of the total variance, while ten axes accounted for 81%. The final communality estimates varied from 67.5% for structure class to 92.6% for concretions size. Six principal factors accounted for only 56.6% of the data variation. In comparison with the surface zone, the factors for the subsurface zone appeared to be highly specialized in explaining the variations of certain types of soil properties. For example, the first factor was specialized in color, coating types and structure class (coating types and structure class showed high association with color, chapter 5). The second factor specialized in texture and consistence (9.9%). The third factor identified the concretions (8.8). The fourth factor was highly correlated with the color (13.3).

The failure of a few axes to be correlated with a large number of soil properties, or to explain a higher portion of the data variations, is another indication of the high variability among the soil morphological properties. Figure 6.3 showed several overlapping groups that resulted from plotting the loadings of different locations on the first and second factors (Table 6.8).

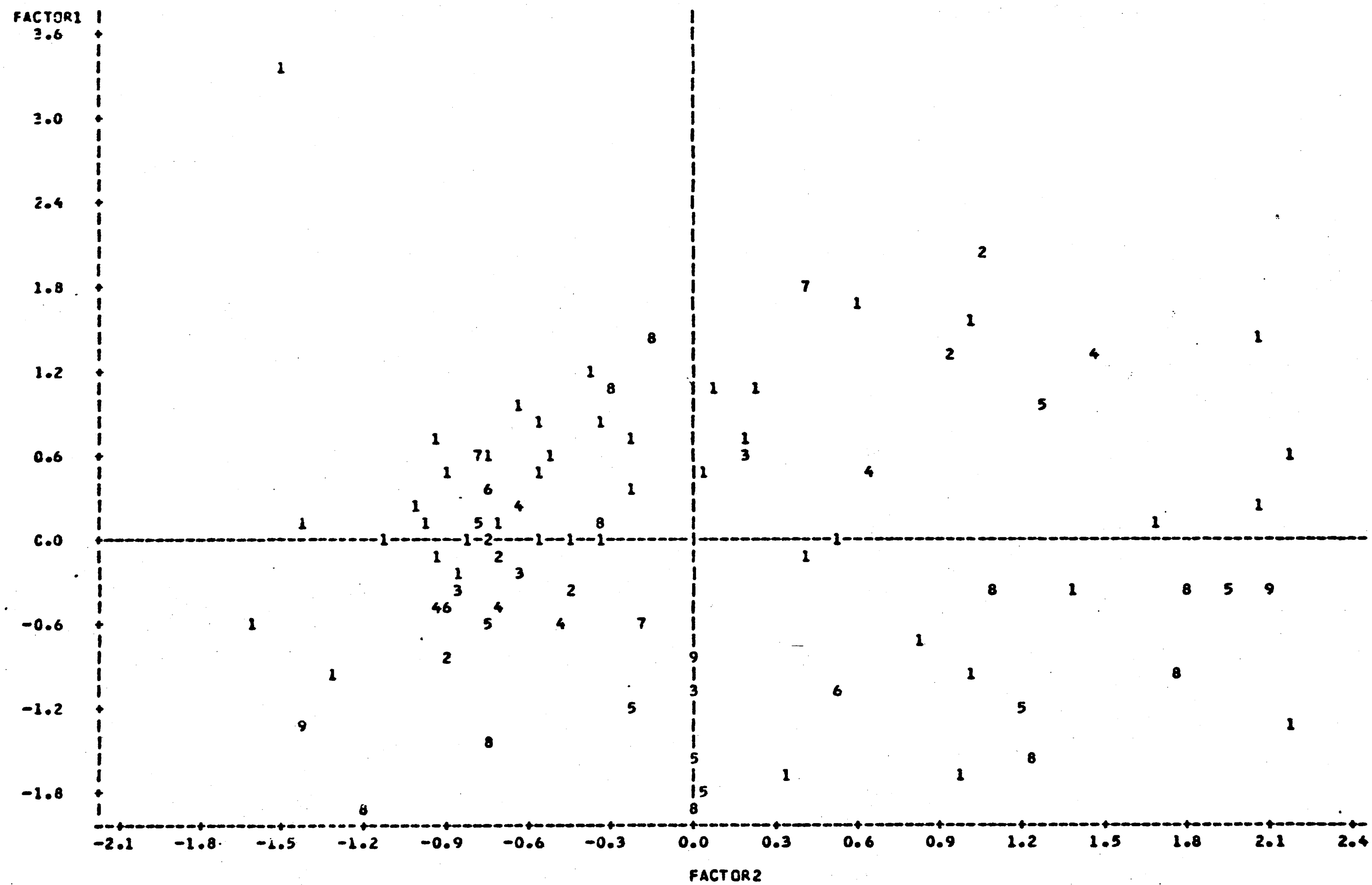


Figure 6.2. Loadings of Different Locations on Factors One and Two For Chemical Properties, Subsurface Zone.

TABLE 6.7

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE MORPHOLOGICAL PROPERTIES, SUBSURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	-0.22233	0.39072	0.32096	0.07523	0.29984	0.16514	0.12320	-0.07394	0.59813	-0.06205
THICK	0.39851	-0.24155	-0.47444	0.27235	-0.20212	0.33532	-0.16357	-0.04078	-0.20325	-0.01651
TEXT	-0.24336	0.74884	0.02292	0.07347	-0.27640	-0.20680	-0.14718	-0.06494	-0.03846	0.07616
DRY	0.44475	0.60669	-0.01627	0.17800	0.11173	-0.05875	-0.35477	0.16319	0.01722	-0.07305
MOIST	0.19525	0.70417	0.03467	0.08524	0.21364	-0.22447	-0.07593	-0.03780	-0.19760	0.30993
STK	0.23960	0.46406	-0.38004	0.23659	0.23404	0.10782	0.29399	0.31165	-0.04543	0.27232
PLCT	0.06854	0.29862	-0.32613	0.50051	0.11620	0.18716	0.44048	0.16292	-0.10705	-0.24286
MABUND	0.79051	0.09129	0.26911	-0.32367	0.07373	0.27580	0.08820	-0.05689	-0.08410	0.09049
MSIZE	0.74038	0.11952	0.26966	-0.33853	0.11088	0.27808	0.14934	-0.10888	-0.11051	-0.07078
MCCNT	0.76631	0.11825	0.23740	-0.20674	-0.07469	0.27655	0.22740	-0.06368	-0.15275	-0.00420
HUE	-0.63415	0.46917	0.31631	-0.10039	0.15504	0.20551	0.07076	-0.07383	-0.09205	-0.18917
VAL	0.56067	-0.14230	0.07954	-0.08426	0.41035	-0.36075	0.17251	-0.13401	0.21235	-0.13319
CHRO	0.74164	-0.33344	-0.27869	0.11088	-0.03200	-0.26983	0.06434	-0.06734	0.06535	0.04578
CLAS	0.55909	0.20405	-0.32159	0.06925	0.30879	-0.03395	-0.27757	0.05153	0.17449	0.07293
GRAS	0.12987	0.17462	-0.10389	0.18093	-0.59677	-0.27091	0.45157	0.16476	0.17646	-0.12921
TYPS	-0.28939	-0.29781	0.28139	-0.35832	0.22024	-0.13390	0.13713	0.62902	-0.07050	0.17065
RQUNT	-0.39341	-0.10367	-0.23348	0.13796	0.37535	-0.24474	0.32346	-0.54798	-0.17098	0.18715
CONQUNT	0.28059	-0.21672	0.60458	0.60189	-0.11371	0.06332	0.04295	-0.05249	-0.00698	0.18421
CONSIZ	0.20535	-0.24080	0.65401	0.54247	-0.13217	-0.06786	-0.01134	0.02535	0.04628	0.28124
CONCOLOR	0.13987	0.01295	0.38701	0.53469	0.23456	-0.14194	-0.15192	0.03846	-0.25313	-0.44273
COATYPE	0.72400	-0.18788	-0.18483	0.03237	0.02811	-0.07135	-0.11300	0.03327	0.24695	-0.08205
PORSIZE	0.24900	0.50405	0.09716	-0.22966	-0.50953	-0.04651	0.02729	-0.19594	0.09961	0.04276
PORORIEN	-0.38708	-0.14192	-0.21362	0.33019	0.03753	0.55854	-0.06363	-0.06492	0.23792	0.16313

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	MABUND	MSIZE	MCONT	HUE	VAL
0.817819	0.739716	0.778219	0.771893	0.781465	0.800348	0.790278	0.918196	0.890761	0.861496	0.853387	0.757110

CHRO	CLAS	GRAS	TYPS	RQUNT	CONQUNT	CONSIZ	CONCOLOR	COATYPE	PORSIZE	PORORIEN
0.840437	0.675263	0.799304	0.899486	0.909006	0.909006	0.926237	0.815213	0.683156	0.696930	0.725482

	1	2	3	4	5	6	7	8	9	10	11	12
EIGENVALUES	5.036754	2.914577	2.246612	2.014768	1.542689	1.265360	1.043364	0.985624	0.844423	0.744056	0.649115	0.569229
PORTION	0.219	0.127	0.098	0.088	0.067	0.055	0.045	0.043	0.037	0.032	0.028	0.025
CUM PORTION	0.219	0.346	0.443	0.531	0.598	0.653	0.698	0.741	0.778	0.810	0.839	0.863

	13	14	15	16	17	18	19	20	21	22	23
EIGENVALUES	0.562688	0.443067	0.429192	0.357253	0.350772	0.278769	0.259541	0.175278	0.116483	0.092963	0.077423
PORTION	0.024	0.019	0.019	0.016	0.015	0.012	0.011	0.008	0.005	0.004	0.003
CUM PORTION	0.888	0.907	0.926	0.941	0.957	0.969	0.980	0.988	0.993	0.997	1.000

TABLE 6.8

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE MORPHOLOGICAL PROPERTIES, SUBSURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	-0.17358	0.08207	0.07056	-0.01445	-0.04340	0.04319	0.09198	0.03075	0.87290	-0.02561
THICK	0.29723	-0.16223	0.02411	0.06932	-0.14107	0.46542	0.29040	0.19304	-0.51057	-0.08107
TEXT	-0.37876	0.65366	-0.08260	-0.18740	0.32641	0.17381	-0.03664	0.06029	0.10104	-0.02072
CNY	0.20649	0.67066	-0.02195	0.15531	-0.03939	0.16143	0.16983	0.36599	0.09601	0.23504
MGTST	-0.03131	0.54019	0.02515	0.14980	-0.01796	-0.02390	0.16220	-0.14539	0.05136	0.02257
STK	0.13980	0.40350	-0.07032	0.08228	0.00316	-0.07035	0.75163	-0.00595	0.01307	-0.18767
PLCT	-0.02585	0.01134	-0.03631	-0.02553	0.16082	0.17747	0.82231	-0.05607	0.03022	0.22238
MABUND	0.25252	0.10409	0.08917	0.89566	-0.07085	-0.00729	-0.02604	0.12671	-0.01254	-0.06145
MSIZE	0.19183	0.04763	0.00050	0.91529	-0.03935	0.02649	-0.00735	0.07900	0.03542	0.06437
MCONT	0.17730	0.04640	0.12204	0.87788	0.11033	0.06946	0.08553	0.19578	-0.08270	0.00152
MLF	-0.78569	0.12128	-0.16093	-0.05754	-0.07202	-0.03517	0.00938	-0.07754	0.39129	0.15285
VAL	0.65602	0.00723	-0.00350	0.31930	0.01183	-0.15024	-0.06691	-0.25895	0.23791	0.26843
CHRC	0.81868	-0.05290	0.10591	0.20566	0.13491	0.09196	0.04852	-0.07979	-0.27593	0.01233
CLAS	0.58957	0.38194	-0.13608	0.13334	-0.24076	0.14421	0.19685	0.16960	0.05540	-0.00245
GRAS	0.09454	-0.01658	0.07604	-0.06691	0.84329	0.03451	0.21913	0.09065	-0.03317	-0.04129
TYPS	-0.14530	-0.19929	-0.00403	-0.07080	-0.13570	-0.89237	-0.06355	0.10058	-0.00478	-0.06851
RGUST	-0.07596	-0.03034	-0.07391	-0.26900	-0.14243	0.07904	0.07540	-0.88958	0.02012	-0.02266
CCNOUNT	0.05734	-0.05656	0.92303	0.13453	0.01465	0.07870	0.01559	0.02355	0.01869	0.15773
CCNSIZ	0.06958	-0.00400	0.94532	0.03411	0.03693	-0.06365	-0.09610	0.04076	0.03254	0.09601
CONCOLOR	0.00326	0.08286	0.37202	-0.02029	-0.11264	0.05702	0.08968	0.05007	0.01111	0.80182
COATYPE	0.74261	-0.02772	0.02205	0.25394	0.01737	0.13619	0.02024	0.20792	-0.04280	0.04037
PORSIZE	-0.09557	0.36478	-0.06706	0.33062	0.51403	0.25952	-0.20236	0.14295	0.05867	-0.19630
PORORIEN	-0.21344	-0.30043	0.12541	-0.33736	-0.34472	0.33892	0.28468	0.07923	0.15912	-0.34320

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.66675	0.16267	0.14945	-0.64584	-0.07095	0.12425	0.08911	0.17364	-0.15446	-0.09439
2	-0.31931	0.76698	-0.22338	-0.14217	-0.22007	0.16065	0.24675	0.09542	0.30676	-0.02688
3	-0.33742	0.00674	0.60377	-0.33224	-0.01695	-0.27893	-0.39223	0.08002	0.31757	-0.26891
4	-0.08529	-0.07160	-0.62727	-0.41499	-0.00373	-0.34397	-0.47253	0.02772	0.01435	0.28166
5	-0.19192	-0.10111	0.14911	0.05292	-0.69001	0.28750	-0.23093	0.33949	-0.36047	0.26572
6	-0.37434	-0.34748	0.02634	-0.36267	0.40575	0.35753	0.33245	0.34107	0.08098	0.28466
7	-0.08995	-0.32517	0.02339	-0.27355	-0.49062	-0.24556	0.49335	-0.48206	0.15528	0.10028
8	0.02590	0.00769	-0.00327	0.15176	-0.04148	-0.66209	0.36945	0.62260	-0.10797	-0.01894
9	0.38119	-0.15576	0.01355	0.21706	-0.15667	0.09802	-0.10147	0.22979	0.76735	0.31153
10	-0.03855	-0.34531	-0.38223	-0.02790	-0.19623	0.20949	0.00279	0.21996	0.14102	-0.76271

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.173606	2.245926	2.014257	3.066619	1.412226	1.391151	1.632249	1.226719	1.378835	1.096639

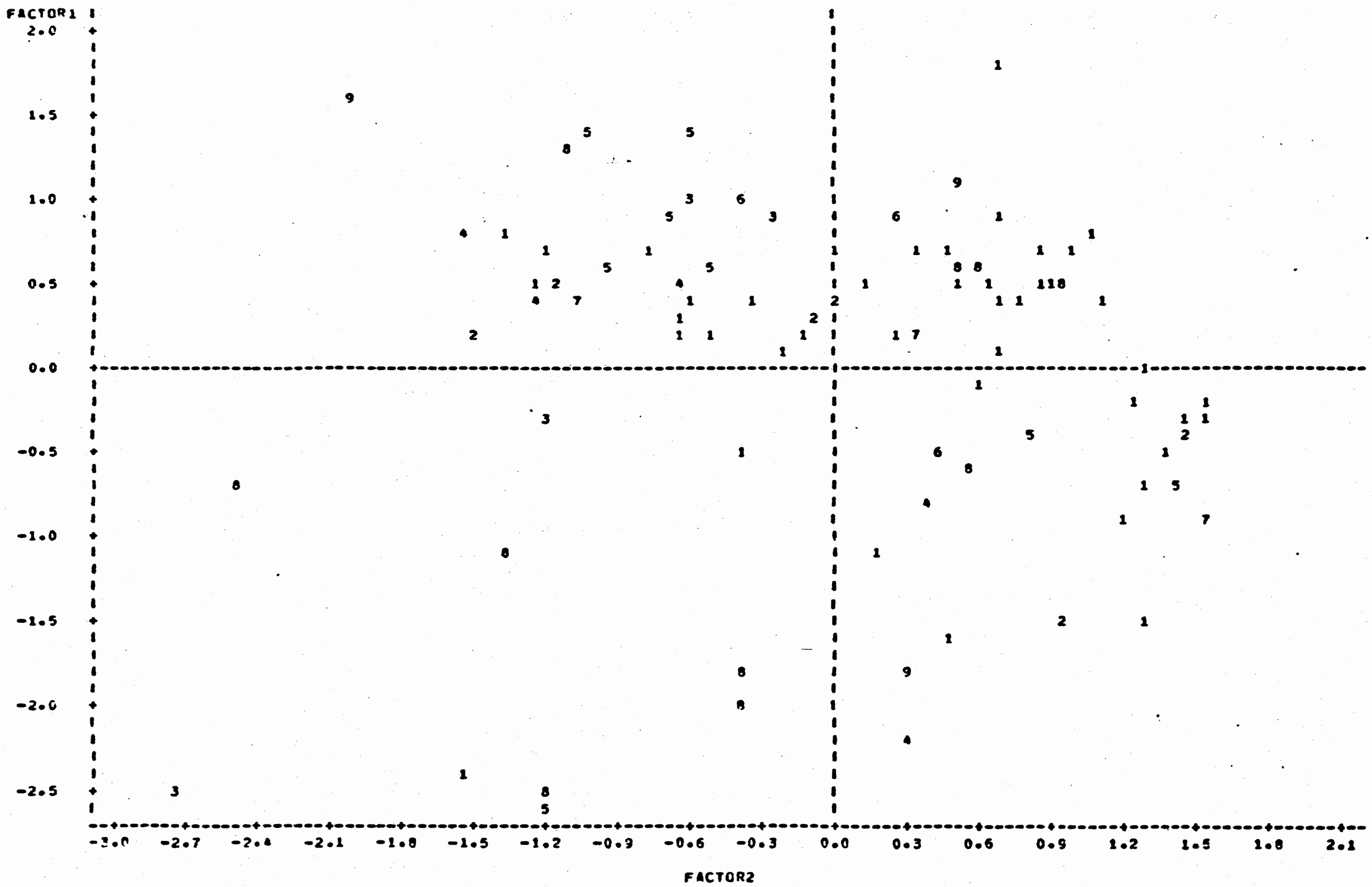


Figure 6.3. Loadings of Different Locations on Factors One and Two for Morphological Properties, Subsurface Zone.

From the previous discussion, it appears that the chemical properties are less variable than the morphological properties in both zones. Few axes effectively explained a large portion of the variance of chemical properties, while a larger number of axes were needed to explain as much variance of the morphological properties. Furthermore, it appears that the constructed factors, for both the chemical and morphological properties of the subsurface, can be associated with the soil properties that are important in explaining general processes, relationships, or soil development.

All Samples, Chemical Data

Total variance was 14 (Table 6.9). The first axis accounted for 43.6% of the variance. The six axes accounted for 92.7%. The first factor accounted for only 31% and six factors explained 72.5% of the total variance. The first six factors for the surface and the subsurface accounted for 85% and 75.4%, respectively. This might suggest that zonal analyses result in a better estimate of the variances. Furthermore, it gives a better comprehension of the magnitude of the variation of each soil property within each genetic zone. This is extremely important if a hypothesis is to be evaluated about the relationships between the different soil properties and external or internal factors.

Final communality estimates for different properties were very high, which indicates that even when all horizons were treated together, the ten factors' model was very effective in scanning the variations of the soil properties in the profile.

TABLE 6.9

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.05939	0.46221	0.35017	0.29159	0.70336	0.18621	0.12359	-0.14991	-0.07698	-0.03904
H	-0.59318	0.64209	0.28060	-0.10513	-0.11740	-0.26928	0.15883	0.02462	0.10863	-0.06295
CEC	0.84076	0.22602	0.18950	-0.26800	0.25646	-0.11212	-0.01530	0.18525	0.04197	-0.08388
CACO3	0.78020	0.17921	0.01651	0.32448	-0.31348	-0.10834	0.30339	0.03210	-0.18079	0.09083
PH	0.83866	-0.40570	0.01646	0.02565	0.07714	0.27456	-0.06658	0.02182	0.03495	0.03910
OM	-0.57076	0.63252	0.05840	0.25924	-0.10061	0.31239	0.00539	0.22825	0.14468	0.14467
FS	-0.43239	-0.64356	0.14237	0.22777	0.35334	-0.31253	0.07008	0.00993	0.13048	0.15793
VFS	-0.51083	-0.63219	0.22458	0.29467	-0.03272	0.10784	0.10695	0.26525	-0.06523	-0.17676
CLAY	0.62633	0.12256	0.70490	0.00680	-0.26598	0.05171	-0.08391	-0.10507	0.02933	-0.00267
SILT	-0.38279	0.28476	-0.84273	-0.16218	0.15583	0.02777	0.05192	0.03546	-0.06195	-0.02470
CA	0.82215	0.26332	-0.20460	0.36346	0.05732	-0.13925	-0.06458	0.05184	0.11800	-0.16318
MG	0.86584	0.15600	0.03928	-0.17585	0.25453	-0.12855	-0.08287	0.22399	-0.09532	0.13081
NA	0.76136	-0.27734	-0.16257	-0.36762	0.01914	0.17679	0.33097	-0.04153	0.17185	-0.00741
BST	0.64582	0.02336	-0.45706	0.57171	-0.06241	-0.05067	-0.05158	-0.07501	0.08424	0.01052

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.999400	0.981832	0.987383	0.990409	0.957872	0.998157	0.995863

VFS	CLAY	SILT	CA	MG	NA	BST
0.993599	0.996609	0.997572	0.991980	0.970781	0.990628	0.975336

	1	2	3	4	5	6	7
EIGENVALUES	6.105712	2.479563	1.797751	1.131126	0.981894	0.486951	0.286573
PORTION	0.436	0.177	0.128	0.081	0.070	0.035	0.020
CUM PORTION	0.436	0.613	0.742	0.822	0.893	0.927	0.948

	8	9	10	11	12	13	14
EIGENVALUES	0.253964	0.159947	0.143938	0.118250	0.048589	0.003802	0.001940
PORTION	0.018	0.011	0.010	0.008	0.003	0.000	0.000
CUM PORTION	0.966	0.977	0.988	0.996	1.000	1.000	1.000

No significant correlations existed with the principal axes 6 to 10 (Table 6.10). The first factor was correlated with very fine sand (3.1%). The second, third, fourth, and eighth factors accounted for 66.3% and were highly correlated with H, pH, silt, clay, Ca, BST, CEC, Mg, and, to a lesser degree, with OM, Na, $CaCO_3$, and very fine sand. The fifth factor was correlated with K (.97).

It appears that when the analyses were done on zonal bases, the highly correlated properties were explained by separate factors, but when all the horizons were treated alike, properties that are not highly correlated among themselves were explained by the same factor. This leaves some of the factors which highly participated in explaining the variations with less meaningful interpretations. The loadings of different locations on factors one and two produced more compacted groups than in the case of zonal analyses, but with clear overlapping (Figure 6.4). This could be attributed to the soil inclusions.

All Samples, Morphological Data

Total variance was 24 (Table 6.11). The first, third, sixth, and tenth axes accounted for 59.1%, 74.5%, and 86.7% of the total variance, respectively. The first three axes accounted for more than its counterparts in the surface and the subsurface zones. Furthermore, the first six factors explained 72.3% of the total variance. This was a higher estimate than for the surface (67.2%) and the subsurface (56.6%). The final communality estimates were also comparably high. They varied from 73.1% for soil stickiness to 97.8% for structure grades.

It appears that the ten axes (for all samples) explained less of the soil variance than the first six factors of the separate zones.

TABLE 6.10

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE CHEMICAL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.02661	-0.15113	0.05477	0.00532	0.97331	-0.01837	-0.05557	0.10772	-0.01293	0.10147
H	-0.04982	-0.92337	-0.01037	-0.25150	0.13541	0.11490	-0.02715	-0.08429	-0.01995	0.15364
CEC	-0.04571	0.16856	0.29006	0.20196	0.12252	0.23831	0.19871	0.83608	-0.03711	-0.14233
CACO3	0.00550	0.09789	0.35645	0.67439	-0.07139	0.24900	0.16678	0.24149	0.49304	-0.05119
PH	0.02050	0.78602	0.32730	0.28484	-0.04987	0.03930	0.20701	0.31440	0.00115	-0.07502
CM	0.03970	-0.49891	-0.14415	-0.07397	0.25108	0.20769	-0.15213	-0.26980	-0.01971	0.72036
FS	0.07212	0.05500	-0.03974	-0.18460	0.03488	-0.94217	-0.05593	-0.21183	-0.04768	-0.11315
VFS	0.01155	0.11491	0.08090	-0.25260	-0.08233	-0.56320	-0.08568	-0.44866	0.00139	0.05868
CLAY	-0.07327	0.06765	0.91091	0.11854	0.03845	0.26990	0.05680	0.24918	0.04256	-0.03742
SILT	-0.09023	-0.13043	-0.96053	0.00290	-0.03037	0.19514	-0.00699	-0.08412	-0.02630	0.05449
CA	-0.02694	0.15824	0.11472	0.83715	0.08667	0.21565	0.05862	0.42977	-0.07715	-0.06426
MG	-0.13277	0.29762	0.17983	0.27401	0.05813	0.17082	0.04241	0.83658	0.12939	-0.07871
NA	-0.06997	0.54397	0.08738	0.12570	-0.16584	0.15603	0.66131	0.36679	0.07361	-0.19303
BST	-0.09690	0.33337	-0.05708	0.91749	-0.03536	0.06096	0.00199	0.05769	0.03260	-0.00407

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	-0.10112	-0.44961	-0.33985	0.49480	0.03945	0.24803	-0.20847	0.53298	0.09178	-0.16814
2	0.22189	-0.57978	-0.09305	-0.16764	0.33765	-0.58093	-0.08367	-0.21817	-0.02369	-0.26684
3	-0.11106	-0.20298	0.85309	0.34550	0.26787	0.13217	-0.05127	-0.07813	-0.01643	-0.03323
4	0.19082	0.00512	-0.13092	0.70645	-0.29023	-0.29191	0.27513	-0.37591	0.08669	0.23105
5	0.04923	0.18054	-0.31462	0.12434	0.72537	0.36873	-0.01265	-0.38417	0.17638	0.09777
6	0.16756	-0.54424	-0.01542	-0.22855	-0.28299	0.43786	-0.16451	-0.31256	-0.06189	0.47208
7	-0.19759	-0.21491	-0.08592	-0.03706	0.16853	0.11159	0.75037	0.10033	-0.53744	0.05660
8	0.59299	0.06249	0.12156	-0.03561	0.25793	-0.14099	0.09826	0.51000	0.07835	0.51586
9	-0.23594	0.14005	-0.09584	0.15827	0.13408	-0.24355	-0.51152	-0.00657	-0.65119	0.35699
10	-0.06417	-0.14824	-0.01926	-0.11505	0.09641	-0.28104	0.09813	0.07375	0.47882	0.46568

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
0.433045	2.338659	2.159096	2.390898	1.101346	1.596563	0.593433	2.285464	0.279374	0.649541

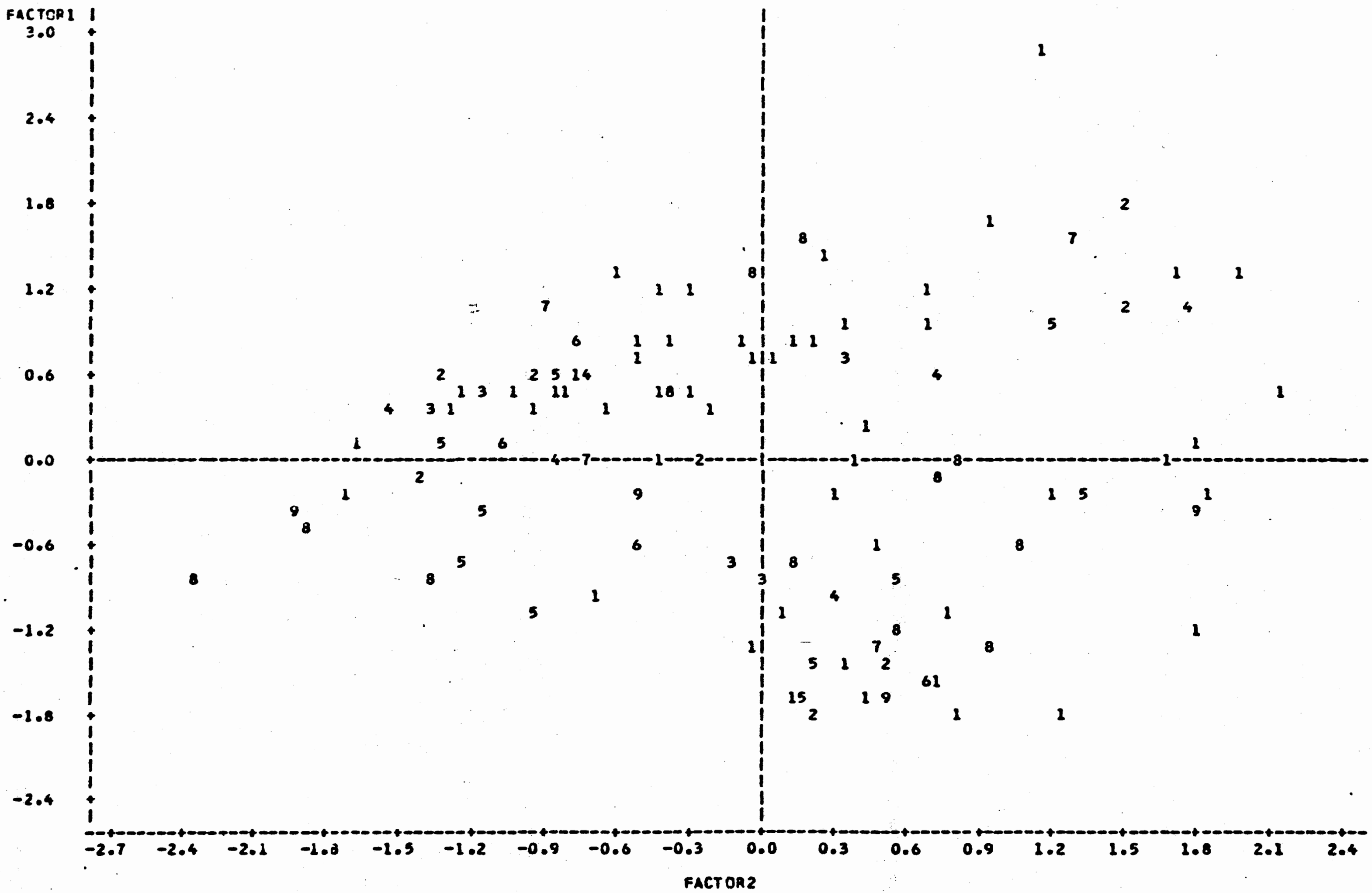


Figure 6.4. Loadings of Different Locations on Factors One and Two for Chemical Properties, All Samples.

TABLE 6.11

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE MORPHOLOGICAL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.17229	0.48229	0.00875	0.44092	-0.44083	0.12831	-0.11596	0.30295	0.05090	0.24324
THICK	0.60245	-0.17074	0.06343	-0.49790	0.10975	0.26545	-0.03128	-0.18641	-0.01522	0.03502
TEXT	0.57352	0.58845	-0.12916	0.13955	0.17400	-0.14422	-0.05791	-0.00609	-0.14048	-0.25277
DRY	0.90443	0.20687	-0.06221	0.04253	-0.00411	-0.00322	0.07257	0.02312	-0.12842	-0.08608
MOIST	0.76828	0.29341	-0.13040	0.15906	0.00974	-0.07645	0.12135	0.06028	-0.15884	-0.14646
STK	0.75071	0.29135	-0.08624	-0.11347	-0.00549	-0.11275	0.11040	0.03750	0.18617	0.02906
PLCT	0.73711	0.32827	0.09101	-0.15640	0.08338	-0.06680	0.17547	-0.00258	0.18701	0.14049
MABUND	0.77179	-0.37057	-0.22152	0.26846	-0.14453	0.16921	0.04444	-0.13842	0.11956	-0.04497
MSIZE	0.72508	-0.36333	-0.26382	0.29318	-0.16577	0.15684	0.09301	-0.14157	0.18799	-0.01412
MCONT	0.75635	-0.35405	-0.19117	0.26366	-0.03445	0.14111	-0.02928	-0.18147	0.22013	-0.03929
HUE	-0.62896	0.47673	-0.04160	0.41233	-0.09340	0.04755	0.14497	-0.14140	0.12892	-0.07359
VAL	0.54158	-0.39963	-0.10269	0.06499	-0.26591	-0.30897	0.16722	0.38379	-0.02637	0.16173
CHRO	0.73302	-0.44961	-0.02134	-0.28414	0.02598	-0.13636	-0.05441	0.18420	-0.07505	0.08365
CLAS	0.65186	0.04424	-0.08888	-0.11195	-0.02301	-0.02289	0.17291	0.06474	-0.15361	0.02393
GRAS	0.51269	0.16365	-0.01369	-0.05517	0.39644	-0.25222	-0.41008	0.17670	0.48278	-0.04293
TYPS	-0.85353	-0.17477	0.00059	0.09755	-0.07542	-0.12920	0.02252	-0.01527	0.13362	-0.03762
RSIZE	-0.18666	-0.16885	0.25729	0.19090	0.48538	0.33810	0.52378	0.39750	0.10964	-0.15711
RCUNT	-0.79573	-0.05296	0.02227	-0.02950	0.04905	-0.16959	0.16189	0.05528	0.08000	0.24901
CONCUNT	0.50086	-0.20979	0.71100	0.30256	0.03059	0.04466	-0.15002	-0.01164	-0.03684	0.03287
CONSIZ	0.43765	-0.18745	0.72347	0.32876	-0.01286	-0.06041	-0.24975	0.00582	-0.10458	-0.07956
CONCOLOR	0.43657	0.11142	0.38450	0.10532	0.09747	-0.38673	0.40636	-0.41506	0.04673	0.20769
CCATYPE	0.89993	0.13203	0.02198	-0.10413	-0.05919	0.02249	0.01029	0.03654	-0.07685	-0.04853
PORSIZE	0.17509	0.01408	-0.37022	0.42211	0.59448	0.14224	-0.17733	-0.05187	-0.22691	0.41973
PORORIEN	0.30105	0.46197	0.31972	-0.36143	-0.16182	0.45970	-0.00992	0.01325	0.11378	0.21779

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	MABUND	MSIZE	MCONT	HUE	VAL
0.834551	0.763718	0.849455	0.896202	0.820759	0.730598	0.780753	0.941093	0.929628	0.908368	0.868635	0.836062
CHRO	CLAS	GRAS	TYPS	RSIZE	RQUNT	CONQUNT	CONSIZ	CONCOLOR	COATYPE	PORSIZE	PORORIEN
0.889445	0.807376	0.947942	0.810961	0.984956	0.766199	0.919947	0.941832	0.903814	0.852341	0.981527	0.835057

	1	2	3	4	5	6	7	8	9	10	11	12
EIGENVALUES	10.136991	2.326573	1.716653	1.601529	1.168490	0.931385	0.924953	0.778851	0.632709	0.583088	0.492669	0.441542
PORTION	0.422	0.097	0.072	0.067	0.049	0.039	0.039	0.032	0.026	0.024	0.021	0.018
CUM PORTION	0.422	0.519	0.591	0.658	0.706	0.745	0.784	0.816	0.842	0.867	0.887	0.906

	13	14	15	16	17	18	19	20	21	22	23	24
EIGENVALUES	0.395852	0.327527	0.272552	0.234484	0.216353	0.202148	0.157356	0.131971	0.109636	0.084493	0.074183	0.058015
PORTION	0.016	0.014	0.011	0.010	0.009	0.008	0.007	0.005	0.005	0.004	0.003	0.002
CUM PORTION	0.922	0.936	0.947	0.957	0.966	0.974	0.981	0.986	0.991	0.994	0.998	1.000

The ability of the first three factors to explain a higher portion of the variation of the soil was reflected by plotting the loading of the different locations on the first three factors (Figures 6.5 and 6.6). More compacted groupings can be observed with some clear dissection. The presence of the overlapping in both figures strongly suggest the presence of a large portion of soil intergrades. These intergrades, which could be regarded as inclusions, can be considered as one of the reasons why the ten factors explained a lesser portion of the soil variations.

The absence of the speciality among factors in explaining only one type of the soil properties was clear (Table 6.12). For example, the second factor accounted for 13.9% of the total and it had a high correlation with mottling and a low correlation with root quantities. The relationships between the mottling and the root quantities is not understood. Similar patterns were also observed for the eighth factor where color variables and structure class were correlated with the same factor.

Chemical and Morphological Data Set

Thirty-eight principal axes were computed to explain the variance of the data. The first ten axes accounted for 81.8% of the variance (Table 6.13). No significant correlations occurred between the soil properties and the ninth axis. All the soil properties showed significant correlations with the first axis except for the sand fractions and the pores.

Six of the constructed factors accounted for 71.8% of the total variance (Table 6.14). Final communality estimates varied from 65.3% for structure grades to 97.7% for silt. The first factor accounted for

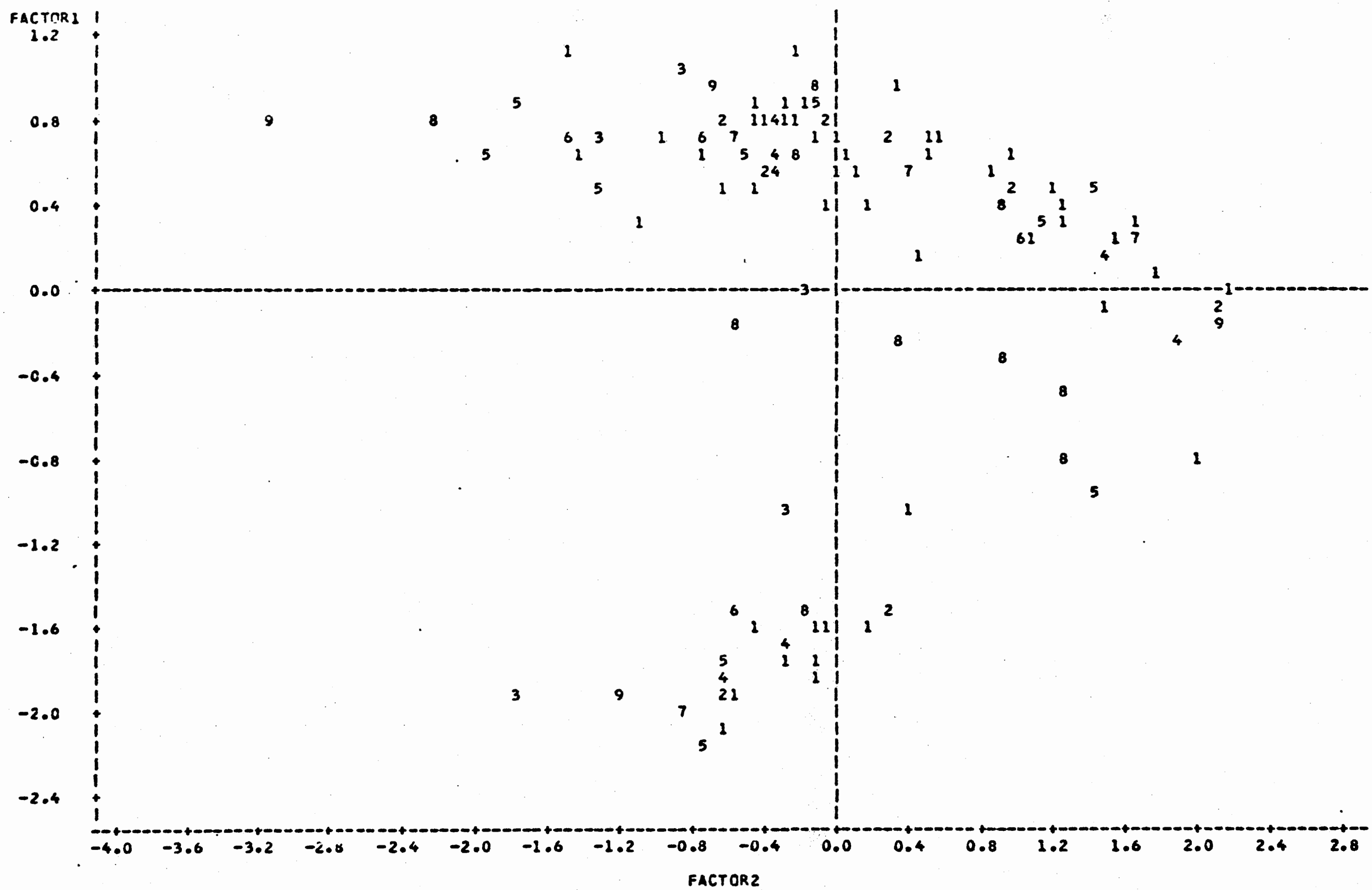


Figure 6.5. Loadings of Different Locations on Factors One and Two for Morphological Properties, All Samples.

