THE SOILS OF RHODESIA AND THEIR CLASSIFICATION

by

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CONTENTS

MAPS

INTRODUCTION

Soil surveys have been carried out in almost all parts of Rhodesia (formerly Southern Rhodesia) by the writer over the past 17 years. Most of the surveys were primarily initiated for utilitarian purposes but the approach, both in the field and subsequently in the laboratory, has always been to acquire knowledge concerning the fundamental constitution of the various soils of the country and their genesis. Such knowledge is an essential prerequisite to sound classification and mapping of the soils. In the ensuing dissertation a system of classification for the soils of Rhodesia has been set forth, together with a fairly comprehensive description of the soils. The more important genetic factors that have contributed to their development are also discussed.

CHAPTER I

A. THE NATURAL FEATURES OF RHODESIA

1. Physical Features and Geology

Rhodesia covers an area of a little over 150,000 square miles. It is situated between 15° 40' and 22° 20' south latitudes, and 25° 15' and 33° 05' east longitudes. In describing the physical features of the country Swift (16) states that :

> "Although its boundaries were determined from political considerations, Southern Rhodesia as a part of Africa has an identity of its own, in that it is a relatively high region surrounded by lower country on all sides. The central portion forms a plateau dominated by a pronounced peneplain and carries the divide between the Zambesi Basin and the Makarikari Depression on the north and west, and the Sabi-Limpopo Basin on the south-east. At its north-eastern end the plateau joins a narrow belt of mountainous country striking north and south along the eastern border. It is only in this narrow area that the altitude rises above six thousand feet, although, owing to the flat nature of the central uplands, more than twenty-one per cent of the area of the Colony is above the 4,000-ft. contour."

In Rhodesia there is a great range of geological materials which differ widely in chemical constitution, mineral composition, and physical nature. These characteristics have a direct bearing on many of the soil properties but particularly on internal soil drainage and, therefore, the ease with which the soil can be leached throughout its evolutionary stages. Over most of the country the boundaries between parent materials from which soils are derived are sharp, and in the vicinity of the Gold Belts (complexes of metamorphosed basaltic and andesitic lavas and sediments, of great age), they commonly occur at close intervals. On the assumption that granite is regarded as an igneous rock, the parent materials of about 60 - 65 per cent of the total area of Rhodesia are derived from rocks of igneous or metamorphosed igneous origin. Deep sands originating from aeolian Kalahari deposits and, to a lesser extent, from some of the weakly consolidated Triassic, Cretaceous, and Permian formations account for about a further 25 per cent of the total area. Thus, parent materials from other less arenaceous sediments which are characteristic of vast tracts of the North American and Eurasian continents, account for only a very small porportion of Southern Rhodesia. One other notable feature of the geology is the Great Dyke which Swift (16) describes as "an elongated mass of ultrabasic and basic rocks stretching in a nearly straight line north-north eastwards for a distance of over 320 miles, and varying in width from two to seven miles".

2. Climate.

In contrast to the very varied geological composition of Rhodesia, climate in the broader sense is relatively uniform over most of the country. Apart from the narrow tract in the Eastern Districts and a similar but much smaller one in the south-eastern part between Bikita and Zimbabwe Ruins, practically all of the mean annuall rainfall is confined to the summer months, the bulk falling between the beginning of December and the first half of March. Precipitation within this period is generally referred to as the main rains, and it is predominantly of the convective type. Prior to the onset of these rains, in the period from about mid September to early November, pronounced desiccation usually takes place owing to high temperatures in conjunction with low relative humidities.

On the central plateau that carries the main water-shed between the Sabi-Limpopo and Zambesi basins, mean annual rainfall varies between about 24 and 36 inches (610 - 915 mm.). In the hotter areas at lower altitude in the Sabi-Limpopo basin, rainfall is appreciably lower and, in minor localities in the south-west, appears to be as low as about 10 inches per annum. In similar areas in the Zambesi basin, rainfall is generally above 20 inches per annum but temperatures are much higher than in the Sabi-Limpopo basin and the effectiveness of rainfall is reduced with respect to leaching, especially in soils with appreciable clay content.

In the two narrow tracts mentioned, mean annual rainfall is above 36 inches; in some limited localities it may even exceed 115 inches. The main climatic distinguishing features of these areas, however, lie not only in rainfall distribution but also in the relatively cool temperatures that prevail. Although most of the rain falls in summer, a significant but variable proportion falls in the remaining months of the year. The amount, in conjunction with the cooler temperatures, is normally sufficient to maintain the soils in a moist condition throughout the year.

B. THE APPROACH TO SOIL CLASSIFICATION

1. Basic principles

Since any system of soil classification is an artificial means by which man attempts to group soils with similar properties, they may be classified on the basis of any chosen characteristic or set of characteristics, depending on the purpose for which the classification is required. If the system of classification is based upon criteria which do not include those relating to pedogenesis, the result will be a purely mechanical classification such as that proposed by Leeper (9), which is based entirely on selected soil characteristics without reference to environment or to pedogenesis. Such classifications have considerable merit in that they allow mutually exclusive groupings to be made in a relatively simple manner without ambiguity. On the other hand, most pedologists agree that classifications which are based on some understanding of the nature of soils should embrace some fundamental pedogenetic principles as distinct from "guesses as to origin". In this context Kubiena (8) states that "to forego genetical investigation would mean to abandon scientific research itself, because describing things in nature without any efforts to understand them means only a beginning of science, not science itself".

The recognition of soil as an organismic natural body began with the work of Dokuchaev, and in the study of classification of soils the approach must be an holistic one which embraces all factors pertaining to the soil and its environment. Apart from factual data relating to the soil itself, this will inevitably involve some considerations relating to pedogenesis. However, the pedogenetic concepts that are incorporated in any system must be realistic ones based upon criteria for which there is strong, if not overwhelming evidence, not only in the field but also in the laboratory where relevant physical, chemical and/or mineralogical information can provide confirmatory evidence.

Thus the description and characterisation of soils will be incomplete unless it includes, in addition to profile morphology and analytical data, some reference to climate, parent material, and vegetation. It should also include an appreciation of local topography in relation to the wider geomorphological land form in so far as this may indicate the age of the soil and many have a direct bearing on the development of the parent material from the native rock. An assessment of all of these inter-related factors is, to a greater or lesser degree, necessary to provide the pedologist with the concrete evidence on which to base his interpretation of the pedogenesis of the soil. A sound system of classification should, therefore, be one in which the soils are grouped according to similarity of fundamental properties of the soil itself but the arrangement of these groupings within the system should, at some level or levels in the hierarchy of differentiae, be determined by considerations that relate primarily to pedogenesis or pedogenetic concepts.

A classification of this nature, which takes into account certain fundamental chemical and mineralogical characteristics, will automatically have profound direct significance for agriculture particularly in regard to the inherent fertility of the soils. The practical value that this implies is important, but incidental. Thomas (18), however, has gone further and has submitted that since "soil is the medium in which plants grow, any characterisation and classification of soils must reflect their ability to support plant growth . . . ". Many pedologists will disagree with this contention. In the writer's view the value to agriculture is a natural corollary of the fact that the soil has been classified primarily on the basis of its fundamental constitution.

2. Existing Systems of Classification

(a) Classification according to climatic zonality

It is only natural that any system of classification which incorporates pedogenetic concepts tends to lay strong emphasis on selected pedogenetic factors that are predominantly operative in differentiating soils in the country in which the classification was evolved. This probably constitutes one of the main reasons why it has not been possible to evolve a classification of this nature that is universally acceptable.

The zonal system of classification initiated by the Russians was developed in, and was mainly applicable to, regions where the contrast in parent materials was very much less sharp than in Rhodesia and where, from region to region, climatic variations are more marked. On the North American and Eurasian continents there are immense tracts where soils are predominantly derived from little or non-metamorphosed sediments of divers geological ages, under a wide range of climatic variations. Under such circumstances it is not surprising, therefore, that climate is the dominant pedogenetic factor which differentiates one group of soils from another. But even within these tracts there are minor areas where certain parent materials give rise to soils which are not in conformity with this generalisation. In recognising this, Glinka (5) called these soils endodynamomorphic, in order to contrast them with the more typical ectodynamomorphic ones. He states, however, that "the endodynamomorphic soils are often a temporary formation, which may persist until the composition of the parent material has changed". (6)

In Rhodesia, however, the relative importance of climate and parent material as pedogenetic factors responsible for soil differences is largely reversed. Broadly, climate, as mentioned earlier, is relatively uniform over large areas, while parent materials are very varied and their distribution, moreover, is complex. Any system of classification in which there is a strong emphasis on zonality according to climate therefore has little practical application. This does not mean, however, that major variations in soils are not attributable to climate but, before any direct comparisons of the effect of climate <u>per se</u> can be made, comparisons must be confined, in the first place, to soils derived from very similar parent materials. In addition, other complicating variables have also to be eliminated. Mohr and van Baren (10), in considering the effects of climate on soils, distinguish between overhead or atmospheric climate and actual soil climate. They state :-

> "When considering climatic influences and climate - the latter conceived as the complex of climatological characteristics of any given place - a sharp distinction should be drawn between the climate in the atmosphere <u>above</u> the soil and the actual climate <u>in</u> the soil itself, i.e. the <u>soil climate</u>. Direct relationship with the soil and with soil forming or soil destroying processes is limited to the soil climate, the atmosphere above only being involved in so far as it exerts any influence on the aforementioned soil climate."

Soil climate, obviously, is largely dependent on overhead climate, but it may be drastically modified by a complex interaction of other factors such as topography and the nature of rock strata which underlie the soil. Therefore, in order to evaluate the direct effects of climate on soils in Rhodesia, comparisons have to be confined not only to soils derived from very similar parent materials but also to areas of similar, normal or upland relief where the interaction of such factors is minimal. This form of zonality is most apparent on upland soils derived from certain basic rocks, notably dolerite. With increasing rainfall soils progress from dark montmorillonitic clays to reddish brown clays in which both 1 : 1 and 2 : 1 lattice minerals are present, and finally to red highly porous clays in which the only clay minerals present are of the 1 : 1 lattice type.

In considering the inter-relationship between climate and parent material in regard to pedogenesis, it is necessary to distinguish broadly between two major groups of parent materials, namely the basic ones of igneous or metamorphosed igneous origin on the one hand, and those of sedimentary origin on the other. This view has also been expressed by Ellis (4) although for a reason that is different from the one given here. Nevertheless, the work of Mohr and van Baren (11) clearly reveals the importance of differentiating between these two types of parent materials. In general the former are chemically far more active or susceptible to profound alteration than the latter since they contain relatively large amounts of primary or first order weatherable minerals such as the pyroxenes, the amphiboles, and olivine in addition to various anorthitic plagioclase felspars. Parent materials of sedimentary origin, however, have resulted from at least one cycle of weathering, erosion and deposition. Unless subsequently subjected to a high degree of metamorphism, the weatherable minerals present will be mainly secondary ones which in general will be far less subject to chemical alteration. It is, perhaps, for this reason that soils formed on certain basic rocks most clearly show some climatic zonality in Rhodesia.

(b) Previous classification in Rhodesia

Because of the real and often striking differences in soils associated with changes in parent material, Ellis (3) suggested an approach to describe the soils of Rhodesia that is radically different to that employed by pedologists in most other parts of the world. His descriptions were based on parent material and included references to mean annual rainfall and temperature, altitude, and the dominant vegetation. It was further suggested that the ordinary place-name nomenclature for soil series be replaced by a description incorporating these factors. In applying this idea, Thomas and Ellis (19) used a descriptive legend of this nature in their Provisional Soil Map, which served as a basis for the Agricultural Survey of Southern Rhodesia (20). Their approach has great merit locally in that it provides agricultural planners with a valuable inventory of soils and related data pertaining to geology, climate and natural vegetation. It does not, however, constitute a true or complete pedological classification which can be interpreted by pedologists in other countries where soil and climatic conditions may be vastly different and, indeed, it was never intended as such.

(c) <u>The 7th Approximation (14)</u>

Towards the end of 1954, collaboration began in providing information on soils for a new comprehensive system of classification being compiled by American pedologists. This classification is now generally referred to as the 7th Approximation but, during the period of collaboration which was rather sporadic, it was then evolving from its 3rd to its 5th Approximations. In these early stages the impression gained was that the classification would evolve as a purely mechanical classification and that many Rhodesian soils which locally are regarded as being widely different would only be separated at low categorical levels. The recently published 7th Approximation represents a considerable advance over the earlier Approximations which had a limited circulation, and is more fully documented with respect to explanatory text and definition of soil characteristics and criteria of classification.

This system of classification, however, is still contentious in many respects. Muir (12) criticises the emphasis placed on diagnostic horizons rather than complete profile characteristics. While readily admitting that it is the most nearly complete system that has been elaborated up to the present and that great care and precision has been taken in defining the classification units, Tavernier (17) indicates that many European pedologists feel that separate orders should be provided for hydromorphic soils and saline (and alkali) soils. Because of the special conditions that favour the formation of such soils in Rhodesia, the writer supports this view.

From observations that have been made locally, it appears that many unlike soils are accommodated in the Alfisol order. These may differ not only in profile morphology but, since they may occur in areas of widely different mean annual rainfall, their constitution with respect to clay mineralogy and reserves of weatherable minerals may also vary markedly. Stephens (15), in discussing the applicability of the system to Australian soils, emphasises the same point. Smith (13) and Kellogg (7), however, both clearly indicate that the system is, as yet, by no means complete and is still in the process of development. While admitting that the system is being developed primarily for use in the United States of America, the scope of the classification implies an intended world-wide application. For this reason, an attempt has been made in Chapter III to correlate or classify many Rhodesian soils (hydromorphic and halomorphic soils excepted) in terms of the 7th Approximation. However, since most of the data on local soils were not originally accumulated for this purpose, and since certain data other than that given are often specifically required for this exercise, the classifications put forward here should be regarded as tentative in some instances.

(d) <u>The classification evolved by the Inter-African Pedological Service</u>

In 1953, the Inter-African Pedological Service (S.P.I.), operating under the auspices of the Commission for Technical Co-operation in Africa South of the Sahara (C.C.T.A.), undertook the compilation of a soil map of Africa at a scale of 1 : 5,000,000 based on data from participating territories. Initially this ranged from systematic soil surveys in a few territories to broad soil-vegetation associations in others and, in view of the wide diversity in the nature of the information, the S.P.I. convened a series of conferences to enable pedologists from the various territories to meet and to agree upon a common basis of approach to soil classification and mapping problems. As a result of these meetings, the development of the legend for the Soil Map of Africa was accomplished by means of a number of draft stages. Of these, the Third was published by D'Hoore (2) and the legend was finalised in its Fifth Draft stage at the S.P.I. conference held in Paris in 1961 (1).

The pedogenetic concepts on which the classification implicit in the legend is based, emerged very largely from the combined thinking of Belgian, French, and Portuguese pedologists who, over a period of time, have acquired an intimate knowledge of African soils, particularly those occurring within the tropics.. These concepts are based in principle upon the degree of weathering and leaching which soils derived from specific types of parent materials have undergone as a result of climatic and other forces that have acted upon them. This approach has provided, for the first time, an eminently suitable framework within which a realistic system of taxonomy for the soils of Rhodesia could be evolved. In addition to morphological characteristics of the profile, the classification takes into account fundamental soils characteristics such as clay mineralogy, reserves of weatherable minerals, base saturation, and cation exchange capacity per unit amount of clay; the last-mentioned being used largely as confirmatory evidence, especially where more precise information concerning clay mineralogy is lacking. These characteristics and criteria are fundamental, since they are directly related to the effect of climate, the extent of the effect being in turn related to the specific type of parent material from which the soil is derived.

A classification which takes all of these characteristics into account should, to a large extent, be capable of interpretation in terms of any of the broadly based systems of classification which regard the soil as a natural product of its environment.

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CHAPTER II

THE CLASSIFICATION OF THE SOILS OF RHODESIA

The soils of Rhodesia have been classified at four categorical levels, namely the soil Order, the soil Group, the soil Family and the soil Series. In the schematic outline shown opposite page 14 it will be seen that these four categorical levels are employed in a simple branching system. The strong influence of the classification used in the legend for the soil map of Africa (4) is clearly evident in the Rhodesian classification but there are some differences in the levels at which certain differentiae are introduced. Moreover, many of the criteria have been modified, sometimes appreciably, to make them more specifically applicable to Rhodesian soils. Nevertheless, the classification will be clearly comprehended by pedologists familiar with the work of **S.P.I.**

THE SOIL ORDERS

Five Orders have been recognized. They are the Weakly Developed soils, the Calcimorphic soils, the Kaolinitic soils, the Halomorphic soils, and the Hydromorphic soils. In the first three there is a broad progression in the degree of weathering that soils derived from specific types of parent materials have undergone while in the remaining two other pedogenetic factors are relatively more important. These primarily include poor internal drainage which, in most instances, is due to topographical situation and/or the physical nature of underlying rock strata. In regard to the broad pedogenetic concepts adopted in the present classification there is an analogy between the soils of the last two Orders and the Intrazonal soils of classification systems based on zonality according to climate.

I <u>Weakly Developed soils</u>

These comprise all soils in which the degree of genetic horizon differentiation is weak for reasons that are given at lower

OUTLINE OF SOIL CLASSIFICATION

Order	Group	Family	Typical Soil Series (described in Appendix A)
I. Weakly Developed Soils	1. Regosols	Very immature regosols of alluvial and colluvial origin	Not placed in soil series
		Mature regosols formed on little-consolidated sandy deposits	Nyamandhlovu K.1
	2. Lithosols	Predominantly sandy lithosols formed on siliceous parent materials	Triangle P.O.
		Predominantly clayey lithosols formed on basic rocks and argillaceous sediments	Matopos E.O.
II. Calcimorphic Soils	3. Vertisols	Vertisols without appreciable free water soluble salts or exchangeable sodium, formed mainly on basic rocks	Chisumbanje B.1, Devuli E.1, Selous X.1
		Vertisols with appreciable water soluble salts and/or exchangeable sodium, formed mainly on Madumabisa shales	Siabuwa Z.1
	4. Siallitic Soils	Siallitic red granular clays formed on basic rocks	Matopos E.1
		Shallow to moderately shallow other siallitic soils, formed on other miscellaneous rocks	Tuli P.2, Triangle P.1, Tuli P.1
		Siallitic highly calcareous soils formed on highly calcareous materials, often on lower slopes	Tuli L.1
		Deep siallitic soils formed on alluviums and colluviums	Sabi U.1, Sabi U.2, Sabi C.1 Sabi C.2

Order	Group	Family	Typical Soil Series (described in Appendix A)
III. Kaolinitic Soils	5. Fersiallitic Soils	Fersiallitic red granular clays formed on basic rocks	Salisbury E.2, Darwendale X.1
		Fersiallitic relatively silt-rich soils formed mainly on sedimentary rocks	Sinoia A.1
		Fersiallitic highly micaceous soils formed on highly micaceous parent materials	Miami F.1, Karoi F.1
		Fersiallitic predominantly sandy soils formed mainly on siliceous rocks	Karoi G.1, Rutenga G.1
		Weakly fersiallitic red clays formed on narrow dolerite dykes intrusive into granite	
	6. Para-ferrallitic Soils	Para-ferrallitic predominantly sandy soils formed mainly on siliceous rocks	Salisbury G.1, Marandellas G.1
		Para-ferrallitic sands formed on little-consolidated sand deposits	Featherstone M.1
	7. Ortho-ferrallitic Soils	Red ortho-ferrallitic clays formed on basic rocks	Chipinga E.1
		Mainly yellow ortho-ferrallitic relatively silty clays formed on Umkondo shales	Chipinga S.1
		Red and yellow ortho-ferrallitic sandy to medium textured soils formed on granites and Umkondo sandstones	Bikita G.1, Melsetter M.1
		Humic ortho-ferrallitic soils	Inyangani G.1

Order	Group	Family	Typical Soil Series (described in Appendix A)
IV. Halomorphic Soils	8. Sodic Soils	Weakly sodic sandy soils	Salisbury GS.3,
		Strongly sodic soils	Mondoro MG.1, Enkeldoorn G.2, Salisbury GS.4
		Saline sodic soils	Sabi U.4
	9. Non-sodic Soils	Saline non-sodic soils	
V. Hydromorphic Soils	10. Calcic hydromorphic Soils	Calcic hydromorphic vertisols	Salisbury E.4
		Calcic hydromorphic clay soils	Mazoe S.3
		Calcic humic hydromorphic clay soils	Mazoe C.2
	11. Non-calcic hydromorphic Soils	Non-calcic hydromorphic sandy soils	Salisbury G.3
		Non-calcic humic hydromorphic soils	Umvuma K.1

categorical levels. At the Group level they are split into Regosols and Lithosols.

