# Numerical Studies in Soil Distribution

Thesis submitted for the degree of Doctor of Philosophy

by

H.E. Cuanalo de la Cerda

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## Abstract

This thesis makes an empirical test of the concept of Soil Series.

In the last 50 years many soil surveys have been made in many parts of the world so that land use can be planned and land management improved. In any one survey the classes of soils recognized have roughly equal variation of some suitable small range. Such classes are most often termed "Soil Series".

In general, Soil Series are considered to be the basic unit of the Natural or General Purpose classification of soils.

Many soil scientists, notably Cline, suggest that soil surveyors are able to define Soil Series because soil profiles form modes in a frequency diagram. They suggest that the job of the surveyor is simply to identify these modes, and thus define the classes.

An empirical test of the concept of Soil Series, in its dual role, both as a profile unit, and as a mapping unit, is made here. This empirical test was made possible by recent developments in computer techniques, in mathematical methods, and by the revival of Adanson's views on taxonomy.

An Euclidian geometric framework in multi-dimensional space is postulated, and is called Property-Geographic space. In it, there are p properties by which a soil profile is characterized, and q geographic co-ordinates by which the soil profile is located on the ground.

Provided soil properties can be coded by ordered scales, a soil profile can be defined by a point in p+q dimensional space. The sub-space of

Property-Geographic space in p dimensions is called Property space.

If the traditional idea that Soil Series is a cluster is correct, then groups of points should appear, in Property space, that are dense relative to the whole. For there to be dense clusters in Property space, a necessary condition is the presence in Property-Geographic space of horizontal or gently sloping hyper-planes separated by relatively steep, preferably vertical, hyper-planes. When projecting the points from Property- Geographic space on to Property space, the horizontal or gently sloping hyper-planes appear as dense clusters separated by the relatively empty space formed by the projection of the relatively steep or vertical hyper-planes.

The property space of this model was first studied using data for 85 soil profiles, each characterized by 37 properties. These profiles had been chosen by stratified random sampling on 27 physiographically defined areas around Oxford.

The profiles were first grouped intuitively in order to have some base for reference.

Principal Component analysis was used to project the 85 points in 37 dimensions on to the two dimensions of the two first principal components, with least possible loss of information.

The comparison between the ordination by Principal Component analysis and the intuitive classification showed, as expected, that the soil profiles grouped intuitively into classes did tend to appear in a given partition of Property space, as seen from the graph of the two first components.

However, it also showed little evidence of clustering of profiles in Property space.

Clusters were sought in all 37 dimensions, using the stability of the classifications produced by Similarity analysis when two standardizations of the soil properties were used. In the first case, soil properties were standardized between the range zero to one, and in the second, to zero mean and unit variance. Theoretically these standardizations should yield similar classifications if profiles are well clustered in Property space. These dendrograms showed that two main groups of the Brown Earths remained stable in spite of changes in standardization. Changing the standardization, however, showed the subdivision of the Gleys to be unstable.

It was then concluded that since most soil properties could sensibly be given the attributes of order and interval, an Euclidian model was appropriate for the study of Property- Geographic space. Furthermore, the combination of ordination by Principal Component analysis, the stability of the classifications produced by Similarity analysis, and the context of an Euclidian model, would give us the means to evaluate the cluster arrangement of soil profiles in Property space.

The p dimensional model was extended to a study of the p+q dimension of Property-Geographic space. A transect a little over 3 Km long, covering a variety of soils in north Oxfordshire, was sampled at 10 m intervals.

At each sampling point a profile was characterized by 63 properties, and a Soil Series allocation made by the local soil surveyor.

Ordination by Principal Component analysis was again used to search visually for clusters in the projection from 63 dimensions of Property space on to two dimensions, from the graph of the first against the second principal component values. The points appeared as a single continuous cloud with three bulbous protudings arms, but with no clusters.

On the ordination, evidence of clustering was also sought numerically by Order-neighbour statistics. The results showed no evidence of clustering.

Clusters were then searched for in the original 63 dimensions of Property space, by Mode analysis. Mode analysis showed that the points in Property space were distributed as a continuous cloud of points with three very weak peaks. Since the three poorly defined clusters did not correspond in number, and consequently in kind, to the Soil Series classification units defined by the soil surveyor, they were not interpreted as being clusters formed at the level of Soil Series classification units.

In the classifications produced by Similarity analysis, the two standardizations of property values yielded rather different groupings. These differences were explained by the lack of well-defined clusters.

The shape of the series of points in Property-Geographic space was studied from its projection from 64 dimensions ($p = 63$, $q = 1$) on to the graphs of the first and second principal component values plotted against distance.

Two kinds of soil variation were apparent; a short range soil variation occuring over a distance of a few tens of metres, and a relatively long

range of variation, occuring over a distance of a few hundreds of metres.

The short range soil variation was eliminated by smoothing the two first principal component values, with a five point linear moving average. After this, the trend appears as being made up of a sequence of mainly sloping and horizontal lines, with lengths of 100 to 300 m, seldom separated by relatively steep lines.

Correlograms were constructed for the two first principal component values, to elucidate the kind and size of the spatial relationship of soil properties. The correlograms studied showed, on average, a linearly decreasing configuration of size 240 m for the first, and 300 m for the second principal component values. On this basis, 92 per cent and 86 per cent respectively of the total variation is explained.

This suggests that the long range soil variation can be explained by a bilateral moving average scheme, 240 ml long for the first component and 300 m for the second component.

This is interpreted as a sequence of almost straight lines, curved at their joints. These lines are, on the average, 240 m long for the first component and 300 m long for the second component. In this way, 92 per cent of the first component and 86 per cent of the second principal component is explained, leaving only 8 per cent of the first component and 14 per cent of the second component to be explained by the erratic variation. Abrupt changes between lines are included within the erratic variation.

The general picture that emerges from the results is that the shape of the points in Property-Geographic space is a sequence of almost straight, sloping and horizontal, hyper-planes. These are sometimes separated by steep hyper-planes, but often there is just a change in the slope of two adjoining hyper-planes.

The lack of clusters in Property space is explained not only by the fact that there are not always steep hyper-planes making the separation between sloping or horizontal hyper-planes, but also by the occurence of relatively long hyper-planes at the same altitude as those steep hyper-planes that make the separation between sloping or horizontal hyper-planes.

Thus, at least for the area studied, soil profiles are distributed in Property space as a single cloud of points, more or less evenly spread, but without any strong clustering. Any soil surveyor who assumes clusters to be present, and who expects his work to reveal them, labours under a delusion. The soil surveyor in fact subdivides Property space into zones of approximately uniform density, though his choice of dividing lines may be guided by the positions of relatively steep hyper-planes, or a change of slope of two adjoining hyper-planes in Property-Geographic space.

There is, however, no guarantee that values in Property space at which either steep hyper-planes, or changes on the slope of two adjoining hyper-planes, occur, are repeated in other areas. The surveyors choice of division is still rather arbituary, and hence differences of opinion and difficulties of grouping over large areas will be frequent.

The use of a classification system on a continuously varying population of soil profiles imposes special characteristics on the classes thus produced. An important one is that a large proportion of the profiles belonging to a Soil Series classification unit are more similar to the profiles of other soil, than to the profiles of their own Series.

# CHAPTER I

## Introduction

This is a study of some of the underlying assumptions of soil classification at the level of Soil Series.

In the last 50 years or so, many detailed soil surveys have been made in many parts of the world so that land use can be planned and land management improved. Most soil surveys have been ad hoc, and the soil classification used local and more or less intuitive, though devised against a background of broad world-wide groupings, Greene (1963). In any one survey the classes of soils recognized have roughly equal variation of some suitable small range. Such classes are often termed "Soil Series". Judging from the continuing demand for surveys this kind of classification must, at least in a large proportion of the cases, be profitable.

However, creating classifications that could embrace both narrowly varying local classes such as these, and broader groupings that can be displayed on small-scale maps for regional or national planning, has proved much more difficult. A further difficulty has been to define nation-wide Soil Series, or classes of comparable variability, so that information can be transferred from place to place over long distances. Avery[1] (1970), considers that this is the most important difficulty facing national organisations undertaking soil surveys, while Kellogg (1963) has stressed the need to make statements, either in words or by small-scale maps, at different levels of generalisation.

1. Avery, B. (1970). Personal communication.

Faced with these problems, organisations have attempted to systematise soil classifications, Marbut (1928), Thorp and Smith (1949), Avery (1956), Soil Survey Staff (1960) and Duchaufour (1965), and much thought and empirical testing has been devoted to them, Mucalhy and Humphries (1967) and Webster (1968). A starting point has often been the search for a "Natural" classification on the Linnaean model.

## 1. The Natural Classification

Linnaeus, at the middle of the eighteenth century, was perhaps the first to voice the need for a natural classification in the biological sciences. The natural classification was intended to be a system which shows "what a thing is" as an individual. Cain (1958) has shown that Linnaean classification was strongly influenced by Aristotelian ideas of Logical Division. These ideas begin with the definition of the subject stated in terms of its "essence". Essence is then what makes things be what they are. A property is an attribute of an object, and follows from its essence. That part of the definition (and essence) which is predicable also of other objects is called the Genus. Objects defined by their essence can be arranged by Logical Divisions.

However, animals, plants, or indeed anything whose essence is unknown, can only be defined in terms of their properties. Objects defined in terms of properties, and not essence, are not amenable to Logical Divisions. So it seems that in Linnaeus's search for the Natural Classification, he was trying to reconcile Aristotelian principles of Logical Divisions with the empirical evidence of over-all affinity obtained from the study of plants.

Probably as a result of Logical Divisions, Linnaeus's groups had to be clear-cut, as far as possible giving rise to exhaustive and mutually exclusive classes. These mutually exclusive classes were arranged in an hierarchy with rank names of Class, Order, Genus, Species and Variety.

A few years later Adanson, (see Sokal and Sneath, 1963) made a considerable contribution to the idea of the Natural Classification by postulating:

a) All parts of an organism must be taken into account when over-all similarity or affinity is to be estimated.

b) A priori principles of what is, and what is not, important, were either superfluous or wrong. (for more details see Cain, 1959).

An important corollary of Adanson's work has been pointed out by Sokal and Sneath (1963), in that by treating every character in the same way he was effectively giving them equal weight.

Later, Darwin (1859) showed that the Natural Classification constructed by non-evolutionists, and based on over-all affinity, could, in fact, be explained in terms of the Theory of Evolution. Since then to most biologists a "Natural Classification" means one with classes phylogenetically determined.

It was not until 1937 that Gilmour (1937) pointed out that logicians have long realized that the central idea underlying natural classes is their great usefulness, and therefore the main function of a classification is to construct classes about which we can make inductive generalisations. On this basis the Natural Classification will be the one that serves the largest number of purposes. Consequently it will be the one with classes about

which the largest number of inductive statements can be made.

## 2. The Natural Soil Classification

Soil Scientists have been strong advocates of Natural or General Purpose Classifications, as opposed to "Artificial" or Single Purpose Classification (Soil Survey Staff, 1951; Avery 1963; Duchaufour, 1965).

Cline (1949) suggests that "the objective" of a Natural Classification "is to show relationships" between soil profile classes "in the greatest number and most important properties". Examples and analogies are drawn from higher plants and animals, where the Natural Classifications as conceived by Cline have been most successful, and where the condition of common ancestry is all important, as explained by the Theory of Evolution. This is not the case for soils, as Crowther (1953) so clearly illustrates when he says "Soil properties depend on the very complex and yet ill-defined conditions of their environment".

Attempts by Jenny (1949) to formulate numerical relationships between the factors of soil formation and soil properties have proved unprofitable, possibly because of the difficulties of measuring these factors.

## 3. The Soil Series

The Soil Series has been chosen as the basic unit on which all the Natural or General Purpose Classification systems have been based. The definition of the Soil Series has varied, but its central concept has remained unaltered. (Soil Survey Staff, 1951, 1960).

The term Soil Series has had a dual meaning, depending on whether it is used as a class of profiles, or as a mapping unit. Its concept as a profile class was elucidated by Cline (1949) in the following terms:

"One may visualize a class (Soil Series) as a group of individuals (soil profiles) tied by bonds of varying strength to a central core. At the center is the modal individual (soil profile) in which the modal properties of the class are typified. In the immediate vicinity are many individuals held by bonds of similarity so strong, that no doubt can exist as to their relationships. At the margin of the group, however, are many individuals less strongly held by resemblance but more strongly held by similarity to this modal individual than to that of any other class".[1]

This notion of Soil Series profile class with a modal profile expressed in terms of over-all similarity is generally believed to be true, at least when considering a small area. Later Cline discusses the Soil Series definition in the following terms:

> "Some properties must be chosen as the basis of grouping. Individuals that are alike in that characteristic are placed in the same group; those that are unlike are placed in different groups. The property chosen as the basis of grouping is called the <u>differentiating characteristic</u> (his italics). If the basis of grouping is good, the differentiating characteristic should be associated with a number of co-varying properties".

1. Later Cline (1963) expressed the same concept in terms of "Pedons" instead of soil profiles. For definition of Pedon see Soil Survey Staff (1960).

He continues later:

> "The class as a whole can be defined precisely in terms of (a) values both of the differentiating and the accessory characteristics of the modal individual, and (b) the respective deviations from those values within the range of the class".

Here the definition of the Soil Series is stated in monothetic terms. That is, for a soil profile to belong to a class a set of conditions, the differentiating characteristics, are necessary and sufficient for membership to a class.

There are two main advantages in classifying by differentiating characteristics, or in Aristotelian terms. First, the classes thus constructed can be arranged in an hierarchy at different levels of abstraction, by grouping objects having one, or a group of properties, in common. Consequently there is an economy in terms of memory and conceptual visualization of large populations. The second main advantage is that rules for allocating a new individual to existing classes, that is the key, are easily constructed. There is, however, a very important implicit assumption in the monothetically based classification, and that is that the classification thus derived will only be a General Purpose or Natural Classification if, and only if, the differentiating criteria are very strongly associated with over-all affinity among the members of a class. Even then, a monothetically based classification will always carry the risk of misclassification when dealing with individuals aberrant in the features selected as the differentiating criteria.

The Soil Series as a mapping unit follows from the definition of the Soil Series as a profile class. As a mapping unit, it is conceived in terms of a geographic delimitation when more than 85 per cent of its area is occupied by the Soil Series as a profile class.

The situation in practice is, however, not as satisfactory as one would like. Powell and Springer (1965), working in Georgia U.S.A. with a soil map at a scale of 1.:15,400, found that the Soil Series mapping units, on the average, contain soil profiles falling outside the definition of Soil Series profile class in 34 per cent of the area. However they conclude that "the mapping . . . . is highly reliable from the standpoint of grouping pedons that can be interpreted similarly". In another instance, McCormark and Wilding (1969), working on a soil map at the same scale, but in Ohio U.S.A., found that inclusions of soil profiles falling outside the defined Soil Series profile class was 63 per cent. Nevertheless, they clearly state, "A low proportion of the delineations are considered improperly mapped". This suggests that experienced soil surveyors arrive at a low level of accuracy because of some misconception about the central concepts of Soil Series as a profile class and Soil Series as a mapping unit.

Knox (1965), on the other hand, states that a soil boundary occurs when there is a maximum lateral rate of change with distance. He points out, however, that an abrupt change in soil properties on the ground is not a common feature. So we are again left with the concept of Soil Series as a profile class in order to define boundaries. He suggests that what we should strive to obtain is the "polypedon", but he is unable to define it.

The fact that the Soil Series profile class, intended as a basic unit for a general purpose system, is defined in monothetic terms, and that the same Soil Series is utilized as a mapping unit, is perhaps presupposing attributes of the population of profiles that the soil profile population does not have. This may be the cause of the very striking and paradoxical acknowledgement of Powell and Springer (1965) and McCormark and Wilding (1969), in that the soils were properly mapped in spite of the very poor relationship between Soil Series profile classes and Soil Series mapping units. The statemant of Knox (1965) that abrupt changes in soil properties with distance defined boundaries, and his acknowledgement that this is not a common feature, still further confuse the issue.

## 4. Aim and Approach

The contradictions found in the literature, the use of the Soil Series profile class to define Soil Series mapping units, and the grouping of both Soil Series profile classes and Soil Series mapping units at different levels of abstraction in an hierarchical system are not, I believe, fully compatible. Therefore, it would be useful and interesting to test empirically both the explicit and implicit assumptions underlying the concept of Soil Series, and so I undertook to do this. My work was made feasible by the popularization of electronic computers.

Electronic computers have provided new ways of examining, classifying and ordering populations, and, perhaps surprisingly, revived Adanson's views on classification. We can now consider almost as many properties of individuals and populations as we wish to, simultaneously, and in doing

so search for pattern and structure in them. In most disciplines this facility has lead to a better understanding of the populations than was possible before, and there is every reason to suppose that it will throw considerable light on soil distributions and on the problem of soil systematics.

It has been shown that numerical methods can be used in soil science, by Hole and Hironaka (1960), Bidwell and Hole (1964), and Rayner (1966). However, in other subjects such as zoology and botany, more advances have been made.

In zoology, Sokal and Sneath (1962) presented a compendium of the numerical approach to classification, putting special emphasis on the justification of the use of numerical methods in classification. Michner and Sokal (1957), Sokal and Michner (1958), and Sokal (1958), found that the numerical classification of 97 species of bees in different sub-genera and genera agreed quite well with the intuitive classification. They also found that the intuitive classification of most sub-genera within four genera agreed with the numerical results, with the exception of two sub-genera. They propose the transfer of these two sub-genera from one genus to another.

In bacteriology, a difficult problem has been the grouping of strains into species. Sneath (1957) showed that many strains of two species of Chromobacterium fell into the expected two groups, using numerical methods. Other workers show how the degree of definition of the groups can be assessed from the results of numerical classification. For example, Colwell and Liston (1961a and 1961b) found that the genera Pseudomonas

and Xanthomonas are formed of well-defined groups. In contrast the genus Vibrio is very hetereogenous.

In plant ecology the works of Goodall (1952 and 1954) were pioneer in the use of numerical methods on the classification and ordination of stands of vegetation. The results of Williams and Lambert (1951 and 1961) showed a very good correspondence between the results of numerical methods with those of intuitive classification. Orloci (1966) also found a very good correspondence between numerical methods of ordination and those intuitively obtained.

Making use of a Mathematical Euclidian framework, which is given in Chapter II, I have applied some methods of Numerical Taxonomy, Multivariate Statistical Analysis, and Time Series, to the study of soil variation. These methods are explained in Chapter III. The numerical methods were tried on two sets of data, using the KDF-9 Computer. The first set was already available, and consisted of the properties recorded in 85 soil profiles, randomly drawn from 17 physiographically defined mapping units. The results are presented in Chapter IV. The second set was specially collected for this work, and consists of 321 soil profiles described at 10m intervals along a transect. The results and conclusions of these are given in Chapter V. Finally, the general conclusions are presented in Chapter VI.

# CHAPTER II

## A mathematical framework for the study of soil classification and soil mapping

The study of soil properties from the point of view of soil mapping and soil classification involves finding and expressing relationships, both between soil properties at points on the land[1] and their geographic location, and between soil properties at points on the land regardless of their geographic location.

The study of these relationships is generally considered to be important, because of their indication of the best possible uses of the available land resources. Relationships between soil properties, but regardless of their location, have been expressed mainly in terms of soil classification. Relationships between soil properties in a landscape and their geographic location has been illustrated in most cases by soil maps.

These relationships can be studied by a mathematical model of points in Euclidian space.

The aim of the development of this model is to study some of the preconceived ideas involved in the classification and mapping of soils, and to compare these with soil profiles as they actually occur in the field.

1. The term soil properties at points on the land is used in its broadest sense, including measurements of the same soil property at different depths from the ground surface. This is commonly called a soil profile description.

This model has two main advantages. Firstly it is simple, and so concepts in soil classification and mapping can be translated into shapes in Euclidian geometry and thus their meaning can be grasped easily. Secondly, several powerful techniques are already available for its study. This model is described below, and some of the numerical techniques for its study are described in Chapter III.

1. The Model

The model considers the values of p soil properties measured at n points in the landscape, each point located by q geographic co-ordinates. Here the measurement:

$$X_{r, k_1, k_2, \ldots k_q}$$

Where $r = 1, 2, \ldots p$

$$0 \leq k \leq n$$

and $q = 1, 2, 3$

Where X is the value of the rth soil property located at distance k of the q geographic co-ordinates. Now, each soil property and each geographic co-ordinate may be thought of as a perpendicular axis in a $p + q$ dimensional space. In this space, a point will represent the p soil properties in q geographic co-ordinates.

A three dimensional representation of two soil properties ($p=2$) and one geographic co-ordinate ($q=1$) is shown in Fig. 2.1.

A four dimensional representation of $q=3$ and $p=1$ can be conceived as

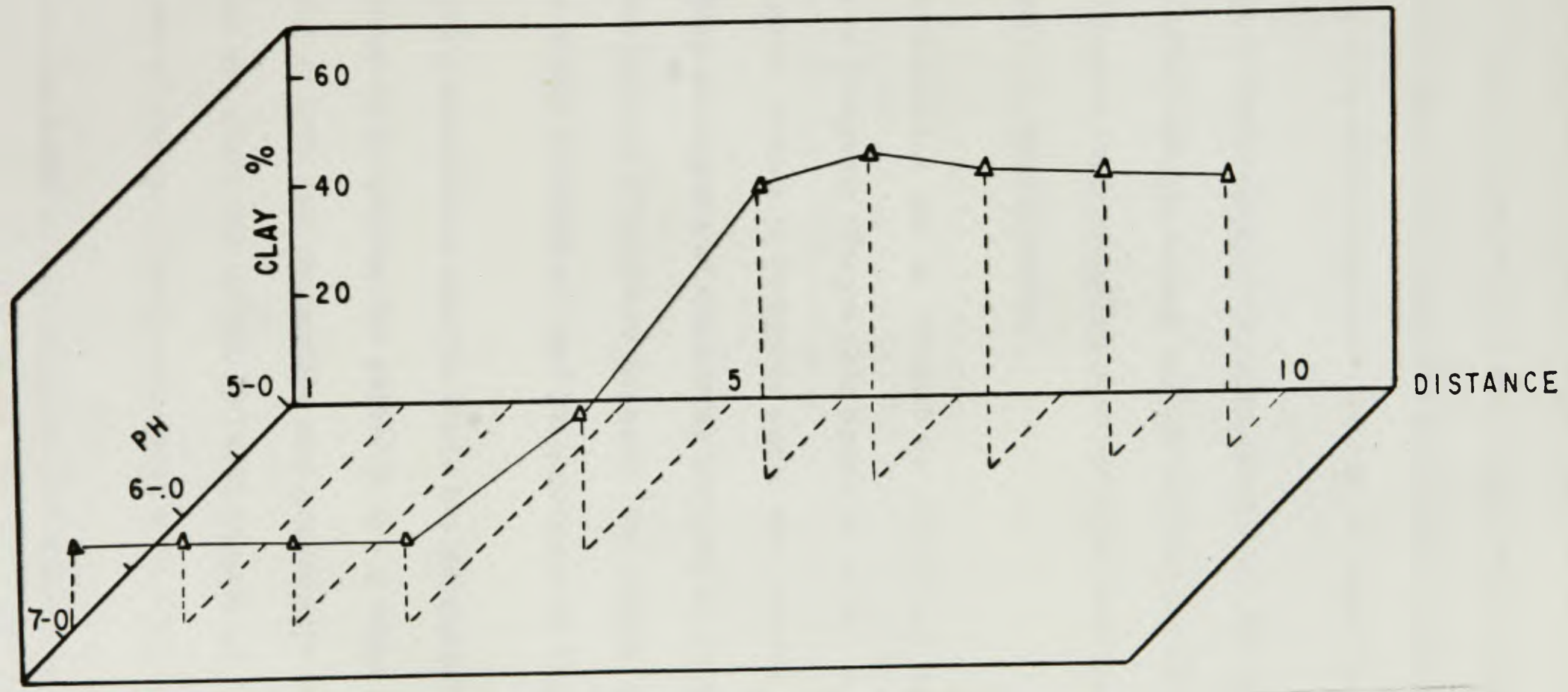



Fig. 2.1 A three dimensional representation of Property - Geographic space.

as a landscape block diagram with points on a sheet (plane) above it. The block diagram represents the three geographic co-ordinates, the point the values of one soil property . p+q dimensions may be thought of by considering the same block diagram with points of different colours lying above it, forming various planes. that is, a hyper-plane of p dimensions.

This p+ q dimensional Euclidian Model can be used to study the similarity relationships among soil profiles from the point of view of soil classification, soil mapping, and the relationships between soil mapping and soil classification.

Soil classification can be studied by projecting the point from p + q dimensions of Property-Geographic space on to the p dimensions of Property space. Points in Property space can provide us with the information regarding the degree of clustering present in a given number of soil profiles, the number of clusters present, the points which form each cluster, the shape of clusters, and the presence of clusters of clusters.

This model can also be used to study the geographic relationships of soil properties by projecting the points in p+ q dimensional space on to selected axes of both soil properties and geographic co-ordinates. For example, we can study the nature of "soil boundaries" by observing the relative rates of change of soil properties with distance.

Relationships between soil mapping and soil classification can be investigated by projecting a given geographic arrangement of points in p + q dimensions of Property-Geographic space, on to the dimensions of

Property space. Alternatively, concepts in soil classification can be translated into geographic terms by projecting the points from Property space to their geographic location in the $p + q$ dimensions of Property-Geographic space.

For example, the Property-Geographic space of Fig. 2.1. can be collapsed on to the Property space by projecting the points from the axis of pH, clay % and distance on to the pH and clay % axis, i.e. projecting the points horizontally on to the left hand plane. In a similar way, a given arrangement of points in the pH and clay % of Fig. 2.1, can be projected on to its geographic location to show its geographic significance, i.e. projecting the points from the left hand side plane to the three dimensional diagram, to show how pH and clay % vary with distance.

Furthermore this model can be used to predict the values of the soil properties at any point in the landscape, if we know the functional relationship between the soil properties and the geographic co-ordinates.

The functional relationship of soil properties with the geographic co-ordinates can be expressed in at least two forms. The first is:

$$f(k_q) = X_r, k_q.$$

Where $f(k_q)$ is a function of the distance $k$ of the geographic co-ordinates, and $X_r, k_q$ are the values of the $r$th property at distance $k$ of the $q$ geographic co-ordinates.

For instance, in Fig. 2.1, we can express the relationship between pH and distance in one dimension by a polynomial of the type

$$X_1 = a + bk + ck^2 + \ldots$$

where $X_1$ is the pH value, k is the distance from the origin, and a, b, c, the polynomial coefficients. The pH value at any point along the transect can be predicted by the knowledge of the distance from the point of interest to the origin.

The second form of expressing relationships between soil properties and their geographic location is:

$$f(X_r, k_1+j, k_2+m, \ldots k_q+s) \quad X_r, k_1, k_2 \ldots k_q.$$

where $f(X_r, k_1+j, k_2+m \ldots k_q+s)$ is the function that relates the values of the rth soil property to the value of the same rth soil property at the fixed distances $k_1, k_2 \ldots k_q$.

For example, in Fig. 2.1, if we knew that the pH of a point along a transect were predicted by the following function,

$$pH_k = \frac{pH_{k+e} + pH_{k+e}}{2}$$

then the pH at location k will be predicted by the average value of the pH at the distance k-e and k+e, when e could be 10m. We could predict the pH value at any point k, if we knew the pH value of two points 20m apart along the transect.

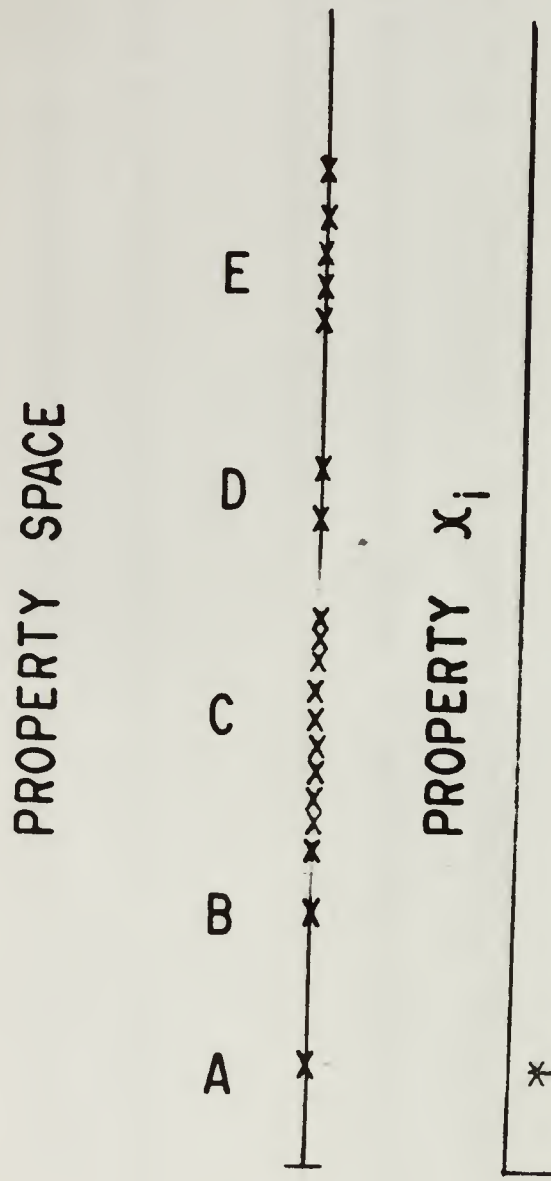
## 2. The basic types of soil variation

Making use of this Euclidian model, together with a large number of sampling points regularly spaced over a landscape, four basic types of soil variation can be expressed by shapes in $p+q$ and in $p$ dimensional space. They are illustrated in Fig. 2.2, in two dimensions for Property-Geographic space and one dimension for Property space.

i. An area where soil properties remain constant should appear in Property-Geographic space as points lying on a smooth horizontal hyper-plane. The projection of these points on to Property space will be represented by a single point. In Fig. 2.2 this is illustrated by area A.

ii. A piece of landscape in which soil properties change gradually, and at the same rate from one part of the landscape to another, will, in $p+q$ dimensions appear as a collection of points on a smooth sloping hyper-plane. In Property space these will appear as an elongated cluster of regularly spaced points. This is illustrated in Fig. 2.2 by area C.

iii. In Property-Geographic space an area with changes in soil properties over small distances, either cyclic or irregular, will appear as points lying on a regularly or irregularly corrugated hyper-plane. The points lying on a regularly corrugated hyper-plane in Property-Geographic space will appear in Property space as a cluster of points, fairly uniformly spaced. The points on the irregularly corrugated hyper-plane in Property-Geographic space will project on to Property space as a cluster of points, irregularly spaced. This is illustrated in Fig. 2.2



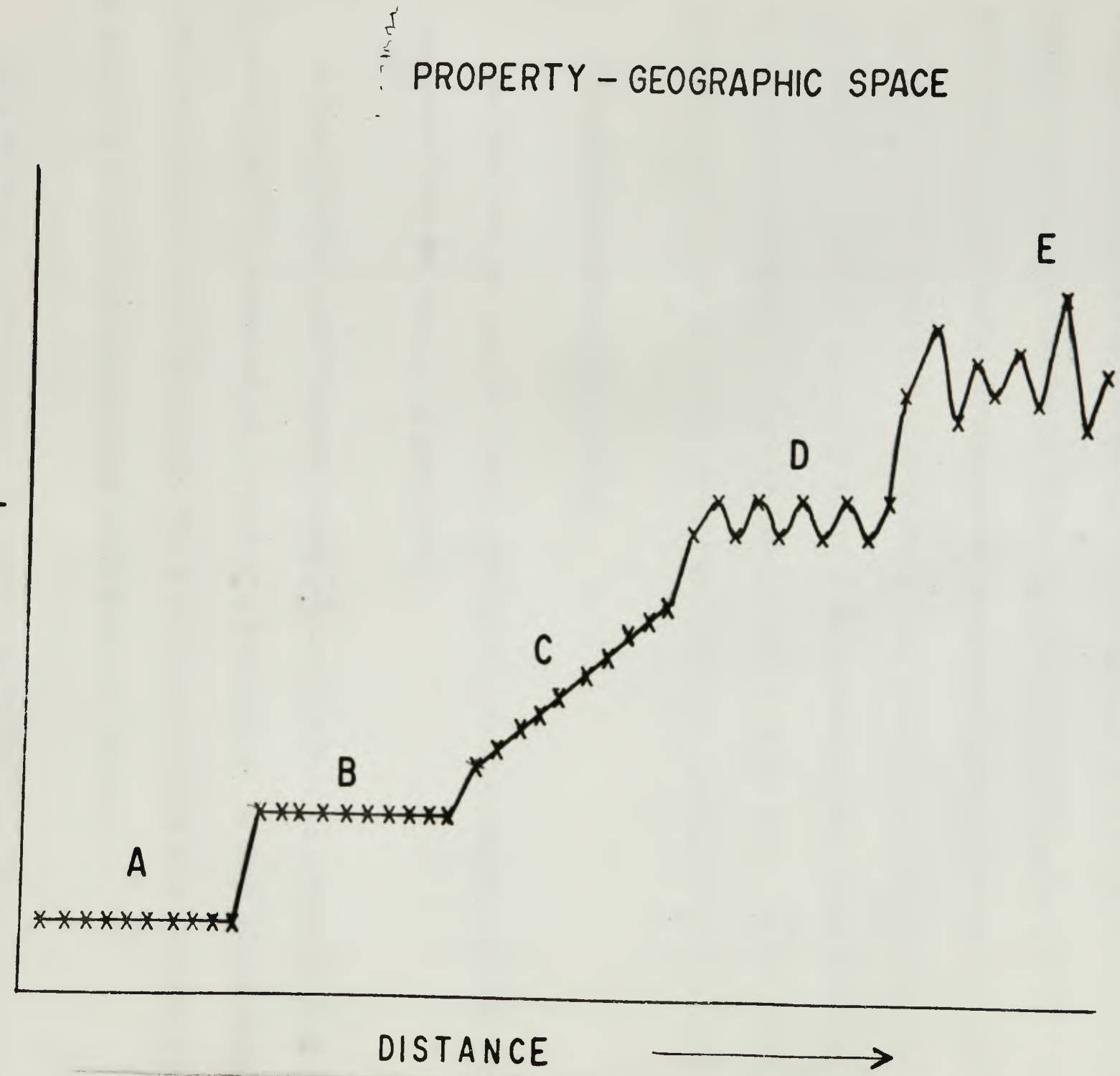




Fig. 2.2 The basic types of soil variation

by area D.and E.

iv. An abrupt and consistent change in soil properties at a given location on the ground, that is well defined "soil boundary", should appear in Property-Geographic space as two hyper-planes separated by a step-like shapes. The projection on to Property space should appear as two points, if the hyper-planes in Property-Geographic space are smooth and horizontal. Otherwise, that is if the hyper-planes are not horizontal or smooth, the points in Property space willappear as two clusters separated by empty hyper-ppace. This is illustrated in Fig. 2.2. by the transition between area A and B, and also by the transition between area D. and E.

## 3. The Soil Series and the Model

The Soil Series profile class conceived of as a mode can now be translated into the terms of the model.

A mode is the most frequent value of a variable or a group of variables. It is empirically pictured as a peak of a histogram. A two dimensional histogram has a horizontal axis which takes the values of a property, and a vertical axis which represents the frequency values.

In a bimodal symmetrical frequency distribution, each mode is separated by a zone of zero frequency or of relatively low frequency. The modes may have different shapes.

Typically the modes are visualized as being two triangular figures, and atypically as two truncated triangular, or even as two rectangular figures.

It is clear that the minimal requirement is the presence of two figures. regarless of shape, separated by an area either at the high of the origin of the frequency axis or at high lower than the peak of the histogram.

Two modes in a two-property scatter diagram can be represented on a plane by two clusters of points. The axes of the plane are the two soil properties, and each point represents the values of one soil observations.

Each mode will be characterized by an area of high point density, separated from other by areas of low point density or empty spaces. Two modes in a p - dimensional space will be represented by two clusters of points separated by a low point density or an empty space, with each point defined by p soil properties.

Therefore, in the p dimensions of Property space, the Soil Series profile class can be conceived of as having the following forms.

i. A spheroidal high point density hyper-volume limited by an empty space.

ii. A spheroidal high point density hyper-volume bounded by a low point density space.

iii An ellipsoidal hyper-volume of sparse, uniform point density limited by an empty space.

Cases (i) and (ii) are the common concept of a mode. Case (iii) is atypical, since there is no one signle soil profile which occurs more frequently than others. Nevertheless this can be considered as being a poorly defined mode.

Each of the three cases of the distribution structure of Property space have a unique counterpart in Property-Geographic space.

A spheroidal high point density hyper-volume limited by an empty space in Property space corresponds in Property-Geographic space to a fairly uniform horizontal hyper-plane, limited by almost vertical slopes.

This is illustrated in two dimensions in Fig. 2.3 by area B, and by the transition between are B and area C.

A spheroidal high point density hyper-volume bounded by a low point density space in Property space, should appear in Property-Geographic space as a fairly uniform horizontal hyper-plane bounded by two short, sloping hyper-planes. This is illustrated in Fig. 2.3 by area A, and by the transition between area A and area B.

An ellipsoidal hyper-volume of uniform point density limited by an empty space in Property space should appear in Property-Geographic space as a sloping hyper-plane, limited by two almost vertical steep slopes. This is illustrated in Fig. 2.3 by area C, and by the transition between area B and area C.

Finally, the distribution in Property space of a single cluster with two modes united by a large hyper-volume with a uniform point density, will be represented in Property-Geographic space by three hyper-planes of more or less the same length, in the form of two horizontal hyper-planes joined by the gradual transition of a sloping hyper-plane. This is illustrated in Fig. 2.3 by areas C and B, and their transition.

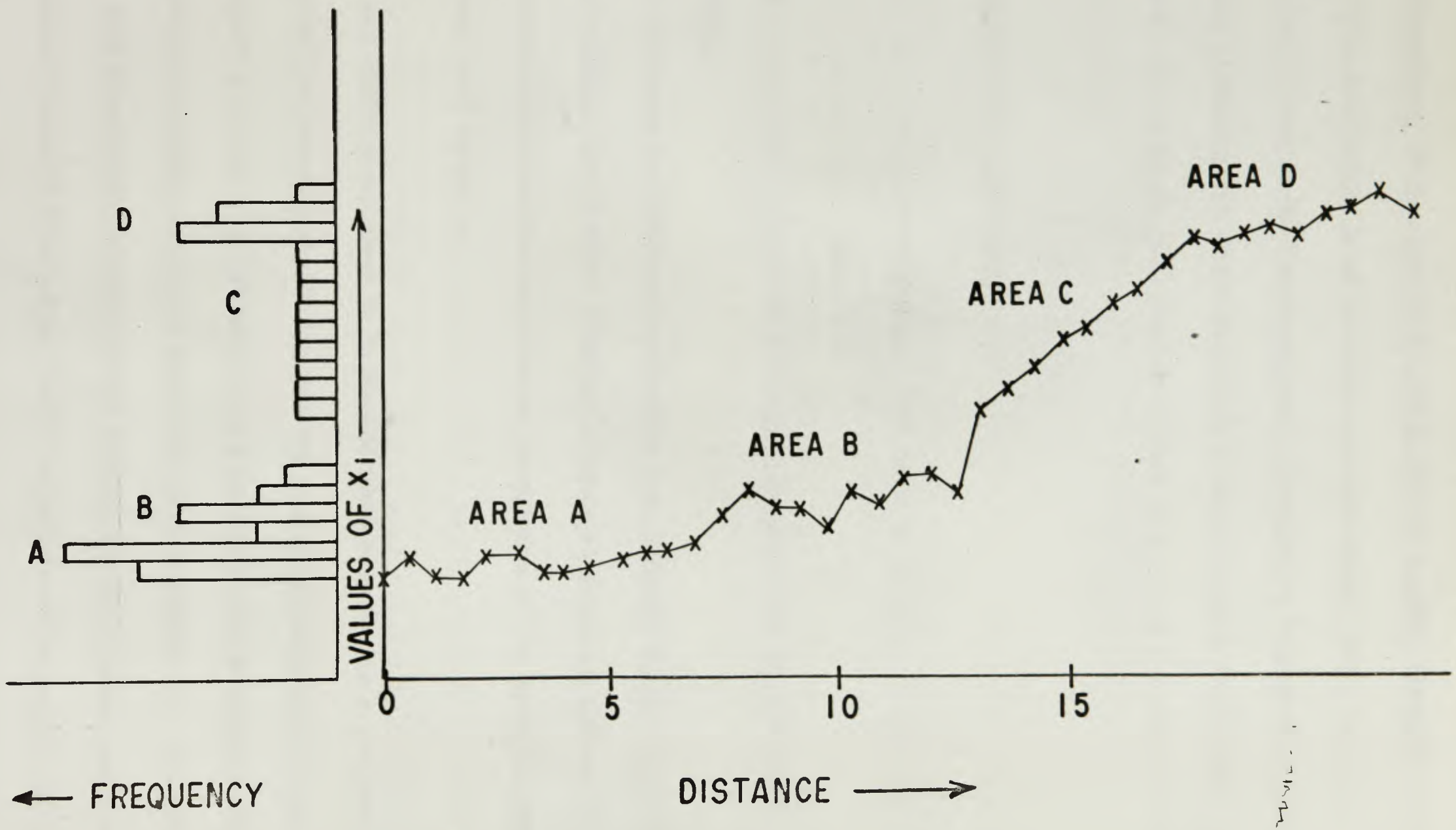



Fig. 2.3 Relationships between Soil Series profile class and Soil Series mapping unit.

Furthermore, if the grouping of Soil Series profile classes at high levels of generalization is to be done in a meaningful way, using an hierarchical system with its consequent economy in terms of memory and conceptual visualization of the population, the modes at Soil Series profile class level should again give rise to modes at each of the different levels of the hierarchy.

4. Assumptions of the Mpdel

There are several assumptions that need to be made for the above approach to be useful. These are:

1. All properties should be taken into account and should have a priori equal weight.

This is known as Adanson's principle (see Introduction). It seems to be reasonable, since when devising a General Purpose system of classification or ordination we have no knowledge of the specific purpose this system will be put to.

A more difficult problem is to decide what constitutes a property. To simplify the problem, I decided to use all recorded properties in one case, (see Chapter IV) and in the second case I used the soil properties that soil surveyors usually record in the field, (see Chapter V). Nevertheless, some of these properties needed to be codified by more than one variable. For instance, in all of this work, seven variables were used to describe soil colour. That is, dominant soil colour was described by three variables; hue, value, and chroma, three were used for colour of mottles, and one more to describe the percentage of mottles. Does soil colour constitute

a single property, or is it made up of seven properties?. The approach I followed was that suggested by Cain and Harrison (1958), in that all properties which are not mathematically correlated may be considered independently and therefore have the status of different properties.

ii. <u>All soil properties can be coded into variables having the attributes of order and equal interval.</u>

Order and interval are attributes possessed, for instance, by the integer numbers 1, 2, 3. . . n. The attribute of order signifies that 1 is always smaller than 2, 2 is always smaller than 3, and so on. Interval means that the magnitude between 1 and 2 is the same as that between 2 and 3, and so on.

This is fairly easily fulfilled by the large majority of soil properties, which describe "dimensions", (such as size of aggregates), "intensity", (such as water tension), and "content", (such as clay percent). The properties which were most difficult to code in the above terms were those describing "kind" and "shape", e.g. kind of stones and structure shape.

To provide a universally accepted code for properties describing "kind" and "shape" will be difficult, not to say impossible, since there is no general principle to invoke. Therefore they can either be left out of the analysis, hoping that the properties closely related to them will show their effect indirectly, or used as a guide for ordering the properties that have order and interval and are most highly correlated with them. I have followed the second approach.

iii. <u>The depth in the soil profiles at which soil properties were recorded are comparable.</u>

Traditionally, soil classification has been the classification of soil profiles expressed in terms of soil horizons. As I understand it, the soil profile is expressed in terms of soil horizons in order to simplify it by means of an abstraction. Thus the soil profile is depicted simply by the kind of horizons and their arrangement.

However, if we want to study soil it will be more realistic to consider it in terms of the soil profile as a whole. If we want to match two soil profiles, we are then compelled to compare either the properties of the soil at the same depth (this was done in the initial study, see Chapter IV), or the soil properties must be compared at a given number of depths --- the first observation near the surface and the other observations on the layers of the soil profile which are most distinct. This means that the soil horizons are used to locate the depths at which the properties defining a soil profile are recorded. This second approach was followed in the main study (for full details see Chapter V).

# CHAPTER III

## Some numerical methods for the investigation of Property space and Property-Geographic space

Several numerical techniques are already available to study the geometrical model described in Chapter II. These are grouped below into methods for the study of Property space, and those for the study of Property-Geographic space.

### 1. Property space

Soil properties at any point on the land will be represented by a corresponding point in Property space. Relationships between these points can be investigated by Numerical Ordination and Numerical Classification.

Ordination. Ordination methods study relationships between points in Property space, by locating their position relative to one or more axes.

Any linear combination $a_1X_1 + a_2X_2 \ldots + a_pX_p$ of the p variates, may be regarded as projections of the points $P_1$, $P_2 \ldots P_n$ on to new axes in Property space. The two dimensional case ($p = 2$) is represented In Fig. 3.1, where the point $P_1$, located by the co-ordinates $X_{11}$, $X_{12}$ on the axes $X_{11}$, $X_{12}$, is projected on to the new axis $Y_{11}$, by $Y_{11} = \cos \alpha X_{11} + \sin \beta X_{12}$, and the projection of $Y_{11}$ on $Y_{12}$ zero.

Some multivariate statistical methods can be interpreted in these, or similar terms. They are Principal Component analysis, Kendall (1957), Seal (1964); Principal co-ordinate analysis, Gower (1966), and Canonical

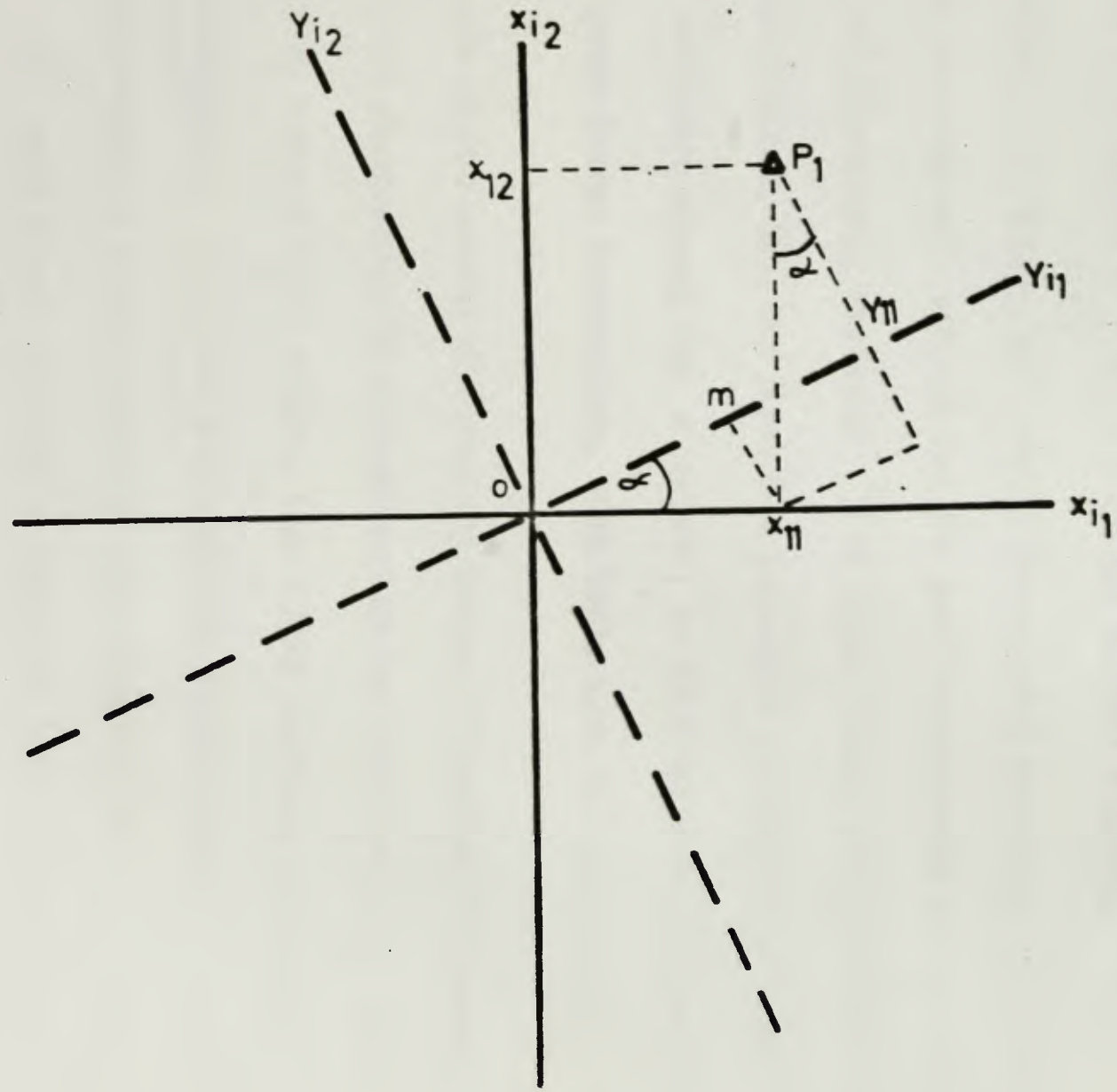



Fig. 3.1 The point $P_1$, located on the $x_j$ axes, is projected on to the $y_j$ axes.

analysis, Seal (1964) Gower (1966b). I shall deal in detail only with Principal Component analysis.

A. Principal Component analysis. The aim of Principal Component analysis is to represent as much of the variation between the n points in the p dimensions of Property space, as is possible on a projection of fewer dimensions. Among all linear functions of the X's, $a_1X_1 + a_2X_2 \cdots + a_pX_p$, with either $\sum_{i=1}^{p} a_i^2 = 1$ or the largest element $\max_{i=1}^{p}\{a_i\} = 1$, one has maximum variance. This is the first principal component. Now, of all linear functions orthogonal to this, say $b_1X_1 + b_2X_2 \cdots + b_pX_p$ with $\sum_{i=1}^{p} a_ib_i = 0$, and with either $\sum_{i=1}^{p} b_i^2 = 1$ or the largest element $\max_{i=1}^{p}\{b_i\} = 1$, one has maximum variance, and this is the second principal component. The process is continued until all the X's are transformed to p orthogonal components of decreasing variance. It is often found, especially if the X's are highly correlated, that the first few principal components account for most of the variation among the n points, so that the problem can be reduced from p to many fewer dimensions, with little loss of information.

Making use of our model of Property space, Principal Component analysis may be geometrically interpreted as the rigid rotation of the p axes of the X's, around their origin, into a new position defined by p principal components. The first principal component will be located so that the sum of squares of the perpendicular distance of the points $p_i$ (i 1, 2 . . .n), on to a new axis (first principal components), is a minimum. The second, third. . . until p new axes (principal components) will be perpendicular to the first, as well as to each other, and will, in decreasing order, minimize the sum of squares of the perpendicular distance

of points $P_i$ on the new axes.

The co-efficients of the principal components (elements of eigenvectors or latent vectors), are the direction cosines that the original axes make with the new axes, or with the principal components, if standardization of the elements of the eigenvector $\sum_{j=1}^{p} a_j^2 = 1$ is used. If the standardization of the elements of the eigenvectors $\max_{j=1}^{p} \{a_j\} = 1$ is used, then the co-efficients of the principal components are the direction cosines that the new axes make with the axes multiplied by a constant, Mendez Ramírez (1970)[1].