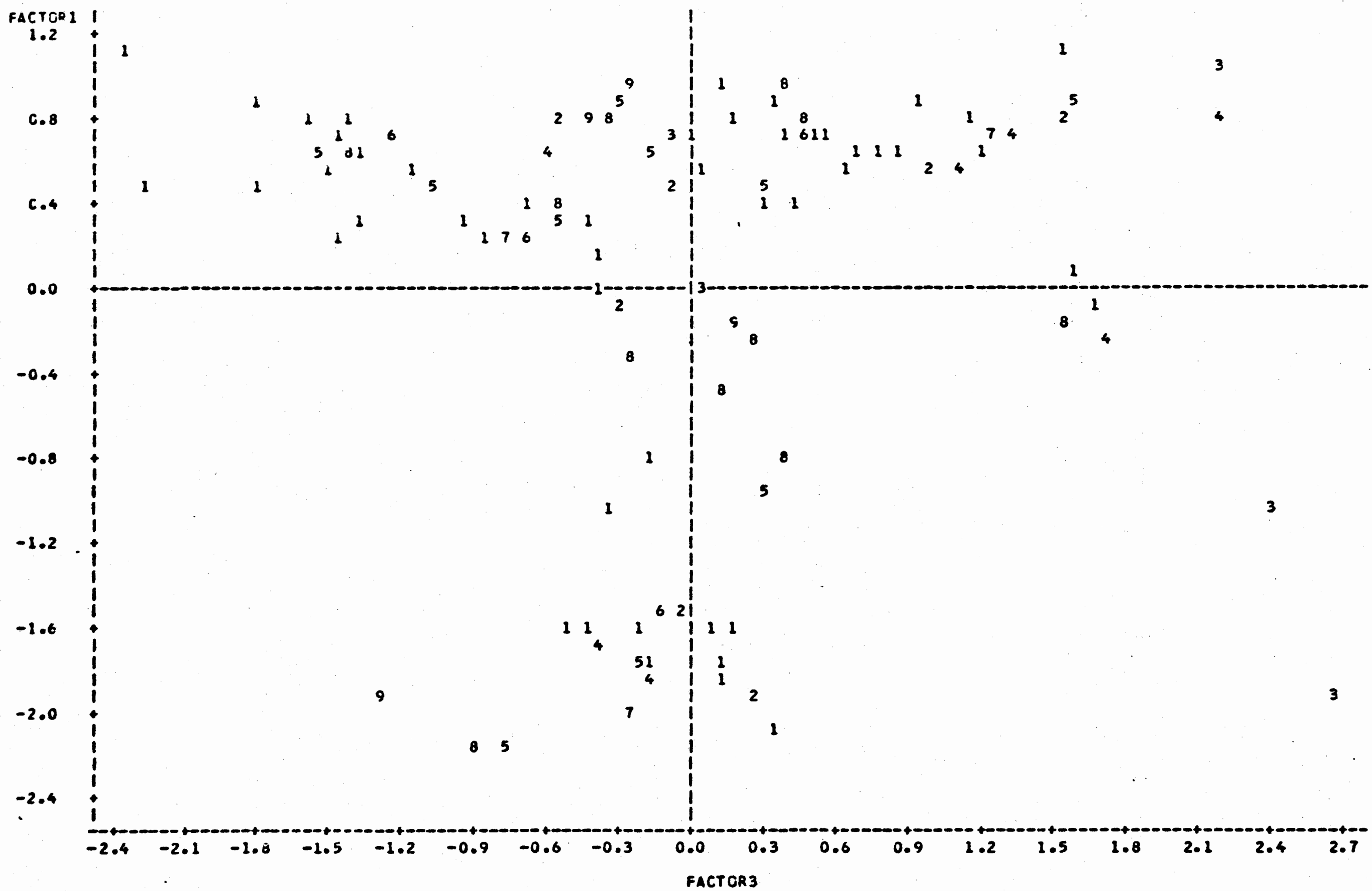


Figure 6.6. Loadings of Different Locations on Factors One and Three for Morphological Properties, All Samples.

TABLE 6.12

ROTATED FACTORS AND CONTRIBUTION TO THE COMMON VARIANCE OF THE MORPHOLOGICAL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.22310	0.04789	0.09621	0.85511	0.03461	0.14589	-0.09725	-0.07318	-0.00870	-0.06815
THICK	0.28934	0.27485	0.08261	-0.47313	0.00679	0.52895	-0.07584	0.29261	0.04872	0.01445
TEXT	0.86546	-0.02176	0.03409	0.09162	0.10712	-0.05703	-0.08579	-0.16066	0.20017	0.04941
DRY	0.81736	0.32360	0.14805	0.03301	0.05275	0.14760	-0.04271	0.23728	0.06111	0.11614
MOIST	0.83494	0.25156	0.08019	0.12206	0.06190	-0.01022	-0.00254	0.14389	0.03727	0.11397
STK	0.83529	0.23604	-0.05693	0.08624	-0.06227	0.23294	-0.04896	0.21493	0.29712	0.25613
PLCT	0.59204	0.14724	0.03086	0.05158	-0.01606	0.37178	0.02814	0.19282	0.28438	0.38423
MABUND	0.32214	0.85123	0.14657	-0.00994	0.06987	0.00909	-0.02999	0.25895	0.00112	0.03315
MSIZE	0.27193	0.88444	0.07705	0.03778	0.05784	-0.00632	-0.01183	0.23819	0.01512	0.07476
MCONT	0.26468	0.84690	0.17217	-0.06202	0.10888	0.01680	-0.03496	0.19634	0.14442	0.05094
HUE	-0.20355	-0.21753	-0.20514	0.40357	-0.03831	-0.19311	0.03540	-0.71246	-0.12040	0.03240
VAL	0.17426	0.32180	0.06802	0.20721	-0.09314	-0.18600	0.02154	0.77214	0.00523	0.12092
CHRO	0.29035	0.31546	0.17410	-0.26562	0.01478	0.09992	-0.06378	0.75546	0.14033	0.00905
CLAS	0.68445	0.30235	0.05378	-0.04415	0.03751	0.18674	-0.01360	0.42607	-0.01255	0.15648
GRAS	0.33009	0.06712	0.12265	-0.04272	0.10214	0.04446	-0.04670	0.11713	0.88666	0.00680
TYPS	-0.70439	-0.25712	-0.16971	0.04747	-0.14675	-0.33956	0.05227	-0.26076	-0.09289	-0.05659
RSIZE	-0.12415	-0.05125	0.08018	-0.06663	0.05527	-0.02607	0.97348	-0.05385	-0.03944	-0.01421
RCUNT	-0.65176	-0.42614	-0.26699	0.08393	0.01572	-0.17230	0.11528	-0.11177	-0.07849	0.14003
CCNOUNT	0.12263	0.19685	0.88803	0.03106	0.01621	0.12924	0.09349	0.13987	0.05796	0.16724
CCNSIZ	0.14213	0.11099	0.93938	0.03555	-0.04522	-0.00240	0.00712	0.10858	0.06095	0.09110
CCNCOLOR	0.27335	0.07844	0.27061	-0.08087	-0.01143	0.02462	-0.01928	0.02488	-0.00272	0.86107
CCATYPE	0.72274	0.30629	0.18688	-0.01637	-0.02871	0.26762	-0.08853	0.32155	0.09730	0.08851
PCRSIZE	0.12959	0.14398	-0.03167	0.02691	0.95983	-0.09934	0.05759	-0.03180	0.08148	-0.01315
PCRORIEN	0.24553	-0.06951	0.07939	0.15376	-0.12034	0.84651	-0.00953	-0.06442	0.02541	0.02949

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.69066	-0.46886	0.24342	-0.03331	0.05408	0.21317	-0.06903	0.37305	0.16878	0.14837
2	-0.51430	-0.44773	0.19990	-0.39130	-0.00123	-0.25090	0.10174	0.48937	-0.12931	-0.11160
3	-0.13789	0.30970	0.79587	-0.02265	-0.27468	0.26477	0.18644	-0.05215	-0.01178	0.26071
4	-0.00053	-0.34042	0.33890	0.52622	0.32049	-0.49529	0.17049	-0.32384	-0.07782	0.06573
5	0.09631	0.20930	0.02232	-0.49080	0.58095	-0.09036	0.43856	-0.12718	0.38203	0.07358
6	-0.06800	-0.31558	0.01114	0.00936	0.16317	0.62310	0.32845	-0.28526	-0.28278	-0.45986
7	0.10893	-0.06697	-0.33781	-0.00460	-0.21377	-0.02907	0.58883	0.06335	-0.41858	0.54500
8	0.06566	0.29263	-0.02373	0.43568	-0.07265	-0.06794	0.46577	0.51734	0.19912	-0.43075
9	-0.30452	-0.35826	-0.17364	0.14850	-0.31518	0.16556	0.16130	-0.17633	0.71217	0.18886
10	-0.34155	0.07776	-0.08404	0.33984	0.55179	0.38327	-0.17651	0.33686	-0.02525	0.39764

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
5.639697	3.344528	2.094795	1.322540	1.029598	1.598864	1.028127	2.533193	1.096844	1.113032

TABLE 6.13

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF ALL SOIL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.20502	0.35371	-0.14263	-0.02881	0.54457	0.10796	-0.17414	-0.24134	0.03036	0.44226
THICK	0.54935	-0.33605	-0.25292	-0.11639	-0.29298	0.18791	0.21656	-0.12566	0.16695	-0.26989
TEXT	0.63493	0.53150	-0.17172	0.14884	0.01235	0.03745	-0.06153	0.11672	-0.01097	-0.02202
DRY	0.90878	0.05838	-0.13319	0.11604	0.04279	0.08982	-0.01442	0.01759	-0.10148	-0.01657
MOIST	0.82199	0.24315	-0.10332	0.15561	0.08046	-0.07158	-0.03723	0.10829	-0.14464	-0.05131
STK	0.74973	0.07685	-0.25386	0.02362	-0.06872	0.09013	-0.08489	0.08924	-0.14434	0.08491
PLCT	0.74446	0.11111	-0.24412	-0.11783	-0.08816	0.18727	0.07741	0.15436	-0.04746	0.10619
MAOUND	0.69678	-0.37686	1.44E-06	0.40523	0.25396	-0.06159	0.07429	-0.08565	0.08977	-0.07226
MSIZE	0.64223	-0.36326	-0.02786	0.44579	0.28854	-0.07000	0.07850	-0.05154	0.07342	-0.07194
MCONT	0.68109	-0.36159	0.04097	0.40013	0.20754	-0.04571	0.07867	-0.05360	0.19302	-0.06676
HUE	-0.57401	0.59534	0.00138	0.11296	0.28853	0.09682	0.02943	0.08529	0.02963	0.07242
VAL	0.45304	-0.48316	0.00795	0.12677	0.24660	-0.15039	-0.21665	0.21093	-0.28161	0.09895
CHRO	0.65680	-0.59342	-0.08304	-0.04140	-0.14208	-0.10288	-0.01356	0.01284	-0.05042	0.06298
CLPS	0.81876	-0.14403	-0.25779	0.01447	0.05483	-0.02389	0.05115	0.12810	-0.10600	-0.07575
GRAS	0.52345	0.09344	0.02518	0.13534	-0.36943	0.10116	-0.14121	0.01916	0.25665	0.34354
TYPS	-0.84475	-0.00479	0.18538	-0.01546	0.03208	-0.10333	-0.07175	0.01758	-0.07272	0.12651
RSIZE	-0.15509	-0.00754	0.32771	-0.05177	-0.00631	-0.01303	0.78752	0.04505	-0.30376	0.13805
ROUNT	-0.77891	0.08638	0.07784	-0.07495	-0.00983	-0.06000	0.04093	0.16895	-0.14891	0.01621
CONQUNT	0.52476	-0.14799	0.54641	-0.28456	0.24929	0.20948	0.10258	0.07768	0.31270	-0.01503
CONSIZ	0.46559	-0.12798	0.56481	-0.29366	0.27105	0.22805	0.00250	0.05700	0.30978	0.07453
CONCOLOR	0.44162	0.01518	0.13096	-0.10027	0.02561	0.32372	0.07191	0.65692	0.01094	0.07636
COATYPE	0.67800	-0.09491	-0.18385	-0.05281	0.07980	0.09311	-0.03382	-0.01151	-0.05250	-0.04412
PORSIZE	0.20865	0.19338	0.16170	0.46458	-0.12164	-0.40167	0.28127	-0.04933	0.27283	0.12692
PORORIEN	0.32725	0.19993	-0.22695	-0.43970	-0.02389	0.37014	0.03326	-0.27304	0.00113	-0.25440
K	-0.12591	0.33754	-0.22483	-0.07029	0.61487	0.06611	0.17845	-0.23227	-0.13706	-0.08421
N	-0.61912	0.32119	-0.47860	0.17167	0.09993	0.05994	0.04976	0.20733	0.26608	-0.13797
CEC	0.79868	0.47105	-0.13909	-0.01845	0.04081	0.09658	0.11824	-0.03797	0.02052	0.11620
CACO3	0.55919	0.45340	0.28801	-0.22309	-0.05345	-0.28471	-0.13374	0.07387	0.09915	-0.22799
PH	0.79198	-0.01653	0.28958	-0.27678	-0.10360	-0.16086	0.04059	-0.19835	-0.09155	0.17152
OM	-0.80770	0.45406	0.00498	-0.04748	0.18715	-0.01968	0.01358	0.00850	0.12294	0.01297
FS	-0.11683	-0.77753	-0.07065	-0.16438	0.39376	0.12588	0.00224	0.01348	-0.03507	-0.02272
VFS	-0.31927	-0.74687	-0.01043	-0.30427	0.17495	-0.19044	-0.09469	0.01422	0.03681	0.09594
CLAY	0.51651	0.36378	-0.34321	-0.37790	0.00633	-0.51497	0.09739	0.08677	0.11617	0.02507
SILT	-0.42550	0.07723	0.37823	0.53686	-0.19570	0.53210	-0.07600	-0.09845	-0.12652	-0.04342
CA	0.57409	0.51529	0.40818	0.03595	0.14321	-0.10237	-0.08007	0.03843	-0.06790	-0.19056
MG	0.79902	0.44348	0.00693	0.01772	0.07205	0.08599	0.04401	-0.05417	-0.09232	0.08232
NA	0.71915	0.04697	0.15226	-0.08654	-0.35510	0.08466	-0.03120	-0.25983	-0.07077	0.18637
EST	0.45367	0.26529	0.67452	0.04066	0.09216	-0.12158	-0.18741	-0.02425	-0.18991	-0.25827

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	MAOUND	MSIZE	MCONT	HUE	VAL	CHRO
0.781612	0.776603	0.756945	0.880693	0.819208	0.688467	0.729419	0.886121	0.851520	0.852856	0.803735	0.727748	0.843319

CLPS	GRAS	TYPS	RSIZE	ROUNT	CONQUNT	CONSIZ	COACOLOR	COATYPE	PORSIZE	PORORIEN	K	N
0.799170	0.652796	0.786678	0.865472	0.680827	0.897459	0.868750	0.770631	0.837491	0.671140	0.669858	0.679389	0.893869

CEC	CACO3	PH	OM	FS	VFS	CLAY	SILT	CA	MG	NA	EST
0.902574	0.830928	0.903533	0.911784	0.823196	0.838725	0.958168	0.976610	0.915275	0.852341	0.791543	0.912767

TABLE 6.14

EIGENVALUES AND CONTRIBUTIONS TO THE COMMON VARIANCE OF ALL SOIL PROPERTIES, ALL SAMPLES

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.69212	-0.44167	0.23369	0.14325	-0.35240	0.25797	-0.04530	-0.16205	-0.17631	-0.02514
2	0.47044	0.78468	0.04961	-0.03234	-0.20360	-0.09917	0.00484	-0.04673	0.18603	0.26712
3	-0.19501	0.05420	0.56275	-0.28798	-0.24057	-0.35190	0.21780	0.06480	-0.55693	0.12609
4	0.41431	-0.26537	-0.29889	-0.52707	0.24307	-0.55525	-0.03894	0.13907	0.04904	0.01157
5	-0.22590	-0.27619	-0.24682	0.02223	-0.49715	-0.08938	-0.04980	0.06421	0.21141	0.71051
6	-0.01813	-0.11759	0.27095	0.53208	0.02505	-0.64655	-0.02204	-0.30763	0.32249	-0.10750
7	0.09920	-0.11555	0.11942	0.02348	0.18233	0.12450	0.88733	0.14042	0.29821	0.13138
8	0.06519	0.03775	-0.09446	0.30624	-0.31643	-0.15157	0.01046	0.81727	-0.01302	-0.31672
9	0.00057	0.10426	-0.61399	0.19182	-0.23669	-0.16148	0.38958	-0.34962	-0.43367	-0.17658
10	0.15659	0.00942	-0.04911	0.45051	0.52935	-0.03040	-0.08233	0.19845	-0.44257	0.49684

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
9.604012	6.127456	2.396896	1.790641	3.164611	2.645603	1.126773	1.419703	2.099522	1.716805

	1	2	3	4	5	6	7	8	9	10
EIGENVALUES	14.552040	4.794864	2.612519	1.984611	1.880896	1.474501	1.045141	0.998452	0.894023	0.854976
PORTION	0.383	0.126	0.069	0.052	0.049	0.039	0.028	0.026	0.024	0.022
CUM PORTION	0.383	0.509	0.578	0.630	0.680	0.718	0.746	0.772	0.796	0.818
	11	12	13	14	15	16	17	18	19	20
EIGENVALUES	0.750743	0.716428	0.623700	0.575175	0.518686	0.427158	0.407053	0.370969	0.319490	0.290101
PORTION	0.020	0.019	0.016	0.015	0.014	0.011	0.011	0.010	0.008	0.008
CUM PORTION	0.838	0.857	0.873	0.888	0.902	0.913	0.924	0.934	0.942	0.950
	21	22	23	24	25	26	27	28	29	30
EIGENVALUES	0.252053	0.220826	0.208101	0.179660	0.143037	0.140019	0.134269	0.125654	0.104319	0.091955
PORTION	0.007	0.006	0.005	0.005	0.004	0.004	0.004	0.003	0.003	0.002
CUM PORTION	0.956	0.962	0.968	0.972	0.976	0.980	0.983	0.987	0.989	0.992
	31	32	33	34	35	36	37	38		
EIGENVALUES	0.072112	0.064800	0.051869	0.047845	0.037373	0.030671	0.002652	0.001259		
PORTION	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000		
CUM PORTION	0.994	0.995	0.997	0.998	0.999	1.000	1.000	1.000		

22.6% of the common variance and was associated only with the morphological properties except for the organic matter. The second factor had higher correlations with chemical properties than with the morphological properties (Table 6.15). The third factor accounted for 6.3% of the common variance and was correlated with the concretions. The fourth factor accounted for 4.7% and was correlated with pores and to a lesser degree with the horizon thickness. The ninth factor was totally correlated with chemical properties and accounted for only 5.5% of the common variance.

It appears that the first six factors were the most important in explaining the data variations. The number of the soil properties that showed high loading decreased as the order of the factor increased.

The first three factors had high correlations with many important soil properties. This was reflected by the compactness of the groups produced by plotting the loadings of different locations on the first three factors (Figures 6.7 and 6.8). Two distinct groups were recognized by plotting the first against the second factor. Three groups were produced by plotting the first against the third factor. However, some locations were too far from the center of the groups. Such situations could be due to the presence of soil inclusions.

It seems that treating the soil horizons alike produced more compacted groups. Moreover, each factor was correlated with many properties whose intercorrelations are not clear cut. This made the interpretation of the factors difficult and less meaningful. Partitioning the data to different genetic zones and different data sets gave better understanding about the extent of the variation of each single property within each horizon. This, in turn, will make the

TABLE 6.15

ROTATED FACTORS OF ALL THE SOIL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.04162	0.20858	0.11913	0.00716	0.03453	0.09311	-0.14362	0.00248	-0.04958	0.83017
THICK	0.54168	0.09986	0.11913	0.44172	0.18836	0.14095	0.01383	-0.06860	-0.23906	-0.38278
TEXT	0.27637	0.74332	-0.01000	0.07361	-0.00385	0.17880	-0.12814	0.18425	0.12972	0.15279
DRY	0.68309	0.47204	0.07325	0.17645	0.23764	0.15134	-0.04898	0.21581	0.12839	0.09958
MOIST	0.55764	0.55538	-0.01090	0.04819	0.11791	0.22423	-0.04359	0.22360	0.26091	0.11690
STK	0.49716	0.42017	-0.05732	0.18008	0.27987	0.19496	-0.10897	0.30649	0.00545	0.08253
PLCT	0.41883	0.45552	0.09612	0.25700	0.25010	0.25555	0.00284	0.36072	-0.10892	0.03695
PAPUND	0.91012	0.05624	0.15873	-0.12107	0.05317	-0.01155	-0.00563	-0.05463	0.07841	0.05153
MSIZE	0.89437	0.04457	0.11751	-0.15439	-0.00998	-0.02538	0.00082	-0.03523	0.06913	0.07232
MCONT	0.86879	0.08436	0.23796	-0.15659	0.04575	-0.01522	-0.03464	-0.06857	0.03906	-0.00754
HUE	-0.58134	0.18553	-0.05583	-0.14155	-0.49767	-0.16545	0.05091	-0.01873	-0.02017	0.35861
VAL	0.60676	-0.27289	-0.05518	-0.16387	0.20593	0.07999	-0.08282	0.36921	0.23076	0.09994
CHRO	0.69733	-0.15622	0.05974	0.04712	0.46326	0.21325	-0.03588	0.14886	-0.03644	-0.20445
CLAS	0.71505	0.24464	0.00783	0.18332	0.15371	0.30710	-0.01057	0.26966	0.05904	-0.01025
GRAS	0.21496	0.46739	0.18705	-0.15186	0.46068	-0.00091	-0.24175	0.08140	-0.21528	-0.08024
TYPS	-0.64388	-0.42603	-0.15366	-0.27220	-0.17002	-0.21954	0.05804	-0.10129	-0.00900	0.04553
PSIZE	-0.13685	-0.04322	0.07790	-0.09679	0.02761	-0.05884	0.90849	0.01985	-0.00576	-0.04531
RGUNT	-0.63619	-0.30853	-0.20821	-0.15371	-0.26449	-0.13277	0.14955	0.04415	-0.01473	-0.04243
CONQUAT	0.26812	0.01352	0.85168	0.09440	0.16126	0.04790	0.08199	0.11335	0.20785	0.00694
CONSIZ	0.19252	-0.01586	0.84907	0.05962	0.20454	0.00981	0.00979	0.12592	0.20212	0.09072
CONCOLOR	0.18391	0.23894	0.38150	0.01456	0.00392	0.03071	0.06550	0.71572	-0.00877	-0.12799
COATYPE	0.68697	0.28794	0.12761	0.28393	0.25422	0.24227	-0.08845	0.20468	0.07671	0.08266
PORSIZE	0.20527	0.40506	0.05512	-0.55411	-0.00239	0.08242	0.16379	-0.33170	-0.01387	-0.10492
PORORIEN	0.04335	0.23841	0.13104	0.74672	0.07490	0.14201	-0.04647	-0.04683	-0.02862	0.07366
K	-0.04741	0.03750	-0.07093	0.25574	-0.42861	0.09367	0.19423	-0.13569	0.07402	0.59262
H	-0.38079	0.06955	-0.25823	-0.05249	-0.70231	-0.00820	-0.15382	-0.04129	-0.39444	0.01829
CEC	0.34815	0.73609	0.15297	0.18930	0.17428	0.26620	0.03872	0.11676	0.03517	0.25040
CACO3	0.04256	0.50917	0.28967	0.03807	0.12282	0.39727	-0.12972	-0.00818	0.53299	-0.10305
PH	0.35437	0.24665	0.30075	0.09394	0.64301	0.31461	0.12437	-0.00899	0.29549	0.05038
OM	-0.75195	-0.05248	-0.07489	-0.12377	-0.48430	-0.08605	0.01221	-0.17523	-0.07014	0.21202
FS	0.32023	-0.79864	0.13084	0.13622	-0.06720	-0.04134	0.03054	0.12730	-0.12948	0.08381
VFS	0.02377	-0.88337	0.05623	-0.06857	0.08408	0.15410	-0.05009	0.00982	-0.11828	-0.05040
CLAY	0.10887	0.39736	-0.02265	0.05205	0.06826	0.87876	-0.03130	0.00541	0.06224	0.05865
SILT	-0.23310	0.08333	-0.05422	-0.09125	-0.07066	-0.94202	0.03843	-0.05540	0.00805	-0.08397
CA	0.18538	0.60355	0.29226	-0.00145	0.05698	0.10918	0.00495	0.05347	0.63362	0.10810
MG	0.35323	0.68521	0.14957	0.15843	0.22169	0.17095	0.04699	0.13346	0.20329	0.26623
NA	0.31309	0.41218	0.15001	0.16769	0.67929	0.04913	0.00213	-0.02648	0.08308	-0.03932
EST	0.12215	0.29116	0.27988	-0.08497	0.16706	-0.05648	0.01877	-0.01655	0.83391	-0.01577

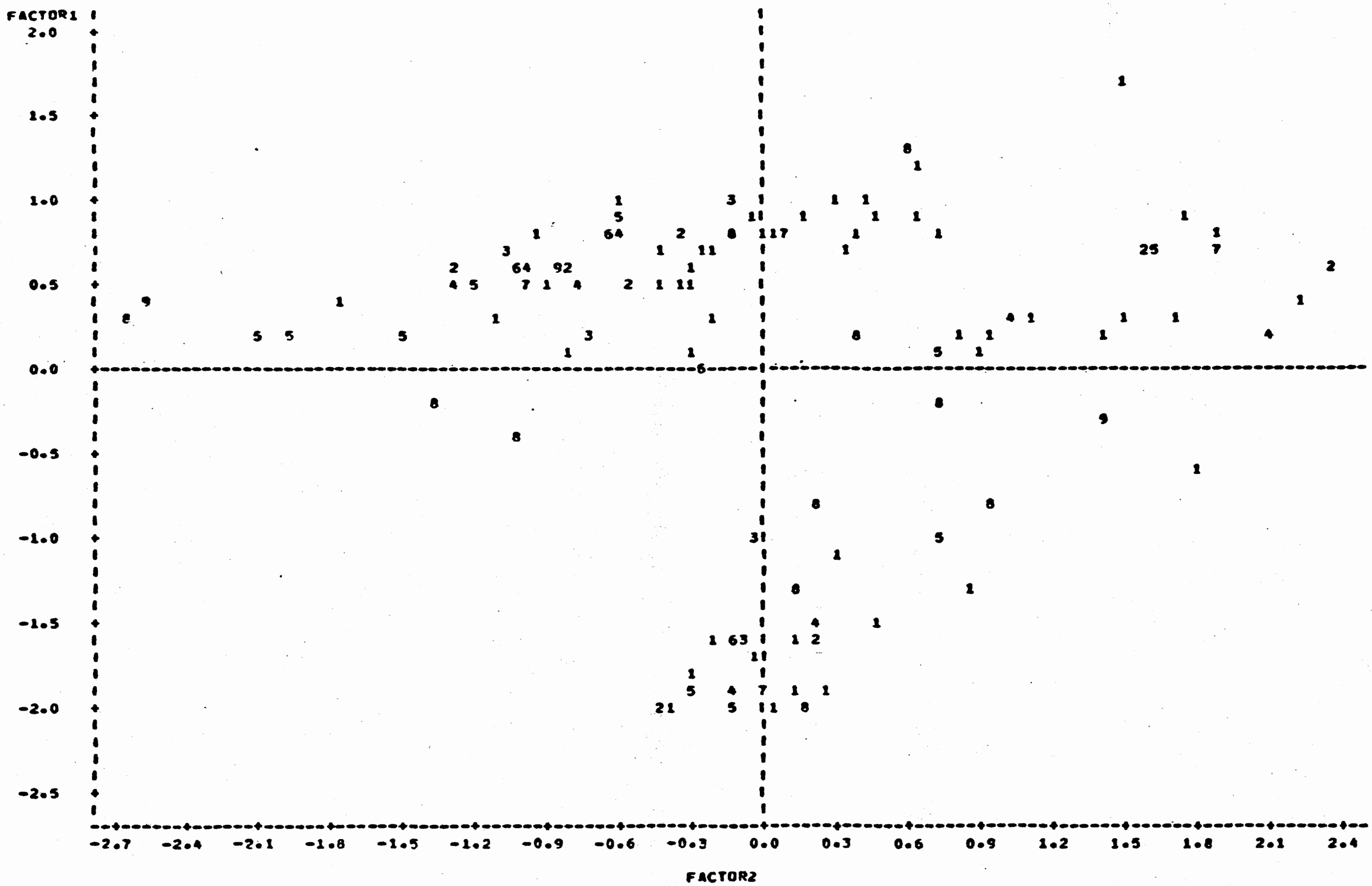


Figure 6.7. Loadings of Different Locations on Factors One and Two, All Properties, All Samples.

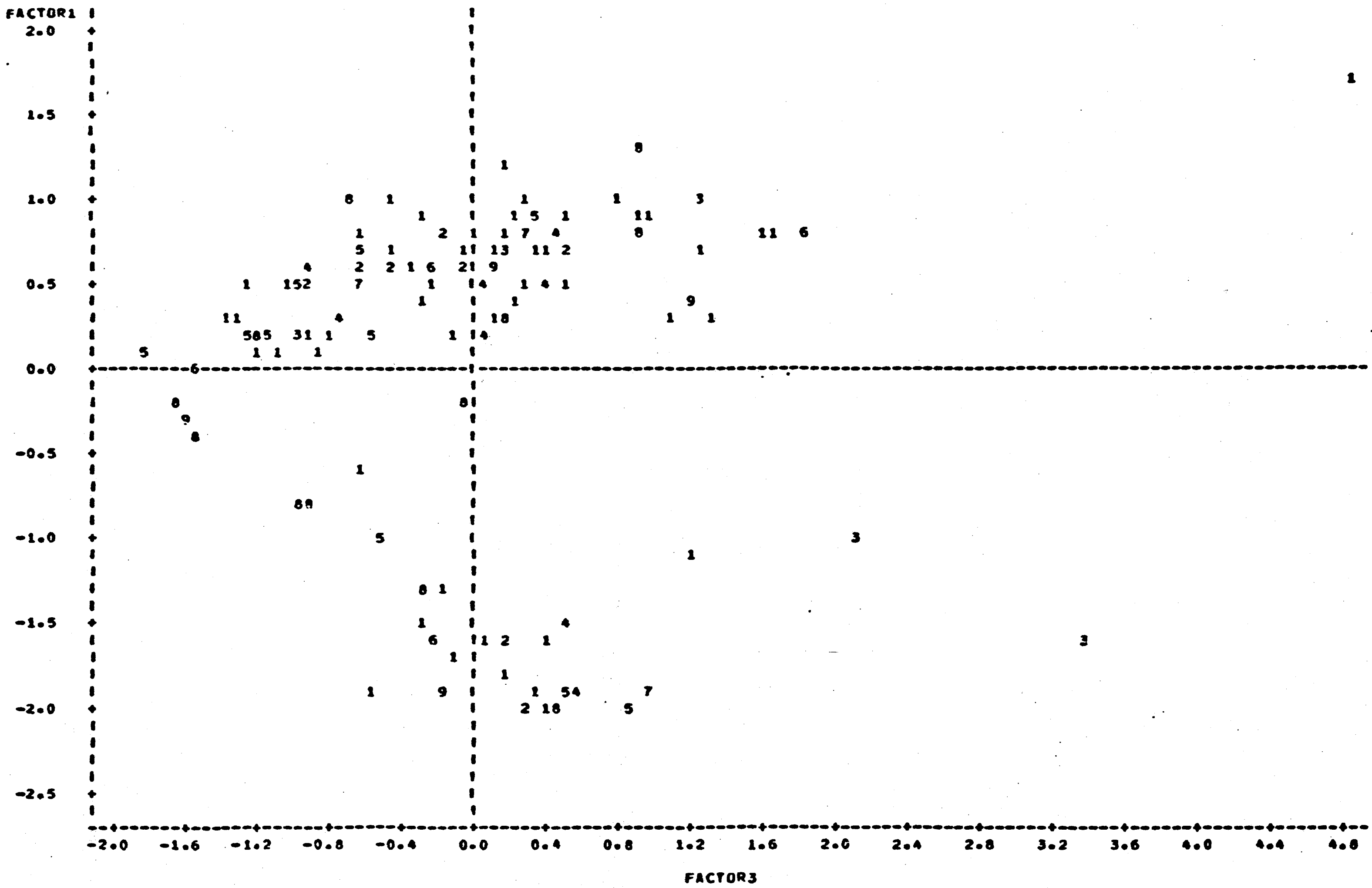
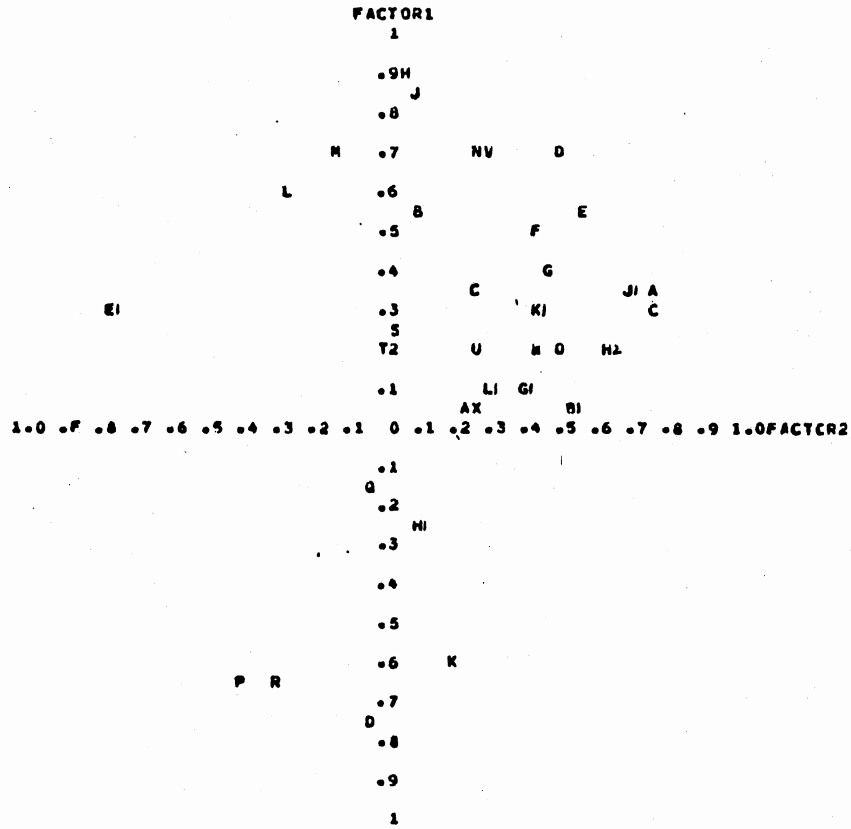
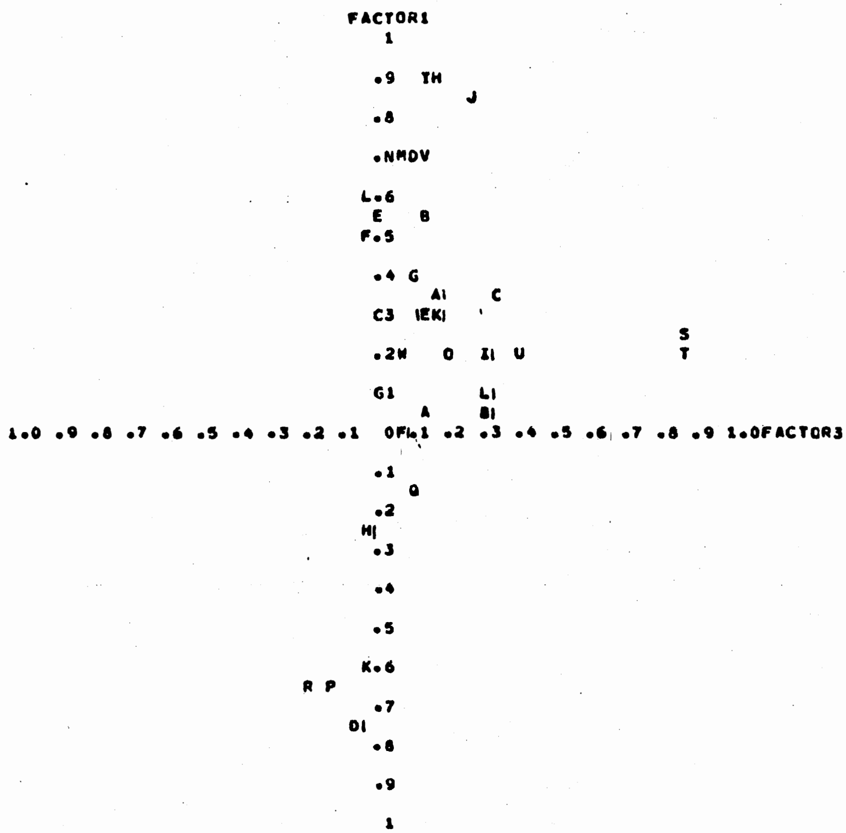


Figure 6.8. Loadings of Different Locations on Factors One and Three, All Soil Properties, All Samples.