II Calcimorphic soils

These are essentially unleached and therefore relatively little-weathered soils. Reserves of weatherable minerals are generally large, base saturation is high and clay minerals are predominantly of the 2 : 1 lattice type. The bases present consist almost entirely of calcium and magnesium. Except in the case of soils derived from ultrabasic rocks, exchangeable calcium exceeds exchangeable magnesium.

The soils of this order correspond very broadly to Marbut's Tropical Pedocals (9). In his description, Marbut states that they include "all soils with fully developed profiles in which lime carbonate is found on some horizons within the solum in higher percentage than in the geological formation beneath." However, many local soils have no free carbonates and some are not fully developed or mature. In fact, some alluvial soils of relatively recent age have been included in this order, where there is a sufficient degree of genetic horizon development to give rise to illuvial or textural B horizons, even if genetically unrelated horizons occur below about 3 feet.

The Calcimorphic soils comprise two groups, viz., Vertisols and Siallitic soils.

III Kaolinitic soils

In contrast to the Calcimorphic soils, the Kaolinitic soils are leached to varying degrees. Owing to greater intensity of weathering, their essential characteristics include a predominance of kaolinite, together with appreciable amounts of free sesquioxides of iron and aluminium. Apart from their broad correlation with the Lateritic Soils of Marbut's Pedalfers, they also correspond, again broadly, to the Kaolisols defined by Sys (13) in equatorial regions of Africa. At lower categorical levels, however, the subdivision of the Kaolinitic soils differs from that employed by Sys and, in fact, follows very closely on the lines of the Portuguese classification evolved for the soils of Angola (1). The Kaolinitic soils have, accordingly, been split at the Group level into Fersiallitic soils, Para-ferrallitic soils, and Ortho-ferrallitic soils.

IV <u>Halomorphic soils</u>

These include, in addition to saline, alkali, and saline-alkaline soils, all soils in which there are hard, dense impermeable, abruptly commencing horizons that are primarily attributable to exchangeable sodium in amounts sufficient to produce some measure of dispersion or deflocculation of the clay colloids. Although de Sigmond (6) has suggested that an appreciable dispersing effect only occurs when the exchangeable sodium status of soils approaches 10 - 15 per cent of the total exchangeable bases, it appears that in some Rhodesian soils, notably the predominantly sandy ones, quite marked deflocculation of the clay fraction can occur below this level. Such soils are also included in this Order. The Halomorphic soils comprise Sodic soils and Non-sodic soils.

V <u>Hydromorphic soils</u>

These embrace all soils that have developed under, and which are subject to a marked degree of wetness that may be either permanent or seasonal. In addition to water table effects, the soils of this Order, with the exception of certain black clays, show marked evidence of hydromorphy either in the form of mottles and gleyed horizons and/or rust-like stains around roots and root channels. In general they correspond to soils in which hydromorphy is regarded as a fundamental criterion in the French classification as described by Duchaufor (7).

Owing to the limited amount of investigation of the Hydromorphic soils, their subdivision at the Group level is somewhat tentative. Of the soils so far examined, those of high clay content appear to have high base saturation, the bases comprising mainly calcium and mangesium, while those that are predominantly sandy are generally leached and strongly acid. On this basis they have been subdivided into a Calcic hydromorphic group and a Non-calcic hydromorphic group.

It may possibly be preferable, however, to differentiate these soils purely on the basis of clay content.

THE SOIL GROUPS

Eleven soil Groups have been recognised and at this second categorical level the main morphological, mineralogical, and chemical characteristics have been defined. Since the classification has been evolved primarily to suit the soils of Rhodesia some Groups described will obviously be too wide to have any appreciable value for some territories of Southern Africa, whereas for others some of the distinctions made at this level may be too narrow. To cite one obvious example, the Siallitic soils, i.e. those, other than Vertisols, that have high base saturation and concomitant characteristics such as predominance of 2 : 1 lattice clay minerals, will be of little use for differentiating between soils in territories where, on account of aridity of climate, the vast majority or even all soils may be of this type.

It should also be apparent that the Group as understood in Rhodesia, cannot be equated in categorical level with the Great or Little Groups of other systems of classification; in any case such terms have varying categorical connotations in different classifications.

In the criteria defined data relating to base saturation and cation exchange capacity per 100 grammes of <u>clay</u> refer to subsoil horizons in which the effects of organic matter are negligible. The latter is normally expressed in milligram equivalents but, for sake of convenience, is referred to as the E/C value in the text below. The analytical methods by which chemical and physical data have been determined are outlined in Appendix A.

Investigations into clay mineralogy and reserves of weatherable minerals have also been confined to subsoil horizons in order to obviate the need for destroying organic matter which otherwise may have side effects on clay mineralogy and weatherable minerals. Owing to the relatively recent acquisition of a suitable microscope comparatively little work has been done on detailed identification or quantitative determination of weatherable minerals. In fact, with the exception of a few special investigations, work on weatherable minerals has thus far been confined to confirming the broad correlation between weatherable mineral status and the degree of weathering that soils have undergone. In regard to the approximate assessment of amounts present, it has been found that many such minerals can readily be recognised in separated sand fractions, either under a hand lens or even by the naked eye where they are abundant.

1. The Regosol Group

The regosols comprise soils, developed on unconsolidated or only weakly consolidated deposits, in which the degree of genetic horizon differentiation is very low. Very young and immature alluvial deposits of current formation have been included in this Group. The vast majority of regosols, however, are deep sands that in spite of greater age show only weakly developed AC profiles. Although they are of relatively recent origin in the geological sense, the main factor responsible for poor genetic horizon development is extreme paucity of clay producing weatherable minerals in the original parent materials. In such soils the silt plus clay content is always less than 15 per cent in all horizons above 72 inches and there are no marked or sudden changes in clay content in any horizon within this depth.

2. The Lithosol Group

In the Rhodesian classification the lithosols include all soils in which rock or gravelly weathering rock commences at depths of less than 10 inches. They may occur extensively on relatively level ground in areas where rainfall is low but in most regions they are associated mainly with broken or hilly country. Owing to the variety of conditions under which they may occur, this is not strictly a genetical grouping but a heterogeneity of soils that for one or more reasons have at least one essential feature in common, namely pronounced shallowness of the solum.

3. The Vertisol Group

The vertisols contain sufficient clay of the swelling type to produce appreciable internal soil movement or churning under a regime in which the soils are alternately moistened and dried. Apart from wide vertical cracks when dry, a characteristic feature is the presence of highly polished surfaces, or slickenslides, that are indicative of internal soil movement. In Rhodesia the critical depth of soil that appears to be necessary for the development of slickenslides is about 15 inches. Almost all swelling clays that are shallower than this are, therefore, not classified as true vertisols. In addition, all soils in which the dominant feature is pronounced wetness throughout most of the year have been excluded from this Group in spite of the presence of slickenslides in the profile. These latter soils are, however, placed in a separate family within the hydromorphic group that has some affinities with the true vertisols.

The vertisols are all highly, or even fully, base saturated and many have free carbonates of calcium and magnesium throughout the solum. Base saturation is invariably greater than 80 per cent. Montmorillonite is the main clay mineral and as a result, E/C values almost invariably exceed 60.

4. The Siallitic Group

The base saturation of these soils is almost invariably greater than 80 per cent and 2 : 1 lattice clay minerals predominate. Apart from obvious morphological differences, siallitic soils of high clay content differ from vertisols in the nature of the 2 : 1 lattice minerals which, instead of montmorillonite consist mainly of illitic to poorly crystalline illite-montmorillonoid mixed layer minerals. The lower limit of E/C values appears to be about 40 in the siallitic soils.

In most siallitic soils, with the exception of very sandy ones, shiny surfaces that may be orientated clay coatings, are discernible under a hand lens in the B horizons. This, in conjunction with increased clay content relative to the surface horizons, strongly suggests that at least some of the clay in the subsoils is of illuvial origin. However, the writer is by no means convinced that shiny surfaces are always indicative of illuvial clay. It seems that such surfaces could be formed on peds simply as pressure faces in any soil that has sufficient clay of the swelling type. Moreover, if shiny faces are attributed to illuvial clay one might expect this phenomenon to be more apparent in sandy soils in which clay should be more readily mobile. No thin-section work has yet been undertaken locally to test this view.

5. The Fersiallitic Group

The clay minerals in fersiallitic soils consist predominantly of kaolinite but, in addition, some minerals of the 2 : 1 lattice type are always present. These latter comprise mainly illite and illite-montmorillonoid mixed layer minerals. Some reserves of weatherable minerals are present and they may be appreciable in some soils. Base saturation exceeds 40 per cent but in most soils it ranges from approximately 50 per cent to 85 per cent. E/C values range from approximately 15 to 40. Easily visible shiny surfaces on peds may be seen in soils of high clay content but they cannot always be discerned with any certainty in soils of relatively low clay content.

As in the Portuguese description (1), horizons containing laterite either as loose concretionary material, or in cemented form, may be present. This laterite, if present, is always an absolute accumulation as described by D'Hoore (5).

6. The Para-ferrallitic Group

Although the soils of this Group have some characteristics that are normally associated with true or ortho-ferrallitic soils described below, they also have some aberrant properties that are more commonly found in fersiallitic soils. In certain respects they resemble some, but not all, of the Ferrisols described by Sys (13). The name para-ferrallitic was proposed by Botelho da Costa (2) for certain soils in which the clay is essentially ferrallitic in character but which also have appreciable reserves of weatherable minerals, some of which are macroscopically visible. In the very similar, if not identical, Rhodesian soils the clay mineral is exclusively kaolinite.

Base saturation ranges from about 30 - 60 per cent and E/C values are less than 15.

In Rhodesia the Group has been extended to include, at least temporarily, certain other soils that have some characteristics normally associated with ferrallitic soils but others which are normally associated with fersiallitic soils. The soils thus included are invariably very sandy in the surface horizons and have small or no reserves of weatherable minerals. Unlike the regosols, however, they have at least one horizon within 72 inches of the surface in which the silt plus clay content is greater than 15 per cent. In these horizons the silt/clay ratio is extremely low but their clay fractions contain sufficient 2 : 1 lattice clay minerals to preclude them from the true or ortho-ferrallitic soils described below. Again, base saturation generally ranges from about 30 to about 60 per cent, but on account of the presence of 2 : 1 lattice clay minerals, E/C values range from about 15 to about 25.

7. The Ortho-ferrallitic Group

The ortho-ferrallitic group has been so called because the intense degree of weathering imposed by climate has given rise under high rainfall to strongly leached, acid soils in which weatherable minerals are practically absent, regardless of the parent material. These soils rarely dry out to any marked degree and in most of them, some of the aluminium sesquioxides have become hydrated to form gibbsite. Base saturation is always lower than 40 per cent, but usually less than 30 per cent. E/C values are lower than 15. As in the typical Ferrallitic soils of the Portuguese classification (1), laterite may or may not be present. If laterite is present it is usually a relative accumulation as defined by D'Hoore (5).

8. The Sodic Group

The soils of this Group are all influenced by the presence of sodium on the exchange complex. Morphologically and otherwise, many of them resemble the solonetz, solodized-solonetz, and solods originally described by the Russians, but such soils are regarded by many authors as constituting a genetic sequence, evolving in the first instance, from solonchaks. This genetic evolution, however, does not appear tenable for most of the sodium-influenced soils of Rhodesia, particularly since most of them have been formed under conditions of relatively high rainfall. They have, therefore, been called sodic soils. Smith (11), for apparently similar reasons, has referred to the sodium-influenced soils formed under humid conditions in Illinois as solonetz-like soils.

Criteria relating to exchangeable sodium percentage and electrical conductivity of the saturation extract are given at the soil Family level.

9. <u>The Non-sodic Group</u>

Non-sodic halomorphic soils comprise those in which the soluble salts are predominantly those of calcium and magnesium and in which exchangeable sodium percentages are very low. Again, their chemical characteristics are more closely defined at the soil Family level.

10. <u>The Calcic hydromorphic Group</u>

The soils of the calcic hydromorphic group are predominantly clayey. As far as is known the lower limit of base saturation is about 50 per cent but in most of the soils thus far examined it is generally greater than 80 per cent and clay minerals of the 2 : 1 lattice type appear to predominate.

Some of the black or dark grey clays show slickenslides in the subsoils and in this respect they show some affinities with the vertisols. Many pedologists would probably prefer to see them classified in the vertisol group. Locally, however, these soils are regarded as being primarily hydromorphic soils and only secondarily vertisolic. Moreover, although they have essentially the same composition as the true vertisols, their genesis is different in some respects. They have evolved under very much moister soil climatic conditions and at least some of the bases present have accumulated partly as a result of importation from adjacent higher lying areas. In the true vertisols other factors, sometimes including aridity of soil climate, have prevented removal of bases released <u>in situ</u>.

11. The Non-calcic hydromorphic Group

On the basis of examinations so far made it appears that all of the predominantly sandy soils subject at some time of the year to excessive wetness have base saturations lower than 50 per cent and have therefore been classified as non-calcic hydromorphic soils. However, no examination has been made of any hydromorphic soils in the Eastern Districts where, owing to the dissected nature of the terrain, they occur to only a very limited extent. While those that are predominantly sandy conform to the generalisation stated above, it is possible that some of the more clayey soils may also have base saturations lower than 50 per cent.

THE SOIL FAMILIES

At this level of abstraction the soils are further sub-divided into broadly similar sub-groups on the basis of profile morphology and texture. Such characteristics are in most instances largely attributable to broad similarity of the parent materials from which they are derived. This generalisation applies mainly to Families falling within the first three Orders. In the case of Families belonging to the Halomorphic and Hydromorphic Orders, however, the characteristics selected as differentiae do not necessarily reflect this relationship since under such conditions parent material as a genetic factor is of subordinate importance.

The soil Family comprises an essential intermediate link between the soil Series and the soil Group. At this level soils that are characterised by a marked accumulation of organic matter in the surface horizons are differentiated. They have been termed humic soils, and their main common requirement is that surface horizons to a depth of at least 10 inches must have a minimum organic carbon content (Walkley-Black value) of 1.6 per cent. This latter criterion has been adopted from the legend for the Soil Map of Africa (4), although the accepted carbon level may be too low for those soils occurring in more temperate regions.

In regard to the sub-divisions of the Halomorphic soils at the Family level, the following analytical criteria have been used :-

The weakly sodic soils must within 48 inches of the surface, have an abruptly-commencing horizon in which the exchangeable sodium percentage (laid down in both the 7th Approximation (12) and the S.P.I. legend (4) as each sodium/cation exchange capacity) is less than 25 per cent and the electrical conductivity of the saturation extract is less than 1 millimho/cm.

The strongly sodic soils have horizons commencing above 48 inches in which the electrical conductivity lies between 1 and 4 millimhos/cm if the E.S.P. lies between 15 and 25 per cent but, in some predominantly sandy soils, an electrical conductivity of less than 1 millimho/cm is permissible provided the E.S.P. is greater than 25 per cent.

The saline sodic soils must have an horizon, which generally occurs above 24 inches, in which the E.S.P. is greater than 15 per cent and the electrical conductivity is greater than 4 millimhos/cm.

The non-~~saline~~ sodic ~~sodic~~ saline soils are those in which the electrical conductivity of one or more horizons commencing above 24 inches is greater than 4 millimhos/cm and the E.S.P. less than 15 per cent. The free water soluble salt content must comprise mainly calcium or magnesium salts.

THE SOIL SERIES

As in most countries the Series constitutes the basic or lowest categorical level of classification in Rhodesia. In regard to the range of characteristics permitted within any particular soil series the principles described in the Soil Survey Manual (12) have been broadly followed. However, a departure from accepted convention has been made in regard to the naming of soil series since for various reasons, the ordinary place-name nomenclature has been found to be unsatisfactory.

Over large tracts of Rhodesia there is frequently a dearth of place names. Moreover, certain names are repeated in several widely separated, sometimes climatically different areas. In view of these difficulties a partially descriptive name was introduced some years ago. Apart from the suggestions made by Ellis (8), this idea is by no means new. In discussing the denomination of tropical soils, Mohr and van Baren (10) quote Bushnell's objection that "Geographical names give no suggestion as to the relationship between different kinds of soils or even between kinds of soils and their characteristics, and may even be misleading in that many series no longer occur in their type locality." (3).

Mohr and van Baren make the point that in the tropics especially, the use of descriptive terms for soils is far more appropriate than series names determined geographically. They are also convinced in the case of sedentary soils particularly, that the parent material should be indicated, together with the essential nature of the soils and, whenever possible, some reference to the stage of weathering or age should be made. Although these latter are not directly given in the partially descriptive names evolved for soil series in Rhodesia they appear, in essence, at higher categorical levels.

In the light of the foregoing the Series in Rhodesia are now given a place name that locally is generally well-known, followed by an alphabetical letter which gives an indication of the nature of the parent material, followed in turn by a numeral. The place name, in addition to having some climatic connotation locally in so far as mean annual rainfall and temperature are concerned, is selected, as far as possible, so that such data may be obtained by reference to climatological maps or publications. The parent material letter may represent one specific parent material only or may represent a group of parent materials which have similar chemical, physical, and mineralogical compositions. Except in the case of a 0 (zero) which is always used to denote a lithosol, the numeral has no fixed connotation and is merely used to differentiate between two or more soil series derived from the same parent material or group of similar parent materials. In regions where soils derived from very similar parent materials regularly show catenal variations, however, the numerals given generally follow the sequence from uplands to lowlands.

In the period of about five years since this scheme of series nomenclature has been introduced no serious difficulties or complications have arisen. It has, in fact, had practical advantages not only in regard to immediate recognition of the essential nature of the soil in many instances, but also in regard to mapping of soils.

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CHAPTER III

A. THE SOILS OF RHODESIA AND THEIR GENESIS

Horizonation and profile development

With certain exceptions, such as sodic soils and some of the hydromorphic ones, the degree of morphological differentiation between horizons within the soil profile is not well-developed in Rhodesian soils and, moreover, the transition from one horizon to the next is generally a gradual one. There is a danger, therefore, that attempts to describe horizons more precisely than on a broad A B C basis may be subjective. This makes classification of the soils in terms of systems that employ precise horizon nomenclature uncertain or even hazardous. Thus, in the detailed profile descriptions given in Appendix A no attempt has been made to name soil horizons and in any case their naming is not necessary to enable the soils to be classified in terms of the system described in Chapter II. With the exceptions noted above, the morphological differentiation between conformable horizons is best developed in the siallitic soils formed under low rainfall but decreases progressively in fersiallitic, para-ferrallitic, and ortho-ferrallitic soils. In the last mentioned the degree of differentiation is often no more apparent than in the sandy regosols.

Relationship between parent rock, parent material, and soils

In spite of differences in intensity of weathering wrought by climate and the resultant effect of fundamentally important characteristics such as reserves of weatherable minerals, base saturation and clay mineralogy, the soils of Rhodesia show a remarkable correlation with the parent rock and/or parent material from which they are derived. This is due not only to the fact that most soils are formed more or less *in situ* but also to the widely different types of parent material, most of which are of igneous origin.

Although soils may be described as being formed *in situ* there are in fact very few, if any, soils that originate directly from the parent rock immediately beneath them since on all land that has any perceptible slope there must inevitably have been some lateral movement of materials. On most parent rocks, particularly those that give rise to soils of high clay content, the movement of parent material does not lead to any noticeable degree of separation or sorting of the component parts. However, in the case of coarse grained granitic rocks and to a lesser extent certain similar gneissic ones, it appears that appreciable separation of components must have taken place to produce certain soil variations that can only be explained by variations in the composition of the parent material. This difference in parent material (as distinct from parent rock) manifests itself not only in the redness of the soil on upland slopes but also in the concomitant higher clay content of the redder soil. This contention has been advanced by Thompson (13) to explain a type of catenal variation that occurs in extensive areas underlain by granite. The mechanics of differential movement are explained in more detail later in this Chapter under the heading Para-ferrallitic Soils.