To facilitate the explanation I shall slightly change the notation:

If $a_{ij}$ is the jth value of the ith eigenvector with standardization $\sum_{j=1}^{p} a_{ij}^2 = 1$ and $a_{ij}^*$ is the jth value of the ith eigenvector with standardization $\max_{j=1}^{p} \{a_{ij}^*\} = 1$, then $a_{i1}^{*2} + a_{i2}^{*2} + \ldots + a_{ip}^{*2} = K_i$ therefore

$$a_{ij} = \frac{a^*_{ij}}{\sqrt{K_i}}$$

This means that for each eigenvector, $a^*_{ij}$ in relation to $a_{ij}$ is multiplied by the constant $\sqrt{K_i}$. So provided $\sqrt{K_1}, \sqrt{K_2}, \ldots \sqrt{K_p}$, are very nearly the same, the geometrical interpretation of standardization $\max_{j=1}^{p} \{a_{ij}^*\} = 1$ is the same as that of $\sum_{j=1}^{p} a_{ij}^2 = 1$, bearing in mind that there has been a change of scale.

1. Mendez Ramírez (1970) (Personal communication).

The complement of the percentage value of each eigenvalue (latent root) is equal to the sum of squares of the residuals, that is the square of distances from the points normal to the fitted line.

If, for example, all n points in p dimensions are co-linear, the first principal component will account for 100 per cent of the total variation, that is the sum of the squares of the residuals is zero. These points can then be represented in one dimension, without loss of information, by plotting the first principal component values so that the distance between every pair of points is the same in p dimensions as in one dimension. The more the points depart from this ideal position, the less the proportion of the total variation will be accounted for by the first principal component, and the more components are needed to represent the real distance between points. The extreme case will be when n points lie uniformly or randomly in a p dimensional hyper-sphere, so that the real distance between points can only be represented by the p principal components.

It is important to notice that Principal Component analysis is dependent on the scale on which the X's are measured. Therefore, if the principal components are going to be useful or meaningful, all the X's must be standardized in the same way.

Two standardizations of property values can be used. They are standardization to zero mean and unit variance, and standardization between the range zero to one. Standardization to zero mean and unit variance is done by subtracting from each observation the property mean, and dividing by its standard deviation. Standardization between the range zero to one

is obtained by subtracting from each observation the minimum observed value of the property, and dividing it by the difference between the maximum and minimum observed values.

Gower (1966a), showed that Principal Component analysis is a special case of Principal Co-ordinate analysis, when Euclidian distance is used as a measure of dissimilarity. Principal Co-ordinate analysis operates on a dissimilarity matrix, unlike Principal Component analysis which operates on the variance co-variance matrix. The advantage of Principal Co-ordinate analysis is that multistage and binary codes can be used, and the analysis can be carried out even though there is missing data.

However, Principal Component analysis has two advantages over Principal Co-ordinate analysis. The first is that the relative contribution of the different properties can be assessed from the co-efficients for each principal component (elements of the eigenvectors), so that "over-all meaning" of each component can be found (this is illustrated in detail in Chapter IV). The second advantage is that Principal Component analysis makes fewer demands on the amount of rapidly accessible computer memory when the number of properties is smaller than the number of objects used in the analysis. This was the case in this work.

Ordination by Principal Component analysis was used to search for clusters on the projection of Property space obtained by plotting the values of the first component against those of the second component. The results of Principal Component analysis were also used to search for the over-all sequence of the horizontal, sloping and vertical hyper-lines which soil

properties make in Property-Geographic space. This was done on the graphs of the first, second, third and fourth component values, each plotted against distance.

B. Order Neighbour statistics. The distribution pattern of points in p dimensions can be investigated by Order Neighbour statistics, Thompson (1956), Dacey (1963). If the co-ordinates of points on a plane are drawn randomly from a rectangular distribution, then the number of points per unit area follows a Poisson distribution. Thompson (1956) has further shown that for such a distribution, the distances of each point to its neighbours of all orders is related to the $\chi^2$ distribution by the following statistic,

$$2\pi d \sum_{i=1}^{n} r_{ik}^2$$

Where n is the number of points from which measurements are taken, d is the average density of points per unit area, $r_{i,k}$ is the distance from the i'th point to its k'th neighbour, and $\pi$ has its usual meaning, i.e. a constant 3.142. This statistic has a $\chi^2$ value with 2 nk degrees of freedom. The comparison between the computed values of a given distribution, with the tabulated values of $\chi^2$, will give a simple test of randomess. If the statistic value is greater than the tabulated values of $\chi^2_1$ at 0.95 probability, it indicates significant overdispersion (regular) of points, the distance being smaller than that expected. A statistic value of less than $\chi^2$ at 0.05 probability indicates significant underdispersion (clustered).

Order Neighbour statistics was used to quantify the degree of clustering, on the projection of Property space obtained by plotting the values of the first component against those of the second component.

Numerical Classifications. Classifications can be numerically constructed either monothetically or polythetically. If a classification is to be constructed monothetically, a property, or a set of properties, has to be selected as a criterion to group or divide the population under study. This property selection can be done in different ways, but if the classification is to be for general purposes, then grouping on over-all affinity — that is polythetically — will be more likely to produce classes about which the largest number of inductive statements can be made.

Polythetically based classifications are numerically derived by the general principle that members of a class must be as similar as possible to each other, and as dissimilar as possible to the members of other classes.

Such classifications are constructed by performing an ordered set of operations on the properties of the individuals to be classified. These sets of operations can be divided into two parts. The first operation or set of operations measures the likeness of affinity between the individuals to be classified. The second, called the sorting strategy, determines the rules by which objects are assigned to classes.

Classes thus constructed can overlap, or be mutually exclusive. In the first case an individual may belong to more than one class. Overlapping classes generate non-hierarchical classifications; examples are given by Parker-Rhodes (1961), and Rice and Lorr (1969).

Hierarchical classifications with mutually exclusive classes can be constructed either by divisive or by agglomerative procedures.

Many divisive procedures have been computationally unsucceseful because too many comparisons are involved, unless no more than about 16 objects are classified, Edwards and Cavalli-Storza (1965) , or the number of classes is specified. MacNaughton Smith (1964) . Agglomerative hierarchical methods have been developed that can deal with a few hundred individuals. These methods have the advantage that generalizations about class, and comparisons between classes, can be made at any level in the hierarchy. Numerical classifications are also more definitive than numerical ordinations, and so are more useful to show relationships between the most similar individuals. However, as Williams and Dale (1965) pointed out, they may also generate the requirement that each level in the hierarchy must be associated with a given level of likeness between the members of a class.

Some of the agglomerative hierarchical methods are referred to as Similarity analysis, and they have been studied comparatively by Lance and Williams (1967), MacNaughton-Smith (1965), Gower (1967), and others.

C. Similarity analysis can be considered in three parts. The first part deals with the kind of property values standardization used. The second part consists of measuring the degree of similarity between every pair of individuals. The third part of the analysis operates on these similarities to form groups, and is called the sorting strategy.

(i) Standardization of property values. Here, as in Principal Component analysis, two standardizations of the property values can be used, namely

standardization to zero mean and unit variance and standardization between the range zero to one.

(ii) Measurements of Similarity Two measures of likeness of similarity idices are available in this model. One is a function distance, ("size") and the other an angular function, ("shape").

If two points, $P_1$ and $P_2$, have co-ordinates $X_{11}$, $X_{12}$ . . . $X_{1p}$ and $X_{21}$, $X_{22}$ . . . $X_{2p}$, the square of Euclidian distance, D, is given by $D_{12}^2 = \sum_{i=1}^{p} (X_{1i} - X_{2i})^2$. The cosine of the angle $P_1\hat{0}P_2$ can be found in terms of the co-ordinates by

$$\cos(P_1\hat{0}P_2) = \cos\lambda = \frac{\sum_{i=1}^{p} X_{1i} X_{2i}}{\sqrt{\sum_{i=1}^{p} X_{1i}^2 \sum_{i=1}^{p} X_{2i}^2}}$$

If the values $X_{1i}$ and $X_{2i}$ are standardized to zero mean and unit variance, the origin, 0, is taken at the means of each property. Then $\cos\lambda$, the similarity index, can be computed directly without standardizing the property values by the correlation co-efficient. If $X_{1i}$ and $X_{2i}$ are the property values standardized between the range zero to one, then the property values need to be standardized first, and from them $\cos\lambda$ has to be computed.

Thus the origin, 0, is taken at zero for all properties. In either way this last formula is an angular measure of similarity.

These two measures are illustrated for two properties, in Fig. 3.2, where the point $P_1$ has the co-ordinate $X_{11}$ and $X_{12}$, point $P_2$, the

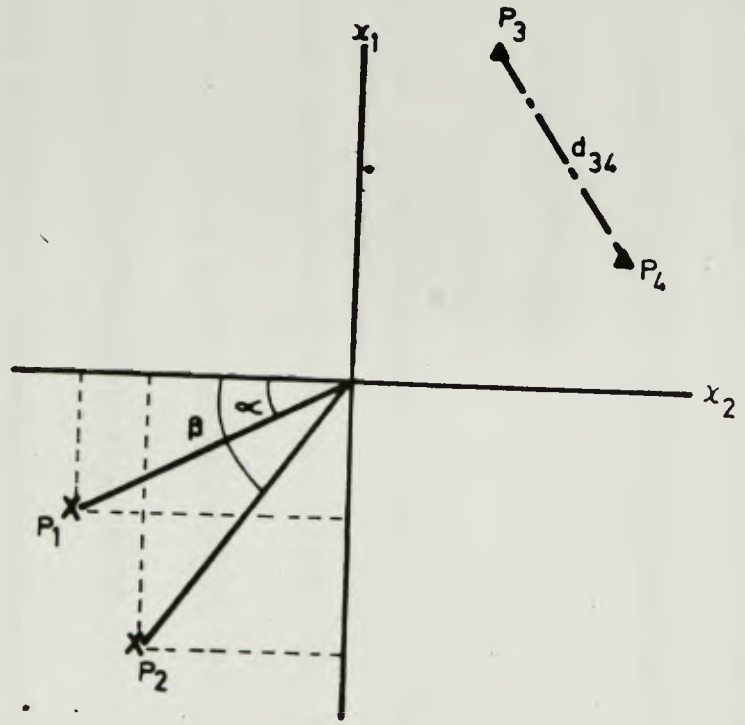



Fig. 3.2 Two dissimilarity measures available in the model: a distance measure $d_{34}$ and an angular measure

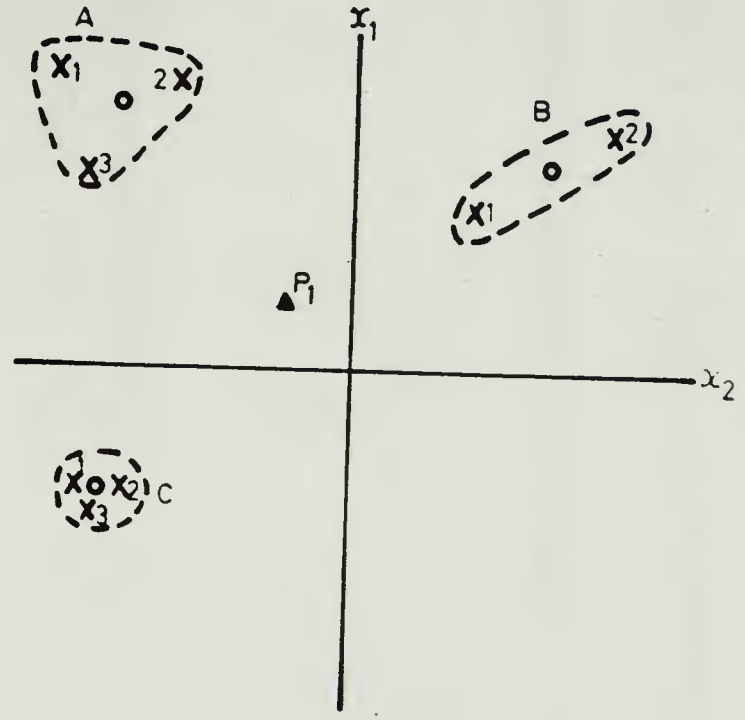



Fig. 3.3 An illustration to compare the sorting strategies

co-ordinates $X_{21}$ and $X_{22}$, and so on.

The square of the distance D between points $P_3$ and $P_4$ is

$D^2 = (X_{31} - X_{41})^2 + (X_{32} - X_{42})^2$. The cosine of $\lambda$ is:

$$\cos \lambda = \cos (\beta - \alpha) = \sin\alpha\sin\beta + \cos\alpha\cos\beta$$

$$= \frac{X_{11}}{\sqrt{X_{11}^2 \; X_{12}^2}} \; \frac{X_{21}}{\sqrt{X_{22}^2 \; X_{21}^2}} + \frac{X_{12}}{\sqrt{X_{11}^2 \; X_{12}^2}} \; \frac{X_{22}}{\sqrt{X_{22}^2 \; X_{21}^2}}$$

$$= \frac{X_{11} X_{22} \quad X_{12} X_{22}}{\sqrt{(X_{11}^2 \; X_{12}^2)\;(X_{22}^2 \; X_{21}^2)}}$$

The table containing the values of the similarity index for all pairs of individuals is the similarity matrix. The similarity matrix contains all the similarity relationships between individuals, but is usually too large to be comprehended as a whole, therefore to understand it, groups are formed by means of a sorting strategy.

(iii) Sorting strategies. The similarity matrix is examined by a sorting strategy in order to form groups and thus facilitate its understanding. All sorting strategies initiate a group by amalgamating the two most similar individuals. The formation of two-member groups is carried out at all stages of grouping, if the similarity between these two individual members is greater than the similarity between one individual and an existing group, or the similarity between two groups. The criteria by which an individual is amalgamated with an existing group, or two groups are fused together to give rise to a new group, vary in the different sorting strategies. To

facilitate the explanations I shall consider three clusters, A, B and C. Each group is made up of the members $a_1$, $a_2$ . . . $a_i$, $b_1$, $b_2$ . . . $b_i$, and $c_1$, $c_2$ . . . $c_i$, where i may vary from 1 to n.

Both the weighted and the un-weighted sorting strategies of Sokal and Michener (1953) use as a criterion the average similarity between the groups. Therefore, A will join B instead of C if the average similarity between the members of A and B is smaller than the average similarity between the members of A and C.

However, these strategies differ in the way the average similarities are computed. For example, suppose group A was previously formed by the fusion of A made of three individual members, $a_1$, $a_2$ and $a_3$, and a new member, P. The weighted pair group will compute the average similarity between A and B from the similarity values of an imaginary individual positioned in the middle of the line from A to B. In contrast, the unweighted pair group will compute the average similarity between A and B by averaging the similarity values of all the individual members of A, that is $a_1$, $a_2$, $a_3$ and $P_1$, with all the individual members of B. These are the two sorting strategies used in this work.

In other sorting strategies, for instance,nearest neighbour, group A will join B instead of C, if $a_i$ is more similar to $b_i$ than to $c_i$. In furthest neighbour sorting strategy, group A will join B instead of C, if the most dissimilar members $a_i$ and $b_i$ are more similar to each other than to the most dissimilar member of $a_i$ and $c_i$.

Lance and Williams (1966b) have shown that all these strategies are special cases of a single linear system defined by four parameters. This in turn gives rise to an infinite number of sorting strategies.

The three strategies, nearest neighbour, weighted, and un-weighted pair group, are illustrated in Fig. 3.3, in two dimensions, using distance as a similarity index. There are nine points and three groups, A, B and C. The point $P_1$ will, by nearest neighbour, join group B, because this point is nearest to one of the members of B. By using weighted pair group, $P_1$ will join group A, because the distance between the points $P_1$ and the weighted mean (represented by a circle) of group A is the smallest. The point $P_1$ will join group C by un-weighted average, since the average distance between this point and the three members of group C is the smallest.

Similarity analysis was employed to estimate the degree of definition of clusters in Property space. Changes in the two standardizations of property values provided a sensitive mechanism to test the stability of the classifications produced, Cuanalo de la C. and Webster (1970). This is because these changes only induce small differences in the values of the similarity indexes. That is, if the population of individuals is well clustered in Property space, small changes in the similarity indexes will not appreciably alter the course of fusion. As a result of small changes in its position, individual $P_1$ may link up with individual $P_3$ instead of $P_2$ at the first fusion, but it will link up with $P_2$ shortly afterwards if they are all in the same small cluster. If, on the other hand, the population is not well clustered, individual $P_1$ is perhaps removed further from $P_2$,

and in the hierarchy is fused initially with $P_3$. But now $P_2$ may find itself more closely linked, not with group $P_1 + P_3$, but with $P_4$ or $P_5$. The particular grouping that occurs in those early stages of agglomeration directs its later course, and as fusion proceeds this course becomes increasingly dependant on small variations in the similarity indexes.

Therefore changes in standardization will have no effect in the classifications produced if the groups in Property space form compact spherical clusters, and are surrounded by relatively large empty spaces.

D. Mode Analysis. Wishart (1968) proposed and developed a classificatory method, called Mode analysis, in which dense hyper-volumes in Property space can be identified and isolated. Mode analysis makes use of successive fusions, as in the nearest neighbour method, but a density threshold, k, has to be reached before carrying out the fusion. Thus around each data point, a sphere of diameter d is envisaged. If the number of points falling inside any sphere is equal to, or larger than k, the sphere is declared "dense", and the point at the centre of this sphere is called "dense". The points inside a "dense" sphere, but not in its centre, are called "non-dense". All the points inside the sphere (dense and non-dense) constitute a mode, and are therefore fused. After this, the diameter, d, of the sphere is increased, and the new "non-dense" points falling inside a "dense" sphere are fused. At the same time, new points will become "dense" points, and fusion will occur among the points in the new spheres, Every time two modes fuse, the remaining points, that is points not falling inside a "dense" sphere, are allocated to the nearest "dense" point.

Mode analysis is illustrated in Fig. 3.4. There are nine individuals along a line. The distance between every pair of individuals represents their dissimilarity values. The ordinate represents their frequencies. As the distance between the points in any group increases or decreases, their frequencies will increase or decrease accordingly. Now, if the threshold, k, is given the value of 3, then point 5 will be declared "dense", since the smallest sphere drawn around any one point, and containing 3 to points, will be centred at point 5. At the same, point 5 corresponds to the area of maximum frequency in the histogram. The points 4 and 6 will be inside a "dense" sphere, (in this case a distance), but will not be "dense" points. The points 4 and 6 will join point 5 to form group B. Later on as the diameter, d, increases, point 2 will be declared "dense", and group A will be formed at a higher level of dissimilarity by adding points 1 and 3 point 2. Later still, group C will be formed in the same manner, but at a still higher value of dissimilarity. Yet later group A will join group B, because the distance between points 4 and 3 is smaller than the distance between points 6 and 7. The results of this analysis are represented by the mode dendrogram shown in Fig. 3.5, where the stems represent modes.

If, however, the three modes A, B and C are more or less of the same height, with a few scattered points between them, (not shown in Fig. 3.4), we will end up with a very similar mode dendrogram to that in Fig. 3.5, and these scattered points will join the mode with the nearest "dense" point.

Two more hypothetical histograms are given in Figs. 3.6 and 3.8. Figs. 3.7 and 3.9 show the kind of mode dendrogram they would give rise to. The capital letters denote the modes of the groups.

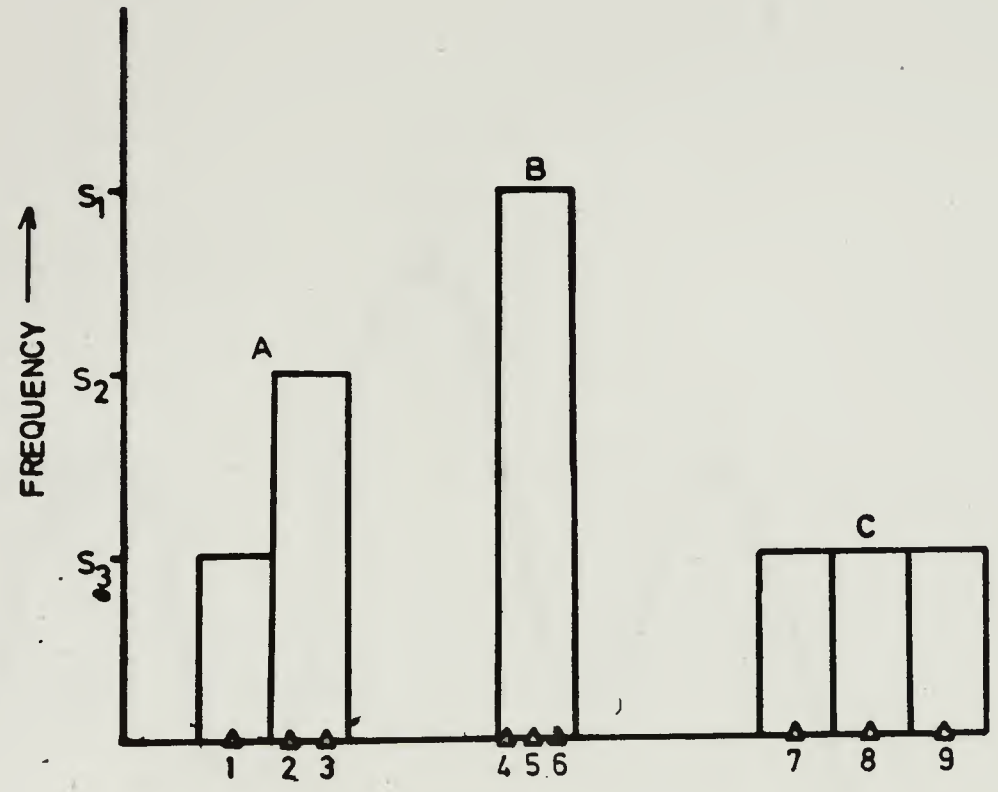



Fig. 3.4 A hypothetical histogram to illustrate mode analysis.

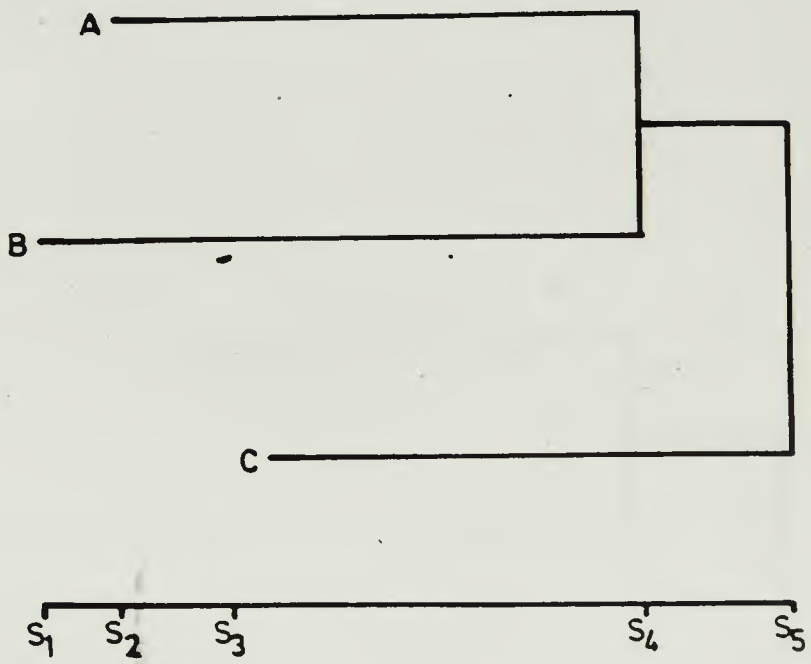



Fig. 3.5 The mode dendrogram of Fig. 2.6

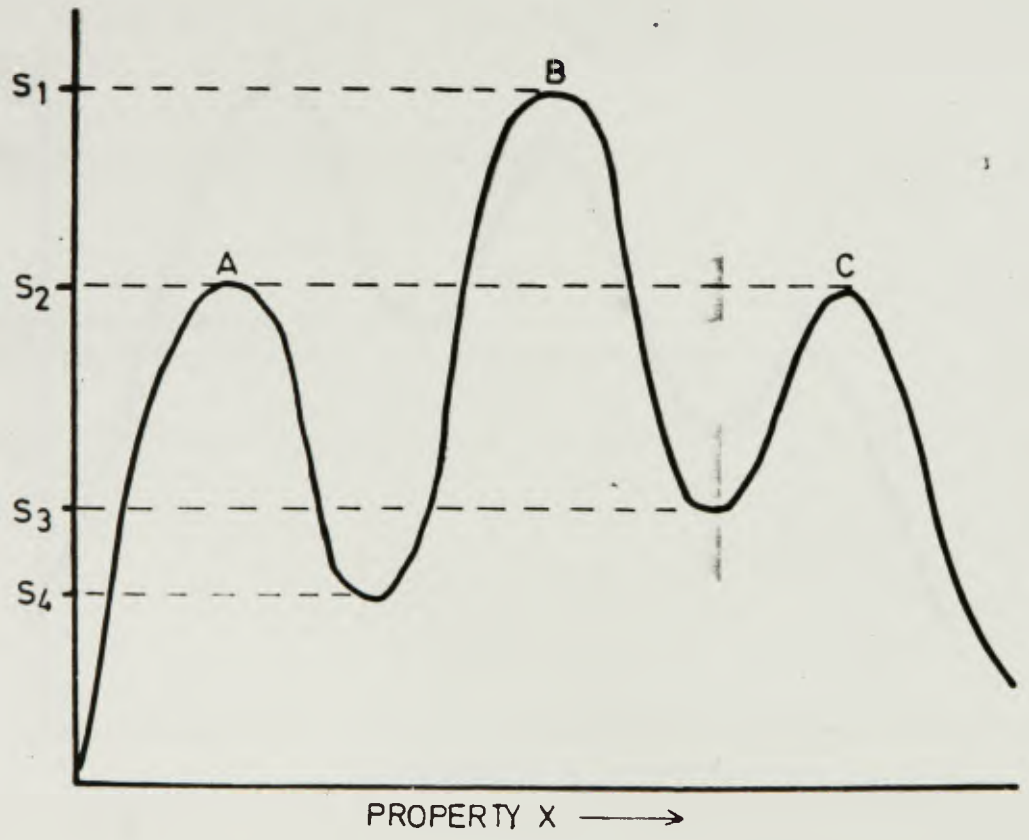
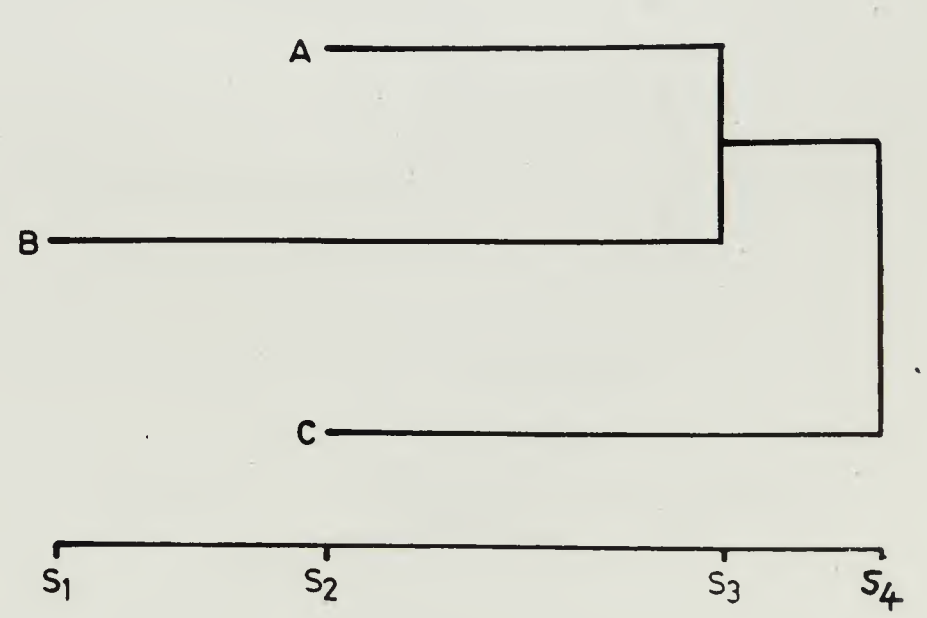



Fig. 3.6 A hypothetical histogram




3.7 The mode dendrogram of Fig. 2.8

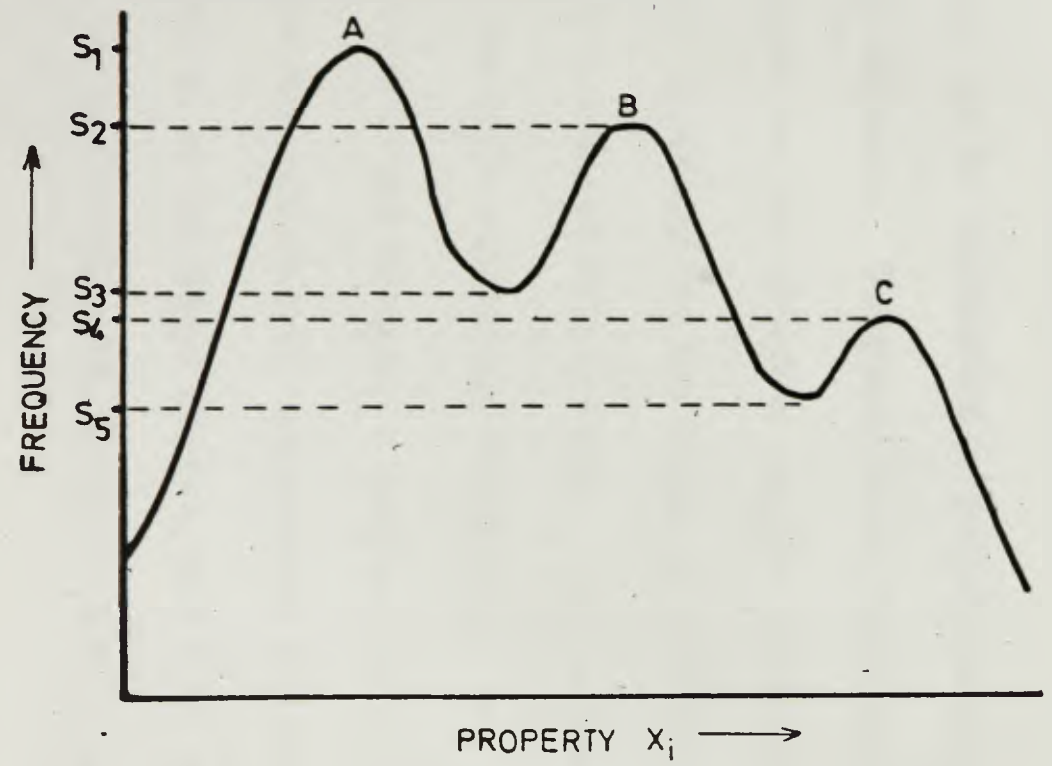



Fig. 3.8 A hypothetical histogram

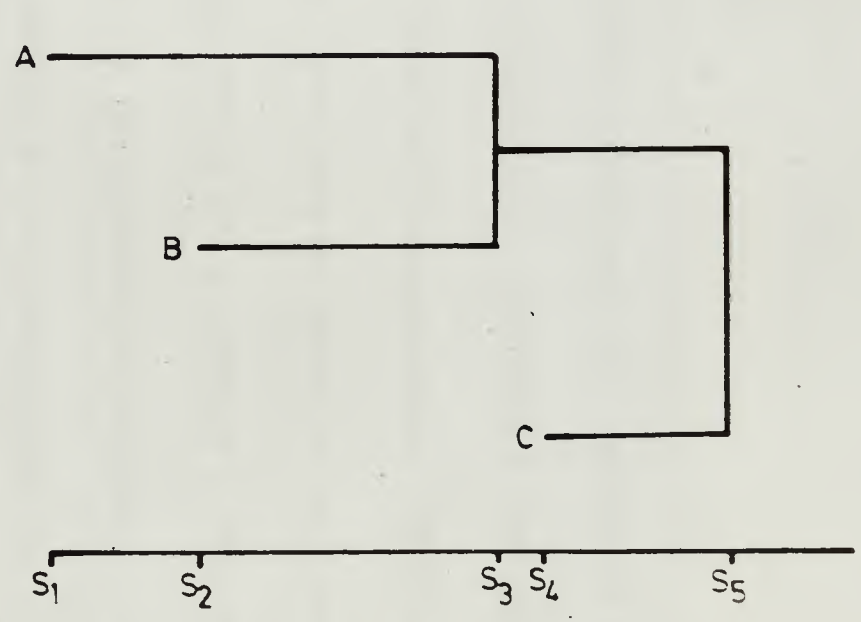



Fig. 3.9 The mode dendrogram of Fig. 3.8

The mode dendrograms obtained by varying the density threshold k were used to estimate both the degree of definition and the number of clusters present in Property space.

2. Property-Geographic space.

Relationships between individual variables, $x_i$, and up to two geographic co-ordinates, may be studied graphically by plotting a line or a surface on the geographic co-ordinates. From the representation with one geographic dimension, it is easy to see that there are at least two kinds of variabilities which may occur together or separately: (a) a change in the values of the variable closely associated with the geographic co-ordinate, and (b) an erratic variation apparently unrelated to the geographic co-ordinate. The first is called trend, and the second random variation.

A. Trend analysis. Trend can be expressed in trigonometric or polynomial functions in terms of distance. Trigonometric functions are useful to describe trend, if we assume that it has a regular wave-like pattern. This assumption is difficult to justify for the study of soil variation. Jenkins (1965) has recently reviewed this method. Polynomial functions are particularly suited to describe relatively simple trends. If, however, the trend we want to describe is not simple, a polynomial of high degree is needed, and its constants are practically impossible to compute. A trial test to fit a polynomial up to the eight degree was done with the data published by Webster and Wong (1968), with rather discouraging results.

B. Moving average. The trend of a series of observations can be found visually in no more than two geographic co-ordinates by drawing a line, or a surface, at the middle of the distance between the tops of the peaks and the bottoms of the troughs of the random variations.

A more consistent procedure, which can be extended to q geographic co-ordinates, is the method of moving average. This is equivalent to fixing a low degree polynomial to a few values at a time, Yule and Kendall (1956). The method consists of computing the trend values at a given set of geographic co-ordinates, by averaging the original values of the variable on the q co-ordinates over a small area around the location under consideration. For instance, in this work this method was used in one geographic dimension (along a transect). The trend value $\mathcal{M}$'s at the distance d will be computed by

$$\mathcal{M}_d = a_{d-m}X_{d-m} + a_{d-m+1} \quad X_{d-m+1} \cdot \cdot \cdot \cdot + a_d X_d \cdot \cdot \cdot \cdot + a_{d+m} X_{d+m}$$

Where $X_d$ is the value of the variable under consideration, 2m 1 is the number of terms, and a's are the co-efficients of the polynomial. The simplest case would be the fitting of a straight line so that the value of a's is the same, and is equal to 1/2 m 1. The moving average method is easy to program in a computer, but the results may be changed by altering either the degree or the number of terms of the polynomial used for smoothing. A trial and error approach is advised by Yule and Kendall (1965), until the desired amount of smoothing is obtained. The same can be said of all methods used in trend analysis, unless there are strong theoretical arguments on which to base a decision as to the number and kind of components

we ought to find.

Smoothing by moving average was used to diminish the short range soil variation, so that the consistent soil variation could be looked at in Property-Geographic space.

C. Correlogram analysis. The spatial relationships of variables may be investigated by correlogram analysis, in one or two geographic dimensions, Yule and Kendall (1950) and Whittle (1954).

This method was used to study the spatial relationships of individual soil properties, and linear combinations of them, on one geographic coordinate. I assumed that the value of a property at any point along this transect was given by a single process with a random element, whose properties remain constant throughout the whole distance. Thus it is a stationary spatial series.

This assumption implies that the values of the property $X_d$ are initially considered to be a random variable, with a frequency distribution function f(X) which is independent of d, the absolute position on the transect. This means that we can estimate the parameters of f(X) by computing their mean, and that all the multivariate distributions involving $X_d$ depend only on the distance difference d-d', and not on the absolute position of d and d'. That is, the joint distribution of $X_d$ and $X_{d-k}$ is the same for all the observations that are k distance apart. This means that the characteristics of the distribution $X_{d-k}$ with respect to $X_d$, can be estimated by plotting the scatter diagram of $X_{d-k}$ against $X_d$. The linear relationships between them can be expressed by the covariance function Cov $(X_d)$ $(X_{d-k})$. Now if the

series of observations is changed, by subtracting the over-all mean and dividing by the standard deviation, their structure will remain unaltered. The co-variance function becomes the correlation co-efficient.

$$r_k = \frac{\text{Cov}\left\{(X_d)\quad(X_{d-k})\right\}}{\left\{\text{Var}\ (X_d)\quad \text{Var}\ (X_{d-k})\right\}^{\frac{1}{2}}}$$

where $r_k$ is the correlation co-efficient between all the observations $k$ distance apart, and Var $(X_d)$ and Var $(X_{d-k})$ are the variance of $X_d$ and $X_{d-k}$.

The plotting of $r_k$ against the values of $k$ is called the correlogram, and this function will be related to the spatial properties of the series of observations, Wold (1938), Whittle (1954), and Jenkins (1965).

Correlogram analysis was used to study the size, kind and length of the spatial relationships of soil properties. This was done under the assumption that the soil properties at any point on the land were given by a set of constraints, (a spatial process) containing a random component.

For example, suppose we have a very large number of observations, each one drawn independently from a random distribution, the correlation co-efficient between the values $X_d$ and $X_d$ will be one. The correlation co-efficients between the values $X_d$ with $X_{d-1}$, $X_d$ with $X_{d-2}$, until $X_d$ with $X_{d-k}$ will be zero, since the observations were drawn independently.

However, suppose instead that the previous observations were smoothed by a 3 point moving average of the type $M_d = 1/3X_{d-1} + 1/3X_d + 1/3X_{d+1}$, using the same notation as used in moving average analysis (see above). Here the correlation co-efficient between $X_d$ and $X_d$ will again be one, but the

correlation co-efficient of $X_d$ with $X_{d+1}$, $X_d$ with $X_{d+2}$ and $X_d$ with $X_{d+3}$ will, in the same order, decrease linearly and attain the value of zero at the distance $k = 4$. These two hypothetical correlograms are shown in Fig. 3.10.



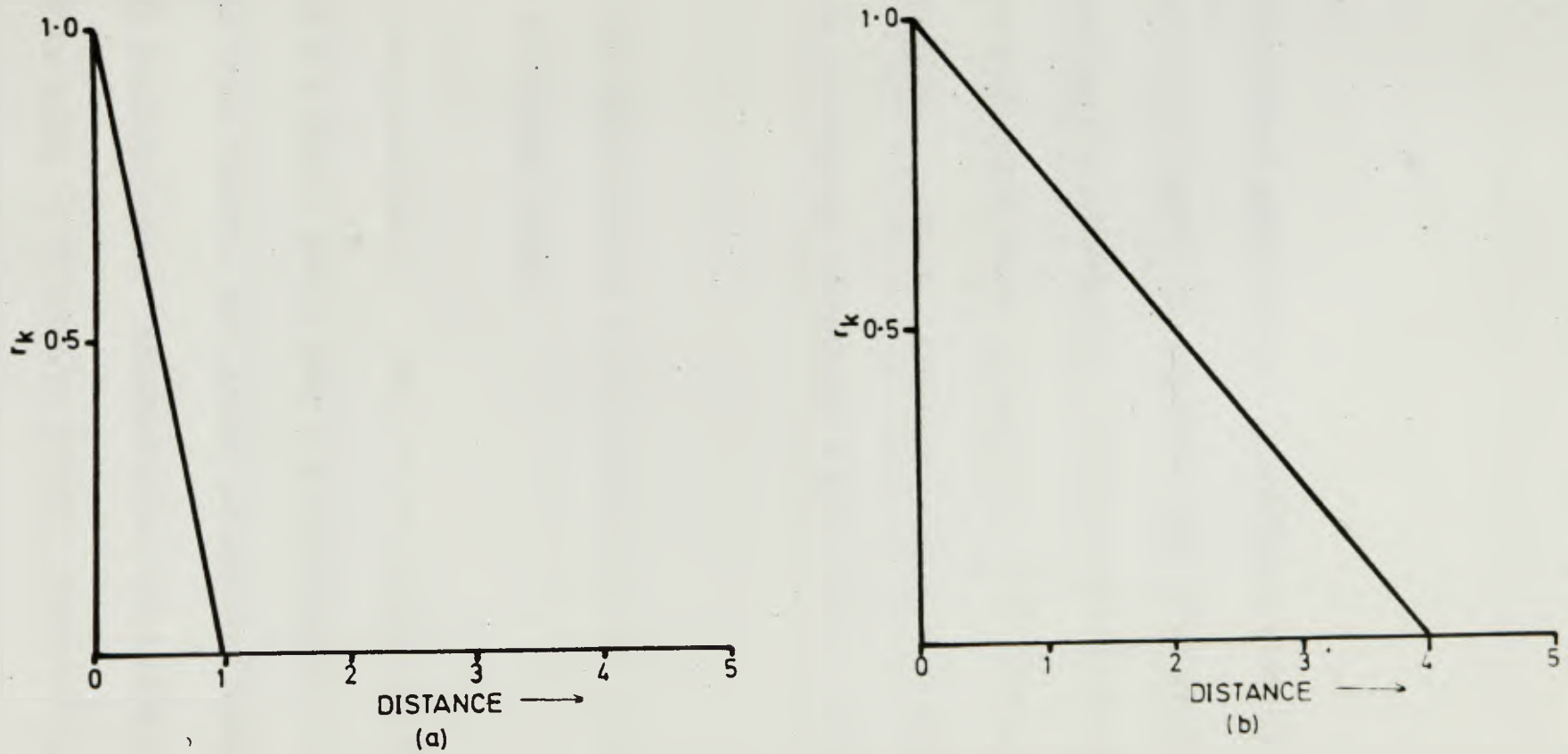



Fig. 3.10 Two hypothetical correlograms

# CHAPTER IV

## Investigation of Property space

### Preliminary Study.

#### 1. Introduction.

The preliminary study had three main aims. Firstly, to test the assumption of the model given in Chapter II, namely that soil properties can be coded as variables having the attributes of order and interval. Secondly, to gain experience and confidence in applying multivariate methods to soil profiles. Thirdly, to fully understand both the advantages and limitations offered by an electronic computer when dealing with soil profile data.

The preliminary study was carried out on 85 soil profiles, to estimate the degree of clustering in Property space.

These profiles were already available. They were randomly drawn from 17 physiographic units for which there was a good intuitive understanding. The field situation was well known, and some statistical analysis had been done, though none of it multivariate. Multivariate classification and ordination had been applied to soils by Hironaka (1960), Bidwell and Hole (1964), Rayner (1966), and Sarker et al, (1966), but because data from idealised profile descriptions, or deliberately chosen representative profiles were used, they gave little insight into the structure of the real soil profile populations.

Consequently the availability of the data, the good intuitive understanding of the soil profile population, but above all the fact that the soil profiles were randomly drawn so that the soil profiles I considered were not restricted to representative types, or to the easily classified ones, made this set of data ideal for such study.

## 2. The Data

The soil profile data used in this part of the study were recorded in a survey by Beckett and Webster (1965b). Profiles were selected by stratified random sampling. An area of about 1,000 $Km^2$, lying immediately west of Oxford, had been subdivided into 17 physiographic units (facet local forms of Beckett and Webster, 1965a), and up to 16 sites had been chosen randomly within each unit for sampling. For this study this set was further randomly sub-sampled to obtain 5 profiles from each of the 17 physiographic units, making 85 profiles in all. Thus, in so far as soil type is related to physiography, all had an equal chance of inclusion.

Measurements had been made at two standard depths, 13 cms and 38 cms, representing topsoil and subsoil respectively. The properties measured included particle size, reaction (pH), Atterberg limits, soil strength, and water tension in situ throughout the year. Also available were short profiles descriptions, from which those properties that were applicable to all 85 profiles at two standard depths were selected. These included colours, mottling, and organic matter. Altogether there were 19 properties for the topsoil and 18 for the subsoil: table 4.1 lists them with their codes, and any preliminary statistical treatment that they received.

A diagrammatic intuitive classification was made by Dr. R. Webster before the numerical results were interpreted. This classification was based as much as possible on profile description: it is given in Fig. 4.1. To facilitate the comparisons with the results of Principal Component analysis, Fig. 4.1 is the mirror image of the diagram originally produced. The horizontal axis was called gleying, and expresses the notion of profile drainage. The vertical axis is named sandiness, and is based on field texture assessment. Classification at several levels was attempted, and the results are indicated by enclosing lines. Apart, perhaps, from the two coarsest groupings, the classification was made without any conscious attempts to conform to external standards. For easy reference the groupings have been given Roman numbers and their names are given in Table 4.2.

3. Numerical Method. All those properties present in all profiles were included in the analysis, and were considered as having equal importance. In order to conform to the choice of model, I attempted to give all the property codes the attributes of order and equal interval (Rayner's "scales"). As mentioned before, these codes are given in Table 4.1.

Two procedures were used to establish relationships among soil profiles: Principal Component analysis followed by the graphing of the two first component values (ordination), Similarity analysis with the results presented by a dendrogram (classification).

A. Principal Component analysis. Principal component analysis was used to look for clusters on the most informative projections of Property space on to two dimensions. These projections were obtained by plotting the first against the second principal component values.

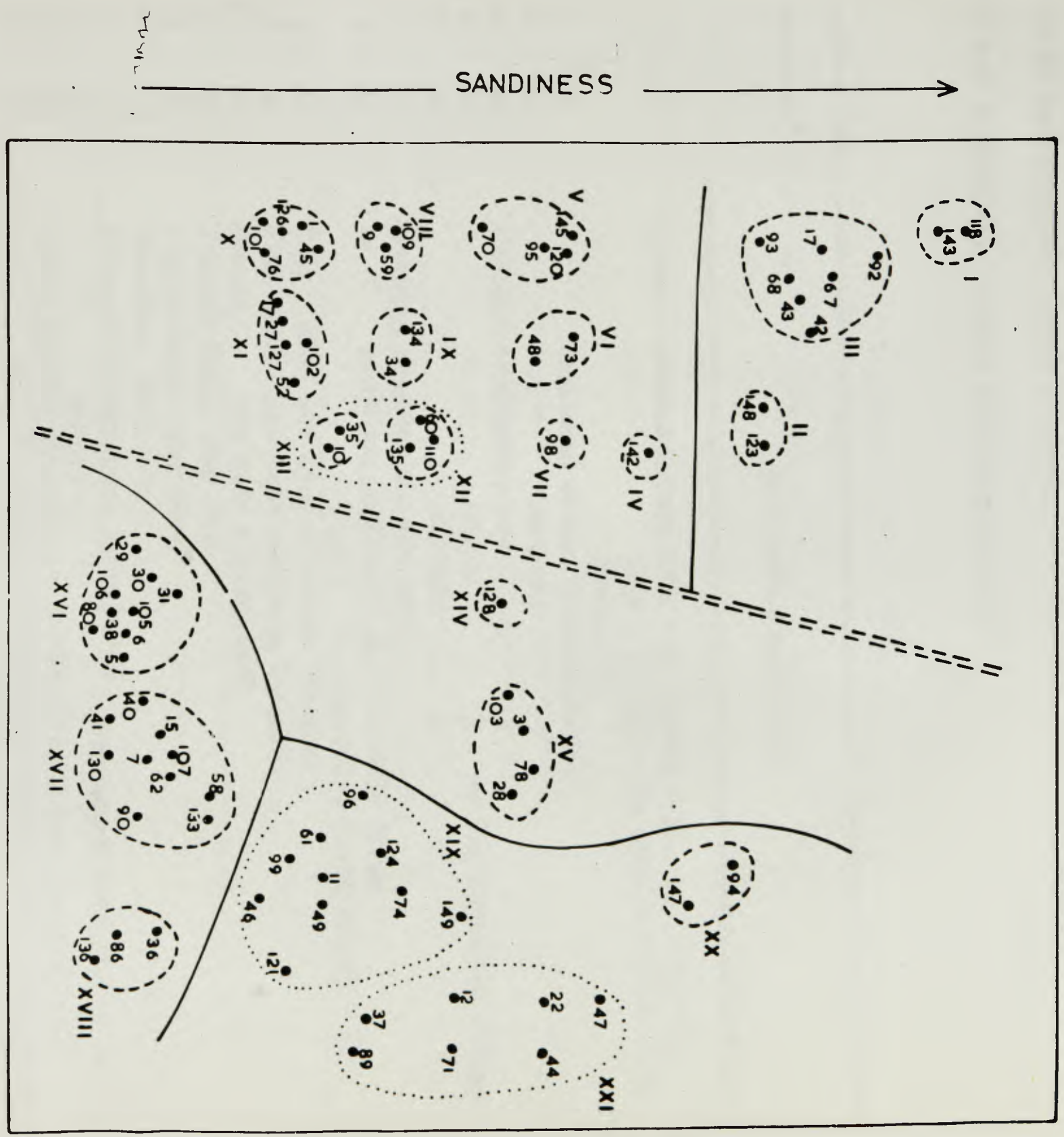



Fig. 4.1
The intuitive classification. The enclosing lines show relationships at different levels of generalization

Table 4.1 - A list of properties for which data were available, and their number and codes used for the classification and ordination of the 85 soil profiles. Each property was recorded for both topsoil (I) and subsoil (II), unless otherwise stated.

| Number I | Number II | Properties and Codes |
|---|---|---|
| 1 | 20 | Colour: dominant hue, 10R = 1, 2.5YR = 2; . . . 5Y = 7; 5GY = 11; 5G = 15; 5BG = 19; 5B = 23, Black = 0. |
| 2 | 21 | dominant value, Munsell scale |
| 3 | 22 | " Chroma, " " |
| 4 | 23 | Colour: subsidiary hue ) |
| 5 | 24 | value ) as for dominant colour |
| 6 | 25 | chroma ) |
| 7 | 26 | Mottling abundance, per cent |
| 8 | 27 | " position, uniform = 0, structure faces grey = 1, structure faces brown = 2. |
| 9 | 28 | Clay silt, per cent of <2mm fraction |
| 10 | 29 | Fine sand, per cent of <2mm fraction |
| 11 | 30 | Stones, per cent of total soil |
| 12 | 31 | Plastic limit, per cent |
| 13 | 32 | Liquid limit, per cent |
| 14 | 33 | Reaction, pH |
| 15 | 34 | Strength in summer, cone index ) averaged over period stated |
| 16 | 35 | " " winter , " " ) |
| 17 | 36 | Water tension in summer ) Normalised (see Beckett and |
| 18 | 37 | " " " winter ) Webster 1965b), and averaged as for strength. |
| 19 | 38 | Peatyness, present = 1, absent = 0 (applied to topsoil only) |

Table 4.2 - The intuitive classification at three levels of generalisation.

| Series or family | Sub-group | Main Group |
|---|---|---|
| I<br>II<br>III | Deep Sandy Brown Earths over Sandstone | |
| IV<br>V<br>VI<br>VII<br>VIII<br>IX<br>X | Shallow, Brown Calcareous soils over Limestone or Limestone gravel | Brown Earths |
| XI | Deep, Brown Calcareous soil over Head | |
| XII<br>XIII | More or less Gleyed Calcareous soil over Limestone gravel | |
| XIV<br>XV | Moderately Gleyed Loamy Alluvium | |
| XVI<br>XVII<br>XVIII | Gleyed Clay with more or less Drift influence | Gleys |
| XIX<br>XX<br>XXI | Very Gleyed soil of variable texture, mainly on Alluvium. | |

Principal component analysis was carried out using standardization of the elements of the eigenvectors so that $\sum_{i=1}^{p} a_i^2 = 1$, and standardization of property values to zero mean and unit variance. For full details on the method see Chapter III.