UND	=A	THICK	=B	TEXT	=C	DRY	=D	MOIST	=E
STK	=F	PLCT	=G	MAUUND	=H	MSIZE	=H	MCONT	=J
HUE	=K	VAL	=L	CHRO	=M	CLAS	=N	GRAS	=O
TYPS	=P	RSIZF	=Q	ROUNT	=R	CONQUAT	=S	CONSIZ	=T
CONCOLOR	=U	COATYPE	=V	PORSIZE	=W	PORURIEN	=X	K	=
H	=	CEC	=A	CACO3	=BI	PH	=CI	OM	=DI
FS	=EI	VFS	=FI	CLAY	=GI	SILT	=HI	CA	=HI
MG	=JI	NA	=KI	BST	=LI				

Figure 6.9. Loadings of Different Soil Properties on the Rotated Factors, All Samples.



BND	=A	THICK	=B	TEXT	=C	DRY	=D	MOIST	=E
STK	=F	PLCT	=G	MABUND	=H	MSIZE	=I	MCONT	=A
HUE	=K	VAL	=L	CHRO	=M	CLAS	=N	GRAS	=O
TYPS	=P	RSIZE	=Q	ROUNT	=R	CONQUNT	=S	CONSIZ	=T
CONCOLOR	=U	COATYPE	=V	PORSIZE	=W	PORORIEN	=A	K	=
H	=	CEC	=A1	CACO3	=B1	PH	=C1	CM	=D1
FS	=E	VFS	=F1	CLAY	=G1	SILT	=H1	CA	=I1
MG	=A	NA	=K1	BST	=L1				

Figure 6.10. Loadings of Different Soil Properties on the Rotated Factors, All Samples.

selection of the properties with the highest loading within each horizon easier and more systematic if data reduction for further analysis is to be undertaken. Moreover, knowing or isolating the properties that exhibit higher variation could be done systematically. This would be helpful in formulating hypotheses about the sources of the variations, especially when external factors are involved in the investigation.

Loading Index

Previously it was shown that

$$X_i = \sum_{j=1}^{m} \lambda_{ij} F_j + \varepsilon_i. \tag{6.31}$$

Thus

$$\text{Var}\ (X_i) = \sum_{j=1}^{m} \lambda^2_{ij} + \psi. \tag{6.32}$$

Where $\sum_{j=1}^{m} \lambda^2_{ij}$ is called the communality, λ^2_{ij} is the portion of X_i variance explained by F_j. Therefore, the total contribution of F_j to the total variance is

$$V = \sum_{j=1}^{p} \lambda^2_{ij} \tag{6.33}$$

$L = (V/N) \times 100$ is the percentage contribution of the F_j to the total variance. N is the number of the variables. λ_{ij} is interpreted either as the correlation between X_i and F_j or the portion of X_i variation explained by F_j. Therefore, $\lambda^2_{ij} \times L = D$ would be a measure of the relative contribution of X_i in explaining the data variance. The magnitude of D would serve as an indicator of the relative variance of X_i in comparison with the other variables in the same set. Tables 6.16, 6.17, and 6.18 show the different soil properties listed according to their D values in a decreasing order. Higher D values indicate higher contribution to the data variance. The D values were calculated for the soil properties within each data set. The indices revealed the significance of investigating the variation of soil properties within each zone.

Different arrangements were found for each different zone and for each chemical and morphological property. However, it was noticed that certain properties occupied the top position of the index within different zones, but with a slight change in the order. This conclusion is in complete harmony with previous knowledge that soil properties are different in their variability within each horizon. This indicates that validity of this approach. For example, studying the D values for the surface and subsurface, the values suggested that properties related to leaching intensity or water holding capacity are the most important properties to consider in further investigation of soil variability. The same pattern was also noticed in case of morphological properties. Properties like texture, consistence, mottling and concretions occupied the top position of different indices listings.

Summary and Conclusions

Previous analysis showed that factor analysis can be a proper tool in studying the variability of different soil properties. Factors' models were very effective in estimating the variance of individual soil properties. Ten factors' model was sufficient for this purpose. However, the first six factors were enough to explain the variation of the chemical properties while ten factors were needed for the morphological

TABLE 6.16

LOADING INDEX (D) FOR THE CHEMICAL PROPERTIES
WITHIN THE DIFFERENT GENETICAL ZONES

Surface zone		Subfurface zone		all samples	
porp.	D	prop.	D	prop.	D
1-H	20.7	BST	14.73	BST	14.45
2-CEC	18.59	Ca	13.48	silt	14.19
3-Ca	17.43	silt	13.00	H	14.14
4-PH	17.04	clay	12.19	clay	12.75
5-Mg	16.69	H	11.20	Ca	12.07
6-BST	15.90	Fs	19.90	CEC	11.64
7-clay	14.53	PH	10.44	Mg	11.64
8-Silt	13.33	Mg	10.21	PH	10.42
9-Na	10.39	Vfs	9.45	CaCo3	7.68
10-Fs	7.65	CaCO3	8.77	K	7.43
11-OM	7.47	CEC	8.43	Na	4.87
12-Vfs	6.23	K	6.26	OM	4.18
13-CaCO3	5.94	OM	5.50	Vfs	3.58
14-K	5.03	Na	3.55	Vfs	3.58

TABLE 6.17

LOADING INDEX (D) FOR MORPHOLOGICAL PROPERTIES
WITHIN THE DIFFERENT GENETICAL ZONES

Surface zone		subsurface zone		all samples	
Prop.	D	Prop.	D	Prop.	D
1-Dry	19.45	msize	11.26	Text	17.89
2-Moist	19.04	Mabund	10.77	Moist	16.19
3-Poroient	19.04	Mcont	19.30	Dry	15.80
4-Conqunt	14.90	Chroma	9.28	Coatype	12.18
5-Rsize	14.90	Hue	8.61	Type	11.52
6-Consize	14.00	Consize	7.94	Class	10.87
7-Coatype	12.19	coatype	7.56	Msize	10.76
8-Plct	7.60	Conqunt	7.45	Mabund	10.28
9-Type	6.45	Moist	6.90	Mcont	10.04
10-Thick	6.27	Val	6.01	Rqunt	9.93
11-Hue	6.14	class	4.80	Stk	9.63
12-Concolor	5.71	Type	4.83	Plct	8.18
13-Class	5.67	Plct	4.77	Consize	7.69
14-Val	5.45	Bnd	4.54	Conqunt	6.89
15-Text	5.07	Gras	4.41	Val	6.29
16-Bnd	5.03	Dry	4.40	Chroma	6.12
17-Chroma	4.86	Text	4.27	Hue	5.34
18-Porsize	4.78	Rqunt	4.20	Pororient	4.84
19-Rqunt	4.67	Stk	3.99	Bnd	4.07
20-Gras	3.72	Concolor	3.15	Gras	3.64
21-Stk	3.42	Posize	1.59	Concolor	3.40
22 –		Thick	1.56	Thick	1.22

TABLE 6.18

LOADING INDEX (D) OF DIFFERENT SOIL PROPERTIES IN THE SOIL PROFILE, ALL SAMPLES

Prop.	D	Prop.	D
1-Mabund	18.72	25-H	4.07
2-Msize	17.9	26-Plct	3.99
3-Mcont	17.11	27-Na	3.84
4-OM	12.71	28-Bst	3.79
5-Vfs	12.39	29-Gras	3.53
6-Class	11.72	30-Ph	3.40
7-Chroma	11.07	31-Bnd	3.1
8-Coatype	10.76	32-Porsize	2.69
9-Dry	10.45	33-Pororient	2.64
10-Fs	10.24	34-Rsize	2.48
11-Type	9.26	35-Concolor	1.92
11-Rqunt	9.26	35-K	1.57
12-CEC	8.76		
13-Text	8.76		
14-Val	8.41		
15-Mg	7.62		
16-Hue	7.60		
17-Moist	7.09		
18-Thick	6.59		
19-Silt	6.19		
20-Ca	5.76		
21-Stk	5.65		
22-Clay	5.55		
23-Conqunt	4.55		
23-Consize	4.55		
24-CaCo3	4.15		

properties. This indicated higher variability exists among the morphological properties. This was true whether the different horizons were treated individually or not. Moreover, better and more meaningful interpretations may be tied with different factors, especially for the subsurface zone. Treating the different horizons alike resulted in a larger number of soil properties correlated with one factor. In this case, the first three factors were the most important in studying the variation of the soil properties. Moreover, better classification resulted from using the factors that are highly correlated with many soil properties. Nevertheless, the final communality estimates for individual properties were lower than when different horizons were treated separately. Also, treating the different horizons separately gave a better estimate on the extent of the variations of the individual soil properties. This is very important if a certain hypothesis about the source of the variation needs to be formulated.

Arrangement of different properties according to the loading index indicated that the properties most related to soil-moisture relationships were the properties that highly contributed to the variability of soil in this area.

CHAPTER VII

FACTOR ANALYSIS, AREA ONE

Abstract

A data set that consisted of 85 horizons (18 locations) was used in this study. A total of 24 morphological and 14 chemical properties were recorded on each horizon (observation). The data set thus consisted of a matrix of 85X38. The data was partitioned to the following sets and subsets: 1) the complete set (referred to as the all samples analysis), 58X38, and two subsets of 85X24, and 85X14; 2) surface zone (includes all horizons with Ap designation) with two subsets, 18X24 and a matrix of 18X14; 3) subsurface zone (includes all horizons with B designation) with two subsets, number of 49X14 and number of 49X24; 4) P.M. zone (includes all horizons with Cr designation) with two subsets, number of 18X14 and number of 18X124. The principal axes and the characteristic roots were computed. Ten factors' model was computed from the principal axes. The final communality estimates, the contributions of different factors to the total variance, and the correlation between the different factors and the soil properties were computed. A loading index to indicate the magnitude of the variation of different soil properties was also formulated.

Ten factors were needed to represent the variations of the morphological properties, while six factors were sufficient for the chemical

properties. This was true regardless of the partitioning procedure which indicated higher variability among the morphological properties. However, partitioning the data helped provide a better interpretation of the different factors. The result was higher efficiency in estimating the variance of the different properties, while using the complete set helped to produce more compacted clustering. In this case, the first three factors were the most important. The chemical properties showed maximum variation in the subsoil. The variation of the properties in the parent material was lower than in the surface and subsurface zones. According to the loading index of the different properties, cation exchange capacity, clay, texture, and consistence were the most variable properties in the soils of this area.

Introduction

The statistical analyses were carried out in a similar fashion to the second area. A description of this area was given in Chapter Two. Three genetic zones were recognized in this investigation, surface zone (includes all horizons whose field designations start with Ap), subsurface zone (includes all horizons whose field designation starts with B), and parent material zone (includes only the Cr horizons). All the above genetic horizons were treated alike (this was referred to as the all samples analysis).

Surface Zone, Chemical Data

Total variance was 14 (Table 7.1). Six and ten axes explained 92% and 99% of the total variance, respectively. No significant correlations were observed between the soil properties and the eighth, ninth,

TABLE 7.1

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.51657	0.58774	0.19258	0.44979	0.28785	-0.05886	0.00446	0.07985	0.14542	0.13570
H	0.33103	-0.26829	0.72115	-0.13704	-0.47948	-0.00245	0.08726	-0.09232	0.09657	0.12982
CEC	0.50021	0.65225	0.05429	0.06367	-0.26666	-0.40741	-0.03822	0.26281	0.05027	-0.08125
CACO3	0.60401	0.26674	-0.06833	-0.51830	0.26523	0.19764	-0.40283	0.06663	0.10678	0.03894
PH	0.59364	0.22437	-0.63664	0.06816	0.23906	0.05136	0.31245	0.01847	0.11911	0.00583
OM	-0.29928	-0.01097	0.63317	-0.45470	0.40489	0.00438	0.27887	0.24096	-0.04015	-0.00861
FS	0.07854	-0.89217	0.09876	0.17045	0.25535	-0.26922	-0.12686	0.02415	0.04647	0.00508
VFS	0.31576	-0.67125	-0.49310	-0.09924	-0.25600	0.12138	0.09450	0.26897	-0.10309	0.10880
CLAY	0.31603	0.80642	-0.10019	-0.35625	-0.00483	-0.13287	0.16125	-0.23837	-0.06374	0.02124
SILT	-0.51871	0.60619	0.10348	0.15285	-0.27883	0.47649	-0.01475	0.13163	0.02948	-0.05925
CA	0.86458	-0.04877	0.38365	0.20942	0.06755	0.06994	-0.00366	0.01416	-0.07980	-0.17197
MG	0.69325	0.60566	0.10488	0.20497	0.03288	-0.06903	-0.10293	0.06920	-0.21231	0.14281
NA	0.94348	-0.13309	0.05686	0.02831	-0.12216	0.05854	0.08468	0.01729	0.20828	-0.00728
BST	0.79263	-0.17911	0.27444	0.30572	0.26697	0.28987	0.06304	-0.07380	-0.05702	0.03108

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.985054	0.992620	0.999387	0.998320	0.984673	0.998823	0.997496

VFS	CLAY	SILT	CA	MG	NA	BST
0.987288	0.992150	0.997303	0.986540	0.987137	0.981158	0.998064

	1	2	3	4	5	6	7
EIGENVALUES	4.654750	3.647778	1.881353	1.074498	0.975655	0.640202	0.419754
PORTION	0.332	0.261	0.134	0.077	0.070	0.046	0.030
CUM PORTION	0.332	0.593	0.727	0.804	0.874	0.920	0.950

	8	9	10	11	12	13	14
EIGENVALUES	0.304622	0.175993	0.111408	0.070350	0.041203	0.002394	0.000000
PORTION	0.022	0.013	0.008	0.005	0.003	0.000	0.000
CUM PORTION	0.971	0.984	0.992	0.997	1.000	1.000	1.000

and tenth axes. The variance accounted by the constructed ten factors' model was 13.8 (98.5%). Six principal factors accounted for 76.3% of the variance (Table 7.2). The final communality estimates were above 98%.

The first factor accounted for 22% of the total variance. It was correlated with exchangeable cations and base saturation. The second factor accounted for 11.3% of the total variance. It was highly correlated with cation exchange capacity (CEC) and, to a lesser degree, with magnesium (Mg). Organic matter (OM) showed a high loading on the third factor which accounted for 7.8% of the variance. The fourth factor was highly correlated with potassium (K) and very fine sand (vfs). The fifth factor strongly identified hydrogen (H) and pH (acidity). No significant correlations were observed with factor number ten.

It seemed that most of the factors were correlated with properties which were highly correlated among themselves (see regression analysis, Chapter III). For example, exchangeable cations and base saturation, pH and hydrogen, cation exchange capacity and magnesium. Except for the first factor, the first seven factors approximately participated evenly in explaining 96% of the variation. This suggested that most of the soil properties considered in this zone have contributed to the heterogeneous soils developed from the Permian Formation.

Surface Zone, Morphological Data

Total variance was 19 (Table 7.3). Six axes explained 74.7% of the total variance, while ten axes accounted for 92.2%. No significant correlations were observed with the ninth and tenth axes. The final communality estimates varied from 84.6% for horizons boundaries (Bnd)

TABLE 7.2

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE CHEMICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.17193	0.11781	0.09593	-0.83039	-0.22624	-0.32049	-0.20466	-0.06187	0.09350	0.18577
H	0.32929	0.07253	0.14192	0.14754	0.90902	0.05607	-0.05628	-0.01812	0.06283	-0.01099
CEC	0.17528	0.90911	-0.11753	-0.10475	0.04080	-0.08407	0.10417	0.30468	0.05765	-0.04073
CA 13	0.27104	0.14526	0.05417	0.11885	-0.08395	0.03346	0.90561	0.24070	0.02113	0.00356
PH	0.35647	0.16475	-0.22793	0.26826	-0.61938	0.08976	0.10353	0.37848	0.40092	0.01255
OM	-0.07401	-0.12350	0.95246	-0.19539	0.17165	0.01571	0.04630	-0.00723	-0.02819	-0.00519
FS	0.13955	-0.24244	0.03139	0.16143	0.07757	0.70468	-0.11692	-0.61242	-0.02051	-0.02142
VFS	0.05490	-0.08529	-0.18702	0.89070	-0.09627	0.18286	-0.02746	-0.26907	0.12932	0.12687
CLAY	0.02907	0.35028	0.01285	-0.14484	-0.08863	-0.12046	0.25045	0.87260	0.03015	-0.00545
SILT	-0.23822	0.00250	-0.00510	-0.32614	0.01097	-0.90772	-0.08407	0.03892	-0.03861	-0.00087
CA	0.90997	0.26654	-8.17E-05	0.07743	0.17014	0.14943	0.12004	0.00551	-0.07400	-0.10130
MG	0.57339	0.57904	-0.15369	-0.16997	-0.07586	-0.09209	0.21314	0.35283	-0.10817	0.27335
NA	0.72523	0.26174	-0.17546	0.35799	0.18221	0.19609	0.21706	0.09290	0.30511	-0.08518
BST	0.97235	-0.05795	-0.02422	0.05819	0.02456	0.14558	0.10395	-0.05105	0.04560	0.08932

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.74832	-0.33014	-0.16977	0.31478	-0.04218	0.24115	-0.29592	0.20831	0.11050	-0.00443
2	0.04717	0.43605	0.01812	0.47238	-0.18252	0.47794	0.15805	-0.54304	0.00183	0.05051
3	0.31787	-0.04071	0.48882	-0.40190	-0.67106	-0.04198	0.05067	-0.13354	-0.15455	0.02159
4	0.37565	-0.09304	-0.45214	-0.37663	0.19703	-0.09953	0.53384	-0.39435	0.01698	-0.12017
5	-0.21749	-0.27494	-0.41367	0.39872	-0.59199	-0.35746	0.24572	0.05591	-0.01032	0.07192
6	0.32733	0.55311	0.00481	0.17350	0.05284	-0.70178	-0.22740	-0.08119	0.04324	-0.03661
7	-0.14025	-0.07693	-0.40454	-0.21670	-0.10559	0.04246	-0.65022	-0.39662	-0.41205	-0.03106
8	-0.05928	-0.54257	0.41826	0.27783	0.22944	-0.26710	-0.06958	-0.53207	0.11238	-0.15945
9	-0.09558	0.00676	-0.11712	-0.24342	-0.14709	0.01816	-0.23078	-0.18546	0.83058	0.34406
10	0.09423	-0.09322	0.06339	0.04382	0.19262	-0.08954	0.08322	-0.06196	-0.29893	0.91173

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.083059	1.576069	1.096376	1.959730	1.391076	1.581285	1.090873	1.644379	0.309880	0.153287

TABLE 7.3

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE MORPHOLOGICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.04658	-0.53242	0.08298	-0.59650	0.05974	-0.25033	-0.20030	0.12835	-0.08893	0.25932
THICK	-0.81249	-0.22974	0.14531	0.06914	0.13033	0.18483	0.20083	0.11879	0.30629	0.15060
TEXT	0.55309	-0.05456	0.65659	-0.12450	0.03656	0.17612	-0.01415	0.36404	-0.06108	-0.08897
DRY	0.57487	0.15232	-0.44685	-0.19044	0.17864	0.25468	-0.13408	0.26988	0.16008	0.24153
MOIST	0.74235	0.35077	0.15687	-0.30341	-0.00143	-0.02404	0.16516	-0.28150	0.23295	-0.09636
STK	0.49905	0.23837	0.72717	-0.01360	0.27796	0.13808	-0.01812	-0.04798	-0.17836	-0.10271
PLCT	0.01203	0.06476	0.64855	0.33105	0.26084	0.49603	-0.00260	-0.11741	0.13003	0.25218
HUE	0.14876	-0.61793	0.42415	0.08017	-0.25000	-0.19788	0.38597	0.09307	-0.08968	0.15159
VAL	0.43518	0.38483	-0.04500	0.32589	0.40037	-0.42303	0.02279	0.26502	0.23887	0.20069
CHRO	0.37192	0.50333	-0.38524	0.08523	-0.34622	0.09352	0.32483	0.11785	0.21395	-0.10329
CLAS	-0.16161	0.08629	-0.16026	-0.71813	0.52748	0.18028	0.09904	0.07327	-0.13054	-0.23644
GRAS	-0.13465	0.21976	0.40748	0.58414	-0.13680	-0.36209	-0.07094	0.13467	-0.01735	-0.24335
TYPS	0.23606	0.32630	-0.25904	0.29595	-0.46289	0.41773	-0.18109	0.16682	-0.38999	0.17866
RSIZE	-0.02930	-0.43854	-0.29899	0.58544	0.32857	0.32074	0.30447	-0.13428	-0.04415	-0.04553
RQUNT	0.26208	-0.67786	-0.06223	0.00894	-0.20674	0.12068	0.07043	0.52028	0.14973	-0.21104
CONCOLOR	-0.59600	0.35146	0.09215	0.19913	0.19493	-0.02242	-0.49219	0.26498	0.07662	-0.05655
COATYPE	-0.27920	0.57798	0.01477	-0.07489	0.14951	-0.26712	0.50756	0.19907	-0.29898	0.22410
PORSIZE	-0.65169	0.42706	0.14668	-0.27642	-0.08127	0.25585	0.25992	0.26726	0.00965	-0.11877
PORORIEN	0.29874	-0.27329	-0.42576	0.43493	0.58945	-0.07326	0.04406	0.11168	-0.21543	-0.13225

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	HUE	VAL	CHRO
0.846324	0.960903	0.932230	0.861165	0.961443	0.976145	0.942928	0.880621	0.953057	0.851799

CLAS	GRAS	TYPS	RSIZE	RQUNT	CONCOLOR	COATYPE	PORSIZE	PORORIEN
0.973860	0.808656	0.950281	0.950897	0.932048	0.886925	0.948402	0.930260	0.965503

	1	2	3	4	5	6	7	8	9	10
EIGENVALUES	3.565516	2.858449	2.526726	2.332270	1.618077	1.283480	1.095922	0.957864	0.680506	0.594659
PORTION	0.188	0.150	0.133	0.123	0.085	0.068	0.058	0.050	0.036	0.031
CUM PORTION	0.188	0.338	0.471	0.594	0.679	0.747	0.804	0.855	0.890	0.922

	11	12	13	14	15	16	17	18	19
EIGENVALUES	0.511689	0.479227	0.221016	0.159563	0.074056	0.030983	0.009998	0.000000	-0.000000
PORTION	0.027	0.025	0.012	0.008	0.004	0.002	0.001	0.000	-0.000
CUM PORTION	0.949	0.974	0.986	0.994	0.998	0.999	1.000	1.000	1.000

to 97% for the soil stickiness (stk).

The first six factors accounted for 60.7% of the common variance. Except for the third factor (13.3%), roughly the ten factors contributed evenly in estimating the variance. The first factor was highly correlated with horizon boundaries (Bnd), chroma, and, to a lesser degree, with moist consistence. The second factor (9.3%) was correlated with hue and concretions (Table 7.4).

It was noticed that in most cases, root size and pores orientation were correlated with the same factor. Also, most of the factors did not show correlation with certain properties, like color or consistence alone. Strong intercorrelations were shown to exist between these properties (see Chapter IV). For example, strong association was observed between the color of the concretions and the hue, structure grades, classes, and dry consistence, chroma and moist consistence, etc. The failure of a few factors to explain larger portions of the common variance was indicated by the even contribution of various factors. However, the high communality estimates suggested that the ten factors' model is capable of scanning the variation of the morphological properties.

Subsurface Zone, Chemical Data

The total variance was 14 (Table 7.5). Six axes accounted for 89.7% of the common variance, while ten axes accounted for 98.6%. No significant correlations were observed with axes 7 to 10. The final communality estimates varied from 96% for CEC to 99.8% for very fine sand. Six factors of the ten principal factors accounted for 71.1% (76.3% for the surface zone) of the common variance.

TABLE 7.4

ROTATED FACTORS AND CONTRIBUTION TO THE COMMON VARIANCE OF THE MORPHOLOGICAL PROPERTIES, SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	-0.68952	-0.22103	-0.03069	0.34340	-0.26075	0.03243	-0.09225	0.24545	-0.19321	-0.16744
THICK	-0.17156	0.19971	-0.36039	-0.07867	0.00281	-0.25164	0.24239	0.14463	-0.31612	0.71595
TEXT	-0.06956	-0.11958	0.85297	-0.00394	-0.15077	0.09877	-0.03333	0.38529	0.05715	0.01440
DRY	0.20318	0.05018	0.07650	0.64212	0.05708	0.49943	-0.14951	0.14643	0.29966	-0.11311
MOIST	0.47072	-0.33472	0.51133	0.25718	-0.25887	0.26035	-0.17256	-0.21606	-0.14812	-0.25894
STK	-0.00931	-0.05158	0.96654	-0.07807	-0.02411	0.07681	0.00683	-0.15997	-0.02858	0.01332
PLCT	-0.02664	0.03925	0.56354	-0.12191	0.09044	-0.00745	-0.09713	-0.18242	0.06896	0.74333
HUE	-0.30560	-0.69205	0.13405	-0.30825	0.00687	-0.07899	0.02674	0.40169	-0.09669	0.13716
VAL	0.16198	0.07543	0.16921	-0.13507	0.15143	0.90628	0.11472	-0.07553	-0.06518	-0.08288
CHRO	0.79677	-0.11010	-0.09239	0.08515	-0.10525	0.22906	0.12123	0.07046	0.26895	-0.18307
CLAS	-0.09459	0.29164	0.12324	0.70813	0.04725	-0.23017	0.34598	-0.03234	-0.38615	-0.19539
GRAS	0.07164	0.20042	0.15068	-0.84919	-0.00041	0.10855	0.08475	0.00813	-0.01887	-0.01085
TYPS	0.23719	0.06393	0.01460	-0.00783	0.01125	-0.04002	-0.00482	-0.00447	0.93914	-0.07681
RSIZE	0.09413	-0.15680	-0.17292	-0.01721	0.86847	-0.10011	-0.12323	0.07009	0.01574	0.32038
RCUNT	-0.05120	-0.19973	-0.00255	0.05041	0.14634	-0.04480	-0.24396	0.89591	0.00574	-0.03687
CCNCOLOR	-0.16716	0.83421	-0.11908	-0.26575	-0.10586	0.05531	0.12135	-0.09912	0.00806	0.19846
CCATYPE	0.06956	-0.00036	-0.04206	-0.05954	-0.06786	0.17520	0.91256	-0.26395	0.00730	-0.02148
PCRSIZE	0.18853	0.38890	-0.06512	0.05622	-0.33066	-0.37973	0.63204	0.04477	-0.07734	0.27400
PCRORIEN	-0.07158	0.03584	-0.01143	0.06733	0.89232	0.31544	-0.06619	0.08895	-0.01122	-0.21509

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.23367	0.40424	0.51168	0.19478	0.09304	0.42385	-0.34220	-0.10317	-0.20016	0.35511
2	-0.49445	0.38607	-0.16845	0.03448	0.30381	-0.23467	-0.39194	-0.47693	0.19908	-0.09388
3	-0.24144	0.08430	0.70359	-0.40633	-0.32736	-0.12703	0.04939	0.00172	0.19760	-0.33116
4	0.18319	-0.05709	-0.06691	-0.66978	0.53844	0.20572	-0.14921	0.03829	-0.28398	-0.27111
5	-0.23658	-0.30518	0.26425	0.31896	0.55561	0.30697	0.13907	0.22330	0.43964	-0.11791
6	0.26437	-0.16337	0.24994	0.44781	0.16079	-0.43558	-0.14090	-0.09329	-0.38662	-0.49680
7	0.39398	0.58681	-0.02885	0.02505	0.20536	-0.09050	0.59390	-0.10086	0.24090	-0.16640
8	0.08848	0.31856	-0.07247	-0.00297	0.04836	-0.30613	-0.38859	0.77446	0.19642	-0.00083
9	-0.41175	0.08760	0.19213	-0.05453	0.29249	-0.34420	0.38438	0.18711	-0.47050	0.41804
10	0.38809	-0.32226	0.18707	-0.20319	0.19323	-0.44999	-0.11793	-0.23851	0.37400	0.46771

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
1.681907	1.760768	2.520931	2.051373	1.903219	1.633195	1.611523	1.426734	1.381850	1.541968

TABLE 7.5

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES FOR SURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.08879	0.54954	-0.56128	0.35461	-0.13423	0.32589	0.33650	0.08496	0.03259	-0.00631
H	-0.61714	0.52878	0.46265	0.03743	-0.11839	-0.15575	0.03602	0.11570	0.06541	0.13856
CEC	0.74901	0.43901	0.38587	-0.13227	0.00016	0.09064	0.11631	-0.01416	0.09689	0.08670
CACO3	0.58331	0.12538	-0.52558	-0.17518	0.11290	-0.50455	0.10473	0.18591	0.13519	0.07525
PH	0.52912	-0.60715	-0.02779	-0.18889	0.43898	0.23842	-0.00234	0.11848	0.09561	-0.11124
CP	-0.40232	0.68653	0.27570	0.14937	0.34403	0.00915	-0.03885	0.34136	-0.07450	-0.11759
FS	-0.77893	-0.49353	-0.07292	-0.20554	-0.16631	0.13671	-0.03197	0.20852	0.01078	0.09140
VFS	-0.32788	-0.59958	0.23579	0.55459	0.24822	-0.19428	0.17655	-0.12067	0.15187	0.01040
CLAY	0.80151	0.42232	0.17768	-0.13423	-0.11513	-0.09815	0.21039	-0.10365	-0.00782	-0.21188
SILT	0.47378	0.65737	-0.25801	0.18588	0.28384	0.01642	-0.33476	-0.14484	-0.10325	0.11807
CA	0.85309	-0.03073	0.14767	0.21499	-0.33430	-0.03233	-0.21845	0.13412	0.07401	-0.09942
MG	0.88746	0.03387	0.18315	-0.01734	0.06204	0.27245	0.03132	0.02894	0.16972	0.19132
NA	0.75517	-0.41727	0.16485	0.04424	0.05080	-0.05991	0.26635	0.08389	-0.35572	0.11597
BST	0.74547	-0.46826	-0.04535	0.34303	-0.19238	-0.02484	-0.17455	0.17018	-0.02747	0.00079

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.996436	0.952347	0.958991	0.999673	0.970149	0.987355	0.997196

VFS	CLAY	SILT	CA	MG	NA	BST
0.998431	0.993213	0.996204	0.990603	0.967873	0.998611	0.992541

	1	2	3	4	5	6	7
EIGENVALUES	5.954316	3.239046	1.274628	0.801851	0.694128	0.595989	0.479171
PORTION	0.425	0.231	0.091	0.057	0.050	0.043	0.034
CUM PORTION	0.425	0.657	0.748	0.805	0.855	0.897	0.931

	8	9	10	11	12	13	14
EIGENVALUES	0.330522	0.243171	0.186801	0.108759	0.078136	0.013480	0.000003
PORTION	0.024	0.017	0.013	0.008	0.006	0.001	0.000
CUM PORTION	0.955	0.972	0.986	0.993	0.999	1.000	1.000

The first factor accounted for 25% of the variance. It was highly correlated with CEC, clay, very fine sand (vfs), and, to a lesser degree, with Ca. According to the regression analysis (Chapter III), Ca showed close relationships with CEC and clay.

Organic matter (OM) showed a high loading on the second factor followed by H. Regression analyses also strongly suggested the close relationship between OM and H. In most cases, potassium (K) showed high loading on one factor. No other property showed significant loading on the same factor at the same time (Table 7.6).

Except for the first factor, the first eight factors estimated an even portion of the common variance. However, the high communality estimates indicated the success of the model in explaining the variance of the data. The failure of a very few factors to explain larger portions of the variance, in addition to the even contribution of the various factors to the common variance, indicated the extreme heterogeneity nature of the soil properties in the subsurface zone. This was reflected by the graph of the loading of different locations on factors one, two, and three (Figures 7.1 and 7.2). Some sort of grouping was produced, but with obvious overlapping. This might also be due to the contribution of a large portion of soil inclusions or soil intergrades.

Subsurface Zone, Morphological Data

Total variance was 24 (Table 7.7). The first six axes accounted for 66% of the total variance, while ten axes accounted for 82.5%. Significant correlations were observed between soil properties and all principal axes. The final communality estimates ranged from 69.5% for

TABLE 7.6

ROTATED FACTORS AND CONTRIBUTION TO THE COMMON VARIANCE OF THE CHEMICAL PROPERTIES, SUBSURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.00606	0.08513	0.95777	-0.11186	-0.15461	0.06601	0.14811	-0.07197	-0.06252	-0.00489
N	-0.01438	0.52106	-0.05939	0.03313	-0.70370	-0.19358	-0.14220	-0.28978	-0.13642	0.14334
CEC	0.91018	0.09138	-0.05346	-0.20463	0.04806	0.03425	0.11698	0.13561	0.08207	0.18756
CACO3	0.22253	-0.13174	0.07322	-0.14331	0.15197	0.91439	0.16843	0.12595	0.05874	-0.00200
PH	0.10941	-0.14132	-0.22565	0.08095	0.91213	0.07578	-0.06873	0.15078	0.09882	0.07607
OM	0.02790	0.88787	0.12641	-0.02812	-0.26790	-0.10705	0.16423	-0.25004	-0.08739	-0.03372
FS	-0.79326	-0.03898	-0.09272	-0.02949	-0.03074	-0.21344	-0.50164	-0.18607	-0.06652	0.14056
VFS	-0.30354	-0.01920	-0.12993	0.91415	0.06298	-0.14071	-0.16005	0.03508	0.05216	-0.00676
CLAY	0.90105	-0.04671	0.02814	-0.22593	0.01634	0.20643	0.08185	0.16523	0.09442	-0.20373
SILT	0.35063	0.14075	0.20208	-0.21765	-0.00824	0.17919	0.85092	0.07752	-0.04350	0.03325
CA	0.53200	-0.14585	-0.07256	-0.09662	0.10369	0.08970	0.08973	0.80257	0.02565	-0.00932
MG	0.71265	-0.13067	-0.00203	-0.09511	0.40271	0.02340	0.13898	0.34527	0.10468	0.34882
NA	0.38752	-0.22659	-0.16345	0.11115	0.38819	0.12293	-0.06124	0.35795	0.67834	0.01382
BST	0.16411	-0.28819	-0.06026	0.13084	0.33621	0.12167	0.06018	0.82730	0.21194	0.03147

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.66734	0.22336	0.03609	0.12421	0.36363	0.25181	-0.21304	-0.45704	-0.19276	-0.03121
2	-0.41052	0.42431	0.33078	-0.33965	0.45838	-0.07056	0.36120	-0.22811	-0.16974	-0.01607
3	-0.43172	0.33770	-0.54083	0.21880	0.18781	0.48679	-0.25528	0.04219	0.09121	0.10812
4	0.07467	0.13945	0.41215	0.65827	0.17599	0.17631	0.29441	0.46631	0.05999	-0.04488
5	-0.01349	-0.41357	0.15002	-0.32221	0.56381	0.13787	-0.40635	0.44205	-0.05316	-0.04686
6	0.03067	0.01524	-0.42476	0.27608	0.43372	-0.69729	0.02225	0.02851	0.07717	-0.24617
7	-0.32139	-0.06530	0.45556	0.28841	-0.01122	-0.16078	-0.52626	-0.39432	0.37571	-0.04648
8	0.21399	0.65146	0.10798	-0.22711	-0.15269	-0.28441	-0.36958	0.39763	0.14018	0.21914
9	-0.18907	-0.05640	0.05478	0.26931	-0.08206	-0.21136	-0.23451	0.01594	-0.60441	0.36306
10	0.09064	-0.18296	-0.04242	0.02623	0.23504	-0.08322	0.19534	-0.09888	0.32472	0.86039

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.515180	1.309360	1.098697	1.066168	1.890168	1.074904	1.158662	1.853707	0.584743	0.248035

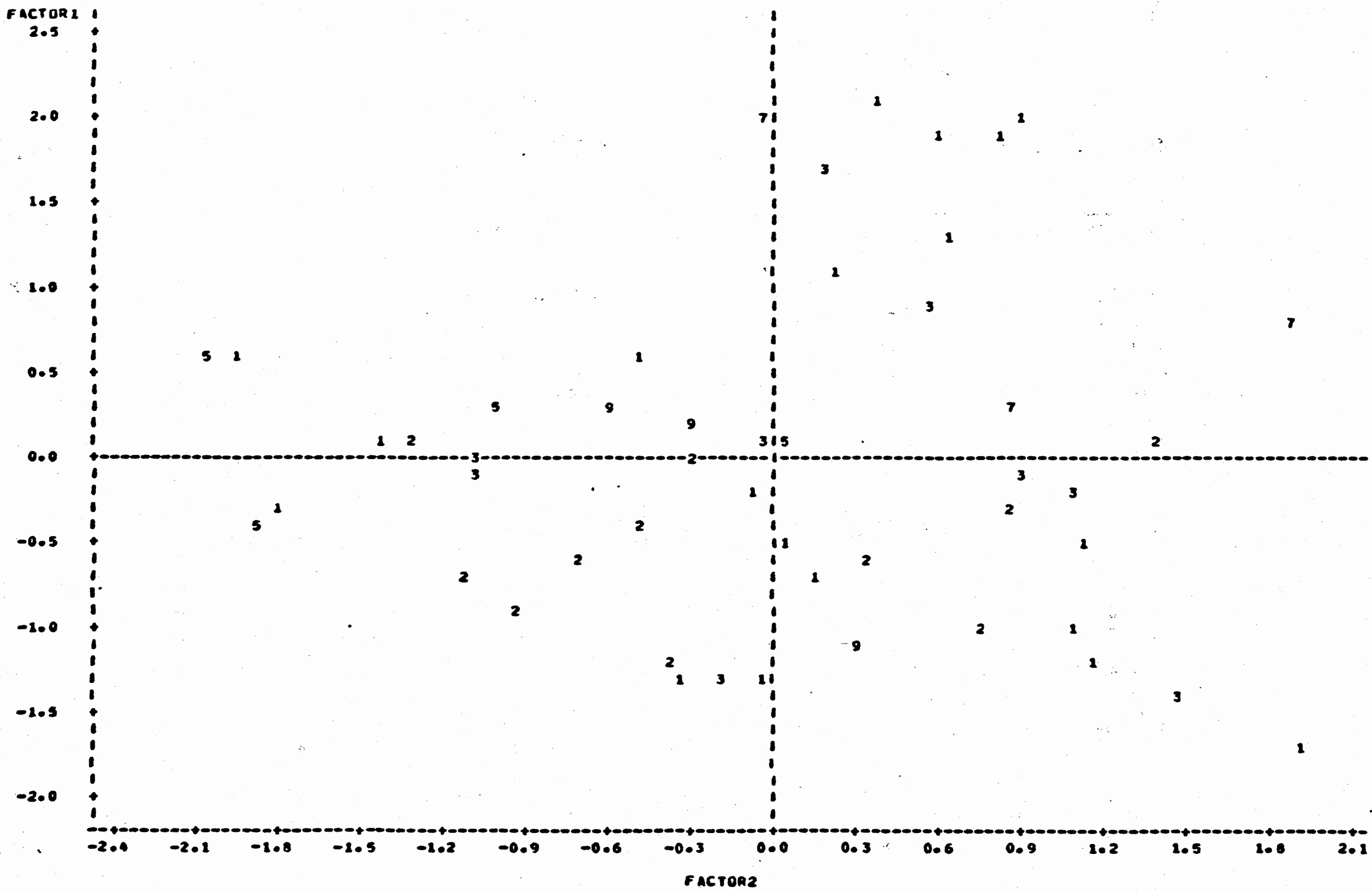


Figure 7.1. Loadings of Different Locations on Factors One and Two for Chemical Properties, Subsurface Zone.