Although almost all soils in Rhodesia are derived in situ within the sense defined above, there are many minor localities where they have been formed on transported materials, notably colluviums and alluviums. The former are most commonly found on and below the pediment at the base of escarpments and the latter in major valleys in which rivers have deposited material that sometimes covers an appreciable area.

Diagnostic importance of the sand fraction

The sand fraction is the least altered part originating from the parent material since most of it normally consists of quartz which, usually, is only weathered by mechanical means. Most of the soils of Rhodesia are predominantly sandy and their sand fractions can be sub-divided into sub-fractions that, by their relative proportions, can almost invariably be related to the parent material from which the soil is derived. By sub-dividing the sand fraction into three separates, namely, coarse (2.0 - 0.5 mm), medium (0.5 - 0.2 mm), and fine (0.2 - 0.02 mm) as in Table I, the high proportion of coarse sand found in soils derived from granite clearly distinguishes them from the finer-grained sands such as those of the Kalahari, Triassic and Umkondo formations. In addition, similarity of components within the sub-fractions, as determined by visual inspection with or without the aid of a hand lens, can also be related to parent material.

TABLE I

Comparison of sand fractions of soils derived in situ and of transported soils.

Profile	Depth inches	C S %	M S %	F S %	Silt + clay %	Approx. ratios C S	M S	F S	Parent material	Group
		Soils derived in situ								
1	33-39	1	13	80	6	0.1	1	6.1	Triassic	Regosol
26	34-41	3	17	66	14	0.2	1	3.9	Triassic	para-ferrallitic
28	29-35	(0.3)	1	61	38	0.3	1	61.0	Umkondo	ortho-ferrallitic
23	35-46	35	16	29	20	2.2	1	1.8	Granite	fersiallitic
24	20-26	28	24	25	23	1.2	1	1.0	"	para-ferrallitic
25	20-24	26	15	18	41	1.7	1	1.2	"	para-ferrallitic
30	26-32	17	11	17	55	1.5	1	1.5	"	ortho-ferrallitic
34	9-14	22	26	25	27	0.8	1	1.0	"	sodic
40	19-24	22	27	35	16	0.8	1	1.0	"	non-calcic hydromorphic
33	20-25	10	26	52	12	0.4	1	2.0	Triassic, some granite	sodic
		Transported soils								
13	20-26	32	13	16	39	2.5	1	1.2	Granitic alluvium	siallitic
14	19-27	19	12	17	52	1.6	1	1.4	"	"
36	18-24	28	13	18	41	2.2	1	1.4	"	saline sodic
15	30-36	8	9	38	45	0.9	1	4.2	Mainly Umkondo colluvium	siallitic

Regardless of the degree of chemical weathering and leaching of the soil, these criteria can often provide valuable information concerning the nature of the parent material in the absence of rock outcrops, or the origin of the parent material in the case of transported soils.

Because of the genetic significance that may be associated with the sand fraction, terms such as coarse or fine textured which are commonly used in soil descriptions to imply relative amounts of sand, silt, and clay have not been followed in Rhodesia. Frequently soils in which clay content increases progressively with depth have sand fractions that also become progressively coarser. Similarly, as will be seen in Table I, soils that are very sandy may have a fine-grained sand fraction while others that have a higher clay content may have a strikingly coarse-grained sand fraction. The terms fine-grained or coarse-grained have therefore been used to describe the nature of the sand fraction. In view of the foregoing, the terms light-textured, medium-textured, or heavy-textured are preferred in general descriptions relating to clay content in spite of often vehement objections expressed by some pedologists to such terms.

DESCRIPTION OF SOILS

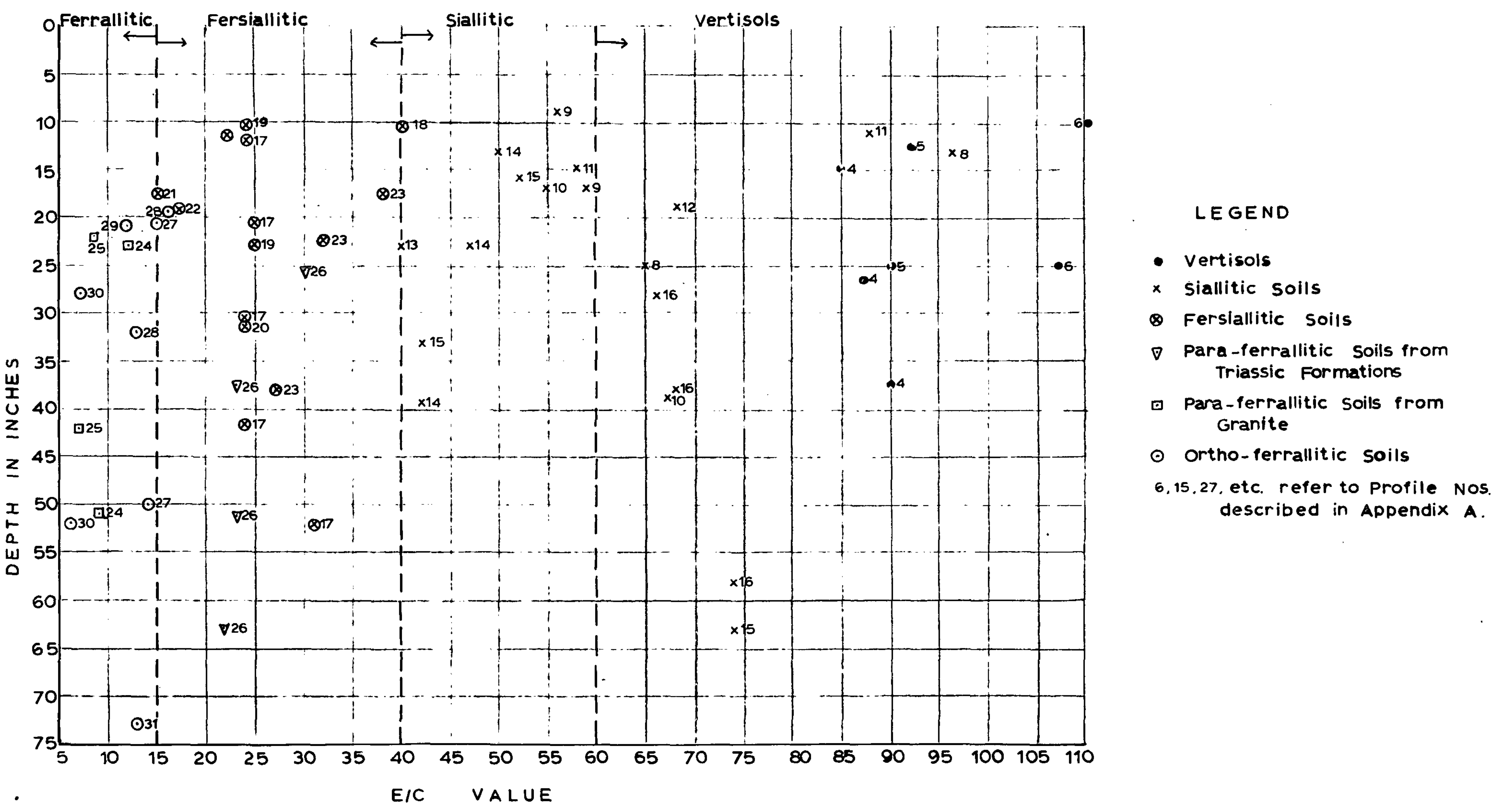
The description of soils is made mainly at the Group level of abstraction. In these descriptions many views relating to the genesis of local soils are presented. In some instances these views are at variance with commonly accepted ideas on pedogenesis relating to apparently similar soils in other parts of the world, but in all cases they seek to explain factual observations that have been made repeatedly.

With the exception of soils belonging to the Halomorphic and Hydromorphic Orders, correlation is made in terms of other systems of classification, notably that employed by the Portuguese (2), because of its close similarity with the system evolved locally. Since the 7th Approximation (11) is intended to be a comprehensive system an attempt has also been made to classify most local soils in terms thereof, although for reasons given in Chapter I the attempted classifications must be regarded as tentative in some instances. Because of basic differences in approach, no attempt has been made to classify soils of the Halomorphic and Hydromorphic Orders. Such soils would be split up into various Orders and sub-orders described in the 7th Approximation.

A diagrammatic representation of E/C values* of sub-surface horizons from soils belonging to Groups that reflect a broad

* E/C value has been defined as cation exchange capacity per 100 grams of clay.

DIAGRAM SHOWING DISTRIBUTION OF SUBSOIL E/C VALUES IN RELATION TO SOIL GROUPS THAT REFLECT DEGREE OF WEATHERING



progression in intensity of weathering is given opposite. The ranges of E/C values described for the classification in Chapter II are also shown. Owing to the interfering effects of organic matter on both exchange capacity and mechanical analysis, the E/C values of surface horizons thus affected are not shown. The E/C values of soils of the Weakly Developed, the Halomorphic, and the Hydromorphic Orders are also not shown on account of the different genetic peculiarities that contribute to the formation of such soils.

Regosols

Apart from insignificant small areas where very young immature soils flank the present day banks of some major rivers, all regosols in Rhodesia consist of deep, highly pervious, fine to medium-grained sands characterised by weakly developed A C profiles (Profile 1, Appendix A). They are formed mainly on aeolian Kalahari deposits and, to a lesser extent, on relatively little consolidated sandstones belonging to certain of the Trassic, Permian, and Cretaceous formations.

The main feature of these sands is their very low or non-existent reserve of weatherable minerals and their low silt/clay ratio. On normal uplands subsoil colour, which in most instances appears to be inherited from the parent material, is either reddish brown or yellowish brown. The general absence of horizon development below the A is undoubtedly due to paucity of clay producing minerals in the original materials. There is, therefore, little variation among the regosols, regardless of the rainfall of the areas in which they are found.

Correlation with other classifications

The soils of this group include Psammitic Regosols and some of the more sandy Chromopsammic and Similar Soils described by Botelho da Costa, Azevedo, Franco, and Ricardo in their classification of the soils of Angola (2).

The majority of these soils also belong to the Orthic Quarzopsamments described in the 7th Approximation (11), but in some instances subsoil chromas are higher than those specified.

Lithosols

All soils underlain by rock or gravelly weathering rock at depths of ten inches or less have been placed in this group. The reasons for their shallow skeletal nature may be steep slopes or aridity of climate in conjunction with resistance of the underlying rock to weathering. Most of them are stony or gravelly and their textures depend very largely on the nature of the rocks from which they are formed; those formed on acidic or highly siliceous rocks are predominantly sandy, while those formed on basic rocks are predominantly clayey (Profiles 2 and 3, Appendix A).

The majority of lithosols occur in broken country in the north-west and in the low rainfall areas of the southern parts, particularly in the south-west.

Correlation with other classifications

The lithosols of Rhodesia correspond very closely to those described in European-derived classifications.

In terms of the 7th Approximation most of them are Lithic orthustents but some, namely the lithosols formed on basalt and certain other basic rocks in areas of low rainfall, are Vertic orthustents.

Vertisols

Morphological characteristics and occurrence

In Rhodesia vertisols are formed mainly on basic igneous rocks although they occur to a much lesser extent on other parent materials capable of producing soils of high clay content, notably certain metamorphosed shales. They are generally, but not invariably, dark coloured soils. Morphologically, all are characterised by a varying degree of internal soil movement or churning which results from alternate wetting and drying of soils that have a high content of expanding montmorillonitic clays. In the soil profile this movement is readily diagnosed by the presence of slickenslides which, in most instances, intersect one another.

Vertisols occur on uplands of normal relief in most parts of the country, especially in the hot dry areas. They also occur in broad depressions in regions where mean annual rainfall, in conjunction with other factors, is not sufficient to give rise to soils that are primarily hydromorphic in spite of the fact that they may show pressure faces or even slickenslides in the profile. Broadly, it appears that true vertisols, i.e. those that dry out to a marked extent during the dry season, occur in depressions mainly in regions where mean annual rainfall is less than about 24 inches (610 mm).

Analytical data

Owing to the strongly montmorillonitic nature of the clay fraction E/C values are very high and almost invariably exceed 60. Base saturation is also high being over 80 per cent in all vertisols so far examined. In fact most are fully base saturated and may even contain free carbonates of calcium and magnesium, particularly in the hot dry parts of the country. The bases in vertisols formed on basic rocks such as basalt, epidiorite, and dolerite show a marked preponderance of calcium relative to magnesium, but in those formed from ultrabasic rocks the reverse calcium/magnesium status obtains. These differences which are accounted for by differences in the base-releasing weatherable primary minerals, are shown in Table II below.

TABLE II

Salient analytical data pertaining to vertisol subsoils

Profile	Depth inches	Clay %	CEC m e %	E/C value	Base saturation %	Ca/Mg ratio	Parent material
4	12-18	77	65.1	85	100	1/0.56	Basalt
	23-30	78	67.8	87	100	1/0.59	
	34-40	80	72.2	100	100	1/0.56	
5	8-17	55	50.5	92	100	1/0.11	Dolerite, some colluvial influence of limestone
	21-29	58	52.4	90	100	1/0.12	
6	7-13	67	73.7	110	100	1/5.27	Ultrabasic rocks of the Great Dyke
	22-28	68	74.7	107	100	1/5.15	

Vertisols of hot areas under low rainfall

The major occurrence of vertisols in Rhodesia is associated with a large tract of Jurassic basalt that occurs in the south of the country where mean annual rainfall is of the order of 12-18 inches (300-455 mm). Under the prevailing hot, semi-arid conditions the vertisols characteristically have a well-developed, loose, granular surface horizon and all are fully base saturated; some are even slightly to moderately calcareous. In the opinion of the writer, the development of the granular surface is a result of extreme desiccation of the upper part of the profile resulting from high soil temperatures that occur in the period from September to the end of November, in conjunction with the completely base saturated nature of these clays. General aridity of soil climate and the known rarity of water-logging under natural conditions may also be important contributory factors. In support of these latter observations it has been noted that while many of these dark vertisols are truly black (N2/0, as in Profile 4, Appendix A) others, probably the majority, have "warmer" colours such as 10YR3/2, 5YR3/1, and a few are even reddish brown (Profile 5, Appendix A). Although the black soils tend to be confined to flatter areas and depressions this is by no means invariably the case.

The granular surface horizon and indeed the upper sub-surface horizon that has not in the immediate past been subjected to the strong compressional forces that take place in the lower subsoil take up water readily, and swell in the process. It has been observed on the Chisumbanje Experiment Station that application of water usually raises the level of the ground surface by a few inches, the amount of rise depending on the degree to which plots have been allowed to dry out prior to irrigation. A large proportion of the granules are completely water-stable and the fact that excellent yields have been obtained with a wide variety of crops for more than 10 years on this station is due primarily to the good physical conditions that characterise these particular vertisols. Van der Merwe (16) suggests that as a result of anaerobic conditions brought about by permanently moist conditions under irrigation, the structure of what are apparently very similar soils in South Africa, appears to deteriorate. To date there has been no conclusive evidence of this at Chisumbanje but if the proposed reasons for the development of the granular surface are valid, some deterioration may eventually take place, particularly if the fully base saturated status of the soils is lowered. One might reasonably expect the deterioration to take place initially in the upper sub-surface horizons since they would never dry out to the same extent as the surface horizon.

Vertisols in other areas

Elsewhere in Rhodesia, vertisols are much less extensive. Since most of them occur in areas of appreciably higher rainfall they tend to be more regularly saturated during the rainy season. In spite of the fact that many of them dry out very considerably in long dry periods between rainy seasons, the degree of surface granulation is never as marked as in those of the hot semi-arid area in the south of the country. In fact as a broad generalisation it appears that surface granulation ceases to exist in vertisols formed in areas where mean annual rainfall approaches about 30 inches (760 mm). Granular structure gives way to a hard, dense, far less permeable, angular blocky ped formation and initial penetration of rainwater to subsoil horizons appears to take place mainly by flow down large vertical cracks as suggested by Theron and van Niekerk (12). Although such vertisols are not calcareous in the upper horizons, base saturation remains high and the clay fraction is still predominantly montmorillonitic.

The lower subsoils of some vertisols, notably those derived from Madumabisa shales (Profile 7, Appendix A), have significant amounts of water soluble salts and sometimes an appreciable exchangeable sodium status.

The vertisols and indeed other soils formed on ultrabasic rocks, notably those of the Great Dyke, have certain peculiarities. Apart from their high content of magnesium-releasing minerals, the ultrabasic rocks frequently contain appreciable amounts of chromium and/or nickel. These features are reflected by markedly inverse calcium/magnesium ratios (see Table II, Profile 6) and, more often than not, by sufficient quantities of available nickel and/or chronium to render them toxic not only to crops but also to many species of vegetation indigenous to the area.

Red fersiallitic clays often occur in association with vertisols on the Great Dyke, and since on most parts of it, rainfall is relatively high, one would expect red clays to be the normal soils. The reasons for the formation of vertisols are not always apparent, since they are frequently found on higher ground than the red clays and often the physical nature of underlying rock formation does not appear to retard internal drainage any more under the vertisols than it does under the red clays. Grim (7), however, has stated that the presence of an appreciable amount of magnesium in basic or ultrabasic rocks favours the formation of montmorillonite. Although most of the vertisols of the Great Dyke have a more markedly inverse calcium/magnesium ratio than the red clays, this is not invariably so.

Correlation with vertisols as defined in the 7th Approximation

The vertisols as defined in the 7th Approximation (where the name was first suggested) comprise two sub-orders, namely the Aquerts and the Usterts. The broad basis of differentiation lies in the degree of seasonal wetness to which the soil is subject. In the drier areas of Rhodesia the vertisols happen to be characterised by markedly granular surface horizons but, according to definition in the 7th Approximation, this feature alone is not adequate for distinguishing between the Usterts and the Aquerts. In fact, purely on the basis of profile morphology most of the very dark vertisols belong to the Grumaquerts according to the key but since they do not regularly attain the specified degree of wetness they should belong, more logically to the Grumusterts. Conversely, many of the vertisols that are subject to periodic complete saturation in Rhodesia are not always mottled and may not contain concretions of iron and manganese at any depth, as laid down in the 7th Approximation.

Siallitic soils

Analytical data

The majority of siallitic soils in Rhodesia occur mainly in the drier parts of the Sabi-Limpopo and Zambesi basins. Since the soils are not subject to intense leaching and weathering base saturation is high (almost invariably greater than 80 per cent) and clay fractions consist mainly of 2 : 1 lattice minerals that, characteristically, give rise to high E/C values as shown in Table III below.

TABLE III

Salient analytical data pertaining to siallitic subsoils

Profile	Depth inches	Clay %	CEC m e %	E/C value	Base saturation %	Parent material
8	10-16 22-28	13 20	12.5 13.0	96 65	100 100	Calcareous material
9	6-12 14-20	63 59	35.5 34.3	56 59	88 97	Epidiorite
10	14-20 36-42	44 33	24.3 22.0	55 67	98 100	Fairly basic gneiss
11	8-14 16-22	17 22	14.9 14.9	88 68	100 100	Intermediate to fairly basic gneiss
12	12-18	8	4.7	58	87	Siliceous gneiss
13	20-26	31	12.5	40	88	Granitic alluvium
14	10-16 19-27 37-42	44 40 42	22.2 18.6 17.7	50 47 42	100 100 100	Granitic alluvium
15	13-19 30-36 60-66	33 39 20	17.1 16.3 14.8	52 42 74	93 100 100	Colluvium off Umkondo formations
16	19-25 35-41 54-61	38 32 28	25.0 21.6 20.7	66 68 74	86 100 100	Colluvium off Umkondo formations

The soils of the Sabi-Limpopo basin

In the Sabi-Limpopo basin most of the soils are derived from gneisses of various ages and origin, formerly referred to as ortho and paragneisses in some of the earlier local geological bulletins. Most of the soils are shallow to moderately shallow and soil texture depends primarily on the amounts of clay-producing minerals in the parent material. Being relatively little-weathered, reserves of weatherable minerals in the soil are appreciable. In separated sand fractions they are easily recognisable not only by means of a hand lens but also by ordinary visual inspection in most instances. The more basic gneisses give rise to brown or reddish brown sandy loams which overlie redder sandy-clay loams (Profile 11, Appendix A), while, at the other end of the range, the highly siliceous gneisses give rise to pale sandy soils (Profile 12, Appendix A). The latter frequently occur in association with sodic soils described later in this Chapter.