B. Similarity analysis. As explained in Chapter III, the stability of the classifications obtained from Similarity analysis was used to test the degree of definition of the points in Property space. The standardization of the property values, the similarity index, and the sorting strategies are given below.

a. Standardization of property values. The property values were standardized in two different ways.

i. Standardization of each property to zero mean and unit variance.

ii. Standardization of each property within the range zero to one.

b. Similarity index. A function of Euclidian distance was used as a dissimilarity index, a form of the average square distance of Sokal and Sneath (1963), namely

$$D_{ik} = \frac{1}{p} \sum_{j=1}^{p} (X_{ij} - X_{kj})^2$$

where $D_{ik}$ is the dissimilarity between the i'th and k'th profile; p is the number of properties per soil profile; $X_{ij}$ is the value of the j'th property for the i'th profile. Since this is an inverse measure of similarity — the greater the similarity the smaller is D — it was scaled to lie between 0 and 1 then subtracted from 1. The resultant similarity index, $S_{ik}$, was

thus equal to 1 for identity and closest to 0 for maximum dissimilarity. After this similarity index was chosen, Moore and Russell (1967) recommended the use of this index.

c. Sorting strategies. Two sorting strategies were used, namely Sokal and Michener's (1958) weighted pair group, and their un-weighted pair group. They were chosen because theoretically they are likely to lead to different results only on the last stages of grouping, and therefore give a test for the presence of clusters of clusters at different levels of abstraction. However, it was later realized that these strategies will give different results only if the groups are not clustered at different levels of abstraction, and only if the clusters are unequal in size.

4. Results.

A. Principal Component analysis. The propertion of the total variation taken up by the first six components is listed in table 4.3. The first eigenvalue is much the largest, and accounts for 29.7 per cent of the total variation. The second principal component accounts for 14.5 per cent, so that the two together represent 44.15 per cent, which is equivalent to 16 soil properties.

The components do not have a precise physical meaning, but the values of elements of the eigenvectors give some idea as to which properties contribute most to them.

In Fig. 4.2, the values of the first eigenvector are plotted against those of the second for each of the 36 properties, to produce a scatter

Table 4.3 - The eigenvalues, the percentage of the variation taken up by the first six principal components, and their cumulative percentage.

| Order | Eigenvalues | % Total Variation | Cumulative % |
|---|---|---|---|
| 1 | 11.00 | 29.74 | 29.74 |
| 2 | 5.37 | 14.51 | 44.25 |
| 3 | 2.86 | 7.74 | 51.99 |
| 4 | 2.66 | 7.19 | 59.18 |
| 5 | 2.23 | 5.76 | 64.93 |
| 6 | 1.52 | 4.10 | 69.03 |

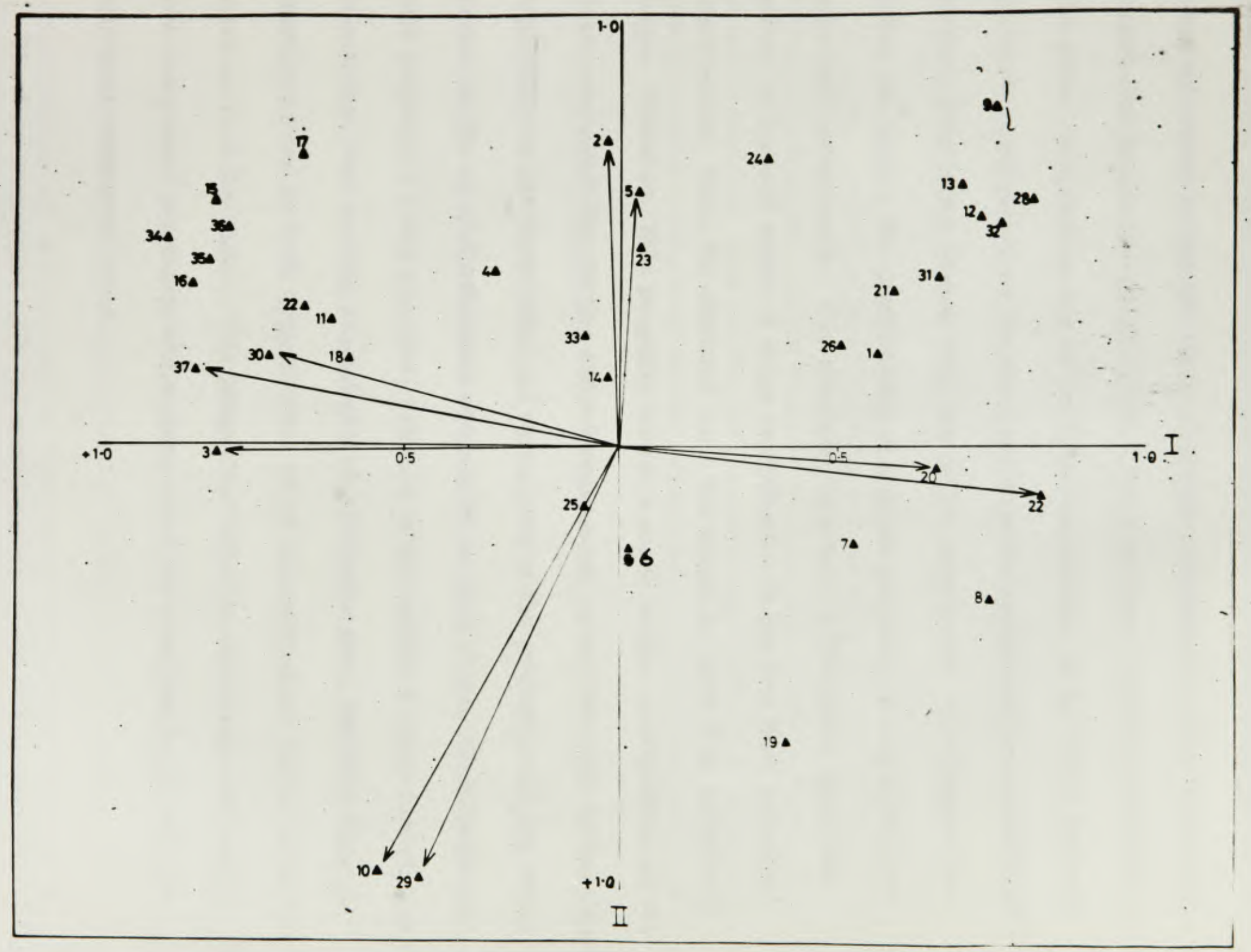



Fig. 4.2 Scatter diagram, in which the elements of the first eigenvector (I) are plotted against those of the second eigenvector (II).

diagram. The distance from the origin to any of these points defines a vector whose length is a direct function of the relative contribution each property makes to the two first principal components. The larger the length, the larger the contribution. Furthermore, the net contribution of a given property to one of the two components, is the ratio between the vector projection on the component under consideration, and the projection of the same vector over the other component. The bigger the ratio, the larger the contribution of a given property to one of the two principal components. For example, property 3 (Chroma, dominant colour of topsoil) makes a large contribution to the two first principal components, since the distance from the origin to point 3 is relatively large. However, this property makes a much larger contribution on the first component than to the second component, since the ratio of the vector projection on the first principal component to the projection of the same vector on the second principal component is very large. This contrasts with property 9 (clay per cent, subsoil) which makes a large contribution to both the first and the second principal components, but it is almost equally shared by both components, since the projection ration on both is more or less the same. The properties with the maximum net contribution to a component are those whose axes make the smallest angle with the principal component axes.

The four properties with the maximum net contribution for each of the first two first components have been drawn as vectors in Fig. 4.2. The values of the first principal component are directly proportional to the values of position of mottles in the subsoil, and the hue of the dominant subsoil colour. They are inversely proportional to the chroma of subsoil

dominant colour, and to topsoil water tension during the winter. The values of the second principal component are directly proportional to the value of both topsoil and subsoil dominant colour, and inversely proportional to percentage of sand in both topsoil and subsoil. Therefore, the value of the first principal component increase as the wetness of the soil increases; the values of the second principal component increase as the percentage of sand content increases.

Fig. 4.3 shows the results obtained by plotting the values of the first principal component against those of the second principal component, for each soil profile. This scatter diagram shows a fairly even distribution of soil profiles in Property space, except for a gap in the upper middle part.

B. Similarity analysis. The dendrogram produced by the un-weighted pair-group and the weighted pair-group are given in Figs. 4.4 and 4.5 respectively. In both cases the properties were standardized in the range zero to one. Fig. 4.6 shows the dendrogram produced by the un-weighted pair-group, but the properties were standardized to zero mean and unit variance. To facilitate comparison between the figures, each stem of a dendrogram has been given a letter, and I shall refer to each stem by a letter proceeded by the number of the figure. There is very good correspondence between the dendrograms produced by the two sorting strategies. Correspondence is between stems 4.4C and 4.5; 4.4D and 4.5D; 4.4J and 4.5L; 4.4I and 4.5K; 4.4H and 4.5I; 4.4G; and 4.5H, and finally 4.4F and 4.5F. The only difference between the two dendrograms is between stems 4.4E and 4.5E. Here 4.5E becomes a sub-stem of 4.4E.

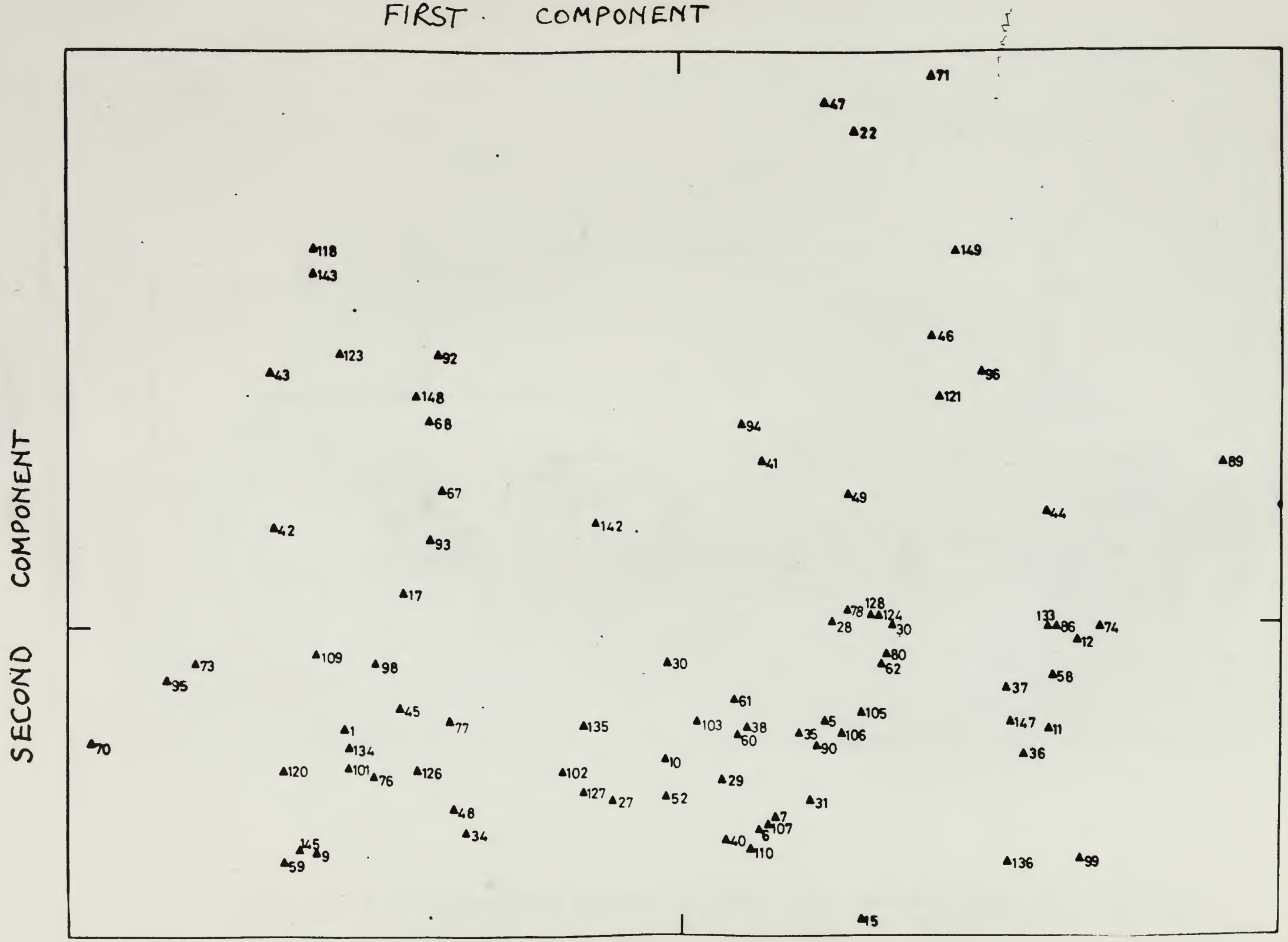



Fig. 4.3 Scatter diagram

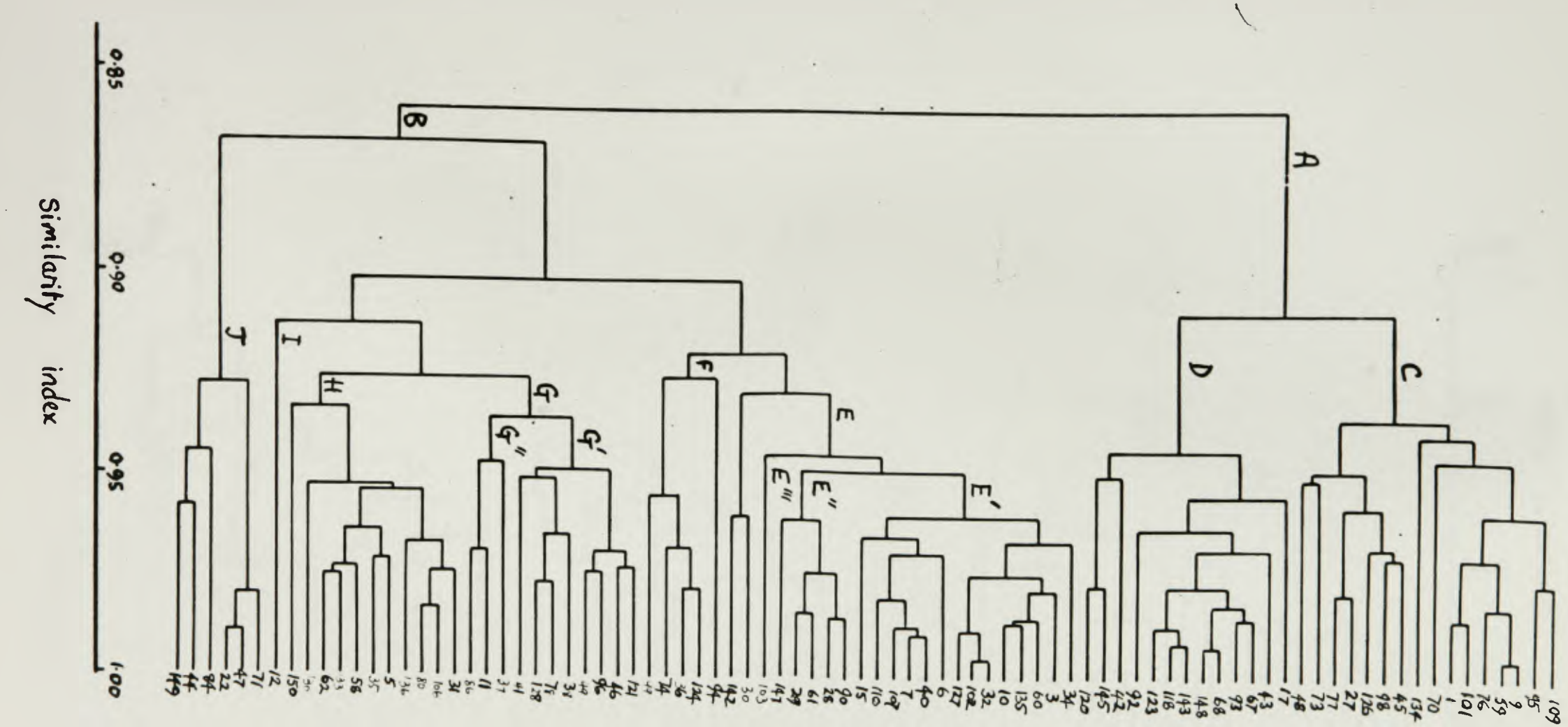



Fig. 4.4 Dendrogram produced from the un-weighted pair group sorting strategy with properties standardized in the ramge 0 to 1.

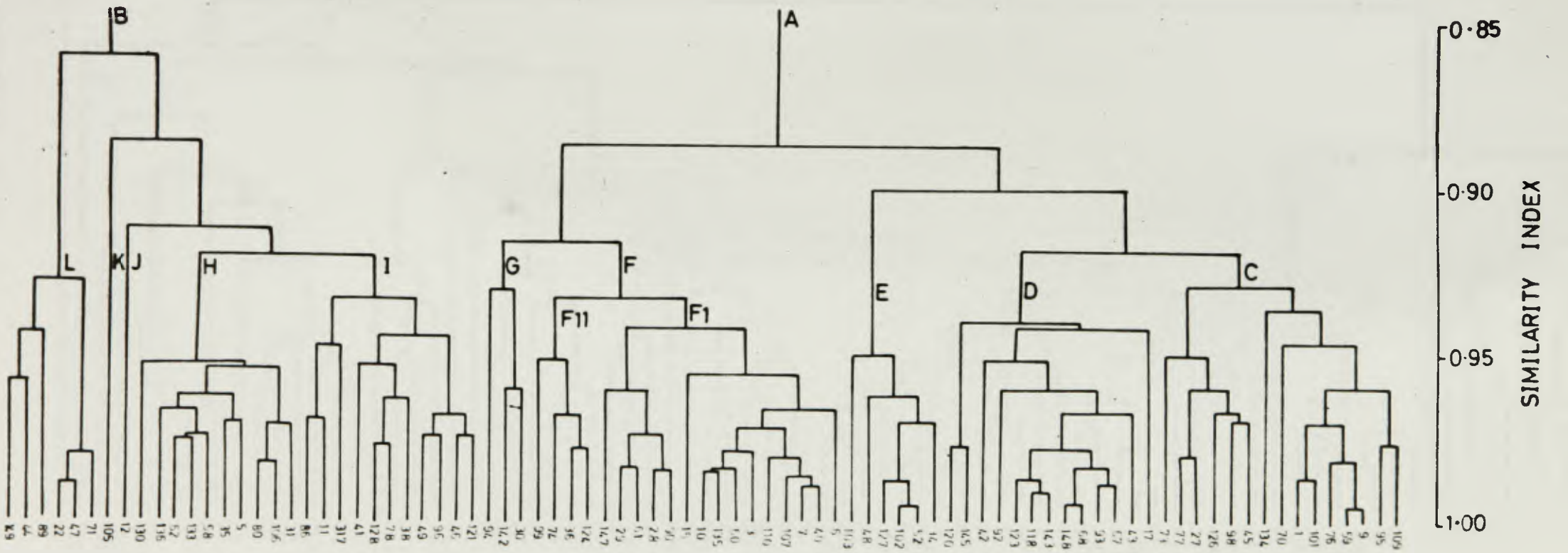



Fig. 4.5 Dendrogram produced from weighted pair group sorting strategy and property standardization in the range 0 te 1.

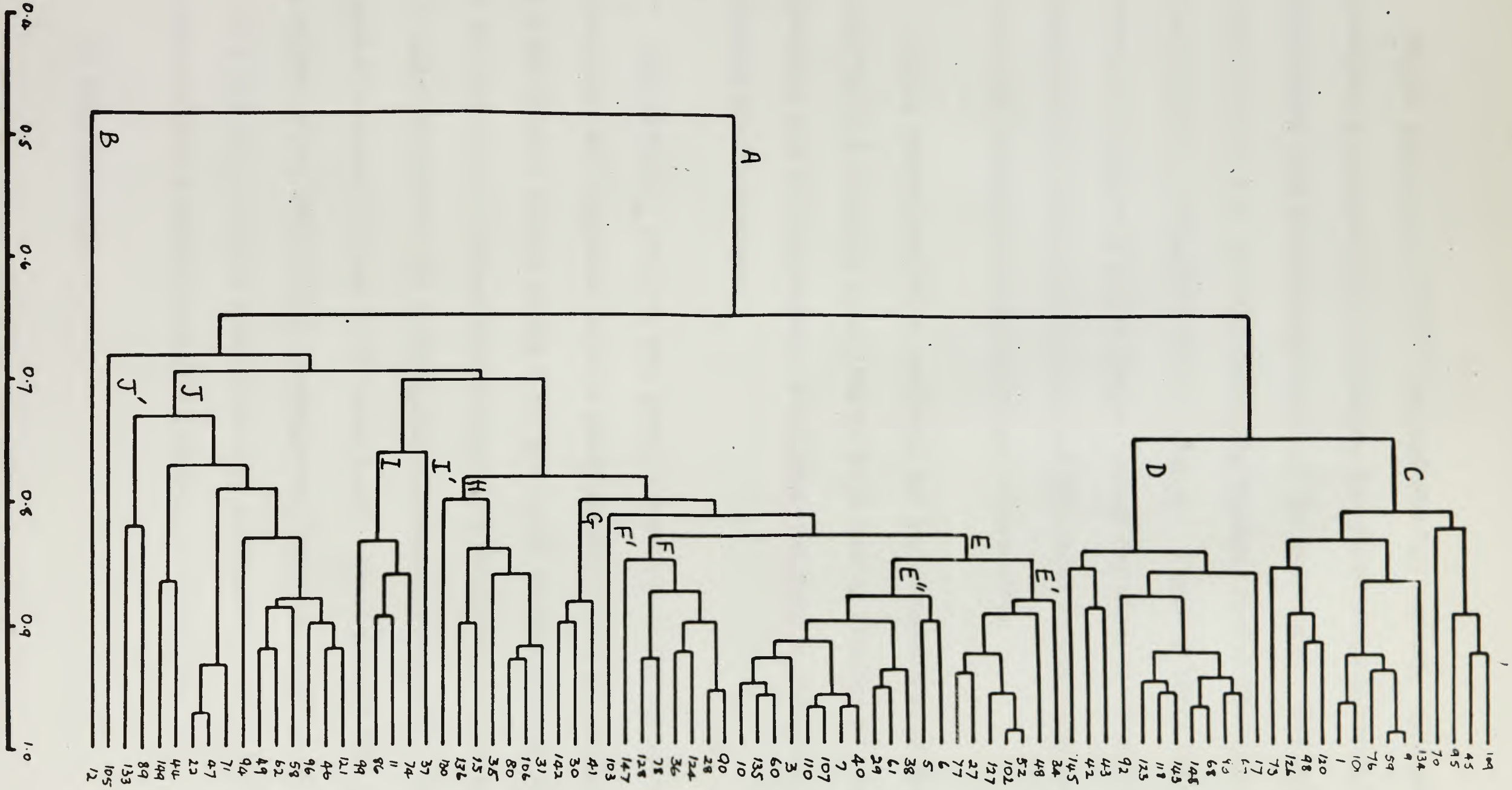



Fig. 4.6 Dendrogram produced for un-weighted pair group sorting strategy property standardization to zero mean and unit variance.

Moore and Russell (1967) obtained similar results; different sorting strategies generated similar groups, and differences between the dendrograms were less at the lower levels of the hierarchy. The comparison between Figs. 4.4. and 4.6 shows the changes in the classification induced by altering the standardization procedure. There is little correspondence between the stems of either figure, except for stem 4.4C which clearly corresponds to stem 4.6, and stem 4.4D which corresponds to 4.6. The rest of the profiles have been grouped differently.

At the lowest level of similarity, the correspondence between Fig. 4.4. and Fig. 4.6 is rather good, but as explained in Chapter III (see Similarity analysis) this correspondence diminishes as more individuals are incorporated into the groups.

For instance, the first two profiles that join at the lowest level of similarity are the same for both dendrograms. That is, profiles 9 and 59 are the first to join in stems 4.4C and 4.6C; profiles 52 and 102 in stems 4.4E' and 4.6E', and profiles 47 and 22 in stems 4.4J and 4.6J. However, as fusion proceeds, the correspondence decreases rapidly. This can be seen by comparing stem 4.4E' with 4.6E'. Here profile 127 joins the profiles 52 and 102 in both dendrograms, but later profiles 10, 135, 60, and 3 join this group in stem 4.4E', in contrast to stem 4.6E' where fusion proceeds with profiles 27 and 77 followed by 48 and 34.

C. Comparisons.

A comparison between the results of Principal Component analysis and the intuitive classification is given in Fig. 4.7. Here the profiles are

FIRST COMPONENT

SECOND COMPONENT

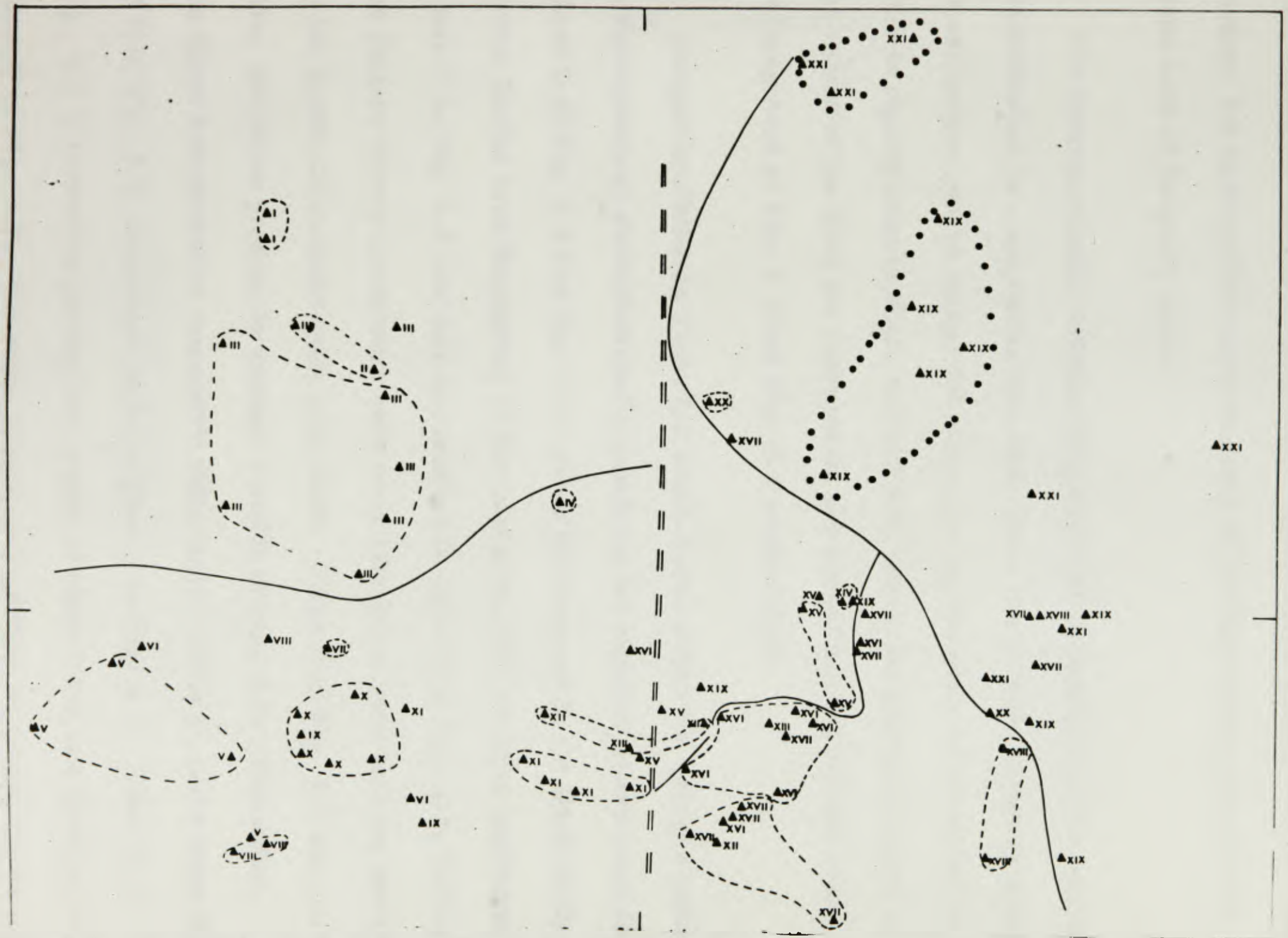


Fig. 4.7 Comparison between the numerical ordination and the intuitive classification, at different levels of abstraction

located by the values of the two first principal components, but are named after the groups defined by the intuitive classification. The enclosing lines attempt to delimit these groups. The correspondence is by no means perfect, but each profile and each group of profiles tends to occupy the same area of Property space.

The correspondence between the numerical ordination and the numerical classification is much better than this, since the groups formed by numerical classification tend to occupy the same area on the plane of the ordination. This is clearly seen in Figs. 4.8 and 4.9, where the profiles located by the values of the first two components are given the stem letters of the dendrograms of Fig. 4.4 and Fig. 4.6 respectively.

Comparison between Figs. 4.8 and 4.9 also shows the changes induced in the numerical classification by modifying the standardization procedure. Class D of Fig. 4.8 and Fig. 4.9, which corresponds to the Deep Sandy Brown Earths over Sandstone, is the only group that remains unaffected. Class C in Fig. 4.8 has lost two profiles to class E of Fig. 4.9, that is the Shallow Brown Calcareous soils over Limestone have lost two profiles to the Brown Calcareous soils over Head. Class E of Fig. 4.8 has, in turn, lost some profiles to classes E and H of Fig. 4.9. Thereafter, the Gleys are classified completely differently. Class J, and a large part of G of Fig. 4.8, is grouped to form class J in Fig. 4.9. Class G of Fig. 4.9 is formed by joining one profile of class G and two profiles of class E of Fig. 4.8. The same joining and splitting of groups can be seen in the remaining soil profiles.

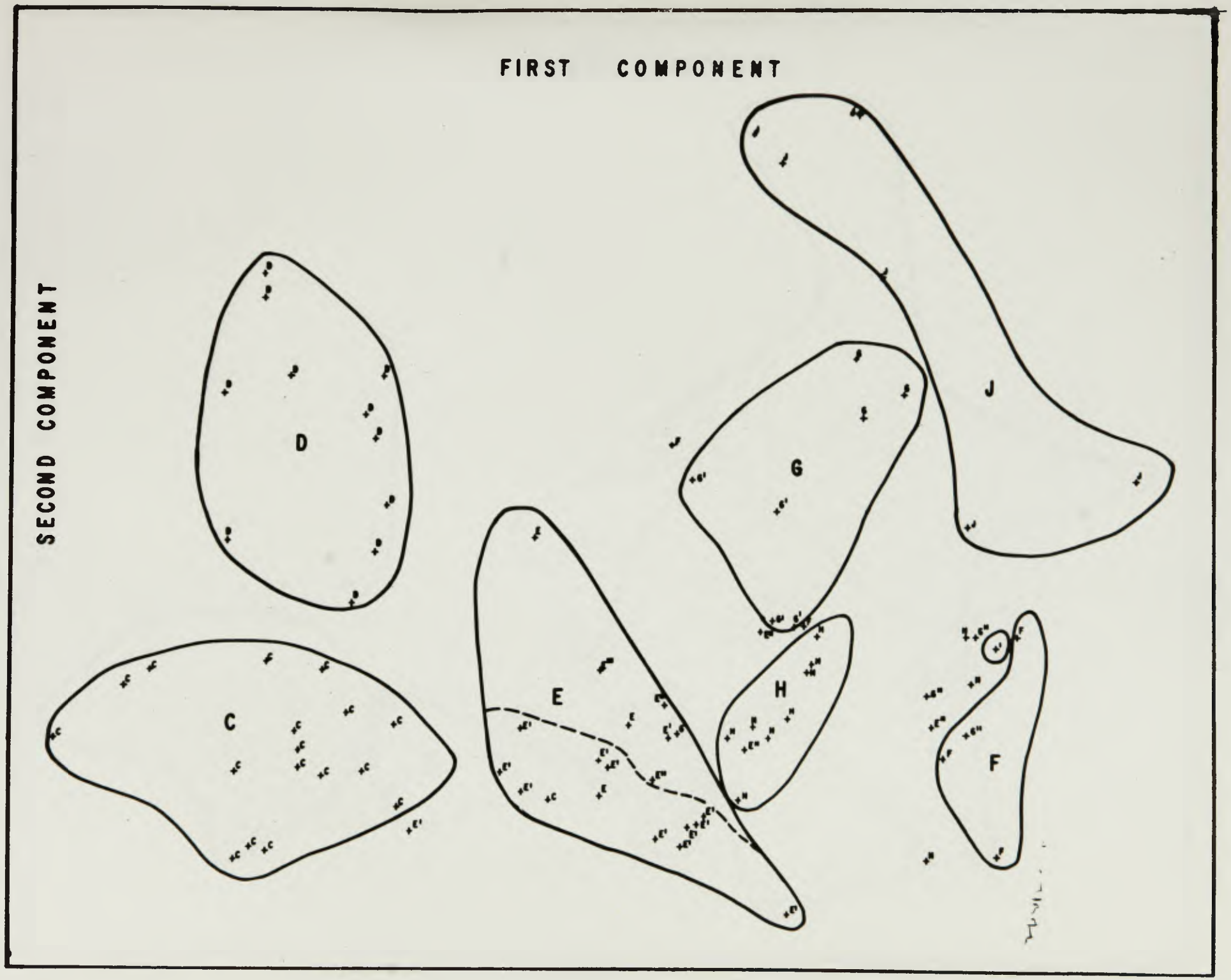



Fig. 4.8 Comparison between the numerical ordination and the numerical classification of Fig. 4.4 (un-weighted pair group and standardization in the range 0 to 1)

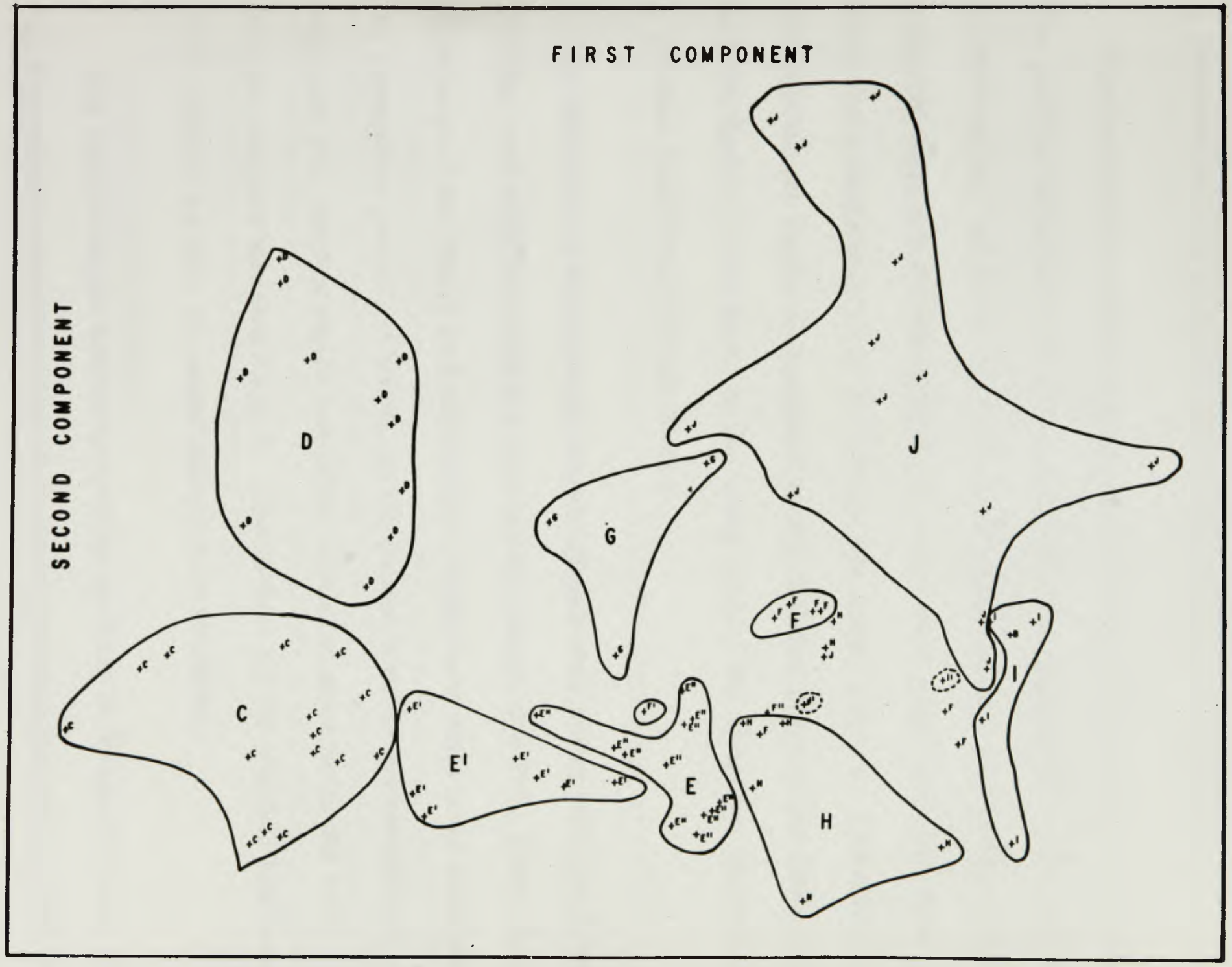



Fig. 4.9 Comparison between the numerical ordination and the numerical classification of Fig 4.6 (Un-weighted pair group and standardization to zero, mean unit variance)

5. Discussion.

The intuitive classification of Fig. 4.1 envisages a set of soil profiles in Property space, grouped into fairly well defined clusters.

The ordination by Principal Component analysis of Fig. 4.7 locates the profiles more or less in the same relative position as in the intuitive classification, but it also shows a striking difference, namely the most complete absence of well defined clusters. Property space as viewed from the ordination of Fig. 4.7 shows few empty spaces. The most noticeable empty space corresponds to the division between the Brown Earths and the Gleys. Even then, in the lower part of the diagram, there is only a gradual transition between them.;

At the level of Sub-groups, empty spaces only occur with the Brown Earths, and correspond to the separation between the Deep Sandy Brown Earths over Sandstone and the Shallow Calcareous soils over Limestone or Limestone gravel. Finally, at the lowest level of generalization, there are only two classes which are fairly well separated from the rest. They are the classes labelled I and V. Thereafter all the classes intermingle with others, or have no empty spaces between them.

The lack of empty spaces to delimit clusters in Property space may be due either to the alteration of distances between the points, induced by projecting points in 37 dimensions on to a plane, or to the loosely clustered nature of the real profile population in Property space.

Similarity analysis throws some light on this issue, especially at the level of Groups and Sub-groups. The dendrograms obtained when the standardization procedure is changed give rise to very much the same groups, namely the Brown Earths and the Gleys. However, in the dendrograms all the more or less Gleyed Calcareous soils over Limestone, and most of the Deep Brown Calcareous soils over Head of the intuitive classification, are considered within the Gleys. At the level of Sub-group both dendrograms form more or less the same number of classes, but the profiles that make up each of these classes vary considerably, except for Deep Brown Earths over Sandstone and to a lesser extent the Shallow Brown Calcareous soils over Limestone.

Thus, the general picture which emerges from the study of these profiles is that of a weakly clustered population of Brown Earths. For the Gleys there is no evidence of clustering.

Consequently, the results of numerical ordination and numerical classification together strongly suggest that the clustered structure of the profiles population in Property space envisaged by the intuitive classification is an imaginary ideal more than an actual fact.

6. Preliminary conclusions

The Euclidian framework is a reasonable and surprisingly simple numerical model for the study of soil systematics.

Most soil properties can be coded sensibly as variables having the attributes of order and interval, so that the codes conform to an Euclidian model.

The intuitive classification assumes that soil profiles form well defined clusters in Property space. The numerical results, on the contrary, show a population of fairly evenly spread soil profiles in Property space with only occasional well defined clusters.

These conclusions inspired me with confidence to carry out the main study, which is described in Chapter V.

# CHAPTER V

## The investigation of Property-Geographic space

### The Main Study

### 1. Introduction

The previous chapter showed that numerical ordination and classification could be used profitably to study the distribution structure of soil profiles in Property space.

Therefore, the concept of Soil Series classifications units conceived by Cline (1949), in terms of clusters, could now be tested empirically. The empirical test was extended to the geographic counterpart of the Soil Series classification units, that is Soil Series mapping units. As explained in Chapter II, for the Soil Series classification units to form clusters in Property space, the Soil Series mapping units should appear as horizontal or sloping hyper-planes, separated by a vertical or almost vertical hyper-plane.

Pomerening and Knox (1962) had already shown that a set of profiles sampled along a transect form modes. They found modes, however, because they followed a circular argument. This is clear when their methodology is analyzed. They first grouped a set of soil profiles into five Soil Series classification units. Then they searched for those properties which presented the largest differences between the means of the classes. Later, using these selected properties, they ran a Discriminant analysis, and found that the values of two discriminant functions formed modes which separated Soil Series classification units.

This means that they did not search for classes in the set of profiles they used, since they started by grouping the soil profiles into classes. Neither did they think of classes for a General Purpose classification, i.e. Soil Series classes, since they first selected those properties whose means showed the largest differences between classes. Finally, they did not produce a classification using Discriminant analysis, but instead found the best multivariate numerical key to the groups they had already defined. Consequently, when they show that the discriminant function values have a multimodal distribution, and that each mode corresponds to one Soil Series profile class, they are showing that this is a good way to define a multivariate numerical key of Soil Series, but they are not demonstrating that Soil Series profile classes form modes or clusters in Property space.

Ideally, the above concepts of Soil Series classification units as clusters should be tested empirically where the soil has already been surveyed, and consequently where the Soil Series classification and mapping units have been defined. Several localities of the same surface area, and containing the same, and only the same, Soil Series, should be selected, each Series covering an approximately equal area. The localities should cover the whole range of soil property variation in each Soil Series.

A very dense soil sampling procedure would be ideal to cover the whole range of soil property variation for each sampled locality. At all sampling points a profile description should be made, and soil samples taken to be analyzed in the laboratory, to increase the precision of field assessment.

After considering limitations of time, money, field access, and computer space, I chose a scheme that though less ambitious than that above, would nevertheless allow me to study the problem.

A locality within a reasonable distance, less than 30 Km, from Oxford, possessing 6 to 10 Soil Series over a relatively short distance was sought. There was no Soil Memoir of the area, but Mr. M.G. Jarvis, of the Soil Survey of England and Wales, responsible for the area, offered to identify the Soil Series and, if necessary, define new ones. The sampling area chosen belongs to only a few land owners, making it easy to obtain permission for access to the land, and the study was reduced to a single transect, so as to minimise the number of Soil profiles needed.

The soil was sampled systematically and an intensity chosen to give 20 to 30 soil profiles for each Soil Series. It was also decided to describe soil profiles and estimate the properties in the field, since limitations in resources did not allow laboratory determinations to be made.

2. <u>The Area and the Data</u>.

The area chosen for study lies on the north edge of the Cotswolds plateau, 25 Km north-northwest of Oxford. Here, five sedimentary geological formations outcrop; they are from youngest to oldest, Great Oolite, Inferior Oolite, Northampton Sands, Upper Lias, Middle Lias, and Lower Lias. The general dip is about $1^{\circ}$ to the southeast, but faulting and dissection make the sequence of the outcrop more complex.

After preliminary exploration a linear transect was drawn in the direction of the dip, so that it would cross as many variations in soil properties as possible within a manageable distance. Small adjustments were made to the transect to avoid damage to crops. The transect was 3.2 Km long and its position is shown in Map 1 (see back cover).

Pits were dug every ten metres, making a total of 321. Most of them were dug by a mechanical excavator. 20 to 30 pits were dug at a time, in 4 to 5 hours, and then covered with strong plywood boards. Each pit was between 1.1 to 1.3 m long, 0.40 to 0.45 m wide, and 0.85 to 1.10 m deep. Profile descriptions were made within one to two weeks of digging.

Each soil profile was described by recording soil properties at 3 depths in layers 5 to 6 cm thick, on a newly exposed face. The depths given below refer to the distance between the ground surface and the middle of each of these layers. The first layer was recorded, in most cases, at 8 cm. The recordings varied, however, between 6 to 12 cm. When the plough layer was equal to or less than 15 cm, the recordings were made at 6 cm. When the plough layer was equal to or more than 25 cm, or there was no plough layer and organic matter had accumulated in the first 4 to 6 cm, recordings were made at a depth greater than 8 cm. The third layer was recorded at depths between 47 and 82 cm, the deeper the soil the deeper the observation. The depth below which I considered the properties of the soil to be constant was recorded between 50 and 65 cm; soils on Northampton Sands and Upper and Middle Lias were mainly recorded at depths between 68 and 75 cm. The depth at which the second layer was recorded

was chosen so that it showed a maximum contrast both to the first and to the third layers. This depth was mainly between 29 and 32 cm, but in extreme cases, 22 cm and 40 cm. Layers of broken rocks less than 5 cm thick, at depths greater than 30 cm, were not taken to be contrasting layers.

The soil was described at each pit using the headings provided by the Soil Survey Staff of Great Britain (1960). Numerical scales were used as far as possible, and for several properties the adjectival descriptions were converted to numerical terms.

The following properties were recorded at each pit:

1. Pit number
2. Date
3. Locality
4. Underlying rock
5. Total depth of pit
6. Profile drainage

At each depth the following observations were made:

7. Horizon, thickness
8. Observation depth
9. Length of horizon transition
10. Moisture content
11. Dominant colour
12. Mottles colour

} Hue, value chroma, on Munsell scale

13. Mottles location
14. Mottles size
15. Mottles per cent
16. Texture class (by feel)
17. Clay per cent " "
18. Silt per cent " "
19. Sand per cent " "
20. Organic matter per cent (by feel and colour)
21. Stones per cent
22. Stones size
23. Stones shape
24. Stones kind
25. Structure development
26. Structure shape
27. Structure size

28. Consistency
29. Number of pores and fissures
30. Diameter of pores
31. Width of fissures
32. Pore orientation
33. Permeability
34. Presence of primary pedological concentrations
35. Form of pedological concentrations, if present
36. Concentration per cent
37. Concentration composition (carbonates, manganiferous concretions)
38. Reaction (pH) in solution (indicator paper Whatman BDH narrow range)

From these properties 63 variables were used to characterize a soil profile. The variables, together with their numbers and codes, are given in Table 5.1. Mr. M. G. Jarvis defined, intuitively, the Soil Series classification and mapping units of the transect under study. He had not mapped previously in this area, and consciously considered only the soil properties observed along the transect in order to define the Soil Series. Consequently only the variation observed in the area, but constrained by systematic coarse groups, was considered in the Soil Series. The Soil Series he produced are given in Figs. 5.1 and 5.2. Figs. 5.1 and 5.2 give the underlying geological material too.

## 3. Numerical Methods

In order to analyze and display the results, the following numerical methods and graphical procedures were used; Principal Component analysis, Order neighbour statistics, Mode analysis, Similarity analysis, Smoothing by Moving Average method, Correlogram analysis, and the graphic representation of soil properties with distance. These procedures were used on 321 profiles, except in Mode analysis and Similarity analysis, where the rapidly accessible computer storage needed for the analysis

Table 5.1 - List of properties, their number and their codes used in this study, for 321 soil profiles. Each property was recorded at three depths I, II, and III, except Structure dimensionality for depth I, which was a constant, and Profile drainage.

| Depth I | Depth II | Depth III | |
|---|---|---|---|
| 1 | 21 | 42 | Colour: Dominant hue; 10R=1, 2.5YR=2. . . 5Y=7; 7.5Y=N=8, 10Y=9, 2.5GR to 10GY=10 |
| 2 | 22 | 43 | " " chroma; Munsell scale |
| 3 | 28 | 44 | " " value ; Munsell scale |
| 4 | 24 | 45 | Colour: Mottles hue |
| 5 | 25 | 46 | " " chroma as for dominant colour |
| 6 | 26 | 47 | " " value |
| 7 | 27 | 48 | " " per cent |
| 8 | 28 | 49 | Fraction less than 2 mm. Clay per cent |
| 9 | 29 | 50 | " " " " Silt per cent |
| 10 | 30 | 51 | Organic matter per cent |
| 11 | 31 | 52 | Stones per cent |
| 12 | 32 | 53 | Stones size cm |
| 13 | 33 | 54 | Structure development; structureless=0, weakly=1 . . . strongly=3 |
| | 34 | 55 | " dimensionality; equidistant=single grain=0 elongated=1 |
| 14 | 35 | 56 | " angularity; rounded=single grain=0, subangular=1, angular=massive=2 |
| 15 | 36 | 57 | " size mm |
| 16 | 37 | 58 | Consistency, non sticky-non plastic=loose=0 non-sticky-slightly plastic=very friable=soft=1 slightly to very sticky-slightly plastic=friable=slightly hard=2 slightly-plastic=firm=hard=3 sticky-very plastic=very firm=4 very sticky-very plastic=extremely firm = very hard=5 |
| 17 | 38 | 59 | Permeability; very rapid=0, rapid=2 . . . very slow=4 |
| 18 | 39 | 60 | Manganese per cent |
| 19 | 40 | 61 | Carbonates per cent |
| 20 | 41 | 62 | Reaction (pH) |
| | | 63 | Profile drainage; excessive=0, freely=1, imperfect=2 poorly=3, very poorly=4 |

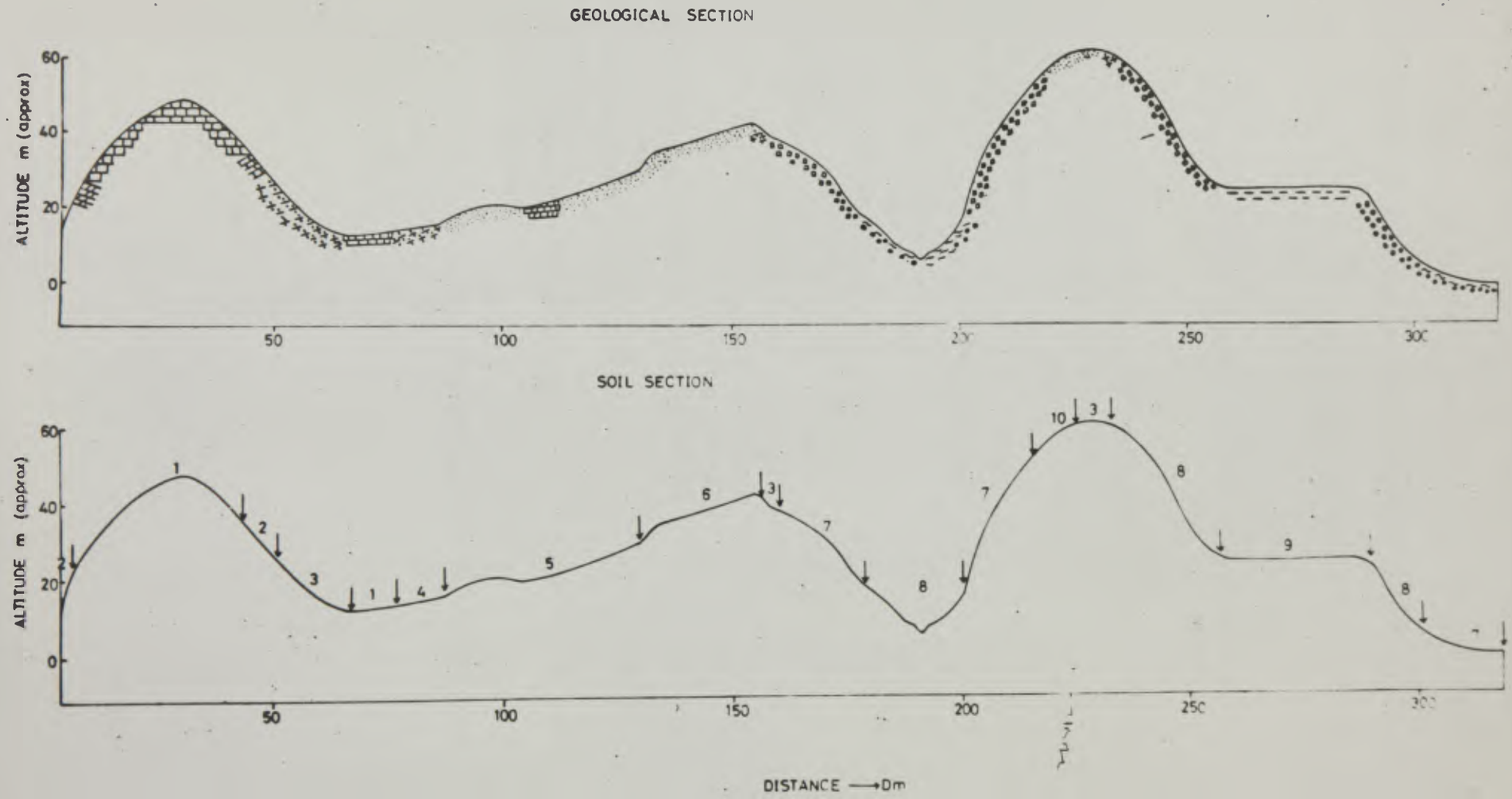
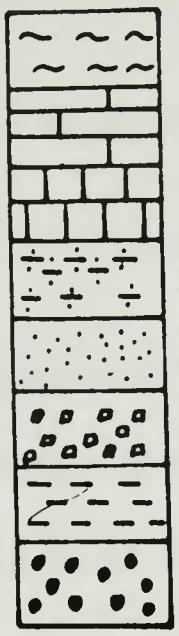



Fig. 5.1 Longitudinal section of the transect




1.— SHALLOW, BROWN CALCAREOUS OVER LIMESTONE, LOAMY

2.— GLEYED CALCAREOUS LOAMY OVER CLAY.