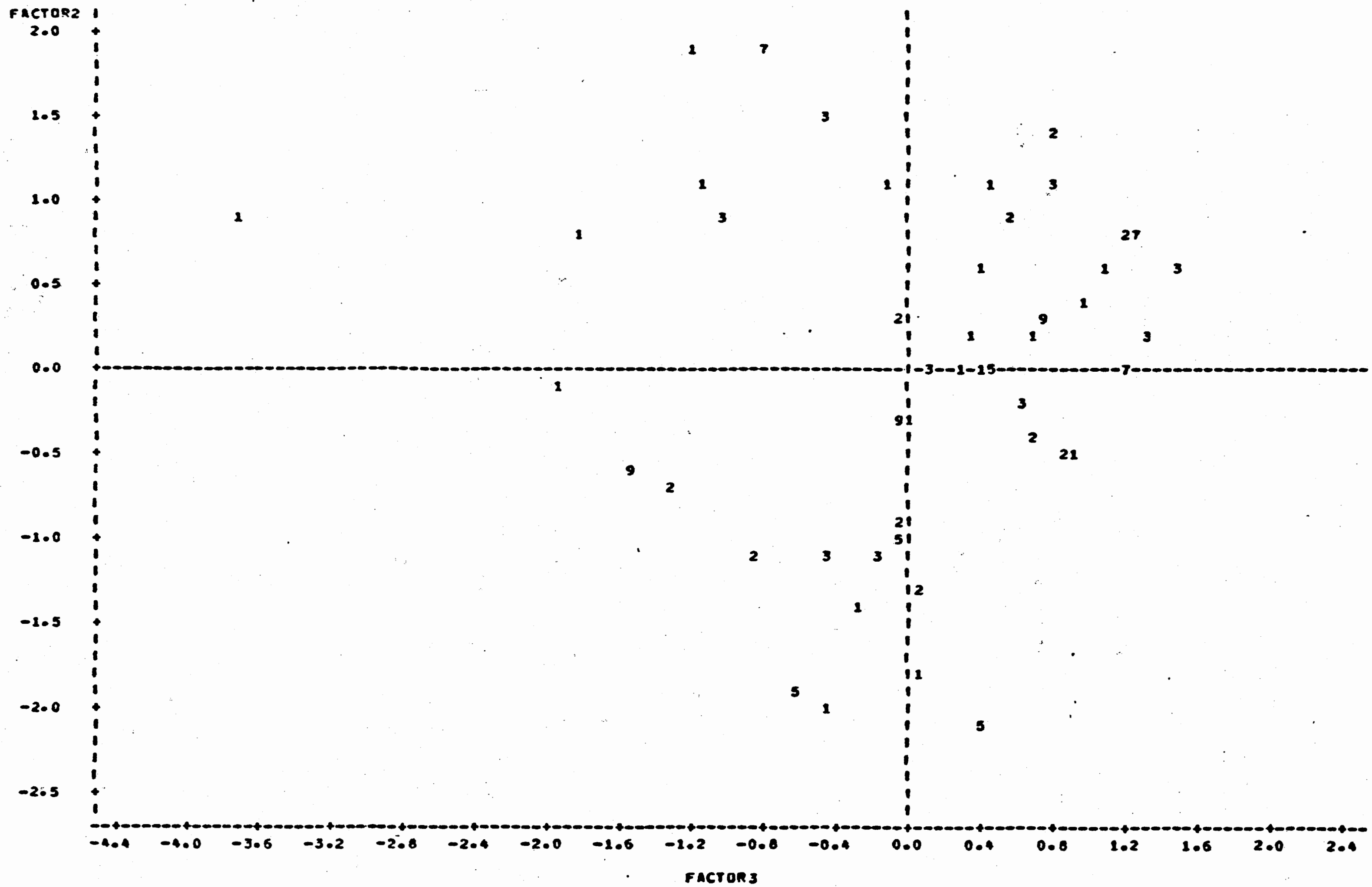


Figure 7.2. Loadings of Different Locations on Factors One and Three for Chemical Properties, Subsurface Zone.

TABLE 7.7

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE MORPHOLOGICAL PROPERTIES, SUBSURFACE ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.27356	0.41520	0.17623	-0.24869	-0.51406	-0.11761	0.24029	-0.12980	-0.04900	0.01990
THICK	0.16964	0.54342	-0.44025	0.18925	-0.03730	-0.24897	0.20372	0.17718	-0.27615	-0.21913
TEXT	0.73348	0.19860	-0.03522	-0.20657	0.06096	-0.00679	0.19961	-0.25877	-0.11564	0.15585
DRY	0.58128	0.41964	-0.10499	-0.25023	0.13771	0.45030	0.05244	0.00694	0.00757	0.10655
MOIST	0.70274	0.32464	0.01365	-0.22251	0.20520	0.03386	-0.00293	0.01659	0.13980	0.01590
STK	0.63973	0.44205	-0.06256	-0.10556	-0.14340	0.23210	-0.13367	-0.15967	0.24240	0.10192
PLCT	0.47486	0.23629	0.18255	0.08743	-0.11934	0.12309	-0.51336	-0.09122	-0.38059	0.02044
MABUND	-0.69226	0.54317	0.09197	-0.02083	0.13836	0.12948	0.08174	-0.29569	-0.06546	-0.03207
MSIZE	-0.69819	0.56850	0.16446	-0.06356	0.08152	0.13479	0.15538	-0.24287	-0.06217	0.01766
MCONT	-0.65026	0.59723	0.13730	-0.07449	-0.08118	0.17953	0.13372	-0.16433	0.01399	-0.16700
HUE	0.00488	-0.14011	0.81137	0.13529	-0.03844	0.21822	-0.04279	-0.00807	0.15201	-0.01726
VAL	-0.53558	0.35054	-0.21182	-0.22187	-0.04100	0.25892	-0.21208	0.16697	0.18071	0.23625
CHRO	-0.03546	0.35090	-0.75916	-0.11348	-0.04168	-0.25484	-0.17895	0.11394	-0.00907	-0.06572
CLAS	0.03574	0.16966	-0.45440	0.36831	-0.36780	0.44026	0.05485	0.11226	0.20726	0.12294
GRAS	0.49055	0.17232	-0.11910	0.31156	0.39288	0.10939	0.46483	-0.08117	0.10249	-0.35141
TYPS	-0.00093	-0.37803	0.00020	-0.67857	0.43077	0.07169	0.06088	0.19713	0.17687	-0.02196
RSIZE	-0.09108	-0.30675	-0.18234	0.36811	0.26281	-0.02999	0.35210	-0.13229	-0.16799	0.65949
ROUNT	0.19198	-0.43795	0.54829	0.25159	-0.25183	0.06850	0.11637	-0.09984	0.21504	-0.15022
CONQUNT	0.16063	0.62021	0.50043	-0.09324	0.06411	-0.47008	0.01669	0.10896	0.13077	0.11136
CONSIZ	0.02097	0.55440	0.56815	-0.02449	0.09453	-0.38692	-0.03307	0.14412	0.10542	0.22556
CONCOLOR	0.11366	0.09096	0.47702	0.07348	-0.15183	0.30100	0.22214	0.51205	-0.47014	0.03163
CGATYPE	-0.13609	0.46059	0.09398	0.38315	0.30588	0.16377	-0.03950	0.47990	0.16584	-0.02004
PORSIZE	0.16897	0.22691	-0.11269	0.76085	-0.04880	-0.19769	-0.10734	-0.05683	0.26373	0.06501
PORORIEN	0.10021	0.11600	0.18585	0.33779	0.50914	0.12588	-0.40791	-0.23250	-0.21645	-0.08565

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	MABUND	MSIZE	MCONT	HUE	VAL
0.695601	0.814271	0.765686	0.861612	0.712259	0.806659	0.768813	0.918492	0.953868	0.915711	0.770687	0.733863

CHRO	CLAS	GRAS	TYPS	RSIZE	ROUNT	CONQUNT	CONSIZ	CONCOLOR	CGATYPE	PORSIZE	PORORIEN
0.829678	0.774975	0.904559	0.868400	0.945739	0.753008	0.936323	0.873698	0.901353	0.766455	0.801625	0.722546

	1	2	3	4	5	6	7	8	9	10	11	12
EIGENVALUES	4.169086	3.745061	3.019834	2.108143	1.401468	1.392743	1.137393	1.031631	0.931793	0.856730	0.715162	0.705945
PORTION	0.174	0.156	0.126	0.088	0.058	0.058	0.047	0.043	0.039	0.036	0.030	0.029
CUM PORTION	0.174	0.330	0.456	0.543	0.602	0.660	0.707	0.750	0.789	0.825	0.855	0.884

	13	14	15	16	17	18	19	20	21	22	23	24
EIGENVALUES	0.587177	0.501076	0.421208	0.309968	0.259640	0.200035	0.179597	0.112990	0.096052	0.070261	0.029204	0.015802
PORTION	0.024	0.021	0.018	0.013	0.011	0.008	0.007	0.005	0.004	0.003	0.001	0.001
CUM PORTION	0.909	0.929	0.947	0.960	0.971	0.979	0.986	0.991	0.995	0.998	0.999	1.000

horizon boundary (Bnd) to 95.3% for mottling. These estimates were considerably lower than their chemical counterparts.

Six factors accounted for 66.9% (60.9% for the surface zone) of the variance (Table 7.8). The first factor accounted for 12.9% of the total variation and exhibited high correlation with texture and consistence. The second factor accounted for 13.6% and was highly correlated with mottling and, to a lesser degree, with value. (Canonical correlation suggested a strong association between the color variables and the mottling). The contributions of the rest of the factors varied from 11% for the third factor to 4.9% for the tenth factor. Color variables, in addition to the root quantity, appeared to have high loading on the third factor (association analysis indicated the strong association between root quantity and color variables). Most of the other factors were correlated with one or two soil properties.

It seemed that the factors, in most cases, were either correlated with one property or with some properties which had strong association (indicated previously by the canonical correlation).

The failure of a few factors to be correlated with a larger number of soil properties was a good indication of the high variability among the morphological properties. This conclusion was substantiated by the clear scattering of the loadings of different locations on the first and second factors (Figure 7.3). However, soil inclusions might also contribute to the high variability.

Parent Material, Chemical Data

Total variance was 14 (Table 7.9). 91.2% and 98.9% of the total variance was explained by six and ten axes, respectively. No

TABLE 7.8

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE MORPHOLOGICAL PROPERTIES, SUBSURFACE ZONE, AREA ONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
PND	0.38760	0.13248	0.00448	0.20661	-0.36333	0.31290	-0.01577	-0.41538	0.20007	0.20585
THICK	0.10042	0.05767	0.68857	0.32880	-0.04644	0.13677	0.36921	0.01427	0.22731	0.09712
TEXT	0.70002	-0.22084	0.08278	-0.03033	0.04136	0.15194	0.23308	-0.34415	0.03515	-0.14256
DRY	0.89200	0.02542	0.10029	-0.10865	0.06050	-0.07257	0.08603	0.12714	0.16830	0.01925
MOIST	0.70995	-0.23843	0.08699	-0.11231	0.07723	0.26175	0.20650	0.04728	-0.03509	0.10304
STK	0.83591	-0.08653	0.02073	0.27446	-0.00495	0.08243	-0.03054	0.00398	-0.10594	0.17252
PLCT	0.39714	-0.18370	-0.00574	0.26713	0.54465	0.09242	-0.22049	-0.18086	0.26968	0.21613
PABUND	-0.13653	0.93058	0.09019	0.02185	0.10447	0.09621	-0.02978	0.04619	-0.05344	-0.02595
PSIZE	-0.11754	0.95254	0.03564	0.00547	0.01174	0.15483	-0.05385	0.04225	0.02219	-0.04621
PCONT	-0.09459	0.91603	0.03534	0.07420	-0.09226	0.09144	-0.02919	0.06950	0.05030	0.18922
HUE	-0.02742	0.04513	-0.81692	0.00431	0.11445	0.19712	-0.03953	0.08827	0.15988	0.10194
VAL	0.01947	0.49398	0.24297	-0.08487	-0.14438	-0.07109	-0.50166	0.37299	-0.07536	0.02544
CHRC	0.05377	0.00170	0.85151	0.11487	-0.08696	-0.05443	-0.08267	0.07067	-0.21106	0.14703
CLAS	0.24876	0.04998	0.13771	0.52637	-0.28993	-0.46054	-0.09464	0.32519	0.03482	-0.04994
GRAS	0.33841	-0.07757	0.02421	0.09511	0.06627	-0.05753	0.85878	0.15974	-0.02199	-0.05642
TYPS	0.03892	-0.16486	-0.03867	-0.88942	-0.11183	-0.65857	-0.02062	0.10546	-0.14001	0.00737
RSIZE	-0.14288	-0.08151	0.00078	0.08946	0.00495	-0.12049	0.04319	-0.00115	-0.01172	-0.94559
PCUNT	-0.11476	-0.27154	-0.76147	0.16210	-0.10193	-0.02307	0.15065	-0.12104	0.02282	0.10666
CONQUNT	0.19724	0.13273	-0.01976	0.07370	-0.01207	0.92425	0.04312	0.03570	0.04383	0.12059
CONSIZ	0.10309	0.18597	-0.11051	0.07114	0.04144	0.88427	-0.07366	0.12087	0.08746	0.01436
CONCOLOR	0.04772	-0.01232	-0.24249	-0.00963	-0.01542	0.10782	0.01420	0.11350	0.90279	0.00713
CCATYPE	0.00938	0.20508	0.06319	0.17622	0.12358	0.22285	0.12726	0.75648	0.18799	0.02318
PORSIZE	-0.00785	-0.14341	0.02857	0.75195	0.11676	0.14882	0.18094	0.27406	-0.24298	-0.10991
PORORIEN	0.06025	0.06761	-0.09972	0.08112	0.81203	0.03364	0.12573	0.12968	-0.05260	-0.04359

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.67298	0.64355	0.03243	-0.09722	0.09889	0.09709	0.26973	0.14491	-0.07748	0.05896
2	-0.43356	0.56354	0.36265	0.29290	-0.04250	-0.44464	-0.04708	0.17352	0.10958	-0.19247
3	0.05714	0.11146	-0.77771	-0.09068	-0.15391	-0.50595	0.02644	-0.06012	0.27234	-0.11447
4	0.25621	-0.09784	-0.14739	0.77199	-0.24941	0.08631	-0.28076	0.30462	0.07655	0.24342
5	0.01099	-0.05304	-0.09277	0.50781	0.52890	0.12879	0.38341	-0.37253	0.20517	-0.32617
6	0.42869	-0.28874	0.32171	0.07131	0.07854	-0.66339	-0.09857	-0.30791	-0.27084	0.01175
7	0.01429	-0.19219	0.06780	0.09368	-0.59889	0.00027	0.61634	0.12799	-0.22783	-0.37770
8	0.17551	-0.34392	0.19079	-0.15537	0.25434	-0.15462	0.10882	0.63064	0.51981	-0.14832
9	-0.14664	-0.04243	-0.29560	0.03794	0.42737	-0.09555	-0.01026	0.45008	-0.68478	-0.15650
10	0.22036	0.05533	0.01981	-0.05697	-0.10305	0.19930	-0.54494	-0.04733	-0.00107	-0.77149

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.101293	3.262118	2.649959	2.049427	1.304823	2.271910	1.398852	1.352978	1.232678	1.171845

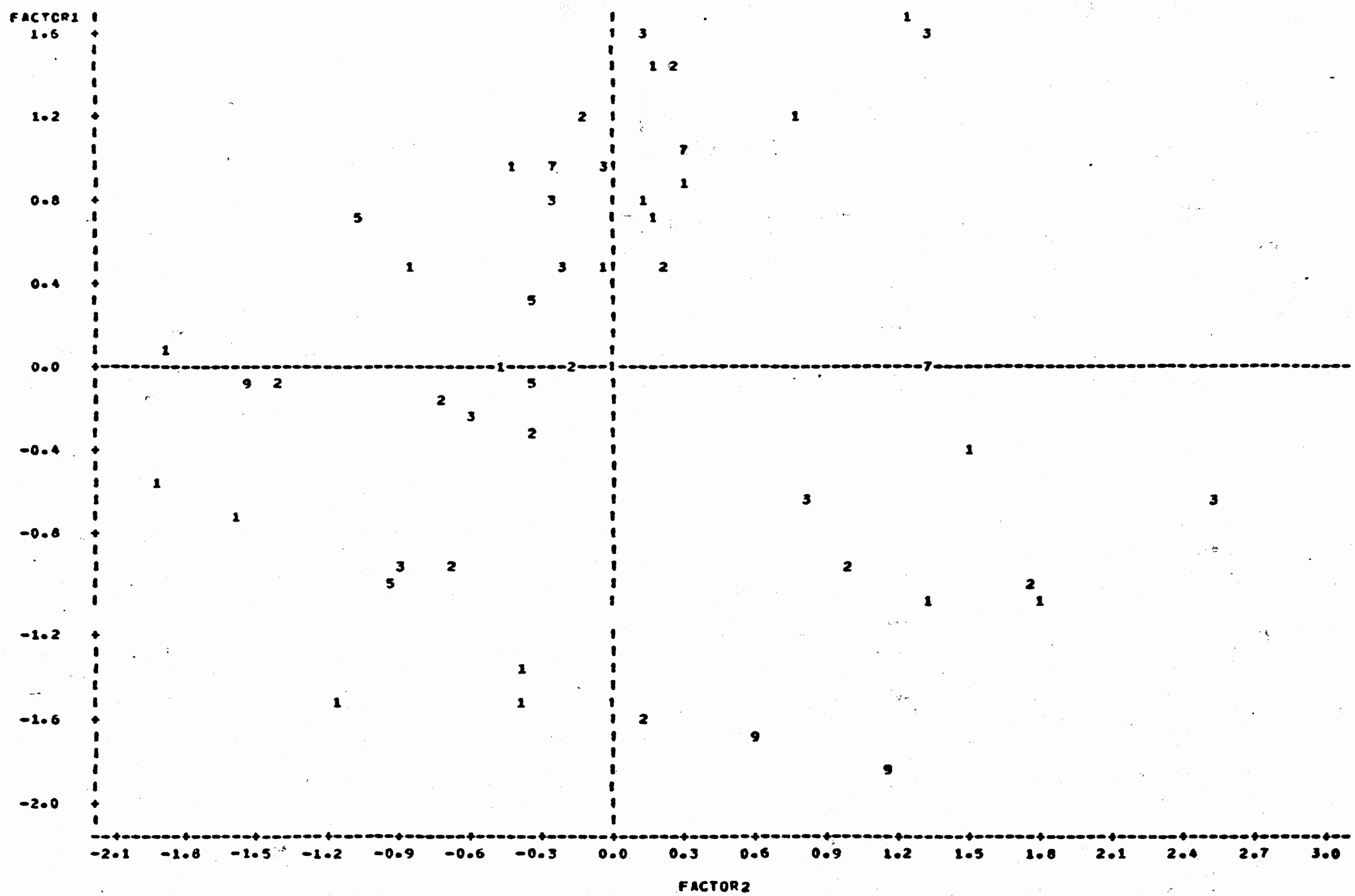


Figure 7.3. Loadings of Different Locations on Factors One and Two for Morphological Properties, Subsurface Zone.

TABLE 7.9

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES, P. M. ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.12490	0.80200	-0.19611	-0.28866	-0.32369	0.22293	0.13226	0.02072	0.03238	0.07812
H	-0.91059	0.03804	0.07386	0.08786	0.16713	0.03419	-0.17628	-0.13933	0.18451	-0.13136
CEC	0.20527	0.10681	0.68111	0.50469	-0.35184	0.18451	0.17124	0.02801	-0.12635	-0.14279
CACO3	0.59095	0.18144	0.15231	0.13070	0.65849	-0.18924	0.18374	-0.22181	-0.11830	0.03706
PH	0.72440	-0.48066	0.06849	-0.26997	-0.16234	-0.23206	0.23567	0.07132	0.00867	0.10915
OM	-0.44551	0.15401	-0.44738	0.69547	0.09656	0.01353	-0.09822	0.13229	-0.09380	0.19894
FS	-0.84960	-0.27310	0.16184	-0.06733	0.21344	0.23963	0.24854	0.05477	0.03810	0.05907
VFS	0.50206	-0.39801	-0.51602	0.24716	-0.40614	-0.24198	-0.07899	-0.13011	-0.01799	-0.09069
CLAY	0.29509	0.63111	0.47801	0.17186	-0.04349	-0.44187	-0.07765	0.08472	0.20032	0.06639
SILT	0.70591	0.51404	-0.00727	-0.27763	0.11600	0.15504	-0.29096	0.00100	-0.17405	-0.04328
CA	0.83721	0.13410	-0.20344	0.32360	0.20269	0.13696	0.15911	0.11356	0.11298	-0.13007
MG	0.80527	-0.11453	0.08673	0.20098	-0.14684	0.38048	-0.04405	-0.24815	0.15721	0.17200
NA	0.44458	-0.56941	0.55497	-0.00427	0.09401	0.10912	-0.32347	0.12097	-0.01493	0.07432
BST	0.82899	-0.15206	-0.32882	-0.02952	0.31275	0.15420	-0.01213	0.16921	0.12346	-0.08248

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.960143	0.974687	0.996462	0.990179	0.986183	0.996635	0.999812

VFS	CLAY	SILT	CA	MG	NA	BST
0.993057	0.998285	0.993995	0.992751	0.993641	0.975643	0.991764

	1	2	3	4	5	6	7
EIGENVALUES	5.752901	2.217710	1.721900	1.243220	1.120940	0.709227	0.467572
PORTION	0.411	0.158	0.123	0.089	0.080	0.051	0.033
CUM PORTION	0.411	0.569	0.692	0.781	0.861	0.912	0.945

	8	9	10	11	12	13	14
EIGENVALUES	0.237260	0.199070	0.173436	0.113025	0.035428	0.008308	0.000002
PORTION	0.017	0.014	0.012	0.008	0.003	0.001	0.000
CUM PORTION	0.962	0.976	0.989	0.997	0.999	1.000	1.000

significant correlations were observed between soil properties and axes 7 to 10. The final communality estimates varied from 96% for potassium to 99% for fine sand.

Six factors accounted for 61% of the common variance. The variance accounted by the ten factors' model was 13.84. The first factor accounted for 13.3% of the total variance (Table 7.10). It was highly correlated with very fine sand and, to a lesser degree, with fine sand, pH, and hydrogen. The second factor identified high correlation with clay, while the third factor showed high correlation with K and Na. Organic matter had a high, but negative loading and H had a positive loading on the fourth factor.

It was observed that the properties correlated with the same factor usually have high correlations among themselves, but they are not the type of properties that could be related to a specific soil process. This conclusion is in harmony with the definition of the Cr horizon where the intensity of most processes are supposed to be minimum. It was noticed, however, that six factors showed to be sufficient in explaining the variation of the chemical data in this zone.

Parent Material Zone, Morphological Data

Total variance was 18 (Table 7.11). The six and ten axes accounted for 82% and 96.2% of the total variance. The amount of variance explained for the P.M. zone was higher than for the surface and subsurface using the same number of axes. This might suggest less variation among morphological properties in this zone. Another support for this conclusion is the higher communality estimates shown by the ten factors' model computed for this zone.

TABLE 7.10

ROTATED FACTORS AND CONTRIBUTION TO THE COMMON VARIANCE OF CHEMICAL PROPERTIES, P. M. ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.11463	0.18227	-0.83627	0.06095	-0.16088	0.02853	0.39775	0.06253	0.11928	0.08766
H	-0.42067	-0.06664	0.02278	-0.32796	-0.15576	-0.14509	-0.31417	-0.49211	-0.13192	-0.53068
CEC	-0.02405	0.21796	0.10560	0.02916	0.00307	0.96056	-0.00987	0.00505	0.11365	0.02554
CACO3	-0.04941	0.22481	0.11813	0.07791	0.85453	0.00310	0.15995	0.39352	0.05491	0.05901
PH	0.43974	0.01726	0.25419	0.61300	0.09275	-0.01688	-0.05993	0.30454	0.09836	0.48706
OM	0.03854	-0.04742	-0.09267	-0.97153	-0.04078	-0.03314	-0.17755	-0.03011	-0.06363	-0.03465
FS	-0.60558	-0.39215	0.08642	-0.12504	-0.12671	-0.04947	-0.52633	-0.37158	-0.12776	-0.08530
VFS	0.94318	-0.11707	0.08470	-0.02286	-0.07623	-0.04578	-0.03134	0.24092	0.09413	0.07927
CLAY	-0.05515	0.92719	-0.10842	0.04327	0.17438	0.24627	0.17444	0.01231	-0.00627	0.01575
SILT	0.01056	0.20424	-0.16734	0.21380	0.18440	-0.02177	0.83407	0.36298	0.11996	0.04657
CA	0.25901	0.11843	-0.05293	-0.02611	0.27898	0.17152	0.17303	0.86356	0.14453	0.06596
MG	0.29238	-0.00500	0.12396	0.18338	0.09874	0.29560	0.22020	0.46507	0.69937	0.09007
NA	-0.01730	0.02436	0.83541	0.33643	-0.03790	0.20817	0.15188	0.14688	0.22864	0.14825
BST	0.23875	-0.07926	0.14939	0.16068	0.16292	-0.19257	0.24386	0.85268	0.12691	0.11865

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.39245	0.17853	0.09848	-0.33065	0.24249	0.12657	-0.36981	0.60660	0.24684	0.23369
2	-0.26581	0.47373	-0.67790	0.20321	0.11825	0.08991	-0.40850	0.00069	-0.04482	-0.11462
3	-0.43336	0.35899	0.38863	-0.37049	0.08998	0.55471	0.00693	-0.27082	0.07615	0.00522
4	-0.22752	-0.14700	-0.17844	-0.71869	-0.13382	-0.48719	-0.25418	-0.17892	-0.10259	0.12599
5	-0.49157	-0.05060	0.29379	0.15313	0.60291	-0.37858	-0.00265	0.31596	-0.13393	-0.14640
6	-0.42615	-0.57462	-0.10422	0.06360	-0.26512	0.27851	-0.21529	0.28021	0.43337	-0.11299
7	0.10079	0.18026	0.47339	0.22932	-0.31490	-0.25981	-0.59844	-0.17972	0.12599	-0.32817
8	-0.26298	0.17277	0.15054	0.14707	-0.51324	0.01790	-0.01684	0.39984	-0.49401	0.43447
9	-0.10151	0.42132	-0.05461	-0.16478	-0.31997	-0.26918	0.47391	0.32176	0.37839	-0.36867
10	-0.15128	0.14362	0.03100	0.25833	0.04961	-0.26395	0.04848	-0.22944	0.55847	0.67065

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
1.857320	1.228069	1.589958	1.674886	0.992477	1.208817	1.482770	2.533286	0.679289	0.596365

TABLE 7.11

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE MORPHOLOGICAL PROPERTIES, P. M. ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
THICK	-0.12640	0.06574	-0.11650	-0.71457	0.30672	0.40021	0.34692	0.13984	0.05622	0.19832
TEXT	0.66745	0.28654	0.11452	0.51529	0.01151	-0.25545	0.00755	0.00819	0.12958	0.20555
DRY	0.60447	0.13165	0.02809	-0.03009	-0.62857	0.28217	0.27043	0.20456	-0.09121	-0.04004
MOIST	0.77926	0.07392	-0.03704	0.22142	-0.17983	0.20915	-0.22378	0.02901	0.10374	0.34016
STK	0.78860	-0.17417	-0.29405	0.31049	0.22204	0.28995	0.10774	-0.07498	0.02847	-0.01149
PLCT	0.53553	-0.28723	-0.42231	0.26588	0.32348	0.37130	0.12902	-0.09714	-0.24512	-0.06624
MABUND	0.67414	0.38951	0.50584	-0.22405	0.19200	-0.01863	0.02694	-0.10496	-0.08514	-0.03480
MSIZE	0.75176	0.35093	0.42536	-0.22369	0.16643	-0.03174	-0.02659	0.01412	0.02915	-0.18690
MCONT	0.75250	0.35237	0.36431	-0.16140	0.28669	-0.03944	-0.07845	0.00116	0.09764	-0.17174
HUE	-0.35519	0.30839	0.33914	0.44613	-0.05063	-0.06643	0.55755	0.32941	0.07643	-0.07438
VAL	-0.11963	-0.54993	0.59547	0.16283	0.09341	0.16102	0.18473	-0.18301	0.39048	0.06493
CHRO	0.45334	0.54374	-0.52915	-0.07996	-0.08006	-0.29252	0.06057	0.21027	-0.05913	0.02739
RSIZE	-0.35430	0.81427	-0.27341	-0.00907	0.00225	0.21083	-0.10025	-0.06692	0.24411	-0.01084
ROUNT	-0.35430	0.81427	-0.27341	-0.00907	0.00225	0.21083	-0.10025	-0.06692	0.24411	-0.01084
CONCOLOR	-0.42491	0.39159	0.55386	0.03552	0.31631	0.00707	-0.06301	0.09805	-0.33062	0.32646
COATYPE	-0.37081	0.28855	-0.28834	0.45327	0.60052	-0.04039	0.10346	-0.00052	-0.04272	-0.07282
PORSIZE	-0.21014	0.56727	0.15585	0.10343	-0.35803	0.07773	0.26084	-0.57510	-0.22207	0.00683
PORORIEN	-0.37485	0.14283	0.41923	0.32687	-0.12133	0.51175	-0.38567	0.24183	-0.11717	-0.15775

FINAL COMMUNALITY ESTIMATES:

THICK	TEXT	DRY	MOIST	STK	PLCT	MABUND	MSIZE	MCONT
0.981136	0.930779	0.984032	0.916576	0.986635	0.951399	0.969670	0.984657	0.976263

HUE	VAL	CHRO	RSIZE	ROUNT	CONCOLOR	COATYPE	PORSIZE	PORORIEN
0.973035	0.955698	0.931664	0.982093	0.982093	0.971481	0.889442	0.983320	0.965944

	1	2	3	4	5	6	7	8	9
EIGENVALUES	5.028399	3.218045	2.352234	1.675798	1.443651	1.048046	0.879673	0.682600	0.570876
PORTION	0.279	0.179	0.131	0.093	0.080	0.058	0.049	0.038	0.032
CUM PORTION	0.279	0.458	0.589	0.682	0.762	0.820	0.869	0.907	0.939

	10	11	12	13	14	15	16	17	18
EIGENVALUES	0.416594	0.349493	0.207140	0.072625	0.027178	0.018659	0.008917	0.000070	0.000000
PORTION	0.023	0.019	0.012	0.004	0.002	0.001	0.000	0.000	0.000
CUM PORTION	0.962	0.981	0.993	0.997	0.998	1.000	1.000	1.000	1.000

Six factors accounted for 68.8% of the common variance. The first factor accounted for 18.7% of the total variance and had a very high correlation with mottling, and a lower correlation with soil texture (Table 7.12). The second factor showed a very high correlation with the roots and accounted for 12% of the common variance. The third factor had a high correlation with stickiness, plasticity, and a lower correlation with moist consistence and concretion and type. Only one factor, namely the seventh, had a high correlation with the hue. All other factors exhibited extremely low correlations with color variables. This suggested the minute nature of the color variability of the parent material. This conclusion is in complete harmony with the hypothesis that genetic development that reflects color changes are not allowed, by definition, in the parent material zone.

The factors computed for morphological properties in this zone were not tied with any interpretation or pattern. This was true since no major process is supposed to be operating in this zone. This was probably the reason why some factors had correlation with several properties that were not correlated, or whose correlation was not direct, for example, concretion and moist or wet consistence. There may be an association between these variables, but it is not yet fully understood.

All Samples, Chemical Data

Total variance was 14 (Table 7.13). 90.3% and 98.2% of the total variance were explained by six and ten axes, respectively. No significant correlations occurred between soil properties and axes 6 to 10. The final communality estimates varied from 94% for H to 99.9% for very fine sand (Table 7.14, Figure 7.4).

TABLE 7.12

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE MORPHOLOGICAL PROPERTIES, P. M. ZONE

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
THICK	0.04587	0.14321	-0.00413	0.96540	0.01006	-0.10652	-0.03708	-0.07242	-0.00970	-0.09136
TEXT	0.46915	0.01264	0.25121	-0.49112	0.04005	-0.17009	0.23451	0.00180	0.10855	0.55578
DRY	0.23541	-0.06904	0.23326	0.00715	0.86820	0.04123	0.17213	0.13964	0.21346	0.13862
MOIST	0.33502	0.02301	0.40501	-0.19981	0.39183	0.02992	-0.19807	-0.08964	0.07227	0.62685
STK	0.26479	-0.08638	0.88693	-0.09857	0.13793	-0.16063	-0.06297	-0.13238	0.00911	0.21519
PLCT	0.02790	-0.19101	0.94098	0.04925	-0.03517	-0.03749	-0.10988	-0.03886	0.09645	0.02696
MABUND	0.95079	-0.07674	0.02521	0.06941	0.07761	0.00328	-0.02132	0.17116	0.03385	0.13188
MSIZE	0.97049	-0.03338	0.07040	-0.00855	0.17000	-0.02468	-0.02192	-0.02470	0.06796	0.03794
MCONT	0.96555	0.02379	0.13487	-0.03857	0.05486	-0.04673	-0.04440	-0.09369	0.05305	0.07048
HUE	-0.05696	0.11285	-0.18171	-0.06659	-0.05346	0.13400	0.93419	0.12331	-0.10346	-0.01255
VAL	-0.00534	-0.25836	-0.03142	-0.00572	-0.00562	0.01952	0.14067	-0.05760	-0.92894	0.03796
CHRO	0.22844	0.26165	0.12481	-0.06085	0.14295	-0.35930	0.06456	-0.06717	0.77836	0.16638
RSIZE	-0.03758	0.91732	-0.14255	0.09081	-0.11919	0.09919	0.07091	0.16474	0.23327	0.00174
RCUNT	-0.03758	0.91732	-0.14255	0.09081	-0.11919	0.09919	0.07091	0.16474	0.23327	0.00174
CONCOLOR	0.17028	-0.01352	-0.42874	0.23693	-0.50915	0.50064	0.24480	0.27891	-0.01086	0.23373
COATYPE	-0.17663	0.33010	0.25750	-0.05848	-0.73299	0.04031	0.34341	0.00026	0.13229	-0.07227
PORSIZE	0.03336	0.32637	-0.14725	-0.09067	0.08040	0.02767	0.13121	0.90534	0.01723	-0.03735
PORORIEN	-0.07731	0.19572	-0.10722	-0.13069	0.03047	0.91509	0.11615	-0.00336	-0.19659	-0.05111

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.63594	-0.21120	-0.47396	0.14314	-0.35711	-0.22069	-0.14596	0.11250	-0.15766	0.26609
2	0.39222	0.67065	0.18827	-0.00795	0.07459	0.09871	0.22719	-0.30780	-0.43104	0.11588
3	-0.50746	0.28982	-0.42240	-0.04242	0.01780	-0.37273	-0.21483	0.15315	-0.51557	-0.06004
4	0.21479	-0.04306	0.39092	-0.66231	-0.19262	-0.22333	-0.42696	0.06568	-0.11768	-0.27037
5	-0.29724	0.00306	0.29030	0.28612	-0.81597	0.03098	-0.02239	-0.25961	-0.09127	0.04999
6	-0.06950	0.30368	-0.49032	-0.43124	-0.28346	0.54797	-0.09037	-0.07819	0.28567	-0.00747
7	-0.04264	-0.13558	-0.18612	-0.36879	-0.13831	-0.44099	0.69160	-0.30349	0.09874	-0.12402
8	0.03694	0.12576	-0.13281	0.17545	0.17450	-0.31371	-0.44829	-0.68563	0.35526	-0.09096
9	-0.04188	-0.53509	-0.11867	-0.09624	0.15454	0.38928	-0.05827	-0.46449	-0.53201	-0.10478
10	-0.19993	-0.08385	0.13273	-0.30841	0.09934	-0.08417	-0.08542	-0.11568	0.02752	0.89548

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.364476	2.162359	2.350966	1.341205	1.822846	1.330425	1.259475	1.065262	1.725521	0.893382

TABLE 7.13

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE CHEMICAL PROPERTIES FOR ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	-0.16563	0.64816	0.48071	-0.12130	-0.40479	0.21294	0.00523	0.30349	0.02978	0.02034
H	-0.58718	0.58198	-0.29019	0.23835	0.31550	0.02691	0.03201	0.09457	0.03878	-0.05609
CEC	0.65820	0.56319	-0.38434	0.08980	-0.07125	-0.05985	-0.04014	0.08286	0.15442	-0.08281
CACO3	0.56792	0.01221	0.38889	-0.47134	0.43427	-0.27063	-0.02272	0.16608	0.10241	-0.05851
PH	0.58420	-0.64076	0.02444	-0.00697	-0.25484	-0.25248	0.17083	-0.08655	0.18510	0.14604
OM	-0.43121	0.71840	0.12063	0.30812	0.16912	-0.11197	0.26947	0.04368	0.13126	0.19630
FS	-0.65840	-0.62559	-0.17736	-0.21416	0.05004	0.20910	0.15274	0.07405	0.14016	-0.03148
VFS	-0.12831	-0.60267	0.30786	0.63511	-0.01401	-0.23099	-0.20171	0.15090	0.00532	-0.06446
CLAY	0.74322	0.50067	-0.26234	-0.09549	-0.03340	-0.08426	-0.23366	0.05462	-0.08684	0.18337
SILT	0.27742	0.79859	0.37943	0.04482	-0.03311	-0.08784	0.14965	-0.27324	-0.12602	-0.11596
CA	0.85932	0.04016	0.07150	0.16481	0.22189	0.35980	-0.11522	-0.05354	0.07557	0.09083
MG	0.88292	0.19167	-0.13848	0.13895	-0.15247	0.04809	0.08828	0.00494	0.20451	-0.18238
NA	0.78298	-0.28235	-0.24045	0.08684	0.02214	-0.03550	0.30731	0.23961	-0.29329	-0.01467
BST	0.72146	-0.42962	0.33353	0.18309	0.18300	0.29739	0.08684	-0.02259	-0.00974	0.02611

FINAL COMMUNALITY ESTIMATES:

K	H	CEC	CACO3	PH	OM	FS
0.995976	0.939373	0.954019	0.999925	0.973478	0.982952	0.997850

VFS	CLAY	SILT	CA	MG	NA	BST
0.999006	0.987948	0.995872	0.981108	0.963227	0.997988	0.980600

	1	2	3	4	5	6	7
EIGENVALUES	5.386038	3.948435	1.161771	0.944622	0.661984	0.532537	0.369035
PORTION	0.385	0.282	0.083	0.067	0.047	0.038	0.026
CUM PORTION	0.385	0.667	0.750	0.817	0.864	0.903	0.929

	8	9	10	11	12	13	14
EIGENVALUES	0.311611	0.264960	0.168328	0.127619	0.094398	0.028657	0.000005
PORTION	0.022	0.019	0.012	0.009	0.007	0.002	0.000
CUM PORTION	0.951	0.970	0.982	0.991	0.998	1.000	1.000

TABLE 7.14

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE CHEMICAL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
K	0.05681	-0.19208	0.92938	-0.11654	-0.00250	-0.09100	-0.11305	0.23313	0.05564	-0.00419
H	0.00264	-0.89623	-0.01057	-0.06382	-0.17006	-0.25517	-0.08469	0.00337	0.16659	0.05455
CEC	0.93057	-0.07597	0.00935	-0.18562	0.02674	0.06758	0.10203	0.09639	0.04348	0.14443
CACO3	0.16731	0.21199	-0.00181	-0.08971	0.92970	0.19533	0.05510	0.11395	-0.02016	-0.00368
PH	0.12097	0.86812	-0.25594	0.17634	0.08404	0.14382	0.15926	-0.11687	0.18393	0.08947
OM	0.00725	-0.68023	0.24181	0.00187	-0.07541	-0.17591	-0.08871	0.32169	0.56009	0.00551
FS	-0.74164	0.01654	-0.16175	-0.08259	-0.15915	-0.15677	-0.03256	-0.57925	-0.02211	0.16606
VFS	-0.27262	0.16116	-0.11975	0.92644	-0.08829	0.09038	0.01233	-0.09978	0.00042	0..7030
CLAY	0.88604	0.05833	0.02548	-0.24251	0.16001	0.11325	0.08400	0.12677	-0.04702	-0.27613
SILT	0.33912	-0.19334	0.30084	-0.18032	0.12378	0.06140	-0.05161	0.82985	0.08736	0.04932
CA	0.52451	0.17321	-0.05691	-0.03272	0.14943	0.79860	0.05202	0.06520	-0.04433	-0.03798
MG	0.77071	0.30199	-0.00027	-0.05515	0.04904	0.35085	0.17173	0.13502	0.00431	0.31898
NA	0.39041	0.38464	-0.22451	0.01699	0.09700	0.30418	0.73432	-0.06140	-0.04352	0.01003
BST	0.06281	0.43598	-0.09168	0.18682	0.18949	0.80883	0.21740	0.04876	-0.03809	0.04539

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.65394	0.44899	-0.08760	0.04412	0.25645	-0.46245	0.24031	0.14139	-0.05867	0.01861
2	0.47271	-0.55591	0.37118	0.30366	0.01422	0.14443	-0.12211	0.42758	0.13405	-0.02753
3	-0.39641	0.17219	0.50474	-0.31165	0.38061	-0.27281	-0.18122	0.45183	0.05977	-0.03813
4	-0.16414	0.25871	0.12172	0.70681	0.48381	0.26127	-0.09396	-0.15486	-0.22612	-0.07383
5	-0.15182	-0.54395	-0.49647	0.01608	0.54588	-0.35270	0.02813	-0.03678	0.06823	-0.07174
6	0.16169	0.16847	-0.29476	-0.35742	0.37424	0.68650	0.04562	0.24112	0.23271	-0.07160
7	-0.27013	0.06442	-0.01389	0.30348	-0.06938	-0.01246	0.57869	0.21022	0.53135	0.40523
8	0.12758	-0.20185	0.49821	-0.27013	0.28954	0.09247	0.46491	-0.55923	0.02008	-0.01121
9	0.16239	0.07993	0.04183	-0.02140	0.13997	-0.06534	-0.57044	-0.35104	0.45658	0.53299
10	0.00186	0.13134	0.03796	0.12488	-0.09388	-0.11808	-0.07990	-0.17145	0.61145	-0.73028

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.461779	2.633436	1.182868	1.087006	1.050839	1.724676	0.696258	1.272609	0.396340	0.243509

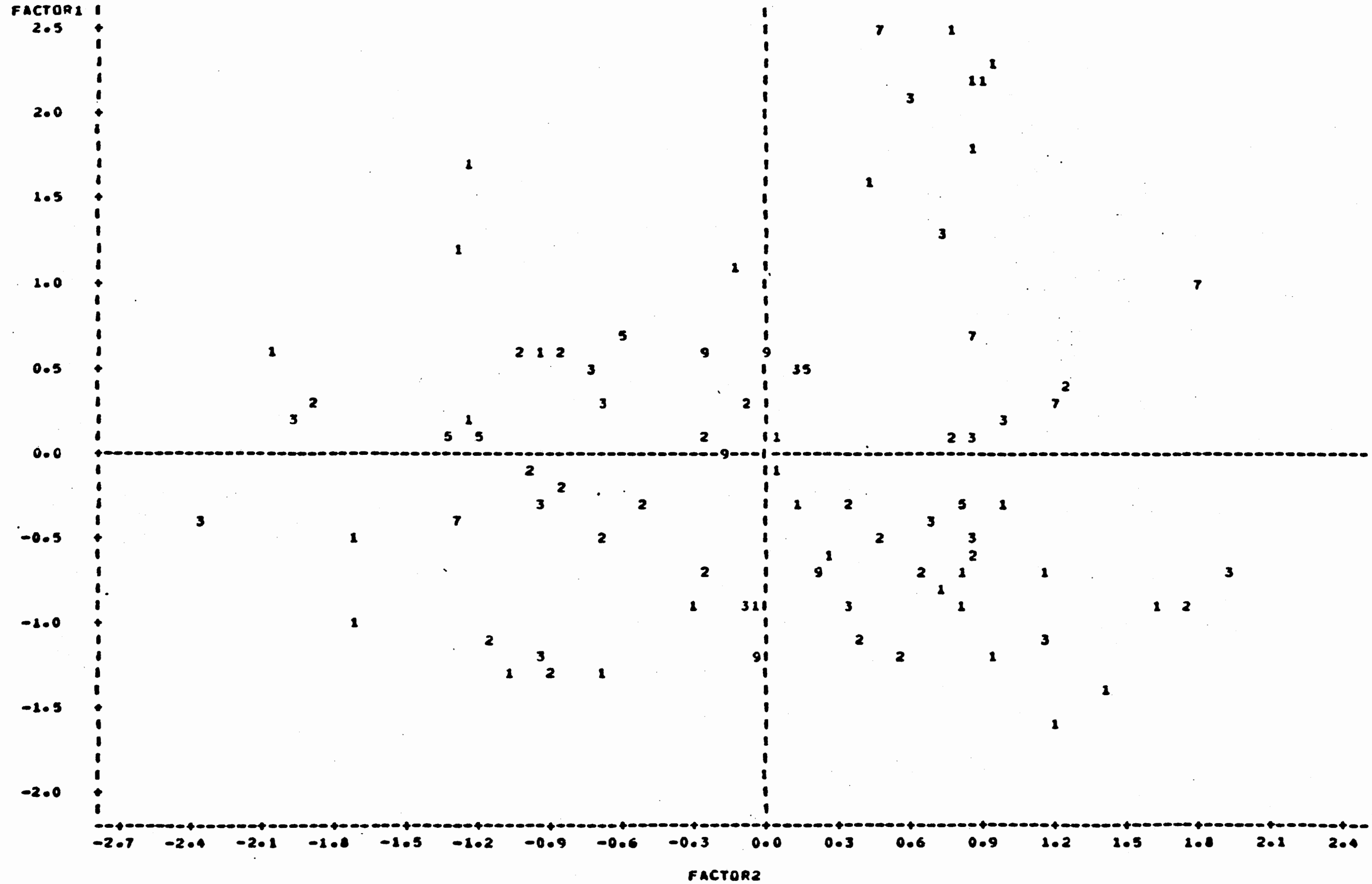


Figure 7.4. Loadings of Different Locations on Factors One and Two for All Chemical Properties, All Samples.

Six principal factors accounted for 79.57% of the common variance (76.3% and 71.1% for the surface and the subsurface zones, respectively). CEC, fine sand, clay, and Mg followed by calcium had high loading on the first factor which accounted for 24.7% of the common variance. The second factor was highly correlated with H and pH and, to a lesser degree, with organic matter and base saturation. The third factor was highly correlated with potassium. As in the case for different zone analyses, potassium appeared to be correlated with factors that did not show any significant correlations with any of the soil properties at the same time. No explanation could be advanced for this pattern.

The fourth factor was highly associated with very fine sand. Similar to the surface and subsurface zones, the properties that were correlated with the same factor had a strong intercorrelation among themselves (regression analysis). It appeared also that even if genetic horizons were treated alike, a six factors' model would be considered sufficient to explain a large portion of the data variance. However, it would not indicate the magnitude of the variation of individual soil properties within different horizons. This is very important if a hypothesis is to be formulated on the sources of variability of different soil properties.

All Samples, Morphological Data

Total variance was 23 (Table 7.15). Ten axes accounted for 86.3% of the total variance. Significant correlations existed with all the principal axes. The final communality estimates varied from 69.7% for concretion type to 97.5% for pore orientation.

TABLE 7.15

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF THE MORPHOLOGICAL PROPERTIES OF ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.75438	0.03900	0.04830	0.01577	-0.01925	-0.29546	-0.01138	0.15747	0.15217	-0.07085
THICK	0.13290	0.30451	-0.19650	0.57176	0.35244	-0.28136	-0.04235	0.15191	0.10779	-0.40946
TEXT	0.63448	0.31330	-0.30201	-0.09107	-0.16604	0.17845	-0.08895	0.11522	0.23282	0.20768
DRY	0.55939	0.39420	-0.28609	-0.17604	-0.06623	0.21566	-0.10186	0.31180	0.08807	0.03312
MOIST	0.71734	0.27254	-0.31060	-0.22752	-0.07470	0.15573	-0.10460	0.04333	0.02858	0.10900
STK	0.72252	0.29653	-0.35398	-0.21513	-0.05305	0.09499	-0.03259	-0.34016	0.07434	-0.11181
PLCT	0.68239	0.08580	-0.25104	-0.16772	0.00970	0.03903	0.04199	-0.45949	-0.04160	-0.36004
MABUND	-0.10265	0.79005	0.37578	-0.26333	0.28719	0.07340	-0.01394	0.05458	-0.07523	-0.01196
MSIZE	-0.08841	0.80761	0.39844	-0.30850	0.22583	-0.01520	-0.04318	0.02756	-0.07659	-0.01584
MCONT	-0.13368	0.79354	0.32384	-0.32219	0.23262	-0.03955	-0.07792	-0.03966	-0.02727	-0.04526
HUE	0.33023	-0.41804	0.59644	-0.19602	-0.11103	0.13746	-0.19033	-0.11919	0.17993	-0.03076
VAL	-0.40235	0.41171	0.09571	0.00977	-0.19643	0.05352	0.52285	-0.13719	0.40132	0.12216
CHRO	-0.30014	0.57278	-0.50850	0.23555	0.06614	-0.04735	-0.00426	0.05456	-0.24806	0.22898
CLAS	0.86128	-0.07176	0.00404	0.02121	0.23946	-0.05570	0.19960	0.07482	-0.01584	0.06249
GRAS	0.87687	-0.13648	-0.02206	0.07677	0.22641	-0.01572	0.10732	0.13145	-0.12402	-0.00315
TYPS	0.50512	-0.41929	0.00517	-0.36751	0.10202	-0.20466	0.26296	0.11931	-0.25084	0.20605
ROUNT	0.43499	-0.62321	0.29827	-0.17795	0.16209	0.03984	-0.26981	0.02366	-0.08430	0.01401
CONQUNT	0.51868	0.42733	0.27270	0.32715	-0.46310	-0.25244	-0.18069	-0.03240	-0.11823	0.06905
CONSIZ	0.47127	0.40608	0.38802	0.30190	-0.49926	-0.19606	-0.12373	-0.04098	-0.14721	0.03455
CONCOLOR	0.53427	-0.04383	0.37251	0.19760	0.14276	-0.06375	0.23213	0.18402	0.34562	0.01513
COATYPE	0.53604	0.07666	0.20724	0.38219	0.23173	0.06035	0.36792	-0.35823	-0.19185	0.23578
PORSIZE	0.10357	0.00969	0.08695	0.56193	0.38471	0.38488	-0.41021	-0.16087	0.14172	0.24764
PORORIEN	0.16486	0.05688	0.22628	0.24453	-0.23210	0.65916	0.27683	0.25013	-0.25784	-0.29263

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	MABUND	MSIZE	MCONT	HUE	VAL
0.713956	0.883429	0.778160	0.748492	0.792440	0.928180	0.910027	0.942115	0.973952	0.922365	0.792953	0.850264

CHRO	CLAS	GRAS	TYPS	ROUNT	CONQUNT	CONSIZ	CONCOLOR	COATYPE	PORSIZE	PORORIEN
0.855794	0.857454	0.889605	0.807100	0.806761	0.963683	0.956245	0.697051	0.895666	0.905732	0.975423

	1	2	3	4	5	6	7	8	9	10	11	12
EIGENVALUES	6.258620	4.042425	2.082006	1.786741	1.292874	1.104448	1.027145	0.819434	0.736186	0.696967	0.59[illegible]24	0.534219
PORTION	0.272	0.176	0.091	0.078	0.056	0.048	0.045	0.036	0.032	0.030	0.026	0.023
CUM PORTION	0.272	0.448	0.538	0.616	0.672	0.720	0.765	0.801	0.833	0.863	0.889	0.912

	13	14	15	16	17	18	19	20	21	22	23
EIGENVALUES	0.390921	0.371858	0.287093	0.268447	0.217312	0.145082	0.108214	0.090073	0.067882	0.045291	0.026840
PORTION	0.017	0.016	0.012	0.012	0.009	0.006	0.005	0.004	0.003	0.002	0.001
CUM PORTION	0.929	0.945	0.958	0.970	0.979	0.985	0.990	0.994	0.997	0.999	1.000

Six factors accounted for 63.7% of the common variance. The ten factors could be divided into two groups according to their contribution to the common variance. The factors 1 to 5 in one group and 6 to 10 in the other group. Each factor contributed evenly to the common variance. This spread of the variance among many factors indicated the nature of the high variability among the morphological properties.

The first factor accounted for 15.1% of the common variance (Table 7.16). It was highly correlated with consistence, and to a lesser degree, with horizon boundaries, and size and strength of the soil structure. The second factor (12.9%) was highly correlated with mottling. The third factor (11%) was highly correlated with hue, chroma, to a lesser degree with root quantity, and concretion type. The fifth factor was correlated with concretion type and size. The ninth factor was correlated with root quantity, and color value. According to the association analysis, root quantity was correlated with the color variables (Tables 7.17 and 7.18, Figure 7.5).

Different factors were correlated with many properties. These properties were intercorrelated. This pattern made it very hard to tie the different factors with any meaningful interpretations. However, it seemed that texture, consistence, size and strength of the structure, mottling, color, and coating types are the most important properties, ordered in sequence according to the magnitude of their variability.

All Data

Total variance was 38 (Table 7.19). 67.5% and 79.6% of the total variance was accounted by six and ten principal axes. Sixteen axes were needed to explain 90.5% of the total variance. The final

TABLE 7.16

ROTATED FACTORS AND CONTRIBUTIONS TO THE COMMON VARIANCE OF THE MORPHOLOGICAL PROPERTIES, ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.46922	-0.05091	0.28506	0.36122	0.32445	-0.14159	-0.15702	0.08216	0.12595	0.32691
THICK	0.00668	0.04288	-0.28605	0.09486	0.10361	-0.01541	0.16577	0.07768	0.04785	0.86252
TEXT	0.84552	-0.01656	-0.02462	0.10531	0.17412	-0.01284	0.08370	0.08982	-0.07274	-0.02085
DRY	0.82317	0.15101	-0.08009	0.03937	0.07457	0.13800	-0.03806	0.02984	0.08183	0.08045
MOIST	0.81110	0.05020	-0.01856	0.17665	0.12250	0.00188	-0.01143	0.25202	0.13175	-0.06690
STK	0.66787	0.04469	-0.00501	0.16764	0.11931	-0.06540	-0.00269	0.65829	0.01125	0.00306
FLCT	0.38404	-0.03679	0.11153	0.21759	0.07304	0.01568	-0.08022	0.81812	0.10532	0.09473
MABUND	0.05460	0.95380	-0.10157	-0.00243	0.04681	0.06790	0.03539	-0.03968	-0.09533	0.01931
MSIZE	0.05198	0.96981	-0.07908	-0.02994	0.12056	-0.00105	-0.02628	-0.01721	-0.08961	0.00392
MCONT	0.04098	0.93590	-0.09965	-0.09705	0.07701	-0.07003	-0.01304	0.04605	-0.10915	0.01977
MLE	-0.02209	-0.03863	0.84110	0.06508	0.13649	0.03924	0.08690	0.03622	0.11027	-0.19519
VAL	-0.11545	0.21877	-0.15812	-0.06768	-0.01636	0.03308	-0.07999	-0.07842	-0.86066	-0.06951
CHRO	0.08949	0.16652	-0.88280	-0.10006	0.03506	-0.06078	0.12526	-0.07638	-0.05771	0.03051
CLAS	0.46488	-0.07075	0.22435	0.70004	0.08332	0.01311	-0.03030	0.15436	0.18027	0.17774
GRAS	0.45141	-0.13283	0.20880	0.65584	0.10406	0.09673	-0.01020	0.15019	0.33175	0.20385
TYPS	0.18311	-0.18165	0.23311	0.57853	-0.10733	-0.12493	-0.40943	-0.01089	0.31944	-0.23370
ROUNT	0.02882	-0.20679	0.63945	0.23969	-0.06543	-0.04816	0.06478	0.00403	0.52015	-0.12435
CONCUNT	0.24118	0.10689	0.00921	0.11926	0.93047	0.01755	0.03730	0.06007	0.01429	0.09218
CCASIZ	0.15797	0.14525	0.07703	0.11638	0.93470	0.11054	0.00646	0.05218	-0.01966	0.04086
CONCOLOR	0.20995	0.00898	0.45577	0.49507	0.16030	0.05193	0.06464	-0.14739	-0.18075	0.33631
CUATYPE	-0.01709	0.01363	-0.01799	0.80311	0.25304	0.11992	0.30517	0.26252	-0.09338	-0.02647
PCRSIZE	0.02872	-0.02718	0.02358	0.09625	0.01096	0.03760	0.93054	-0.05874	0.10215	0.11410
PORORIEN	0.07237	-0.00678	0.07353	0.07181	0.09906	0.97224	0.05190	-0.00891	-0.03896	-0.01499

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.62211	-0.09621	0.29952	0.52294	-0.30234	0.04391	-0.00096	-0.28722	-0.22326	-0.12190
2	0.28789	0.71817	-0.44042	-0.09798	-0.30077	0.04091	-0.05680	-0.08505	0.27439	-0.14107
3	-0.40702	0.44077	0.63340	0.16419	-0.33875	0.16192	-0.07643	0.23540	0.05302	0.08292
4	-0.25476	-0.36852	-0.27156	0.16527	-0.38215	0.21069	-0.52569	0.13393	0.10615	-0.44972
5	0.12321	-0.35565	0.03596	-0.41274	-0.60505	0.19568	0.33290	0.00058	0.25598	0.32552
6	0.24160	0.02220	0.08795	-0.13305	0.32265	0.70585	-0.44622	-0.06555	0.08285	0.32108
7	0.14479	0.06984	0.14192	-0.56239	-0.19925	-0.28504	-0.43618	0.03027	-0.57051	-0.01164
8	-0.30170	-0.01661	0.02268	0.05389	-0.08421	-0.27121	-0.29515	-0.77451	0.21726	0.30076
9	-0.29123	0.10113	-0.41920	0.21828	-0.18352	0.31618	0.19153	-0.10491	-0.63329	0.31494
10	-0.17079	0.05034	0.18965	-0.32826	0.08179	0.36674	0.30101	-0.46993	-0.12107	-0.59774

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
3.481148	2.968622	2.498389	2.532526	2.101920	1.063572	1.239108	1.352229	1.413058	1.196275

TABLE 7.17

PRINCIPAL AXES AND COMMUNALITY ESTIMATES OF ALL PROPERTIES OF ALL SAMPLES

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.71476	-0.12936	0.15166	0.09944	-0.07702	0.12163	-0.05463	-0.38597	0.02109.	-0.15279
THICK	0.15554	0.26569	0.11034	0.30500	-0.59921	-0.09857	0.02598	-0.20389	-0.19857	0.03378
TEXT	0.75941	0.25999	-0.03285	-0.19719	-0.04348	-0.10829	-0.02693	0.12456	0.18228	-0.27768
DRY	0.59627	0.29111	0.11654	-0.22842	-0.11320	0.16241	-0.05283	0.13449	0.30747	-0.02926
MOIST	0.76539	0.15866	0.05619	-0.28150	-0.02867	0.10222	-0.04189	0.18765	0.11242	0.05284
STK	0.73228	0.15997	0.11904	-0.30984	-0.12634	0.23737	-0.23886	0.20495	-0.09629	0.12052
PLCT	0.52629	-0.05579	0.11299	-0.23053	-0.12039	0.28656	-0.31718	0.19817	-0.21437	0.22655
MABUND	-0.09356	0.44190	0.76037	-0.17562	0.06978	0.00360	0.30448	0.04891	0.08810	-0.03566
MSIZE	-0.07975	0.45379	0.78245	-0.19385	0.10362	0.03250	0.27638	-0.04958	0.10112	0.03103
MCONT	-0.12256	0.44875	0.75026	-0.26717	0.05297	0.03476	0.20801	-0.05778	0.04872	0.01681
HUE	0.16093	-0.57106	0.22229	0.16647	0.41971	0.08169	-0.17686	-0.02080	0.24467	-0.00032
VAL	-0.35758	0.48904	0.12051	0.02852	0.24554	0.15931	-0.06539	0.06992	-0.31332	-0.40041
CHRO	-0.15471	0.67992	-0.06671	-0.10846	-0.44818	-0.16862	0.11127	0.05095	-0.05269	0.05968
CLAS	0.76369	-0.26895	0.14819	0.12772	-0.15586	0.28266	0.09853	0.02462	-0.14064	-0.03749
GRAS	0.61121	-0.29077	0.05525	0.16863	-0.15776	0.19914	0.12502	0.03478	-0.04267	0.01479
TYPS	0.47205	-0.42062	-0.18077	-0.11822	0.25287	0.28806	0.33239	-0.09918	-0.16292	0.21432
RSIZE	0.13676	-0.44406	0.01417	0.24734	-0.22285	-0.17835	0.49282	0.15273	0.19020	0.23798
RCUNT	0.28050	-0.76742	0.02653	0.09014	0.08754	0.07018	0.05339	-0.01588	0.25479	0.20507
CONCUNT	0.53994	0.32754	0.31081	0.35716	0.19589	-0.24535	-0.33037	-0.23102	0.01613	0.18637
CONSIZ	0.46191	0.27129	0.39063	0.38847	0.28624	-0.23817	-0.33292	-0.16900	-0.00240	0.19965
CONCOLOR	0.44038	-0.19041	0.26026	0.37024	0.07751	0.07674	0.02725	-0.05431	-0.15385	-0.21219
COATYPE	0.44797	-0.05352	0.24621	0.48796	-0.14077	0.18566	0.08353	0.20223	-0.35529	-0.01068
PORSIZE	0.05572	-0.05500	0.10307	0.41039	-0.35622	-0.28307	-0.01755	0.47449	0.10840	0.08709
PORORIEN	0.10857	0.02363	0.12223	0.39335	0.17266	0.09480	-0.07059	0.49841	0.26992	-0.29957
K	0.27427	-0.41870	0.28342	-0.15506	0.21800	-0.42093	0.21180	0.01766	-0.37252	-0.04585
M	0.05237	-0.81005	0.03499	-0.18559	-0.20813	0.07778	-0.06182	-0.18445	0.12785	-0.25781
CEC	0.62422	0.11835	-0.13705	-0.03706	-0.10571	-0.08994	0.01295	-0.23144	0.15854	-0.18118
CACO3	0.26776	0.40621	-0.35838	-0.35167	0.30271	-0.20168	-0.08845	0.20342	-0.12671	0.10612
PH	-0.03777	0.77489	-0.11211	0.17472	0.19464	0.29596	-0.04025	0.05865	0.02330	0.14869
CM	0.22600	-0.67153	-0.05997	-0.11447	0.10619	-0.00320	0.08792	-0.06513	0.04228	0.03520
FS	-0.61328	-0.03231	0.28008	0.03885	-0.18645	0.15696	-0.21465	-0.10655	0.12713	0.13389
VFS	-0.54641	0.12844	-0.29002	0.34250	0.24279	0.30797	0.27919	0.02726	-0.02888	-0.09253
CLAY	0.31202	0.25295	-0.21626	-0.11838	-0.19805	-0.18983	0.02971	-0.01493	-0.03470	-0.19750
SILT	0.70707	-0.32707	-0.01299	-0.14218	0.36284	-0.22677	0.12799	0.16708	-0.14174	0.07069
CA	0.53435	0.54803	-0.34289	0.15720	0.10055	-0.19755	0.12892	-0.09604	0.10517	-0.01789
MG	0.70379	0.46530	-0.18140	0.14950	0.14652	-0.00879	0.17252	-0.16780	0.13727	-0.09146
NA	0.34843	0.69532	-0.25075	0.02248	-0.12341	0.28201	0.16236	-0.20348	0.06917	0.17134
BST	0.13448	0.71872	-0.30154	0.18997	0.29441	0.03494	0.15865	0.02868	0.04464	0.11376

FINAL COMMUNALITY ESTIMATES:

BND	THICK	TEXT	DRY	MOIST	STK	PLCT	MABUND	MSIZE	MCONT	HUE	VAL	CHRO
0.756976	0.651884	0.824453	0.663893	0.761666	0.867158	0.796250	0.921493	0.963913	0.903946	0.710376	0.735690	0.753051

CLAS	GRAS	TYPS	RSIZE	ROUNT	CONOUNT	CONSIZ	CONCOLOR	COATYPE	PORSIZE	PORORIEN	K	M
0.829513	0.857527	0.786103	0.717762	0.799276	0.919072	0.908386	0.519724	0.730773	0.636978	0.636806	0.768419	0.864611

CEC	CACO3	PH	OM	FS	VFS	CLAY	SILT	CA	MG	NA	BST
0.844465	0.697634	0.798168	0.853623	0.893332	0.758367	0.905876	0.879776	0.814509	0.873761	0.864914	0.790476

TABLE 7.18

ROTATED FACTORS OF ALL PROPERTIES, ALL SAMPLES

ROTATED FACTOR PATTERN A1

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
BND	0.55617	-0.22045	-0.01018	0.46754	0.11706	0.28935	0.05161	-0.22618	-0.09940	0.13866
THICK	0.10420	-0.01569	0.01462	0.33845	-0.66896	0.20731	0.10224	-0.03187	-0.15422	-0.01674
TEXT	0.63257	0.02556	0.06873	0.02688	-0.01674	0.05428	-0.06392	0.16382	0.08463	0.28961
DRY	0.59065	0.09460	0.23269	0.00449	0.02494	0.02256	0.05079	0.10919	-0.18177	0.45083
MCIST	0.61466	0.06422	0.11409	0.07946	0.08328	0.03593	0.08980	0.03982	0.07318	0.57790
STK	0.44296	0.04438	0.06727	0.16826	-0.01209	0.07274	-0.04810	-0.01884	0.03707	0.79162
PLCT	0.20295	-0.05065	-0.07210	0.24865	0.05304	0.09868	-0.00442	-0.06092	0.06271	0.81563
MABUND	-0.01572	0.09031	0.94361	0.00939	-0.09368	0.04089	-0.07628	0.07433	0.02807	-0.00463
MSIZE	-0.02476	0.10579	0.96505	-0.00222	-0.06158	0.10833	-0.06626	-0.02445	-0.01099	0.01226
MCCNT	-0.05593	0.05615	0.92260	-0.04870	-0.11524	0.08122	-0.12989	-0.06161	-0.01503	0.05780
HUE	-0.04597	-0.29408	-0.05408	0.15634	0.70548	0.26102	0.13005	0.10776	0.00303	0.00661
VAL	-0.17535	0.26334	0.24112	0.04488	-0.09914	-0.10456	-0.70910	0.08449	0.01722	-0.18301
CHRO	0.08723	0.30553	0.19941	-0.23678	-0.73066	-0.08974	-0.05506	0.03044	-0.10149	0.00945
CLAS	0.40227	-0.14935	-0.04790	0.66310	0.12665	0.01667	0.20110	-0.02694	0.05631	0.37780
GRAS	0.46921	-0.12022	-0.12396	0.60324	0.13879	0.04554	0.32193	0.00985	0.06072	0.33896
TYPS	0.17936	0.05190	-0.16988	0.34337	0.44261	-0.20377	0.31549	-0.39757	0.26013	0.20442
RSIZE	0.00253	-0.14755	-0.03533	0.20531	0.01796	-0.13213	0.74984	0.16943	0.14559	-0.15045
RCUNT	0.00406	-0.37978	-0.21332	0.18680	0.52930	0.04432	0.53227	-0.01413	0.01844	0.09306
CCNCUNT	0.30459	0.20196	0.11625	0.18959	-0.00660	0.84727	-0.02208	0.03700	0.03775	0.12194
CCNSIZ	0.18675	0.19364	0.16255	0.20187	0.07863	0.85720	-0.03653	0.09211	0.08317	0.10553
CCNCOLOR	0.20395	-0.12796	0.01793	0.60081	0.16586	0.22371	-0.02272	0.10844	0.10127	-0.01940
CCATYPE	0.04580	0.07907	-0.01007	0.76395	-0.09453	0.13006	0.07245	0.22983	0.12892	0.19535
PCRSIZE	-0.07112	-0.05380	-0.08098	0.11535	-0.28944	0.11849	0.33265	0.63040	0.04234	0.03859
PCRORIEN	0.09669	0.10938	0.03560	0.18976	0.27239	0.00403	-0.08837	0.69592	-0.10082	-0.04149
K	0.06647	-0.36136	0.12135	0.17363	0.13901	0.10494	0.09981	-0.08759	0.73520	-0.00711
H	0.03318	-0.80267	-0.20751	0.11532	0.27818	-0.19608	0.14824	-0.12694	-0.09381	-0.01251
CEC	0.85162	-0.02582	-0.10034	0.17954	-0.02460	0.18880	0.08967	-0.10998	-0.01178	0.14040
CACO3	0.32099	0.42989	-0.12578	-0.38021	-0.01380	0.00221	-0.19425	-0.05063	0.36671	0.27286
PH	0.02344	0.78640	0.14246	-0.03226	-0.10580	0.08543	-0.25384	0.02830	-0.26391	0.06691
CM	0.01487	-0.53392	-0.28190	0.14690	0.49630	-0.11454	0.36527	-0.15425	0.21976	0.04833
FS	-0.72263	-0.18392	0.20168	-0.22862	-0.11972	0.01052	-0.08195	-0.00073	-0.44673	-0.15376
VFS	-0.37540	0.43949	-0.10606	0.08170	0.12423	-0.33105	-0.13126	0.03210	-0.17866	-0.48079
CLAY	0.84373	0.06452	-0.13366	0.12924	-0.24620	0.07385	0.00217	-0.00646	0.17262	0.24361
SILT	0.42084	-0.06099	-0.09932	0.16278	0.38748	0.10944	0.20992	-0.01106	0.61938	0.26952
CA	0.66525	0.53033	-0.10998	-0.00609	-0.15755	0.20605	0.03291	-0.00358	0.06596	-0.07647
MG	0.76572	0.45308	0.01719	0.19417	0.00659	0.19800	0.02530	-0.06475	-0.00478	-0.00735
NA	0.43325	0.63907	0.06955	0.07659	-0.27838	-0.00246	0.02046	-0.26345	-0.30139	0.14[illegible]8
BST	0.26246	0.82442	0.02574	-0.07770	-0.07578	0.08270	-0.10282	0.01129	-0.01820	-0.10777

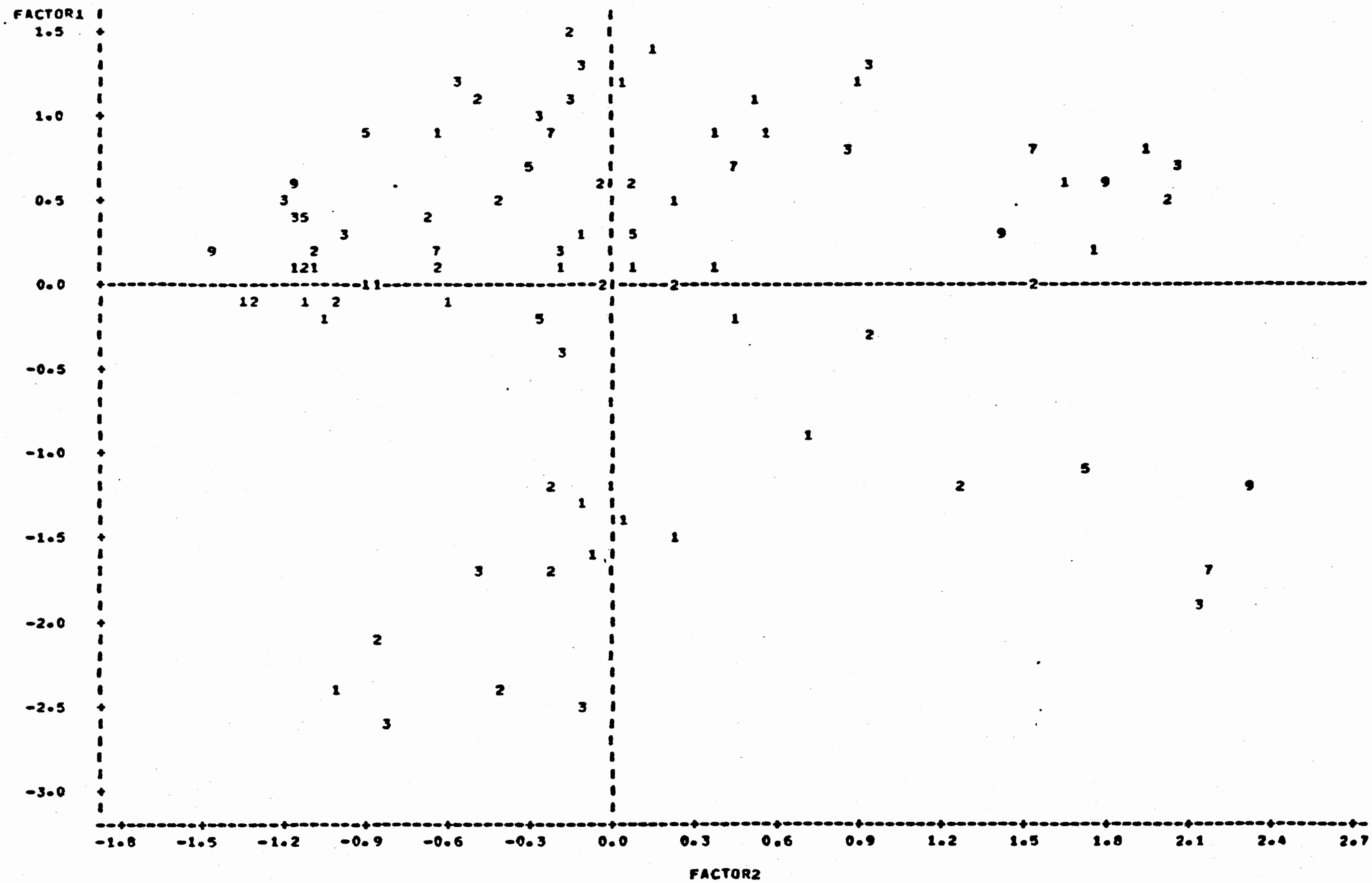


Figure 7.5. Loadings of Different Locations on Factors One and Two for All Morphological Properties, All Samples

TABLE 7.19

CONTRIBUTIONS TO THE COMMON VARIANCE, ALL PROPERTIES, ALL SAMPLES

ORTHOGONAL TRANSFORMATION MATRIX

	1	2	3	4	5	6	7	8	9	10
1	0.74796	-0.02954	-0.07621	-0.36639	0.11265	0.22842	0.17334	0.02156	-0.17681	-0.41592
2	-0.23111	0.67348	-0.33530	-0.18075	0.43822	-0.12873	0.33626	0.03421	-0.15769	0.01417
3	-0.20010	0.31993	0.80777	-0.25401	0.03869	0.32161	-0.02734	-0.13336	-0.02064	-0.12922
4	0.16887	0.25727	0.25442	0.55505	0.03576	-0.38649	-0.15039	0.38915	-0.18477	-0.41670
5	-0.04471	-0.36157	0.08043	0.12535	0.76470	0.18972	-0.26053	0.06581	-0.34879	0.17453
6	-0.15522	-0.21233	0.04536	-0.42167	0.31269	-0.40151	-0.16704	0.19540	0.56039	-0.33444
7	0.13611	-0.22053	0.35920	-0.22666	-0.03812	-0.52656	0.46115	0.14394	-0.26999	0.40922
8	0.14018	0.16230	0.01102	-0.06189	-0.03839	0.34539	-0.03943	0.78101	0.26634	0.38317
9	-0.30956	-0.05376	-0.16269	-0.42966	-0.32595	-0.04220	-0.38120	0.29041	-0.57280	-0.15634
10	0.39811	0.35119	0.02014	-0.16478	0.02792	-0.28793	-0.61498	-0.26757	0.04111	0.39426

PROPORTIONAL CONTRIBUTIONS TO COMMON VARIANCES BY ROTATED FACTORS

FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5	FACTOR6	FACTOR7	FACTOR8	FACTOR9	FACTOR10
6.294209	4.347191	3.278090	2.979139	2.955214	2.171728	2.151563	1.408090	1.781854	2.893522

	1	2	3	4	5	6	7	8	9	10
EIGENVALUES	9.603464	7.349451	3.122005	2.171146	1.980865	1.406345	1.346637	1.248109	1.074291	0.958287
PORTION	0.253	0.193	0.082	0.057	0.052	0.037	0.035	0.033	0.028	0.025
CUM PORTION	0.253	0.446	0.528	0.585	0.638	0.675	0.710	0.743	0.771	0.796
	11	12	13	14	15	16	17	18	19	20
EIGENVALUES	0.858285	0.790973	0.711597	0.658649	0.581826	0.538684	0.455780	0.408524	0.384919	0.347740
PORTION	0.023	0.021	0.019	0.017	0.015	0.014	0.012	0.011	0.010	0.009
CUM PORTION	0.819	0.840	0.858	0.876	0.891	0.905	0.917	0.928	0.938	0.947
	21	22	23	24	25	26	27	28	29	30
EIGENVALUES	0.295699	0.274048	0.211557	0.198068	0.160913	0.130368	0.123466	0.114415	0.103516	0.083265
PORTION	0.008	0.007	0.006	0.005	0.004	0.003	0.003	0.003	0.003	0.002
CUM PORTION	0.955	0.962	0.968	0.973	0.977	0.981	0.984	0.987	0.990	0.992
	31	32	33	34	35	36	37	38		
EIGENVALUES	0.067035	0.063001	0.055381	0.048680	0.034522	0.021336	0.017152	0.000002		
PORTION	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.000		
CUM PORTION	0.994	0.995	0.997	0.998	0.999	1.000	1.000	1.000		

communality estimates varied from 51.9% for the color of the concretions to 92% for the mottling abundance (Table 7.17). The final communality estimates were higher for the chemical properties when the zones were treated separately.