In practically all but the very sandy soils, clay content increases quite markedly in the subsoils to give rise to textural horizons that, in the 7th Approximation (11) conform to the requirements laid down for argillic horizons. Where the soil is sufficiently deep, lower horizons frequently contain free carbonates of calcium and magnesium. These carbonates, which usually appear as pseudomycelia, appear to be at least partially illuvial in origin. They are sometimes also found in the underlying weathered rock in the case of shallower soils (Profile 11, Appendix A). Siallitic soils that are calcareous throughout the solum (Profile 8, Appendix A) occur to only a very limited extent, usually on lower slopes in areas where the country rock is rich in calcium-releasing minerals.

Apart from soils formed on alluviums and colluviums such as those in the lower Sabi Valley (alluviums - Profiles 13 and 14; colluviums - Profiles 15 and 16, Appendix A), the generally shallow nature of siallitic soils is not entirely attributable to low intensity of weathering. Although mean annual rainfall is low there are periods when the intensity of rainfall greatly exceeds the rate at which the soil can absorb water and much run-off occurs. A considerable removal of surface material thus results, particularly on ground that has any appreciable slope. The deeper soils, therefore, are found mainly on broad, relatively level interfluvial crests away from major rivers and watercourses where insequent drainage has given rise to uneven, sloping ground.

In regard to major irrigation projects now being developed in the south-eastern lowveld, practically all of the soils suitable for irrigation are found on these interfluvial crests where relatively basic gneisses have given rise to comparatively deep, brown sandy loams over reddish brown sandy clay loams.

The soils of other areas

In the Zambesi catchment siallitic soils are formed for the greater part on parent materials of the Triassic and Permian formations. On equivalent slopes the soils tend to be deeper than those formed on gneisses in the southern part of the country, probably on account of higher rainfall and the less consolidated nature of most of these formations. Reserves of weatherable minerals are much less evident in the soils and a relatively high proportion of them are sodium-releasing. Siallitic soils in this region, therefore, are more frequently associated with sodic soils than is the case elsewhere.

Siallitic soils are also formed on basic rocks not only in all dry hot regions but also in areas where mean annual rainfall ranges up to about 25 inches (635 mm) per annum. They therefore extend onto the central plateau in the western part of the country (Profile 29, Appendix A). These latter soils are brown to reddish brown clays, often with a granular micro-structure and their occurrence under relatively high rainfall is probably accounted for by their high clay content, which would tend to prevent appreciable leaching, and the abundance of weatherable minerals in basic parent materials. Although the clay fraction is predominantly of the 2 : 1 lattice type, it usually consists of illite or illite-montmorillonoid mixed layer minerals. Some kaolinite is almost invariably present, particularly in the redder soils. The clay fraction of the red siallitic clays thus differs quite considerably from the strongly montmorillonitic clay fraction of the vertisols. To the south of Bulawayo there is an appreciable area where reddish brown siallitic clays occur in association with vertisols on the same parent material. While the latter are always found in lower-lying areas, they also occur adjacent to red clays on the uplands. In such instances, the reasons for this are thought to be associated with differences in the physical nature of the underlying rock formation and its effect on internal drainage, but this is difficult to assess in the field.

Correlation with other classifications

The majority of siallitic soils in Rhodesia correspond to the Reddish Brown Semi-arid Soils of the Portuguese classification (2). Some, however, belong to those of the Grey Brown Semi-arid Soils described as having a strongly siallitic clay fraction.

Classification in terms of the 7th Approximation is much more difficult. While many cannot be satisfactorily classified on the basis of the information recorded, it appears that the siallitic soils of Rhodesia would belong to at least three different orders and would therefore, according to the 7th Approximation, comprise a very heterogeneous group. To cite a few examples, Profiles 9, 15, and 16 (Appendix A) appear to meet the requirements laid down for Rhodustalfs except that base saturation in the argillic horizon is very high and increases with depth. Profile 13, however, which lies only a few miles from Profiles 15 and 16 in very similar topography does not appear to belong to this Great Group in spite of a similar arrangement of horizons. Except for very high phosphate status, even as determined by an anion exchange resin method (9), the epipedon of Profile 13 would appear to be mollic and the soil should then belong to the Argustols. According to the 7th Approximation, however, only anthropic epipedons may have a phosphate content in excess of 250 ppm P_2O_5 but in the lower Sabi Valley the very high phosphate status of most virgin soils formed on granitic alluvium originates, almost certainly, from known phosphate deposits (apatite) that occur a little higher up in the catchment area. Many of the profiles of mature soils developed on alluviums and colluviums in this area have epipedons that are essentially mollic in character but which do not conform to all of the criteria laid down, notably on account of limitations in depth, excessive phosphate status, or colour.

Some of the siallitic soils formed on gneisses in Rhodesia have ochric epipedons and, from the general descriptions given in the 7th Approximation, they appear to belong to the Haplargids.

Fersiallitic soils

Analytical data

In general the fersiallitic soils have been subjected to an increased degree of weathering compared with soils so far described. Although base saturation may often be high and reserves of weatherable minerals appreciable in a few instances, they are generally lower than in less weathered soils. The higher intensity of weathering is, however, reflected by the predominance of kaolinite in the clay fraction and concomitantly lower E/C values which generally range from about 15-40. In Table IV the main analytical characteristics of fersiallitic soils derived from various parent materials are summarized.

TABLE IV

Salient analytical data pertaining to fersiallitic subsoils

Profile	Depth inches	Clay %	CEC m e %	E/C value	Base saturation %	Parent material
17	9-15	70	17.1	24	75	Epidiorite
	17-24	68	17.1	25	83	
	27-34	64	15.2	24	80	
	38-45	63	15.0	24	83	
	48-56	62	19.1	31	87	
	59-65	51	22.9	45	100	
18	9-16	42	16.9	40	80	Ultrabasic
19	8-13	33	7.9	24	66	Arkose
	20-26	32	8.0	25	66	
20	9-14	28	6.1	22	84	Highly micaceous
	29-34	24	6.0	25	87	
21	15-20	27	4.1	15	78	Micaceous phyllite
22	17-23	36	6.2	17	60	Granitic
23	14-19	11	4.2	38	50	Granite
	20-25	13	4.1	32	61	
	35-46	14	3.8	27	68	

Occurrence

Fersiallitic soils are confined almost entirely to normal uplands with good external drainage. Their development is as much dependent on the nature of the parent material as on climate. In areas where rainfall is relatively low they are formed mainly on parent materials with low weatherable mineral content that give rise to very permeable sandy to medium textured soils (Profile 23, Appendix A). As rainfall increases towards the central plateau, fersiallitic soils tend to be confined to progressively more basic parent materials (Profile 17, Appendix A) or other materials that give rise to predominantly clayey soils. While this is the general trend other, often inter-related factors, complicate this broad generalisation. On the plateau the physical nature of the underlying rock formation may retard internal drainage and such rocks may also be resistant to weathering. Both circumstances can prevent leaching in relatively light-textured soils and so give rise to fersiallitic soils (Profile 19, Appendix A). Furthermore, sloping ground associated with encroaching cycles of erosion are also important since the rejuvenation of the landscape leads to the formation of soil in which the reserve of weatherable minerals and base status are higher than they would be in otherwise similar soil on a very much older but level land surface. (Profiles 20, 21, and 22, Appendix A)

The fersiallitic soils have been placed into four main families on the basis of soil texture and profile morphology which are determined very largely by the parent material from which they are derived. Broadly, these families comprise the red clays formed on basic rocks, the relatively silty soils formed on various consolidated parent materials of sedimentary and metamorphosed sedimentary origin, the highly micaceous soils formed on mica-rich materials, and the predominantly sandy soils formed mainly on siliceous rocks such as granite, certain gneisses, sandstones, etc.

The red clays

Virtually all of the red clays have a pronounced crumb or granular micro-structure and most exhibit a sub-angular macro-structure when dry. Subsoils frequently show blue-black, metallic looking, ferro-manganese stains and concretions. Included with this family are the red clays formed on ultrabasic rocks which, in common with vertisols formed on the same parent material, have a far higher exchangeable magnesium than calcium status and, sometimes, associated nickel and/or chromium toxicity. (Profile 18, Appendix A)

The family does not include most of the red clays formed on many narrow dolerite dykes intrusive into the main body of granite (see Map 2, Provisional Geological map) in areas where mean annual rainfall is of the order of 30-36 inches (760-915 mm). These latter soils are only weakly fersiallitic since reserves of weatherable minerals, base saturation, and E/C value are considerably lower than in normal fersiallitic red clays that occupy more extensive areas. They have therefore been placed in a separate family.

Although no conclusive reasons can be advanced for the weakly fersiallitic nature of the red clays on narrow dolerite dykes, the underlying formation is probably very permeable since the weathering rock generally shows a marked spheroidal pattern. This may indicate that the dykes were well-shattered and broken. In addition, the soils are surrounded by highly permeable para-ferrallitic soils (described later) with which they also form marginal intergrades,colloquially referred to as "contact" soils.

The relatively silty soils

The relatively silty soils, in contrast to the red granular clays, are characterised even under natural vegetation by poorly developed, unstable micro-structure. This is readily destroyed at the surface by the kinetic energy released by raindrops during storms of high intensity. In the dry state the surface horizon has varying degrees of denseness and compaction, which in pronounced form, severely reduces the rate at which the soil can accept water in spite of the fact that the subsoil may often be quite permeable. Most of these soils are shallow.

It is thought that part of the reason for the adverse physical condition of these soils lies in their mechanical composition since, under local climatic conditions, the denseness and compaction always appear to take place in soils that have a relatively high silt content. Most of them also have a fine or very fine-grained sand fraction.

In the field it has frequently been noted that many of the relatively silty soils, particularly those derived from metasediments that give rise to yellowish or pale soils, are mottled at varying depths below the topsoil in spite of the fact that they may occur in positions of good external drainage where it is known that the soils are not subject to any marked degree of seasonal wetness. This suggests that a higher proportion of iron compounds is more readily hydrated and reduced (and thus mobilised) than in the red clays. In order to test this theory some simple laboratory experiments were carried out some years ago in which red clays and silty soils were treated with reducing agents to observe comparative times taken to achieve decolorisation. It was noted that decolorisation occurred much more readily in the latter but the results were then not properly recorded. However, further experiments have since been made using samples selected from those for which profile descriptions and analytical data are given in Appendix A. The experiments were carried out as follows :-

The original or starting colour was redetermined on the sieved soil when 4 gm were suspended in 75 ml of water in a beaker at room temperature. (Colour obtained under these conditions, as one might expect, sometimes differs from that noted when the profile description was made). One gram of sodium hydrosulphite ($Na_2S_2O_4$) was then stirred in and colours were determined after 5 minutes, 10 minutes, 15 minutes and 60 minutes.

The results are shown in Table V below.

TABLE V

Rates of decolorisation

Profile	27	29	17	19
Depth (inches)	18-24	18-24	17-24	8-13
Group	Ortho-ferrallitic	Ortho-ferrallitic	Fersiallitic	Fersiallitic
Parent material	Dolerite	Shale	Epidiorite	Arkose
Starting colour	10R4/6	5YR5/8	2.5YR4/6	10YR5/6
After 5 minutes	5YR3/4	7.5YR5/6	5YR3/4	2.5Y6/4
After 10 minutes	"	7.5YR5/4	"	2.5Y7/4
After 15 minutes	"	10YR5/6	"	"
After 60 minutes	"	10YR5/4	5YR3/3	"

It will be seen that in addition to the relative stability of redness and value in the soils derived from basic igneous rock compared with those of the soils derived from sediments, the colour of the ortho-ferrallitic silty soil is relatively less easily reduced than that of the fersiallitic one. Complete reduction of hue to a light of neutral grey was obtained on all soils by employing 4 gm of sodium hydrosulphite and boiling.

It is thought that since the major part of the iron in fersiallitic soils derived from most sediments appears to be relatively easily mobilised, the manner in which it is compounded or associated with the clay fraction may be weaker than in the case of soils derived from basic rock. This, in turn, may contribute to poor structural stability. Low total amount of iron present may also be an important factor.

<u>The highly micaceous soils</u>

The majority of these soils occur in the north in the Karoi-Miami area. Those in the Karoi area are derived from phyllites (Profile 21, Appendix A) and those in the Miami area from micaceous gneisses (Profile 20, Appendix A). Partly on account of resistance to weathering, particularly of the phyllites, and partly due to the undulating topography of the landscape in which they occur, most of the highly micaceous soils tend to be shallow.

<u>The predominantly sandy soils</u>

Most of the sandy fersiallitic soils occur in the fairly dissected country that lies between the central plateau and the lower-lying parts of the Sabi-Limpopo basin. Almost all are derived from granite which, under relatively low rainfall, gives rise to permeable, coarse-grained, very sandy soils. The formation of fersiallitic soils under relatively low rainfall is probably accounted for by the very pervious nature of such soils and the relative ease with which leaching can therefore occur.

Similar fersiallitic soils also occur in an equivalent position to the north of the central plateau towards the Zambesi basin.

Correlation with other classifications

The fersiallitic soils of Rhodesia correspond closely to soils described as such by Portuguese authors (2). They also correspond, in broad concept, to the Sols Ferrugineux Tropicaux of the French classification (1).

In terms of the 7th Approximation it appears that many should belong to the Ultustalfs but they cannot, on the basis of the criteria laid down, be placed in this Great Group with absolute certainty for the following reasons :-

(1) Not all fersiallitic soils have argillic horizons and even in soils in which the increase in clay content in the subsoils meets that stipulated for argillic horizons, it is quite likely that in some cases at least, the increase is due to differential formation of clay in place and not to illuviation.

(2) In the description of this Great Group weatherable minerals are stated to be scarce. Although this term is not precise, the weatherable mineral status of the soils represented by Profiles 20, 21 and 23 (Appendix A) definitely do not conform to such a description. On the other hand, if most fersiallitic soils on normal uplands are not placed in this Great Group there appears to be no other logical place for them in the 7th Approximation.

Para-ferrallitic soils

Analytical data

This group comprises two somewhat dissimilar sub-groups or families that have certain features that are normally associated with true ferrallitic soils but which have other anomalous characteristics that exclude them from the Ortho-ferrallitic group. All of the para-ferrallitic soils, however, are formed on parent materials that give rise to predominantly sandy soils and they occur mainly on those parts of the plateau where mean annual rainfall is higher than about 28 inches (710 mm). On the one hand, the soils derived from granite have clay fractions that are essentially ferrallitic but the soils contain appreciable reserves of weatherable minerals, and, on the other hand, the soils derived from certain of the Triassic formations have no weatherable minerals and extremely low silt/clay ratios but their clay fractions contain some 2 : 1 lattice minerals. Their main analytical characteristics are contrasted in Table VI below :-

TABLE VI

Salient analytical data pertaining to para-ferrallitic subsoils

Profile	Depth inches	Silt %	Clay %	CEC m e %	E/C value	Base saturation %
		Soils derived from granite				
24	20-26	4	19	2.3	12	26
	48-54	4	22	2.0	9	40
25	20-24	5	36	3.1	9	26
	40-44	5	40	3.7	7	30
		Soils derived from Triassic formations				
26	20-31	1	4	1.2	30	50
	34-41	1	13	3.0	23	57
	46-56	1	20	4.7	23	60
	60-66	1	17	3.7	22	70

The soils derived from granite

The para-ferrallitic soils formed on granite range from highly porous coarse-grained sands throughout the profile to similar sandy loams over yellowish red sandy clay loams. Their clay fractions consist practically entirely of kaolinite and amorphous sesquioxides of iron and aluminium and are thus essentially ferrallitic in character. However, the soils have appreciable reserves of weatherable minerals, some of which are often macroscopically visible and this anomalous feature distinguishes them from true or ortho-ferrallitic soils described later. Thompson (15) has suggested two main reasons for this anomaly.

(1) On the plateau where there is a pronounced dry season the essentially ferrallitic nature of the clay fraction may be explained by the fact that the granites are relatively low in clay producing minerals and bases and therefore typically give rise to acid coarse-grained sandy soils of low water-holding

capacity and high permeability. The low water-holding capacity promotes leaching, especially under a regime of predominantly convective precipitation, as compared with heavier textured soils.

(2) In contrast to the ortho-ferrallitic soils described below, the predominantly sandy para-ferrallitic soils dry out quickly at the end of the rainy season. As a result the time during which weatherable minerals, particularly the coarser-grained felspars, are subjected to the weathering process is much more limited. These factors could account for soils with the apparently incongruous characteristics of having ferrallitic clay fractions associated with appreciable reserves of weatherable minerals.

In the Marandellas area soils derived from granite, though still essentially para-ferrallitic, tend to intergrade towards the ortho-ferrallitic group (Profile 25, Appendix A). It is perhaps significant that in this area rainfall is slightly higher than on most other parts of the plateau and soil textures are somewhat heavier than elsewhere. Soils may consequently be expected to remain moist for a longer period than in most granite areas on the plateau. To the east of Rusape, furthermore, as the region is approached in which ortho-ferrallitic soils predominate, soils similar to those at Marandellas occur.

Although predominantly sandy, the soils derived from granite are somewhat variable with respect to the relative proportions of sand, silt, and clay, even within a particular area where the composition of the granite is apparently uniform with respect to clay producing weatherable minerals. The reddest and heaviest-textured soils tend to be formed in the highest-lying catenal positions adjacent to hills and outcrops while the paler sandier soils tend to occupy lower catenal positions. Thompson (13) gives the following explanation :-

Granite is a coarsely crystalline rock made up of free quartz, felspars, mica, ferro-magnesian minerals and other minor accessory minerals such as apatite, zircon and epidote. In the breakdown and weathering of the original rock the component parts do not all weather at the same rate. Some such as quartz cannot be chemically weathered at all and individual grains can only be reduced in size by mechanical means. The specific gravities of the components enumerated above are arranged roughly in ascending order. Under the sorting influence of various transporting agencies such as water, parent materials can be laid down which differ considerably in composition from that of the original parent rock. Under such conditions one might expect, at the base of hills or on the higher crests, that there would tend to be a local concentration of the heavier felspathic and ferro-magnesian minerals which would give rise to the heaviest textured soils, while at the lower end of the catena the parent material would tend to be more siliceous.

These catenal variations have also been observed in fersiallitic soils derived from granite but they are more frequently apparent in the case of the para-ferrallitic soils.

The soils derived from Triassic formations

The para-ferrallitic soils formed on weakly consolidated Triassic sandstones are also highly pervious but they differ from those formed on the granites in that they are all very sandy at the surface, and in most weatherable minerals cannot be detected even by microscopic examination of the fine sand fraction. They are, in fact, only distinguished from the regosols, with which they are associated, by the presence of one or more horizons above 72 inches in which the silt plus clay content is greater than 15 per cent (Profile 26, Appendix A). Their lack of weatherable minerals, and their extremely low silt/clay ratios impart some ferrallitic properties to these soils but their clay fractions have sufficient 2 : 1 lattice clay minerals to exclude them from the true ferrallitic soils. The reasons for the presence of 2 : 1 lattice minerals in pervious soils that lack weatherable minerals, are not understood.

Correlation with other classifications

The para-ferrallitic soils formed on granite correspond very closely to the Quartz-Feldspathic Chromosols of Humid Regions described in the Portuguese classification for the soils of Angola (2), while the para-ferrallitic soils formed on the weakly consolidated Triassic sandstones resemble certain of the Chromopsammic and Similar Soils in which clay content is stated as "sometimes reaching 15-20% in low levels of the profile."

In the 7th Approximation there appears to be no logical place for most para-ferrallitic soils. Those derived from granite are excluded from the Oxisols since the definition given for oxic horizons does not permit the presence of appreciable weatherable minerals. Those derived from Triassic formations are likewise excluded from this Order since some 2 : 1 lattice clay minerals are present.

Some of the granite-derived, very sandy soils in which there is no appreciable increase in clay content may have cambic horizons and may, therefore, belong to the Ochrepts. It is felt, however, that the para-ferrallitic soils should more logically be accommodated in the sub-order Ustox, or possibly even Idox. In either case, this would necessitate recognition and definition of an additional diagnostic horizon that is similar to the Oxic horizon but which allows for the presence of an appreciable reserve of weatherable minerals.