3.— ARGILLIC BROWN EARTH, LOAMY:

4.— BROWN CALCAREOUS, LOAMY.

5.— ACID BROWN EARTH, COARSE LOAMY OR SANDY.

6.— GLEYED BROWN EARTH, COARSE LOAMY OR SANDY.

7.— SURFACE WATER GLEYED, CLAYEY

8.— GLEYED BROWN EARTH, LOAMY OVER CLAY

9.— SHALLOW RANKER OVER IRONSTONE

10.— FERRITIC BROWN EARTH LOAMY

Fig. 5.2 Key to Fig. 5.1

increases with the square of the number of profiles used. In this case alternate profiles, making a total of 161, were used, which was equivalent to increasing the distance between profiles from 10 to 20 m.

Full details of these are given in Chapter III, and only a short resume is given here.

A. Principal Component analysis. This analysis was used to represent as much of the variation between soil properties as was possible, in a few uncorrelated variables called principal components.

B. Order Neighbour statistics. This method was used to estimate the distribution pattern of points on a plane, from the knowledge of the distance of each point to its neighbour of all orders. These distances are related to the distribution of $\chi^2$. Consequently, the presence of clusters can be detected.

C. Mode analysis. Mode analysis as a classification method identifies and isolates the elements belonging to hyper-spheres of high point density, that is, clusters.

D. Similarity analysis. Similarity analysis was carried out using the un-weighted pair group sorting strategy, the squared taxonomic distance as a similarity index, and two standardizations of property values. These were standardization to zero mean and unit variance, and standardization between the range zero to one. A small modification was introduced, namely that the dissimilarity index for standardization to zero mean and unit variance was not transformed to a similarity index.

E. Smoothing by Moving Average. Smoothing by a five point Linear moving average was employed to remove local variation, and thus reveal the most consistent soil variation associated with changes in geographic locations.

F. Correlogram analysis. Correlogram analysis was used to estimate the form, the magnitude, and distance over which there were spatial relationships of soil properties. This was done by computing the auto-correlation co-efficient between pairs of the same soil property along the transect, these pairs being displaced by a distance 0, 1, 2. . . . n.

## 4. Results

To make the results clear they are presented in two groups, (A) results of Property space and (B) results of Property-Geographic space. Some results of Principal Component analysis are, however, relevant to both, and these are presented with those of Property space.

A. Property space.

(a) Principal Component analysis. Principal component analysis was used mainly to study the distribution pattern of the 321 points in two or three dimensions, instead of in the 63 dimensions of Property space. This analysis also gives the variance accounted for by each principal component. This information will be presented first.

Principal Component analysis was performed both on all 321 profiles, and on 161 alternate soil profiles (odd numbers). Four Principal Component analyses on 321 profiles resulted from the combination of two standardizations of the elements of the eigenvectors, with two standardizations of the property values.

Standardizations of the eigenvectors were:

(i) Standardization of the elements of the eigenvectors so that

$$\max \sum_{i=1}^{p} a_i = 1.$$ (For notation see Principal Component analysis, Chapter III). This standardization is called M.

(ii) Standardization of the elements of the eigenvectors so that

$$\sum_{i=1}^{p} a_i^2 = 1.$$ This standardization is called S.

Principal Component analyses with standardization M were carried out first, and the results used in further numerical analysis. It was not until Rayner and Beckett, (1970), commented that this standardization could induce undesirable distortions in the model, that the principal component with standardization S was tried. A mistake in the data was noticed too, the reaction (pH) in profile 25 at depth III had a value of 80.0 instead of 8.0. The corrected data tape was used in the Principal Component analysis, using standardization S. These results are used to test the empirical findings of Méndez Ramírez (1970) (see Principal Component analysis, Chapter III), and the effect of the mistake in the pH value on the results.

Two different standardizations of property values were tried to test the stability of numerical ordination produced by Principal Component analysis. The standardization procedures were the same as those used in Similarity analysis in Chapter IV, namely:

(i) Standardization of each property to zero mean and unit variance; thus the values of each property of each profile were expressed in units of standard derivations about their mean. This standardization is called I.

(ii) Standardization of each property in the range zero to one, making the smallest value of property zero, and the largest, one. This standardization is called II.

The proportion of the total variation accounted for by the first eight principal components, their cumulative percentage, and their corresponding eigenvalues, are given in tables 5.2 and 5.3 for the five Principal Component analyses performed. That is, analyses with 321 soil profiles and standardizations SI, SII, MI, and MII, and analysis with 161 soil profiles with standardization MI.

A comparison of table 5.2 with the top two thirds of table 5.3 shows very much the same values. The small differences are due to a mistake in the data tape (reaction pH in profile 25 depth III was punched 80.0 instead of 8.0 when the analyses with standardization MI and MII were carried out.).

The comparison between analyses with standardization SI with SII, and MI with MII, shows that the variation explained by the first principal component is considerably larger for standardizations SII and MII than for standardizations SI and MI. This is an increase of 10.40 for standardization SII, and 10.09 for standardization MII. This apparent improvement is gained by giving more weight to the variables with very few stages than to the continuous ones. It can be observed if we compare the histograms obtained from three properties with the largest absolute values in the first eigenvector for the 321 soil profiles. These histograms are given in Figs. 5.3 and 5.4.

Table 5.2 - Principal Component results. Eigenvector standardized.to $\sum_{i=1}^{p} a_i^2 = 1$, Eigenvalues, the proportion of the total variation taken up by the first eight principal components, and the cumulative percentage.

Property values standardized to zero mean unit variance (Standardization SI)

321 profiles.

| Order | Eigenvalue | Per cent Total variation | Cumulative percentage |
|---|---|---|---|
| 1 | 12.887 | 20.46 | 20.46 |
| 2 | 8.149 | 12.93 | 33.39 |
| 3 | 5.499 | 8.73 | 42.12 |
| 4 | 3.209 | 5.09 | 47.21 |
| 5 | 2.681 | 4.26 | 51.47 |
| 6 | 2.252 | 3.57 | 55.04 |
| 7 | 1.935 | 3.07 | 58.12 |
| 8 | 1.704 | 2.70 | 60.82 |

Property values standardized by range (Standardization SII). 321 soil profiles.

| Order | Eigenvalue | Per cent Total variation | Cumulative percentage |
|---|---|---|---|
| 1 | 1.0099 | 30.60 | 30.06 |
| 2 | 0.4618 | 13.74 | 43.80 |
| 3 | 0.2292 | 6.82 | 50.62 |
| 4 | 0.1375 | 4.09 | 54.71 |
| 5 | 0.1269 | 3.78 | 58.49 |
| 6 | 0.1213 | 3.61 | 62.00 |
| 7 | 0.1111 | 3.31 | 65.41 |
| 8 | 0.0993 | 2.96 | 68.36 |

Table 5.3 - Principal Component results. Eigenvector standardization so that $\max_{i=1}^{p} \{a_i\} = 1$. Eigenvalues, the proportion of the total variation taken up by the first eight principal components, and the cumulative percentage.

Property values standardized to zero mean unit variance (standardization MI). 321 soil profiles.

| Order | Eigenvalue | Per cent total variation | Cumulative percentage |
|---|---|---|---|
| 1 | 12.8670 | 20.42 | 20.42 |
| 2 | 7.8865 | 12.52 | 32.94 |
| 3 | 5.2667 | 8.36 | 41.30 |
| 4 | 3.1851 | 5.06 | 46.30 |
| 5 | 2.6815 | 4.26 | 50.61 |
| 6 | 2.2518 | 3.57 | 54.19 |
| 7 | 1.9352 | 3.07 | 57.26 |
| 8 | 1.7029 | 2.70 | 59.96 |

Property values standardized by range (standardization MII). 321 soil profiles.

| Order | Eigenvalue | Per cent total variation | Cumulative percentage |
|---|---|---|---|
| 1 | 1.0090 | 30.51 | 30.51 |
| 2 | 0.4527 | 13.69 | 44.19 |
| 3 | 0.2083 | 6.30 | 50.49 |
| 4 | 0.1334 | 4.03 | 54.53 |
| 5 | 0.1269 | 3.84 | 58.36 |
| 6 | 0.1213 | 3.67 | 62.03 |
| 7 | 0.1100 | 3.33 | 65.36 |
| 8 | 0.0922 | 3.00 | 68.36 |

Property values standardized to zero mean unit variance (standardization MI). 161 (odd number soil profiles).

| Order | Eigenvalue | Per cent total variation | Cumulative percentage |
|---|---|---|---|
| 1 | 12.7750 | 20.28 | 20.28 |
| 2 | 7.9097 | 12.56 | 32.83 |
| 3 | 5.4423 | 8.64 | 41.47 |
| 4 | 3.1617 | 5.03 | 46.50 |
| 5 | 2.5623 | 4.07 | 50.57 |
| 6 | 2.2911 | 3.64 | 54.20 |
| 7 | 1.8934 | 3.01 | 57.21 |
| 8 | 1.8864 | 2.99 | 60.20 |

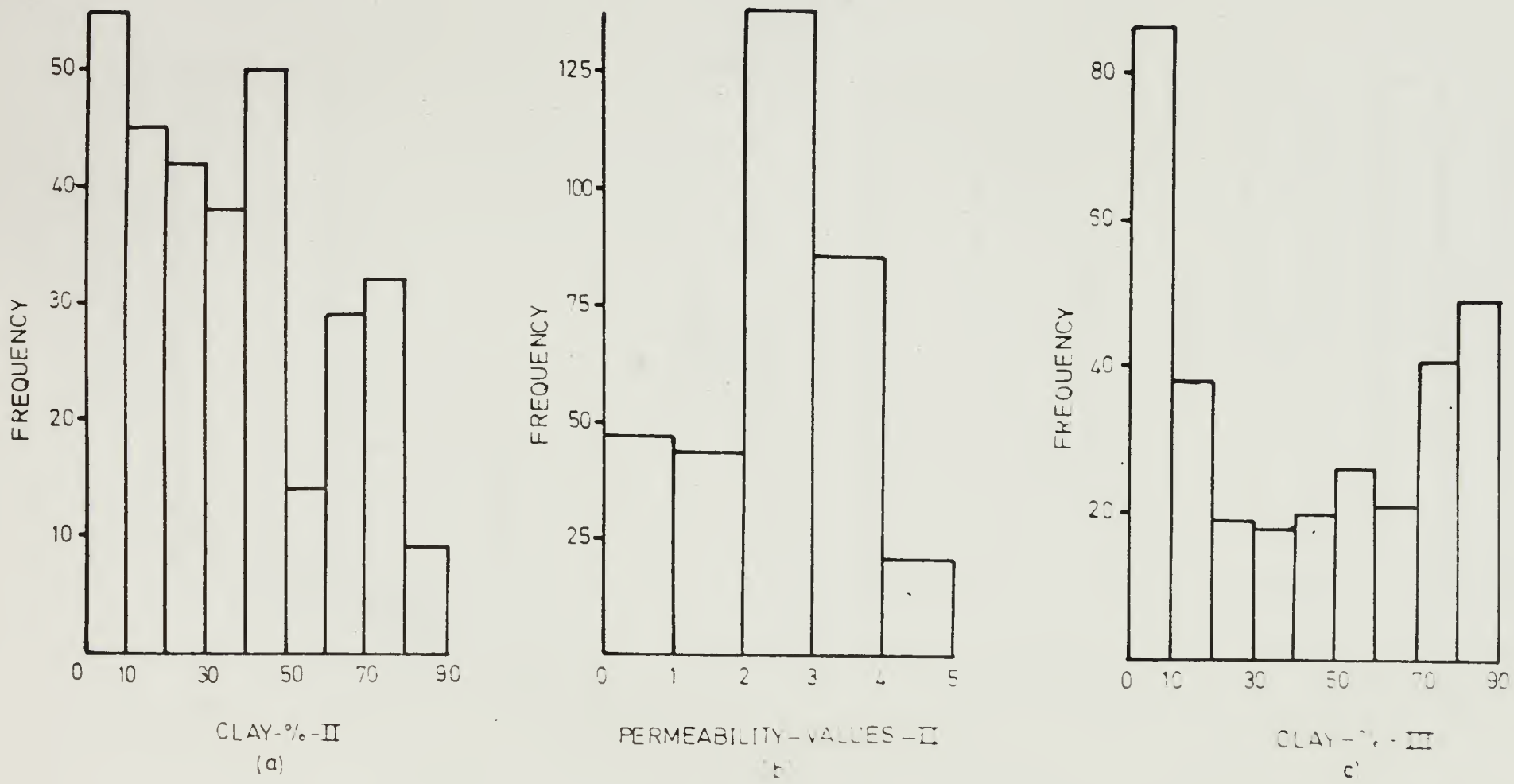



Fig. 5.3 Histograms of the properties corresponding to the three largest elements of the first eigenvector. Standardization II.

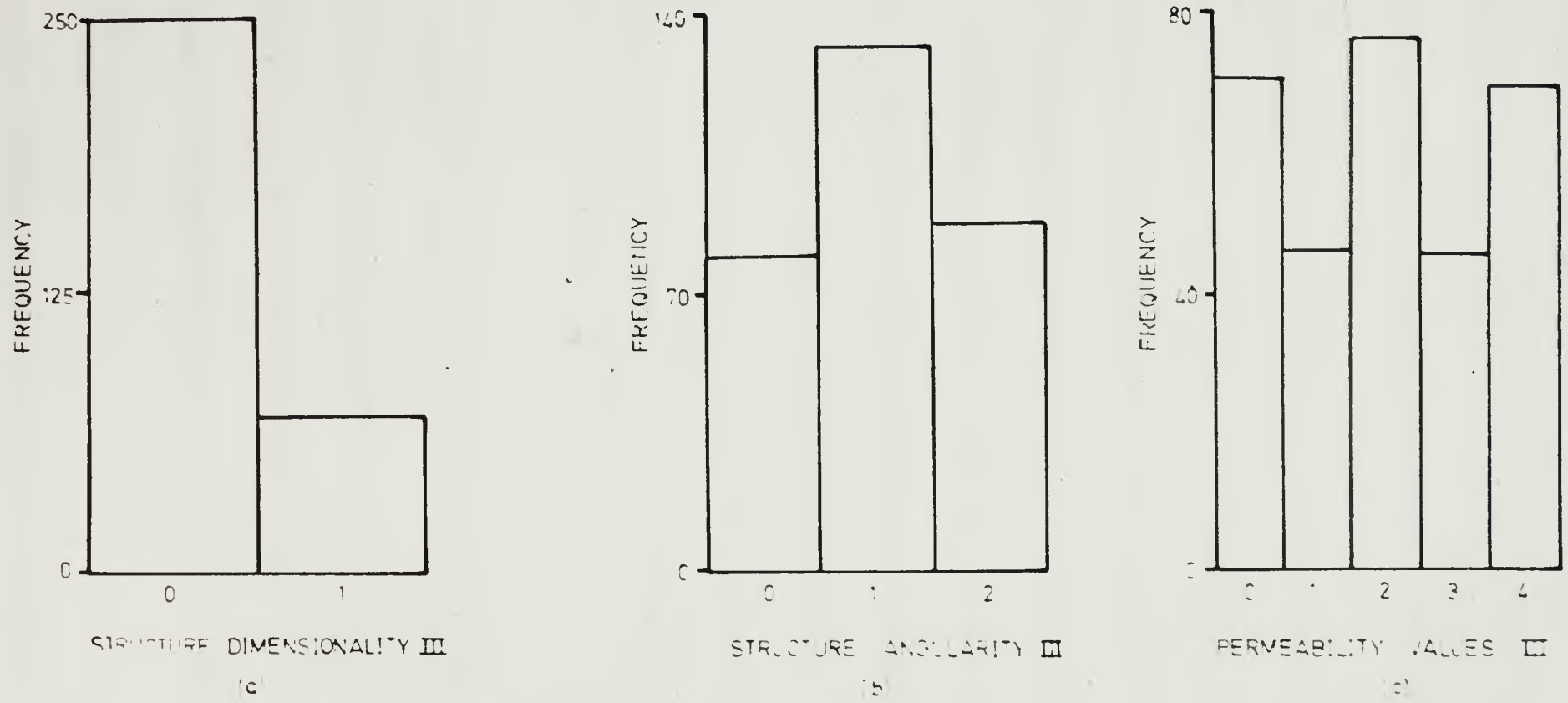



Fig. 5.4 Histograms of the properties corresponding to the three largest elements of the first eigenvector. Standardization MII.

Comparison between the analysis with 321 profiles and that with 161 profiles (odd numbers given in table 5.3), both with standardizations MI, shows, as one would expect, that an increase in the number of profiles used in the analysis scarcely alters the proportion of the variation accounted for by each component, provided that the added profiles lie within the limits of variation of the initial profile set. This is shown in table 5.4, where the five largest elements of the two first eigenvectors and their corresponding properties are given.

Table 5.4 also shows that the elements corresponding to properties Permeability and Clay per cent for depths III and II have the highest values, but with the same sign. One would expect them to have opposite signs. That is, as the clay per cent increases, the permeability will decrease. The reason for this apparent contradiction is that in the transect under study there is a large proportion of shallow soil underlaid by fractured stone strata. The texture of the material inside the cracks is clayey. Therefore, even though the texture of these horizons is clayey, the permeability is higher than in the corresponding horizons of sandy texture, because of the large number of cracks.

The graph of the first against the second principal component values, for each soil profile, represents the most informative projection of Property space on to a plane. These projections are presented in Fig. 5.5 for standardizations MI; Fig. 5.6 for standardizations MII; and Fig. 5.7 for standardizations SI; Fig. 5.8 for standardizations SII.

All the figures, however, show the same general configuration of the points in Property space, namely a Y-shaped cloud of points horizontally placed, with no clear or distinct clusters.

Table 5.4 - List of the five variables with the largest eigenvector elements, for the analyses with 321 and with 161 profiles (odd numbers). Both analyses were carried out with eigenvector standardization M.

| Number | Variable | Depth | Elements of the eigenvectors of 321 profiles | Elements of the eigenvectors of 161 profiles |
|---|---|---|---|---|
| **Property values standardized to zero mean unit variance. (Standardization MI).** | | | | |
| **First Principal component.** | | | | |
| 59 | Permeability | III | 1.000 | 1.000 |
| 38 | Permeability | II | 0.983 | 0.986 |
| 49 | Clay per cent | III | 0.973 | 0.983 |
| 28 | Clay per cent | II | 0.969 | 0.983 |
| 56 | Structure: angularity | III | 0.964 | 0.977 |
| **Second Principal component.** | | | | |
| 12 | Stone size | I | 1.000 | 1.000 |
| 33 | Structure: development | II | 0.928 | 0.914 |
| 10 | Organic matter | I | -0.916 | -0.954 |
| 19 | Carbonates per cent | I | 0.876 | 0.916 |
| 41 | pH | II | 0.868 | 0.915 |
| **Property values standardized between the range zero and one(Standardization MII)** | | | | |
| **First principal component.** | | | | |
| 59 | Permeability | III | 1.000 | |
| 56 | Structure: angularity | III | 0.9940 | |
| 55 | Structure: dimensionality | III | 0.985 | |
| 49 | Clay per cent | III | 0.896 | |
| 44 | Colour: dominant chroma | III | -0.731 | |
| **Second principal component.** | | | | |
| 33 | Structure: development | II | 1.000 | |
| 27 | Mottles per cent | II | -0.814 | |
| 52 | Stones per cent | III | 0.924 | |
| 9 | Silt per cent | II | 0.797 | |
| 54 | Structure: development | III | 0.794 | |

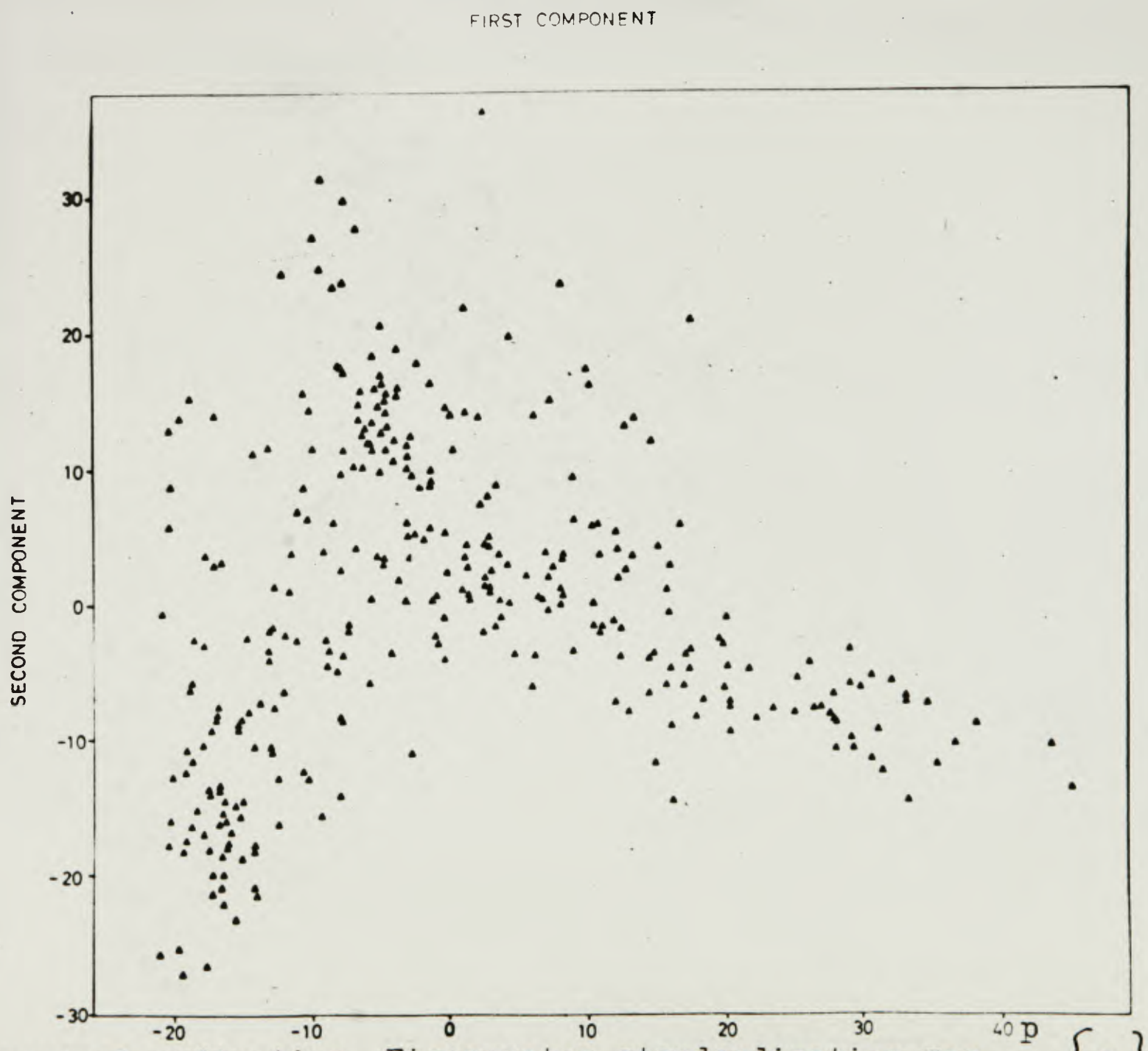
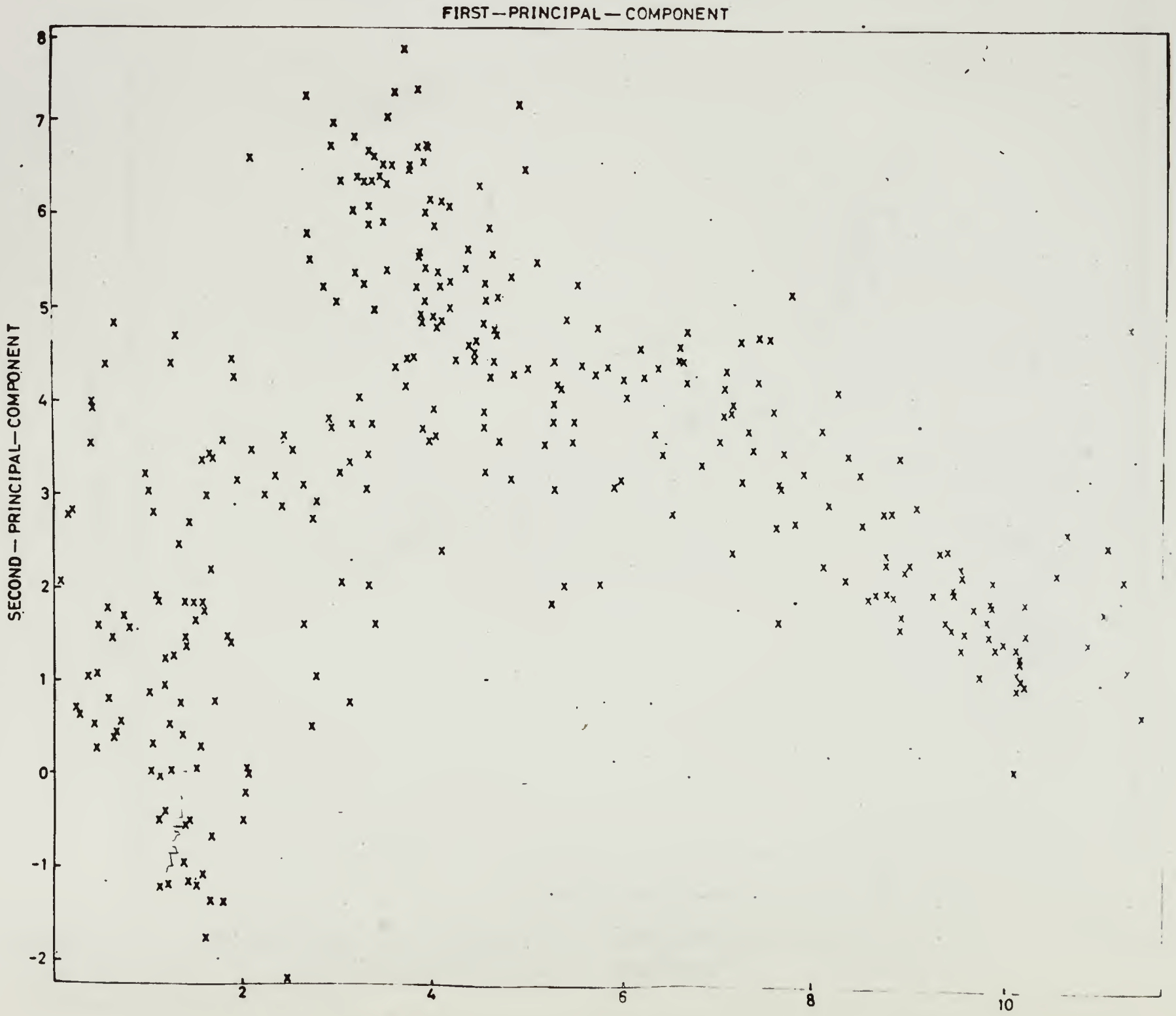



Fig. 5.5 Numerical ordination. Eigenvector standardization $\max_{i=1}^{p} \{a_i\} = 1$ Property values standardized to zero mean and unit variance. Standardization MI

Fig. 5.6 Numerical ordination. Eigenvector standardization $\max_{i=1}^{p} \left\{ a_i \right\} = 1$ Property values standardized between zero and one. Standardization III.



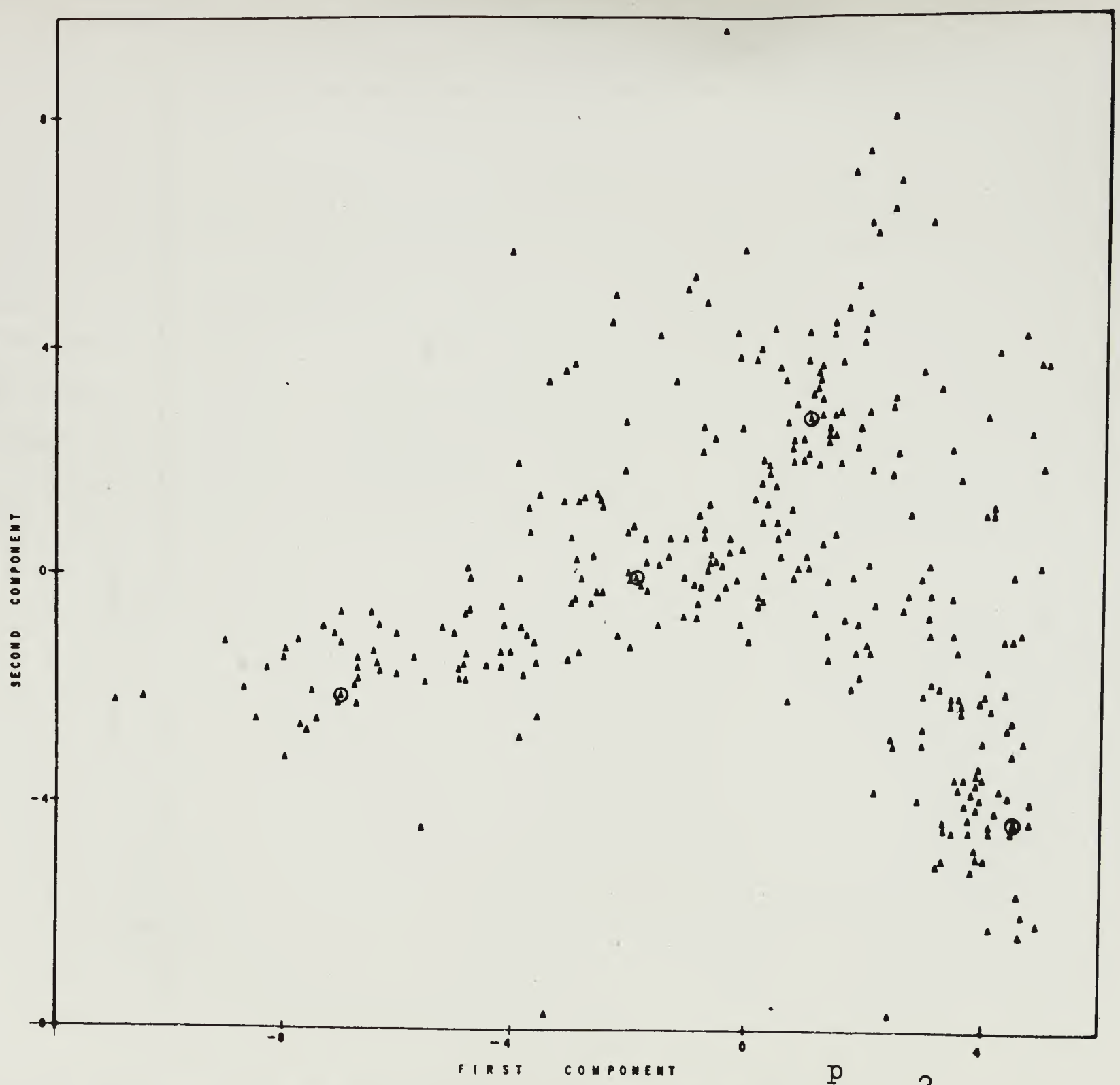
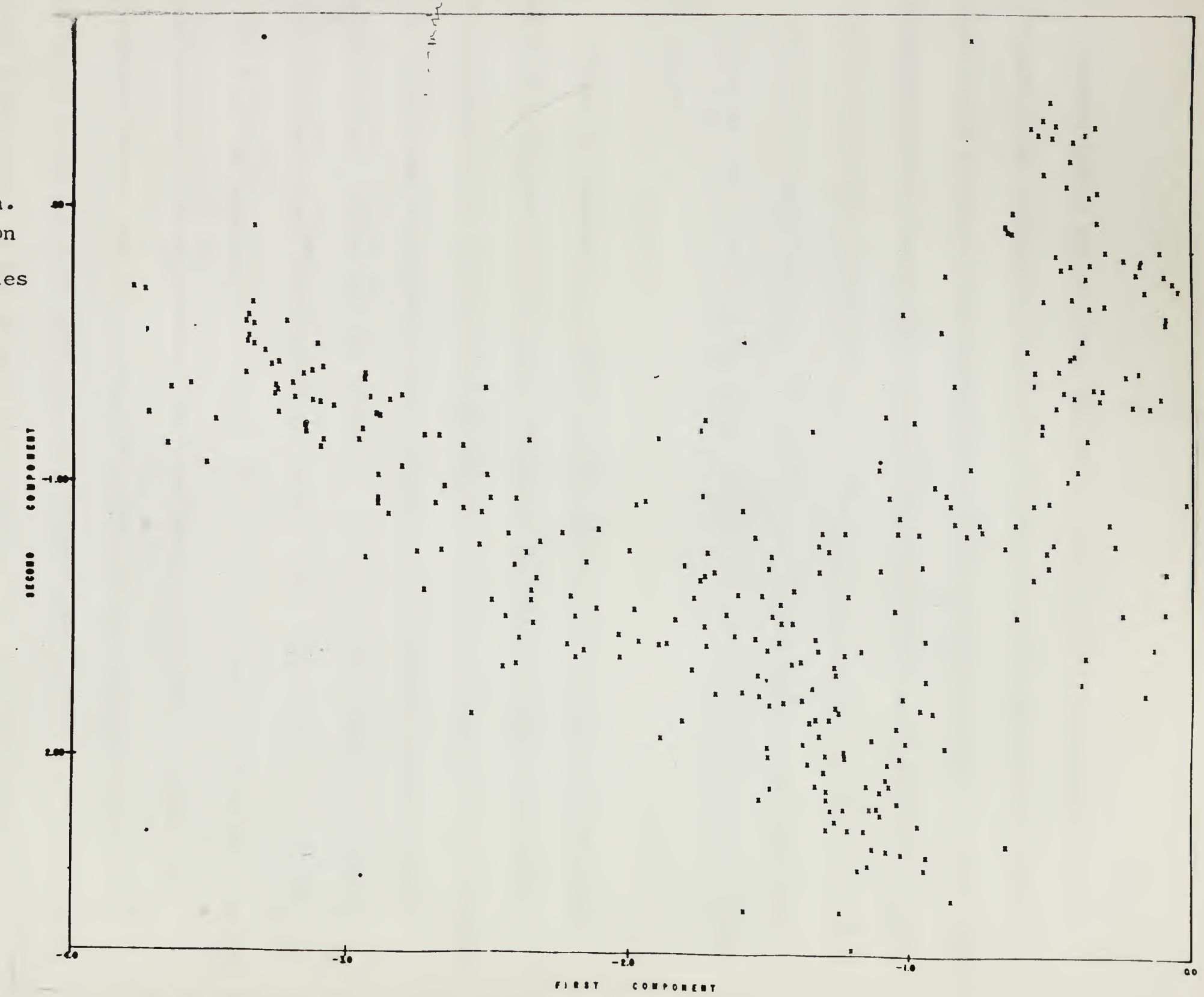



Fig. 5.7 Numerical ordination. Eigenvector standardization $\sum_{i=1}^{p} a_i^2 = 1$. Property values standardized to zero mean and unit variance. (Standardization SI).

Fig. 5.8. Numerical ordination.
Eigenvector Standardization
$\sum_{i=1}^{p} a_i^2 = 1$ Property values
Standarized between range
zero to one.
(Standardization SII).



As one would expect from Mendez's result (1970), (see page No.24), changes in the standardization of the eigenvectors brings about a change of scale in the principal component values. This change of scale is clear from the comparison between Fig. 5.5 and 5.7, and between 5.6 and 5.8. Fig.5.7 is the rotated image of Fig. 5.5. To compare Figs. 5.6 and 5.8, Fig. 5.8 needs to be rotated through 180° in the plane of the paper. Besides these changes in scale, there is no other difference that can be appreciated from the figures.

There is, however, a small displacement of the location of the points, induced by eigenvector standardization M in relation to the eigenvector standardization S. The amount of displacement is obtained from the square root of the sum of squares of the elements of the first and of the second eigenvectors. These are the values $\sqrt{K_1}$ and $\sqrt{K_2}$ (for details on notation see Principal Component analysis Chapter III). The ratio $\sqrt{K_1}$ over $\sqrt{K_2}$ is 1.0231 for the results given in Fig. 4.5, meaning that if a Principal Component analysis with eigenvector standardization S showed a cluster with diameter 10 mm, the use of standardization M would stretch the cluster diameter along the first principal component by 0.23 mm, i.e. a change of about 2 per cent. In the results presented in Fig. 4.6, the ratio $\sqrt{K_1}:\sqrt{K_2}$ is 0.928, meaning that if we start with the same cluster of 10 mm diameter. the eigenvector standardization M would compress the diameter along the first principal component by 0.72 mm, i.e. about 7 per cent.

The components <u>per se</u> have no precise physical meaning, but from inspection of the co-efficient values for each component one gets an idea of

their over-all meaning. The first component in Figs. 5.5 and 5.6 is interpreted as a function of profile texture, the sandy soils being on the left side and the clay soils on the right. The second component is considered to be a function of soil depth; the shallow soils being in the upper part and the deep soils in the lower part.

The components have the same meaning for Figs. 5.7 and 5.8, that is texture for the first and soil depth for the second. The profile locations, however, are different. For Fig. 5.7 the clay soils are on the left and the sandy on the right, the shallow soils in the upper part and the deep ones in the lower part. In Fig. 5.8 the clay soils are on the left and the sandy soils on the right, the deep soils are shown above the shallow soils.

Returning to Fig. 5.5, there, the different kinds of soils are intermingled, but a general pattern can be recognized: in relation to Jarvis' classification the points on the upper left part correspond to the Shallow Brown Calcareous over Limestone soils, changing towards the centre into the Shallow Ranker over Ironstone soils, followed by the Ferralitic Loamy Earths and the Brown Calcareous Loamy soils, which in turn lie next to the Gleyed Calcareous Loamy-over-Clay soils near the centre of the diagram.

The points in the middle of the left side correspond mainly to the Argillic Brown Earth Loamy soils.

The points on the lower left represent mainly the Gleyed Brown Earth, Coarse Loamy or Sandy soils, changing gradually towards the centre to the Acid Brown Earth, Coarse Loamy or Sandy soils, which meet the Calcareous Loamy-over-Clay soils at the centre of the diagram.

Finally, the lowest right hand corner represents the Surface Water Gleyed Clayey soils, which towards the centre lie next to the Gleyed Brown Earths, Loamy-over-Clay soils, which in turn meet the Gleyed Calcareous Loamy-over-Clay soils at the centre of the diagram.

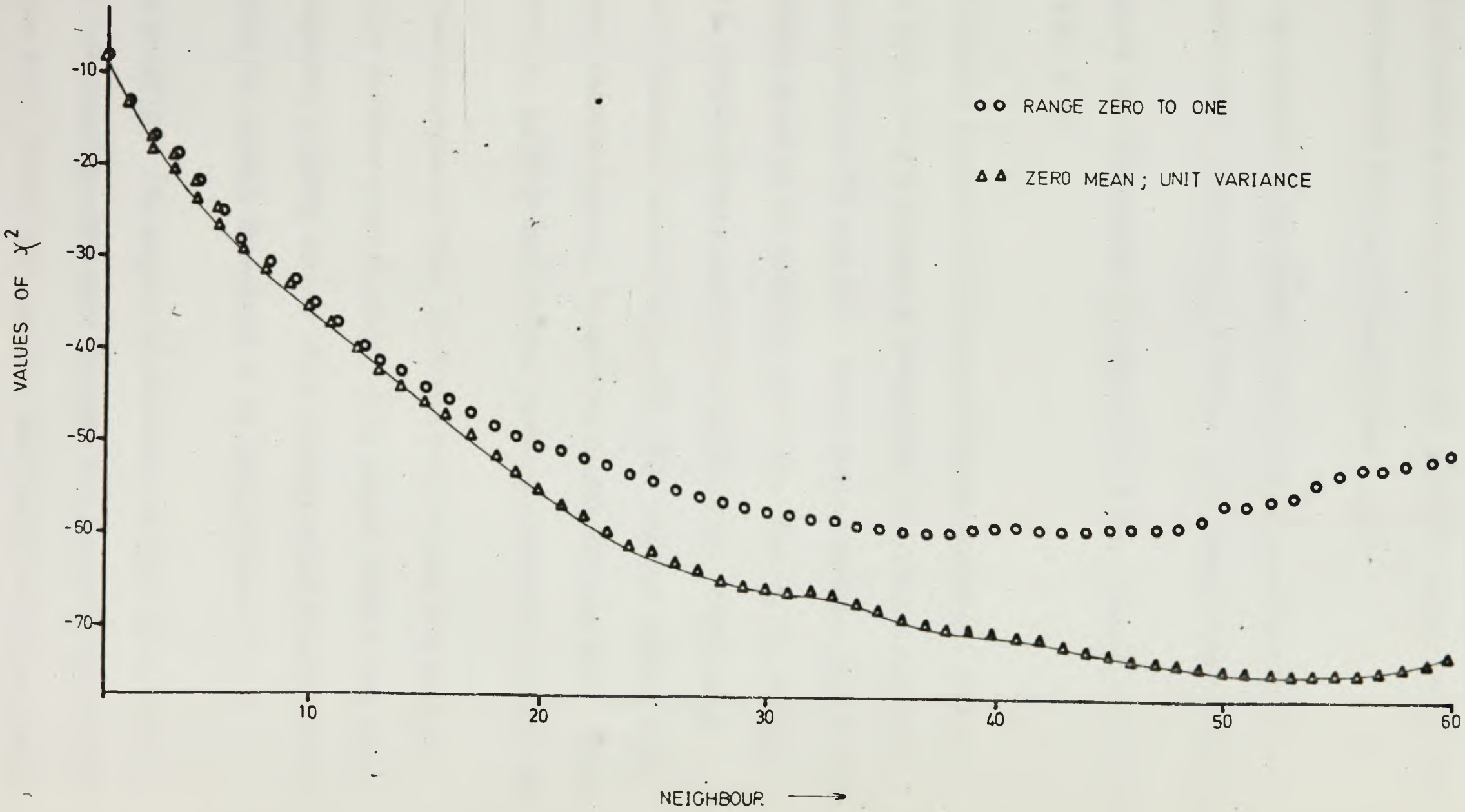
b. Order neighbour statistics. In the search for clusters, i.e. modal classes, this method was used to investigate the distribution arrangement of points in Property space, as projected on the scatter diagram produced from plotting the first against the second principal component values. This analysis was performed on the scatter diagrams of Figs. 5.6 and 5.7, obtained by standardizations MI and MII respectively. The values $\chi^2_c$ were computed up to the sixtieth neighbour. Since there were always many degrees of freedom (640), $\chi^2_c$ s were transformed to the values of the normal deviates by the expression $2\chi^2_c - \sqrt{2n-1}$. Here, n represents the degrees of freedom. On this basis, $\chi^2_c$ s of less than 2.3263 would be expected at 1 per cent of probability from an undispersed population of points on a plane.

Results of both analyses are given in Fig. 5.9, where the values of the $\chi^2_c$ s are plotted against their corresponding order neighbours.

The computed values of $\chi^2_c$ for standardizations MI and MII show a consistent underdispersed distribution curve from the first to the sixtieth neighbour. This confirms that the points in Property space defined by the two first components make a single cluster.

The larger values of $\chi^2_c$ s obtained for standardization MII, when compared with those of standardization MI, are attributed to the slightly more clustered nature of the points.

Fig. 5.9 The computed values of the order neighbour statistics



c. Mode analysis. The search for clusters was continued, but now in the original 63 dimensions of Property space. Mode analysis was performed on 161 soil profiles (odd numbers) with property values standardized to zero mean and unit variance (standardization I).

To evaluate the relative point density of the clusters defined by Mode analysis, two values of k were tried, 3 and 5. (for details see Chapter III).

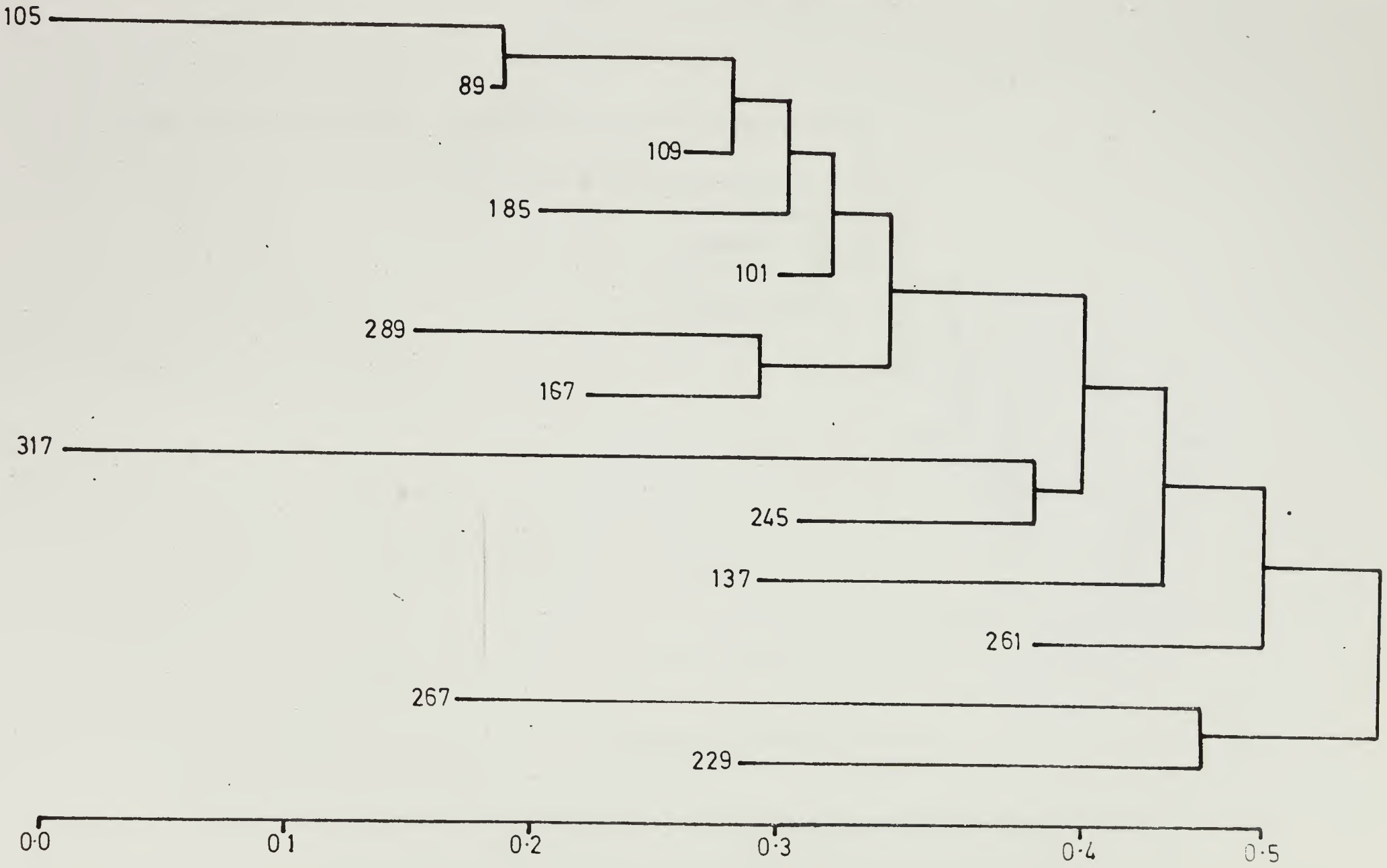
Results obtained with the density parameter k=3 are given in Fig. 5.10, and with k=5 in Fig. 5.11.

Fig. 5.10 shows the presence of two well defined clusters, centred at points 105 and 317. As the volume is increased, two more clusters appear, centred at profiles 289 and 267. Later more clusters appear, but these rapidly become fused to the existing clusters. Fig. 5.11, on the contrary, shows a simple cluster centred on profile 256. Very much later a new cluster appears, centred at profile 103. As the volume is increased, two more clusters appear, located on points 109 and 253. These clusters are, however, quickly fused to the clusters centred on profile 103.

The picture that emerges in Figs. 5.10 and 5.11 is that of a single cluster with a fairly uniform point density. This single cluster has four hyper-volumes with only slightly larger than average point density, since they disappear when the density threshold k is changed from 3 to 5.

d. Similarity analysis. The degree of stability, or lack of it, shown by varying the standardization, was also examined as a means of identifying structure in the data. Similarity analysis was also used in the search

Fig. 5.10 Mode dendrogram with 63 properties and k= 3.