Six factors accounted for only 58% of the common variance. This was quite a bit lower than the amount of variance explained by the same factors when the profile was partitioned to different zones. This was true for both the chemical and morphological properties. The first factor (16.6%) was correlated with texture, consistence, structure strength, CEC, Mg, fine sand, Ca, Na, and silt. The second and ninth factors accounted for 11.4% and 4.7% of the common variance, respectively and were totally correlated with chemical properties. It was noticed that morphological properties showed higher loadings on different factors. The third factor identified mottling with the higher loading, while the sixth factor identified concretion size and the color with the higher loadings. The seventh factor identified the root quantity and size.

It was observed here that a high correlation existed between the morphological properties and the different factors. This singled out the morphological properties to be the prime contributers to the soil variations or heterogeneity. A high variability among the morphological properties was also observed when different genetic horizons were treated separately.

Since the first and the second factors were correlated with many properties, plotting the loadings of the locations on those two factors produced several compact groups (Figure 7.6). Plotting the loading for only the chemical data (Figure 7.4), or the morphological properties

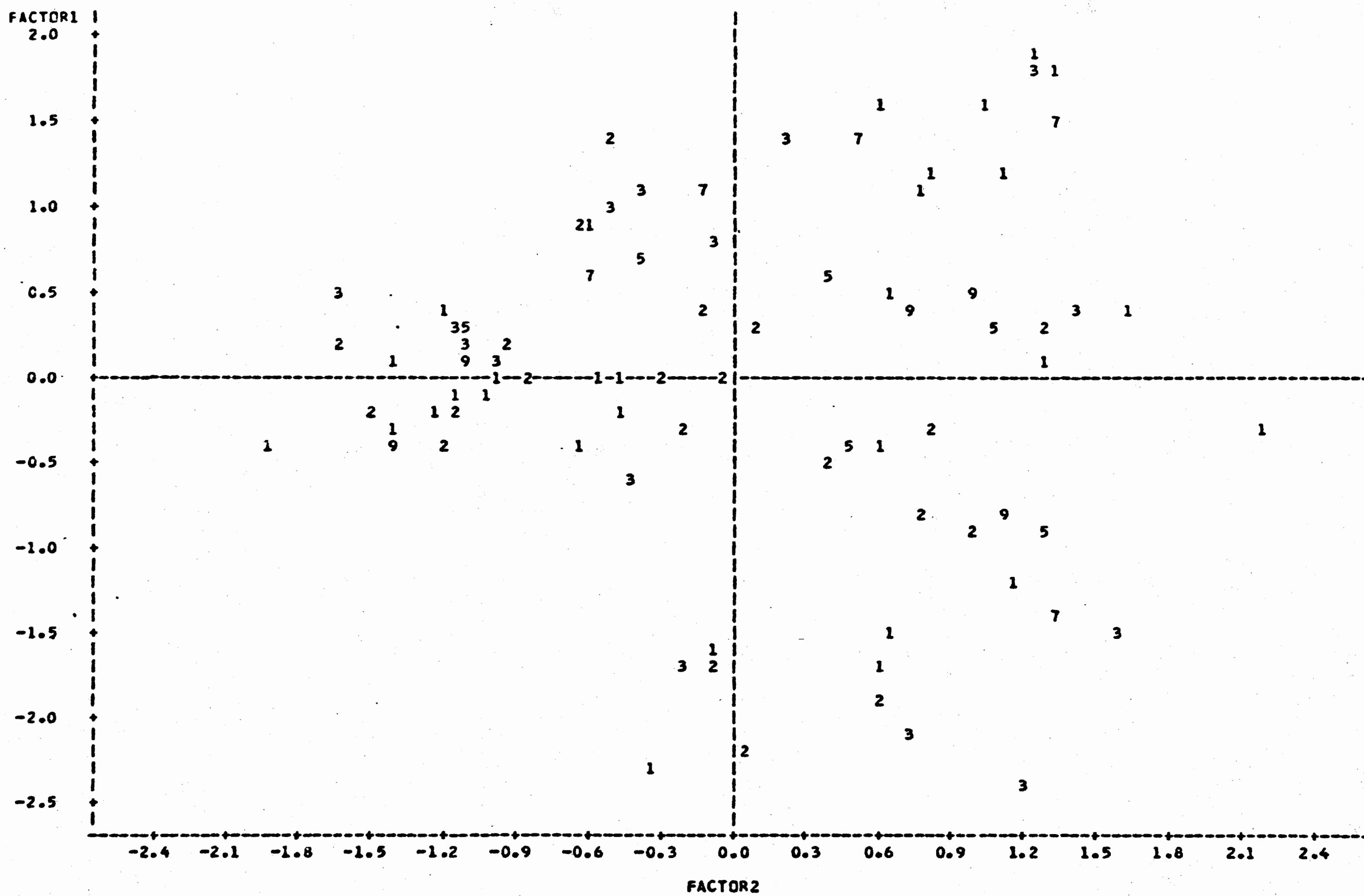


Figure 7.6. Loadings of Different Locations on Factors One and Two for All Properties, All Samples.

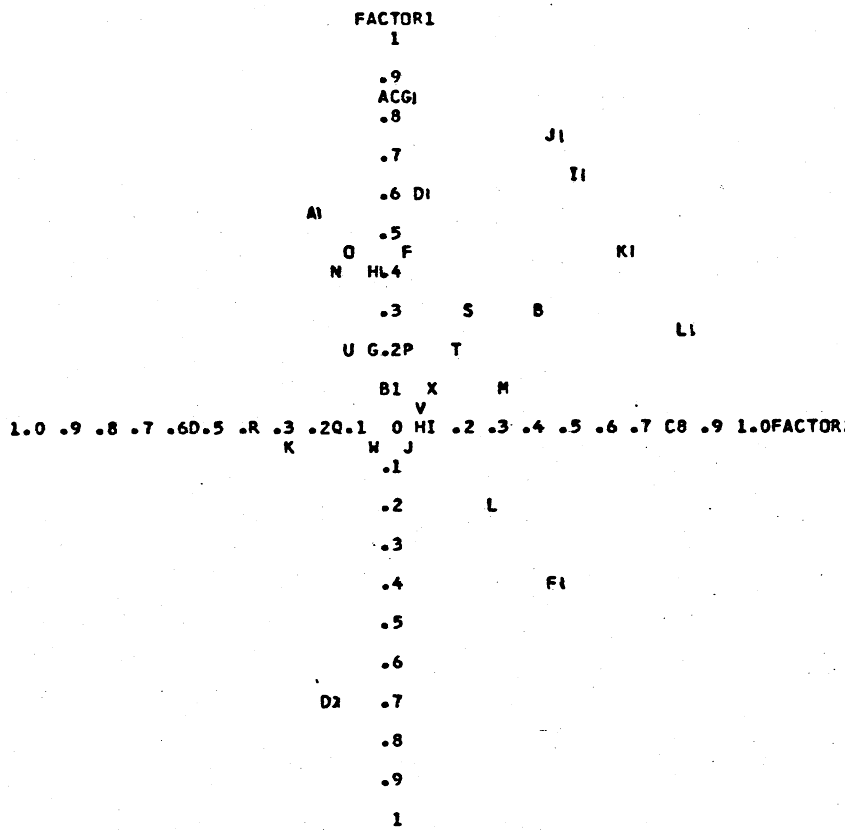
alone (Figure 7.5) did not produce clusters as compacted as when all the data were combined together. Figure 7.7 shows the many soil properties with high loading on the first two factors after the Varimax rotation.

Loading Index

Loading index values (D) were calculated in a similar fashion to area two (Tables 7.20, 7.21, and 7.72). Different arrangements resulted for different horizons. Many properties, like CEC, clay, and texture, occupied the top position for different horizon listings, especially for the subsurface and for all horizons treated together. Sodium and the base saturation occupied the top positions for the surface zone only (the number of samples required to sample the true mean as a function of the standard deviation in Chapter II, showed that sodium and base saturation were among the highest for the same zone. The behavior of the same variables in the subsurface was also confirmed by the lower position occupied on the loading index list). This is considered as a clue to the validity of this index.

Summary and Conclusions

Principal component and factor analysis demonstrated to be a sufficient tool in scanning the variation of different soil properties. However, the results depended on the manner by which the soil units were selected (individual horizons, or profiles). Different answers resulted when different genetic horizons were treated alike or separately. Each case showed to have some advantage over the other. If the horizons were treated separately, estimates of the individual



BND	=A1	THICK	=B1	TEXT	=C	DRY	=D1	MOIST	=D
STK	=F	PLCT	=G	MABUND	=H	MSIZE	=I	MCONT	=J
HUE	=K	VAL	=L	CHRO	=M	CLAS	=N	GRAS	=O
TYPS	=P	RSIZE	=Q	ROUNT	=R	CONQUNT	=S	CONSIZ	=T
CONCOLOR	=U	COATYPE	=V	PORSIZE	=W	PORORIEN	=X	K	=
H	=	CEC	=A	CACO3	=B	PH	=C1	OM	=D
FS	=D2	VFS	=F1	CLAY	=G1	SILT	=H1	CA	=I1
MG	=J	NA	=K1	BST	=L1				

Figure 7.7. Loadings of Different Soil Properties on Factors One and Two of All Properties, All Samples.

TABLE 7.20

LOADING INDEX (D) OF DIFFERENT CHEMICAL PROPERTIES
WITHIN THE DIFFERENT GENETICAL ZONES

Surface zone		subsurface zone		P.M zone		All samples	
Prop.	D	Prop.	D	Prop.	D	Prop.	D
1- BST	20.72	CEC	20.71	Ca	13.40	CEC	21.36
2- Ca	18.24	Clay	20.30	BST	13.10	Clay	19.57
3- Na	11.42	FS	15.60	FS	11.80	H	15.23
4- VFS	11.09	Mg	12.60	OM	11.30	Mg	14.64
5- K	9.65	PH	11.20	K	8.00	PH	14.23
6- CEC	9.36	BST	8.90	CEC	7.90	FS	13.53
7- Silt	9.36	OM	7.40	Clay	7.60	OM	8.69
8- Clay	8.89	K	7.20	Silt	7.30	BST	8.07
9- H	8.20	Ca	7.00	Na	7.30	Ca	7.87
10-Mg	7.15	CaCO3	6.40	CaCO3	5.10	K	7.35
11-OM	7.05	VFS	6.30	FS	5.00	VFS	6.66
12-CaCO3	6.46	Silt	6.00	PH	4.50	CaCO3	6.49
13-Fs	5.70	Na	3.20	H	4.40	Silt	6.27
14-PH	3.81	H	2.50	Mg	4.00	Na	.73

TABLE 7.21

LOADING INDEX (D) FOR DIFFERENT MORPHOLOGICAL PROPERTIES WITHIN DIFFERENT GENETICAL ZONES

Surface zone		subsurface zone		P.M zone		All samples	
Prop.	D	Prop.	D	Prop.	D	Prop.	D
1- Stk	12.51	Msize	12.30	Mcont	17.60	Msize	12.10
2- Text	9.61	Mabund	11.80	Msize	17.60	Mabund	11.60
3- Pororient	7.92	Mcont	11.5	Mabund	16.90	Mcont	11.40
4- Gras	7.80	Dry	10.00	Plct	12.00	Text	10.90
5- Rsize	7.57	Stk	9.10	Stk	10.40	Dry	10.10
6- Val	7.12	Text	8.30	Rqunt	10.20	Moist	9.90
7- Coatype	7.04	Chrom	8.00	Rsize	10.20	Chrom	8.40
8- Chrom	6.58	Hue	7.40	Dry	7.70	Conqunt	7.90
9- Type	6.45	Consize	7.40	Thick	7.10	Consize	7.90
10-Concolor	6.41	conqunt	7.20	Pororient	6.30	Hue	7.70
11-Rqunt	6.08	Type	6.70	Hue	6.10	Coatype	7.00
12-Clas	5.44	Rqunt	6.40	Chrom	5.80	Stk	6.80
13-Moist	4.50	Rsize	4.90	Coatype	5.40	Clas	5.40
14-Dry	4.40	Gras	4.30	Porsize	4.90	Porsize	4.70
15-Plct	4.40	Concolor	4.10	Text	4.10	Gras	4.70
16-Hue	4.40	Pororient	3.50	concolor	2.60	Val	4.50
17-Bnd	4.20	Val	3.30	moist	2.20	Rqunt	4.50
18-Porsize	3.40	Coatype	3.20			Pororient	4.30
19-		Clas	2.01			Plct	4.00
20-		Plct	1.60			Thick	3.90
21-		Bnd	.99			Type	3.70
22-						Bnd	3.30
23-						Concolor	2.60

TABLE 7.22

LOADING INDEX (D) FOR ALL SOIL PROPERTIES
WITHIN THE SOIL PROFILE

Prop.	D	Prop.	D
1- CEC	12.00	28- OM	3.20
2- Clay	11.70	29- Silt	2.90
3- Text	11.40	30- Val	2.90
4- Mg	9.80	31- Concolor	2.80
5- FS	8.60	32- K	2.60
6- BST	7.70	33- VFS	2.20
7- Mabund	7.60	34- Rqunt	2.20
8- Ca	7.50	35- CaCO3	2.10
9- Mcont	7.30	36- Pororient	1.80
10-H	7.30	37- Porsize	1.50
11-PH	7.10	38- Type	1.50
12-Moist	6.20		
13-Dry	5.80		
14-Bnd	5.20		
15-Plct	5.10		
16-Stk	4.70		
17-Coatype	4.50		
18-Na	4.50		
19-Chroma	4.20		
20-Consize	4.20		
21-Conqunt	4.10		
22-Hue	3.90		
23-Msize	3.90		
24-Gras	3.70		
25-Thick	3.50		
26-Clas	3.40		
27-Rsize	3.20		

variances were very high for different soil properties. At the same time, the magnitude of the variability of each soil property within each horizon is scanned better. This is very important if hypotheses on the differential movement of soil constituents or soil genesis are to be formulated. Moreover, more meaningful interpretations were possible for the different factors when horizons were treated separately.

Lower communality estimates resulted when all the horizons were treated alike. The first few axes accounted for a higher proportion of the variance. In addition, many properties were correlated with a single factor which helped to produce a more compacted cluster. One common pattern prevailed in this study regardless of the way the horizons were treated. This pattern was that the morphological properties were higher in variability than the chemical properties (this conclusion was also reached by a different route in Chapter II).

A larger number of axes were needed in the case of the morphological properties to explain the same variation exhibited by the chemical properties. Six factors were sufficient in the case of the chemical properties regardless of the method by which the horizons were treated, but ten factors were required for the morphological properties.

The variation of the chemical properties was the highest in the subsurface zone. The variation of the chemical and morphological properties was minimum in the parent material. This conclusion is consistent with the definition of the Cr (P.M.) horizons.

According to the D values, the variation of each property depended on the horizons in question. However, common properties were observed to occupy the top position with different arrangements like CEC, clay, texture, and consistence. Therefore, these properties were considered to contribute to a higher portion of the variability of the soil in this area. They were followed by the hydrogen, fine sand, mottling, base saturation, pH, and sodium.

CHAPTER VIII

CLUSTER ANALYSIS

Abstract

A total of 85 and 109 horizons from two areas were used in this study with 25 morphological and 17 chemical properties in the similarity matrix. The chemical data were normalized first then the whole set was transformed by the Talkington method (65) so that the maximum distance between any two individuals would be $\sqrt{2}$. The similarity matrix was then converted to a dendogram using the unweighted average agglomerative procedure. Three different similarity measurements were recognized from each dendogram. The horizons were then classified into different groups according to the similarity level. 18 and 23 transition matrices were constructed and classified according to the information theory by Norris (48). This procedure was repeated three times. The pedons indicated that the similarity measurements chosen to classify the horizons from the primary dendogram had a very little effect on the number of the groups produced each time. Exact similarity occurred between pedons of the same series in area one, but of different series in area two. The pedons interchanged their positions between the different groups as the initial similarity level was changed. Moreover, the pedons within one group did not belong to series that occur adjacent to each other in the field. This suggested that both areas

should be designated as soil complex units. The author feels that in an area where the variations of the soil-forming factors were kept minimum to this level of similarity between the pedons within each series is not sufficient to draw different mapping units on both areas.

Introduction

Man is known to be a natural classifier since the dawn of history. Classification became an artistic way of remembering the many properties of different objects. As man's knowledge about his surroundings increased, his classification grew to be more complicated and more systematic.

In the most general terms, classification is the process of giving names to a collection of objects which are thought to be similar to each other in some respect (Everitt, 25). Gilmour (27) attempted to distinguish two different classifications. A natural classification of living things is one which groups together individuals having a larger number of attributes in common; whereas, an artificial classification is composed of groups having only a smaller number of common attributes.

As a natural system, soil was not excluded from classification by man as his knowledge of this system improved. Many attempts to classify the soil were undertaken in many countries, but the most comprehensive and recent system is the one published by the United States Department of Agriculture in 1976. Recently, and with the vast improvement in high speed computers, systematic classifications based on more quantitative attributes have been attempted in many areas. The earliest numerical approach to classification of the soil was by Hole and Hironaka (34).

Many problems have to be solved and precautions taken in order to reach a sensible quantitative classification of soils. Also many steps are involved in achieving such a classification. These steps may include the selection of the soil units, the selection of the soil properties, the measure of similarity to be used, and the methods of displaying the results in an easily interpreted format.

Before discussing these problems, a definition of the quantitative groups, which result from what is known as the clustering method and are called clusters, might be appropriate. Many definitions were given to the cluster, but the most acceptable definition is the one given by Everitt (24, p. 44). "A cluster may be described as a continuous region of space containing a relatively high density of points, separated from other such regions by regions containing a relatively low density of points."

Selection of the Soil Units

One major obstacle in the numerical classification of soil is the anisotropy of soils (whether profiles, pedons, or other soil units) (Moore and Russel, 44). A solution to the problem that it presents must be found before a numerical classification scheme can be achieved. The anisotropy of soil profiles is reflected in the separation of the profile into horizons, which can be considered to be isotropic (Knox, 39; Russel and Moore, 60). As a solution to this, Ryner (54), suggested numerical classification of soil on the basis of a sequence of similar horizons as preferable to considering the entire profile as a unit and then using profile properties (Sarkar and Bidwell, 61).

A second solution to this problem is the comparison of each horizon with all other horizons studied (Ryner, 54). This method requires too much computation time, and some of the comparisons might not be usable. For example, the A1 horizon of one soil may be similar to the C horizon of another soil.

A third solution is to compare horizons which occur at the same depth in different profiles (Moore and Russell, 44).

Selection of Soil Properties

Soil properties can be divided into four main groups: 1) dichotomous properties, such as the presence or absence of mottles; 2) multistate unranked properties, such as the form of a structure unit, which may take one of several possible states; 3) multistate ranked properties, such as the size of the class of peds; 4) continuously varying properties, such as cation exchange capacity of the soil.

The selection of soil characteristics is a critical step in numerical classification. Sarkar, Bidwell, and Marcus (61) stated that too closely related characters might exert a double emphasis on a certain property and unduly influence the classification. Grigal and Arneman (28) thought that deletion of some characters probably would be necessary for numerical taxonomy of soils to be effective. They objected to deleting characters on the basis of correlation because it would result in losing information on some soils and they suggested using factor analysis instead.

Rohlf (58) found correlated characters in a numerical classification somewhat desirable. Sneath and Sokal (63) suggested deleting any properties that are a logical consequence of another. However, when two characters with high empirical (but not logical) correlations are available, both should be included unless they are caused by a single factor. Arkley (2) indicated that the number of soils included should be large, the general kinds of soil included should be well represented, and the selection of soil properties even more important. He noticed that eventhough all kinds of soil properties can be included, properties highly correlated like moist and dry color or redundant properties should be avoided. As a general rule, if a character can be considered as a linear combination of other properties, then it would not add any power to, or improve the classification.

Weighting the Soil Variables

Sneath and Sokal (63) presented argument in favor of weighting all variables equally, especially where classification is intended to be a natural, or basic classification for general use rather than one for a specific objective. They gave many reasons for equal weighting. The most important are: 1) equal weighting, employing as many characters as possible, results in general classification which can be of general use to many purposes; 2) it is difficult to be completely objective in assigning different weight to characters; 3) equal weighting appears automatically during the mathematical computations of numerical classification.

They also favor the use of a large number of variables in numerical taxonomy on the grounds that the use of many variables greatly evens out the effective weight which each one contributed. Arkley (1) agreed that in the first stage of analysis, the use of a large number of variables standardized so as to give equal weight to each is certainly a sound approach. The extensive covariance among soil variables in widely differing data sets is strong evidence that a long list of soil variables is not necessary to classify soils effectively by either conventional or numerical methods.

Standardization of Soil Variables

1. It is clearly inappropriate to compare differences in variables with range of 0.0 to 1.0 with variables with a range of 100 to 1000. For continuous variables, standardization may be achieved by many formulas:

$$Z_i = \frac{(X_i - \bar{X})}{S_{X_i}} \tag{8.1}$$

where Z has zero mean and unit variance, X_i is the unstandardized variables, $\bar{X}$ is the mean, S_{X_i} is the standard deviation of X_i. This procedure is the most accepted way of continuous variables standardization, or

$$X' = (X - X_{min})/(X_{max} - X_{min}) \tag{8.2}$$

where X' is the standardized variable.

2. Another method of equalizing the contribution of the discrete and continuous variables is based upon the information theory that has been developed by Burr (12). Continuous variables are standardized to a mean of 0.0 and a standard deviation of $\pm\sqrt{2}$ by the formula

$$X' = (X - \bar{X})/1.414\ SD_x \tag{8.3}$$

and multistate variables by the formula

$$M'^2 = M(t-1)/2tp_s(S_m - 1) \tag{8.4}$$

where M' is the standardized variable; M is the unstandardized variable (as coded); t is the total number of individuals (soils) with no missing data; p_s is the proportion of t in state S (S_n/t); S_n is the number of individuals in state S; S_m is the number of possible states of variable M.

3. Another method of equating the weight of all properties was proposed by Talkington (65),

$$D_{ija}^2 = (X_{ia} - X_{ja})^2 \leq 2 \tag{8.5}$$

the detailed use of this formula is given in the statistical approach section. The problem of highly skewed data should be considered in the standardization of variables. In some cases, it would be appropriate to use a logarithmic or square root transformation for a known skewed distribution as was done by Russell (60).

Measures of Similarity or Differences

Sneath and Sokal (63) used the term similarity coefficient to indicate the measures of either similarities or differences. Four classes of similarity coefficients have been used.

1. Distance Coefficients. The simplest form of distance measurement is called Mean Character Difference (MCD) and has been used by Russell (60) and Webster (68).

$$MCD_{jk} = \frac{1}{n}\sum_{i=1}^{n}|X_{ij} - X_{ik}| \tag{8.6}$$

where X_i........X_n are standardized variables i and k are two individuals such as soil properties. A much more commonly used distance coefficient is the Euclidean distance

$$D_{jk} = \left[\sum_{i=1}^{n}(X_{ij} - X_{ik})^2\right]. \tag{8.7}$$

The average Euclidean distance coefficient has the advantage of being readily visualized and can be plotted in two or three dimensions. This coefficient has been used by many authors (Cipra, 20; Grigal and Arneman, 28; Moore, 45; Webster and Burrough, 68; and Caunalo and Webster, 18).

Another distance has been used by some workers and called the Canberra Metric by Lance and Williams (40). It has been used by Webster and Burrough (68).

$$D_{ijk} = \sum_{k=1}^{p}\left[(X_{ij} - X_{ik})/(X_{ij} + X_{ik})\right] \tag{8.8}$$

where X_{ij}, X_{ik} are the values of the kth properties for the ith and the jth sites, p is the number of soil properties.

2. <u>Similarity Coefficients</u>. These coefficients were suggested by Bray and Curtz (10).

$$SI = \sum_{i=1}^{n}\left[(|X_{ik} - X_{jk}|)/\sum_{j=1}^{n}(X_{ik} + X_{jk})\right] \tag{8.9}$$

all variables must be standardized to common range and positive sign.

This coefficient has been used by Holz and Hironoka (34), Bidwell and Hole (7), Bidwell (8), Sarkar (61), and Moore and Russell (45).

3. Simple Matching Coefficient. This coefficient is usually used for data as a two state character (0,1). It has been used by Russell (60) and Brisbane and Ravira (11). It involves considerable loss of information and is not recommended for soil classifications.

4. Product Moment Correlation Coefficient. This coefficient was used by several workers: Cipra (20), Cuanolo and Webster (18), Moore and Russel (44), Moore (45), and Russel (60). One disadvantage of using this coefficient is that it is a measure of pattern rather than magnitude of differences.

Moore and Russel (44) compared all the above coefficients and concluded that the Euclidean distance is probably the most appropriate for soil because it is sensitive to magnitude. Webster (69) criticized Euclidean distance measure because it is sensitive to magnitude. However, his criticism is valid when very few soil properties are used.

Sorting Strategies

Generally, the matrix of pairwise similarity coefficients produced from the analysis of the data is very large. The number of pairs is n(n-1)/2, where n is the number of individuals. Thus a similarity matrix usually cannot be adequately interpreted by simple visual inspection.

The most commonly used procedure in displaying the similarity matrix in soil studies is the system called "the sequential, agglomerative, hierarchic, non-overlapping, clustering method" by Sneath and Sokal (63). The results are generally presented in the form of a dendogram or phenogram. There are varieties of algorithms for the definition of maximum similarity between clustering of individuals.

1. Single Linkage or Nearest Neighbor Clustering. This method uses the criterion for joining based upon the two most similar individuals between two clusters. This method did not win the acceptance of many soil scientists. However, some soil workers used this method, such as Ryner (33), and Muir (47).

2. Complete Linkage or Farthest Neighbor Clustering. This is based upon the similarity of the least similar pair of individuals in the two clusters.

3. Average Linkage Clustering. This is the most commonly used clustering method in soil studies. It is intermediate between the extremes of the two methods described above. Many soil workers used this method, Berkham and Norris (6), Bidwell and Hole (7), Bidwell (8), Cipra (20), Caunalo and Webster (18), and Sarkar (61). The centroid method is similar to the average linkage method. It is a very attractive method to soil scientists because it can be represented in two or more dimensions.(Campbel, 15; Caunalo and Webster, 18; and Moore and Russell, 61).

4. Variable Group Clustering. By this procedure, it is possible to allow several individuals and/or clusters to join at a single step in the procedure (Arkley, 2). The criterion for joining were based upon the change within group variance. This procedure is described in detail in Sneath and Sokal (63).

5. Flexible Sort Clustering by Lance and Williams (40).

$$D_{(ij)_k} = a_i D_{ik} + a_j D_{jk} + bD_{ij} + c|D_{ik} - D_{jk}| \qquad (8.10)$$

D_{ij} is a measurement of difference or dissimilarity, i and j are joined pair of individuals or groups, and k is a candidate for joining the group. a is a parameter that could be 1/2 of a function of the numbers of the individuals. It has been used by Campbell (15), Moore (45), Russel and Moore (60), and Russel (61).

6. Information Content Clustering Method. This method of clustering technique is based upon information theory that has been developed by Norris and Dale (48). Moore (45) applied this method to all two state variables (transition matrix). This method will be used in this investigation and the detail of the procedure will be given later.

7. The Divisive Method. The divisive method begins with the whole population and progressively divides it into smaller and smaller groups using the similarity matrix. The method uses separation on a primary variable with high communality together with minimum variance and t-test and discrimenant function to increase the separation of the groups. This method requires too much computing time. It has been used by very few soil scientists (Norris, 49).

Statistical Approach

Two types of characters were used in this study, continuous characters represented by the chemical properties, and discrete characters represented by the morphological properties. The types of the characters and the coding system are found in Appendix B.

All the soil characters were scaled so that the square of the maximum distance which they could contribute along their coordinate axis in n-dimensional space was 2 (Talkington, 65). A two-stage character will be given for example, $\sqrt{2}$ for present and 0 for absent ($D^2 = (\sqrt{2} - 0)^2 = 2$). The interval 0 to 2 was divided into as many classes as necessary for multistate variables. The continuous variables were normalized first and then scaled linearly in the range $\sqrt{2}$, 0 so the Euclidean distance of maximum 2 for the continuous characters can be computed from the following formula:

$$D^2_{ij} = \frac{1}{2n} - \sum_{k=1}^{n'} (X_{ik} - X_{jk})^2 \qquad (8.11)$$

where n is the number of variables, n' is the total number of the state including one state for each quantitative variable.

Distance matrices of 85x85 and 109x109 were computed for both areas using 85 and 109 pedogenic horizons, respectively. The numerical analysis of different pedons were based on the result of the dendogram obtained from the distance matrix by the agglomerative method (the unweighted, average linkage method). At this stage, the different horizons were classified into two different groups. The horizons were assigned to different groups and then the relative position of the pedogenic horizons was used to construct a transition matrix. The transition matrices were then classified to produce the final pedon clusters.

This procedure is summarized in the following steps: 1) the 85 and 109 samples from 18 and 23 pedons were classified into different groups based on the dendogram produced by using only the soil characters. The groups were numbered 1...N for each area; 2) tables of profile descriptions that show the number of the group in which each horizon was classified by the dendogram and using a different similarity level were prepared; 3) the sequence of the numbers describing each pedon was converted to a transition matrix. Each profile was represented by a different transition matrix for each change in the similarity level. The dimension of the matrix is N X N, where N is the number of the groups recognized from the initial dendogram for a specified similarity level; 4) the 23 and 18 transition matrices, each representing one pedon, were classified based on the primary grouping of their horizons. The relative position of the different horizons in the pedon was considered in building the transition matrix.

Norris (48) discussed the method of clustering such matrices. In this method, each possible entry in the transition matrix is considered as a single state of a multistate variable. The information content of the matrix is defined as

$$I = X_{..} \mathrm{Ln} X_{..} - \sum_{ij} X_{ij} \mathrm{Ln} X_{ij} \tag{8.12}$$

where $X_{..} = \sum_{ij} X_{ij}$. Two transition matrices A and B can be compared by calculating I_A, I_B, and I_{A+B}. Then by computing ΔI,

$$\Delta I = I_{A+B} - I_A - I_B \tag{8.13}$$

where ΔI is a measure of the information change. The pair of matrices, giving minimum information, are then joined together.

Results and Discussion

Twenty-three morphological and 16 chemical properties were used to calculate the similarity matrix (109 X 109 for area two and 85 X 85 for area one). The lower triangle of the similarity matrix was punched on

IBM cards and inputed for the initial clustering of different horizons regardless of the pedons from which they came. The relative position of the different horizons was not considered at this stage. The soil properties were the only factors affecting the horizons similarity. This route was followed because an equal number of horizons is not required to obtain the cluster of the different pedons. Other routes require equal number of horizons in order to compute the similarity matrix. To do this, equal intervals have to be sampled from each pedon. This will lead to some samples being collected from two different genetic horizons.

Figures 8.1 and 8.2 show the dendograms for the initial horizons of both areas. Four major groups were recognized for the first area. The recognized groups represented different genetic horizons. The surface horizons were well separated in one group and all the argillic horizons in another group. The argillic horizons of pedon 11 and 10 were classified into the B300 group. This classification was considered proper since B300, by definition, has more than 50% of the argillic horizon characteristics. Also, few of the B300 horizons were classified with the Cr00 group. This could partly be due to the difficulty in recognizing the lower boundary of the solum where the change between the parent material and the solum is very gradual. The occurrance of B20t (pedon 1), B21t (pedon 5), and B200 (pedon 6) with the surface group could be due to errosion where these locations occupy a very mild convex position.

Figure 8.2 shows a cluster of 109 horizons for area two. All the Ap00 horizons, except for the Ap00 horizons for pedon one, were classified into one group. From the author's experience during the field

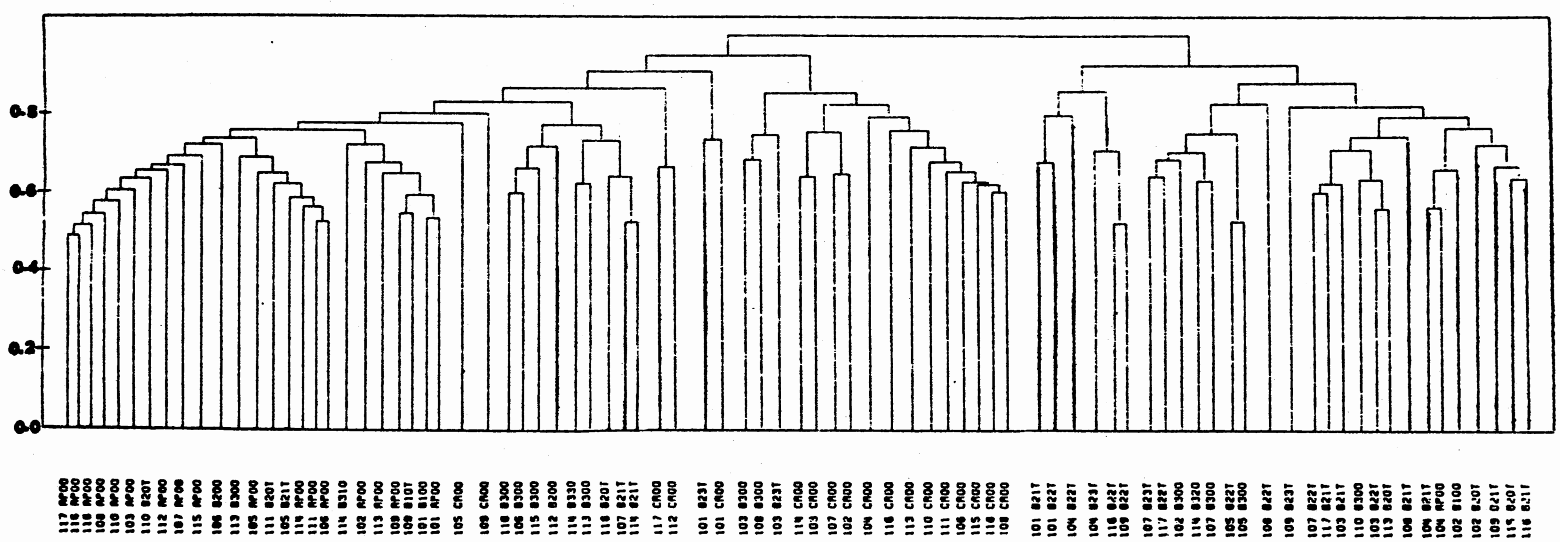


Figure 8.1. Dendogram Cluster of the Pedogenic Horizons, Area One.

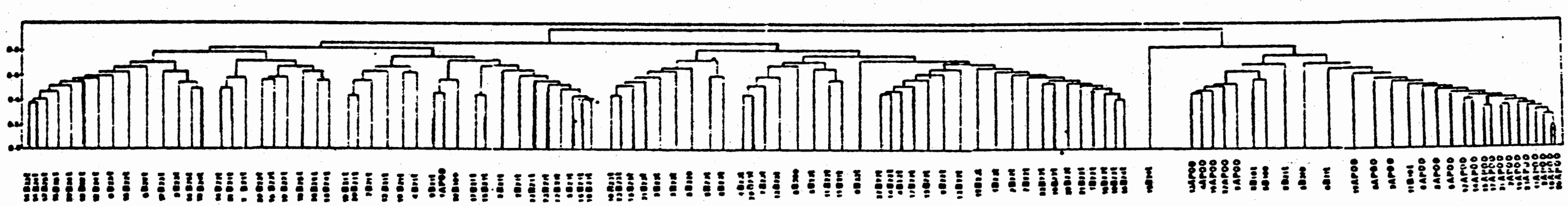


Figure 8.2. Dendogram Cluster of the Pedogenic Horizons, Area Two.