Ortho-ferrallitic soils

Occurrence

The Ortho-ferrallitic soils are formed on areas of high or relatively high altitude where mean annual rainfall is greater than roughly 40 inches (1015 mm). In such areas there is generally sufficient orographic precipitation in winter to prevent any marked drying out of the subsoils in most years. Lower mean annual and lower mean maximum temperatures are also important factors that tend to prevent drying out of the soils. Under such conditions virtually all reserves of weatherable minerals are destroyed and highly porous, strongly leached soils are formed. Their clay fractions consist of kaolinite and sesquioxides of iron and aluminium and, in most soils, some of the sesquioxides of aluminium become hydrated to give rise to often appreciable amounts of gibbsite. Occasionally small amounts of goethite are also present but this is a much more prominent constituent, together with gibbsite, in the weathering crust-like zones that coat certain rocks, particularly dolerite. In the case of dolerite these weathering zones are often very thick.

Ortho-ferrallitic soils have been found in three areas in Rhodesia. These are the Eastern Districts area which is by far the largest, the Bikita area which is much smaller, and finally a very small area in the north, near Umvukwes. In the first two, fairly regular orographic winter precipitation occurs, but in the third this is not a feature of the climate and the soils are probably maintained in a moist condition for a large part of the year mainly as a result of relatively cool temperatures.

Analytical data

Owing to the highly weathered and leached nature of all ortho-ferrallitic soils base saturation is generally lower than 30 per cent with E/C values of less than 15 in subsoil horizons not appreciably influenced by organic matter. As shown in Table VII this applies irrespective of the parent material from which the soil is derived.

TABLE VII

Salient analytical data pertaining to ortho-ferrallitic subsoils

Profile	Depth inches	Clay %	CEC m e %	E/C value	Base saturation %	Parent material
27	18-24	68	10.3	15	20	Dolerite
	48-52	68	9.7	14	20	
28	17-22	22	3.5	16	14	Umkondo sandstone
	29-35	21	2.8	13	29	
29	18-24	57	6.8	12	13	Umkondo shale
30	26-32	46	3.0	7	47	Granite
	49-55	49	3.1	6	45	
31	70-76	44	5.6	13	2	Granite

The Eastern Districts

Although the influence of parent material is still clearly evident in the morphology of the profile and the texture of the soil, the boundaries between soils formed on different parent materials in the Eastern Districts in general are much more diffuse than in other areas of Rhodesia. In some parts there are extensive areas where the soils have a range of characteristics that are intermediate between those associated with particular parent materials.

In the Eastern Districts the main parent materials are dolerite, granite, and shales and sandstones of the Umkondo system. The soils formed on dolerite are invariably red clays (Profile 27, Appendix A) which contain appreciable amounts of gibbsite. In the Inyangani area, where rainfall is very high (up to 160 inches or 4065 mm per annum in places) laterite that has been formed by the process described as "relative accumulation" by D'Hoore (5) occurs extensively. In parts it appears as irregular shell-like brown coatings around weathering zones surrounding dolerite stones that have been exposed, as well as in large nodular masses which are frequently soft inside.

The soils formed on Umkondo shales are moderately shallow to moderately deep, relatively silty clays with yellowish red subsoils (Profile 29, Appendix A). Although gibbsite is always present in the clay fraction, the amounts are much smaller than in the red clays formed from dolerite. In contrast to relatively silty fersiallitic soils with similar proportions of sand, silt, and clay, they have a permeable crumbly structure in the surface horizons under natural conditions, which cultivation tends to destroy to some extent. This sometimes results in some degree of compaction and surface capping.

All of the granites in the Eastern Districts are intruded with numerous very small dolerite dykes and stringers in addition to the larger mappable intrusions, with the result that almost all soils that are derived primarily from granite, show some influence of dolerite. The majority of soils are coarse-grained sandy clay loams over red sandy clays or clays in which a coarse-grained sand fraction is always evident. Again, gibbsite is always present in the clay fraction, usually in appreciable quantities. In isolated localities subsoil colours are yellowish brown or reddish yellow. The yellowish brown subsoil colour sometimes occurs where locally the topography is flat or relatively flat, and the latter colour in areas where there is no influence of dolerite. In some profiles, soft white particles that have a felspathic appearance may be observed, but in all cases so far examined these have been found to consist of highly-weathered pseudomorphs.

The soils formed on Umkondo sandstones and quartzites consist of fine-grained loamy sands or sandy loams over red sandy loams and sandy clay loams (Profile 28, Appendix A). Their clay fractions do not usually contain gibbsite except in areas where rainfall is very high (roughly over 60 inches or 1520 mm per annum), and even then it is present only in small quantities. As in the case of the soils derived from granite, yellow subsoils occur to a very limited extent in relatively flat areas, usually of low relief.

Limited areas of humic ortho-ferrallitic soils occur in the Eastern Districts. They are confined almost entirely to eastern or south-eastern facing aspects, on relatively sandy soils, usually under dense forest in sheltered valleys. The reasons for the formation of humic soils in these valleys are not fully understood. While the sheltering effect of forest may tend to bring about a cooler, and possibly a moister, soil climatic regime throughout the year, no logical explanation can be advanced for preferential formation on relatively sandy soils.

The Bikita and Umvukwes areas

In the Bikita area the ortho-ferrallitic soils are derived mainly from granite (Profile 30, Appendix A) and, to a much lesser extent, from dolerite. Unlike the Eastern Districts, the granite in the Bikita area is not often intruded by dolerite dykes or stringers, and the majority of subsoil hues are 5YR or yellower. These same observations apply also to the very small area of ortho-ferrallitic soils formed on granite in the Umvukwes area.

Correlation with other classifications

The ortho-ferrallitic soils of Rhodesia belong to the Typical Ferrallitic soils of the Portuguese classification outlined by Botelho da Costa (3) and, of course, to soils of the same name described by Aubert and Duchaufor (1).

Although the suborders of the Oxisols are somewhat tentatively differentiated in the 7th Approximation, most ortho-ferrallitic soils appear to belong to the Udox.

Halomorphic soils

Halomorphic soils comprise sodic soils and non-sodic soils. Apart from a small known area where saline but nevertheless strongly acid soils occur on alluvium in the lower Sabi Valley, all Halomorphic soils in Rhodesia belong to the Sodic group. This acid saline area was only briefly examined in July, 1948 and subsequent analysis showed that the predominant salt was calcium chloride. Although no actual spring could be found, subterranean seepage water charged with this salt was assumed to be responsible for the salinity since the lower subsoils were found to be very moist to wet. The surface horizons were, by comparison, relatively dry in spite of a higher content of this hygroscopic salt. While this is the only known occurrence of non-sodic saline soils in Rhodesia, there may be others and provision for them has accordingly been made in the classification.

Occurrence and main genetic factors that give rise to sodic soils

Sodic soils occur in almost all areas where mean annual rainfall is less than about 40 inches (1015 mm) mainly in small isolated pockets, particularly where rainfall is relatively high. In fact, they have not been found only in areas where ortho-ferrallitic soils occur and in most of the larger tracts of Kalahari deposits that are deep or thick in the geological sense. These tracts occur only towards the west of Rhodesia. On the other hand, the most frequent occurrence of sodic soils does not coincide with areas in which rainfall is lowest since rather special factors favour their formation. These factors include parent material that is relatively rich in sodium-releasing weatherable minerals in conjunction with conditions that prevent leaching. Such conditions may be low rainfall *per se*, low-lying catenal position, or very flat topography underlain by impervious rock strata.

Thus, in the low rainfall areas of the southern lowveld sodic soils, with certain localised exceptions, occupy only a very insignificant total area since most parent materials are not particularly rich in sodium-releasing minerals. In the Zambesi catchment, however, sodic soils occur more extensively than anywhere else in Rhodesia in spite of the fact that mean annual rainfall is higher than in the south of the country but they are derived mainly from certain of the Triassic and Permian formations that on weathering release large amounts of sodium. On such formations, particularly the Triassic, sodic soils often occupy extensive areas and are found even on steep upper slopes in undulating terrain. The surface horizons are generally sandy and the transition between this and the dense impermeable horizons below is abrupt.

Sodic soils also occur frequently, but in small areas, on the plateau even where rainfall is relatively high. Practically all are derived either entirely from granite (Profile 34, Appendix A) or else underlying granite rock strata play an important part in their genesis (Profiles 32, 33 and 35, Appendix A). Since albitic plagioclases are often the main weatherable constitutents, an appreciable amount of sodium is released. In the case of granite of the "castle kopje" type described by Thompson (13), the underlying rock is well-jointed and facilitates removal of soluble products, but in the case of the "dwala" or "whale-back" type, the granite occurs in extensive, unjointed, impermeable masses. Sodic soils, usually in association with hydromorphic soils, are therefore most commonly found on the latter type, particularly where topography is relatively flat over extensive areas.

This combination of genetic and geomorphological factors is an interesting one for it permits the formation of sodic soils under a climatic condition that is considerably more humid than is normally associated with such soils. Apart from the frequent occurrence of sodic soil on such formations, strong corroborative, if not conclusive, evidence for the genesis outlined has been provided by a now abandoned granite quarry in the high water table country to the west of Salisbury. The quarry, covering about 1½ acres, was excavated to a depth of about 70 to 80 feet, and the solid unjointed nature of the granite was clearly evident. Before it had to be abandoned owing to flooding, largely by lateral seepage from above following successive years of abnormally heavy rainfall, an extensive area of finely-crushed granite about two feet thick had been laid down to provide access during the wet season. For some years, a short time after the rainy season, a white, sometimes thick, efflorescence consisting practically entirely of sodium bicarbonate with some carbonate appeared on the surface. This was obviously brought about by rapid weathering of sodium-releasing minerals in the finely crushed granite as a result of the greatly increased surface area, accompanied by capillary water movement and surface deposition on evaporation.

Genesis of the profile morphology

It has consistently been observed, especially in the higher rainfall areas, that sodic soils derived from parent materials that give rise to predominantly sandy soil, show permeable sandy surface horizons (unless truncated) that overlie very abruptly commencing, hard, dense, impermeable subsoil horizons of markedly higher clay content. The change between surface and subsoil is in fact so abrupt as to form a sharp-line. The depth at which the dense horizon commences tends to be greater in the case of soils that are only weakly sodic than in those that are strongly sodic. In the former, exchangeable sodium percentage is less than 25 per cent and in many instances may even be less than 15 per cent, the level commonly accepted as being necessary to produce deflocculation of the clay colloids. However, on the central plateau some of the dense horizons in which the clay fraction is obviously deflocculated to some extent, have exchangeable sodium percentages which are appreciably lower than this. The pH value of the dense horizon, moreover, is not necessarily high, particularly if the clay complex is not fully saturated. This is illustrated by Profile 32 in Table VIII in which analytical data pertaining to all sodic soils is given.

TABLE VIII

Salient analytical data pertaining to sodic soils

Profile	Depth inches	Clay %	pH	Conductv. micromhos	CEC m e %	Base saturation %	ESP %	Parent material
		Weakly sodic soil						
32	0-7	10	5.1	very	6.4	64	-	Granite, with
	15-21	6	5.8	low,	2.8	64	-	some influence
	22-27	22	5.2	not	8.6	98	7	of metasediments
	45-50	41	5.1	recorded	11.9	88	5	
		Strongly sodic soils						
33	0-7	3	5.8	0.14	1.7	53	-	Triassic sands
	12-18	1	7.2	0.20	0.5	80	-	with some
	20-25	10	7.8	0.42	3.4	100	59	influence of
	46-52	12	7.7	0.37	3.5	97	17	granite.
34	0-2	5	6.4	0.58	4.1	78	11	Granite
	5-7	23	8.0	1.13	11.7	100	53	
	9-14	21	8.7	1.53	8.8	100	70	
35	0-1	9	6.1	0.70	5.5	67	-	Granite with
	2-7	38	8.5	1.06	24.0	100	41	some influence
	14-20	54	8.7	1.00	30.9	100	51	of metasediments
	29-35	51	8.9	0.82	27.8	100	52	
		Saline sodic soil.						
36	0-4	16	10.1	15+	20.4	100	100	Mainly granitic
	7-13	22	10.3	15+	9.6	100	100	alluvium
	18-24	33	10.0	approx 12	14.0	100	89	

It is interesting to note that soils that also have low exchangeable sodium percentages and a morphology that is normally associated with solodized-solonetz have been reported in South Dakota by White (18). It has been suggested by some investigators that high exchangeable magnesium status may contribute to the effects normally associated with sodium-affected clays, but in Rhodesia no evidence for this contention has yet been found. If the presence of magnesium in addition to some sodium were an important factor locally one might expect many of the magnesium rich soils in low catenal positions on the Great Dyke to exhibit a solodized-solonetzic or solidic morphology but, as yet, no such soils have been found. In o~~t~~ther areas, however, it has been noted that sodic soils of relatively high clay content throughout the solum rarely, if ever, show an abrupt change between the upper horizon and the sodium-affected areas, although the change may often be distinct. Most of these latter soils occur in areas where rainfall is low.

The correlation between sharp sodic horizon differentiation in the case of sandy soils and the much less marked or even diffuse equivalent change associated with soils of appreciable clay content lead the writer to surmise that lateral water movements across the upper boundary of sodic horizons must be responsible for sharp-line changes. Obviously, this could only take place where the surface horizons are freely permeable as in the case of predominantly sandy soils. Furthermore, it seemed most improbable that such abrupt transitions could be accounted for by vertical migration of clay from surface to underlying horizons.

Substantiation for this theory was obtained by visiting the sites of several sodic soils on the plateau (including the sites of Profiles 32 and 33) as soon as possible after appreciable rain had fallen in the latter part of the rainy season. New soil pits were excavated. In almost all cases where there was more than about 6 inches of permeable sandy surface soil, water charged with varying amounts of deflocculated clay was observed seeping into the freshly excavated pits along the upper surface of the sodic horizons. In most but not all instances where the surface horizon was shallower, the surplus water had already disappeared. Samples taken from the upper part of the sodic horizon were later placed in test tubes and very carefully covered with a 3 inch depth of distilled water. Within a period of about 16 hours (overnight) the supernatant water attained varying degrees of turbidity owing to diffusion of clay colloids and the degree of turbidity increased, markedly in some instances, with further passage of time.

It would appear highly likely, therefore, that clay in the seepage water originates at least in part from the upper surface of the sodic horizon and that in some respects this surface may be regarded as a subsoil erosion one. Provided that no trucation takes place one might expect that the surface of the sodic horizon will be lowered with the passage of time as clay, but not the coarser sandy fraction, is removed laterally down-slope. In the analytical data given in Table VIII it will be seen that where sodic soils have an appreciable depth of permeable surface soil (Profiles 32 and 33) there is a definite eluvial horizon immediately above the sodic one.

The sodic soils have been so named because their genesis appears to be different from that hitherto suggested for the solonetz and solodized-solonetz which, morphologically, they closely resemble. In any case it appears most unlikely that the Rhodesian soils evolved from solonchaks in view of the relatively humid conditions under which the majority occur.

Most of the sodic soils of Rhodesia are characterised by horizons that have varying degrees of saturation with sodium but low total salinity. Saline sodic soils (Profile 36) occur to only a very limited extent and are confined to pockets of accumulation, such as pans, in areas of low rainfall.

Hydromorphic soils

The soils of this order have not been investigated in the same detail as those of other Orders and the criteria that differentiate them at lower levels in the system of classification are therefore somewhat tentative. Broadly, however, two main groups have been distinguished on the basis of base saturation and clay content since these two features have a marked bearing on concomitant characteristics such as clay mineralogy and permeability within the solum. The parent materials that give rise to predominantly clayey soils also release relatively large amounts of calcium and magnesium, whereas those that give rise to predominantly sandy soils tend to be relatively low in base releasing minerals. The two groups have therefore been called calcic hydromorphic soils and non-calcic hydromorphic soils. The main analytical data are shown in Table IX.

TABLE IX

Salient analytical data pertaining to calcic and non-calcic hydromorphic soils

Profile	Depth inches	Clay %	Base saturation %	CEC m e %	E/C value	pH	Parent material and Group
37*	0-1 2-5 15-23 30-38	56 68 63 72	97 96 100 100	60.6 69.7 54.0 58.6	108 103 86 81	6.7 6.9 8.6 7.6	Epidiorite; calcic (vertisol)
38	0-6 12-18 24-30 40-46	33 51 48 50	71 90 86 76	31.4 29.6 21.9 20.7	95 58 46 41	5.6 6.5 6.9 6.7	Mainly metasediments; calcic
39	0-8 11½-15 19-26	36? 30? 44?	100 100 98	55.9 95.3 48.3	156 317 111	6.3 6.3 6.3	Colluvium off epidiorite; calcic (humic)
40*	0-3 19-24 40-44	5 12 12	65 22 20	2.3 2.3 3.0	46 19 25	5.6 4.7 5.1	Granite; non-calcic
41	0-3 4-8 10-16 20-26	6? 7? 7? 2	2 1 1 20	30.6 14.4 19.2 1.0	510 206 274 50	3.7 3.8 3.6 4.3	Triassic or Kalahari; non-calcic(humic)

* pH values done by the older, now obsolete, method (on the 1 : 5 soil/water suspension). Values thus obtained are about 0.7 to 1.0 units higher than those obtained on the saturated paste or in M/100 calcium chloride suspension.

Calcic hydromorphic soils

The calcic hydromorphic soils do not cover extensive areas but are confined to broad depressions or vleis that flank watercourses in those parts of the country where mean annual rainfall is higher than about 24 inches (610 mm). These vleis may also constitute the sources of more permanent streams.

Most of the calcic soils are lower catenal associates of fersiallitic soils formed on basic rocks or the more argillaceous matasediments and they are all dark grey or black clays which, particularly in the case of the sediments, may be mottled in the subsoil. Base saturation is always high and some proportion of the bases are thought to originate from higher lying ground. The depressions in which they occur are often referred to locally as "base-accumulating" vleis. Although no specific criteria for base saturation can be given it appears that a base saturation of 50 per cent would be realistic in separating calcic from non-calcic soils.

Presumably on account of high base status and poor drainage both internal and external, the clay fraction of calcic soil tends to be montmorillonitic. Many, if not most of the black clays derived from basic rocks show slickenslides (Profile 37, Appendix A), but such soils are regarded as being primarily hydromorphic and for secondary reasons vertisolic, as indicated in Chapter II.

Non-calcic hydromorphic soils

In addition to vleis, non-calcic hydromorphic soils also occupy extensive areas where topography on the plateau is relatively flat, and is underlain by the impermeable granite formation described earlier.

Non-calcic soils in the vleis are, in the main, lower catenal associates of para-ferrallitic soils derived from granite and Triassic sandstones and, to a lesser extent, of regosols of the Kalahari and Triassic formations. Since the soils are typically sandy they are permeable at least in the upper part of the solum and bases rarely accumulate presumably because they tend to be removed by lateral water movement.

Humic hydromorphic soils

For reasons not fully understood organic matter sometimes accumulates in very minor, widely separated areas in both calcic and non-calcic soils to give rise to humic hydromorphic soils. In soils so far examined the horizons rich in organic matter have very low pH values and are base-depleted in the case of the non-calcic soils (Profile 41) while in the calcic soils (Profile 39) equivalent pH values range from slightly acid to almost neutral on account of high base saturation.

Special Features of Some Rhodesian soils

Stone-lines

Stone lines or gravel horizons, which in the main comprise sub-angular to sub-rounded quartz stones, commonly occur in most Rhodesian soils with the exception of regosols. Their thickness, even within a particular locality, may range from a sometimes discontinuous single stone layer, to three feet or more. As noted by Ireland, Sharpe and Eargle (8), most of them appear between the solum and underlying weathering rock. This is particularly noticeable in undulating to broken country where road cuttings often clearly reveal their primary origin from quartz veins in the rock. Sharpe (10) attributes the position of these stone lines at the base of the soil, immediately above the rock, to soil creep and to relatively more rapid movement of the surface layers. This explanation seems to be entirely satisfactory in undulating or broken country. However, the occasional occurrence in Rhodesia of very irregular stone lines that are not underlain by weathering rock in very flat country on the plateau is very much more difficult to explain. In such areas the depth at which stone lines may be encountered even in an excavation covering an area of 6 x 3 feet, may vary from a few inches below the soil surface to several feet. As in most areas of Rhodesia soil boundaries still change sharply according to parent material from which they are derived and this would seem to rule out any large scale soil movements to explain the presence of such stone lines. Some authors, including de Heinzelin (4) who refers to stone lines as "nappes de gravat", have postulated biological activities, such as reworking of the soil by termites, as being at least partly responsible for formation of definite stone lines. Although numerous species of termite are widespread in Rhodesia it is difficult to visualise how reworking of the soil could give rise to such undulating stone lines. In the absence of more precise local knowledge the mode of their occurrence must remain largely a matter of conjecture.