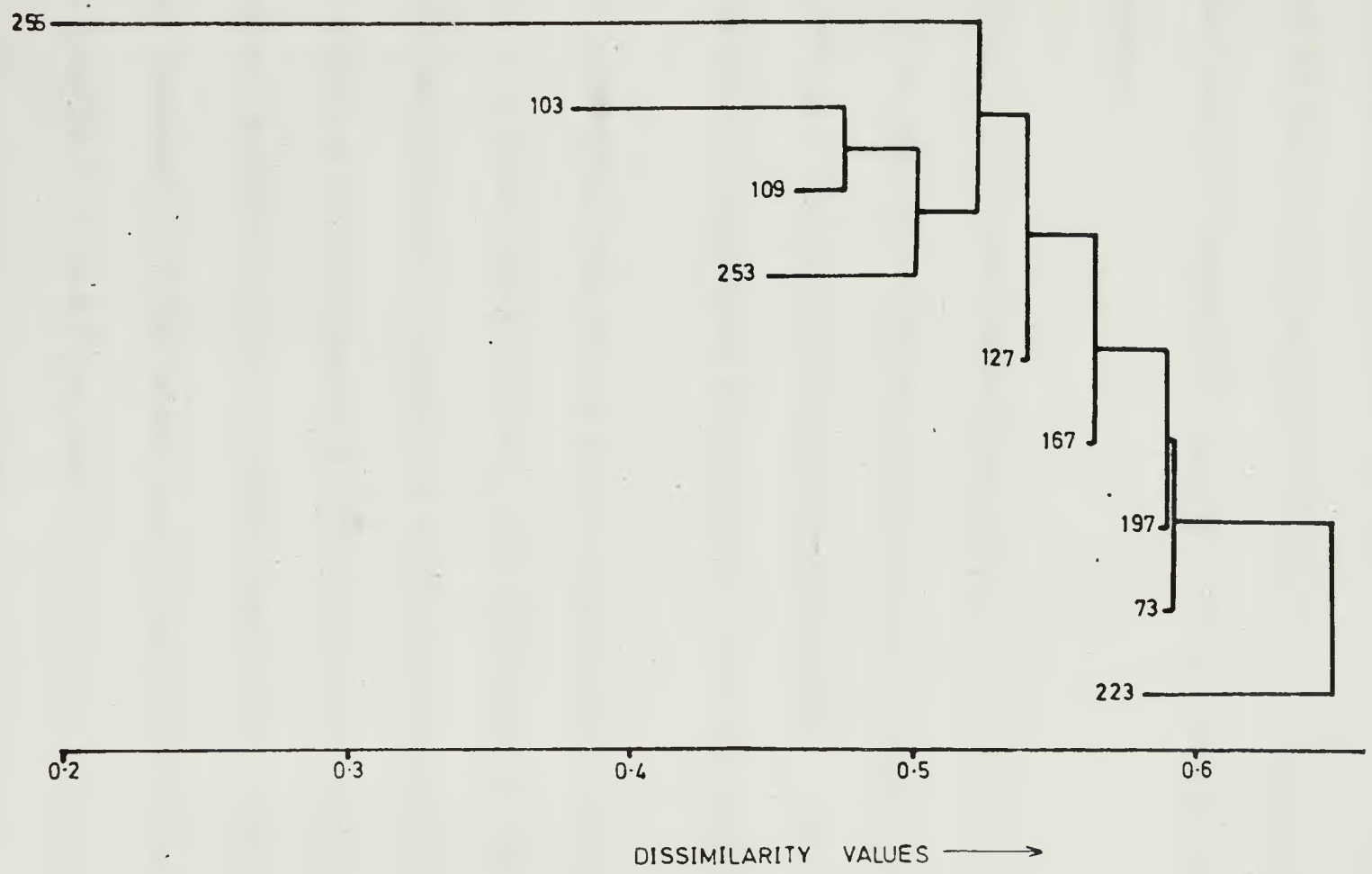



Fig. 5.11 Mode dendrogram with 63 properties and k= 5

for clusters. For details on the stability of a classification see Similarity analysis in Chapter III.

Dendrograms produced by Similarity analysis are given in Figs. 5.12 and 5.13. The first was obtained by standardizing the original variables to zero mean and unit variance, the second by standardization between the range zero to one. Comparison between the two dendrograms resembles the results obtained in Chapter IV, in that the classifications produced are very different.

Nevertheless, if we look at them together it may allow us a better appreciation of the pattern of clustering, when compared with the results of Mode analysis and Principal Component analysis. This comparison may indicate why Similarity analysis dendrograms are so appealing to the intellect.

I began by examining the stems at the lowest level of similarity. If the individuals in a stem were too few, say less than 5, then the stem was ignored. If the individuals belonging to a stem were to heterogeneous, according to the degree of homogenity I would expect in a given class, the next pair of stems departing from it were examined. My job was made simpler by my knowledge of the location of similar profiles. I know, for example, that profile 131 is 20 m north of profile 129, and that both are very similar. Other intuitive knowledge is that profiles 11, 13, and 15 are very similar to 37, 39 and 41, and so on.

I shall refer to the stem by the figure number followed by a letter. Stem 5.12 A is very similar to stem 5.15 A, and the members of the class are

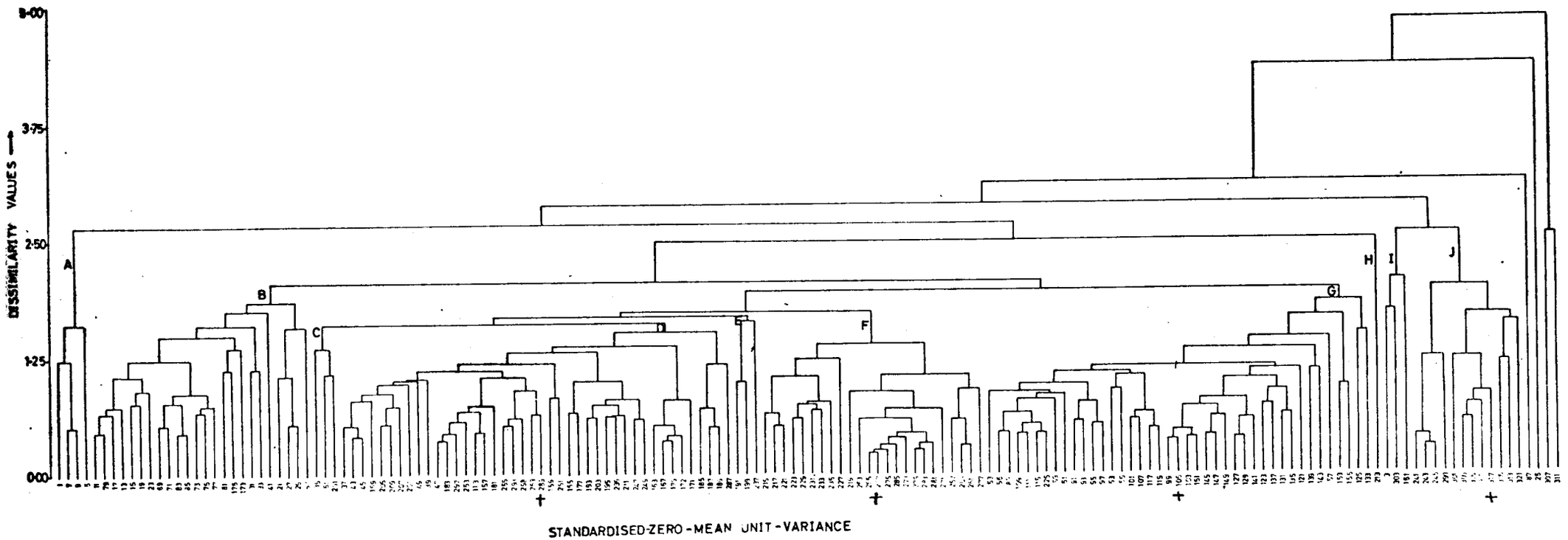



Fig. 5.12 Dendrogram of similarity analysis.

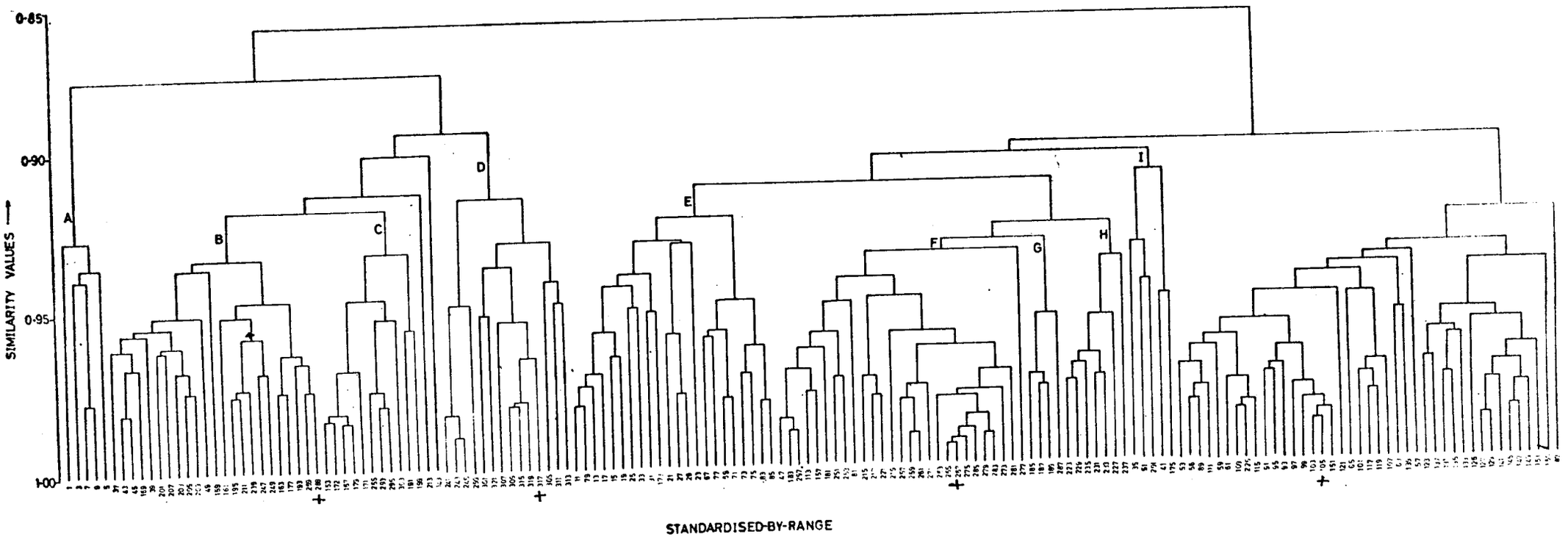



Fig. 5.13 Dendrogram of similarity analysis

very calcareous clays. Stem 5.12 B corresponds fairly well to stem 5.13 B, and both are made of silty loam or loamy soils over limestone. Stem 5.12 G and stem 5.13 J correspond rather well, and they are made up mainly of deep sandy loam soils on Northampton sands. It seems that the clusters that remain unaltered, in spite of changes in standardization of property values, are groups of soil profiles very similar among themselves and appreciably different from the remaining profiles.

The remaining groups are very different, and none of them bear much resemblance to Jarvis' classification (see Figs. 5.1 and 5.2 in section 1 of this chapter).

Drawing intuitively from my field work, I think that Fig. 5.12 makes no distinction between the Surface Water Gleys developed on the slopes of the Upper Lias and the Gleyed Brown Earths developed on the Lower Lias and some parts of the Upper Lias. It does, however, bring together the Silty Loam to Loamy soils developed on the Ironstone of the Middle Lias and on a thin ironstone stratum of Northampton sands. In contrast, Fig. 5.13 distinguishes between the Surface Water Gleys on Upper Lias, and the Gleyed Brown Earths developed on the Lower Lias and on some of the Upper Lias. It makes an untidy group of the Loamy soils developed on the Ironstone of the Middle Lias and on the Northampton sands.

The soils in Fig. 5.12 seem to have been grouped mainly on texture, and its correlated properties. Also, Fig. 5.13 has grouped soils with very similar colour and structure, with little regard for the other properties.

The groups in Fig. 5.12 are based mainly on properties coded as continuous variables, in contrast to the groups formed in Fig. 5.13, where the emphasis is given to properties coded as discrete variables with relatively few possible values.

B. Property-Geographic space.

(a) Principal Component analysis.

I will now present the shape of Property-Geographic space as viewed from plotting principal component values against distance. All were obtained by eigenvector standardization M.

The values of the first four principal components plotted against distance are given in Figs. 5.14 and 5.15: property values were standardized to zero mean and unit variance. Each of these represents a projection in two dimensions of Property-Geographic space. Together they represent the most informative projection (in terms of soil variation) of Property-Geographic space, originally in 64 dimensions, here in five dimensions.

Fig. 5.16 gives the values of the first two components plotted against distance, but here the property values were standardized in the range zero to one. Fig. 5.17 shows, again, the first two principal component values against distance, but using only 161 profiles, (odd numbers) and having the property values standardized to zero mean and unit variance.

Graphs 5.14 to 5.17 have the same horizontal scale. Their vertical scales differ because the distance between the minimum and the maximum values of each graph is kept constant.

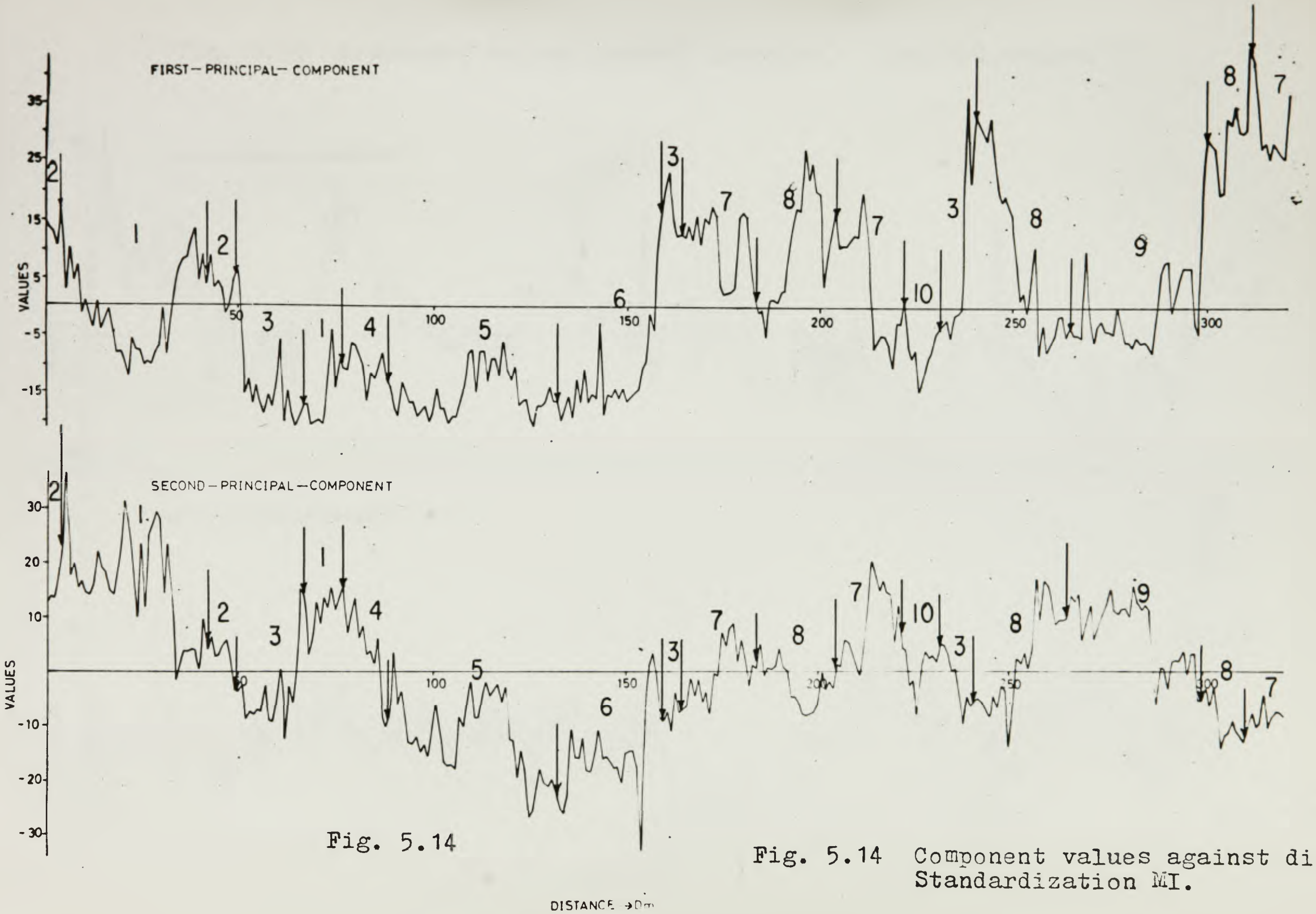



Fig. 5.14

Fig. 5.14 Component values against distance Standardization MI.

Fig. 5.15 Component values against distance. Standardization MI.

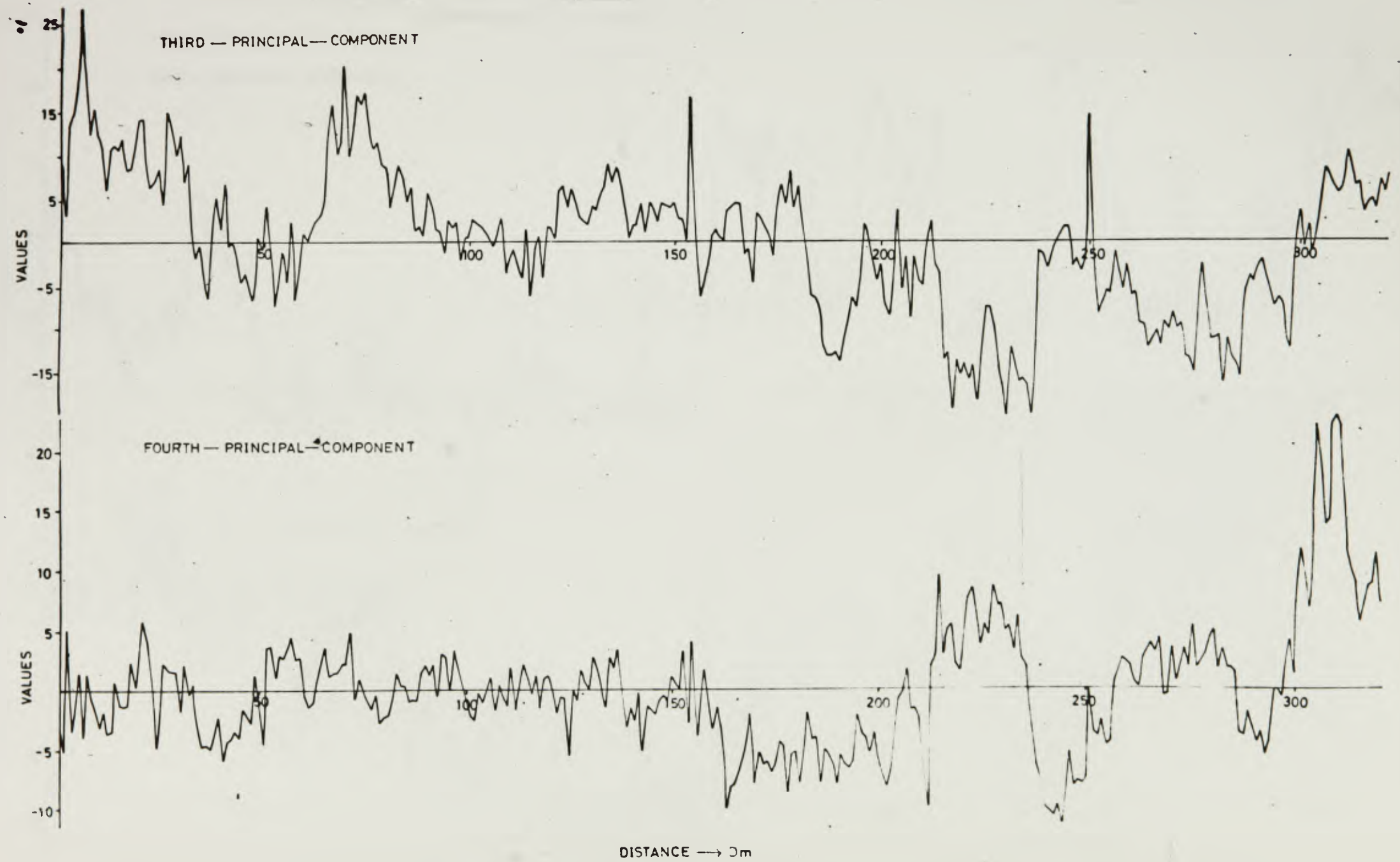


Fig. 5.16 Principal component values against distance. Standardization MII.

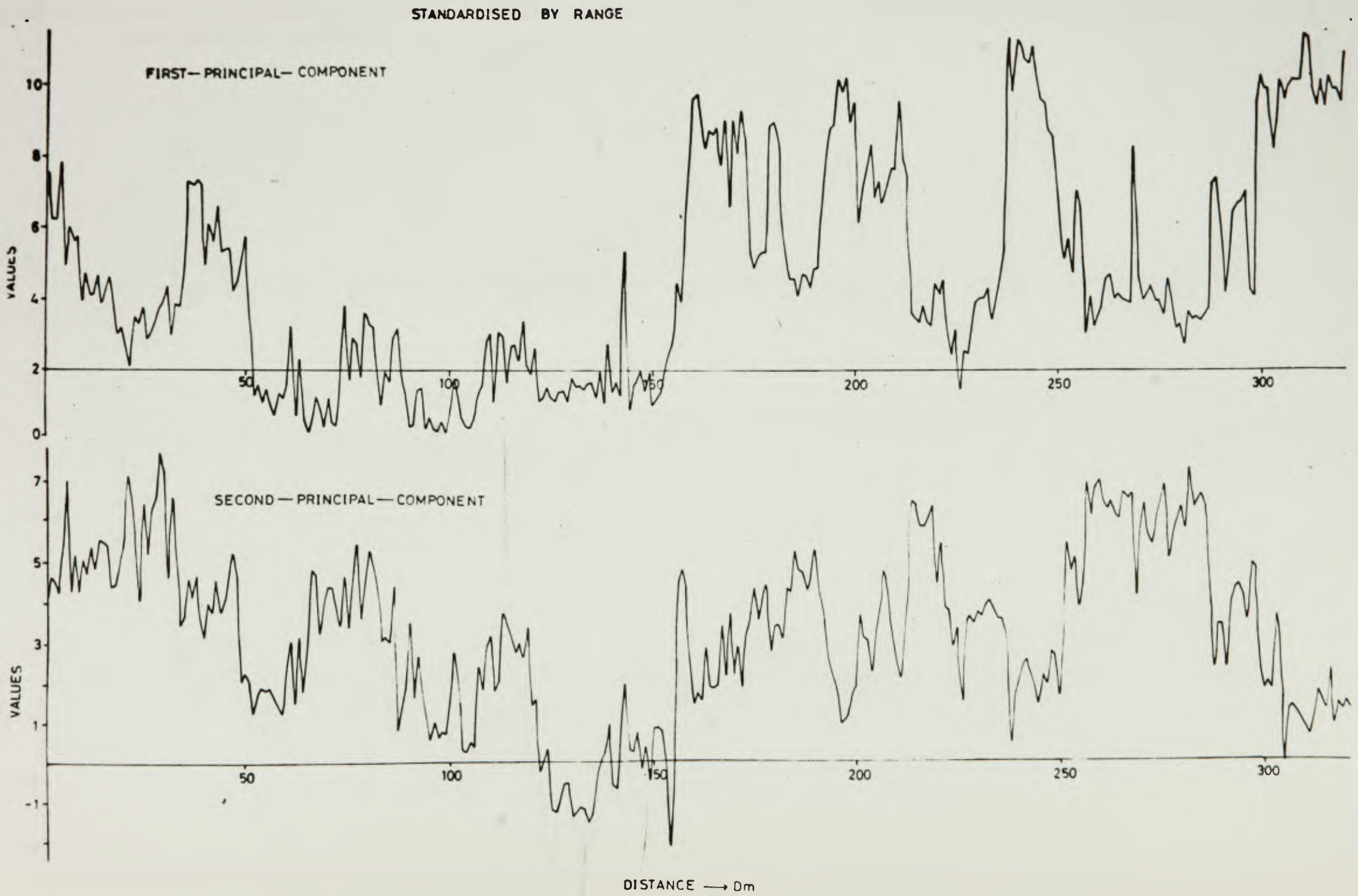
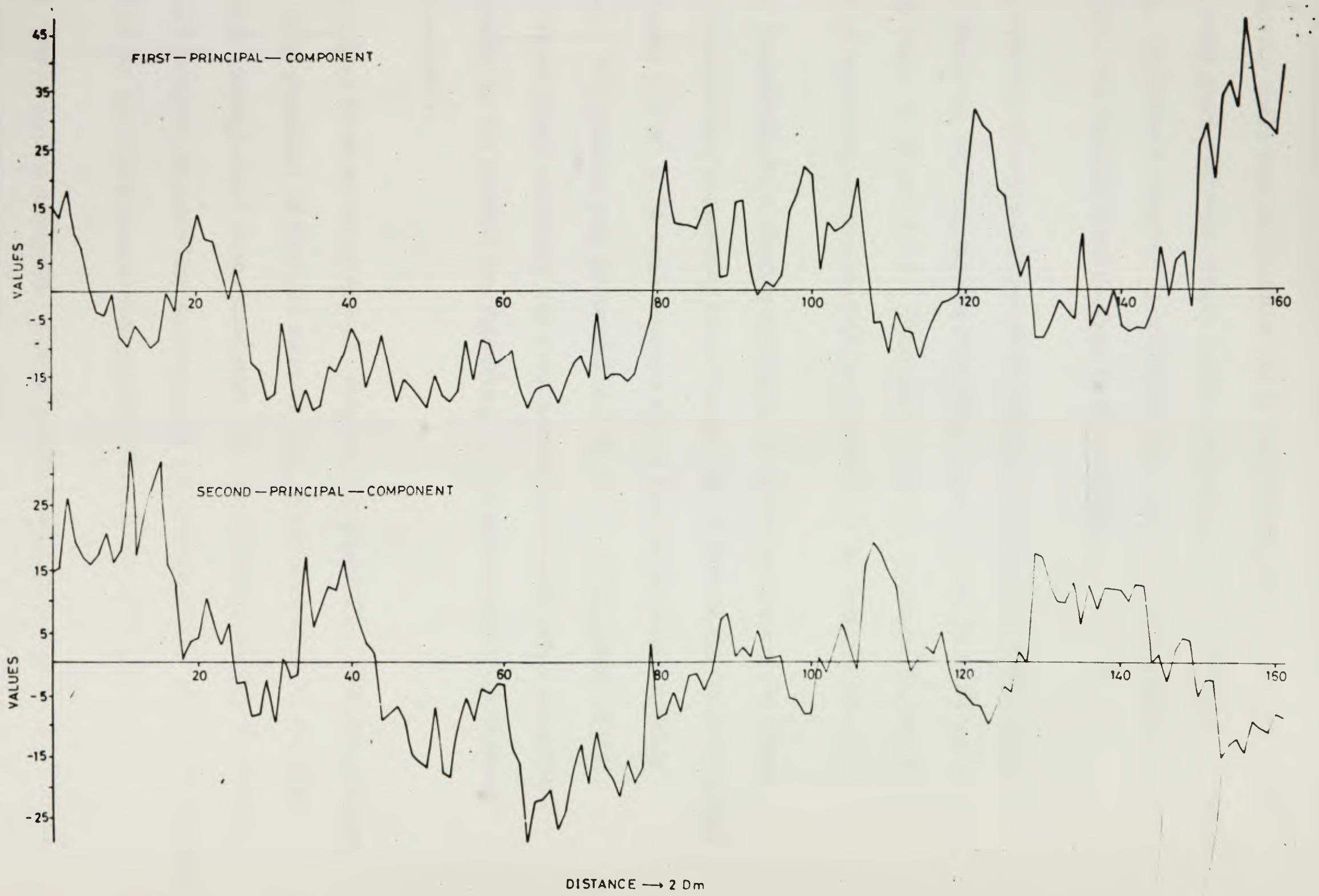


Fig. 5.17 Principal component values using only odd number profiles in the analysis. Standardization MI.



In the comparison of the first component values against distance, where the property value standardization has been varied, Figs. 5.14 and 5.16 show a very good correspondence in the general pattern of variation. Peaks, troughs, slopes and plateaus occur at the same place in the transect, regardless of the standardization used in the analysis.

Comparison between the two first principal component values plotted against distance, but varying the sampling interval from 10 to 20 m, is given in Figs. 5.14 and 5.17. This again shows very much the same pattern of variation, regardless of the increase in the sample interval.

(b) Smoothing by a Moving average. In order to remove the short range variation and reveal any broad trend, the values of the first principal components of Fig. 5.14 were smoothed by a five point linear moving average. The results are presented in Fig. 5.18. Here much of the erratic short range variation has been removed, and the trend appears. (For details on the method see Smoothing by Moving average in Methods in this chapter).

The trend is made up mainly of sloping and horizontal, almost straight, lines. The presence of straight lines is to a small extent due to the kind of moving average used in the analysis. An observer will notice this if he tries to imagine a smooth line drawn along the mean position of the unsmoothed values of the first and second component values given in Fig. 5.14.

(c) Correlogram analysis. Correlogram analysis was used to estimate both the size, kind, and length of spatial relationships of soil properties. The correlograms for the first six principal components obtained by standardizing the property values to zero mean and unit variance, using 321 profiles,

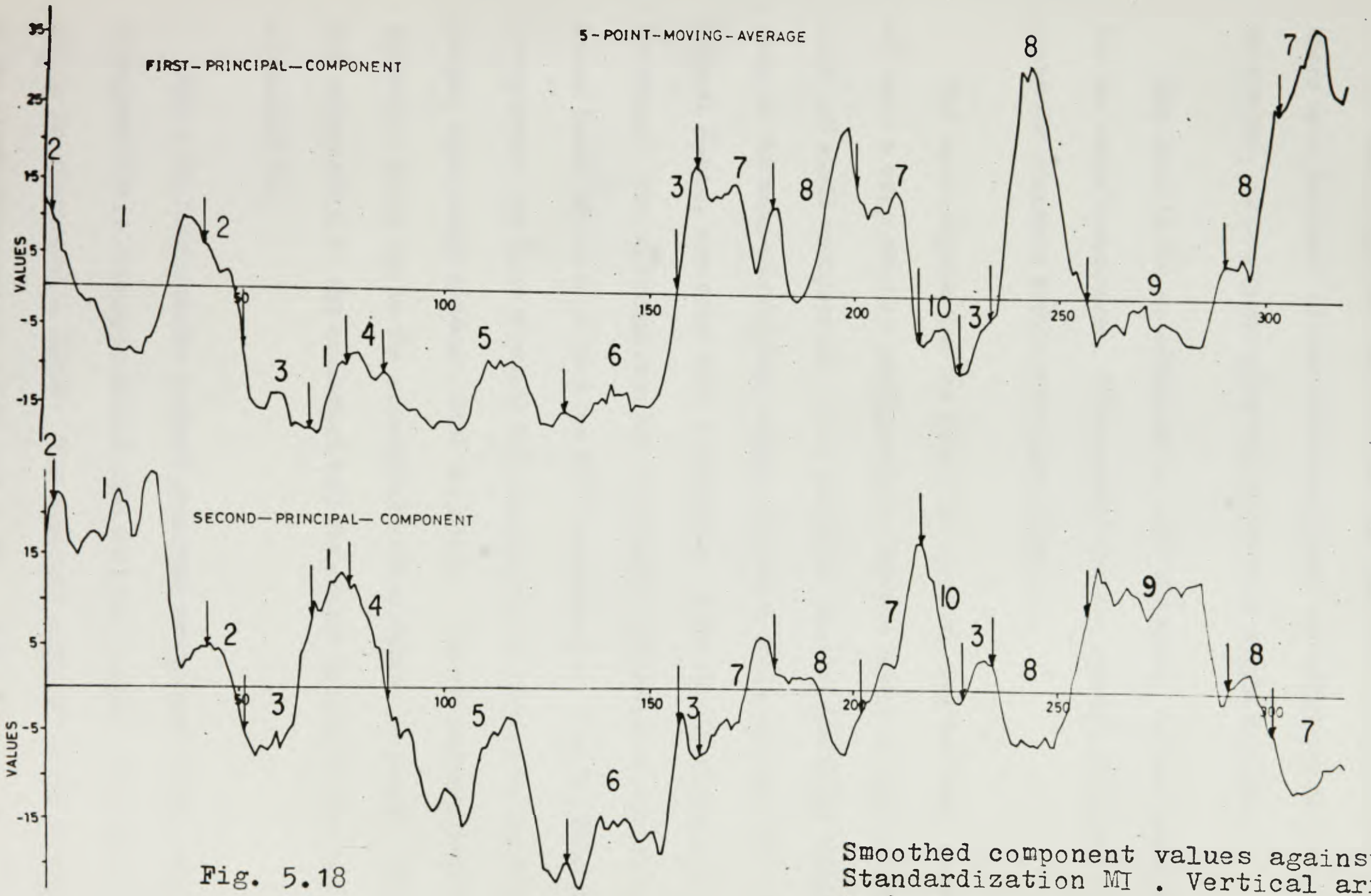



Fig. 5.18

Smoothed component values against distance. Standardization MI . Vertical arrows and numbers correspond to the soil boundaries and mapping units of Figs. 5.1 and 5.2 respectively

are given in Figs. 5.19, 5.20, and 5.21.

The correlograms from the first to the sixth component show that there is a decrease of the auto-correlation co-efficients (r) as distance increases, up to a point after which there is slight increase.

The drop in the co-efficient, r, with distance, is very nearly exponential for the sixth component. This means that the spatial relations of points along the transect occur over short distance.

The correlogram for the first, the second, and the third components all have a very similar configuration, but one which is different from the fifth and sixth components. For the first, second and third component the drop in the auto-correlation values is first a steep straight fall, later almost linear, and after this a minimum, until finally there is a slight increase. The correlogram for the fourth component is somewhere inbe-tween those of the third and the fifth components. For the first three components the first straight fall segment is attributed to the very short range, apparently random, soil variation. The second segment is inter-preted as being due to the consistent soil variation or trend. The other two segments i.e. the minimum and the slight increase, are not easily accounted for.

Since the first and the second principal component values show more; straightforward correspondence with soil properties, they will be the only two to be discussed in detail. The straight segment of the correlogram of the first component is attributed to the trend. The correlogram is prolonged so that it crosses both axes, then the r axis is met at 0.92,

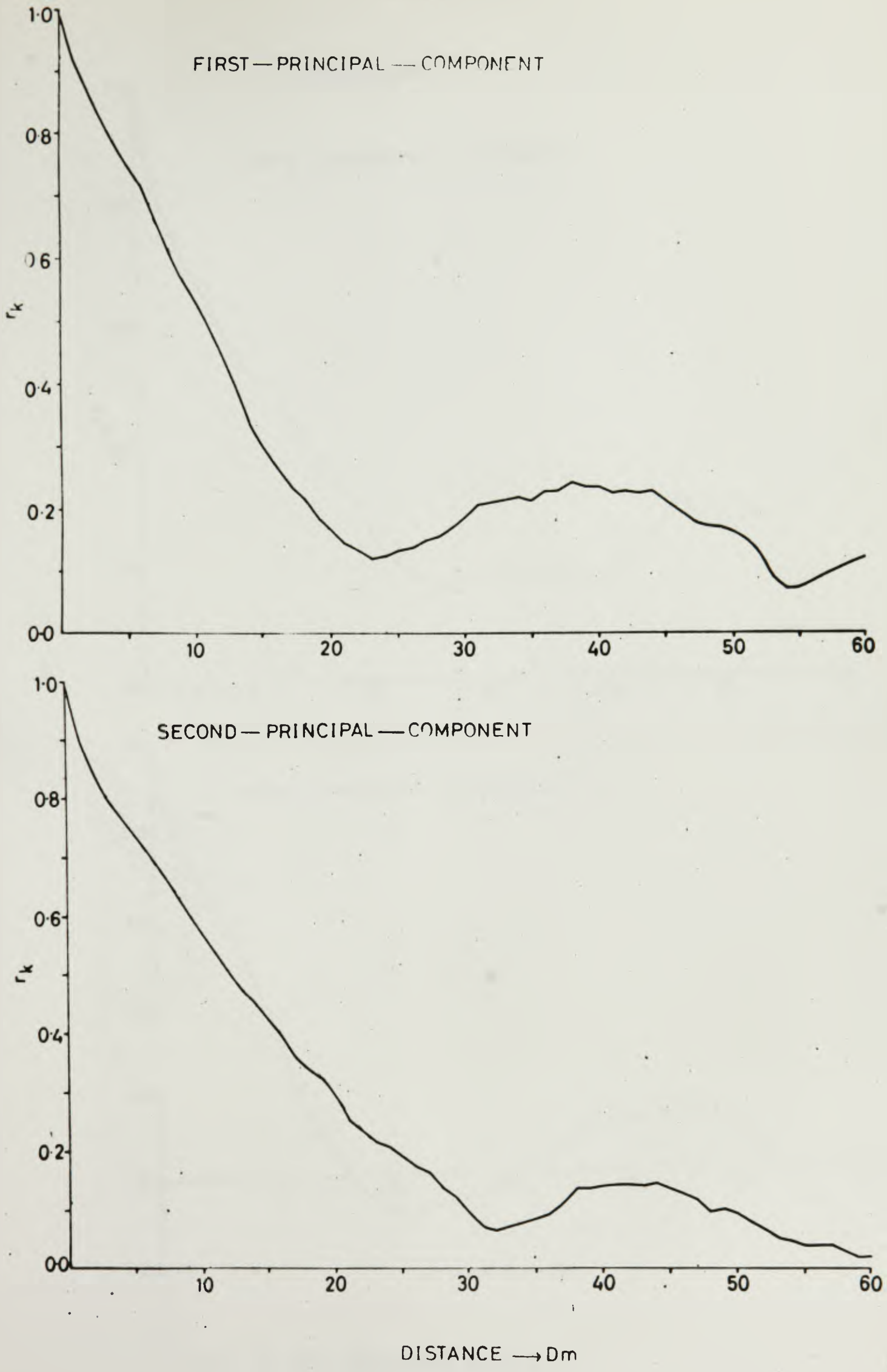
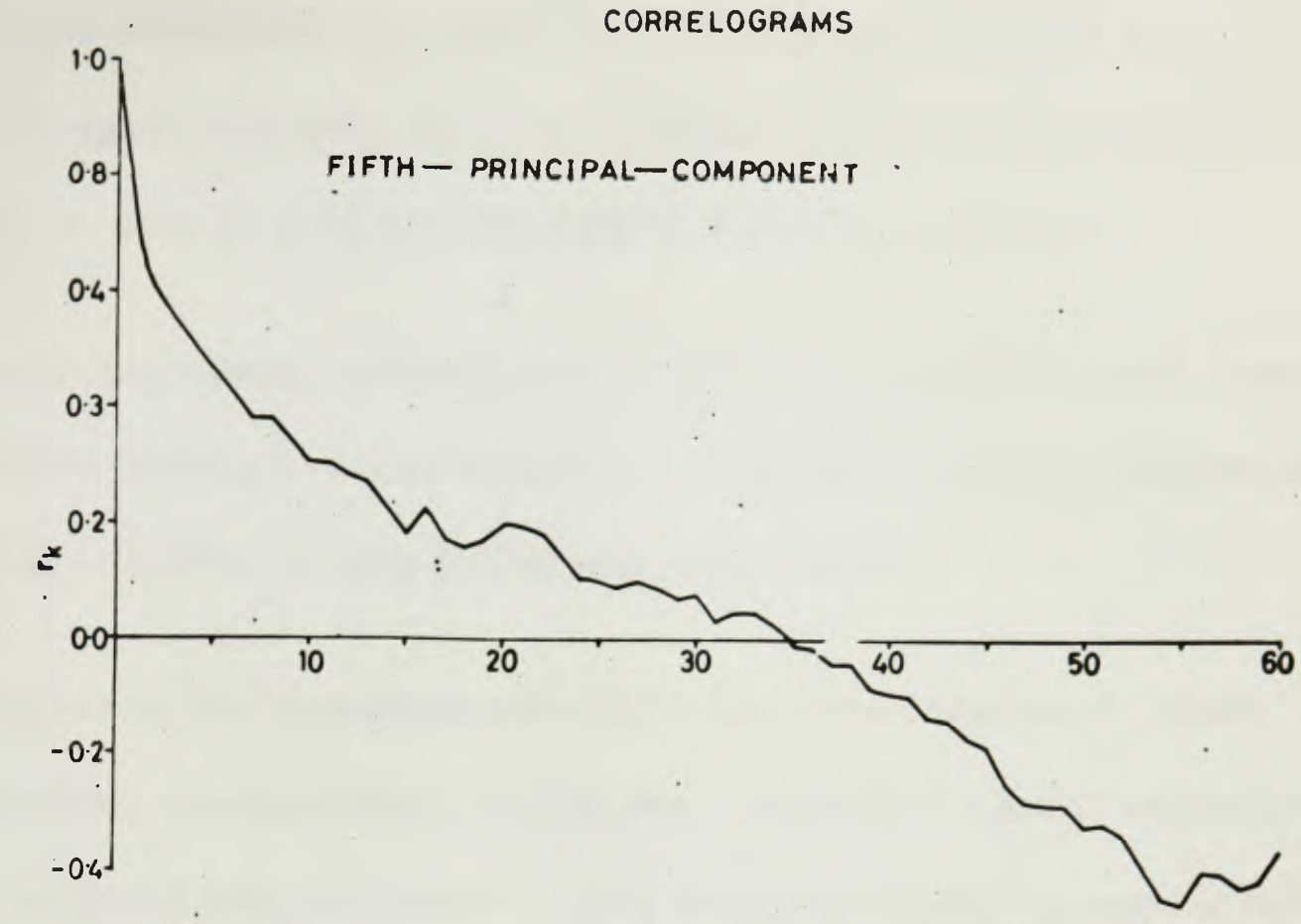



Fig. 5.19 Correlograms




Fig. 5.20 Correlograms



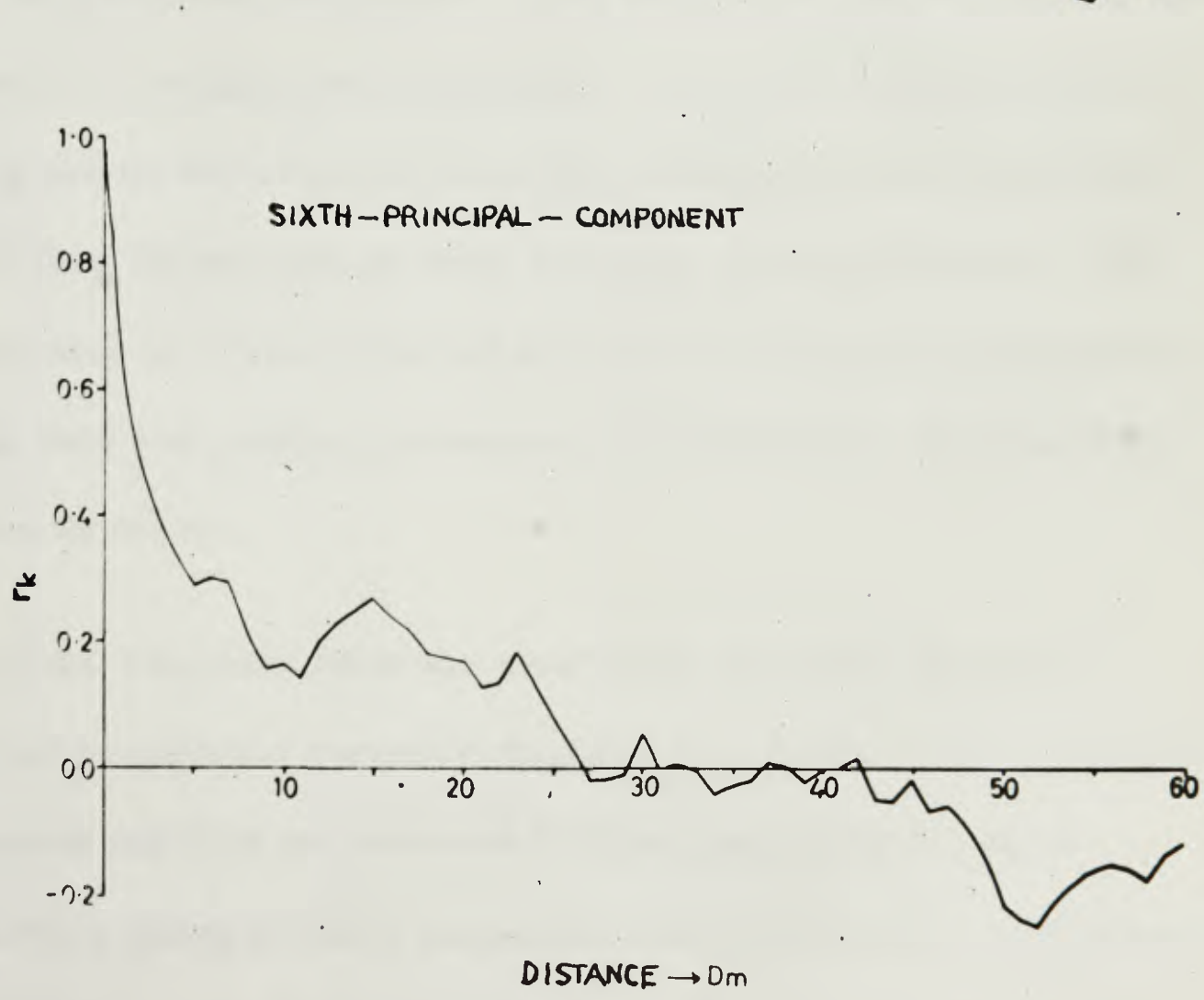




Fig. 5.21 Correlograms

and the axis of distance at 24 Dm. The correlogram for the second component shows something very similar. The main segment of the correlogram is again straight, and if the straight segment is prolonged it crosses the r axis at 0.86 and the axis of distance at 30 Dm.

The linearly decreasing correlogram is similar to that computed from a bilateral linear moving average scheme, containing a random component, Yule and Kendall (1950), Whittle (1954) and Wold (1938).

The main reason the correlograms of the first two components show linearly decreasing configuration, is that they reflect the spatial relationship of many original soil properties. This was found after computing the correlograms of 33 original soil properties. The large majority of these correlograms can be described by a moving average scheme, and in this manner more than 70 per cent of their variation can be explained. Six original properties have been selected to show the range of correlograms produced, and they are grouped by texture, reaction, (pH), permeability, and percentage of stones.

Correlograms computed from the continuous variables (the large majority of soil properties) resemble those of Fig. 5.22. Fig. 5.22 shows the correlograms for clay per cent and silt per cent, both for depth I. Fig. 5.23 shows a graph of these properties against distance. A moving average model 200 m long for clay, and 400 m long for silt, will explain in both cases approximately 80 per cent of their variation. Notice in Fig. 5.23 that the clay per cent oscillates more frequently than the silt per cent. This is reflected in the length of the moving average scheme.

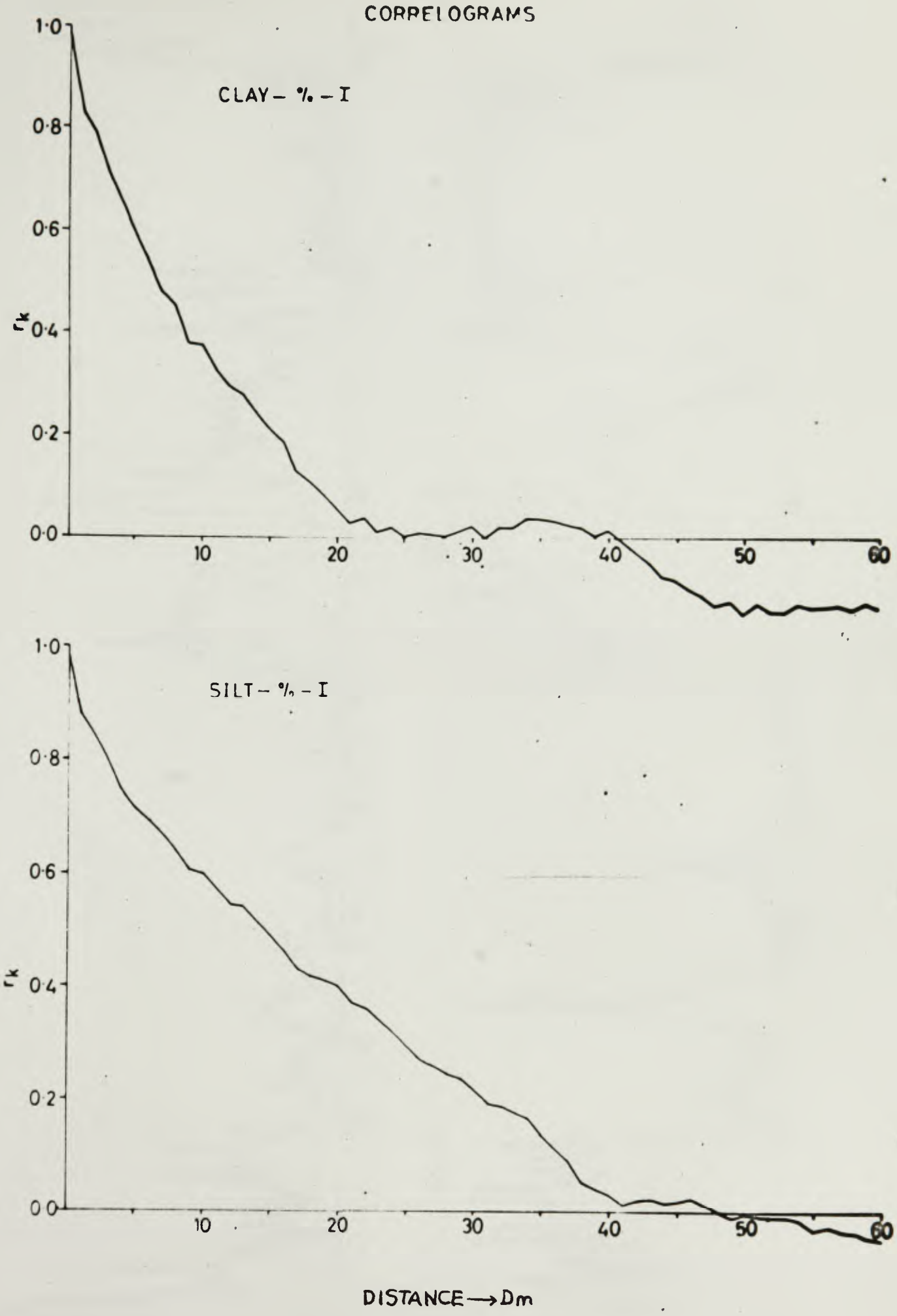



Fig. 5.22 Correlograms

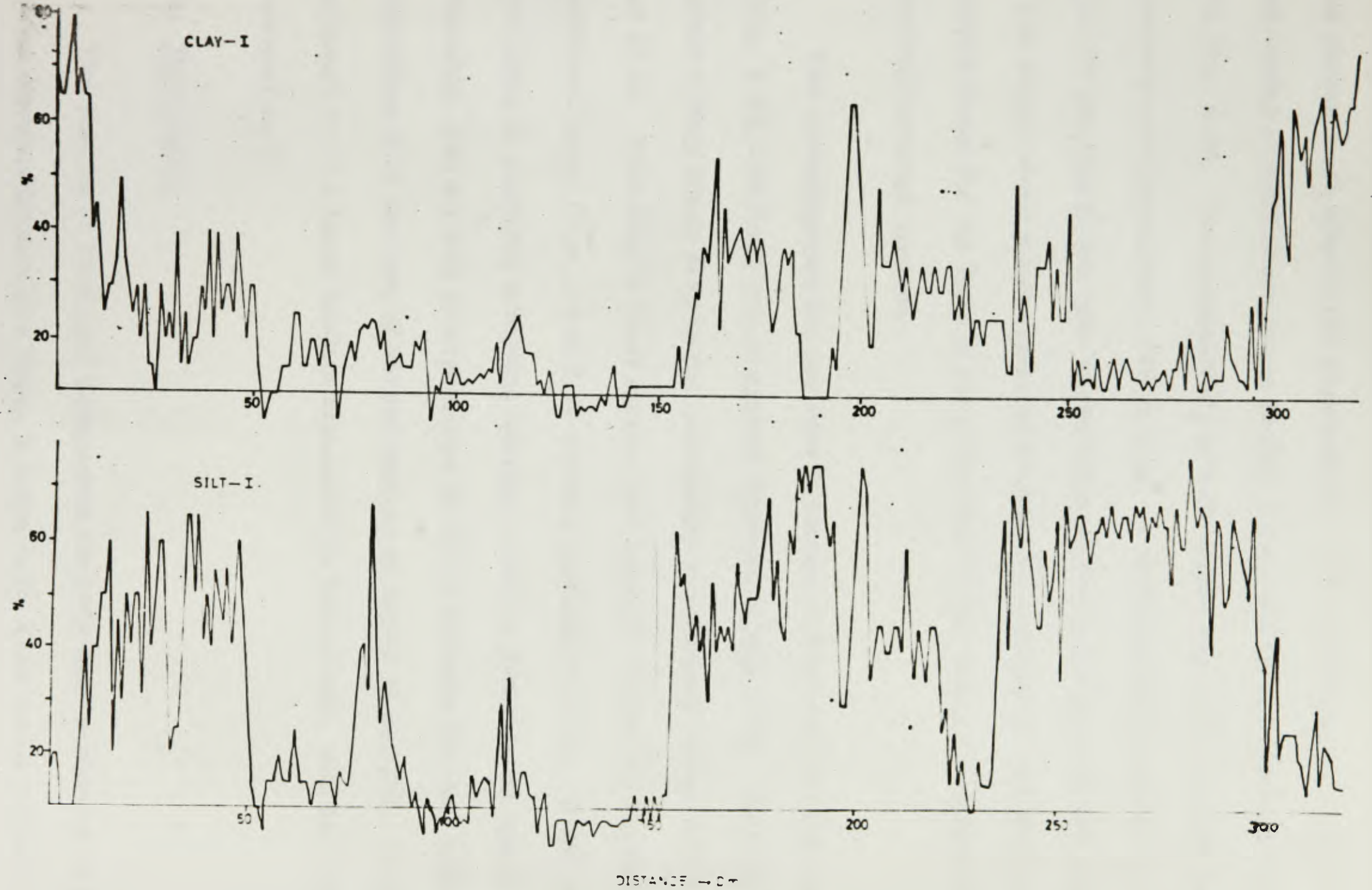



Fig. 5.23 Graphs of property values against distance

Other soil properties behave differently, and permeability and per cent of stones were chosen for illustration. The correlograms for permeability at depths II and III are given in Fig. 5.24, and their values against distance in Fig. 5.25. The permeability of both depths can again be explained by a moving average scheme, 260 m long. A linear moving average will account for 90 per cent of the total variation at depth II, but only 76 per cent at depth III. The larger short range variation at depth III, compared with that of depth II, will account for the drop in the proportion of the variation explained by a moving average process.