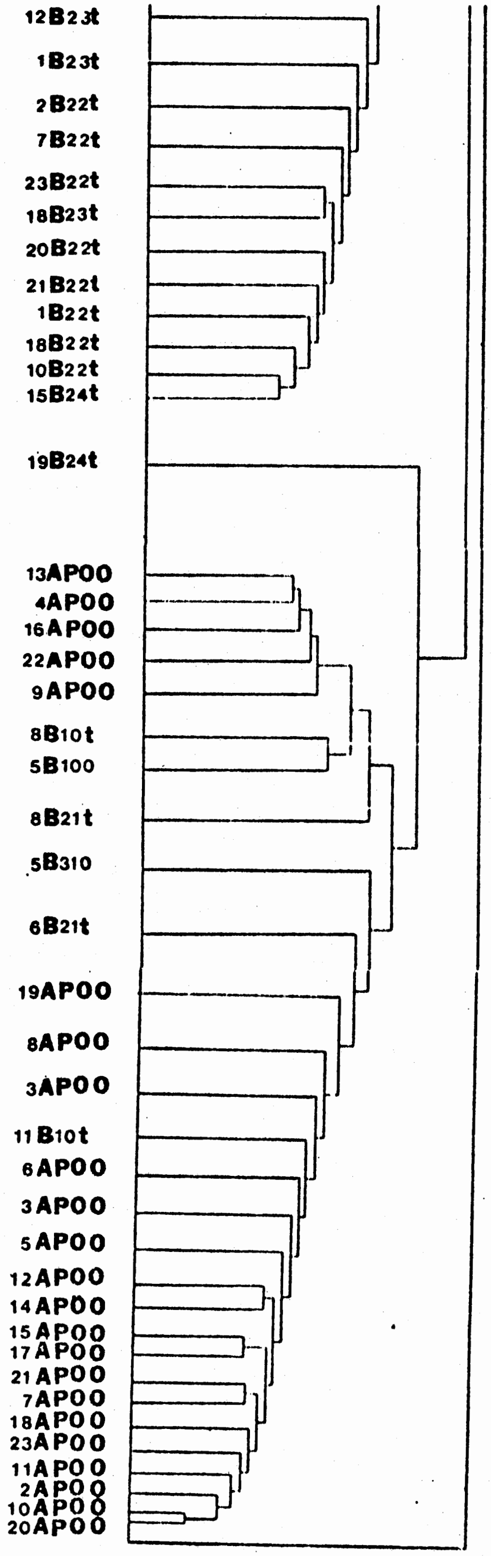


Figure 8.2. (Continued)

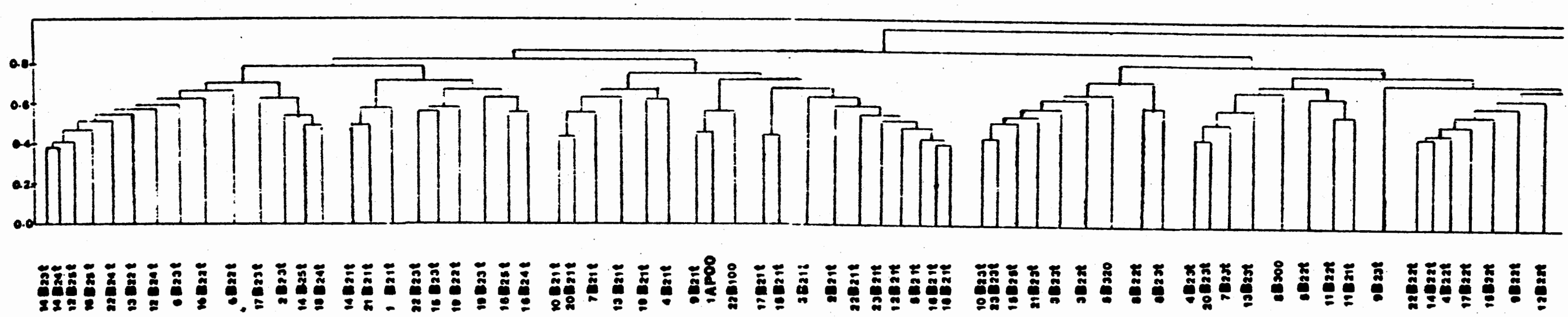


Figure 8.2. (Continued)

are given in Tables 8.1, 8.2, and 8.3. Similarity levels of .70, .72, and .80 were used for area two. The groups resulting for different levels are given in Tables 8.4, 8.5, and 8.6. The next stage was to build the different transition matrices from Tables 8.1 to 8.6. Each table will yield a group of matrices of different dimensions for each table, the number of the matrices is equal to the number of the pedons in the area. The dimension of the matrix in each group is equal to the number of the groups established using a specific similarity level. Table 8.7 is an example of how the transition matrix was built for pedon number 5 (area two, similarity level .72 extracted from Table 8.5). The entry in the transition matrix (Table 8.7) takes into account the relative position of the genetic horizons in the profile. The author feels that in this respect, the transition matrix method is advantageous over other methods.

The three groups of transition matrices were classified separately and different clusters were drawn accordingly. Figures 8.3, 8.4, and 8.5 show different clusters for area one and Figures 8.6, 8.7, and 8.8, for area two. A similarity coefficient of 23 was recognized for pedons of area one, and 35 for pedons of area two. The clusters of both areas show the extreme similarity between some pedons. If two or more pedons were written on the same line, this would indicate that both pedons were exactly similar. One should be cautious, however, because this did not mean that in reality the two pedons are 100% similar to each other, but they were only similar in respect to the properties used to compute their similarity. The exact similarity between two or more pedons was noticed to occur between pedons of the same series in area one and between pedons of different series in area two.

Table 8.8 shows the different, major groups established for area one using the three similarity measurements. Two major groups can be recognized in each case, but with very few pedons forming small groups. However, the pedons were interchanged between different groups when the initial similarity level was changed. Moreover, since similar pedons within each group did not belong to series that occur adjacent to each other in the field, drawing lines to separate the different pedons would be impossible. Table 8.9 shows the different groups established for area two from clusters numbered (Tables 8.6, 8.7, and 8.8). Two major groups were also recognized in each case, but with very few pedons forming small groups. However, the pedons were interchanged between the different groups as the similarity level was changed. This might indicate that even in a small area, the high level of homogeneity as intended in soil survey operations is not possible to achieve. Furthermore, it may also indicate that soil inclusions may occupy a larger portion of the mapping unit. Therefore, it is reasonable to assume that both areas should be designated as complex units.

Summary and Conclusions

Soil survey operations are based on the systematic examination of the soil profiles in the field where changes are thought to occur. The lines that delineate the mapping unit are usually drawn using criteria chosen in advance and given heavy weighting in deciding the type of soil. Dissimilar soils within the delineation are called soil inclusions.

Mathematical classification, as in this study, uses many criteria. Some of them are used in the conventional classification and some are not. Many studies, as well as this study, showed that the kind of soil investigation some doubts were experienced about assigning Ap00 to this horizon. The texture of this horizon was finer than any of the surface horizons in the entire study area. No explanation could be advanced at that time. Therefore, the author feels that the horizon allocation with the B2t group was proper. Most of the B22t, the B23t, B21t or the B24t and B25t horizons were classified into different groups, but with very few inclusions within each group. The occurrence of some different horizons inside other groups could be due to the fact that the B2t subdivisions are established by the vertical subdivision of a thick horizon. Therefore, the wavey topography (as was shown in Chapter II) of the horizons lead to one horizon designation in a certain location and to another designation in another location within the same area. Therefore it is possible for one horizon to be designated as B22t in one pedon to be designated as B21t or B23t in another pedon.

In the next stage, the different horizons were classified into different groups using different similarity levels. The criterion for choosing the similarity level is subjective, but depends on the minimum similarity exhibited between the different horizons. The validity of such classification can be tested by the Wilk's criterion. This test is based on maximizing the between groups sum of squares and minimizing the within groups sum of squares. The classification which gives a maximum Wilk's criterion value could be used to determine the number of clusters present.

Three levels of similarity measurements were used to investigate the effect of the primary grouping on the number of the final pedons clustering. Similarity levels of .73, .76, and .80 were used for area one. The groups classification resulting from these similarity levels

TABLE 8.1

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D=.76), AREA ONE

HOR.	LOCATIONS NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
AP00	02	02	01	20	01	01	01	01	02	01	01	01	02	01	01	01	01	01
B100	02	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B20t	-	-	-	-	-	-	-	-	02*	-	-	-	-	-	-	-	-	-
B200	-	-	-	-	-	01	-	-	-	-	-	05	-	-	-	-	-	-
B20t	-	21	-	-	-	-	-	-	-	01	01	-	19	-	21	-	-	06
B21t	13	-	19	20	01	-	06	19	21*	-	-	-	-	06	-	21	19	-
B22t	13	-	19	14	16	-	19	17*	02*	-	-	-	-	-	-	15	16*	-
B23t	08	-	09	15	-	-	16	-	18*	-	-	-	-	-	-	-	-	-
B300	-	16	09	-	16	05	16	09*	-	19	01	-	06	-	05*	-	-	05
B310	-	-	-	-	-	-	-	-	-	-	-	-	-	02	-	-	-	-
B320	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-
B330	-	-	-	-	-	-	-	-	-	-	-	-	-	06	-	-	-	-
Cr00	08	10	10	11	03	12	10	12	04*	12	12	07	12	10*	12*	12	07*	12

* indicates the presence of discontinuity

TABLE 8.2

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D=.73), AREA ONE

	LOCATIONS NUMBER																	
HOR.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
AP00	03	03	01	27	02	02	01	01	03	01	02	01	03	02	01	01	01	01
B100	03	27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B10t	-	-	-	-	-	-	-	-	03*	-	-	-	-	-	-	-	-	-
B200	-	-	-	-	-	01	-	-	-	-	-	06	-	-	-	-	-	-
B20t	-	28	-	-	-	-	-	-	-	01	02		25	-	28	-	-	08
B21t	18	-	25	27	02	-	08	26	28*	-	-	-	-	08	-	29	25	-
B22t	18	-	25	19	22	-	25	23*	20*	-	-	-	-	-	-	20	21*	-
B23t	10	-	12	20	-	-	21	-	24*	-	-	-	-	-	-	-	-	-
B300	-	21	11	-	22	06	21	11*	-	25	02	-	07	-	06*	-	-	06
B310	-	-	-	-	-	-	-	-	-	-	-	-	-	03	-	-	-	-
B320	-	-	-	-	-	-	-	-	-	-	-	-	-	21	-	-	-	-
B330	-	-	-	-	-	-	-	-	-	-	-	-	-	07	-	-	-	-
Cr00	10	14	13	15	04	17	14	17	05*	17	17	09	17	13*	17*	16	09*	17

* indicates the presence of discontinuity.

TABLE 8.3

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON
THE PRIMARY DENDOGRAM (D=.80), AREA ONE

HOR.	LOCATIONS NUMBER																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
AP00	01	01	01	15	01	01	01	01	01	01	01	01	01	01	01	01	01	01
B100	01	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B10t	-	-	-	-	-	-	-	-	01*	-	-	-	-	-	-	-	-	-
B200	-	-	-	-	-	01	-	-	-	-	-	04	-	-	-	-	-	-
B20t	-	15	-	-	-	-	-	-	-	01	01	-	15	-	15	-	-	04
B21t	10	-	15	15	01	-	04	15	15*		-	-	-	04	-	15	15	-
B22t	10	-	15	10	12	-	15	13*	11*	-	-	-	-	-	-	11	12*	-
B23t	06	-	07	11	-	-	12	-	14*	-	-	-	-	-	-	-	-	-
B300	00	12	07	-	12	04	12	07*	-	15	01	-	04	-	04*	-	-	04
B310	-	-	-	-	-	-	-	-	-	-	-	-	-	01	-	-	-	-
B320	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-
B330	-	-	-	-	-	-	-	-	-	-	-	-	-	04	-	-	-	-
Cr00	06	08	08	09	02	09	08	09	03*	09	09	05	09	08	09*	09	05*	09

* indicates the presence of discontinuity.

TABLE 8.4

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D=.70), AREA TWO

	LOCATIONS NUMBER																						
HOR.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP00	06	16	16	15	16	16	16	16	15	16	16	16	15	16	16	15	16	16	16	16	16	15	16
B100	-	-	16	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16	-
10t	-	-	-	-	-	-	-	15	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
B21t	03	07	07	05	07	16	05	15	06	05	11	07	05	03	07	07	07	07	05	05	03	07	07
B22t	13*	13*	08*	13*	11*	01*	13	09*	13*	13*	11**	13	01	13	13	01	13*	07	04	13*	13	13	13*
B23t	13*	02*	08**	10*	-	01*	10*	09*	12**	08*	-	13*	10*	01*	04	01*	02*	13*	04	10*	08*	14	08*
B24t	-	-	-	-	-	-	-	-	-	-	-	01*	-	01*	13	04*	-	02*	14*	-	-	01	-
B25t	-	-	-	-	-	-	-	-	-	-	-	01*	-	02*	08*	04*	-	-	-	-	-	-	-
B300	-	-	-	-	-	-	-	10**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B310	-	-	-	-	16*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B320	-	-	-	-	08*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*=11, **=111, indicates the presence of discontinuity.

TABLE 8.5

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D=.72), AREA TWO

	LOCATIONS NUMBER																						
HOR.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP00	04	10	10	09	10	10	10	10	09	10	10	10	09	10	10	09	10	10	10	10	10	09	10
B100	-	-	10	-	09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	04	-
B10t	-	-	--	-	-	-	-	09	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-
B21t	02	04	04	03	04	10	03	09	04	03	06	04	03	02	04	02	04	04	03	03	02	04	04
B22t	07*	07*	05*	07*	06*	01*	07	05*	07	07*	06*	07	01	07	07	01*	08*	07	02	07*	07*	07	07*
B23t	07*	01*	05**	06*	-	01*	06*	05*	07**	05*	-	07*	06*	01*	02	01*	01*	07*	02	06*	05*	02	05*
B24t	-	-	-	-	-	-	-	-	-	-	-	01*	-	01*	07	02*	-	01*	08*	-	-	01	-
B25t	-	-	-	-	-	-	-	-	-	-	-	01*	-	01*	05*	02	-	-	-	-	-	-	-
B300	-	-	-	-	-	-	-	06**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B310	-	-	-	-	10*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B320	-	-	-	-	05**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

* =11, ** =111, indicates the presence of discontinuity.

TABLE 8.6

SUMMARY OF THE HORIZONS CLASSIFICATION BASED ON THE PRIMARY DENDOGRAM (D=.80), AREA TWO

HOR.	LOCATIONS NUMBER 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AP00	02	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06	06
B100	-	-	06	-	06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	02	-
B10t	-	-	-	-	-	-	-	06	-	-	06	-	-	-	-	-	-	-	-	-	-	-	-
B21t	01	02	02	02	02	06	02	06	02	02	04	02	02	01	02	02	02	02	02	02	01	02	02
B22t	04*	04	03*	04*	05*	01*	04	03*	04*	04*	04*	04	01	04	04	01	04*	04	01	04*	04*	04	04*
B23t	04*	01*	03**	04*	-	01*	04*	03*	04**	03*	-	04*	04*	01*	01	01*	01*	04*	01	04*	03*	01	03*
B24t	-	-	-	-	-	-	-	-	-	-	-	01*	-	01*	04	01*	-	04*	05*	-	-	01	-
B25t	-	-	-	-	-	-	-	-	-	-	-	01	-	01*	03*	01*	-	-	-	-	-	-	-
B300	-	-	-	-	-	-	-	04*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B310	-	-	-	-	06*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B320	-	-	-	-	03**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*** =11, ** =111, indicates the presence of discontinuity.**

TABLE 8.7

TRANSITION MATRIX FOR PEDON NO. 5 (D=.72), AREA TWO

	01	02	03	04	05	06	07	08	09	10
01	00	00	00	00	00	00	00	00	00	00
02	00	00	00	00	00	00	00	00	00	00
03	00	00	00	00	00	00	00	00	00	00
04	00	00	00	00	00	01	00	00	00	00
05	00	00	00	00	00	00	00	00	00	00
06	00	00	00	00	00	00	00	00	00	01
07	00	00	00	00	00	00	00	00	00	00
08	00	00	00	00	00	00	00	00	00	00
09	00	00	00	01	00	00	00	00	00	00
10	00	00	00	00	01	00	00	00	01	00

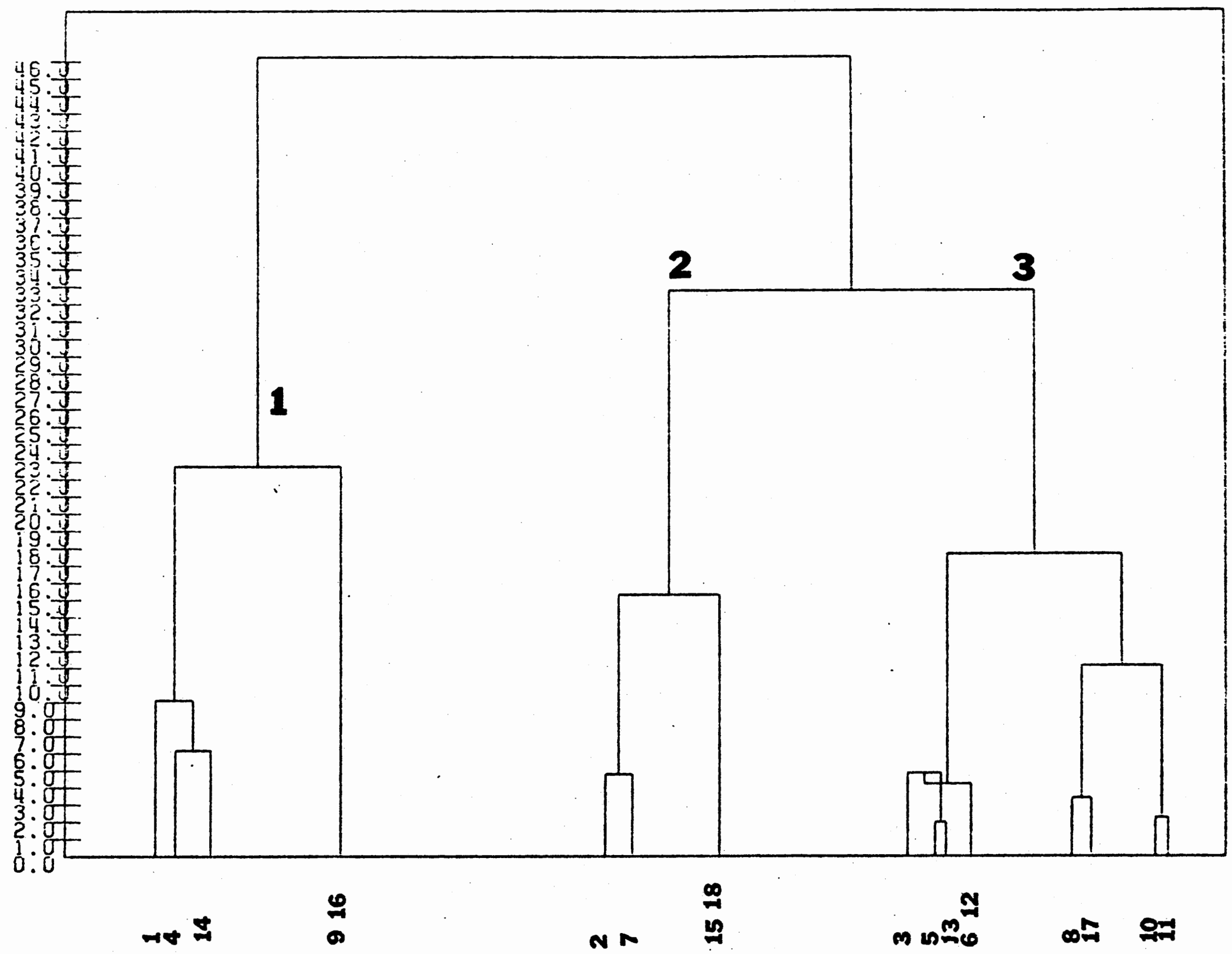


Figure 8.3. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D=.73), Area One.

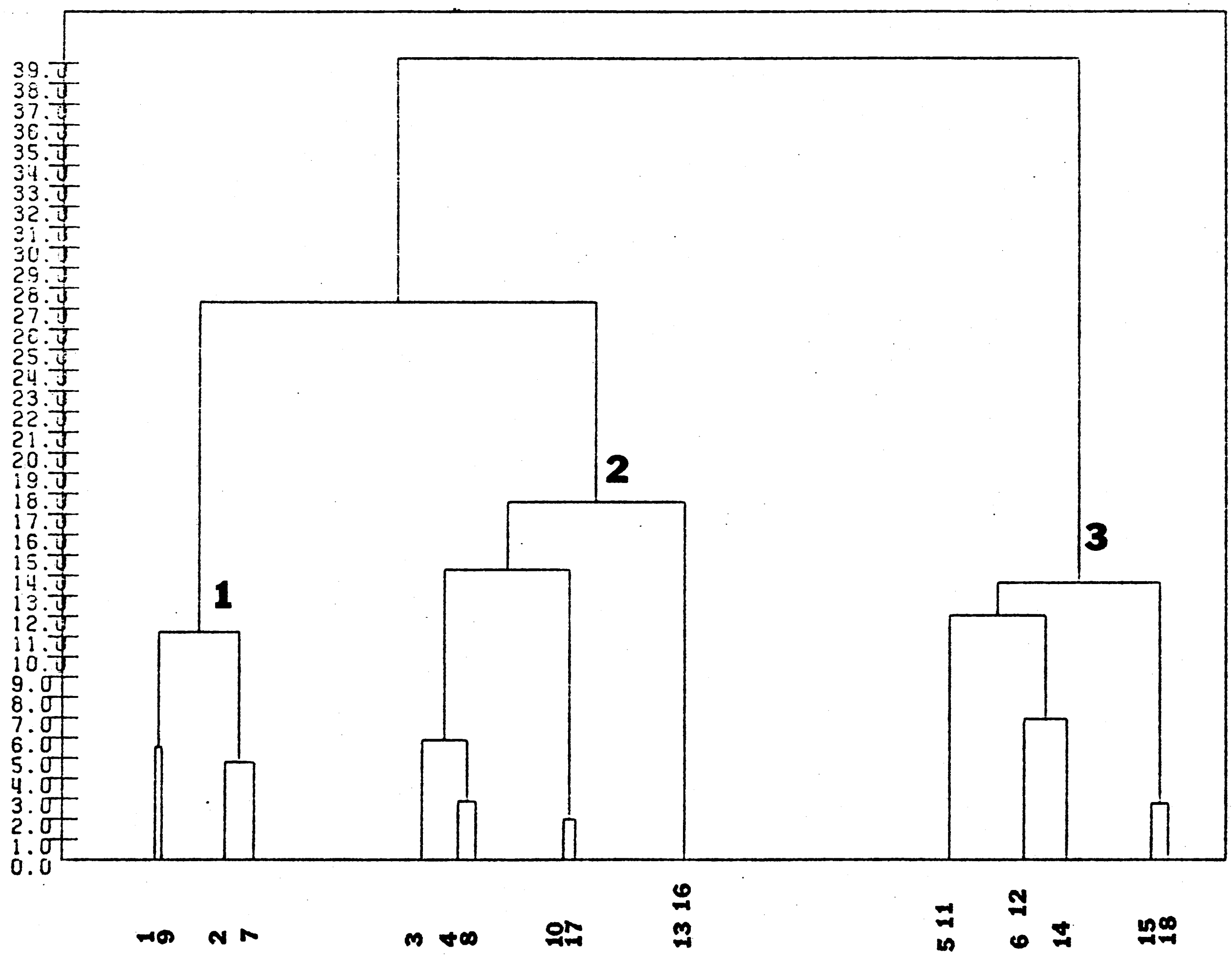


Figure 8.4. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D=.76), Area One.

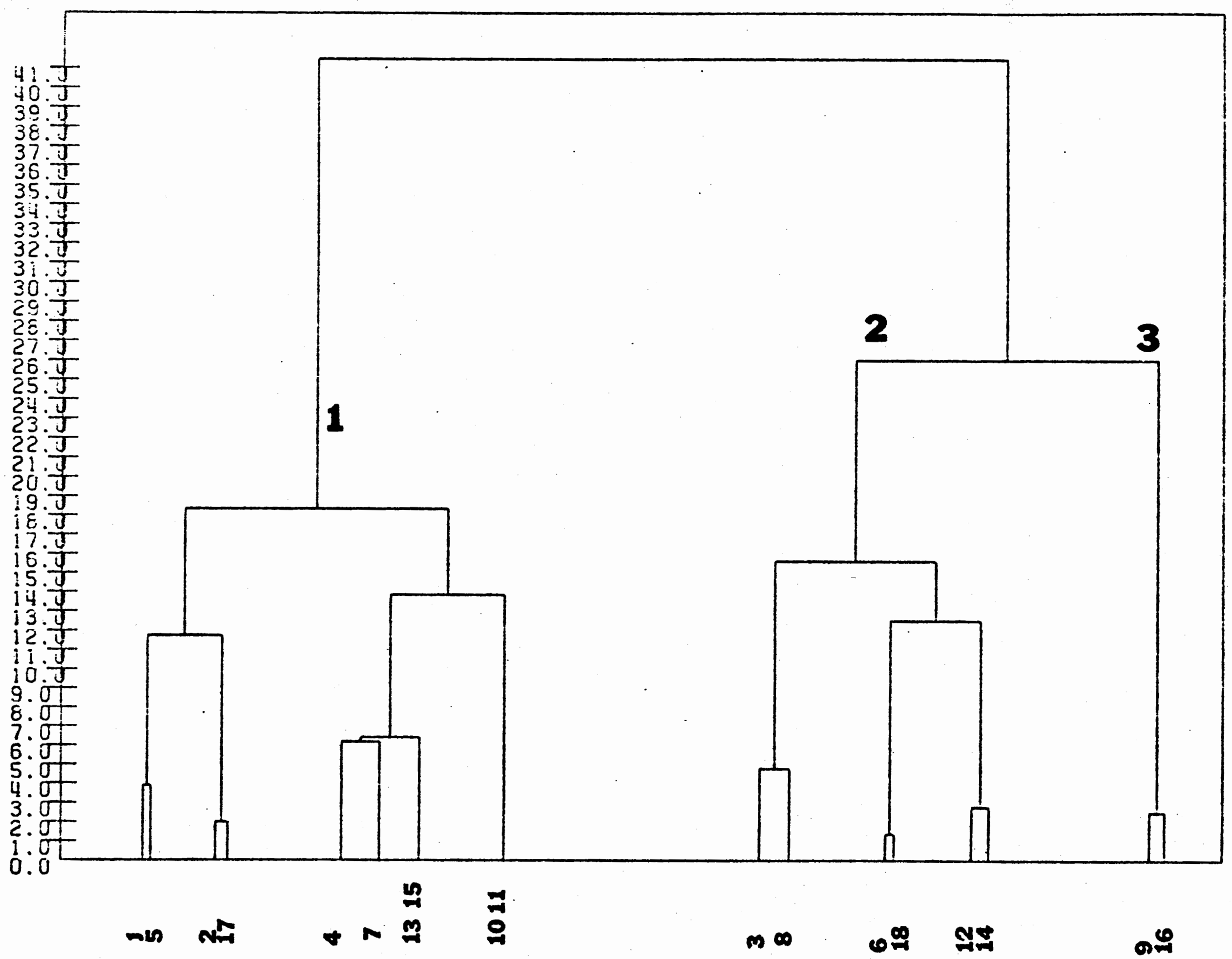


Figure 8.5. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D=.80), Area One.

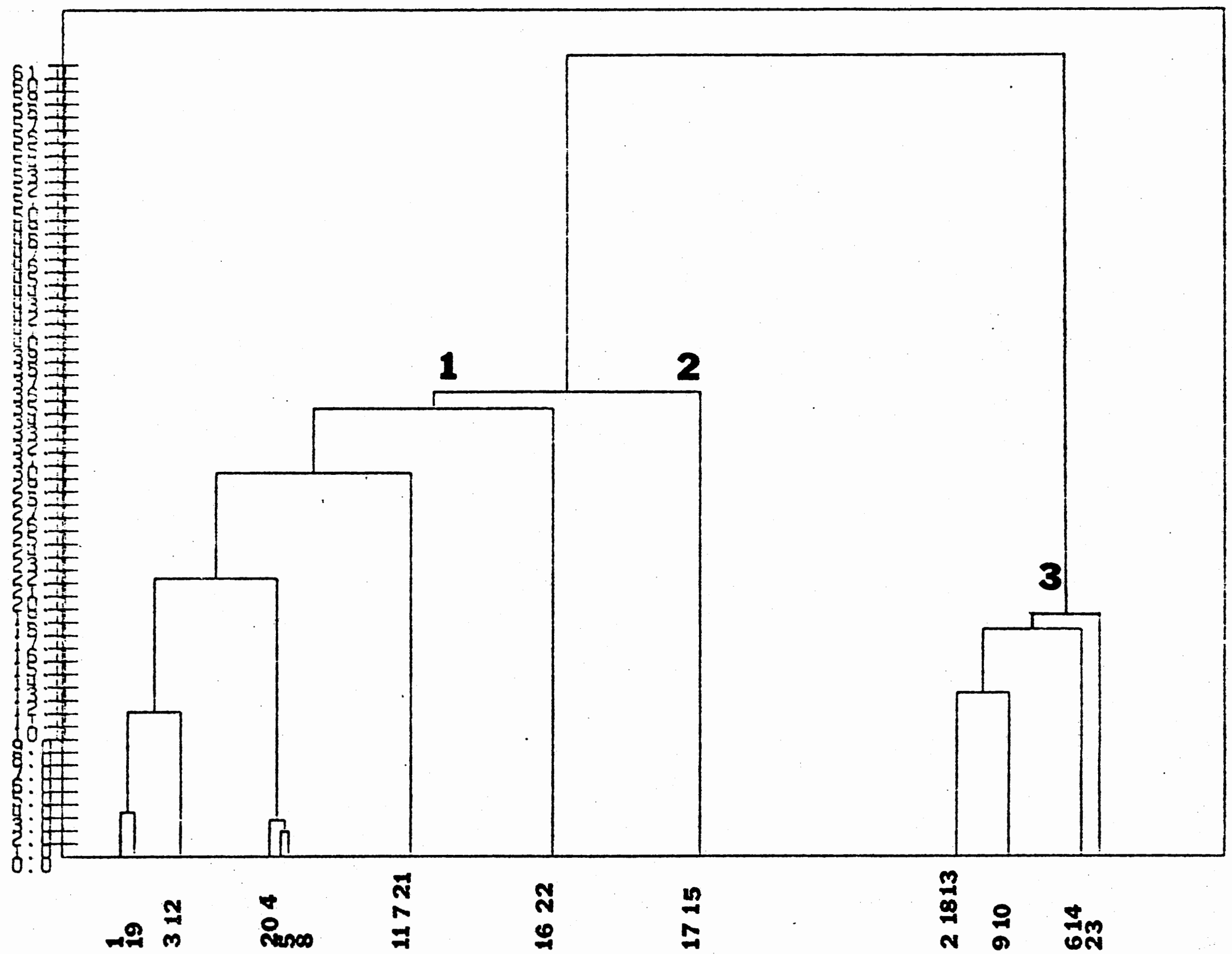


Figure 8.6. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D=.70), Area Two.

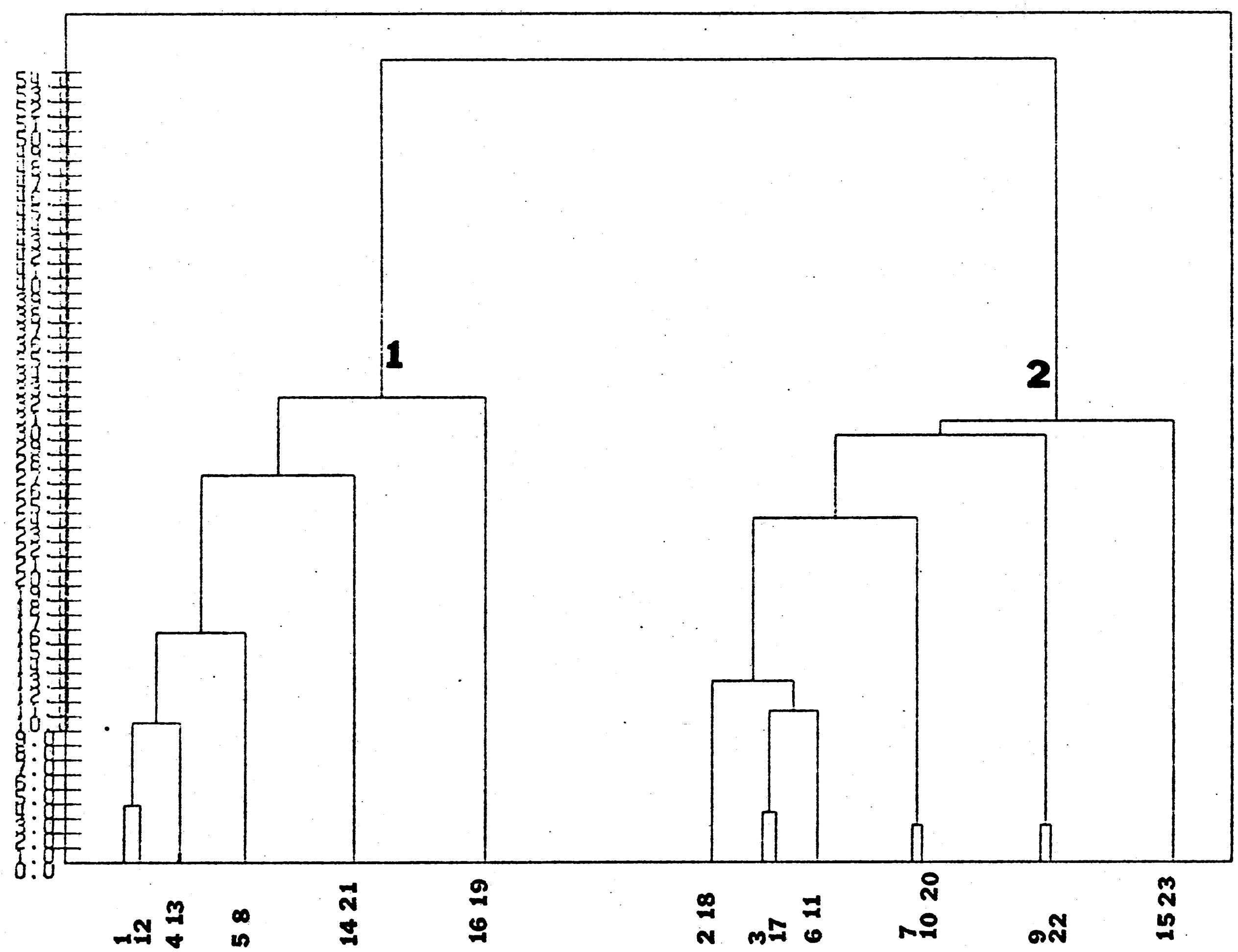


Figure 8.7. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D=.72), Area Two.

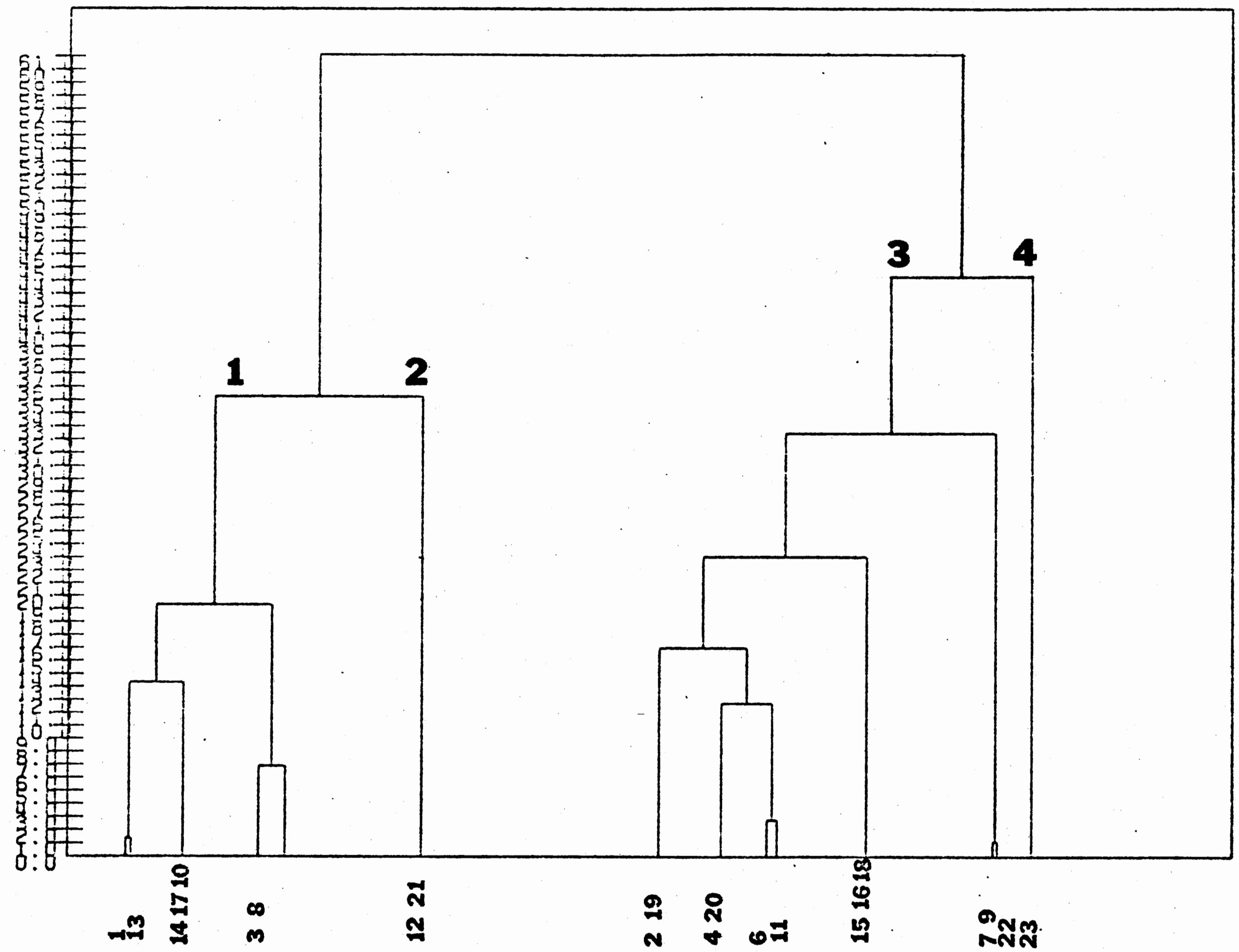


Figure 8.8. Dendogram of the Individual Pedons Obtained from the Primary Dendogram (D=.80), Area Two.

TABLE 8.8

FINAL PEDONS CLASSIFICATION OBTAINED FROM
THE PEDONS DENDOGRAMS, AREA ONE

.73*						.76*						.80*					
G1		G2		G3		G1		G2		G3		G1		G2		G3	
P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S
1	D	2	B	3	A	1	D	3	A	5	A	1	D	3	A	9	c
4	A	7	C	5	A	9	D	4	A	11	C	5	A	8	C	16	D
14	D	15	D	13	D	2	B	8	C	6	C	2	B	6	C		
9	D	18	A	6	C	7	C	10	C	12	C	17	C	18	A		
16	D			12	C			17	B	14	D	4	A	12	C		
				8	C			13	D	15	D	13	D				
				17	B			16	D	18	A	15	D				
				10	C							10	C				
				11	C							11	C				

* the similarity level, G = group established from the pedons clusters.
S = the series from which the pedon was sampled in the field.
P = the number of the pedons.

TABLE 8.9

FINAL PEDONS CLASSIFICATION OBTAINED FROM THE PEDONS DENDOGRAMS, AREA TWO

.70*						.72*				.80*							
G1		G2		G3		G1		G2		G1		G2		G3		G4	
P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S
1	F	17	H	2	F	1	F	2	F	1	F	12	G	2	F	23	F
19	G	15	G	18	G	12	G	18	G	13	G	21	H	19	G		
3	F			13	G	4	E	3	F	14	G			4	E		
12	G			9	E	13	G	17	H	17	H			20	F		
20	F			10	E	5	E	6	E	10	E			6	E		
4	E			6	E	8	E	11	E	3	F			11	E		
5	E			14	G	14	G	7	E	8	E			15	G		
18	E			23	F	21	H	10	E	5	E			16	G		
11	E					16	G	20	F					18	G		
7	E					19	G	9	E					7	E		
21	H							22	G					9	E		
16	G							15	G					22	G		
22	G							23	F								

*= the similarity level, G = group established from the pedons clusters.
S = the series from which the pedon was sampled in the field.
P = the number of the pedons.

characters used have a strong impact on the outcome. The author feels that treating the soil as an anisotropic medium is a reasonable approach based on the genesis theory. Thus the transition matrix approach is a proper method to deal with this problem. However, it hinders using some of the properties that are characteristics of the whole profile and not the individual horizon which are, at the same time, important in the conventional classification systems. Therefore, if an unbiased comparison between the mathematical and the conventional classification is needed, then the transition method would be the ideal one, if modified to include such properties.