<u>Laterite</u>

Three main types of laterite or lateritic horizons have been distinguished. Two of them are of current formation but the third is undoubtedly of older origin and in some instances may be associated with previous cycles of erosion. The laterites of present day formation comprise those formed by processes of absolute and relative accumulation as described by D'Hoore (5). In the case of the former, iron, manganese, and aluminium compounds in mobile form move either vertically or horizontally and are precipitated locally, whereas in the case of the latter, intense weathering preferentially removes bases together with the more siliceous products of weathering to give rise to a relative accumulation of such compounds.

In the geological sense relative accumulation may be regarded as true laterite since it is produced only under conditions of intense weathering and is therefore only found in association with ortho-ferrallitic soils in minor localities in Rhodesia. On the other hand, absolute accumulation is much more widespread and is more like ferricrete since, in the process of deposition and subsequent hardening many diverse materials are usually incorporated to give rise to lateritic conglomerate. Absolute accumulation occurs mainly on the plateau and is associated with fersiallitic and para-ferrallitic soils particularly in a low catenal position flanking hydromorphic soils of depressions or vleis. They are also found in the contact zone between soils derived from iron-rich parent material, such as banded iron-stone, and those formed from more siliceous materials.

The older laterite is also found mainly on the plateau. It usually occurs as a capping on hill tops either in an unjointed mass or as broken remnants. Less frequently, scattered boulders of this type of laterite are also found on interfluvial crests in gently undulating country. These older laterites are all extremely indurated and the great majority of them are strongly conglomeritic. The latter feature would suggest that they were originally formed by the process of absolute accumulation. This is of considerable interest since it indicates that, on the plateau at least, there have been no major climatic changes for a considerable period of time. In fact the writer is of the opinion that most soils in Rhodesia conform to those that might be expected under the present day climate and that there is little, if any convincing evidence to suggest any evolution of soils under climatic conditions materially different from the present. It should also be noted that there is a very considerable variation in rainfall in any particular area (see data for maximum and minimum rainfall, Appendix B). In a few minor localities there are soils that some pedologists may consider to show features that suggest evolution under a more humid condition than the present. In such instances, it seems to the writer that it would be equally valid to attribute any such features to the cumulative effect of high seasonal rainfalls, even although they occur at infrequent intervals, as it would be to invoke past pluvials.

B. ECOLOGY AND SOILS

In most so-called "natural" systems of classification the importance of vegetation as a soil-forming factor is recognised, mainly through its effects in regard to re-cycling of bases and contribution to organic matter status. Specific kinds or types of vegetation are, however, determined practically entirely by soil and climatic factors. This is very clearly evident in Rhodesia.

Vincent and Thomas (17) state :-

> "Southern Rhodesia is the meeting place for three major vegetation groups or floral regions. The northern and central portions are dominated by the most southerly extension of the great Central African Brachystegia woodland. In the southern lowveld this vegetation meets that of the Natal and Northern Transvaal lowveld, while in the west and south-west it merges with, and finally gives way to, the Kalahari vegetation. ....
> Irrespective of the region to which it belongs, the vegetation of Southern Rhodesia falls into one of four major vegetation formations governed by climatic factors, predominantly rainfall, but modified by temperature. These formations are Forest, Grassland, Woodland, and Bushland. ....
> Within each of the above vegetation formations many vegetation types occur which are the result of secondary factors, primarily the soil factor.

Each of these in turn has its variants due to relief, aspect, and hydrological and other modifying conditions."

Forest

In Rhodesia forest is confined to relatively small scattered areas and it comprises two main types, namely, evergreen montane forest and partly deciduous riverine forest. The former occurs mainly in sheltered frost-free valleys of southerly to easterly facing aspect in regions of high rainfall in the Eastern Districts and to the south of Bikita. They are thus always associated with ortho-ferrallitic soils. Typical constituents are *Cussonia umbellifera*, *Trichilia chirindensis*, *Khaya nyasica*, *Macaranga mellifera*, and *Parinari curatellaefolia*.

Riverine forests are confined to fringes flanking major rivers where two essential conditions obtain. These are alluvially deposited soils that permit lateral water movement from the river to support forest vegetation and the absence of regular frosts. The latter requirement is met mainly in hot regions at low altitude where, in general, rainfall is low. With few exceptions, therefore, riverine forests are associated with siallitic soils that are deep. *Trichilia emetica*, *Lonchocarpus capassa*, *Acacia tortilis*, *A. albida*, *Kigelia pinnata*, and *Pseudocadia zambesiaca* are among the most common large trees. In the Zambesi basin *Tamarindus indica* is also very common but this tree has not been observed in the Sabi-Limpopo basin.

Grassland

True grassland without trees occurs only to a very limited extent in Rhodesia, mostly as a tufted sward in the higher-lying more exposed parts of the Eastern Districts. Typical species include *Loudetia simplex*, *monocymbium ceresiiforme*, and *Eragrostis* and *Sporobolus spp*.

Grassland with scattered trees is, however, much more widespread especially on the plateau where it is almost invariably associated with high water tables and, therefore, with hydromorphic soils. As indicated earlier, the majority of hydromorphic soils are non-calcic ones and these *Hyparrhenia spp*. may often be dominant where the degree of wetness is not pronounced but in the wetter areas they give way to grasses such as L. simplex, M. ceresiiforme, and Andropogon eucomus. Sedges may also appear. Except in very wet areas where Syzygium guineense is sometimes locally dominant, Parinari curatellaefolia is always most prominent in the scattered tree vegetation.

On calcic hydromorphic soils Imperata cylindrica, Alloteropsis semialata and Setaria spp. are common among the grasses and, if present, trees consist practically entirely of Acacia spp.

Relatively small areas of grassland, usually with few trees, also occur on parts of the Great Dyke where the soils have sufficient amounts of available nickel and/or chromium to be toxic to most trees. The scattered trees that remain comprise mainly Diplorhynchus condylocarpon and Combretum sp.

Woodland and Bushland

These two vegetation forms are considered simultaneously since the main differences lie in the height of trees and their spacing. In woodland the trees are taller and tend to be more widely spaced than in bushland. The close spacing in bushland is accentuated by the prevalence of shrubs which locally may occur in sufficient numbers to give rise to dense thicket.

Woodland and bushland, together cover by far the greater part of Rhodesia, and within each the species vary according to soil and climatic changes. In general the density of grass cover associated with each varies in inverse proportion to the density of the tree cover.

Brachystegia spiciformis (msasa) - Julbernardia globiflora (mnondo) woodland is probably the most extensively occurring type of woodland in Rhodesia. In general it occurs under mean annual rainfall ranging from 40 inches (1010 mm) to about 28 inches (710 mm) in the case of heavy textured soils, and from 40 inches to about 24 inches (610 mm) on predominantly sandy soils. It is always associated with permeable soils and soils that have good external drainage such as those on hillsides. In areas of relatively high rainfall msasa tends to assume dominance over mnondo but towards the lower limits given above, the reverse situation obtains.

As rainfall diminishes the character of the woodland changes as species better adapted to drier conditions replace first msasa, and later mnondo.. This change takes place first on the heavy-textured soils probably because effectiveness of rainfall with respect to depth of penetration is less than in the case of predominantly sandy soils, although other more obscure factors including inherent fertility may also be important. Such species include *Piliostigma thonningii*, *Sclerocarya caffra* (marula), *Kirkia acuminata*, and various *Combretum spp.* and *Acacia spp.* Although some tall trees remain, most become shorter and numerous shrubs, such as *Flacourtia indica*, *Dichrostachys cinerea*, *Ziziphus mucronata*, and *Grewia spp.* appear until woodland gradually gives way to bushland. Within this transition *Colophospermum mopane* (mopani) appears, firstly on sodic soils where it generally occurs in small isolated groups, and then as scattered, tall trees which gradually become more numerous as more arid conditions are encountered. In the hotter areas at low altitude in the Sabi-Limpopo and Zambesi basins, mopani may be regarded as being broadly dominant since it is found not only in association with other trees but also as a woodland in pure stand over large tracts of country. The conditions governing its occurrence are discussed more fully below.

Specific soil-vegetation correlations

During the course of numerous soil investigations in all parts of Rhodesia it has repeatedly been observed that certain plants, notably trees or associations of these, can be correlated with particular kinds of soil. Most of the correlations that have been established concern trees for two main reasons. Firstly, trees can be recognised relatively easily from a distance and secondly their shape and distribution are often clearly recognisable from the air or on airphotographs. While many of the soil-vegetation correlations described below will apply specifically to Rhodesia or to certain parts of it, some at least, are known to have a wider application.

Acacia albida

This large tree has only been observed in hot areas at low altitude on siallitic alluvial soils. Wherever it becomes a prominent constituent of riverine vegetation, the soils are always very sandy either throughout the solum or below about 18 inches.

Acacia tortilis - Euphorbia ingens - Albizzia harveyii woodland

This vegetation association comprises an almost park-like woodland only on deep siallitic soils of alluvial or colluvial origin, again in hot areas at low altitude. The soils are always medium textured and relatively permeable and, almost invariably, are calcareous below about 4 feet. A. tortilis alone has no particular significance since it occurs on a wide variety of soils including sodic ones. In the drier parts of the country it is also the first tree to reappear on cultivated land that has been abandoned. Similarly, E. ingens may also occur on a wide variety of site conditions provided that they are physiologically dry ones. This may even include shallow soil underlain by solid rock on steep slopes in areas of relatively high rainfall.

Acacia xanthophloea (Fever tree)

This tree is locally dominant on low-lying sites subject to periodic flooding only in hot areas at altitudes of less than about 1,800 feet above sea level. The soils are almost invariably alkaline and sodic at some depth.

Afzelia quanzensis (Pod-mahogany)

This very large tree seldom occurs in any great concentration but it is always associated with very sandy soils. It occurs as a minor constituent, therefore, of masasa-mnondo woodland on regosols in the west of Rhodesia. It also occurs in association with other vegetation on relatively deep very sandy soils in the hotter parts of the Sabi-Limpopo and Zambesi basins. These latter soils are usually siallitic but occasionally are fersiallitic.

Baikiaea plurijuga (Rhodesian teak) and Burkea africana

These trees are found mainly on regosols. Both are constituents of msasa-mnondo woodland but while B. plurijuga is confined almost entirely to regosols in the west of Rhodesia, B. africana has a more widespread distribution.

Brachystegia boehmii

This tree is normally a minor constituent of msasa-mnondo woodland but, where locally it becomes numerous, relatively shallow soils of moderately impeded internal drainage are indicated. It also occurs as a woodland in almost pure form over large tracts on shallow soils in undulating country in the upper reaches of the Zambesi basin.

Colophospermum mopane

The mopani tree is unique because its significance in regard to soil depends primarily on the climate of the area in which it is found. The specific conditions under which mopani occurs were described by Ellis (6) in 1950 and by Thompson (14) in 1960, and they are summarized below:

Since mopani is essentially a zerophytic tree it occurs in hot areas where mean annual rainfall is less than about 18 inches (455 mm) on almost all soils, deep or shallow, sodic or not. On moderately deep to deep, relatively permeable siallitic soils it often occurs in pure form as a woodland in which the trees are evenly spaced and well-grown and in which there are few young saplings. A small shrub, Grewia bicolor is frequently common in the understory.

On sodic soils, however, the character of the woodland is different. Trees are generally smaller and often gnarled, spacing though irregular, is generally much closer, and in parts young saplings may be so numerous that they form thicket-like patches. The shrub that is usually found in this type of mopani woodland is Euclea undulata.

As rainfall increases edaphic factors assume more importance and mopani tends to be confined to sites and soils that become physiologically progressively drier. Thus where rainfall is only slightly higher than in its normal habitat, the tree will occur mainly on shallow soils with appreciable slope, or on soils that have dense impermeable horizons at shallow depth. Finally, where mean annual rainfall is considerably higher, i.e. above about 20-24 inches (510-610 mm), it occurs only on sodic soils at sites where practically all water is shed by run-off. Thus, on the plateau where rainfall is relatively high the occurrence of mopane invariably indicates sodic soils.

Combretum apiculatum

In the Sabi-Limpopo basin dominance of this small tree in bushland almost invariably denotes shallow, sandy siallitic soils.

These soils are usually derived from siliceous gneisses that tend to occur as narrow ridges which, colloquially, are referred to as "apiculatum ridges" because of the characteristic vegetation they support.

Combretum elaeagnoides

Marked dominance of this small tree, which occurs in the Zambesi basin, always indicates deep, well-drained, predominantly sandy siallitic soils in which clay content increases gradually with depth. On such soils C. elaeagnoides is generally associated with some C. apiculatum and some Kirkia acuminata. C. elaeagnoides is also a constituent of dense, often impenetrable thicket that is characteristic of regosols in the hotter drier parts of the Zambesi basin. Other constituents of this thicket, locally known as "jesse", are Diospyros spp., Dichrostachys cinerea, Combretum celastroides, Commiphora spp., and Acacia spp.

Combretum ghasalense

Marked localised dominance of this tree is almost invariably associated with relatively deep, medium to heavy textured soils in which there is some degree of compaction and mottling in the subsoils but never salinity or alkalinity. The tree is therefore most commonly found in well-grassed relatively low-lying areas that receive some run-off from higher ground. Since it is easily damaged by frost it occurs in Rhodesia mainly at altitudes below about 3,500 feet. The soil may be either siallitic or, less frequently, fersiallitic.

Combretum imberbe - Colophospermum mopane - Acacia nigrescens woodland

This type of woodland is most commonly found on soils derived from basic gneisses in areas of low rainfall in the Sabi-Limpopo basin. The woodland is invariably associated with relatively deep, reddish brown, medium to moderately heavy textured, permeable, siallitic soils that form on broad, relatively flat, interfluvial crests (see Siallitic soils, page 38). Under natural conditions when over-grazing does not take place, the grass cover, which consists mainly of Urochloa spp., is moderately thick.

Eriosema engleranum

This small 3-4 foot high shrub occurs mainly on the plateau where mean annual rainfall exceeds about 28 inches (710 mm).

Wild (19) has suggested that its incidence may be encouraged by overgrazing and too frequent veld fires. This may well be so but it has also been noted that its marked prominence almost invariably indicates the presence of laterite in subsoil horizons, particularly where it occurs on the lower slopes of uplands on which the soils are red fersiallitic clays. The lateritic horizons may either be hard and cemented or they may consist of loose, pisolitic concretionary material.

Hyphaene crinita

In Rhodesia this palm is confined to hot areas at low altitude. It grows as a tall slender palm on deep fertile siallitic soils in sites where it is able to tap free water at depth. In most instances either the soil or the water is slightly to moderately saline. H. crinita also occurs as a shrub with leaves at ground level on truncated, strongly sodic soils that are subject to periodic inundations of short duration.

Parinari curatellaefolia and Syzygium guineense (Waterberry)

As indicated earlier these two trees are infallible indicators of non-calcic hydromorphic soils on the plateau wherever they become a dominant constituent of a widely spaced tree population. S.guineense tends to be confined to the wetter areas. It should be noted, however, that in the Eastern Districts and in other areas where ortho-ferrallitic soils occur, P. curatellaefolia is often a common constituent of woodlands and forests.

Sesbania sp.

This leguminous annual grows to about 6-8 feet tall and is normally a minor constituent on siallitic alluvial soils flanking major rivers in hot areas at low altitude. However, on cultivated lands that have been abandoned, particularly those with heavy-textured soils, it assumes dominance often to the extent of forming an impenetrable mass. It may persist as a significant constituent for periods of up to 8 years and since the indigenous inhabitants seldom remove the larger trees from cultivated areas, the occurrence of Sesbania sp. is often the only indication of relatively recent cultivation. This applies particularly on heavy textured soils that are not heavily timbered in the natural state.

Terminalia sericea

This small silvery leafed tree is always indicative of very sandy soils that may be regosols or, if they are derived from granite, they may be para-ferrallitic or fersiallitic soils depending on the climate of the area. Although it is a widely distributed tree it occurs mainly in the west of the country. It does not occur in very hot dry areas at low altitude.

Uapaca kirkiana

This tree is normally a minor constituent of msasa-mnondo woodland but where it becomes dominant in localised areas it is invariably indicative of relatively shallow, gravelly soil in which internal drainage is not markedly impeded. The gravel may consist of quartz stones (usually sub-rounded) or it may be lateritic. Since the tree grows only on relatively well-drained soils, the laterite generally consists of shattered or broken lumps. In most instances such laterite is not of present day formation but is usually a remnant of older origin.

Xeromphis obovata

Localised dominance of this short thorny shrub is invariably associated with shallow sandy soils that are often stony. Although most are lithosols, the slightly deeper ones may be fersiallitic or siallitic soils depending on the climate.

Identification and interpretation of vegetation on airphotographs

In Rhodesia most aerial photography is carried out during part of the winter period, usually between May and July, when the atmosphere is clearest with respect to haze and, of course, devoid of cloud. Apart from all the broad inferences and interpretations that can be gained by examining stereo pairs, considerable experience in correlating vegetation as seen on the ground with that shown on the airphotograph, is an essential prerequisite to reliable recognition of vegetation type. It is also important, particularly in areas of low rainfall, to know the approximate order of incidence of leaf fall of deciduous trees that, from their shape or pattern of distribution, can be recognised on airphotographs. In fact, the ease with which interpretations can be made is often dependent on many species being devoid of leaves at the time of photography, especially in the low-veld where woodland and bushland tend to be relatively dense. In this way, to cite an obvious example, "apiculatum ridges" are clearly distinguishable from mopani woodlands even where tree spacing patterns are similar, since the vegetation on the former is almost invariably leafless before photography normally commences. The latter generally loses its leaf by about July in the Sabi-Limpopo basin, and by about September in the major valleys in the Zambesi basin; these are obviously very broad generalisations.

From the point of view of carrying out soil surveys in fairly dense woodland or bushland country, the employment of airphotographs is essential. One of their main uses lies in the mapping of soil boundaries that coincide with observed vegetation changes, and in being able to locate oneself on the ground. In both respects, it is desirable, but not essential, that the state of leaf fall in bushland or woodland should be similar to that when the airphotographs were taken. It should be emphasized that, except in rare cases, it is not possible to map soils on the basis of stereo examination of airphotographs alone without adequate examination of soils in the field. But even in the case of the exceptions, mapping can only be on a broad basis at fairly high categorical level and, in any event, some prior initial ground correlation has to be made originally.

The soil map (Map I)

Since a large amount of information has been accumulated concerning soils in most parts of Rhodesia, it has been possible to prepare a soil map at a scale of 1 : 1,000,000 on which a considerable degree of factual detail can be shown. As far as possible the mapping units comprise units of classification, or complexes of them, mainly at the soil Family level. These mapping units represent the most commonly occurring soils. Complexes are shown by the symbols of their constituents in order of incidence. For completeness, two classification units are included in the Key although the soils that belong to them cannot be mapped at this scale. The mapping units, for practical reasons, refer to soils occurring on normal or upland relief, catenal associations are not shown. Hydromorphic soils of vleis occupy relatively minor areas within most mapping units and their inclusion in units that already comprise complexes would detrimentally complicate the map. However, non-calcic hydromorphic soils that occur extensively on the plateau are shown in complex with other soils. Similarly, lithosols occuring in broken country or in undulating terrain in the drier areas are shown either as such or in complex with other soils. Small areas of lithosols sometimes associated with catenas are not shown. Sodic soils, like the non-calcic hydromorphic soils, appear only in complexes owing to the sporadic nature of their occurrence, even in places where collectively they comprise the major part.

Parent material boundaries have been taken mainly from the Provisional Geological Map (Map 2), since in numerous soil investigations it has been found that soil boundaries coincide with mapped geological boundaries in most instances. However, in the few places where this coincidence has not been exact, some departure from the parent material boundaries shown on the geological map has been made on the soil map.