The correlograms for per cent of stones at depths II and III are given in Fig. 5.26, and their values against distance in Fig. 5.27. Both correlograms show a very sharp drop in the correlation co-efficient values over a distance of 50 m. This drop is most marked for depth II, where the correlation co-efficient drops from 1.0 to 0.52 within a distance of 10 m. It will be unrealistic to postulate a moving average model to describe its spatial relationship, and my only interpretation is that it reflects the very high inconsistency of per cent of stones present at depths II and III. There appears to be a large random component in this series, and any trend is masked by it.

## 4. Discussion

The results of Principal Component analysis with variations in property value standardization (see Figs. 5.3 and 5.4), show that a property standardization between the range zero to one gives more weight to properties with few stages than to the continuous ones. Therefore, since most soil

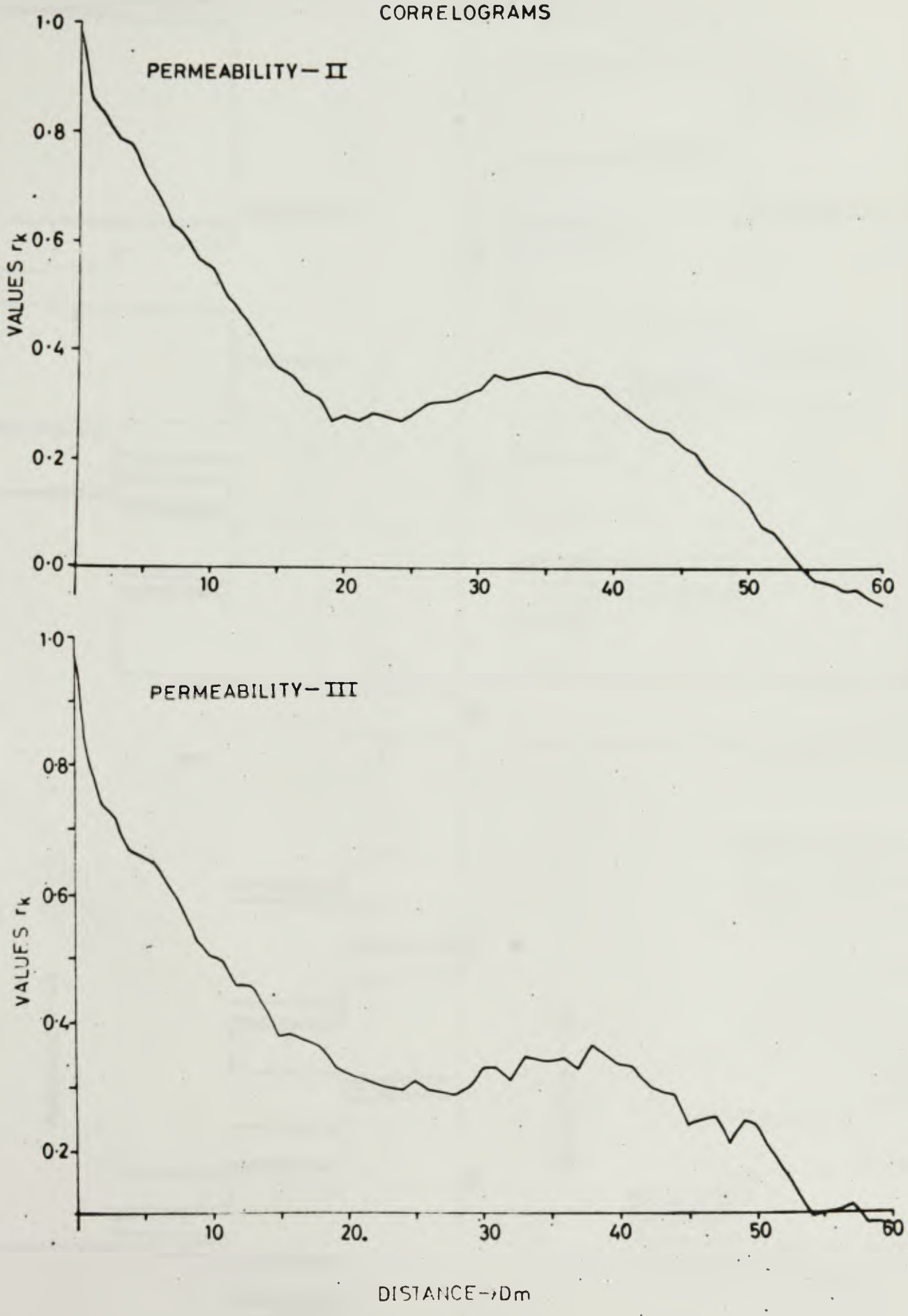
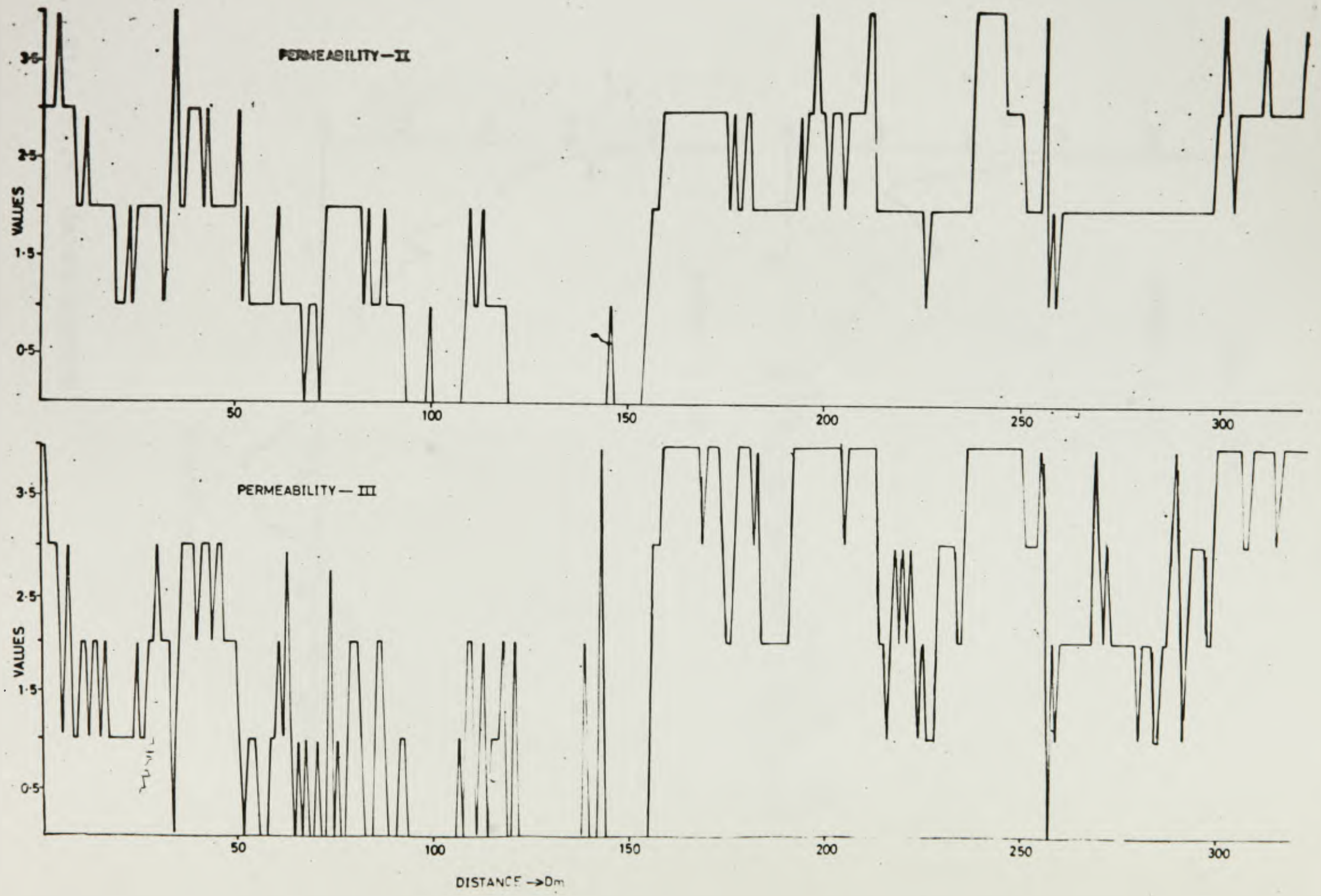



Fig. 5.24 Correlograms

Fig. 5.25 Graphs of property values against distance



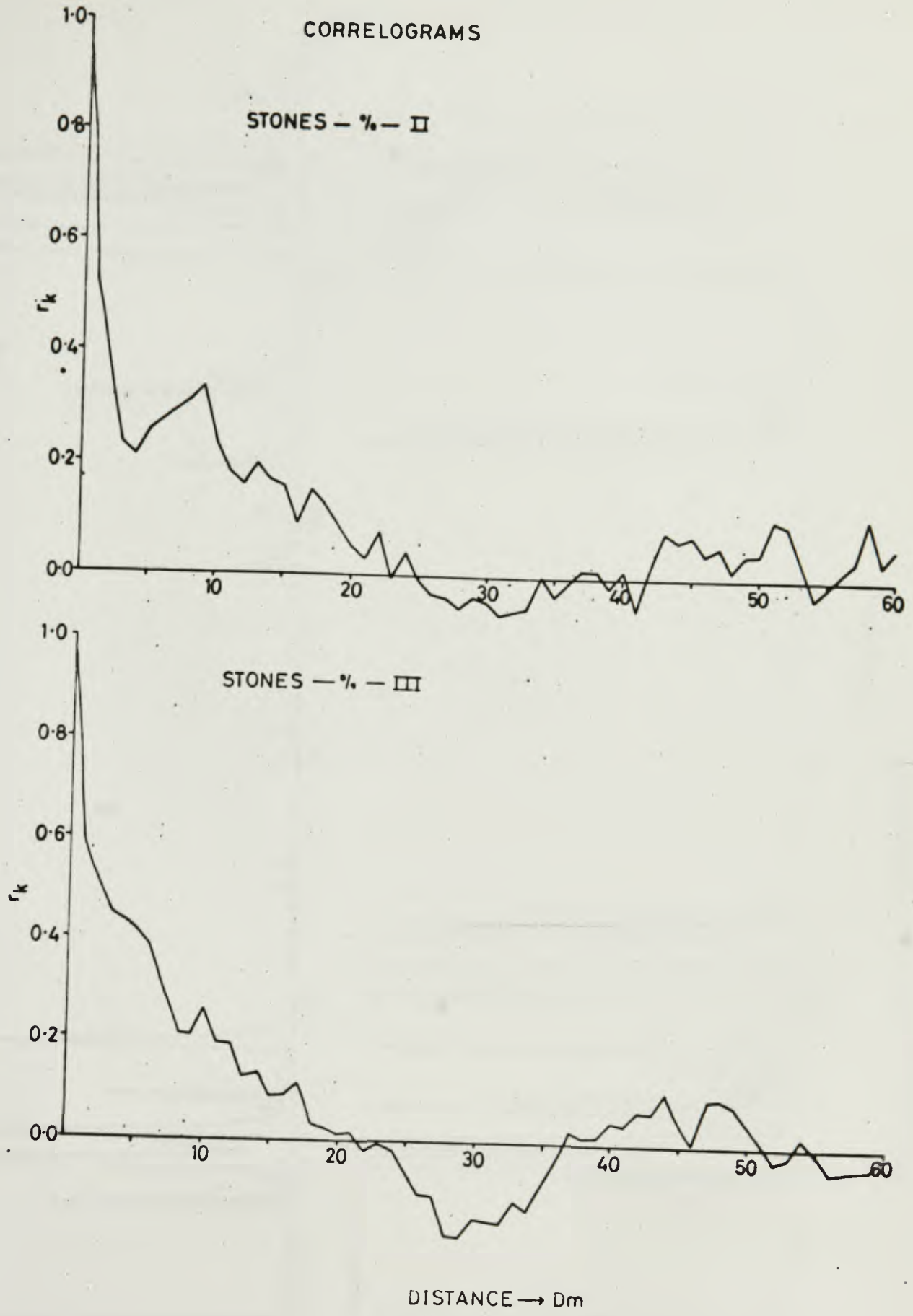



Fig. 5.26 Correlograms

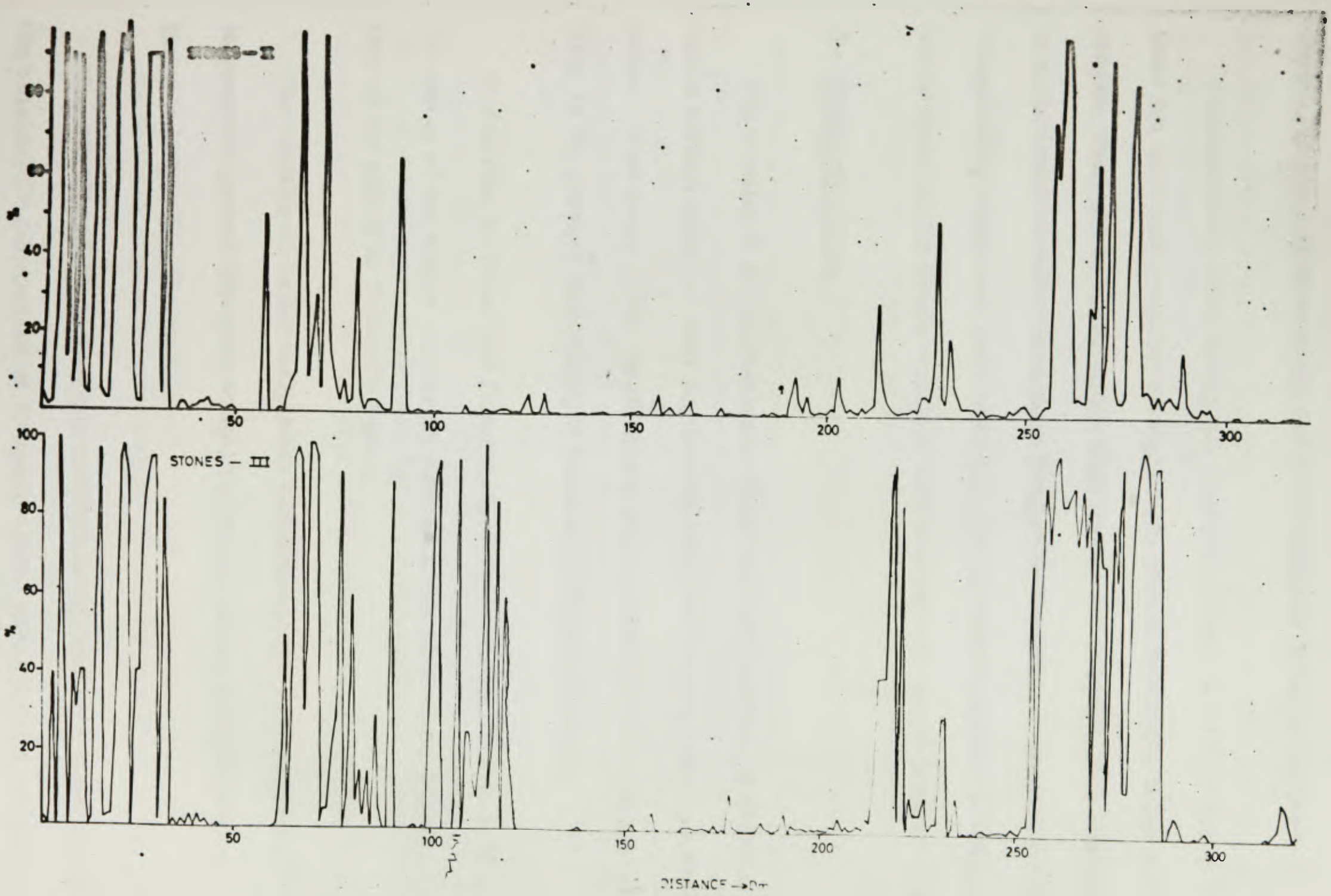



Fig. 5.27 Graphs of properties against distance

properties can be coded by continuous variables, the use of property value standardization to zero mean and unit variance is more appropiate.

Consequently, when designing property codes, it will be better to have for each soil property a single code with a relatively large number of stages, than two or more codes with rather few stages. For example, it is undesirable to code "structure shape" by the codes "dimensionality" and "angularity" which can each take only two or three stages. A better code would have been a single variable with a relatively large number of stages.

A. Property space.

The results of all the analyses show that soil profiles in Property space form a more or less continuous cloud with three broad protruding arms. Few parts of the cloud have a point density greater than average. This is the picture that emerges from the different results.

Ordination by Principal Component analysis (Figs. 5.5 to 5.8) gives the shape of the single cluster as well as some idea of the density distribution of the points in Property space.

The results of Order-neighbour statistics (Fig. 5.9) support the impression gained from the visual inspection of the ordinations, in that there is only a single cluster.

The results of Mode analysis and Similarity analysis showed that in the original 63 dimensions of Property space there were no clusters which correspond to the intuitively defined classes. Modd analysis showed that there was only a single cluster with a fairly uniform point density, and

only four hyper-volumes with slightly more than average point density. These cluster centres do not correspond in number to the Soil Series as intuitively defined, so they are not considered to be the cluster centres of the intuitively defined Soil Series.

Similarity analysis supports the view that there is only a single cluster with a fairly uniform point density, since the classification produced by changing soil property standardization varied considerably.

On the whole, there is good correspondence between results obtained from the ordination by Principal Component analysis and the results of Mode analysis. The mode centres of Fig. 5.10 have been marked by circles in the graph of the first against the second principal component values, shown in Fig. 5.7. Here, it is clear that the cluster centres formed by Mode analysis do mark the hyper-spaces with the highest point density.

On the other hand, the correspondence between the clusters formed by Mode analysis, (Fig. 5.10), and the groups formed by Similarity analysis, is not a clear one. In the results of Similarity analysis, (Figs. 5.12 and 5.13), the cluster centres of Mode analysis have been marked by crosses in front of the profile numbers.

Here there is no straightforward correspondence between the results of Mode and of Similarity analysis, since Mode analysis finds four modes, and Similarity analysis either finds too few groups at high values of similarity, or too many at low values of similarity. Besides, the mode centres of Fig. 5.10 do not always appear as well defined clusters in the similarity

dendrogram. Cluster centres of profiles 105 and 205 appear as well defined clusters, since other profiles join them at a relatively low level of similarity. However, cluster centres at profiles 317 and 289 do not join adjacent profiles at a low level of similarity.

These differences are due to the different manner in which clusters are formed, and to the way they grow for each analysis. In Mode analysis one can imagine a hyper-sphere being drawn around each point, and onee the density threshold is fulfilled a cluster is formed, and all the points falling inside this hyper-sphere are joined to form a mode. As the diameter of the hyper-sphere grows, more points are assigned to the existing modes, or new points form new modes. In contrast, in Similarity analysis, a cluster is formed whenever two points are nearer to each other than is any one point to an existing cluster, or one cluster to another cluster. Therefore if we have, say, three pairs of points and two of these pairs nearer to each other than is the third pair, Similarity analysis will form three clusters, two of them joining at a lower level of similarity than the third pair. Mode analysis, on the contrary, with a density threshold equal to 3, will form only one mode (cluster), as explained in detail in Chapter III.

B. Property-Geographic space.

All the results show that Property-Geographic space is made up of a sequence of sloping and horizontal, almost straight, hyper-lines. These are, in some cases, separated by almost vertical hyper-lines, but in most cases they join without the latter being present.

The graphs of the first four components against distance given in Figs. 5.14 and 5.15 are, as mentioned in the results, the most informative projections of the shape of the hyper-lines in Property-Geographic space. The first two components account for the largest amount of variation (32.9%), and they express a pattern of soil variation that is comprehensible from the landscape transect under study. This can be seen from the comparison of the diagrammatic representation of the transect given in Fig. 5.1, with the graph of the first two principal component values against distance of Fig. 5.14. Here, parent materials, Soil Series, and topography, change where the principal component values change.

Correspondence between the diagrammatic representation of the transect and the graph of the principal component values against distance, is clearer when the component values are smoothed by a five point linear moving average, as shown in Fig. 5.18. The correspondence increases because the erratic short range variation has been diminished, and the long range variation, or trend, appears more clearly. These smoothed values show that the trend, is made up mainly of almost straight lines, if we take distances of more or less the same length as that covered by each Soil Series. Many of these lines, however, are sloping. There are few horizontal lines. Neither the sloping nor the horizontal lines are commonly separated by vertical (or near vertical) lines. This lack of near vertical lines is to some extent due to the smoothing.

This is clearly seen when Fig. 5.14 and Fig. 5.18 are compared. These results together show, however, that transitional change in soil properties is rather frequent.

The correlograms of the two first principal component given in Fig. 5.19 support the results of the moving average smoothing, in that abrupt changes in soil properties are not common.

Correlogram analysis of the two first components is interpreted as being generated by a bilateral moving average scheme containing a random component. This scheme establishes that the property values at any point in the transect are given by a linear function of the property values at both sides of the point under consideration, (the trend), plus a random component.

The correlogram for the first component is then interpreted as being generated by a bilateral moving average scheme 24 Dm (240 m) long. It has a "memory" of about 12 Dm on each side of any point on the transect. 92 per cent of the total variation is attributed to the scheme, or trend, and 8 per cent is attributed to the random component, or very short range soil variation over this distance.

For the second component, the interpretation is similar. There, the same bilateral moving average scheme explains the trend. In this case it is 30 Dm long, and accounts for 86 per cent of the total variation.

Thus the general picture that emerges from the interpretation of both correlograms, is that the trend of the hyper-lines in Property-Geographic space is a sequence of nearly straight segments curved at the points where they meet.

The shape of this trend explains between 92 and 84 perceent of the total soil variation, and the complement, that is between 8 and 16 per cent, is attributed to the random component.

The shape of correlograms obtained from the first two principal component values is a consequence of the spatial relationship of most soil properties, as shown in Fig. 5.22. Therefore, the spatial relationship of the principal component values seems unlikely to be caused by any oversimplification or distortion induced by the use of Principal Component analysis to reduced the dimensionality of the problem.

C. Relationship between Property-Geographic space and Property space.

The projection of horizontal lines in Property-Geographic space on to Property space gives rise to round clusters in Property space. In contrast, projection of sloping lines from Property-Geographic space on to Property space produces elongated clusters. This is illustrated in Fig. 5.28, where the profiles number 262 to 285, made up of fairly uniform soil, are marked by squares. They form a round cluster in Property space, previously shown in Fig. 5.5. Profiles number 299 to 321, whose properties change gradually but continuously, have been marked by circles, and they do form an elongated cluster. Profiles number 262 to 285 are on a small escarpment on Middle Lias, and are Shallow Ranker profiles over Ironstone. In contrast, profiles 299 to 321 lie on a slope on the Lower Lias clay and are Clayey Surface Water Gley profiles.

There are few empty hyper-spaces in Property space, and those that exist correspond to combinations of properties that are not present in the transect studied. Some of this empty hyper-space corresponds to vertical or almost vertical hyper-lines in Property-Geographic space.

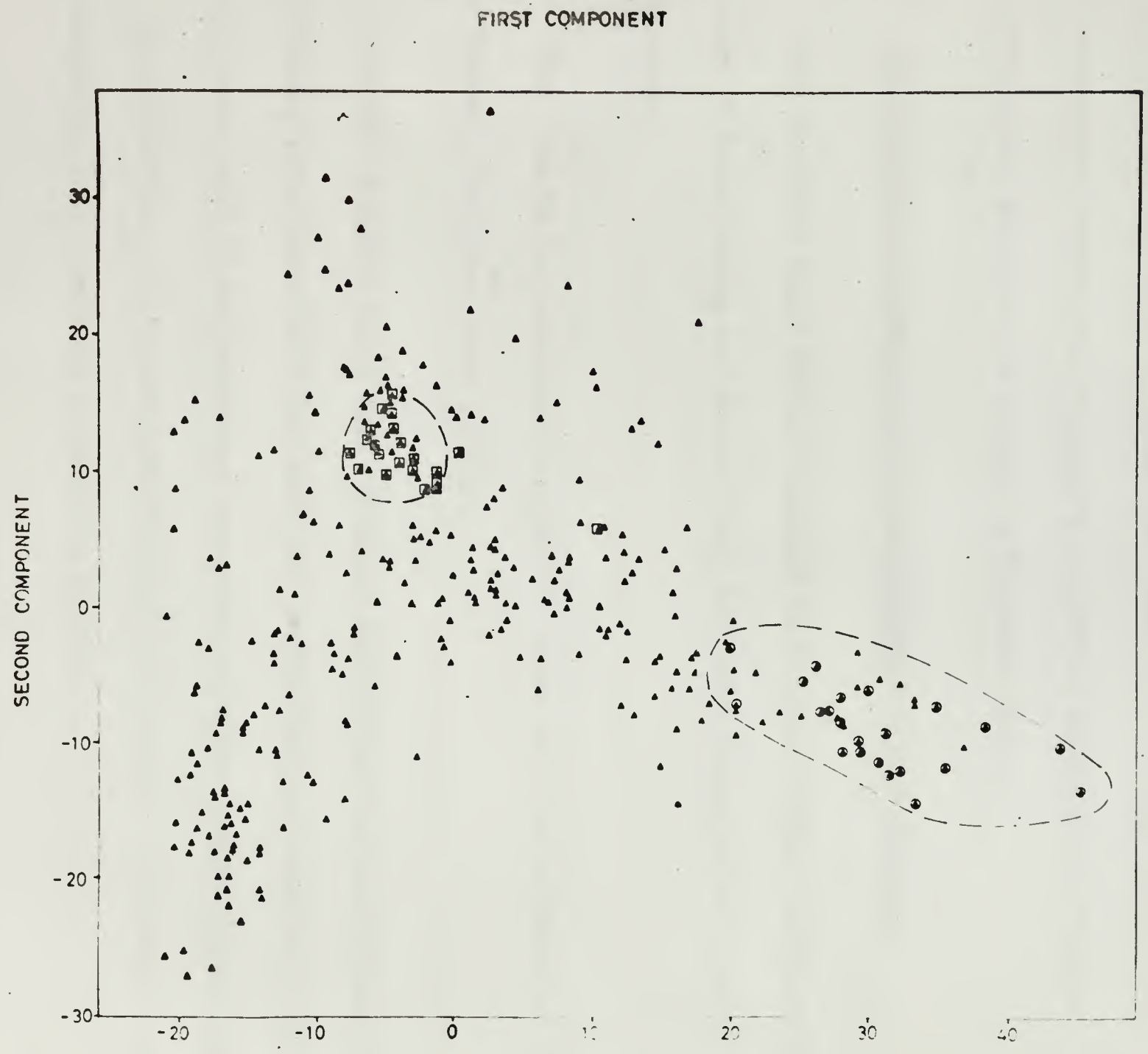



Fig. 5.28 Scatter diagram showing the projection of profiles of uniform soils and of soils with a transitional change

Therefore, if in Property-Geographic space there are no frequent vertical or almost vertical hyper-lines marking the separation between horizontal or sloping hyper-lines, there cannot be clusters in Property space. If sloping hyper-lines, positioned at the same altitude for each mapping unit, join the transition between horizontal and sloping hyper-lines, there is no reason whatsoever for empty or almost empty hyper-spaces, and consequently clusters, to appear in Property space.

D. Relationship between soil classification and soil mapping.

The fact that there are no clusters in Property space contradicts the claim of Pomerening and Knox (1962) that soils form natural groups or classes.

The results in Property-Geographic space can also explain the finds of Walker, Hall and Protz (1968).

These authors found that for some landscapes the use of trend analysis, by fitting a polynom, will increase the prediction precision of the properties at a given point of the landscape compared with the prediction precision by a classification, i.e. a constant value for each class. However, for other landscapes they found the opposite to be true.

The prediction precision of trend analysis will be superior to that of a classification when there is a gradual and consistent change in soil properties from one part of the landscape to other. When there is no such gradual change, because of the presence in Property-Geographic space of vertical or almost vertical hyper-planes separating almost horizontal hyper-planes, a constant value for each horizontal hyper-plane, that is

a classification, will give a more precise prediction than will trendanalysis.

The results presented here show that there are no clusters in Property space, yet the soil surveyor, produced soil classes which he thought useful for many purposes. Therefore, he must have partitioned Property space meaningfully. To have done so with such apparent ease, with no density gaps in Property space, suggests that the surveyor was strongly guided by more obvious boundaries in Property-Geographic space.

The transect under study shows three kinds of boundaries which correspond to changes in the shape of the hyper-lines in Property-Geographic space.

i. The first can be considered as vertical hyper-lines in Property-Geographic space, which correspond to empty hyper-volumes in Property space.

I is illustrated by the boundary at 156 Dm. in Fig. 5.1 where the Gleyed Brown Coarse Loamy or Sandy soil on Northampton sands is separated from the Argillic Brown Earth Loamy soils on the Upper Lias.

The boundary corresponds to vertical hyper-lines in Figs. 5.14 and 5.18, and to an empty hyper-space in Property space, the lower empty space of Fig. 5.28.

ii. This second kinf of boundary corresponds, in Property-Geographic space, to vertical hyper-lines that do not correspond to empty hyper-volumes in Property space.

The best examples of these are boundaries at 256 Dm and 282 Dm. Here, the Shallow Ranker over Ironstone soil is bounded on either side by Gleyed Brown Earth Loam over Clay (see Fig. 5.1). In Figs. 5.14 and 5.18 these boundaries correspond to almost vertical lines. However, these vertical lines do not correspond to empty space in Fig. 5.28, where the profiles have been marked with squares.

iii. Finally, the third kind of boundary corresponds to changes in the slope of two neighbouring hyper-lines in Property-Geographic space, and will obviously not correspond to empty hyper-volumes in Property space, since there is a gradual change of soil properties.

The best example of this is the boundary at 86 Dm (see Fig. 5.1). It separates the Brown Calcareous Loamy soil from the Gleyed Brown Earth coarse Loamy or Sandy Loamy soil. The boundary corresponds, for each principal component, to the junction of two lines, each with a different slope. In Figs. 5.1 and 5.18 another example of such a boundary is the one at 125 Dm. Here the Acid Brown Earth coarse Loamy or Sandy soil merges gradually with the Gleyed Brown Earth coarse Loamy or Sandy soil. This boundary corresponds in Figs. 5.14 and 5.18 to an almost vertical line for the first component, and to the junction of two lines at different angles for the second component.

Of these three kinds of boundaries, the first two are easy to find in the field. The third, that is the one associated with a gradual change in soil properties, will always cause surveyors to wonder whether these soil profiles are sufficiently similar to belong to the same class, or sufficiently different to belong to separate classes.

Since this third kind of boundary involves not only degree of soil similarity, but also the interaction of the environmental factors and land uses, it shall be called an "Interpreted boundary".

It would be expected that the location of the interpreted boundaries will vary when considering two areas that present differences in environmental conditions and or land use. In this case, even when dealing with very similar soil which occurs in these two areas, the location of boundaries will almost invariably be made at different "critical values". Thus the definition of the Soil Series classification units will be rather similar in the two areas, but "out of phase". This "out of phase" definition of similar soil classes explains Avery's concern about the systematization of the definition of Soil Series profile classes at regional or national levels.

# CHAPTER VI

## General Conclusions

The description of soil variation in much of soil survey rests on the concept of the Soil Series. By classifying soil profiles into Soil Series, relationships between soil properties regardless of their geographic location can be expressed. Soil profiles are also grouped into Soil Series to express geographic relationships between soil properties by means of soil maps.

### 1. The General Purpose classification of soils.

Soil Series are often thought of as the basic unit of the "Natural" classification of soils, or in Gilmour's (1937) terms, the basic unit of the General Purpose classification of soils.

Cline, (1949) suggested the concept of Soil Series on the basis that each Soil Series forms a mode in a frequency diagram.

I have interpreted Cline's (1949) classes as being constructed on the basis of over-all soil similarity. Thus I argue that to construct soil classes based on over-all similarity, to be used for General Purposes, Adanson's ideas (see Sokal and Sneath, 1963) should be applied. Adanson suggested that in the construction of such classes all properties should, a priori, be taken into account.

In Adanson's terms, then, modes become clusters when two or more properties are considered.

Therefore, as explained in Chapter II, for soil properties to form clusters the geographic soil property distribution pattern must fulfill the two following conditions.

First, changes in property values between Soil Series mapping units must be abrupt.

Second, the property values that mark abrupt changes between Soil Series mapping units should not cover relatively large areas in other parts of the landscape.

The results presented here show little evidence of clusters in Property space. When present, these clusters are extremely poorly defined, and always occur at levels of generalization higher than the Soil Series classification unit.

The lack of clusters in Property space is attributed, in some cases, to the occurrence in other parts of the landscape of relatively large areas having the property values that mark the abrupt changes between mapping units, and in other cases to the gradual change of soil properties along the transect (lack of abrupt changes between mapping units).

Therefore, if the Soil Series classification units are interpreted in terms of clusters, and with Adanson's ideas in mind, then Soil Series classification units do not occur as clusters.

The soil surveyor, however, did define Soil Series classification and mapping units. He must have done so as a consequence of locating boundaries on the ground.

It was shown in the discussion in Chapter V, that in the transect under study there were at least three kinds of boundaries. Two kinds correspond to abrupt changes in soil properties with distance. The third kind of boundary corresponds to gradual changes in soil properties with distance.

The third kind of boundary corresponds to gradual changes in soil properties. It is this third kind that is the most difficult to establish, and the question is always present as to whether soil profiles are sufficiently similar to belong to the same class, or sufficiently different to belong to different classes. In this case external factors other than soil profile similarity enter into consideration. These are, the use for which the survey is intended, the local land use, the land form, the climate, the vegetation and so on.

Thus, when the soil surveyor defines Soil Series classification units, what he does is to subdivide the continuum of soil variation into ranges of roughly the same magnitude. This subdivision is guided by abrupt geographic changes in soil properties, but is based to a large degree on both soil similarity and external factors.

On the other hand, the use of a classification system on a continuum will establish classes with a large proportion of members that are more similar to the members of other classes than they are to their own class. Thus, two of the attributes expected of a classification with mutually exclusive classes are ignored, i.e. that qualitative inductive statements apply to almost all the members of a given class, and that many statements are different for different classes.

2. An Alternative to the General Purpose classification of soils.

An alternative that arises from this work, is the use of Principal Component analysis as an ordination method. This analysis can be programed into a computer in such a way that it can be performed on thousands of soil profiles.

Once the analysis has been carried out, either on the whole set of profiles or on a "representative" sample, it will show how efficiently the problem has been reduced from the total number of soil properties considered in the analysis, to a few principal components. The results of this work suggest that, provided care is taken in the design of the codes, no more than four principal components are needed to express over-all soil similarity adequately.

In this system, a profile could be represented by a point whose position is determined in Property space by the values of the first few components. Soil profiles that are similar will have similar component values. The first component will take into account all the properties used to characterize a soil profile, but its value will be determined by the properties that are most highly correlated, and in largest number. The second principal component will again take into account all the properties used to characterize a soil profile, but will give more weight to the properties least correlated with the first group but most correlated among themselves. The third and fourth principal components will follow the same pattern. Each component can be given a name by examining the relationships between properties, plotting the elements of the eigenvectors, as was done in Chapter IV.

Ordination by Principal Component analysis can fulfill the requirements of a General Purpose system, viz, naming, transfer of information, inductive statements about groups, and geographic display.

i. Naming. The name of a particular soil profile could be given by an ordered list of numbers i.e. a vector, each number being the values of one of the first few principal components. The name of a group of soil profiles could be given by a list of ordered pairs of values; the first of each pair being the minimumof the range of interest, the second the maximum. For instance, the profile group between - 2 to - 3 in the first principal component, +1 to +2 in the second, and so on.

The range of variation given to each component could be made at regular intervals, and each interval could be given a name in words. Alternatively, the subdivision could be based on the traditional names of the classes already established. The range of each class could be established from the location, on this framework, of the soil profiles accepted within the class.

ii. Information transfer. An important use of any General Purpose system is the transfer of information gathered from one area, to another area with similar soils.

Information which could be useful in an area might be obtained by transfering it from another area with closely similar component values.

Alternatively, an ordination system could be implemented, requiring computing and tretrieval facilities. If it is known what properties, and up to what degree, a group of soil properties are responsible for a given behaviour

of soils, then the information transfer can be more reliably based not on over-all similarity, but only on those soil properties directly related to the information that is needed.

iii. Inductive statements. Quantitative inductive statements about any collection of soil properties can be made at any level of generality, by selecting the appropriate interval in the ordination framework. We can also discuss the relation between one interval and another of the same magnitude, but displaced to a given distance, or, to decrease the range of variation in soil properties, discuss small intervals contained within a large one.

iv. Geographic display. The geographic display of soil properties can be made on maps by contouring, for each principal component, the component values at each geographic location. This work suggests that two, three, or four of these maps should be sufficient. The soil profiles found on a given isometric line, here called an Isoped, will have similar values for those properties which give the largest weight to the particular principal component. The Isoped intervals can be made as wide as is appropriate for differant map scales. Component values can also be smoothed. Following this original idea, Webster and Burrough (1972) illustrated such maps.

However, to carry out a General Purpose system of soil ordination, and to be able to exploit its maximum value, order is needed in describing soil profiles. Every property must be specified, codable on an equal interval scale, and must be applicable in all instance. This difficulty will increase as the soil profiles under study become more and more dissimilar.

Thus, numerical ordination methods may give us means of describing soils in a manner which is more precise than is any classification system as yet devised.

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# APPENDIX A

## Computer programs

### Principal Component analysis

### Auto and cross covariance

A

```
FAABC4001APU
COMPONENT ANALISIS.NORMALIZED AND STANDARIZED DATA.
H.E.CUANALO.SOIL SC.1968;
SAVE;
TEXT;
TL1200;→

begin library A6,A12, A14,A30,B10;

   integer sites,prop,roots,vectors,punch,i,j,k,r,f,jj;
    real ss,s,sj,sk,xy,m,proy,st;
   open(20); open(30);
   punch:=read(20);  if punch > 0 then open(10);
   write text(30,[[3c10s]PRINCIPAL[ss]COMPONENT[ss]ANALYSIS[cc5s]]
   copy text(20,30,[↑↑]);
   st:=read(20);roots:=read(20); vectors:=read(20);
   sites:=read(20); prop:=read(20);

   begin real array t[1:sites,1:prop],v[1:prop×(prop+1)/2],
       sp[1:8×prop+2×vectors],vect[1:prop,1:vectors],ro[1:prop];

procedure standat( t, sites, prop);
   real array t;   integer sites, prop;
   begin real ma, mi;   integer i,j;
       for j:=1 step 1 until prop do
       begin ma:= -80;     mi:= 10000;
             for i:= 1 step 1 until sites do
             begin if t[i,j]> ma then ma:=t[i,j];
             if t[i,j]< mi then mi:= t[i,j];
             end;
             for i:= 1 step 1 until sites do
             t[i,j]:=(t[i,j] -mi)/(ma-mi);
       end;
   end;

procedure DUMMY;
KDP9 0/0/0/0;
L203; JP242;
EXIT;
ALGOL;

       for i:=1 step 1 until sites do
       for j:=1 step 1 until prop do
          t[i,j]:=read(20);
```

B

```
if st< 0 then
begin write text(30,[[cc8s]STANDARIZATION[ss]TO[ss]ZERO[ss]
        MEAN-UNIT-VARIANCE[c4s]CORRELARION[ss]MATRIX[ss]
        UPPER-TIANG.[ss]BY[ss]ROWS[cc]]);

     forj:=1 step 1 until prop do
     begin s:=ro[j]:=0;
        for i:=1 step 1 until sites do
        s:=s+t[i,j];
        m:=s/sites;
        for i:=1 step 1 until sites do
        begin t[i,j]:=t[i,j]-m;
            ro[j]:=ro[j]+t[i,j]↑2;

        end;
end;

     r:=0;
     for j:=1 step 1 until prop do
     begin f:=0;
        for k:=j step 1 until prop do
        begin r:= r+1; xy:=0;
            for i:=1 step 1 until sites do
            xy:=xy+t[i,j]×t[i,k];
            v[r]:=xy/sqrt(ro[j]×ro[k]);
            write(30,format([ss-d.dddd]),v[r]);
            f:=f+1;
            if f>10 then
            begin new line(30,1);
                  f:=0;
            end;
        end;
        new line(30,2);
        ro[j]:=sqrt(ro[j]/(sites-1));
        for i:= 1 step 1 until sites do
        t[i,j]:=t[i,j]/ro[j];
     end;
end
```

```
else
begin standat(t,sites,prop);
    write text(30,[[c8s]STANDARIZATION[ss]BY[ss]RANGE[c6s]
              VARIANCE-COVARIANCE-MARTIX[ss]UPPER-TRIAG
              [ss]BY[ss]ROWS[cc]]);

    jj:=r:=0;
    for j:=1 step 1 until prop do
    begin for k:=j step 1 until prop do
    begin
       ss:=sj:=sk:=0;
    jj:=jj+1;
       for i:= 1 step 1 until sites do
       begin ss:=ss+t[i,j]xt[i,k];
            sj:=sj+t[i,j];
            sk:=sk+t[i,k];
       end;
       v[jj]:=(ss-((sjxsk)/sites))/(sites-1);
       write(30,format([ss-nddd.dddd]),v[jj]);
       r:=r+1;
       if r> 10 then
       begin new line(30,1);
           r:=0;
           end;
           end;
           new line(30,2); r:=0;
        end;
   end;

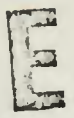
P2918(prop,v,sp,vect,ro,vectors,prop,1,1,1,1,fail);

write text(30,[[cc4s]EIGENVALUES[sss]LARGEST[ss]
  TO[ss]SMALLEST[c]]);
j:=0; s:=0;
for r:=1step 1 until prop do
begin write(30,format([sss-d.ddddm+nd]),ro[r]);
  j:=j+1; s:=s+ro[r];
  if j>7 then
  begin new line(30,1);
      j:=0;
  end;
end;
```

```
write text(30,[[cc27s]p.c.[s]TOTAL[c4s]ORDER[3s]
   EIGENVALUES[3s]VARIATION
   [3s]CUMUL.p.c.[cc]]);
sk:=0;
for r:=1 step 1 until roots do
begin write(30,format([-ndddddd]),r);
   write(30,format([ssss-d.dddd10+nd]),ro[r]);
   write(30,format([-nddddd.dd]),ro[r]×100/s);
   sk:= sk+(ro[r]×100/s);
   write(30,format([-nddddddd.ddc]),sk);
end;

write text(30,[[cc4s]VALUES[ss]OF[ss]EIGENVECTORS[cc]]);
for j:=1 step 1 until vectors do
beginr:=0;
   fork:=1 step 1 until prop do
   begin write(30,format([sss-d.dddd10+nd]),vect[k,j]);
        r:= r+1;
        if r>7 then
   begin r:=0;
            new line(30,1);
        end;
   end;
   new line(30,2);
end;

write text(30,[[cc4s]PROYECTIONS[4s]VALUES[c4s]OR
   [ss]COMPONENTS[ss]VALUES[cc]]);
r:= 0;  gap(10,30);
for k:=1 step 1 until vectors do
begin f:=0;
   for i:=1 step 1 until sites do
   begin
   proy:=0;
   begin for j:=1 step 1 until prop do
        proy:=proy+t[i,j]×vect[j,k];
        write(30,format([sss-d.ddddd10+nd]),proy);
        f:= f+1;
        if f>7 then
        begin f:=0;
           new line(30,1);
           r:= r+1;
        end;
```



```
   if punch >0  and punch ≥ k then
        begin
        write(10,format([ss-d.dddd10+nd;c]),proy);
        if r> 2 then
        begin r:= 0;
           gap(10,30);
        end;
        end;
     end;
     end;
new line(30,3);
end;

go to next;
fail: write text(30,[[ccss]PROCEDURE[ss]P2198[ss]FAILS
          [ss]MATRIX[ss]SINGULAR[cc]]);
next: end; close(30); close(20); if punch >0 then close(10);
end →
```

M

FAABC4001RPU→

3;

↑DATA-TEST↑

1;

5;

3;

6;

5;

27; 13.1; 5.2; 2.4; 2.5;

25; 12.2; 5.5; 3.1; 2.2;

23; 6.7; 4.4; 2.4; 2.0;

21; 5.9; 6.3; 3.0; 1.7;

20; 3.9; 4.3; 2.2; 1.9;

18; 1.4; 2.9; 1.3; 1.4;

→→

FAABC4001RPU 18/05/70
STR30 09920WD 13H54M27S

PRINCIPAL COMPONENT ANALYSIS

DATA-TEST
STANDARIZATION BY RANGE
VARIANCE-COVARIANCE-MARTIX UPPER-TRIAG BY ROWS

| | | | | |
|---|---|---|---|---|
| 0.1366 | 0.1426 | 0.0730 | 0.0778 | 0.1232 |
| 0.1553 | 0.0844 | 0.0927 | 0.1267 | |
| 0.1196 | 0.1170 | 0.0572 | | |
| 0.1296 | 0.0646 | | | |
| 0.1215 | | | | |

EIGENVALUES LARGEST TO SMALLEST

| | | | | |
|---|---|---|---|---|
| $5.2203_{10}$ -1 | $1.2256_{10}$ -1 | $8.8595_{10}$ -3 | $7.4183_{10}$ -3 | $1.7545_{10}$ -3 |

| ORDER | EIGENVALUES | P.C. TOTAL VARIATION | CUMUL.P.C. |
|---|---|---|---|
| 1 | $5.2203_{10}$ -1 | 78.78 | 78.78 |
| 2 | $1.2256_{10}$ -1 | 18.50 | 97.28 |
| 3 | $8.8595_{10}$ -3 | 1.34 | 98.62 |
| 4 | $7.4183_{10}$ -3 | 1.12 | 99.74 |
| 5 | $1.7545_{10}$ -3 | 0.26 | 100.00 |

VALUES OF EIGENVECTORS

| | | | | |
|---|---|---|---|---|
| 9.1970E -1 | 1.0000E +0 | 7.1208E -1 | 7.6665E -1 | 8.2461E -1 |
| -5.5657E -1 | -4.1374E -1 | 1.0000E +0 | 9.8150E -1 | -6.4993E -1 |
| -2.5006E -1 | -7.5427E -1 | -9.0090E -2 | 2.7191E -1 | 1.0000E +0 |

| PROJECTIONS OR COMPONENTS | VALUES | | | | |
|---|---|---|---|---|---|
| 3.69452E +0 | 3.54930E +0 | 2.19638E +0 | 2.35222E +0 | 1.46941E +0 | 0.00000 |
| -3.46957E -1 | 4.55966E -1 | 1.88495E -1 | 1.40392E +0 | 3.94367E -1 | 0.00000 |
| 1.13119E -1 | 5.95508E -2 | 2.03499E -1 | 8.48716E -2 | 3.46666E -1 | 0.00000 |

STORAGE 005138

RAN/EL/000M03S/000M04S

M

FAABC4001RPU→

3;

↑DATA-TEST↑

0;

5;

3;

6;

5;

27; 13.1; 5.2; 2.4; 2.5;

25; 12.2; 5.5; 3.1; 2.2;

23; 6.7; 4.4; 2.4; 2.0;

21; 5.9; 6.3; 3.0; 1.7;

20; 3.9; 4.3; 2.2; 1.9;

18; 1.4; 2.9; 1.3; 1.4;

→→

FAABC4001R-U 14/05/70
STR30 14016WD 16H14N20S

PRINCIPAL COMPONENT ANALYSIS

DATA-TEST

STANDARIZATION TO ZERO MEAN-UNIT-VARIANCE
CORRELARION MATRIX UPPER-TIANG. BY ROWS

1.0000 0.9793 0.5556 0.5844 0.9565

1.0000 0.6190 0.6533 0.9221

1.0000 0.9396 0.4747

1.0000 0.5151

1.0000

EIGENVALUES LARGEST TO SMALLEST
3.8954E +0 9.6620E -1 6.6742E -2 5.9205E -2 1.2414E -2

| ORDER | EIGENVALUES | P.C. TOTAL VARIATION | CUMUL.P.C. |
|---|---|---|---|
| 1 | 3.8954E +0 | 77.91 | 77.91 |
| 2 | 9.6620E -1 | 19.32 | 97.23 |
| 3 | 6.6742E -2 | 1.33 | 98.57 |
| 4 | 5.9205E -2 | 1.18 | 99.75 |
| 5 | 1.2414E -2 | 0.25 | 100.00 |