The initial similarity used to classify the different horizons based on the primary dendogram had a little effect on the number of the groups into which different pedons were classified. However, the pedons interchanged their positions between different groups each time the similarity level was changed. Moreover, the pedons within a specific group did belong to different series that are not adjacent to each other on the field. This makes the separation of different series, based on the mathematical classification, hard to achieve. This might indicate, if one submitted to the validity of the cluster analysis, that the series, as defined in the context of homogeneity, may not exist at any level in the field even in a small area where the variation of the soil forming factors are minimum. This might also suggest that a larger portion of the mapping unit is occupied with soil inclusions In this case, it is reasonable and safer to call such a unit a soil complex. This conclusion applies to both areas.

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APPENDIX A

LIST OF SIMPLE STATISTICS FOR

AREA ONE AND TWO

TABLE 1

SIMPLE STATISTICS FOR THE AP ZONE BY AREA

	Mean		STD		Min Value		Max Value		C.V.%		N. Samples	
	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2
K	0.6	0.4	0.4	0.1	0.2	0.3	1.5	0.6	74.5	19.5	56	4
H	5.7	5.2	1.4	1.2	2.1	2.0	8.0	7.6	24.4	23.6	6	6
CEC	22.7	20.0	4.4	3.9	17.2	15.3	34.5	33.6	19.6	19.4	4	4
OM	1.9	1.3	0.3	0.2	1.3	1.0	2.5	1.7	17.0	12.5	3	2
pH	6.6	6.1	0.5	0.6	5.4	5.4	7.3	7.8	8.0	9.8	1	1
$CaCO_3$	0.8	0.4	0.5	0.4	0.1	0.1	1.9	1.1	59.7	98.3	36	97
Ca	9.2	9.0	3.5	2.8	3.0	6.2	16.7	18.3	37.7	30.7	14	9
Na	0.6	0.2	1.6	0.1	0.1	0.1	3.3	0.6	289.2	47.1	836	22
Mg	5.2	4.3	2.0	1.1	2.6	3.0	10.3	8.5	32.1	26.1	10	7
FS	30.6	11.8	9.1	2.6	15.9	6.8	55.5	17.4	29.7	22.3	9	5
VFS	10.4	10.8	1.8	1.5	6.0	7.9	13.7	14.1	17.6	13.4	3	2
Silt	36.5	55.6	6.5	10.5	21.1	32.0	49.4	67.2	17.8	18.9	2	4
Clay	22.6	21.8	6.6	9.7	11.2	13.0	38.6	40.8	29.4	44.6	9	20
BST	72.3	69.5	23.6	10.5	21.4	57.0	100.0	100.0	32.7	15.1	11	2
Slope	1.7	0.6	1.0	0.1	0.5	0.5	3.5	1.0	57.5	19.1	33	4
Thickness	7.8	9.0	3.0	2.2	4.0	5.0	28.0	13.0	34.7	24.4	12	6
D Dark L	13.1	28.5	4.5	6.1	8.0	10.0	15.0	36.0	38.2	21.4	15	5
D Bu	7.3	36.2	12.8	13.9	0.0	0.0	44.0	74.0	175.4	38.4	308	15
D Rooz	13.3	11.4	5.7	3.1	4.0	7.0	26.0	19.0	42.7	26.7	18	7
D Crotv	13.7	8.2	16.3	4.3	0.0	0.0	48.0	12.0	119.2	52.1	142	27
D Concr	10.3	29.2	9.3	11.5	0.0	4.0	30.0	52.0	90.0	39.5	81	16
D Mot	9.8	23.3	12.4	13.2	0.0	7.0	35.0	50.0	126.5	56.5	160	32
D Bwbod	5.4	5.0	5.5	2.5	2.0	2.0	25.0	12.0	101.5	49.4	103	24
D Clay Flm	5.4	9.2	4.4	2.1	0.0	5.0	14.0	13.0	81.2	22.9	66	5
D Sliksd	4.4	21.6	6.0	33.7	0.0	0.0	18.0	77.0	134.4	155.9	181	243
D Presfs	4.7	8.4	6.1	21.4	0.0	0.0	18.0	74.0	130.0	253.8	169	644
D Strk	10.5	67.1	10.7	33.9	0.0	0.0	34.0	91.0	101.4	50.4	103	25
Drang	4.5	4.1	0.5	0.3	4.0	4.0	5.0	5.0	11.2	8.3	1	1
Perm	2.0	1.1	0.8	0.3	1.0	1.0	3.0	2.0	38.3	26.5	15	7

n for AR1 = 18
n for AR2 = 23
AR1 = Area 1
AR2 = Area 2

TABLE 2

SIMPLE STATISTICS FOR THE ROOT ZONE BY AREA

	Mean		STD		Min Value		Max Value		C.V.%		N. Samples	
	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2
K	0.4	0.4	0.4	0.1	0.2	0.3	1.4	0.5	78.1	14.8	61	2
H	5.2	5.1	1.4	1.1	2.9	2.0	7.9	6.5	26.3	21.5	7	5
CEC	25.1	21.7	5.0	4.3	17.7	15.3	36.5	35.3	20.1	19.7	4	4
OM	1.6	1.3	0.3	0.2	1.0	1.0	2.1	1.7	18.2	13.3	3	2
pH	6.9	6.2	0.6	0.6	5.9	5.6	7.6	7.8	8.5	9.8	1	1
$CaCO_3$	1.0	0.5	0.6	0.4	0.1	0.1	2.1	1.1	55.6	72.7	31	53
Ca	11.7	10.0	4.6	3.1	3.2	6.6	20.7	18.3	39.3	30.8	15	10
Na	1.5	0.3	2.1	0.3	0.1	0.1	6.3	1.2	135.7	80.7	184	82
Mg	7.4	4.8	2.2	1.1	3.1	3.0	11.7	8.0	29.5	23.2	9	5
FS	28.6	11.4	9.7	2.7	15.9	6.2	55.5	17.4	34.1	23.4	12	6
VFS	9.8	10.4	2.2	1.5	6.0	7.2	13.5	14.1	21.9	14.7	5	2
Silt	35.0	53.4	6.0	9.9	21.1	32.2	45.1	64.8	17.1	18.6	3	4
Clay	26.6	24.8	7.9	919	11.2	13.0	40.4	42.6	29.7	40.0	9	16
BST	81.0	70.6	22.2	9.9	27.0	60.7	100.0	100.0	27.4	14.0	8	2
Slope	1.7	0.6	1.0	0.1	0.5	0.5	3.5	1.0	5.7	1.9	1	4
Thickness	16.7	78.7	10.4	10.8	4.0	40.0	37.0	92.0	62.3	13.8	39	2
D Dark L	13.1	28.5	4.5	6.1	8.0	10.0	28.0	36.0	34.7	21.4	12	5

n for AR1 = 18
n for AR2 = 23
AR1 = Area 1
AR2 = Area 2

TABLE 3

SIMPLE STATISTICS FOR SUBSOIL BY AREA

	Mean		STD		Min Value		Max Value		C.V.%		N. Samples	
	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2	AR1	AR2
K	0.4	0.4	0.4	<0.1	0.1	0.3	1.3	0.4	65.0	8.0	42	1
H	3.8	3.4	2.2	0.7	0.7	2.6	7.1	5.1	95.0	20.3	90	4
CEC	28.1	30.8	6.8	2.9	18.2	24.6	40.6	34.9	57.4	9.4	33	1
OM	0.8	0.4	0.4	0.1	0.4	0.3	1.5	0.6	24.3	24.5	6	6
pH	7.3	7.4	0.8	0.5	5.7	6.3	8.3	8.1	42.6	6.0	18	1
$CaCO_3$	1.5	1.0	1.2	0.4	0.2	0.1	5.2	1.7	10.9	36.9	1	14
Ca	19.2	14.1	12.3	2.5	4.2	10.6	40.8	23.1	74.9	17.5	56	3
Na	3.5	1.8	4.4	0.9	<0.1	0.2	11.7	2.8	63.9	51.2	41	26
Mg	9.1	7.7	3.4	1.0	3.3	5.2	15.0	8.8	125.9	12.7	159	2
FS	24.4	12.0	11.3	3.5	3.2	6.7	44.9	18.5	36.7	29.0	14	8
VFS	8.4	9.2	4.2	1.5	2.6	6.0	18.9	12.0	46.5	16.8	22	3
Silt	32.9	42.3	5.9	6.5	17.1	22.9	42.6	52.5	50.7	15.4	26	2
Clay	34.3	36.6	10.3	6.6	19.2	24.2	52.0	46.8	18.1	18.1	3	3
BST	75.0	77.4	43.0	7.7	33.5	58.6	100.0	17.6	29.9	19.1	9	4
RZD	5.6	3.0	3.6	2.2	1.0	1.0	13.0	7.0	65.0	72.5	42	53
Thickness	16.7	78.7	10.4	10.8	4.0	40.0	37.0	92.0	62.3	13.7	39	2

n for AR1 = 18
n for AR2 = 23
n for RZD1 = 15
n for RZD2 = 12
AR1 = Area 1
AR2 = Area 2

TABLE 4

SIMPLE STATISTICS FOR THE CR ZONE BY AREA

	Mean	STD	Min Value	Max Value	C.V.%	N. Samples
K	0.1	0.2	0.1	0.9	262.8	69
H	2.0	1.6	<0.1	5.2	79.6	48
CEC	16.7	5.6	8.2	31.9	33.5	11
OM	0.2	0.2	<0.1	0.6	64.1	41
pH	7.9	0.8	6.3	9.3	10.3	1
$CaCO_3$	1.7	3.2	0.1	14.7	189.8	360
Ca	12.0	10.1	3.1	33.4	84.5	71
Na	3.0	2.9	<0.1	9.4	95.2	91
Mg	6.0	2.3	1.8	11.0	39.1	15
FS	47.6	13.6	29.0	76.2	28.6	8
VFS	15.3	9.0	4.1	34.3	58.7	35
Silt	19.2	7.8	6.0	37.4	40.7	17
Clay	17.9	5.2	10.7	28.6	28.9	8
BST	91.7	64.5	36.7	100.0	59.0	35
Slope	1.7	1.0	0.5	3.5	57.5	33
Thickness	7.9	3.4	1.0	18.0	11.2	1

n = 18

TABLE 5

SIMPLE STATISTICS FOR SERIES A, AREA ONE

	Mean			STD			Min Value			Max Value			C.V.%			N. Samples		
	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr
K	0.3	0.5	0.2	0.1	0.4	0.4	0.2	0.1	0.1	0.4	1.0	0.9	18.6	83.3	177.6	4	69	315
H	6.0	4.0	2.0	0.5	2.3	1.1	5.6	1.4	0.6	6.6	7.0	3.1	7.8	57.8	56.1	1	33	32
CEC	26.5	27.0	16.6	7.5	7.0	2.2	18.8	20.7	14.6	36.5	36.9	19.5	28.1	25.9	13.1	8	7	2
OM	1.7	0.7	0.2	0.2	0.3	0.1	1.5	0.5	0.1	1.9	1.1	0.4	12.0	39.7	54.1	2	16	29
pH	7.0	6.1	7.6	0.4	0.9	0.6	6.4	6.0	6.9	7.3	8.1	8.1	5.8	13.0	7.2	1	2	1
$CaCO_3$	0.8	1.1	0.9	0.8	0.7	0.5	0.1	0.2	0.6	1.9	1.8	1.6	94.0	63.2	61.3	88	40	38
Ca	11.5	20.3	8.7	2.3	12.0	6.6	8.9	5.2	3.2	14.2	34.5	18.1	20.2	59.1	74.8	4	35	56
Na	1.8	3.4	3.0	1.1	5.3	5.0	0.9	<0.1	0.1	3.3	10.1	9.4	57.2	156.5	159.1	33	245	253
Mg	7.2	9.6	6.2	2.3	3.8	1.8	5.0	4.3	3.9	10.3	13.3	8.4	32.4	39.6	29.4	11	16	9
FS	32.5	22.9	47.2	16.8	10.1	13.4	15.9	8.6	29.0	55.5	31.3	61.4	51.9	44.1	28.4	27	19	8
VFS	11.6	11.2	10.5	1.6	5.4	1.9	9.3	6.5	9.3	13.1	18.9	13.5	14.0	48.1	18.3	2	23	3
Silt	32.6	32.0	23.1	7.8	5.3	10.7	21.1	27.9	14.6	38.0	39.5	37.4	23.9	16.5	46.0	6	3	21
Clay	23.4	33.6	19.0	11.5	8.9	4.9	11.2	24.9	14.5	38.6	45.5	24.2	49.3	26.5	25.5	24	7	7
Bst	78.6	74.5	85.5	3.1	40.6	20.9	75.2	40.0	61.9	82.1	100.00	100.0	4.0	47.5	24.0	1	23	6
Slope	1.7			0.9			1.0			3.0			56.3			32		
Thickness	9.3	17.0	7.5	3.8	9.3	2.1	5.0	8.0	5.0	14.0	25.0	10.0	40.8	54.6	27.8	17	30	8
D Dark L	11.8			2.2			10.0			15.0			18.9			4		
D Burl	0.0			0.00			0.0			0.0								
D Rooz	10.8			4.4			6.0			15.0			41.2			17		
D Crotv	19.5			22.9			0.0			48.0			117.4			138		
D Concr	5.5			6.4			0.0			11.0			115.5			133		
D Mot	19.0			16.4			0.0			35.0			86.1			74		
D Bwbod	4.5			2.6			2.0			8.0			58.8			35		
D Clay Flm	8.0			5.9			0.0			14.0			73.6			54		
D Sliksd	1.3			2.5			0.0			5.0			200.0			400		
D Presfs	1.3			2.5			0.0			5.0			200.0			400		
D Strk	3.8			4.8			0.0			10.0			127.7			163		
Drang	4.5			0.6			4.0			5.0			12.8			2		
Perm	2.0			0.8			1.0			3.0			40.8			17		

n = 4

TABLE 6

SIMPLE STATISTICS FOR SERIES B, AREA ONE

	Mean			STD			Min Value			Max Value			C.V.%			N. Samples		
	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr
K	0.9	0.6	0.1	0.6	0.6	0.1	0.5	0.1	0.1	1.4	1.0	0.1	66.6	106.0	60.1	44	112	36
H	6.1	2.6	1.3	0.3	0.5	1.6	5.9	2.2	0.1	6.3	2.9	2.3	4.6	20.0	125.7	1	4	158
CEC	23.7	26.9	26.7	0.9	1.3	7.4	23.0	26.0	21.4	24.3	28.0	31.9	3.9	5.0	27.8	1	1	8
OM	2.0	0.7	0.2	0.01	0.3	0.1	2.0	0.6	0.1	2.1	0.9	0.2	0.3	34.0	58.4	1	10	34
pH	6.7	8.0	8.5	0.4	0.5	0.4	6.4	7.6	8.2	7.0	8.3	8.7	5.7	6.3	4.3	1	1	1
$CaCO_3$	1.0	1.2	1.0	0.4	0.7	0.0	0.7	0.7	1.0	1.3	1.7	1.0	39.0	56.2	0.0	15	32	1
Ca	8.8	16.2	12.0	4.1	5.5	10.7	5.8	12.3	4.4	11.7	20.1	19.6	47.2	34.0	89.3	22	12	80
Na	0.1	2.5	5.2	1.9	1.8	0.3	0.1	1.3	5.0	1.3	4.0	5.5	2.5	70.3	6.6	1	49	44
Mg	7.6	9.6	6.4	0.6	0.9	1.4	7.2	9.0	5.4	8.1	10.2	7.4	8.3	9.0	22.3	1	1	5
FS	24.3	31.5	47.1	6.8	8.2	19.2	19.5	25.7	35.0	29.1	37.3	59.3	27.9	26.1	36.5	8	7	13
VFS	8.0	5.8	20.0	2.9	2.3	20.4	6.0	4.2	5.5	10.0	7.4	34.3	35.9	39.5	102.6	13	16	105
Silt	39.0	30.6	14.9	6.8	2.2	0.7	34.2	29.0	14.4	43.8	32.2	15.4	17.5	7.3	4.7	3	1	1
Clay	28.7	32.1	18.1	2.8	8.2	3.9	26.7	26.3	15.3	30.7	38.0	20.8	9.6	25.7	21.5	1	7	5
BST	73.5	80.5	85.5	28.2	28.2	7.2	53.6	84.3	47.0	93.4	100.0	100.0	38.3	30.8	55.8	15	10	31
Slope	1.6			0.1			1.5			1.7			8.8			1		
Thickness	6.0	11.5	9.0	2.8	2.1	2.8	4.0	10.0	7.0	8.0	13.0	11.0	47.1	18.5	31.4	22	3	10
D Dark L	16.5			2.1			14.0			17.0			13.7			2		
D Burl	6.5			9.2			0.0			13.0			141.4			200	4	
D Rooz	7.5			5.0			4.0			11.0			66.0			44		
D Crotv	4.0			5.7			0.0			8.0			141.4			200		
D Concr	11.5			2.1			10.0			13.0			18.5			3		
D Mot	8.5			12.0			0.0			17.0			141.4			200		
D Bwbod	13.5			16.3			2.0			25.0			.120.5			144		
D Clay Flm	7.5			0.7			7.0			8.0			9.4			1		
D Sliksd	0.0			0.0			0.0			0.0			-			-		
D Presfs	0.0			0.0			0.0			0.0			0.0			-		
D Strk	13.5			0.7			13.0			14.0			5.2			1		
Drang	4.0			0.0			4.0			4.0			0.0			1		
Perm	2.0			0.0			2.0			2.0			0.0			1		

n = 6

TABLE 7

SIMPLE STATISTICS FOR SERIES C, AREA ONE

	Mean			STD			Min Value			Max Value			C.V.%			N. Samples		
	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr
K	.5	0.4	0.1	0.3	0.5	0.1	0.2	0.1	0.1	1.1	1.3	0.1	66.4	110.2	107.5	44	121	101
H	6.6	3.4	3.0	1.1	3.0	2.0	5.0	0.7	0.2	8.0	7.1	5.2	16.6	68.5	67.2	3	47	45
CEC	20.6	22.7	14.0	3.0	3.7	2.2	17.1	18.2	12.2	24.3	27.7	16.9	14.5	16.5	15.9	2	3	3
OM	1.9	1.0	0.3	0.3	0.5	0.2	1.4	0.4	0.1	2.1	1.5	0.6	14.1	48.5	76.0	2	24	58
pH	6.2	6.8	7.6	0.6	0.9	1.1	5.4	5.7	6.3	7.0	7.9	8.8	9.7	13.2	14.0	1	2	2
$CaCO_3$	0.6	1.0	0.7	0.2	0.5	0.5	0.5	0.5	0.1	1.0	2.0	1.3	39.4	51.7	68.2	16	27	47
Ca	9.6	14.2	7.6	4.4	12.8	5.5	2.9	4.2	4.0	16.7	39.8	18.7	45.7	90.0	72.3	21	81	52
Na	0.6	1.6	1.9	1.4	4.0	1.0	0.1	0.1	0.8	2.1	8.9	3.1	219.6	250.0	54.4	482	625	30
Mg	5.2	6.3	5.4	2.3	1.9	2.8	2.6	3.3	3.7	8.7	8.8	11.0	45.6	30.1	50.8	21	9	26
FS	33.6	32.7	56.6	5.2	6.3	13.9	26.4	28.5	56.6	41.0	44.9	76.2	15.6	18.5	24.6	2	3	6
VFS	10.6	9.2	14.2	1.9	3.5	9.8	8.9	5.5	4.1	13.7	14.7	30.9	18.1	37.6	61.9	3	14	47
Silt	37.9	32.8	14.6	5.0	3.7	5.6	32.2	28.0	6.0	45.2	37.0	21.8	13.1	11.2	38.3	1	2	1
Clay	17.9	25.3	14.4	3.8	3.3	2.6	12.7	19.2	10.7	22.7	28.9	18.0	21.0	13.0	17.9	4	2	3
BST	75.7	97.8	98.0	32.2	58.0	42.2	21.5	33.5	66.0	100.0	100.0	100.0	42.6	69.7	41.5	18	49	17
Slope	2.6			10.5			2.0			2.5			18.9			4		
Thickness	7.7	12.5	9.5	1.2	9.3	4.4	6.0	4.0	6.0	9.0	27.0	18.0	15.8	46.5		3	22	
D Dark	12.2			1.9			10.0			15.0			16.0	74.2		3	55	
D Burl	3.3			8.2			0.0			20.0			244.9			500		
D Rooz	13.5			5.2			8.0			21.0			38.3			15		
D Crotv	17.7			14.7			0.0			3.5			83.1			69		
D Concr	5.7			6.7			0.0			16.0			119.0			142		
D Mot	6.5			10.1			0.0			20.0			155.0			240		
D Bwbod	4.5			2.8			2.0			9.0			62.5			39		
D Clay	6.2			4.4			0.0			13.0			72.1			52		
D Sliksd	2.1			3.5			0.0			8.0			161.0			259		
D Presfs	3.5			5.7			0.0			13.0			161.4			261		
D Strk	6.5			10.1			0.0			20.0			155.0			240		
Drang	4.6			0.5			4.0			5.0			11.0			1		
Perm	2.5			0.8			1.0			2.0			33.5			11		

n = 6

TABLE 8

SIMPLE STATISTICS FOR SERIES D, AREA ONE

	Mean			STD			Min Value			Max Value			C.V.%			N. Samples		
	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr	A	B	Cr
K	.7	0.2	<0.1	0.5	0.1	0.1	0.2	0.1	<0.1	1.5	0.3	0.1	80.6	35.2	405.7	65	12	1646
H	4.5	3.4	1.2	1.5	1.6	1.1	2.1	1.4	<0.1	5.7	5.4	2.7	33.0	46.0	85.4	11	21	73
CEC	22.0	34.8	16.2	2.6	4.9	6.3	19.8	27.3	8.2	26.6	40.7	27.1	11.9	13.9	38.8	1	2	15
OM	2.0	0.8	0.2	0.4	0.3	0.2	1.3	0.5	0.1	2.5	1.2	0.4	22.5	38.1	69.3	5	15	48
pH	6.7	7.7	8.3	0.3	0.3	0.7	6.3	7.1	7.2	7.1	8.0	9.3	4.5	4.0	8.3	1	1	1
$CaCO_3$	0.9	2.3	3.3	0.5	1.6	5.3	0.2	0.7	0.7	1.6	5.2	14.2	53.2	67.4	159.6	28	45	255
Ca	7.5	24.4	18.6	2.6	13.7	13.7	4.1	7.6	5.5	10.2	40.8	33.4	35.4	56.0	73.7	13	31	54
Na	0.1	5.8	3.5	1.9	4.6	3.1	<0.1	1.1	<0.1	1.9	11.7	6.1	190.0	79.8	86.3	361	64	75
Mg	6.0	11.5	6.0	1.3	2.9	2.8	3.7	8.5	1.8	7.1	15.0	8.8	20.9	25.5	46.0	4	65	21
FS	28.3	14.7	39.1	6.1	10.4	9.2	21.3	3.2	29.7	39.1	31.4	54.5	21.5	71.0	23.5	5	50	6
VFS	10.2	6.6	17.9	0.9	4.2	7.5	9.2	2.6	10.3	11.3	14.2	30.1	9.20	26.7	41.7	1	7	17
Silt	36.8	34.2	22.4	7.5	9.2	7.1	26.6	17.1	15.3	49.4	42.7	33.2	20.4	17.9	31.6	4	3	10
Clay	24.7	44.4	20.6	2.7	7.9	6.6	19.8	35.5	11.4	27.3	52.1	28.6	1.0	41.7	32.2	4	17	10
BST	64.2	76.0	90.9	23.9	42.2	38.7	36.6	59.5	45.6	92.4	100.00	100.0	37.2	41.7	40.0	14	17	16
Slope	0.8			0.6			0.5			2.0			76.8			59		
Thickness	7.7	22.3	6.3	4.0	12.6	2.8	4.0	6.0	1.0	15.0	37.0	9.0	52.0	44.3		27	20	
D Dark L	14.0			7.5			8.0			28.0			53.6	56.3		29	32	
D Burl	16.3			17.6			0.0			44.0			108.0			117		
D Rooz	16.8			5.8			9.0			26.0			34.3			12		
D Crotv	9.0			16.0			0.0			41.0			177.8			316		
D Concr	17.8			10.5			0.0			30.0			59.0			35		
D Mot	7.5			12.1			0.0			28.0			161.7			261		
D Bwbod	4.2			2.6			2.0			8.0			63.3			40		
D Clay Flm	2.3			2.6			0.0			7.0			110.7			123		
D Sliksd	10.3			6.4			0.0			18.0			62.3			39		
D Presfs	9.7			8.3			0.0			18.0			65.3			43		
D Strk	18.0			12.0			0.0			34.0			66.6			44		
Drang	4.7			0.5			4.0			5.0			11.1			1		
Perm	1.5			0.5			1.0			2.0			36.5			13		

n = 6

TABLE 9

SIMPLE STATISTICS FOR SERIES E, AREA TWO

	Mean		STD		Min Value		Max Value		C. V.%		N. Samples	
	A	B	A	B	A	B	A	B	A	B	A	B
K	0.4	0.4	0.1	0.1	0.3	0.4	0.6	0.4	28.9	5.6	8	1
H	5.3	3.9	0.9	0.9	3.6	2.7	6.6	5.1	16.9	23.7	3	6
CEC	18.3	28.6	2.2	3.1	15.4	24.6	22.2	34.3	12.0	10.8	1	1
OM	1.4	0.4	0.2	0.1	1.2	0.3	1.7	0.6	12.2	29.3	2	9
pH	6.0	7.1	0.5	0.5	5.5	6.3	6.9	7.7	7.6	7.5	1	1
$CaCO_3$	0.5	0.7	0.3	0.4	0.1	0.1	0.9	1.2	75.8	50.3	48	25
Ca	8.1	12.8	0.9	1.7	6.2	10.7	9.0	14.7	11.2	12.9	1	2
Na	0.2	1.1	0.1	1.1	0.1	0.2	0.4	2.8	58.3	100.6	34	100
Mg	3.9	7.1	0.6	1.3	3.4	5.2	4.8	8.6	14.4	18.2	2	3
FS	11.6	15.3	3.0	2.8	8.3	10.8	17.0	18.5	25.8	18.4	7	3
VFS	11.0	10.1	1.0	0.9	9.7	9.1	12.8	12.0	9.2	8.3	1	1
Silt	57.7	41.3	8.3	7.7	46.4	22.9	67.2	47.0	14.3	18.8	2	4
Clay	20.0	33.3	8.4	7.3	13.2	24.2	34.2	46.7	42.0	21.9	18	5
BST	69.3	74.4	7.7	8.8	60.6	58.7	79.6	84.3	11.0	11.8	1	1
Slope	0.6	0.2	0.2		0.5		1.0		31.4		8	
Thickness	8.8	74.8	1.9	17.9	6.0	40.0	12.0	92.0	21.8	23.9	5	6
D Dark L	28.5		8.2		10.0		36.0		28.6		8	
D Burl	36.1		9.5		29.0		53.0		25.3		7	
D Rooz	12.6		4.4		7.0		19.0		35.2		12	
D Crotv	8.1		3.9		0.0		12.0		48.1		23	
D Concr	36.6		8.6		29.0		50.0		23.4		6	
D Mot	31.0		10.4		12.0		50.0		33.5		11	
D Bwbod	6.6		3.4		4.0		12.0		51.6		27	
D Clay Flm	9.3		1.0		7.0		12.0		17.1		3	
D Sliksd	0.0		0.0		0.0		0.0		-		1	
D PresFs	0.0		0.0		0.0		0.0		-		1	
D Strk	72.4		26.6		30.0		91.0		28.5		8	
Drang	4.0		0.0		4.0		4.0		0.0		0	
Perm	1.3		0.5		1.0		2.0		37.0		14	

n = 8

TABLE 10

SIMPLE STATISTICS FOR SERIES F, AREA TWO

	Mean		STD		Min Value		Max Value		C.V.%		N. Samples	
	A	B	A	B	A	B	A	B	A	B	A	B
K	0.4	0.4	0.1	0.1	0.3	0.3	0.5	0.4	13.7	3.9	2	1
H	4.6	3.1	1.2	0.3	2.8	2.8	5.9	3.4	26.2	8.3	7	1
CEC	21.8	31.8	6.8	1.2	16.2	30.8	33.6	33.8	31.3	3.6	10	1
OM	1.3	0.4	0.2	0.1	1.1	0.3	1.5	0.4	12.4	14.4	2	2
pH	6.5	7.7	0.6	0.4	5.8	7.3	7.2	8.0	8.8	4.8	1	1
$CaCO_3$	0.3	1.1	0.4	0.3	0.1	0.8	0.6	1.5	150.9	26.2	227	7
Ca	10.0	13.6	3.5	0.6	6.6	13.1	15.0	14.5	35.1	4.2	12	1
Na	0.3	2.3	0.2	0.4	0.2	1.8	0.6	2.7	54.5	16.5	30	3
Mg	4.7	7.8	2.2	0.4	3.0	7.2	8.5	8.4	46.3	5.6	21	1
FS	10.6	11.6	2.4	1.5	6.8	9.8	12.9	13.3	22.9	12.8	5	2
VFS	9.9	9.0	1.4	1.0	7.9	7.9	11.4	10.5	13.8	11.2	2	1
Silt	61.4	40.7	3.8	5.2	55.4	34.4	64.8	46.8	6.3	12.8	1	2
Clay	18.0	38.6	6.9	3.1	13.0	35.5	30.0	42.9	38.5	7.9	15	1
BST	69.8	75.1	8.9	3.4	62.8	72.0	84.0	79.9	12.7	4.4	2	1
Slope	0.6		0.1		0.5		0.6		9.8		1	
Thickness	9.2	21.2	2.7	2.7	6.0	79.0	12.0	85.0	29.2	3.3	9	1
D Dark L	30.6		4.4		24.0		35.0		14.4		2	
D Bur L	32.8		5.9		24.0		40.0		18.0		3	
D Rooz	12.4		1.8		10.0		15.0		14.7		2	
D Crotv	10.0		2.8		6.0		12.0		28.3		8	
D Concr	22.8		11.9		4.0		34.0		52.0		27	
D Mot	23.4		8.0		12.0		34.0		34.4		12	
D Bwbod	4.0		0.0		4.0		4.0		0.0		0	
D Clay Flm	9.2		2.7		6.0		12.0		29.2		9	
D Sliksd	15.4		34.4		0.0		77.0		223.6		500	
D PresFs	11.0		24.6		0.0		55.0		46.9		22	
D Strk	74.8		35.1		2.0		91.0		0.0		11	
Drang	4.0		0.0		1.0		4.0		0.0		10	
Perm	1.0		0.0		1.0		1.0		0.0		15	

n = 5

TABLE 11

SIMPLE STATISTICS FOR SERIES G, AREA TWO

	Mean		STD		Min Value		Max Value		C.V.%		N. Samples	
	A	B	A	B	A	B	A	B	A	B	A	B
K	0.4	0.4	<0.1	<0.1	0.3	0.3	0.5	0.4	12.0	5.6	1	1
H	4.8	3.3	1.4	0.5	2.0	2.7	6.3	4.2	28.9	15.6	8	2
CEC	20.5	32.4	2.3	2.7	17.3	27.7	22.2	39.9	11.0	8.5	1	1
OM	1.2	0.3	0.1	0.1	1.0	0.3	1.4	0.4	11.4	17.8	1	3
pH	62.0	7.5	0.8	0.3	5.6	7.1	7.8	7.8	12.3	3.9	2	1
$CaCO_3$	0.5	1.2	0.4	0.3	<0.1	0.7	1.1	1.7	89.4	29.8	80	9
Ca	10.0	16.1	3.8	3.4	7.6	11.8	18.3	23.1	38.4	21.3	15	5
Na	0.2	2.0	<0.1	0.7	0.2	0.5	0.3	2.8	21.5	35.6	5	13
Mg	4.4	8.2	0.7	0.7	3.5	6.8	5.5	8.9	16.1	8.5	3	1
FS	12.0	9.0	2.7	2.6	9.0	6.7	17.4	14.5	22.5	28.9	5	8
VFS	11.5	7.7	1.9	1.6	8.8	6.0	14.1	10.9	16.4	21.2	3	5
Silt	47.8	45.0	14.4	5.0	32.2	36.7	64.6	52.3	30.1	11.1	3	5
Clay	28.7	38.3	12.1	6.7	14.3	27.9	40.9	46.8	42.2	17.5	9	3
BST	72.3	82.5	15.4	7.3	60.8	76.0	100.0	97.5	21.2	8.8	5	1
Slope	0.6		0.1		0.5		0.7		9.6		1	
Thickness	9.3	80.0	2.6	4.2	5.0	71.0	13.0	83.0	28.3	5.3	8	1
D Dark L	27.1		6.2		18.0		34.0		22.7		5	
D Bur L	39.4		22.8		0.0		74.0		57.8		33	
D Rooz	9.9		1.2		8.0		12.0		12.3		2	
D Crotv	7.3		5.1		0.0		12.0		69.4		48	
D Concr	27.4		13.4		9.0		52.0		48.9		24	
D Mot	19.3		16.9		9.0		49.0		87.5		77	
D Bwbod	4.0		0.0		4.0		4.0		0.0		1	
D Clay Flm	9.3		2.6		5.0		13.0		28.3		8	
D Sliksd	51.3		35.7		0.0		76.0		69.6		48	
D PresFs	11.9		27.6		0.0		74.0		232.7		542	
D Strk	77.9		34.3		0.0		91.0		44.1		20	
Drang	4.4		0.5		4.0		5.0		12.1		2	
Perm	1.0		0.0		1.0		1.0		0.0		1	

n = 7

TABLE 12

SIMPLE STATISTICS FOR SERIES H, AREA TWO

	Mean		STD		Min Value		Max Value		C.V.%		N. Samples	
	A	B	A	B	A	B	A	B	A	B	A	B
K	0.4	0.3	0.1	0.1	0.3	0.3	0.4	0.4	19.6	16.3	3	3
H	6.5	3.1	1.0	0.5	5.7	2.6	7.6	3.6	15.0	15.8	2	3
CEC	19.8	31.4	4.1	1.8	15.3	29.3	23.5	32.5	20.9	5.6	4	1
OM	1.2	0.4	0.1	0.1	1.1	0.4	1.3	0.5	8.8	14.2	1	2
pH	5.6	7.7	0.2	0.1	5.4	7.5	5.8	7.7	2.6	1.9	1	1
$CaCO_3$	0.2	1.1	0.4	0.2	0.1	0.9	0.6	1.3	215.3	19.5	364	4
Ca	7.6	13.8	0.8	0.4	7.0	13.6	8.4	14.2	9.9	2.6	1	1
Na	0.2	2.1	0.1	0.1	0.2	2.0	0.3	2.2	29.6	5.6	9	1
Mg	4.1	7.8	0.6	0.3	3.5	7.5	4.5	8.2	14.2	4.3	2	1
FS	14.0	10.4	0.6	0.9	13.4	9.8	14.5	11.5	3.9	8.6	1	1
VFS	10.5	10.1	1.3	0.6	9.1	9.6	11.6	10.8	12.2	6.2	2	1
Silt	58.6	41.5	1.8	9.5	56.7	35.8	60.4	52.5	3.1	22.8	1	5
Clay	16.9	37.9	2.4	8.8	15.3	27.9	19.7	44.5	14.3	23.3	5	5
BST	63.0	77.5	7.4	7.1	57.1	72.4	71.2	85.6	11.7	9.2	1	1
Slope	0.6		0.1		0.5		0.6		10.2		1	
Thickness	8.7	82.0	2.1	1.7	7.0	80.0	11.0	83	9.5	2.1	1	1
D Dark L	28.0		2.6		25.0		30.0		31 1		10	
D Burl	34.7		10.8		27.0		47.0		20.2		4	
D Rooz	10.3		2.1		8.0		12.0		86.9		76	
D Crotv	7.7		6.7		0.0		12.0		15.0		2	
D Concr	24.0		3.6		20.0		27.0		65.1		42	
D Mot	12.0		7.8		7.0		21.0		65.5		42	
D Bwbod	4.7		3.1		2.0		8.0		24.0		6	
D Clay Flm	8.7		2.1		7.0		11.0		173.2		300	
D Sliksd	20.3		35.2		0.0		61.0		173.2		300	
D Presfs	18.7		33.3		0.0		56.0		134.0		180	
D Strk	15.3		20.7		1.0		39.0		0.0		1	
Drang	4.0		0.0		4.0		4.0		0.0		1	
Perm	1.0		0.0		1.0		1.0		0.0		1	

n = 3

APPENDIX B

VARIABLES USED IN CALCULATING THE SIMILARITY MATRIX

VARIABLES USED IN CALCULATING THE SIMILARITY MATRIX

Field Observations (Discrete variables)

Horizon boundaries

abrupt	= 1
clear	= .6
gradual	= .3
diffuse	= .2

Texture

sandy	= 1
loamy sand	= 1.5
sandy loam	= 2
loam	= 3.4
silt loam	= 3.9
silt	= 1.2
sandy clay loam	= 5.5
clay loam	= 6.6
silty clay loam	= 6.7
sandy clay	= 9
silty clay	= 10
clay	= 10

Structure

Class

very fine	= 1
fine	= 2
medium	= 3
coarse	= 4
very coarse	= 5

Grade

structureless	= 1
very weak	= 2
weak	= 3
moderate	= 4
strong	= 5
very strong	= 6

Consistence

Plasticity

non-plastic	= 1
slightly plastic	= 2
plastic	= 3

Consistence (continued)

Dry

loose = 1

soft = 2

slightly hard = 3

hard = 4

very hard = 5

extremely hard = 6

Moist

loose = 1

very friable = 2

friable = 3

firm = 4

very firm = 5

extremely firm = 6

Stickiness

non-sticky = 1

slightly sticky = 2

sticky = 3

Mottles

Abundance

few = 1

common = 2

many = 3

very many = 4

Mottles (continued)

Size

fine = 1

medium = 2

coarse = 3

Contrast

faint = 1

distinct = 2

prominent = 3

Color

Hue

10 YR = 6

7.5YR = 7

5 YR = 8

2.5YR = 9

Chroma = 1, 2, 3, 4, 5, 6, 7, 8
(as coded on the Munsell Chart)

Value = 1, 2, 3, 4, 5, 6, 7, 8
(as coded on the Munsell Chart)
(as

Roots

Size

fine = 1

medium = 2

coarse = 3

Abundance

few = 1

common = 2

many = 3

Root score = size + abundance

Concretions

Abundance

non-present	= 0
few	= 1
common	= 2
many	= 3

Size

fine	= 1
medium	= 2
coarse	= 3

Kind

white	= 1
black	= 3

Coating

non-present	= 0
organic	= 1
oxides	= 3
clay	= 5

Pores

Size

very fine	= 1
fine	= 2
medium	= 3
coarse	= 4

Chemical Data (Continuous variables))

Clay %	Ca
Fine sand %	K
Very fine sand %	Ca/Mg
pH	H
Organic matter %	$CaCO_3$
CEC	Very fine sand/Silt
Clay/CEC	Silt/Clay
Na	Base saturation
Mg	

VITA

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