The boundaries between different soils formed on the same parent materials have been determined by soil investigations ranging from fairly detailed soil surveys in some areas to broad reconnaissance in others. In the latter, the correlation of soils with types of vegetation has been an invaluable aid. For example, dominance of Parinari curatellaefolia in the scattered tree vegetation in fairly open country is an infallible indicator of sandy, non-calcic hydromorphic soils on the plateau. This type of country is clearly recognisable from the air or on air photographs, and it contrasts markedly with the Brachystegia spiciformis-Julbernardia globiflora woodland that normally occurs on well-drained soils on this tract.

In Rhodesia there is only one appreciable area where no pedological examination of the soils has been made. This lies in the extreme west and comprises mainly the Wankie National Game Park. The geological map (Map II) shows it to be entirely Kalahari sands and one might, therefore, assume the soils to be regosols. However, the peculiar drainage pattern shown by watercourses in some parts, and the high incidence of pans in other areas, are features not normally associated with regosols. Moreover, it is known that *Colophospermum mopane* occurs extensively and mean annual rainfall is greater than 20 inches (510 mm). Under these conditions Thompson (14) has shown that *Colophospermum mopane* almost invariably indicates sodic soils. More recently, extensive areas of black clays, that are probably vertisols formed on basalt, have been reported. In view of the uncertainty concerning the soils and their distribution in this area, no definite information has been shown on the soil map.

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SUMMARY

Rhodesia (formerly Southern Rhodesia) is a relatively high-lying region dominated by a central plateau surrounded by lower country on all sides. It embraces a wide diversity of geological materials and about two-thirds of its total area comprise those of igneous or metamorphosed igneous origin. Deep, loose, mainly aeolian sands account for approximately a further 25 per cent. Sediments that have been subject to at least one cycle of erosion and that are characteristic of vast tracts of the North American and Eurasian continents consequently constitute only a very minor part of Rhodesian soil parent materials. Whereas changes in parent material occur frequently at close intervals, climate, on the other hand, is relatively uniform over large areas. As a result the importance of parent material as a pedogenetic factor responsible for soil differences is very evident. For this reason systems of classification in which there is a strong emphasis on zonality according to climate have, for the greater part, little practical value. At the same time, early local attempts to classify the soils primarily on the basis of parent material were also not satisfactory. Some attempt has been made to classify in terms of the 7th Approximation of the comprehensive system proposed by U.S.D.A. soil survey staff but while many soils can be satisfactorily classified, many others cannot. In any case many of the data accumulated over the past 17 years do not include information specifically required for this exercise.

A sound system of classification should, in the view of the writer, be one in which the soils are grouped according to similarity of fundamental properties of the soil itself. The arrangement of these groupings within the system should, however, be based at least in part on some pedogenetic principle that is applicable to, or process that is operative in, the region in which the system is evolved. The pedogenetic concept of degree of weathering and leaching imposed by climatic and other forces on soils derived from specific types of parent materials is implicit in the classification evolved by the Inter-African Pedological Service (S.P.I.) for the soil map of Africa.

This approach provided, for the first time, an eminently suitable foundation on which to base a realistic system of classification for Rhodesian soils.

In schematic outline the Rhodesian classification employs four categorical levels, namely Order, Group, Family, and Series, in a simple branching system. There are five soil orders, namely Weakly Developed soils, Calcimorphic soils, Kaolinitic soils, Halomorphic soils and Hydromorphic soils. The first three reflect the broad progression in intensity of weathering but in the remaining two, other factors, notably those that give rise to retarded internal soil drainage, are more important genetic considerations. At the Group level of abstraction, differentiae include certain fundamental characteristics such as reserves of weatherable minerals, base saturation, and clay mineralogy. The Soil Family provides a convenient and essential link between the soil Group and the soil Series. While subdivision at the Family level is mainly on the basis of soil texture and certain morphological characteristics, criteria relating to exchangeable sodium percentage and electrical conductivity are defined in the case of soils belonging to the Halomorphic Order. Although the concept of the soil Series as defined in the U.S.D.A. Soil Manual has been closely followed, a departure from commonly accepted convention has been made in regard to nomenclature - the ordinary place name has been replaced by an almost equally concise, partially descriptive one.

In describing the soils of Rhodesia, mainly at the Group level, correlations are made with other systems of classification, notably that evolved by Portuguese pedologists for the soils of Angola, and the 7th Approximation.

While most soils in Rhodesia are regarded as being derived <u>in situ</u> it is fully realised that on all land with perceptible slope there must inevitably be some movement or creep of materials. In certain cases this gives rise to parent materials that differ somewhat in composition from that of the parent rock from which they originated. Since the majority of soils in Rhodesia are predominantly sandy, the diagnostic value of the sand fraction assumes importance. Sand fractions are separated into three different-sized sub-fractions which, by their relative proportions and individual components, can be related to the parent material from which the soil is derived. Examination by these means is often of value when transported soils are encountered, or in areas where there are no rock outcrops.

The Weakly Developed Soils comprise regosols, which are deep sands with weakly developed AC profiles, and lithosols which are heterogeneous soils shallower than 10 inches, over consolidated weathering rock.

The Calcimorphic soils comprise vertisols and siallitic soils. The clay fraction of the former is always predominantly montmorillonitic while in the latter it often consists either of illite or poorly crystalline illite-montmorillonoid mixed layer minerals. In the hotter, drier areas vertisols are characterised by well-developed, friable, granular surface horizons with excellent physical conditions for plant growth and therefore for cropping under irrigation. Vertisols formed under more humid conditions, however, have much denser, harder surface horizons. Siallitic soils are confined mainly to the hotter drier areas of Rhodesia.

The Kaolinitic soils comprise three Groups, namely fersiallitic, para-ferrallitic (a name originally suggested by Botelho da Costa to describe certain soils occurring in Angola), and ortho-ferrallitic soils. Fersiallitic soils tend to be formed on parent materials that give rise to sandy soils mainly in areas where rainfall is relatively low. As rainfall increases towards the central plateau, fersiallitic soils tend to be formed on progressively more basic parent materials or other materials that give rise to predominantly clayey soils. Para-ferrallitic soils are confined to parent materials that give rise to predominantly sandy soils on the higher rainfall parts of the central plateau. Although their clay fractions are essentially ferrallitic in character, para-ferrallitic soils have significant reserves of weatherable minerals. This apparently anomolous feature is thought to result from their rapid annual desiccation at the end of the rainy season. Ortho-ferrallitic soils are intensely weathered soils that are found only in areas of Rhodesia where there is normally sufficient winter rainfall to maintain the soil in a moist condition all the year round.

Halomorphic soils in Rhodesia are represented almost entirely by sodic soils, which morphologically resemble solonetz and solodized-solonetz. Their genesis, however, is different since it appears most unlikely that they evolved from solonchaks in view of the relatively humid conditions under which most of them are found. Lateral water movements across the surface of the dense impermeable sodic horizon is thought to be responsible for the very abrupt change between surface and subsoil horizons.

Hydromorphic soils occur mainly on the central plateau, most frequently in broad depressions. They comprise two main types namely, calcic hydromorphic soils and non-calcic hydromorphic soils. The former are predominantly clayey soils with high base saturation while the latter are predominantly sandy leached soils of low base saturation.

In Rhodesia vegetation types are determined mainly by soil and climatic conditions. Many soil-vegetation correlations have been established and confirmed over the years. Most vegetation types are clearly recognisable both from the air and on airphotographs and this is of particular value when mapping soils on a broad reconnaissance basis.

A new soil map of Rhodesia which shows considerable detail in spite of the 1 : 1,000,000 scale, is presented.

ABSTRACT

The natural features of Rhodesia, which include a diversity of soil parent materials of igneous origin, are contrasted with those of the North American and Eurasian continents. Existing systems of classification are discussed in relation to their suitability for application to local soils. The work of the Inter-African Pedological Service provided for the first time a suitable foundation on which to base a realistic system of classification for the soils of Rhodesia. In schematic outline this classification employs four categorical levels, ranging from soil Order to soil Series, in a simple branching system. The soils of Rhodesia and their genesis are discussed and correlations are made with the Portuguese classification evolved for the soils of Angola, and with the 7th Approximation of the comprehensive system of the U.S.D.A. soil survey staff. Many of the soil-vegetation associations that have been established are also discussed. A new soil map of Rhodesia at a scale of 1 : 1,000,000 is presented.

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APPENDIX A

DESCRIPTIONS OF TYPICAL PROFILES AND ANALYTICAL DATA

Notes on Profile Descriptions

Terms used for consistence and structure are as defined in the Soil Survey Manual (7).

Textural classes used in Southern Rhodesia since 1941, are based on Stobbe (8), namely :-

Sand	more than 85% sand
Loamy sand	80-85% sand
Loam	less than 50% sand and less than 20% clay
Sandy loam	50-80% sand and less than 20% clay
Silty loam	more than 50% silt and less than 20% clay
Clay loam	less than 50% sand, and 20-30% clay
Sandy clay loam	more than 50% sand, and 20-30% clay
Silty clay loam	more than 50% silt and 20-30% clay
Clay	less than 50% sand and 30-50% clay
Sandy clay	more than 50% sand and 30-50% clay
Silty clay	more than 50% silt and 30-50% clay
Heavy clay	more than 50% clay of predominantly 2 : 1 lattice type.

In practice in Southern Rhodesia, silty soils as defined do not occur. The term "relatively silty" is used where the silt fraction is significantly higher than normal. Where used, the terms "coarse-, medium-, or fine-grained" refer to the nature of the sand fraction.

Word descriptions of colour refer to the dry soil and the Munsell notations for dry and moist soil, respectively, are given in brackets unless otherwise stated.

The following abbreviations are used :-

ann rain = mean annual rainfall,

P.M. = parent material, and

veg. = vegetation.

Notes on Analytical Data

Analytical data refer to the fine earth fraction passing a 2 mm round-hole sieve and are expressed on an oven-dry basis. Where given, the percentage gravel = $\frac{\text{gravel}}{\text{gravel + soil}} \times 100$. The methods of analysis employed are outlined below and abbreviations used in the tables are also indicated.

Mechanical analysis

Hydrometer method, soil dispersed with sodium hexametaphosphate reagent; sedimentation times of 5 minutes for silt + clay reading, and 5 hours for clay reading; coarse and medium sand fractions separated by sieving, fine sand calculated by difference.

Particle sizes are :-

Coarse sand (C.S.)	2.0 - 0.5 mm	Silt	0.02 - 0.002 mm
Medium sand (M.S.)	0.5 - 0.2 mm	Clay	less than .002 mm
Fine sand (F.S.)	0.2 - 0.02 mm.		

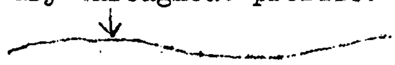
pH (sat)	Determined in the saturated paste.
pH (1 : 5)	Determined in a 1 : 5 soil/water suspension (old method).
Cond (sat)	Electrical conductivity in millimhos/cm of the saturation extract.
Cond (1 : 5)	Electrical conductivity in millimhos/cm of a 1 : 5 soil/water suspension (old method).
TEB	Total exchangeable bases (or total extractable bases in base saturated soils) in milligram equivalents per cent. Obtained in most instances by summation of exchangeable metal cations determined in N ammonium acetate (pH 7) extract, following N/2 acetic acid treatment in the case of base saturated soils, as described by Thompson (9). Where no individual exchangeable cations are given, TEB was determined by the method of Bray and Wilhite (1).
CEC	Cation exchange capacity in milligram equivalents per 100 grams of soil. Determined by removal of ammonium ions by distillation (2) following extraction with N ammonium acetetate pH7 and washing with 96% ethyl alcohol.
free CO''_3	Free carbonates in milligram equivalents per cent, obtained by difference between total extractable bases and cation exchange capacity. In rare cases when the soils contain sulphates and chlorides the free carbonate figure will include water soluble cations.
Ca, Mg, K, Na	Exchangeable cations expressed in milligram equivalents per cent. Determined in N ammonium acetate (pH7) extract. Unless otherwise stated Na is corrected for water soluble Na determined in the saturation or 1 : 5 extracts, but in base saturated soils Ca and Mg include free carbonates as defined above.
BS	Percentage base saturation, i.e., 100 x TEB/CEC
E/C value	Cation exchange capacity in milligram equivalents per 100 grams of clay. Since organic matter is not destroyed, this value is significant only in sub-soil horizons. It is also not accurate in the case of sub-soils with very low clay content.
ESP	Exchangeable sodium percentage, i.e., 100 (Exch Na - w/s Na)/CEC.
W/S cations and anions	Water soluble cations and anions, where given, are expressed in milligram equivalents per cent or in milligram equivalents per litre of the saturation extract.
Org. C%	Walkley-Black values, determined by the method described by Piper (4), expressed as a percentage.
T.N.%	Total nitrogen by a macro Kjeldahl method expressed as a percentage.

Available P_2O_5 ppm	Available phosphorus pentoxide, where given, by anion-exchange resin extraction by the method of Saunder and Metelerkamp (6), expressed in parts per million.
Mineral N ppm	Mineral nitrogen (nitrate + ammonia), before and after incubation, where given, by method of Saunder, Ellis and Hall (5), expressed as parts per million.

SOIL DESCRIPTIONS AND ANALYTICAL DATA

REGOSOL

Profile 1. Nyamandhlovu K.1 series, examined August 1958. Soil dry throughout profile.

Site  Gently undulating country near Chirundu in Zambezi Valley.

Ann. Rain Approx. 20 inches (510 mm)

Veg. Short Combretum spp. and Terminalia spp.

P.M. Triassic sands.

Description

0-7" Brown (10YR4/3, 3/3) fine-grained sand. Changes very gradually to :-

7-12" Brown (7.5YR4/3, 3/3) similar sand. Changes very gradually to :-

12-29" Reddish brown (5YR4/4, 3/4) similar sand. Changes very gradually to :-

29-45" Yellowish red (5YR4/6, 3/6) similar sand. Changes very gradually to :-

45-61" Yellowish red (5YR4/8, 3/8) similar sand.

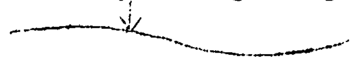
Analytical data

Depth (inches)	0-7	15-21	33-39	48-54
C.S.%	1	1	1	1
M.S.%	14	13	13	16
F.S.%	78	80	80	76
Silt %	3	trace	1	1
Clay %	4	6	5	6
pH (1 : 5)	5.7	5.0	5.2	5.4
TEB	2.6	0.4	0.5	0.7
CEC	4.9	2.9	2.7	2.8
BS	53	14	18	25
E/C value	122	48	54	47

Remarks Under a hand lens no weatherable minerals could be detected in any horizon. The clay fraction was not examined, but D.T.A. of the clay fraction of a very similar soil occurring under somewhat lower rainfall in the Nyamandhlovu area showed mainly 2 : 1 lattice clays (mainly illitic) and a little kaolinite.

LITHOSOLS

Profile 2 Triangle P.O series, examined September 1962.
Soil dry throughout profile.

Site  On break of slope in moderately undulating country near Triangle Sugar Estates.

Ann. Rain Approx. 18 inches (455 mm)

Veg. Scattered stunted *Colophospermum mopane* and *Combretum apiculatum*.

P.M. From highly siliceous gneiss formation striking east-west.

Description

0-6" Yellowish brown (10YR5/4, 3/4), soft structureless fine to medium-grained sand. Some sub-rounded quartz gravel and pebbles. Changes fairly abruptly to :

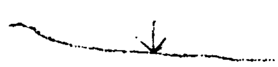
6-15" Hard, relatively little-weathered, pale gneiss.

Analytical data

Depth (inches)	0-6
C.S.%	11
M.S.%	27
F.S.%	50
Silt %	5
Clay %	7
pH (sat)	5.1
TEB	2.5
CEC	4.2
Ca	1.2
Mg	1.0
K	0.3
B.S	60
E/C value	62

Remarks The country in which the profile was sited is underlain by gneisses which differ widely in chemical composition and mineralogy. They were formerly called paragneisses. The soils derived from the more basic gneisses are generally deeper and heavier-textured.

Profile 3 Matopos E.O series, examined May 1953.
Soil slightly moist.

Site  On gentle slope, at Matopos Research Station.

Ann. Rain Approx. 20 inches (510 mm)

Veg. Scattered *Acacia spp.*, occasional *Sclerocarya caffra*. Dominant grass is *Heteropogon contortus*.

P.M. From epidiorite (a metamorphosed basalt).

Description

0-5" Dark reddish brown (5YR3/4, 3/2) clay. Slightly hard consistence, feeble subangular macro-structure, fairly pronounced medium crumb to granular micro-structure. Changes gradually to :

5-9"	Similar (5YR3/3, 3/3) clay with similar structure. Fairly numerous sub-rounded quartz pebbles. Changes clearly to :-
9-16"	Sub-rounded quartz pebbles fairly loosely packed. Very little soil-like material. Some weathering epidiorite fragments mainly towards 16 inches. Changes clearly to :-
16-30"	Variably weathered epidiorite. Soft and reddish-orange with numerous black ferromanganese stains where well-weathered (mainly in upper part), hard and pale green where little weathered (mainly in lower part).

Analytical data

Depth (inches)	0-4	6-9
C.S. + M.S.%	6	4
F.S.%	28	19
Silt %	29	26
Clay %	37	51
pH (1 : 5)	7.1	7.0
TEB	29.6	33.4
CEC	28.9	32.8
free CO''_3	0.7	0.6
Ca	17.7	19.3
Mg	11.2	13.7
K	0.6	0.2
Na*	0.1	0.2
BS	100	100
E/C value	78	64

* Not corrected for water-soluble sodium.

Remarks — No investigation of the clay fraction was made.

VERTISOLS

Profile 4 — Chisumbanje B1 series, examined December 1956. The upper part of the solum was very moist due to heavy rain prior to examination.

Site — On flat topography to east of Sabi river near Chisumbanje in cleared but not cultivated land. Slight gilgai micro-relief.

Ann. Rain — Approx. 18 inches (405 mm)

Veg. — Thick grass, mainly Urochloa, on micro-knolls but generally bare in micro-depressions.

P.M. — From basalt.

Description

0-1"/3" — Variable depth, dark grey (N2/0 moist) heavy clay. Very moist, very friable in situ but true consistence is very firm. Very fine granular micro-structure discernible even in the moist state, but the wide vertical cracks, normally evident in the dry state, have closed up. In spite of moisture status soil mass takes up water readily. Some isolated very small hard carbonate concretions. Numerous roots. Changes irregularly and very indistinctly to :-

1"/3"-10" — Very dark grey (N2/0 moist) heavy clay. Very moist. Similar in every way to horizon above but some of the larger granules show slickenslide surfaces. Some small hard carbonate concretions. Numerous roots. Changes fairly sharply to :-

10-32" — Very dark grey (N2/0 moist) heavy clay. Slightly moist. This horizon consists of huge blocks up to 12 inches across separated by 2 to 3 inch wide vertical cracks. The blocks themselves have a moderate angular blocky structure which is irregular owing to internal movements. Intersecting slickenslides are prominent. Some hard carbonate concretions up to ½ inch diameter, and some isolated quartz and agate pebbles. Dry consistence is very hard and the soil mass takes up water slowly swelling visibly in the process. Fairly numerous roots which, in the vicinity of the wide cracks, have been broken and torn apart by shrinkage on drying out. Changes fairly distinctly to :-

32-41" — Black (N2/0 moist) heavy clay. Slightly moist becoming moderately moist with depth. Irregular, moderate angular blocky structure. Pronounced intersecting slickenslides. Vertical cracks narrow rapidly to not more than 1/10th inch wide. Consistence, because of the moisture status, is somewhere between very hard and extremely firm. Soil mass takes up water very slowly, swelling in the process. Fairly numerous small carbonate concretions becoming more numerous with depth. Fairly numerous roots. Changes distinctly to :-

41-56" — Highly calcareous gravelly weathering basalt. Numerous large hard carbonate concretions in addition to soft powdery free carbonate. Several tongues and thin stringers of black clay occur mainly in the first 2-3 inches of this horizon. General colour is light yellowish grey. Isolated fine roots.