VALUES OF EIGENVECTORS

| | | | | |
|---|---|---|---|---|
| 9.7935₁₀ -1 | 1.0000₁₀ +0 | 6.3334₁₀ -1 | 8.5946₁₀ -1 | 9.3153₁₀ -1 |
| -5.7515₁₀ -1 | -4.1425₁₀ -1 | 1.0000₁₀ +0 | 9.3442₁₀ -1 | -7.0734₁₀ -1 |
| -3.5837₁₀ -1 | -7.6677₁₀ -1 | -2.0071₁₀ -1 | 4.1127₁₀ -1 | 1.0000₁₀ +0 |

| PROYECTIONS OR COMPONENTS | VALUES VALUES | | | | |
|---|---|---|---|---|---|
| 4.29694₁₀ +0 | 3.92499₁₀ +0 | -5.05620₁₀ -2 | 6.00477₁₀ -1 | -2.12013₁₀ +0 | -6.65172₁₀ +0 |
| -1.98311₁₀ +0 | 2.61420₁₀ -1 | -4.74405₁₀ -1 | 2.97765₁₀ +0 | 1.06926₁₀ -1 | -8.88483₁₀ -1 |
| -1.23432₁₀ -1 | -1.47738₁₀ -1 | 2.04335₁₀ -1 | -1.73171₁₀ -1 | 6.22523₁₀ -1 | -3.62517₁₀ -1 |

STORAGE 005136

RAN/EL/0000035/0000040

K'

```
FAABC1405APU
AUTO AND CROSS COVARIANCE-P.
H.E.CUANALO OXON;
SAVE;
OPT;
TL1500;→

begin library A6,A12,A14,A30;

      integer prop,site, mautolag, mcrosslag, s,punch,
a, r, f, ss, k,inv;
      open(20); open(30);
      inv := read(20); punch:=read(20);
      copy text (20,30,[↑↑]);
      site:= read(20);   prop:= read(20);
      mautolag:= read(20);   mcrosslag:= read(20);

      begin real array o[1:prop, 1:site], m[1:prop],
       c[1:prop, 0:mautolag],
         ac[1:propx(prop-1)x0.5, 0:mcrosslag];

      if punch>0 then open(10);
         if inv> 0 then
         begin
         for r:= 1 step 1 until site do
         for s:= 1 step 1 until prop do
            o[s,r]:= read(20);
         end

         else
         begin
         for s:= 1 step 1 until prop do
         for r:= 1 step 1 until site do
            o[s,r]:= read(20);
         end;

         for s:= 1 step 1 until prop do
            m[s]:= 0;
         for s:= 1 step 1 until prop do
         for r:= 1 step 1 until site do
            m[s]:= m[s]+o[s,r];

         write text(30,[[4c10s]MEANS[c4s]PROP.[c]]);
```

```
for s:= 1 step 1 until prop do
begin m[s]:= m[s]/site;
   write(30,format([6s-nddd]), s);
   write(30,format([5s-d.dddd10+ndc]), m[s]);
end;

for s:= 1 step 1 until prop do
for r:= 1 step 1 until site do
   o[s,r]:= o[s,r] -m[s];
for s:= 1 step 1 until prop do
for k:= 0 step 1 until mautolag do
begin c[s,k]:= 0;
   for r:= 1 step 1 until site-k do
   c[s,k]:= c[s,k]+o[s,r]×o[s,r+k];
end;

write text(30,[[bc10s]AUTO-COVARIANCE[2s]VALUES[2c
   5s]LAGS[2s]FROM[2s]ZERO[2s]TO]);
write (30,format([2s-ndddd]),mautolag);
new line(30,2);

for s:= 1 step 1 until prop do
begin write text(30,[[c2s]PROPERTY[ss]NUMBER[sss]]);
   write(30,format([3s-nddd]), s);
new line(30,1);
   f:= 0;
   for k:= 0 step 1 until mautolag do
   begin write(30,format([4s-d.dddd10+nd]),
      c[s,k]/(site-k));
      f:= f+1;
      if f>5 then
      begin new line(30,2);
            f:= 0;
      end;
   end;
new line(30,3);
end;

write text(30,[[p4c8s]AUTO-COVARIANCE[2s]COEFFICIENTS
   [2c]]);
if punch>0 then gap(10,40);
for s:= 1 step 1 until prop do
begin write text(30,[[css]PROPERTY[ss]NUMBER[sss]]);
   write(30,format([3s-ndddc]), s);
   f:= 0;
```

```
    for k:= 0 step 1 until mautolag do
    begin
      write(30,format([4s-d.dddd]),(c[s,k]/(site-k))
       /(c[s,0]/site));
if punch>0 then write(10,format([-nddd.dddd;c]),
(c[s,k]/(site-k))/(c[s,0]/site));
       f := f+ 1;
       if f>5 then
       begin new line(30,1);
            f:= 0;
       end;
    end;
    new line(30,3); f:=0;if punch>0 then gap(10,40);
end;


if mcrosslag > 1 then
begin    for s:= 1 step 1 until propx(prop-1)x0.5 do
    for k:= 0 step 1 until mcrosslag do
       ac[s,k]:=0;
ss:=0;
for s:= 1 step 1 until prop-1 do
for a:= s+1 step 1 until prop do
begin ss:= ss+1;
    for k:= 0 step 1 until mcrosslag do
    for r:= 1 step 1 until site-k do
    ac[ss,k]:=ac[ss,k]+o[s,r]xo[a,r+k];
end;

write text(30,[[p3c5s]CROSS-CORRELATION[2s]VALUES[ss]
       FROM[ss]ZERO[ss]TO]);
write(30,format([7s-ddddc]),mcrosslag);
ss:= f:= 0;
for s:= 1 step 1 until prop-1 do
begin for a:= s+1 step 1 until prop do
    begin ss:= ss+1;
       write text(30,[[c3s]PROPERTY[s:]NUMBER[sss]]);
       write(30,format([4s-ndddss]),s);
     write text(30,[[ss]AGAINST[ss]PROPERTY[ss]NUMBER
          [ss]]);
        write (30,format([4s-ndddc]),a);
       for k:= 0 step 1 until mcrosslag do
       begin write(30,format([3s-d.dddd10+nd]),
                  ac[ss,k]/(site-k));
            f:= f+1;
            if f> 5 then
            begin new line(30,1);
                 f:= 0;
            end;
```

```
        end;
    end;
    new line(30,2);
    f:= 0;
end;


write text(30,[[p3c5s]CROSS-CORRELATION[2s]COEFFICIENTS[c]]
ss:= f:= 0; if punch>0 then gap(10,40);
for s:= 1 step 1 until prop-1 do
begin for a:= s+1 step 1 until prop do
    begin ss:= ss+1;
        write text(30,[[csss]PROPERTY[ss]NUMBER]);
        write (30,format([7s-nddddss]),s);
        write text(30,[[ss]AGAINST[ss]PROPERTY[ss]NUMBER]);
        write(30,format([4s-ndddddddc]),a);
        for k:= 0 step 1 until mcrosslag do
        begin write(30,format([2s-d.dddd]),
                (ac[ss,k]/(site-k))/((sqrt(c[s,0]x
            c[a,0]))/site));
if punch>0 then write(10,format([-nddd.dddd;c]),
        (ac[ss,k]/(site-k))/((sqrt(c[s,0]xc[a,0]))/site));
                f:= f+1;
                if f≥10 then
                begin new line(30,1);
                        f:= 0;
                    end;
            end;
            new line(30,2); if punch>0 then gap(10,40);
            f:= 0;
        end;
    end;
    end; close(20);  close(30); if punch>0 then close(10);
end→
```

```
-1;
1;
↑TITLE-TEST-ABC↑
4;
2;
2;
2;
1;  2;  3;  2;
4;  6;  8;  7;

→→
```

FAABC1405APII 24/11/69
STR30 13920WD 16H48M40S

RAN/EL/000M06S/001M12S/001M14S SIZE 721 OK

TITLE-TEST-ABC

MEANS

| PROP. | | |
|---|---|---|
| | 1 | 2.0000m +0 |
| | 2 | 6.2500m +0 |

AUTO-COVARIANCE VALUES

LAGS FROM ZERO TO 2

| | | | |
|---|---|---|---|
| PROPERTY NUMBER 1 | | | |
| 5.0000m -1 | 0.0000 | | -5.0000m -1 |
| PROPERTY NUMBER 2 | | | |
| 2.1875m +0 | 4.7917 | -1 | -2.0625m +0 |

CROSS-CORRELATION VALUES FROM ZERO TO 2

PROPERTY NUMBER 1 AGAINST PROPERTY NUMBER 2

1.0000E +0 3.3033E -1 -8.7500E -1

AUTO-COVARIANCE COEFFICIENTS

| PROPERTY NUMBER | | |
|---|---|---|
| 1.0000 | 0.0000 | -1.0000 |

| PROPERTY NUMBER | | |
|---|---|---|
| 1.0000 | 0.2190 | -0.0429 |

CROSS-CORRELATION COEFFICIENTS

PROPERTY NUMBER 1 AGAINST PROPERTY NUMBER 2

0.0562 0.3187 -0.8367

RAN/EL/0001035/0001035/0001055

# APPENDIX B

## The Data

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 8.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 7.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 6.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | | | | | | | | | |

Property 1. Depth I. Colour: dominant hue.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 3.0 | 2.0 | 2.0 | 4.0 | 3.0 | 4.0 | 3.0 | 4.0 | 3.0 |
| 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 |
| 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 |
| 5.0 | | | | | | | | | |

Property 2. Depth I. Colour: dominant chroma.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 5.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 1.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 2.0 | 3.0 | 1.0 | 3.0 | 1.0 | 3.0 | 2.0 | 3.0 |
| 2.0 | 2.0 | 1.0 | 0.0 | 1.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 6.0 |
| 4.0 | 4.0 | 8.0 | 4.0 | 6.0 | 8.0 | 8.0 | 6.0 | 4.0 | 4.0 |
| 6.0 | 6.0 | 6.0 | 4.0 | 4.0 | 2.0 | 4.0 | 6.0 | 4.0 | 6.0 |
| 4.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 |
| 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 |
| 3.0 | 5.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 2.0 | 4.0 | 2.0 |
| 2.0 | 2.0 | 3.0 | 3.0 | 4.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 |
| 1.0 | | | | | | | | | |

Property 3. Depth I. Colour: dominant value.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 3.0 | 6.0 | 3.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 7.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | | | | | | | | | |

Property 4. Depth I. Colour of mottles: hue

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 6.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 5.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 3.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 2.0 | 2.0 | 4.0 | 3.0 | 3.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 3.0 | 7.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 3.0 | 4.0 | 4.0 | 5.0 | 3.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 |
| 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 6.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | | | | | | | | | | |

Property 5. Depth I. Colour of mottles: chroma.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6.0 | 6.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 1.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 5.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 6.0 | 3.0 | 3.0 | 8.0 | 6.0 | 6.0 | 2.0 | 2.0 |
| 6.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 1.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 1.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 8.0 | 4.0 | 3.0 |
| 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 2.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 2.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| 4.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 1.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 4.0 | 4.0 | 2.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 6.0 | 4.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 4.0 | 2.0 | 6.0 | 2.0 |
| 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 2.0 | 6.0 | 3.0 | 3.0 | 3.0 |
| 5.0 | 6.0 | 4.0 | 6.0 | 6.0 | 4.0 | 6.0 | 8.0 | 6.0 | 8.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 4.0 | 4.0 | 4.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 8.0 |
| 4.0 | 4.0 | 8.0 | 4.0 | 6.0 | 8.0 | 8.0 | 6.0 | 4.0 | 4.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.0 | 6.0 |
| 4.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 8.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 6.0 | 2.0 | 6.0 | 4.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 |
| 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 |
| 3.0 | 5.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 2.0 | 4.0 | 5.0 |
| 6.0 | 5.0 | 3.0 | 3.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 4.0 | 3.0 | 1.0 | 1.0 |
| 2.0 | | | | | | | | | |

Property 6. Dept I. Colour of mottles: value.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 5.0 | 0.0 | 0.0 | 30.0 | 15.0 | 10.0 | 0.0 | 0.0 |
| 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 40.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | 10.0 | 0.0 |
| 30.0 | 30.0 | 20.0 | 25.0 | 25.0 | 15.0 | 20.0 | 40.0 | 0.0 | 10.0 |
| 10.0 | 20.0 | 20.0 | 25.0 | 20.0 | 30.0 | 40.0 | 25.0 | 15.0 | 25.0 |
| 28.0 | 0.0 | 25.0 | 30.0 | 0.0 | 10.0 | 20.0 | 20.0 | 30.0 | 10.0 |
| 20.0 | 25.0 | 0.0 | 0.0 | 4.0 | 12.0 | 0.0 | 10.0 | 5.0 | 4.0 |
| 8.0 | 15.0 | 18.0 | 12.0 | 30.0 | 18.0 | 12.0 | 25.0 | 28.0 | 24.0 |
| 15.0 | 30.0 | 10.0 | 10.0 | 45.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20.0 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 40.0 | 30.0 | 15.0 | 15.0 | 15.0 | 0.0 | 0.0 |
| 0.0 | 25.0 | 0.0 | 0.0 | 0.0 | 20.0 | 20.0 | 20.0 | 25.0 | 30.0 |
| 30.0 | 15.0 | 30.0 | 30.0 | 30.0 | 10.0 | 10.0 | 50.0 | 40.0 | 15.0 |
| 10.0 | 5.0 | 10.0 | 35.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 20.0 | 0.0 | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 40.0 | 30.0 | 15.0 | 40.0 |
| 25.0 | 25.0 | 25.0 | 30.0 | 15.0 | 25.0 | 25.0 | 40.0 | 40.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 |
| 2.0 | 5.0 | 0.0 | 0.0 | 50.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 25.0 | 12.0 | 0.0 | 20.0 | 45.0 | 0.0 | 0.0 |
| 20.0 | | | | | | | | | |

Property 7. Depth I. Per cent of mottles.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 70.0 | 65.0 | 65.0 | 70.0 | 80.0 | 65.0 | 70.0 | 65.0 | 65.0 | 40.0 |
| 45.0 | 35.0 | 25.0 | 30.0 | 30.0 | 35.0 | 50.0 | 35.0 | 30.0 | 25.0 |
| 30.0 | 20.0 | 30.0 | 15.0 | 15.0 | 10.0 | 30.0 | 20.0 | 25.0 | 20.0 |
| 40.0 | 15.0 | 25.0 | 15.0 | 20.0 | 20.0 | 30.0 | 25.0 | 40.0 | 20.0 |
| 40.0 | 25.0 | 30.0 | 30.0 | 25.0 | 40.0 | 30.0 | 20.0 | 30.0 | 30.0 |
| 15.0 | 10.0 | 5.0 | 10.0 | 10.0 | 10.0 | 15.0 | 15.0 | 15.0 | 25.0 |
| 25.0 | 15.0 | 15.0 | 20.0 | 20.0 | 15.0 | 20.0 | 20.0 | 15.0 | 15.0 |
| 5.0 | 15.0 | 18.0 | 20.0 | 16.0 | 22.0 | 23.0 | 22.0 | 24.0 | 23.0 |
| 18.0 | 22.0 | 14.0 | 16.0 | 16.0 | 18.0 | 15.0 | 15.0 | 15.0 | 20.0 |
| 18.0 | 22.0 | 12.0 | 5.0 | 12.0 | 10.0 | 15.0 | 12.0 | 12.0 | 15.0 |
| 12.0 | 12.0 | 13.0 | 12.0 | 13.0 | 14.0 | 13.0 | 15.0 | 14.0 | 20.0 |
| 12.0 | 20.0 | 21.0 | 23.0 | 25.0 | 22.0 | 18.0 | 18.0 | 18.0 | 12.0 |
| 13.0 | 10.0 | 15.0 | 12.0 | 6.0 | 6.0 | 12.0 | 12.0 | 12.0 | 6.0 |
| 8.0 | 7.0 | 8.0 | 8.0 | 7.0 | 10.0 | 8.0 | 12.0 | 16.0 | 8.0 |
| 8.0 | 8.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| 12.0 | 12.0 | 12.0 | 12.0 | 20.0 | 12.0 | 18.0 | 25.0 | 30.0 | 28.0 |
| 38.0 | 35.0 | 45.0 | 55.0 | 22.0 | 45.0 | 35.0 | 38.0 | 40.0 | 42.0 |
| 38.0 | 35.0 | 40.0 | 35.0 | 40.0 | 35.0 | 30.0 | 22.0 | 26.0 | 35.0 |
| 38.0 | 35.0 | 38.0 | 22.0 | 22.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| 10.0 | 10.0 | 20.0 | 15.0 | 30.0 | 55.0 | 65.0 | 65.0 | 55.0 | 45.0 |
| 30.0 | 20.0 | 20.0 | 50.0 | 35.0 | 35.0 | 35.0 | 40.0 | 35.0 | 30.0 |
| 35.0 | 30.0 | 25.0 | 30.0 | 35.0 | 30.0 | 30.0 | 35.0 | 30.0 | 30.0 |
| 36.0 | 35.0 | 25.0 | 30.0 | 25.0 | 35.0 | 20.0 | 25.0 | 25.0 | 20.0 |
| 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 15.0 | 15.0 | 50.0 | 25.0 | 30.0 |
| 25.0 | 15.0 | 35.0 | 35.0 | 35.0 | 40.0 | 25.0 | 35.0 | 25.0 | 25.0 |
| 45.0 | 12.0 | 18.0 | 13.0 | 14.0 | 14.0 | 12.0 | 18.0 | 12.0 | 12.0 |
| 14.0 | 18.0 | 12.0 | 16.0 | 18.0 | 14.0 | 14.0 | 14.0 | 12.0 | 14.0 |
| 12.0 | 14.0 | 14.0 | 16.0 | 12.0 | 16.0 | 16.0 | 22.0 | 12.0 | 22.0 |
| 18.0 | 12.0 | 12.0 | 16.0 | 12.0 | 14.0 | 14.0 | 14.0 | 24.0 | 18.0 |
| 16.0 | 14.0 | 14.0 | 12.0 | 28.0 | 12.0 | 30.0 | 14.0 | 38.0 | 46.0 |
| 46.0 | 62.0 | 44.0 | 36.0 | 65.0 | 60.0 | 55.0 | 60.0 | 50.0 | 60.0 |
| 62.0 | 67.0 | 60.0 | 50.0 | 65.0 | 62.0 | 58.0 | 60.0 | 65.0 | 65.0 |
| 75.0 | | | | | | | | | |

Property 8. Depth I. Per cent of Clay.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.0 | 20.0 | 20.0 | 10.0 | 10.0 | 10.0 | 10.0 | 15.0 | 25.0 | 40.0 |
| 25.0 | 40.0 | 40.0 | 50.0 | 50.0 | 60.0 | 20.0 | 45.0 | 30.0 | 50.0 |
| 40.0 | 50.0 | 50.0 | 30.0 | 65.0 | 40.0 | 45.0 | 60.0 | 60.0 | 40.0 |
| 20.0 | 25.0 | 25.0 | 40.0 | 65.0 | 65.0 | 50.0 | 65.0 | 40.0 | 50.0 |
| 40.0 | 55.0 | 50.0 | 45.0 | 55.0 | 40.0 | 50.0 | 60.0 | 45.0 | 35.0 |
| 15.0 | 10.0 | 10.0 | 5.0 | 15.0 | 15.0 | 15.0 | 20.0 | 15.0 | 15.0 |
| 15.0 | 25.0 | 15.0 | 15.0 | 15.0 | 10.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| 15.0 | 10.0 | 17.0 | 15.0 | 14.0 | 18.0 | 32.0 | 40.0 | 41.0 | 32.0 |
| 67.0 | 38.0 | 26.0 | 34.0 | 29.0 | 22.0 | 20.0 | 15.0 | 20.0 | 15.0 |
| 10.0 | 13.0 | 8.0 | 5.0 | 12.0 | 10.0 | 5.0 | 8.0 | 8.0 | 10.0 |
| 13.0 | 8.0 | 7.0 | 8.0 | 7.0 | 16.0 | 12.0 | 15.0 | 16.0 | 15.0 |
| 8.0 | 15.0 | 29.0 | 12.0 | 35.0 | 18.0 | 12.0 | 17.0 | 17.0 | 13.0 |
| 12.0 | 5.0 | 10.0 | 13.0 | 3.0 | 3.0 | 8.0 | 8.0 | 8.0 | 3.0 |
| 7.0 | 8.0 | 7.0 | 7.0 | 8.0 | 5.0 | 7.0 | 8.0 | 8.0 | 7.0 |
| 7.0 | 7.0 | 8.0 | 8.0 | 8.0 | 13.0 | 8.0 | 8.0 | 13.0 | 8.0 |
| 13.0 | 8.0 | 13.0 | 13.0 | 40.0 | 63.0 | 52.0 | 55.0 | 50.0 | 42.0 |
| 47.0 | 40.0 | 45.0 | 30.0 | 53.0 | 40.0 | 45.0 | 42.0 | 45.0 | 40.0 |
| 57.0 | 50.0 | 45.0 | 50.0 | 50.0 | 50.0 | 55.0 | 63.0 | 69.0 | 50.0 |
| 57.0 | 45.0 | 42.0 | 63.0 | 58.0 | 75.0 | 70.0 | 75.0 | 70.0 | 75.0 |
| 75.0 | 75.0 | 65.0 | 60.0 | 65.0 | 40.0 | 30.0 | 30.0 | 40.0 | 50.0 |
| 65.0 | 75.0 | 70.0 | 35.0 | 40.0 | 45.0 | 45.0 | 40.0 | 40.0 | 45.0 |
| 45.0 | 40.0 | 60.0 | 45.0 | 35.0 | 45.0 | 40.0 | 35.0 | 45.0 | 45.0 |
| 40.0 | 25.0 | 30.0 | 15.0 | 25.0 | 15.0 | 20.0 | 15.0 | 10.0 | 10.0 |
| 20.0 | 15.0 | 15.0 | 15.0 | 25.0 | 50.0 | 65.0 | 40.0 | 70.0 | 65.0 |
| 60.0 | 70.0 | 60.0 | 55.0 | 45.0 | 45.0 | 60.0 | 50.0 | 55.0 | 65.0 |
| 35.0 | 68.0 | 60.0 | 62.0 | 66.0 | 66.0 | 63.0 | 57.0 | 63.0 | 63.0 |
| 66.0 | 62.0 | 68.0 | 64.0 | 62.0 | 66.0 | 66.0 | 61.0 | 68.0 | 66.0 |
| 68.0 | 61.0 | 66.0 | 64.0 | 68.0 | 64.0 | 64.0 | 53.0 | 68.0 | 60.0 |
| 60.0 | 78.0 | 68.0 | 64.0 | 68.0 | 66.0 | 51.0 | 40.0 | 66.0 | 62.0 |
| 49.0 | 51.0 | 66.0 | 60.0 | 57.0 | 53.0 | 50.0 | 66.0 | 42.0 | 39.0 |
| 37.0 | 18.0 | 36.0 | 46.0 | 20.0 | 25.0 | 25.0 | 25.0 | 25.0 | 20.0 |
| 18.0 | 13.0 | 25.0 | 30.0 | 15.0 | 23.0 | 22.0 | 20.0 | 15.0 | 15.0 |
| 15.0 | | | | | | | | | |

Property 9. Depth I. Per cent of Silt.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 4.0 | 6.0 | 6.0 | 6.0 | 6.0 | 7.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 8.0 | 15.0 | 12.0 | 8.0 | 12.0 | 10.0 | 10.0 | 12.0 | 12.0 | 20.0 |
| 7.0 | 9.0 | 8.0 | 8.0 | 8.0 | 9.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 12.0 | 13.0 | 12.0 | 12.0 | 6.0 | 12.0 | 12.0 | 9.0 | 9.0 | 8.0 |
| 8.0 | 8.0 | 8.0 | 7.0 | 8.0 | 8.0 | 8.0 | 10.0 | 10.0 | 10.0 |
| 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 13.0 | 12.0 | 9.0 | 8.0 |
| 8.0 | 8.0 | 8.0 | 9.0 | 8.0 | 9.0 | 9.0 | 9.0 | 11.0 | 13.0 |
| 13.0 | 25.0 | 25.0 | 25.0 | 28.0 | 25.0 | 20.0 | 12.0 | 18.0 | 12.0 |
| 12.0 | 22.0 | 28.0 | 28.0 | 22.0 | 11.0 | 18.0 | 14.0 | 12.0 | 14.0 |
| 12.0 | 14.0 | 14.0 | 14.0 | 12.0 | 14.0 | 14.0 | 16.0 | 19.0 | 14.0 |
| 13.0 | 14.0 | 18.0 | 30.0 | 24.0 | 8.0 | 9.0 | 13.0 | 14.0 | 18.0 |
| 14.0 | 22.0 | 12.0 | 18.0 | 18.0 | 12.0 | 12.0 | 9.0 | 15.0 | 18.0 |
| 18.0 | 14.0 | 12.0 | 12.0 | 10.0 | 10.0 | 10.0 | 9.0 | 10.0 | 9.0 |
| 9.0 | 10.0 | 9.0 | 10.0 | 9.0 | 12.0 | 10.0 | 6.0 | 8.0 | 8.0 |
| 8.0 | 6.0 | 6.0 | 8.0 | 6.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 8.0 | 8.0 | 8.0 | 8.0 | 6.0 | 8.0 | 8.0 | 8.0 | 8.0 | 10.0 |
| 8.0 | 6.0 | 6.0 | 6.0 | 6.0 | 8.0 | 6.0 | 6.0 | 8.0 | 6.0 |
| 6.0 | 7.0 | 6.0 | 6.0 | 8.0 | 6.0 | 8.0 | 6.0 | 6.0 | 7.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 8.0 | 8.0 | 8.0 | 8.0 | 7.0 | 8.0 | 8.0 | 8.0 | 8.0 | 7.0 |
| 10.0 | 9.0 | 8.0 | 9.0 | 9.0 | 8.0 | 8.0 | 7.0 | 8.0 | 20.0 |
| 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| 9.0 | 8.0 | 6.0 | 7.0 | 9.0 | 9.0 | 9.0 | 9.0 | 8.0 | 9.0 |
| 6.0 | 6.0 | 6.0 | 8.0 | 7.0 | 6.0 | 7.0 | 6.0 | 6.0 | 6.0 |
| 8.0 | 7.0 | 8.0 | 7.0 | 7.0 | 7.0 | 9.0 | 9.0 | 7.0 | 7.0 |
| 8.0 | 9.0 | 9.0 | 9.0 | 8.0 | 8.0 | 7.0 | 8.0 | 10.0 | 8.0 |
| 9.0 | 8.0 | 8.0 | 9.0 | 9.0 | 8.0 | 8.0 | 8.0 | 9.0 | 9.0 |
| 9.0 | | | | | | 8.0 | 8.0 | 9.0 | 9.0 |

Property 10. Depth I. Per cent of Organic Matter.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10.0 | 3.0 | 4.0 | 20.0 | 30.0 | 30.0 | 8.0 | 20.0 | 5.0 | 5.0 |
| 0.0 | 4.0 | 4.0 | 8.0 | 5.0 | 3.0 | 3.0 | 5.0 | 3.0 | 5.0 |
| 15.0 | 5.0 | 5.0 | 3.0 | 2.0 | 4.0 | 20.0 | 10.0 | 15.0 | 8.0 |
| 10.0 | 3.0 | 4.0 | 1.0 | 1.0 | 2.0 | 2.0 | 4.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 0.5 | 1.0 | 1.0 | 0.5 | 0.0 | 2.0 | 1.0 | 0.5 |
| 0.5 | 0.0 | 2.0 | 1.0 | 1.0 | 30.0 | 30.0 | 3.0 | 0.5 | 30.0 |
| 5.0 | 3.0 | 5.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 3.0 | 5.0 |
| 0.5 | 3.0 | 3.0 | 4.0 | 2.0 | 2.0 | 0.5 | 0.0 | 0.5 | 0.5 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 |
| 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 1.0 | 0.5 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 |
| 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 70.0 | 0.1 | 0.0 | 0.1 | 0.1 |
| 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.1 | 0.1 | 0.0 | 0.1 | 0.5 | 0.1 | 0.2 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.3 |
| 0.1 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |
| 0.0 | 1.0 | 0.5 | 1.0 | 0.5 | 0.5 | 0.0 | 0.0 | 0.5 | 0.5 |
| 0.5 | 0.5 | 1.0 | 0.5 | 1.0 | 0.5 | 0.5 | 0.5 | 2.0 | 2.0 |
| 1.0 | 3.0 | 5.0 | 5.0 | 3.0 | 1.0 | 1.0 | 0.5 | 0.5 | 1.0 |
| 1.0 | 1.0 | 0.5 | 0.5 | 5.0 | 3.0 | 1.0 | 0.5 | 2.0 | 0.5 |
| 1.0 | 5.0 | 3.0 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| 0.2 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | 3.0 | 1.0 | 0.0 |
| 0.5 | 0.0 | 0.2 | 1.0 | 0.1 | 0.2 | 1.5 | 2.0 | 0.5 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 | 1.0 | 2.0 |
| 1.0 | 0.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.3 | 2.0 | 0.3 |
| 1.0 | 0.2 | 0.2 | 0.1 | 0.0 | 0.5 | 0.2 | 0.2 | 0.2 | 0.1 |
| 0.2 | 1.0 | 0.5 | 0.1 | 0.1 | 1.0 | 0.2 | 0.3 | 0.1 | 1.0 |
| 0.0 | | | | | | | | | |

Property 11. Depth I. Per cent of Stones.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 3.0 | 2.0 |
| 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 8.0 |
| 8.0 | 4.0 | 2.0 | 5.0 | 2.0 | 2.0 | 2.0 | 4.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 3.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.5 | 1.5 | 1.0 |
| 3.0 | 1.5 | 1.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 0.0 | 1.0 | 3.0 | 2.0 |
| 1.0 | 0.0 | 2.0 | 1.0 | 3.0 | 2.0 | 3.0 | 2.0 | 1.0 | 6.0 |
| 3.0 | 6.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 3.0 |
| 0.5 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 4.0 | 0.0 | 2.0 | 0.5 |
| 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 0.0 |
| 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 2.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.5 |
| 0.0 | 1.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.4 | 1.0 | 0.0 | 0.4 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.3 | 1.0 | 2.0 |
| 0.1 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |
| 0.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.0 | 0.0 | 0.5 | 0.5 |
| 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 3.0 | 4.0 | 3.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 1.0 | 0.1 | 1.0 | 0.5 | 1.0 | 2.0 | 1.0 |
| 0.3 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 3.0 | 1.0 | 0.0 |
| 0.5 | 0.0 | 1.0 | 2.0 | 0.5 | 1.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 | 1.0 | 2.0 |
| 2.0 | 1.0 | 1.0 | 0.5 | 2.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.5 |
| 1.0 | 0.5 | 1.0 | 0.5 | 0.0 | 2.0 | 0.5 | 0.5 | 0.5 | 0.5 |
| 0.5 | 0.5 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 | 2.0 | 2.0 |
| 0.0 | | | | | | | | | |

Property 12. Depth I. Size of Stones in cm.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | | | | | | | | | |

Property 14. Depth I. Structure: angularity.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 2.0 | 2.0 | 3.0 | 2.0 | 6.0 | 4.0 | 6.0 | 4.0 | 2.0 |
| 3.0 | 4.0 | 2.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 6.0 |
| 6.0 | 8.0 | 8.0 | 8.0 | 2.0 | 3.0 | 4.0 | 3.0 | 3.0 | 4.0 |
| 8.0 | 8.0 | 6.0 | 6.0 | 4.0 | 4.0 | 6.0 | 5.0 | 6.0 | 5.0 |
| 6.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 1.0 | 6.0 | 1.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 8.0 | 8.0 | 4.0 | 8.0 | 4.0 | 4.0 | 3.0 |
| 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 6.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 |
| 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 6.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 6.0 | 5.0 |
| 6.0 | 4.0 | 6.0 | 5.0 | 6.0 | 5.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 2.0 | 2.0 | 4.0 | 5.0 | 5.0 | 6.0 | 4.0 | 5.0 | 5.0 | 4.0 |
| 6.0 | 5.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 |
| 3.0 | 4.0 | 6.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 2.0 | 4.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 2.0 | 5.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 10.0 |
| 6.0 | 6.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 6.0 | 5.0 | 5.0 | 4.0 | 6.0 | 4.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 8.0 | 10.0 | 10.0 | 7.0 | 7.0 | 7.0 |
| 7.0 | 8.0 | 7.0 | 7.0 | 8.0 | 8.0 | 8.0 | 7.0 | 8.0 | 7.0 |
| 8.0 | | | | | | | | | |

Property 15. Depth I. Structure: size in mm.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 |
| 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 |
| 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 |
| 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 3.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 4.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 4.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 | 3.0 | 2.0 |
| 3.0 | | | | | | | | | |

Property 16. Depth I. Consistency.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 |
| 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | | | | | | | | | |

Property 17. Depth I. Permeability.

0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10.0 | 10.0 | 10.0 | 10.0 | 9.0 | 12.0 | 12.0 | 8.0 | 9.0 | 8.0 |
| 10.0 | 6.0 | 10.0 | 10.0 | 10.0 | 10.0 | 8.0 | 10.0 | 7.0 | 10.0 |
| 10.0 | 6.0 | 7.0 | 6.0 | 3.0 | 4.0 | 10.0 | 6.0 | 6.0 | 10.0 |
| 6.0 | 6.0 | 1.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.5 | 2.0 | 2.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.5 | 0.2 | 0.0 | 0.5 |
| 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 5.0 | 1.0 | 5.0 | 12.0 |
| 6.0 | 7.0 | 10.0 | 22.0 | 18.0 | 12.0 | 9.0 | 4.0 | 8.0 | 5.0 |
| 5.0 | 6.0 | 4.0 | 8.0 | 2.5 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.3 | 7.5 | 7.0 | 7.0 | 7.0 |
| 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.2 | 7.5 |
| 7.0 | 7.0 | 7.0 | 7.0 | 7.5 | 7.0 | 7.0 | 7.0 | 7.0 | 6.9 |
| 6.8 | 6.8 | 6.5 | 6.8 | 6.2 | 6.0 | 6.0 | 6.3 | 6.2 | 6.2 |
| 6.5 | 6.3 | 6.0 | 6.8 | 6.0 | 6.3 | 6.2 | 6.0 | 6.2 | 6.0 |
| 6.5 | 6.2 | 6.0 | 6.0 | 6.0 | 5.8 | 5.8 | 5.8 | 5.7 | 6.2 |
| 6.3 | 6.0 | 6.0 | 6.0 | 6.4 | 6.0 | 7.3 | 7.0 | 7.3 | 7.0 |
| 6.5 | 7.2 | 7.2 | 7.3 | 7.3 | 7.0 | 7.2 | 7.4 | 6.9 | 7.0 |
| 7.4 | 7.2 | 7.0 | 7.0 | 7.0 | 7.0 | 6.5 | 5.8 | 5.8 | 6.8 |
| 6.0 | 6.0 | 6.3 | 5.5 | 5.8 | 6.8 | 5.8 | 5.8 | 5.7 | 5.6 |
| 6.0 | 6.2 | 5.8 | 5.8 | 5.6 | 5.6 | 6.0 | 6.0 | 5.7 | 6.0 |
| 5.6 | 5.8 | 5.8 | 5.8 | 5.8 | 6.0 | 6.0 | 6.0 | 5.9 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 5.8 | 6.0 | 6.0 | 5.9 | 6.0 | 6.0 |
| 5.0 | 6.0 | 5.0 | 6.0 | 6.0 | 6.0 | 6.2 | 6.0 | 5.9 | 6.0 |
| 5.0 | 5.8 | 6.0 | 6.0 | 6.0 | 6.0 | 5.9 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 5.0 | 5.8 | 5.9 | 5.9 | 5.0 | 6.0 | 6.0 | 5.9 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 5.8 | 6.0 | 6.0 |
| 6.7 | 6.3 | 6.0 | 6.2 | 6.3 | 5.0 | 5.8 | 5.8 | 5.5 | 6.0 |
| 6.0 | 5.8 | 5.8 | 5.5 | 6.0 | 6.0 | 6.0 | 5.5 | 5.5 | 6.0 |
| 6.0 | 5.5 | 6.0 | 6.3 | 5.8 | 6.5 | 5.5 | 7.0 | 6.5 | 6.5 |
| 6.5 | 6.5 | 6.3 | 7.0 | 6.0 | 6.3 | 5.8 | 6.0 | 5.8 | 5.5 |
| 5.5 | 5.5 | 5.2 | 5.0 | 5.2 | 5.7 | 5.2 | 5.2 | 5.3 | 5.5 |
| 4.3 | 5.4 | 5.5 | 5.5 | 5.5 | 4.5 | 5.2 | 5.2 | 5.5 | 5.8 |
| 5.7 | 5.5 | 5.6 | 5.5 | 5.5 | 5.5 | 5.4 | 5.3 | 5.5 | 6.2 |
| 5.5 | 6.0 | 6.0 | 6.0 | 5.9 | 6.0 | 6.3 | 6.0 | 6.2 | 6.0 |
| 6.1 | 5.9 | 5.0 | 6.0 | 6.0 | 6.0 | 5.0 | 6.4 | 6.1 | 5.9 |
| 6.1 | 5.6 | 6.0 | 5.0 | 5.9 | 6.1 | 6.3 | 5.6 | 6.2 | 6.0 |
| 5.0 | 6.0 | 6.1 | 6.0 | 6.0 | 6.1 | 6.0 | 5.8 | 5.9 | 6.0 |
| 6.0 | 6.3 | 6.0 | 5.8 | 5.9 | 5.9 | 5.8 | 5.9 | 6.0 | 5.9 |
| 5.0 | 5.8 | 5.7 | 6.0 | 6.0 | 5.9 | 6.0 | 5.9 | 5.9 | 5.7 |
| 5.7 | 6.0 | 5.0 | 6.0 | 5.8 | 5.9 | 6.2 | 5.7 | 5.7 | 5.8 |
| 5.0 | | | | | | | | | |

Property 20. Depth 1. Reaction (pH).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 3.0 | 6.0 | 6.0 | 5.0 | 5.0 | 7.0 | 7.0 | 7.0 |
| 7.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 7.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 |
| 3.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 3.0 | 3.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 7.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 8.0 | | | | | | | | | |

Property 21. Depth II. Colour: dominant hue

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 6.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 |
| 6.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 6.0 | 6.0 | 5.0 | 5.0 | 6.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 6.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 6.0 | 6.0 | 4.0 | 5.0 | 6.0 | 5.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 6.0 |
| 6.0 | | | | | | | | | |

Property 22. Depth II. Colour: dominant chroma.

2.0 6.0 6.0 6.0 2.0 6.0 5.0 6.0 3.0 8.0 6.0 8.0 4.0 4.0 4.0 4.0 8.0 4.0 6.0 4.0 6.0 8.0 8.0 6.0 8.0 3.0 4.0 5.0 5.0 8.0 1.0 1.0 0.0

6.0 4.0 6.0 6.0 4.0 4.0 8.0 6.0 8.0 6.0 6.0 4.0 8.0 4.0 6.0 4.0 3.0 4.0 4.0 8.0 6.0 6.0 6.0 6.0 6.0 4.0 4.0 5.0 4.0 4.0 1.0

4.0 4.0 4.0 4.0 8.0 4.0 6.0 4.0 4.0 8.0 4.0 4.0 6.0 3.0 3.0 4.0 8.0 8.0 6.0 8.0 6.0 6.0 6.0 6.0 4.0 4.0 4.0 5.0 4.0 4.0 1.0

6.0 6.0 6.0 4.0 8.0 4.0 8.0 4.0 4.0 8.0 3.0 4.0 4.0 1.0 4.0 1.0 8.0 4.0 4.0 8.0 2.0 6.0 6.0 6.0 4.0 4.0 4.0 4.0 5.0 5.0 4.0 2.0 1.0

5.0 4.0 4.0 6.0 4.0 4.0 8.0 4.0 4.0 6.0 4.0 4.0 8.0 3.0 1.0 3.0 2.0 6.0 4.0 8.0 6.0 6.0 8.0 6.0 4.0 4.0 4.0 5.0 5.0 3.0 1.0

8.0 4.0 6.0 4.0 4.0 4.0 8.0 4.0 4.0 8.0 4.0 4.0 8.0 6.0 4.0 6.0 4.0 4.0 4.0 8.0 4.0 4.0 6.0 4.0 4.0 4.0 4.0 5.0 4.0 4.0 1.0

8.0 4.0 6.0 4.0 4.0 4.0 8.0 4.0 4.0 8.0 4.0 4.0 8.0 6.0 4.0 6.0 4.0 4.0 4.0 8.0 4.0 4.0 6.0 4.0 4.0 4.0 4.0 5.0 4.0 4.0 1.0

8.0 4.0 6.0 4.0 4.0 4.0 8.0 4.0 4.0 8.0 4.0 4.0 8.0 6.0 4.0 6.0 4.0 4.0 4.0 8.0 4.0 4.0 6.0 4.0 4.0 4.0 4.0 5.0 4.0 4.0 1.0

Property 23. Depth II. Colour: dominant value.

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5.0

Property 24. Depth II. Colour of mottles: chroma.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 5.0 | 5.0 | 7.0 | 7.0 | 5.0 | 7.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 |
| 5.0 | 5.0 | 4.0 | 3.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 6.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 6.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 6.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 | 6.0 | 5.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 6.0 | 4.0 | 5.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 7.0 | 7.0 | 6.0 |
| 6.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 |
| 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 8.0 | 4.0 | 5.0 |
| 5.0 | 5.0 | 7.0 | 6.0 | 5.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 6.0 | 6.0 | 3.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 6.0 | 6.0 | 6.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 5.0 |
| 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 3.0 | 5.0 | 4.0 | 5.0 | 6.0 |
| 7.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 6.0 |
| 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | | | | | | | | | |

Property 25. Depth II. Colour of mottles: value.

8.0
6.0
6.0
3.0
6.0
2.0
6.0
6.0
8.0
8.0
4.0
4.0
8.0
8.0
3.0
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4.0
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6.0
5.0
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6.0

Property 26. Depth II. Colour of mottles: value.

40.0
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15.0
50.0
40.0
15.0
0.0
5.0
0.0
20.0
15.0
15.0
45.0
25.0
10.0
40.0
40.0
45.0
0.0
20.0
50.0
10.0
0.0
40.0
30.0
0.0
45.0
10.0
45.0
25.0

20.0
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0.0
25.0
30.0
0.0
45.0
22.0
15.0
40.0
45.0
45.0
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0.0
30.0
25.0
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30.0
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30.0
40.0

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25.0
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30.0
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15.0
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35.0
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40.0
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50.0
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10.0
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5.0
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15.0
40.0
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20.0
20.0
20.0
35.0
8.0
50.0
28.0
45.0
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20.0
50.0
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18.0
12.0
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Property 27. Depth II. Per cent of mottles.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 85.0 | 75.0 | 75.0 | 65.0 | 85.0 | 80.0 | 65.0 | 70.0 | 75.0 | 60.0 |
| 50.0 | 70.0 | 40.0 | 60.0 | 50.0 | 35.0 | 45.0 | 45.0 | 40.0 | 30.0 |
| 40.0 | 40.0 | 40.0 | 30.0 | 30.0 | 35.0 | 45.0 | 35.0 | 60.0 | 50.0 |
| 45.0 | 10.0 | 50.0 | 40.0 | 45.0 | 40.0 | 40.0 | 60.0 | 80.0 | 80.0 |
| 20.0 | 40.0 | 40.0 | 40.0 | 30.0 | 55.0 | 40.0 | 30.0 | 40.0 | 40.0 |
| 60.0 | 20.0 | 20.0 | 20.0 | 15.0 | 20.0 | 15.0 | 10.0 | 20.0 | 20.0 |
| 25.0 | 15.0 | 15.0 | 15.0 | 5.0 | 15.0 | 15.0 | 5.0 | 20.0 | 20.0 |
| 5.0 | 8.0 | 18.0 | 30.0 | 18.0 | 25.0 | 33.0 | 23.0 | 18.0 | 28.0 |
| 22.0 | 22.0 | 10.0 | 26.0 | 12.0 | 14.0 | 20.0 | 25.0 | 25.0 | 10.0 |
| 12.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 20.0 |
| 5.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 8.0 | 18.0 | 18.0 |
| 8.0 | 14.0 | 18.0 | 12.0 | 13.0 | 12.0 | 7.0 | 6.0 | 8.0 | 6.0 |
| 6.0 | 3.0 | 6.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 6.0 | 4.0 | 2.0 |
| 2.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 6.0 | 6.0 |
| 4.0 | 6.0 | 3.0 | 7.0 | 13.0 | 12.0 | 15.0 | 25.0 | 46.0 | 60.0 |
| 70.0 | 50.0 | 60.0 | 63.0 | 60.0 | 70.0 | 46.0 | 48.0 | 45.0 | 60.0 |
| 45.0 | 45.0 | 70.0 | 70.0 | 55.0 | 33.0 | 35.0 | 38.0 | 45.0 | 48.0 |
| 50.0 | 50.0 | 38.0 | 35.0 | 35.0 | 15.0 | 15.0 | 10.0 | 10.0 | 10.0 |
| 15.0 | 10.0 | 25.0 | 40.0 | 50.0 | 80.0 | 70.0 | 80.0 | 65.0 | 65.0 |
| 55.0 | 45.0 | 40.0 | 60.0 | 20.0 | 60.0 | 55.0 | 75.0 | 60.0 | 65.0 |
| 75.0 | 70.0 | 25.0 | 35.0 | 45.0 | 40.0 | 42.0 | 35.0 | 35.0 | 40.0 |
| 40.0 | 45.0 | 35.0 | 35.0 | 30.0 | 20.0 | 30.0 | 35.0 | 35.0 | 35.0 |
| 35.0 | 30.0 | 25.0 | 30.0 | 30.0 | 20.0 | 25.0 | 90.0 | 70.0 | 90.0 |
| 80.0 | 80.0 | 75.0 | 80.0 | 75.0 | 60.0 | 55.0 | 70.0 | 70.0 | 70.0 |
| 40.0 | 28.0 | 28.0 | 28.0 | 29.0 | 65.0 | 45.0 | 55.0 | 45.0 | 38.0 |
| 45.0 | 40.0 | 40.0 | 35.0 | 40.0 | 40.0 | 25.0 | 40.0 | 35.0 | 38.0 |
| 45.0 | 40.0 | 45.0 | 25.0 | 25.0 | 38.0 | 42.0 | 32.0 | 22.0 | 30.0 |
| 24.0 | 18.0 | 18.0 | 22.0 | 18.0 | 14.0 | 12.0 | 16.0 | 22.0 | 34.0 |
| 18.0 | 12.0 | 18.0 | 16.0 | 28.0 | 18.0 | 25.0 | 24.0 | 62.0 | 65.0 |
| 70.0 | 70.0 | 42.0 | 68.0 | 75.0 | 65.0 | 70.0 | 65.0 | 65.0 | 65.0 |
| 78.0 | 75.0 | 70.0 | 68.0 | 68.0 | 70.0 | 70.0 | 70.0 | 75.0 | 70.0 |
| 75.0 | | | | | | | | | |

Property 28. Depth II. Per cent of clay

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10.0 | 15.0 | 10.0 | 25.0 | 10.0 | 5.0 | 10.0 | 15.0 | 10.0 | 10.0 |
| 25.0 | 15.0 | 40.0 | 15.0 | 20.0 | 30.0 | 35.0 | 35.0 | 20.0 | 35.0 |
| 25.0 | 30.0 | 30.0 | 20.0 | 50.0 | 25.0 | 35.0 | 15.0 | 20.0 | 30.0 |
| 40.0 | 60.0 | 40.0 | 45.0 | 50.0 | 45.0 | 40.0 | 35.0 | 15.0 | 15.0 |
| 70.0 | 40.0 | 45.0 | 45.0 | 50.0 | 35.0 | 45.0 | 45.0 | 35.0 | 40.0 |
| 30.0 | 10.0 | 10.0 | 5.0 | 5.0 | 15.0 | 15.0 | 15.0 | 10.0 | 15.0 |
| 20.0 | 20.0 | 10.0 | 5.0 | 10.0 | 15.0 | 15.0 | 25.0 | 15.0 | 15.0 |
| 20.0 | 12.0 | 17.0 | 20.0 | 22.0 | 45.0 | 32.0 | 37.0 | 32.0 | 32.0 |
| 43.0 | 43.0 | 10.0 | 34.0 | 18.0 | 11.0 | 15.0 | 15.0 | 15.0 | 10.0 |
| 8.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 5.0 |
| 5.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 7.0 | 7.0 |
| 7.0 | 6.0 | 12.0 | 13.0 | 12.0 | 10.0 | 3.0 | 3.0 | 12.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 6.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 3.0 | 4.0 | 2.0 |
| 2.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 |
| 4.0 | 4.0 | 4.0 | 8.0 | 12.0 | 13.0 | 20.0 | 30.0 | 26.0 | 25.0 |
| 20.0 | 35.0 | 30.0 | 22.0 | 25.0 | 25.0 | 34.0 | 47.0 | 40.0 | 30.0 |
| 40.0 | 40.0 | 20.0 | 25.0 | 35.0 | 47.0 | 50.0 | 42.0 | 40.0 | 47.0 |
| 35.0 | 35.0 | 42.0 | 50.0 | 55.0 | 70.0 | 70.0 | 75.0 | 75.0 | 75.0 |
| 65.0 | 70.0 | 60.0 | 45.0 | 30.0 | 10.0 | 25.0 | 15.0 | 25.0 | 35.0 |
| 25.0 | 45.0 | 45.0 | 30.0 | 50.0 | 30.0 | 25.0 | 15.0 | 30.0 | 20.0 |
| 10.0 | 20.0 | 15.0 | 35.0 | 35.0 | 30.0 | 28.0 | 40.0 | 50.0 | 25.0 |
| 25.0 | 25.0 | 15.0 | 25.0 | 20.0 | 15.0 | 25.0 | 20.0 | 15.0 | 15.0 |
| 15.0 | 20.0 | 20.0 | 15.0 | 20.0 | 30.0 | 25.0 | 5.0 | 20.0 | 5.0 |
| 15.0 | 15.0 | 20.0 | 15.0 | 15.0 | 20.0 | 30.0 | 20.0 | 20.0 | 20.0 |
| 40.0 | 52.0 | 47.0 | 47.0 | 46.0 | 20.0 | 30.0 | 20.0 | 30.0 | 47.0 |
| 30.0 | 35.0 | 40.0 | 30.0 | 35.0 | 35.0 | 50.0 | 25.0 | 50.0 | 37.0 |
| 30.0 | 25.0 | 30.0 | 50.0 | 65.0 | 37.0 | 28.0 | 43.0 | 58.0 | 45.0 |
| 49.0 | 62.0 | 67.0 | 58.0 | 67.0 | 56.0 | 45.0 | 59.0 | 58.0 | 46.0 |
| 32.0 | 38.0 | 57.0 | 58.0 | 57.0 | 57.0 | 45.0 | 51.0 | 23.0 | 25.0 |
| 20.0 | 20.0 | 32.0 | 17.0 | 15.0 | 20.0 | 15.0 | 20.0 | 20.0 | 10.0 |
| 7.0 | 15.0 | 15.0 | 24.0 | 15.0 | 15.0 | 20.0 | 15.0 | 15.0 | 15.0 |
| 15.0 | | | | | | | | | |

Property 29. Depth II. Per cent of Silt

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 3.0 | 2.0 | 3.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 | 4.0 | 3.0 |
| 3.0 | 3.0 | 2.0 | 4.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 3.0 |
| 4.0 | 3.0 | 3.0 | 2.0 | 2.0 | 4.0 | 4.0 | 3.0 | 1.0 | 2.0 |
| 2.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 6.0 | 4.0 | 4.0 | 5.0 | 1.0 | 4.0 | 4.0 | 4.0 | 6.0 |
| 3.0 | 3.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 10.0 | 3.0 | 5.0 | 6.0 | 6.0 | 6.0 | 6.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.0 |
| 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 4.0 | 6.0 | 4.0 | 3.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 |
| 6.0 | 4.0 | 4.0 | 4.0 | 8.0 | 6.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 3.0 |
| 3.0 | 6.0 | 6.0 | 7.0 | 6.0 | 6.0 | 7.0 | 6.0 | 7.0 | 7.0 |
| 7.0 | 6.0 | 7.0 | 10.0 | 6.0 | 3.0 | 5.0 | 4.0 | 5.0 | 4.0 |
| 3.0 | 6.0 | 4.0 | 5.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 6.0 | 3.0 | 4.0 | 4.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 1.0 | 2.0 | 3.0 | 4.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 3.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 1.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 2.0 | 3.0 | 4.0 | 5.0 | 3.0 | 3.0 | 4.0 |
| 3.0 | 5.0 | 4.0 | 5.0 | 3.0 | 4.0 | 2.0 | 3.0 | 3.0 | 4.0 |
| 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 3.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 3.0 | 3.0 |
| 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 6.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 3.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 3.0 | | | | | | | | | |

Property 30. Depth II. Per cent of Organic Matter.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 3.0 | 1.0 | 2.0 | 60.0 | 95.0 | 12.0 | 90.0 | 5.0 | 90.0 |
| 15.0 | 5.0 | 4.0 | 90.0 | 95.0 | 5.0 | 3.0 | 3.0 | 80.0 | 95.0 |
| 90.0 | 98.0 | 80.0 | 8.0 | 2.0 | 2.0 | 90.0 | 90.0 | 90.0 | 90.0 |
| 2.0 | 95.0 | 0.0 | 0.0 | 0.0 | 2.0 | 2.0 | 0.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 3.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.5 | 1.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 0.1 | 5.0 | 8.0 | 10.0 | 99.0 | 30.0 | 8.0 | 20.0 | 30.0 |
| 3.0 | 98.0 | 20.0 | 12.0 | 7.0 | 3.0 | 8.0 | 2.0 | 3.0 | 40.0 |
| 4.0 | 0.5 | 3.0 | 3.0 | 3.0 | 2.0 | 0.5 | 0.2 | 0.5 | 35.0 |
| 65.0 | 25.0 | 0.5 | 0.0 | 0.3 | 0.5 | 0.0 | 0.0 | 0.5 | 0.0 |
| 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.1 |
| 0.0 | 0.0 | 1.0 | 0.2 | 0.1 | 0.5 | 1.0 | 1.0 | 0.5 | 0.2 |
| 0.5 | 0.2 | 3.0 | 5.0 | 0.1 | 0.0 | 0.3 | 5.0 | 0.5 | 0.0 |
| 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.1 | 0.0 | 0.2 |
| 0.1 | 0.1 | 0.5 | 0.0 | 0.1 | 0.0 | 0.1 | 0.1 | 0.2 | 0.5 |
| 0.2 | 1.0 | 0.1 | 0.0 | 0.0 | 2.0 | 5.0 | 0.1 | 1.0 | 2.0 |
| 1.0 | 0.0 | 0.5 | 0.5 | 4.0 | 0.2 | 0.3 | 0.1 | 0.1 | 0.1 |
| 0.1 | 0.0 | 2.0 | 0.1 | 0.5 | 0.5 | 0.3 | 0.2 | 0.3 | 0.3 |
| 0.0 | 0.0 | 0.0 | 0.5 | 0.1 | 1.0 | 0.5 | 0.0 | 0.5 | 0.0 |
| 5.0 | 10.0 | 3.0 | 1.0 | 5.0 | 1.0 | 0.5 | 1.0 | 1.0 | 0.5 |
| 2.0 | 1.0 | 10.0 | 5.0 | 1.0 | 2.0 | 1.0 | 0.5 | 2.0 | 1.0 |
| 2.0 | 3.0 | 30.0 | 8.0 | 4.0 | 2.0 | 1.0 | 0.5 | 1.0 | 1.0 |
| 1.0 | 2.0 | 1.0 | 5.0 | 5.0 | 4.0 | 10.0 | 50.0 | 5.0 | 3.0 |
| 20.0 | 8.0 | 5.0 | 2.0 | 2.0 | 2.0 | 2.0 | 0.5 | 2.0 | 0.5 |
| 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 2.0 | 1.0 | 2.0 | 3.0 | 3.0 |
| 1.0 | 0.2 | 0.3 | 2.0 | 3.0 | 3.0 | 75.0 | 60.0 | 95.0 | 95.0 |
| 75.0 | 4.0 | 5.0 | 4.0 | 4.0 | 28.0 | 25.0 | 65.0 | 6.0 | 18.0 |
| 90.0 | 8.0 | 4.0 | 4.0 | 6.0 | 60.0 | 85.0 | 45.0 | 6.0 | 7.0 |
| 6.0 | 3.0 | 6.0 | 3.0 | 5.0 | 6.0 | 4.0 | 3.0 | 18.0 | 4.0 |
| 2.0 | 1.0 | 1.0 | 3.0 | 2.0 | 3.0 | 0.5 | 0.5 | 0.2 | 0.4 |
| 0.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.5 | 1.0 |
| 0.0 | 0.0 | 0.0 | 0.3 | 0.6 | 1.0 | 0.3 | 0.8 | 0.5 | 0.4 |
| 0.0 | | | | | | | | | |

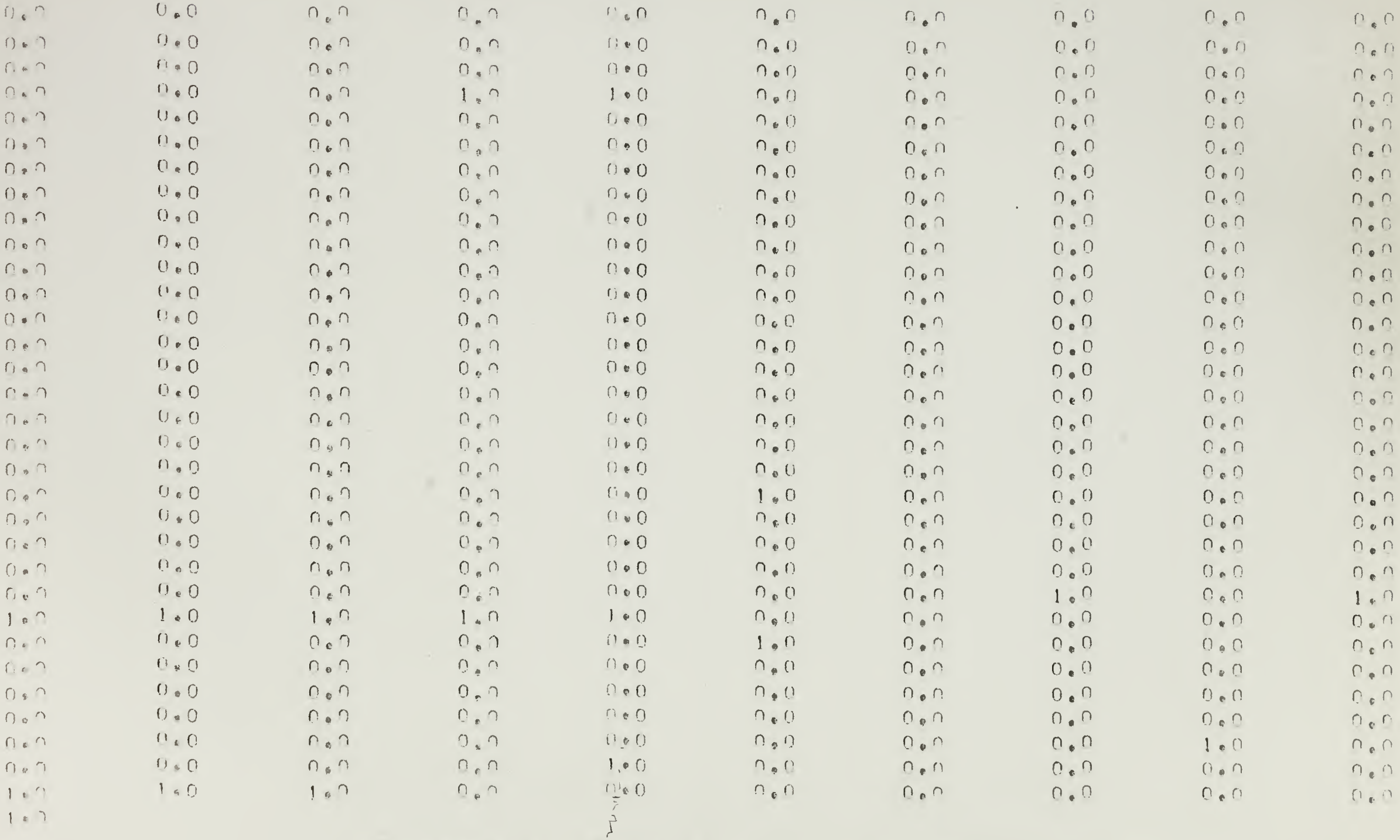
Property 31. Depth II. Per cent of Stones

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.3 | 1.5 | 0.5 | 0.5 | 4.0 | 12.0 | 1.0 | 7.0 | 2.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 4.0 | 12.0 | 10.0 |
| 8.0 | 8.0 | 4.0 | 5.0 | 2.0 | 2.0 | 12.0 | 14.0 | 14.0 | 12.0 |
| 1.5 | 10.0 | 0.0 | 0.0 | 0.0 | 2.0 | 1.0 | 0.0 | 0.3 | 0.5 |
| 1.0 | 2.0 | 3.0 | 2.0 | 1.0 | 2.0 | 0.0 | 1.0 | 2.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 2.0 | 3.0 | 3.0 | 5.0 | 10.0 | 3.0 | 1.0 | 4.0 | 6.0 |
| 4.0 | 7.0 | 4.0 | 4.0 | 4.0 | 2.0 | 3.0 | 1.0 | 2.0 | 4.0 |
| 3.0 | 0.3 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 2.0 | 8.0 |
| 6.0 | 6.0 | 3.0 | 0.0 | 2.0 | 2.0 | 0.0 | 0.0 | 2.0 | 0.0 |
| 2.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.0 |
| 0.0 | 0.0 | 3.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 3.0 | 2.0 |
| 1.0 | 3.0 | 8.0 | 4.0 | 1.0 | 0.0 | 1.0 | 2.0 | 2.0 | 0.0 |
| 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 1.0 | 0.0 | 0.5 |
| 0.0 | 0.5 | 2.0 | 2.0 | 0.5 | 0.0 | 1.0 | 2.0 | 0.5 | 2.0 |
| 0.4 | 0.5 | 0.3 | 0.0 | 0.0 | 0.0 | 2.0 | 1.0 | 0.5 | 0.5 |
| 1.0 | 0.0 | 1.0 | 1.0 | 0.4 | 2.0 | 4.0 | 1.0 | 1.0 | 0.5 |
| 0.5 | 0.0 | 3.0 | 0.5 | 2.0 | 1.0 | 1.0 | 0.5 | 0.5 | 0.5 |
| 0.0 | 0.0 | 0.0 | 1.0 | 0.5 | 2.0 | 2.0 | 0.3 | 1.0 | 2.0 |
| 0.0 | 0.5 | 2.0 | 2.0 | 0.3 | 1.0 | 1.0 | 0.0 | 0.5 | 0.0 |
| 0.5 | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 | 0.5 | 0.5 | 0.5 |
| 1.0 | 4.0 | 3.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 0.5 | 0.5 |
| 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 3.0 | 1.0 | 3.0 | 1.0 |
| 4.0 | 3.0 | 1.0 | 3.0 | 1.0 | 2.0 | 6.0 | 6.0 | 3.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 0.5 | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.5 |
| 0.5 | 2.0 | 1.0 | 0.5 | 2.0 | 2.0 | 3.0 | 1.0 | 3.0 | 3.0 |
| 6.0 | 2.0 | 2.0 | 2.0 | 3.0 | 7.0 | 6.0 | 3.0 | 12.0 | 12.0 |
| 8.0 | 2.0 | 2.0 | 3.0 | 3.0 | 8.0 | 6.0 | 6.0 | 5.0 | 4.0 |
| 4.0 | 3.0 | 6.0 | 2.0 | 6.0 | 0.5 | 10.0 | 8.0 | 3.0 | 5.0 |
| 2.0 | 2.0 | 1.0 | 0.5 | 2.0 | 0.5 | 1.0 | 1.0 | 2.0 | 2.0 |
| 0.0 | 0.5 | 0.5 | 0.0 | 0.0 | 0.0 | 0.5 | 1.0 | 1.0 | 0.5 |
| 0.0 | 0.0 | 0.0 | 0.5 | 1.0 | 1.0 | 0.0 | 0.5 | 0.5 | 1.0 |
| 1.0 | | | | | | 0.5 | 1.0 | 2.0 | 0.5 |

Property 32. Depth II. Size of Stones in cm.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 3.0 | 2.0 | 1.0 | 2.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 0.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 2.0 |
| 2.0 | 1.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 1.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 1.0 | 3.0 | 3.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | | | | | | | | | |

Property 33. Depth II. Structure: development.



Property 34. Depth II. Structure: dimensionality

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | | | | | | | | | |

Property 35. Depth II Structure: angularity.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 4.0 |
| 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 |
| 4.0 | 1.0 | 3.0 | 8.0 | 8.0 | 4.0 | 4.0 | 4.0 | 5.0 | 7.0 |
| 2.0 | 3.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 4.0 | 2.0 | 4.0 |
| 2.0 | 3.0 | 2.0 | 1.0 | 2.0 | 2.0 | 0.0 | 2.0 | 0.0 | 2.0 |
| 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 3.0 | 2.0 | 3.0 | 2.0 |
| 1.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 3.0 | 2.0 | 2.0 | 3.0 | 0.0 |
| 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 2.0 | 3.0 |
| 2.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 3.0 | 3.0 | 0.0 | 4.0 | 0.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 3.0 | 4.0 | 4.0 | 0.0 | 4.0 | 4.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 5.0 | 3.0 | 4.0 | 4.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 40.0 | 3.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 3.0 | 2.0 | 5.0 | 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 |
| 4.0 | 3.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 0.0 | 3.0 | 2.0 | 1.0 | 3.0 |
| 3.0 | 2.0 | 4.0 | 2.0 | 3.0 | 1.0 | 1.0 | 80.0 | 3.0 | 80.0 |
| 80.0 | 80.0 | 60.0 | 60.0 | 60.0 | 4.0 | 4.0 | 3.0 | 3.0 | 10.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 30.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 |
| 3.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 3.0 | 4.0 | 3.0 | 4.0 |
| 6.0 | 3.0 | 3.0 | 5.0 | 3.0 | 4.0 | 4.0 | 4.0 | 40.0 | 8.0 |
| 20.0 | 6.0 | 4.0 | 6.0 | 60.0 | 8.0 | 8.0 | 6.0 | 6.0 | 4.0 |
| 60.0 | 70.0 | 60.0 | 6.0 | 7.0 | 4.0 | 8.0 | 6.0 | 7.0 | 7.0 |
| 50.0 | | | | | | | | | |

Property 36. Depth II Structure: Size mm.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 4.0 | 2.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 3.0 | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 3.0 | 2.0 | 2.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 3.0 | 3.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 2.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 4.0 | 3.0 | 3.0 |
| 3.0 | 4.0 | 3.0 | 5.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 3.0 |
| 2.0 | 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 4.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 |
| 4.0 | 3.0 | 4.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 4.0 | | | | | | | | | |

Property 37. Depth II. Consistency.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 |
| 1.0 | 1.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 1.0 | 2.0 | 3.0 | 4.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 3.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 1.0 |
| 1.0 | 0.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 2.0 |
| 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 3.0 | 3.0 | 4.0 | 3.0 | 3.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 4.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 4.0 | 1.0 | 2.0 | 1.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 3.0 |
| 4.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| 4.0 | | | | | | | | | |

Property 38. Depth II. Permeability.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 12.0 | 10.0 | 12.0 | 0.0 |
| 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 12.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| 10.0 | 10.0 | 10.0 | 10.0 | 8.0 | 4.0 | 10.0 | 12.0 | 6.0 | 14.0 |
| 10.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.5 | 0.5 | 4.0 | 4.0 |
| 12.0 | 3.0 | 0.5 | 0.0 | 0.0 | 1.0 | 2.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.5 | 0.0 | 0.0 | 0.0 |
| 2.0 | 0.0 | 4.0 | 2.0 | 4.0 | 12.0 | 16.0 | 16.0 | 12.0 | 16.0 |
| 12.0 | 18.0 | 20.0 | 22.0 | 25.0 | 20.0 | 20.0 | 12.0 | 15.0 | 12.0 |
| 4.0 | 13.0 | 12.0 | 9.0 | 8.0 | 6.0 | 0.5 | 0.0 | 0.0 | 0.5 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 2.5 | 0.0 | 3.5 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 8.0 | 15.0 | 3.0 | 8.0 |
| 1.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 2.0 | 0.0 |
| 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.3 | 0.0 |
| 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 0.5 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | | | | | | | | | |

Property 40. Depth II. Per cent of Carbonates.

Property 41. Depth II. Reaction (pH).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7.0 | 5.0 | 5.0 | 5.0 | 5.0 | 7.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 6.0 | 5.0 | 6.0 | 7.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 6.0 | 4.0 | 4.0 | 7.0 | 7.0 | 7.0 | 7.0 | 5.0 |
| 7.0 | 7.0 | 7.0 | 7.0 | 6.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 3.0 | 3.0 | 4.0 | 4.0 | 5.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 6.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 6.0 |
| 6.0 | 5.0 | 7.0 | 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 8.0 | 8.0 |
| 8.0 | 8.0 | 5.0 | 5.0 | 8.0 | 8.0 | 8.0 | 5.0 | 8.0 | 8.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 4.0 | 8.0 | 8.0 | 8.0 | 6.0 | 8.0 | 5.0 | 8.0 |
| 5.0 | 7.0 | 8.0 | 8.0 | 7.0 | 7.0 | 5.0 | 7.0 | 8.0 | 8.0 |
| 8.0 | 8.0 | 6.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 4.0 | 3.0 |
| 5.0 | 5.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 5.0 | 8.0 | 8.0 | 8.0 |
| 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 8.0 | 4.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 8.0 | 5.0 | 5.0 |
| 5.0 | 6.0 | 5.0 | 5.0 | 5.0 | 6.0 | 5.0 | 4.0 | 8.0 | 8.0 |
| 8.0 | 8.0 | 5.0 | 5.0 | 6.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 8.0 | 8.0 | 5.0 | 5.0 | 8.0 | 5.0 | 8.0 | 8.0 | 8.0 | 6.0 |
| 8.0 | | | | | | | | | |

Property 42. Depth III Colour: dominant hue.

5.0 6.0 7.0 8.0 6.0 5.0 5.0 6.0 5.0 6.0 5.0 5.0 5.0 7.0 6.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 6.0 6.0 6.0

2.0 5.0 5.0 7.0 5.0 5.0 5.0 5.0 5.0 5.0 6.0 5.0 6.0 5.0 5.0 7.0 8.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 7.0 6.0

6.0 7.0 5.0 7.0 6.0 4.0 5.0 5.0 5.0 5.0 6.0 6.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

7.0 7.0 5.0 4.0 5.0 4.0 5.0 5.0 5.0 5.0 6.0 6.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

7.0 7.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

8.0 8.0 7.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 6.0 4.0 5.0 6.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

7.0 7.0 8.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

7.0 6.0 8.0 5.0 4.0 4.0 5.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

7.0 6.0 7.0 5.0 5.0 4.0 5.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

3.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0

Property 43. Depth III. Colour: dominant Chroma.

Property 44. Depth III. Colour: dominant value.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 7.0 | 5.0 | 5.0 | 4.0 | 5.0 |
| 6.0 | 5.0 | 6.0 | 7.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 5.0 |
| 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 6.0 | 4.0 | 4.0 | 5.0 | 6.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 |
| 7.0 | 5.0 | 4.0 | 4.0 | 5.0 | 4.0 | 5.0 | 3.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 3.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 3.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 5.0 |
| 4.0 | 3.0 | 2.0 | 3.0 | 3.0 | 5.0 | 5.0 | 4.0 | 3.0 | 3.0 |
| 4.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 3.0 | 4.0 |
| 5.0 | 5.0 | 3.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 8.0 | 5.0 | 5.0 | 5.0 | 8.0 | 5.0 | 5.0 | 5.0 |
| 8.0 | 5.0 | 8.0 | 8.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 8.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 6.0 | 6.0 |
| 4.0 | 7.0 | 6.0 | 5.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 4.0 |
| 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 4.0 | 6.0 |
| 5.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 3.0 |
| 4.0 | 5.0 | 6.0 | 5.0 | 5.0 | 6.0 | 7.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 5.0 |
| 4.0 | 5.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 5.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 8.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 8.0 | 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 4.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 8.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | | | | | | | | | |

Property 45. Depth III. Colour: of Mottles: hue.

5.0 5.0 7.0 6.0 6.0 8.0 7.0 6.0 7.0 7.0
5.0 5.0 4.0 4.0 5.0 8.0 5.0 5.0 5.0 5.0
7.0 5.0 7.0 4.0 7.0 7.0 5.0 8.0 7.0 5.0
8.0 5.0 5.0 4.0 6.0 6.0 5.0 5.0 5.0 5.0
5.0 5.0 4.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
6.0 5.0 5.0 4.0 4.0 4.0 5.0 4.0 5.0 5.0
5.0 5.0 6.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0
6.0 7.0 6.0 5.0 6.0 5.0 5.0 6.0 5.0 5.0
5.0 6.0 5.0 7.0 6.0 6.0 5.0 5.0 6.0 5.0
6.0 5.0 5.0 5.0 5.0 5.0 6.0 5.0 5.0 5.0
7.0 5.0 5.0 5.0 6.0 6.0 5.0 5.0 5.0 5.0
5.0 5.0 5.0 3.0 5.0 5.0 4.0 6.0 5.0 5.0
5.0 4.0 4.0 6.0 4.0 5.0 5.0 4.0 5.0 4.0
4.0 4.0 6.0 4.0 8.0 7.0 7.0 5.0 5.0 4.0
7.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
5.0 5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0
6.0 5.0 6.0 5.0 6.0 8.0 5.0 6.0 5.0 5.0
6.0 5.0 5.0 6.0 5.0 4.0 5.0 5.0 5.0 5.0
5.0 5.0 6.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0
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| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.0 | 30.0 | 40.0 | 20.0 | 40.0 | 0.0 | 20.0 | 50.0 | 50.0 | 0.0 |
| 25.0 | 0.0 | 0.0 | 0.0 | 20.0 | 0.0 | 15.0 | 6.0 | 20.0 | 30.0 |
| 0.0 | 0.0 | 40.0 | 10.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 | 20.0 | 10.0 | 10.0 | 0.0 |
| 40.0 | 50.0 | 40.0 | 40.0 | 30.0 | 10.0 | 0.0 | 0.0 | 40.0 | 40.0 |
| 20.0 | 30.0 | 10.0 | 8.0 | 2.0 | 0.0 | 0.0 | 15.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.0 | 10.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 25.0 | 30.0 | 30.0 | 44.0 | 30.0 | 15.0 | 15.0 | 0.0 |
| 0.0 | 5.0 | 5.0 | 0.0 | 25.0 | 20.0 | 20.0 | 0.0 | 30.0 | 10.0 |
| 0.0 | 0.0 | 30.0 | 0.0 | 30.0 | 10.0 | 0.0 | 15.0 | 0.0 | 0.0 |
| 40.0 | 40.0 | 20.0 | 15.0 | 3.0 | 3.0 | 15.0 | 15.0 | 15.0 | 20.0 |
| 0.0 | 40.0 | 0.0 | 0.0 | 0.0 | 25.0 | 20.0 | 10.0 | 0.0 | 10.0 |
| 0.0 | 50.0 | 0.0 | 0.0 | 20.0 | 50.0 | 35.0 | 50.0 | 40.0 | 30.0 |
| 15.0 | 8.0 | 28.0 | 3.0 | 3.0 | 40.0 | 10.0 | 8.0 | 40.0 | 14.0 |
| 50.0 | 22.0 | 45.0 | 18.0 | 25.0 | 28.0 | 50.0 | 45.0 | 38.0 | 24.0 |
| 23.0 | 5.0 | 50.0 | 50.0 | 5.0 | 25.0 | 0.0 | 50.0 | 45.0 | 45.0 |
| 40.0 | 25.0 | 48.0 | 35.0 | 22.0 | 40.0 | 28.0 | 40.0 | 25.0 | 45.0 |
| 48.0 | 35.0 | 42.0 | 2.0 | 15.0 | 30.0 | 45.0 | 35.0 | 30.0 | 40.0 |
| 45.0 | 40.0 | 0.0 | 25.0 | 0.0 | 30.0 | 5.0 | 20.0 | 30.0 | 40.0 |
| 60.0 | 40.0 | 40.0 | 20.0 | 40.0 | 40.0 | 30.0 | 40.0 | 50.0 | 20.0 |
| 20.0 | 40.0 | 30.0 | 30.0 | 40.0 | 20.0 | 20.0 | 20.0 | 40.0 | 40.0 |
| 40.0 | 40.0 | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 40.0 |
| 20.0 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 50.0 | 0.0 | 0.0 | 20.0 |
| 35.0 | 30.0 | 40.0 | 0.0 | 0.0 | 40.0 | 45.0 | 60.0 | 40.0 | 40.0 |
| 35.0 | 10.0 | 30.0 | 40.0 | 30.0 | 50.0 | 40.0 | 50.0 | 40.0 | 40.0 |
| 40.0 | 15.0 | 40.0 | 40.0 | 28.0 | 30.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 40.0 | 35.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 45.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 40.0 | 35.0 | 45.0 |
| 30.0 | 40.0 | 40.0 | 35.0 | 45.0 | 35.0 | 0.0 | 0.0 | 40.0 | 40.0 |
| 30.0 | 25.0 | 45.0 | 35.0 | 35.0 | 40.0 | 40.0 | 20.0 | 35.0 | 35.0 |
| 38.0 | 40.0 | 45.0 | 40.0 | 30.0 | 45.0 | 40.0 | 35.0 | 35.0 | 25.0 |
| 15.0 | | | | | | | | | |

Property 48. Depth III Per cent of Mottles.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 85.0 | 85.0 | 70.0 | 65.0 | 80.0 | 0.0 | 25.0 | 80.0 | 30.0 | 25.0 |
| 35.0 | 20.0 | 50.0 | 10.0 | 10.0 | 0.0 | 25.0 | 15.0 | 10.0 | 10.0 |
| 10.0 | 10.0 | 50.0 | 35.0 | 40.0 | 10.0 | 20.0 | 40.0 | 40.0 | 50.0 |
| 5.0 | 15.0 | 30.0 | 3.0 | 10.0 | 60.0 | 70.0 | 80.0 | 80.0 | 45.0 |
| 20.0 | 50.0 | 65.0 | 40.0 | 50.0 | 60.0 | 45.0 | 30.0 | 50.0 | 50.0 |
| 5.0 | 3.0 | 5.0 | 5.0 | 2.5 | 5.0 | 0.0 | 5.0 | 15.0 | 25.0 |
| 25.0 | 15.0 | 60.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 0.0 | 3.0 | 3.0 | 38.0 | 3.0 | 15.0 | 34.0 | 3.0 | 12.0 | 20.0 |
| 16.0 | 6.0 | 6.0 | 6.0 | 6.0 | 32.0 | 30.0 | 5.0 | 5.0 | 5.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 5.0 | 3.0 | 3.0 | 3.0 | 18.0 |
| 8.0 | 10.0 | 3.0 | 3.0 | 3.0 | 3.0 | 15.0 | 3.0 | 25.0 | 10.0 |
| 3.0 | 30.0 | 10.0 | 3.0 | 26.0 | 15.0 | 3.0 | 22.0 | 6.0 | 3.0 |
| 23.0 | 3.0 | 3.0 | 8.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 50.0 | 2.0 |
| 2.0 | 2.0 | 70.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 3.0 | 12.0 | 1.0 | 50.0 | 50.0 | 55.0 | 75.0 | 75.0 |
| 80.0 | 75.0 | 75.0 | 78.0 | 18.0 | 80.0 | 75.0 | 75.0 | 60.0 | 75.0 |
| 75.0 | 75.0 | 75.0 | 45.0 | 15.0 | 40.0 | 55.0 | 70.0 | 75.0 | 75.0 |
| 75.0 | 70.0 | 75.0 | 45.0 | 35.0 | 15.0 | 15.0 | 15.0 | 10.0 | 20.0 |
| 10.0 | 65.0 | 80.0 | 60.0 | 80.0 | 85.0 | 90.0 | 80.0 | 80.0 | 90.0 |
| 80.0 | 85.0 | 80.0 | 55.0 | 80.0 | 85.0 | 60.0 | 80.0 | 80.0 | 80.0 |
| 85.0 | 70.0 | 85.0 | 40.0 | 30.0 | 10.0 | 30.0 | 50.0 | 45.0 | 40.0 |
| 50.0 | 50.0 | 20.0 | 10.0 | 35.0 | 15.0 | 15.0 | 10.0 | 50.0 | 45.0 |
| 50.0 | 70.0 | 70.0 | 50.0 | 50.0 | 70.0 | 85.0 | 90.0 | 90.0 | 90.0 |
| 80.0 | 80.0 | 85.0 | 65.0 | 85.0 | 85.0 | 85.0 | 80.0 | 80.0 | 80.0 |
| 80.0 | 45.0 | 65.0 | 48.0 | 65.0 | 55.0 | 45.0 | 60.0 | 55.0 | 60.0 |
| 55.0 | 50.0 | 55.0 | 55.0 | 60.0 | 60.0 | 50.0 | 60.0 | 80.0 | 70.0 |
| 65.0 | 65.0 | 60.0 | 60.0 | 40.0 | 25.0 | 35.0 | 36.0 | 5.0 | 15.0 |
| 5.0 | 8.0 | 8.0 | 35.0 | 26.0 | 18.0 | 18.0 | 32.0 | 60.0 | 34.0 |
| 12.0 | 14.0 | 32.0 | 45.0 | 48.0 | 55.0 | 28.0 | 43.0 | 70.0 | 75.0 |
| 70.0 | 75.0 | 75.0 | 75.0 | 81.0 | 80.0 | 70.0 | 80.0 | 78.0 | 80.0 |
| 82.0 | 78.0 | 75.0 | 75.0 | 70.0 | 75.0 | 75.0 | 70.0 | 75.0 | 75.0 |
| 80.0 | | | | | | | | | |

Property 49. Depth III Per cent of Clay.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.0 | 10.0 | 20.0 | 10.0 | 15.0 | 0.0 | 15.0 | 10.0 | 10.0 | 25.0 |
| 25.0 | 50.0 | 30.0 | 30.0 | 20.0 | 0.0 | 55.0 | 15.0 | 20.0 | 20.0 |
| 30.0 | 30.0 | 20.0 | 20.0 | 25.0 | 20.0 | 5.0 | 10.0 | 25.0 | 20.0 |
| 80.0 | 60.0 | 40.0 | 3.0 | 15.0 | 35.0 | 25.0 | 15.0 | 15.0 | 20.0 |
| 70.0 | 40.0 | 25.0 | 45.0 | 30.0 | 30.0 | 40.0 | 40.0 | 20.0 | 20.0 |
| 5.0 | 3.0 | 5.0 | 5.0 | 2.5 | 5.0 | 5.0 | 5.0 | 15.0 | 25.0 |
| 25.0 | 15.0 | 15.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 5.0 | 3.0 | 3.0 | 22.0 | 3.0 | 25.0 | 26.0 | 3.0 | 13.0 | 5.0 |
| 30.0 | 7.0 | 7.0 | 8.0 | 7.0 | 23.0 | 20.0 | 5.0 | 5.0 | 5.0 |
| 7.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 7.0 |
| 2.0 | 5.0 | 3.0 | 3.0 | 3.0 | 3.0 | 15.0 | 3.0 | 35.0 | 30.0 |
| 3.0 | 20.0 | 15.0 | 3.0 | 14.0 | 15.0 | 3.0 | 18.0 | 3.0 | 3.0 |
| 22.0 | 3.0 | 3.0 | 6.0 | 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 1.0 | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 | 10.0 | 1.0 |
| 2.0 | 2.0 | 20.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 2.0 | 3.0 | 8.0 | 1.0 | 40.0 | 30.0 | 25.0 | 20.0 | 20.0 |
| 15.0 | 20.0 | 20.0 | 27.0 | 15.0 | 15.0 | 20.0 | 20.0 | 30.0 | 20.0 |
| 20.0 | 20.0 | 20.0 | 40.0 | 15.0 | 45.0 | 30.0 | 20.0 | 15.0 | 15.0 |
| 10.0 | 15.0 | 15.0 | 45.0 | 55.0 | 70.0 | 70.0 | 75.0 | 75.0 | 65.0 |
| 65.0 | 25.0 | 15.0 | 30.0 | 10.0 | 10.0 | 5.0 | 15.0 | 15.0 | 5.0 |
| 10.0 | 5.0 | 10.0 | 10.0 | 10.0 | 10.0 | 30.0 | 10.0 | 10.0 | 10.0 |
| 10.0 | 20.0 | 5.0 | 20.0 | 20.0 | 30.0 | 40.0 | 10.0 | 10.0 | 35.0 |
| 15.0 | 15.0 | 15.0 | 10.0 | 25.0 | 15.0 | 15.0 | 5.0 | 40.0 | 45.0 |
| 25.0 | 15.0 | 20.0 | 25.0 | 20.0 | 25.0 | 10.0 | 5.0 | 5.0 | 5.0 |
| 15.0 | 15.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 15.0 | 15.0 | 15.0 |
| 10.0 | 30.0 | 15.0 | 27.0 | 20.0 | 20.0 | 30.0 | 20.0 | 20.0 | 20.0 |
| 20.0 | 25.0 | 25.0 | 20.0 | 15.0 | 15.0 | 30.0 | 15.0 | 15.0 | 20.0 |
| 10.0 | 10.0 | 15.0 | 15.0 | 40.0 | 20.0 | 45.0 | 19.0 | 25.0 | 15.0 |
| 5.0 | 47.0 | 17.0 | 55.0 | 49.0 | 47.0 | 54.0 | 48.0 | 20.0 | 46.0 |
| 18.0 | 45.0 | 48.0 | 40.0 | 32.0 | 30.0 | 42.0 | 32.0 | 15.0 | 13.0 |
| 25.0 | 15.0 | 15.0 | 15.0 | 11.0 | 5.0 | 10.0 | 10.0 | 17.0 | 15.0 |
| 5.0 | 12.0 | 15.0 | 15.0 | 20.0 | 15.0 | 10.0 | 15.0 | 15.0 | 15.0 |
| 10.0 | | | | | | | | | |

Property 50. Depth III. Per cent of Silt.

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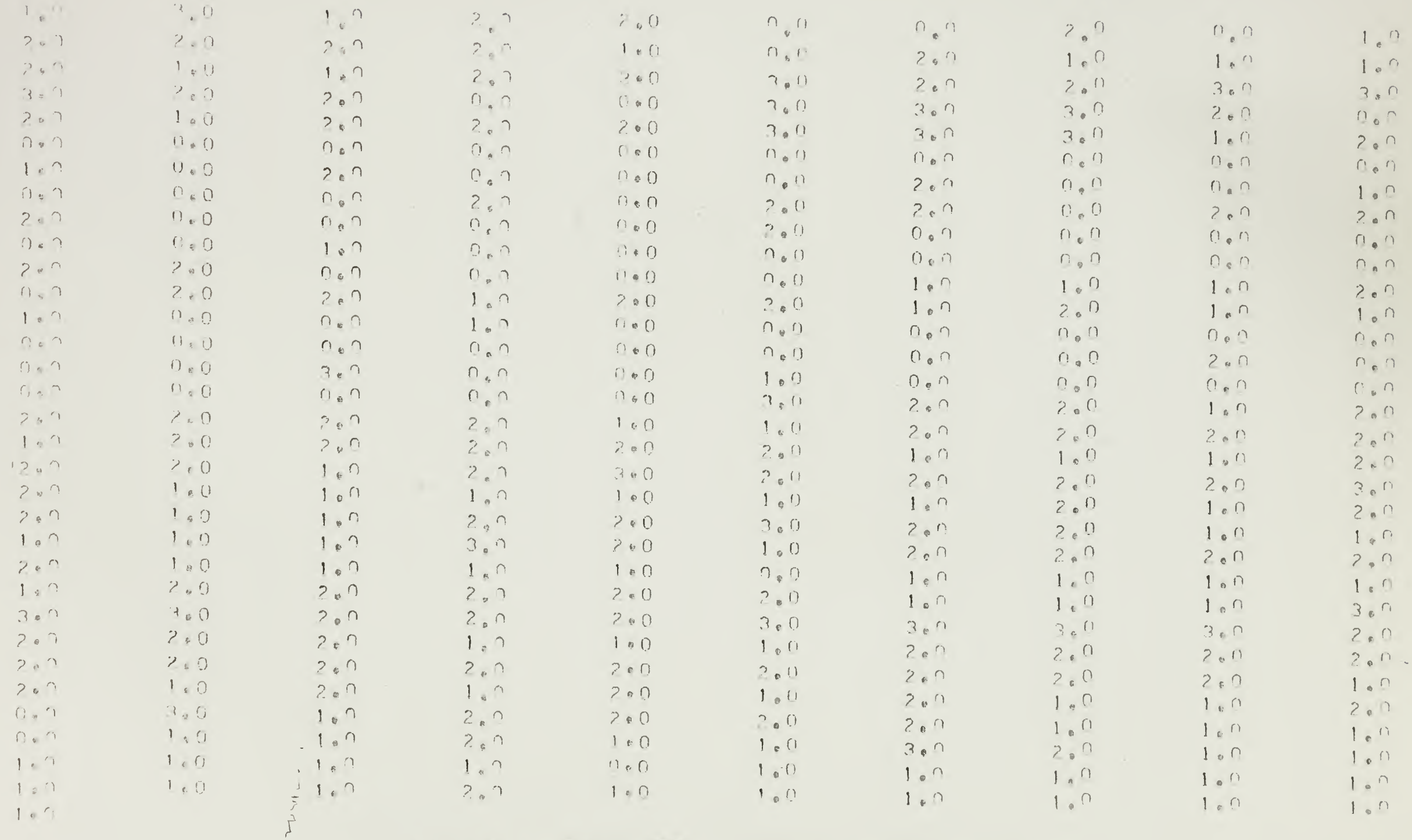
Property 51. Depth III. Per cent of Organic Matter.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.0 | 2.0 | 0.0 | 40.0 | 0.0 | 100.0 | 40.0 | 0.0 | 40.0 | 30.0 |
| 40.0 | 40.0 | 0.0 | 2.0 | 60.0 | 99.0 | 2.0 | 3.0 | 3.0 | 25.0 |
| 95.0 | 95.0 | 90.0 | 0.0 | 40.0 | 40.0 | 80.0 | 90.0 | 95.0 | 95.0 |
| 1.0 | 85.0 | 70.0 | 0.0 | 2.0 | 0.0 | 2.0 | 0.5 | 3.0 | 0.0 |
| 3.0 | 1.0 | 2.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 10.0 | 50.0 | 3.0 | 45.0 | 98.0 | 95.0 | 30.0 | 99.0 | 99.0 |
| 95.0 | 1.0 | 5.0 | 5.0 | 20.0 | 30.0 | 92.0 | 0.0 | 8.0 | 60.0 |
| 7.0 | 15.0 | 3.0 | 15.0 | 0.0 | 30.0 | 5.0 | 0.0 | 0.0 | 90.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 1.0 | 0.0 | 1.0 | 0.0 | 50.0 |
| 90.0 | 95.0 | 0.0 | 0.0 | 0.0 | 0.0 | 95.0 | 0.2 | 25.0 | 25.0 |
| 15.0 | 8.0 | 20.0 | 99.0 | 10.0 | 20.0 | 85.0 | 0.0 | 60.0 | 20.0 |
| 10.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.2 | 1.0 | 0.0 | 0.0 |
| 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.1 | 2.0 | 0.1 | 0.0 | 0.0 | 0.1 | 5.0 | 0.2 | 0.0 | 0.0 |
| 0.3 | 0.0 | 0.0 | 0.1 | 1.0 | 1.0 | 1.0 | 0.5 | 0.5 | 1.0 |
| 5.0 | 0.2 | 2.0 | 0.5 | 3.0 | 0.0 | 10.0 | 1.0 | 0.3 | 0.1 |
| 0.5 | 0.1 | 0.2 | 0.5 | 1.0 | 1.0 | 0.5 | 0.0 | 0.5 | 1.0 |
| 1.0 | 0.0 | 2.0 | 1.0 | 1.0 | 1.0 | 0.5 | 1.0 | 0.5 | 1.0 |
| 85.0 | 0.5 | 2.0 | 1.0 | 4.0 | 0.5 | 2.0 | 0.5 | 1.0 | 2.0 |
| 30.0 | 4.0 | 3.0 | 15.0 | 40.0 | 40.0 | 40.0 | 90.0 | 95.0 | 3.0 |
| 1.0 | 0.0 | 10.0 | 5.0 | 5.0 | 5.0 | 10.0 | 1.0 | 3.0 | 3.0 |
| 0.5 | 30.0 | 0.0 | 2.0 | 10.0 | 0.0 | 0.5 | 0.0 | 0.5 | 0.0 |
| 85.0 | 1.0 | 0.5 | 0.5 | 1.0 | 1.0 | 1.0 | 0.5 | 2.0 | 1.0 |
| 70.0 | 3.0 | 3.0 | 70.0 | 1.0 | 75.0 | 90.0 | 75.0 | 96.0 | 98.0 |
| 99.0 | 85.0 | 88.0 | 90.0 | 75.0 | 90.0 | 75.0 | 85.0 | 0.5 | 80.0 |
| 3.0 | 70.0 | 7.0 | 80.0 | 65.0 | 95.0 | 12.0 | 12.0 | 85.0 | 95.0 |
| 0.0 | 95.0 | 80.0 | 95.0 | 95.0 | 70.0 | 0.0 | 0.0 | 3.0 | 6.0 |
| 0.0 | 0.0 | 0.3 | 0.0 | 0.5 | 0.0 | 1.0 | 2.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1.0 | 0.0 | 1.0 | 0.1 | 2.0 | 3.0 | 10.0 | 8.0 | 4.0 | 0.0 |

Property 52. Depth III. Per cent of Stones.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 8 | 7 | 0 | 4 | 0 | 12 | 1 | 0 | 2 | 1 |
| 2 | 2 | 0 | 0 | 1 | 6 | 2 | 2 | 2 | 6 |
| 10 | 15 | 0 | 0 | 0 | 2 | 4 | 10 | 15 | 12 |
| 1 | 12 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 3 | 0 | 6 | 8 | 0 | 10 | 6 | 10 | 8 |
| 8 | 1 | 0 | 2 | 4 | 6 | 6 | 0 | 3 | 3 |
| 4 | 10 | 0 | 8 | 6 | 0 | 2 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10 | 10 | 0 | 0 | 10 | 2 | 0 | 0 | 0 | 0 |
| 6 | 6 | 0 | 6 | 0 | 0 | 2 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 4 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 |
| 0 | 1 | 0 | 2 | 5 | 1 | 0 | 0 | 0 | 0 |
| 2 | 1 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 0 |
| 0 | 0 | 5 | 2 | 5 | 2 | 0 | 0 | 0 | 0 |
| 1 | 6 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 8 | 0 | 4 | 0 | 0 | 0 | 0 |
| 2 | 3 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 2 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 3 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 |
| 10 | 6 | 0 | 3 | 0 | 4 | 0 | 0 | 0 | 0 |
| 3 | 6 | 0 | 7 | 0 | 6 | 0 | 0 | 0 | 0 |
| 6 | 8 | 0 | 4 | 0 | 6 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 5 | 2 | 0 | 0 | 0 | 0 |
| 2 | | | | | | | | | |

Property 53. Depth III. Stones Size in Cm.



Property 54. Depth III. Structure: development.

Property 55. Depth III. Structure: dimensionality.

Property 56. Depth III. Structure: angularity.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.0 | 4.0 | 1.0 | 1.0 | 2.0 | 0.0 | 12.0 | 1.0 | 15.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 0.0 | 2.0 | 2.0 | 1.0 | 2.0 |
| 1.0 | 1.0 | 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| 0.0 | 1.0 | 2.0 | 0.0 | 0.0 | 12.0 | 8.0 | 4.0 | 5.0 | 0.0 |
| 2.0 | 4.0 | 3.0 | 4.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 |
| 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 2.0 |
| 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 4.0 | 2.0 |
| 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 2.0 | 2.0 | 2.0 |
| 0.0 | 2.0 | 0.0 | 2.0 | 1.5 | 1.0 | 3.0 | 2.0 | 2.0 | 3.0 |
| 3.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 |
| 0.0 | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 2.0 | 2.0 | 150.0 | 120.0 |
| 60.0 | 80.0 | 80.0 | 8.0 | 60.0 | 30.0 | 120.0 | 80.0 | 4.0 | 40.0 |
| 40.0 | 60.0 | 80.0 | 2.0 | 2.0 | 3.0 | 3.0 | 3.0 | 100.0 | 80.0 |
| 100.0 | 3.0 | 6.0 | 4.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 4.0 |
| 2.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 80.0 | 80.0 | 120.0 | 60.0 |
| 2.0 | 6.0 | 3.0 | 8.0 | 3.0 | 3.0 | 3.0 | 3.0 | 8.0 | 8.0 |
| 40.0 | 1.0 | 60.0 | 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 2.0 | 3.0 | 2.0 | 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 3.0 |
| 1.0 | 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 2.0 | 120.0 | 120.0 | 120.0 |
| 120.0 | 120.0 | 60.0 | 80.0 | 80.0 | 60.0 | 60.0 | 20.0 | 30.0 | 10.0 |
| 10.0 | 4.0 | 3.0 | 3.0 | 40.0 | 3.0 | 3.0 | 2.0 | 3.0 | 2.0 |
| 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 70.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 |
| 0.0 | 2.0 | 2.0 | 2.0 | 2.0 | 3.0 | 2.0 | 60.0 | 80.0 | 40.0 |
| 0.0 | 4.0 | 60.0 | 40.0 | 60.0 | 40.0 | 3.0 | 3.0 | 100.0 | 120.0 |
| 100.0 | 80.0 | 30.0 | 60.0 | 180.0 | 180.0 | 180.0 | 180.0 | 180.0 | 180.0 |
| 180.0 | 180.0 | 180.0 | 60.0 | 180.0 | 180.0 | 180.0 | 180.0 | 180.0 | 120.0 |
| 180.0 | | | | | | | | | |

Property 57. Depth III. Structure: Size in mm.

Property 58. Depth III. Consistency.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.0 | 4.0 | 3.0 | 3.0 | 3.0 | 1.0 | 2.0 | 3.0 | 1.0 | 1.0 |
| 2.0 | 2.0 | 1.0 | 2.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 |
| 1.0 | 1.0 | 1.0 | 1.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 3.0 |
| 2.0 | 2.0 | 2.0 | 0.0 | 1.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 3.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 1.0 | 0.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.0 |
| 2.0 | 1.0 | 3.0 | 1.0 | 0.0 | 1.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| 1.0 | 0.0 | 0.0 | 3.0 | 0.0 | 1.0 | 0.0 | 0.0 | 2.0 | 2.0 |
| 2.0 | 1.0 | 0.0 | 0.0 | 0.0 | 2.0 | 2.0 | 1.0 | 0.0 | 0.0 |
| 0.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 2.0 | 2.0 |
| 0.0 | 1.0 | 2.0 | 0.0 | 1.0 | 1.0 | 1.0 | 2.0 | 0.0 | 0.0 |
| 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 |
| 0.0 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 3.0 | 3.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 |
| 4.0 | 3.0 | 4.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 2.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 2.0 | 2.0 | 1.0 | 2.0 | 3.0 | 2.0 | 3.0 |
| 2.0 | 3.0 | 2.0 | 1.0 | 2.0 | 1.0 | 1.0 | 1.0 | 3.0 | 3.0 |
| 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 3.0 | 3.0 | 3.0 | 3.0 | 4.0 | 3.0 | 0.0 | 2.0 | 1.0 | 2.0 |
| 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 4.0 | 3.0 |
| 2.0 | 3.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 |
| 2.0 | 2.0 | 2.0 | 1.0 | 1.0 | 2.0 | 2.0 | 3.0 | 4.0 | 2.0 |
| 1.0 | 2.0 | 3.0 | 3.0 | 3.0 | 3.0 | 2.0 | 2.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 3.0 | 3.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | 4.0 | 4.0 | 3.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| 4.0 | | | | | | | | | |

Property 59. Depth III. Permeability.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 2.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 1.0 | 0.5 | 1.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.0 | 4.0 | 10.0 | 10.0 | 10.0 | 30.0 | 14.0 | 12.0 | 18.0 | 12.0 |
| 10.0 | 10.0 | 12.0 | 12.0 | 14.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 |
| 13.0 | 18.0 | 12.0 | 14.0 | 14.0 | 14.0 | 16.0 | 14.0 | 16.0 | 16.0 |
| 12.0 | 14.0 | 12.0 | 0.0 | 0.0 | 0.0 | 1.0 | 3.0 | 8.0 | 2.0 |
| 15.0 | 8.0 | 12.0 | 2.0 | 0.0 | 1.0 | 2.0 | 0.0 | 0.0 | 0.0 |
| 8.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 20.0 | 0.0 | 0.5 | 0.5 |
| 8.0 | 8.0 | 12.0 | 0.5 | 6.0 | 16.0 | 20.0 | 10.0 | 17.0 | 18.0 |
| 22.0 | 8.0 | 25.0 | 11.0 | 9.0 | 20.0 | 20.0 | 15.0 | 12.0 | 18.0 |
| 15.0 | 3.0 | 12.0 | 0.0 | 0.0 | 20.0 | 0.0 | 0.0 | 0.0 | 8.0 |
| 5.0 | 3.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 |
| 12.0 | 12.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 12.0 | 0.3 | 12.0 |
| 0.0 | 0.0 | 0.0 | 16.0 | 0.0 | 20.0 | 20.0 | 0.0 | 12.0 | 0.0 |
| 0.0 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 |
| 0.0 | 0.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 3.0 | 3.0 | 3.0 | 2.3 | 0.5 | 0.0 | 0.0 | 0.0 |
| 2.0 | 0.0 | 0.5 | 2.0 | 12.0 | 20.0 | 18.0 | 3.0 | 3.0 | 3.0 |
| 0.0 | 0.0 | 0.0 | 3.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 3.0 | 0.0 | 13.0 | 12.0 | 14.0 | 1.5 | 14.0 | 12.0 | 0.0 |
| 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 1.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.5 | 0.1 |
| 0.2 | 1.0 | 0.1 | 0.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 3.0 | 1.0 | 6.0 | 8.0 | 0.5 | 3.0 | 2.0 |
| 0.5 | 0.0 | 0.0 | 0.0 | 1.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.5 | 1.0 | 0.5 | 0.0 | 1.0 | 0.0 | 0.0 | 0.2 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 0.5 | 0.5 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7.0 | | | | | | | | | |

Property 61. Depth III. Per cent of Carbonates.

Property 62. Depth III. Reaction (pH).

Property 63. Profile drainage.