Analytical data

Depth (inches)	0-7	12-18	23-30	34-40
C.S.%	2	2	2	1
M.S.%	2	1	1	1
F.S.%	8	10	8	7
Silt %	12	10	11	11
Clay %	76	77	78	80
pH (sat)	7.3	7.4	7.4	7.6
Cond (sat)	0.48	0.44	0.47	0.55
TEB	100.7	102.1	102.0	109.6
CEC	65.5	65.1	67.8	72.2
free CO_3''	35.2	37.0	34.2	37.4
Ca	66.0	65.6	64.2	70.1
Mg	34.7	36.5	37.8	39.5
K	2.1	2.0	2.0	2.1
Na*	0.7	1.2	2.0	2.8
BS	100	100	100	100
E/C value	86	85	87	90
ESP	3	3	3	3

* Not corrected for water soluble sodium.

Additional data — Each soil sample was split and half sent to the United States Salinity Laboratory, Riverside, California, while Mr. B.D. Soane, a staff member of this Branch, was in the United States of America on a scholarship training programme, and the following additional data were made available. The methods used are indicated in square brackets and are described in the United States Salinity Laboratory Manual (10).

Depth (inches)	0-4	12-18	23-30	34-40
Moisture Retention %				
[30] 1/3 atmosphere	64	64	66	68
[31] 15 atmospheres	43	44	44	48
Hydraulic cond. (cm/hr)				
[34b] Initial	1.4	0.9	0.7	0.6
[34b] Final	1.0	1.0	0.7	0.5
Surface area (m^2/gm)				
[25] Total	587	557	not	567
[25] External	224	250	done	260
[37] Air water permeability ratio	998	1119	1597	1593

According to D.T.A. and X-ray data the clay fraction at the 23-30 inch level consists practically entirely of montmorillonite.

Remarks — At the Chisumbanje Experiment Station these soils have been irrigated for over 10 years. Although they present difficulties in management, a variety of crops has been grown and a high level of productivity has been maintained. In this area the vertisols have an appreciably greater depth of relatively permeable, loose, granular-structured surface material than those occurring in areas under higher rainfall conditions where such soils are normally much denser throughout and take up water much less readily.

Profile 5 — Birchenough E.1 series, examined August 1954.
Soil dry or nearly so throughout profile.

Site — On flat topography on Devuli ranch about 1 mile from Sabi River approximately 6 miles below Sabi-Devuli confluence. Pronounced gilgai micro-relief; numerous, mainly round, dolerite stones and small boulders brought to surface by self-churning process.

Ann. Rain — Approx. 17 inches (405 mm)

Veg. — Short scrub of Colophospermum mopane and Combretum spp.

P.M. — From dolerite, with some colluvial influence off adjacent limestones of the Umkondo system.

Description

0-$1\frac{1}{2}$" — Reddish brown (5YR4/4, 3/4) clay. Loose granular material, but the granules themselves are hard. Takes up water very readily, swelling in the process. Some wide vertical cracks up to $\frac{1}{2}$ inch wide. Although no discrete carbonate concretions can be seen, the material is calcareous. Numerous roots. Changes clearly to :-

$1\frac{1}{2}$-7" — Dark reddish brown (5YR3/4, 3/3) clay. Very hard consistence. This horizon consists of elongated blocks separated by vertical cracks up to $\frac{1}{2}$ inch wide, giving the appearance of a coarse prismatic structure but the blocks themselves have a strong but irregular medium angular blocky structure. A few large rounded dolerite stones rest on the elongated blocks and are in the process of being brought to the surface from below. A few poorly defined slickenslide surfaces are discernible. Takes up water fairly readily, swelling in the process. Calcareous as above, fairly numerous roots. Changes gradually to :-

7-19" — Dark reddish brown (about 4YR3/4, 3/4) heavy clay. Similar to horizon above, but the vertical cracks are wider (up to 1 inch) and they contain granular material and some larger peds which have fallen in from the overlying horizons. Fairly numerous well-developed slickenslides. Calcareous as above, fairly numerous roots, many of the finer ones torn apart. Changes gradually to :-

19-31" — Dark reddish brown (about 4YR3/4, 4/4) heavy clay. Very slightly moist becoming slightly moist with depth. Similar to horizon above but cracks become narrower with depth due to increase in moisture content. Well developed intersecting slickenslides. Some discrete carbonate concretions near 31 inches. A few roots. Changes clearly to :-

31-36" — Mainly orange weathering dolerite gravel impregnated with soil-like material similar to that above. A few carbonate concretions and soft filamentous deposits. Changes fairly clearly to :-

36-56" — Dolerite which is weathering spheroidally, varying in colour from orange to yellowish green, with numerous hard unweathered cores. Numerous carbonate concretions and soft deposits.

Analytical data

Depth (inches)	0-1	2-6	8-17	21-29
M.S. + C.S.%	11	10	11	8
F.S.%	27	22	19	20
Silt %	20	19	15	14
Clay %	42	49	55	58
pH (1 : 5)	8.5	8.7	8.8	8.9
Cond (1 : 5)	0.14	0.12	0.17	0.24
TEB	82.7	144.6	165.6	180.7
CEC	45.2	50.7	50.5	52.4
free CO''_3	37.5	93.9	115.1	128.3
Ca	68.6	128.0	147.2	158.4
Mg	10.9	15.2	16.8	19.1
Na	0.2	0.2	0.7	2.3
K	3.0	1.2	0.9	0.9
BS	100	100	100	100
E/C value	108	103	92	90
ESP	<1	<1	1	4
W/S Na	-	-	trace	trace

Remarks — The round surface stones undoubtedly originated from hard unweathered cores similar to those found in the speroidally weathering dolerite. The red colour of the soil is very unusual and, unfortunately, at the time of examination and laboratory analysis no facilities for investigating the nature of the clay fraction were available. Reddish-coloured vertisols occur only to a very limited extent in Rhodesia, the only known examples being confined to the Sabi and Zambezi Valleys.

Profile 6 — Selous X.I series, examined January 1963. Soil moist throughout profile due to rains.

Site —  On very slight slope on eastern side of Great Dyke near Selous. Numerous unweathered somewhat heterogeneous basic or ultrabasic surface stones, which although irregular in shape, are sub-rounded.

Ann. Rain — Approx. 33 inches (840 mm)

Veg. — Mainly open grassland with some scattered *Diplorhynchus condylocarpon*.

P.M. — From ultrabasic rocks of the Great Dyke.

Description

0-5" — Very dark grey (N 3/0, 2/0) heavy clay. Top half inch dry. Below this slightly moist becoming moist with depth. Very hard consistence, becoming extremely firm with depth. Weakly developed coarse angular blocky structure. In some parts there is about a ½ inch surface layer of loosely packed, hard granules. The dry surface peds take up water very slowly. Numerous roots. Changes gradually to :-

5-16" — Black (N2/0 moist) heavy clay. Moist, extremely firm consistence. The drying surface shows angular blocky cracking but a fine to medium granular micro-structure is easily discernible. A few small slickenslides are evident near 16 inches. Takes up water slowly. Numerous roots. Changes very gradually to :-

16-34" Black (N2/0 moist) heavy clay. Moist, very similar horizon except that there are numerous very well developed intersecting slickenslides. Numerous fine roots. Changes fairly abruptly to :-

34-50" Weathering rock, mainly soft ranging in colour from orange to yellowish green. Some tongues of clay similar to above horizon, and some soft greyish white carbonate deposits. Occasional fine roots.

Analytical data

Depth (inches)	0-5	7-13	22-28
C.S.%	1	2	2
M.S.%	4	3	2
F.S.%	23	18	17
Silt %	15	10	11
Clay%	57	67	68
pH (sat)	6.0	6.3	6.5
Cond (sat)	0.18	0.24	0.23
TEB	64.6	74.7	74.7
CEC	65.9	73.7	72.6
free CO''_3	nil	1.0	2.1
Ca	10.8	11.9	12.1
Mg	53.6	62.7	62.3
K	0.2	0.1	0.1
BS	98	100	100
E/C value	116	110	107

Remarks The clay fraction consists practically entirely of montmorillonite. The differential thermal analysis diagram (from the 22-28 inch level) is practically identical to that obtained on the sample taken from Profile 4. In this section of the Great Dyke the vertisols often occur in association with red fersiallitic clays for reasons that are not always clearly apparent, although it is thought that in some instances differences in calcium/magnesium ratio and in the physical nature of the underlying rock strata are important.

Profile 7 Siabuwa Z.1 series, examined June 1956. Soil slightly moist becoming moist with depth.

Site On relatively level topography in partially cleared land at Siabuwa. Moderate gilgai micro-relief.

Ann. Rain Approx. 25 inches (635 mm)

Veg. Most of the trees left standing are *Colophospermum mopane* and an occasional *Combretum spp*.

P.M. From Madumabisa shale (frequently coal-bearing and often containing appreciable quantities of gypsum).

Description

0-8" Dark grey (10YR4/1, 2/1) clay. Very slightly moist. Pronounced medium to coarse granular structure in top inch or so, fine to medium angular blocky below. Some ½" wide vertical cracks. Takes up water readily, swelling in process. Numerous roots. Changes fairly sharply to :-

8–19"	Dark greyish brown (2.5Y4/2 moist) heavy clay. Slightly moist. Very hard consistence, coarse angular blocky structure tending towards prismatic. Some slickenslides. Numerous small carbonate concretions. Takes up water fairly slowly, swelling in process. Fairly numerous roots. Changes gradually to :-
19–29"	Olive (5Y5/3 moist) heavy clay. Moderately moist. Consistence between very hard and extremely firm. Strong angular blocky cracking, somewhat irregular. Some pronounced slickenslides. Numerous small carbonate concretions. Some darker (10YR2/1 to 2.5Y4/2) patches, presumably material from overlying horizons. Takes up water extremely slowly. Few roots. Changes almost imperceptibly to :-
29–52"	Olive (5Y5/3 moist) heavy clay. Consistence as above. Weak angular blocky cracking. Some weakly developed slickenslides. Numerous small carbonate concretions. Some darker (5Y4/2) mottles. Takes up water extremely slowly. Occasional fine roots.

Analytical data

Depth (inches)	0–6	10–16	20–26	36–42
C.S.%	9	4	4	no mech.
M.S.%	15	5	3	anal. due
F.S.%	10	14	15	to flocculation
Silt %	28	23	7	
Clay %	38	54	70	
pH (1 : 5)	8.4	8.5	7.8	7.8
Cond (1 : 5)	0.15	0.19	2.8	3.0
TEB	37.0	160.0	151.0	91.0
CEC	28.4	32.6	31.1	28.8
free CO''_3	8.6	127.4	120.0	62.2
Na	–	–	0.1	0.5
BS	100	100	100	100
E/C value	75	60	44	–
ESP	–	–	1	2
W/S Na	–	–	0.3	0.4
W/S Ca	–	–	13.4	14.0
W/S SO_4	–	–	13.6	13.6
W/S HCO'_3	–	–	0.5	0.4

Remarks

The mechanical analysis of these samples is suspect due to partial flocculation which may have been brought about by the presence of $CaSO_4$.

Water soluble cations and anions are expressed in m.e.%. The electrical conductivity and the water soluble salt analysis were done by a method that is now obsolete, using a 1 : 5 soil/water ratio. The main salt in the extract is gypsum and the presence of this in the soil interferes badly with determinations of exchangeable sodium by the method described by Piper (3). The exchangeable sodium percentages given are therefore probably low. Total extractable bases were done by the method of Bray and Wilhite (1), which is also now no longer used in this laboratory. The result is, therefore, inevitably low since sulphates (and chlorides, when present) are not measured by this method.

No investigation of the separated clay fraction was made.

SIALLITIC SOILS

Profile 8 — Tuli L.1 series, examined May 1962. Soil dry throughout profile.

Site — In cultivated land on lower slope in gently undulating country in the Tuli area.

Ann. Rain. — Approx. 14 inches (355 mm)

Veg. — Vegetation surrounding cultivated land consists mainly of short *Colophospermum mopane* and *Combretum spp.*

P.M. — Highly calcareous material frequently formed on lower slopes in areas of low rainfall where the country rock (usually basic gneisses) is relatively rich in calcium-releasing weatherable minerals.

Description

0-7" — Dark greyish brown (10YR4/2, 3/2) structureless fine to medium-grained loamy sand. Soft consistence. Calcareous but without visible carbonate deposits. Changes gradually to :-

7-18" — Dark brown (10YR4/3, 3/2) similar loamy sand. Soft consistence, calcareous. Some soft fialmentous carbonate deposits and some small hard concretions that have a finely crystalline appearance. Fairly numerous roots. Changes fairly sharply to :-

18-31" — Pale brown (10YR6/3, 5/3) sandy loam. Soft consistence. As a whole this horizon appears in the field to be composed mainly of soft carbonate deposit together with numerous hard concretions that have a finely crystalline appearance. Few roots. Changes fairly sharply to :-

31-50" — Fairly soft weathering greenish gneissic rock, becoming harder with depth. Calcareous in upper parts, with some deposits extending to depth down joints. The harder, relatively unweathered rock is not calcareous (no effervescence with HCl). Occasional roots mainly in upper part.

Analytical data

Depth (inches)	0-5	10-16	22-28
Gravel %	5.1	13.7	20.2
C.S.%	23	17	11
M.S.%	15	18	15
F.S.%	47	46	44
Silt %	6	6	10
Clay %	9	13	20
pH (sat)	7.6	7.4	7.7
Cond (sat)	0.44	0.80	0.48
TEB	22.4	34.8	271.6
CEC	11.0	12.5	13.0
free CO''_3	11.4	22.3	258.6
Ca	19.0	31.5	257.2
Mg	2.5	2.5	13.5
K	0.6	0.5	0.3
Na*	0.3	0.2	0.6
BS	100	100	100
E/C value	122	96	65
ESP	3	2	5

* Not corrected for water soluble sodium.

Remarks — Most of the hard carbonate concretions were retained in the gravel fraction. The percentage gravel is a measure of the hard concretionary carbonate in the subsoil horizons.

No examination of the clay fraction was made.

Profile 9 — Matopos E.1 series, examined May 1962. Soil dry throughout profile.

Site —  On about 1% slope about 4 miles south-west of Bulawayo.

Ann. Rain — Approx. 23 inches (585 mm)

Veg. — Short scrub *Acacia spp.*, thick grass cover, mainly *Heteropogon contortus*.

P.M. — From epidiorite.

Description

0-5" — Dark reddish brown (5YR4/3, 3/3) heavy clay. Soft consistence. Moderate coarse crumb to granular structure. Very numerous roots. Changes gradually to :-

5-12" — Red (2.5YR4/6, 3/6) heavy clay. Soft consistence. Moderate medium sub-angular blocky macro-structure, moderate medium crumb to granular micro-structure. Numerous black ferro-manganese stains. Numerous roots. Changes gradually to :-

12-21" — Red (2.5YR4/6, 3/6) very similar horizon with some fragments of very weathered epidiorite, increasing with depth. Fairly numerous roots. Changes fairly sharply to :-

21-32" — Weathering epidiorite, mainly soft. Few roots.

Analytical data

Depth (inches)	0-4	6-12	14-20
C.S.%	2	1	1
M.S.%	2	2	2
F.S.%	36	11	12
Silt %	8	23	26
Clay %	52	63	59
pH (sat)	5.8	5.7	5.9
Cond (sat)	0.16	0.16	0.13
TEB	33.9	31.4	33.2
CEC	35.8	35.5	34.3
Ca	20.5	17.1	18.3
Mg	13.2	14.2	14.8
K	0.2	0.1	0.1
BS	95	88	97
E/C value	69	56	59

Remarks — The clay fraction at the 14-20 inch level consists mainly of illite-montmorilloroid mixed layer minerals, together with some kaolinite.

Profile 10 — Tuli P.2 series, examined May 1962. Soil moist throughout profile due to pit being flooded with water three weeks earlier. Profile cleaned up prior to examination.

Site — In very flat area subject to run-off in the Tuli area.

Ann. Rain — Approx. 14 inches (355 mm)

Veg. — Woodland consisting entirely of Colophospermum mopane. Some Euclea undulata in understory.

P.M. — From fairly basic gneiss.

Description

0-5" — Very dark greyish brown (10YR3/2 moist) medium to coarse grained sandy loam. Friable consistence. Numerous roots. Changes gradually to :-

5-12" — Similar (10YR3/2 moist) sandy clay loam. Friable to firm consistence. Fairly numerous roots. Changes clearly to :-

12-22" — Dark yellowish brown (10YR3/4 moist) sandy clay. Firm consistence, some coarse angular blocky cracking with prismatic tendency beginning to develop on drying. Some diffuse yellowish brown (10YR5/6 moist) mottling. A few roots. Changes very gradually to :-

22-36" — Very similar (10YR3/4 moist) horizon but very isolated hard carbonate concretions. Changes gradually to :-

36-44" — Dark yellowish brown (10YR4/4 moist) sandy clay. Firm to friable consistence. Some scattered hard carbonate concretions. Numerous sub-rounded quartz stones and pebbles, which are coated with carbonate, occur on the floor of the pit. Immediately below these (about 2" down) weathering gneiss commences.

Analytical data

Depth (inches)	0-5	14-20	36-42
C.S.%	24	19	14
M.S.%	22	12	15
F.S.%	32	20	26
Silt%	11	5	12
Clay%	11	44	33
pH (sat)	5.8	6.7	7.8
Cond (sat)	0.35	0.16	0.50
TEB	9.0	23.7	22.8
CEC	9.4	24.3	22.0
free CO_3''	nil	nil	0.8
Ca	5.7	11.7	15.9
Mg	2.3	9.0	4.2
K	0.6	2.0	1.6
Na	0.4	1.0	1.1
BS	96	98	100
E/C value	86	55	67
ESP	4	4	5

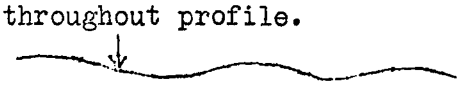
Remarks

The clay fraction at the 36-42 inch level appears to consist practically entirely of poorly crystalline illite-montmorillonoid mixed layer minerals.

When dry the subsoils are generally very hard and dense.

A hydraulic conductivity measurement, made *in situ* at the 12 inch level, gave a result of 0.02 inches per hour over a 24 hour period. The apparatus used is an automatic-recording one which has an outer guard ring in addition to the inner infiltrometer ring. The constant head of free water above the soil is adjusted to between 1 and 1½ inches. The apparatus was designed and tested by the writer and Mr. A. du Toit of this Department.

Profile 11 Triangle P.1 series, examined in May 1962. Soil dry throughout profile.

Site  On gentle slope in slightly undulating country in the Tuli area.

Ann. Rain Approx. 14 inches (355 mm)

Veg. *Colophospermum mopane* scrub. Some *Grewia bicolor*.

P.M. From intermediate to fairly basic gneiss.

Description

0-6" Dark brown (7.5YR4/2, 3/2) fine to medium grained structureless sandy loam. Slightly hard consistence. Numerous roots. Changes gradually to :-

6-14" Reddish brown (5YR5/3, 3/4) similar sandy loam. Hard consistence. Numerous roots. Changes gradually to :-

14-24" Reddish brown (5YR4/3, 3/3) sandy clay loam. Hard to very hard consistence. Very feeble coarse sub-angular blocky structure. Fairly numerous roots. Changes fairly sharply to :-

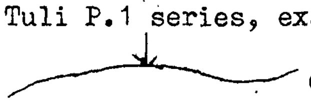
24-45" Weathering gneiss with a little quartz gravel near 24 inches. Fairly numerous soft filamentous carbonate deposits, probably of illuvial origin. Where the weathering rock is fairly hard it does not effervesce with HCl. Occasional fine roots.

Analytical data

Depth (inches)	0-6	8-14	16-22
C.S.%	17	15	15
M.S.%	24	22	22
F.S.%	39	39	36
Silt %	9	7	5
Clay %	11	17	22
pH (sat)	6.2	6.7	6.8
Cond (sat)	0.18	0.30	0.20
TEB	10.7	16.6	16.0
CEC	11.3	14.9	14.9
free CO''_3	nil	1.7	1.1
Ca	8.0	13.2	12.8
Mg	2.1	3.0	2.8
K	0.6	0.4	0.4
BS	95	100	100
E/C value	103	88	68

Remarks — No examination of the clay fraction was made.

Profile 12 — Tuli P.1 series, examined in May 1962.

Site —  On crest in moderately undulating country near Tuli.

Ann. Rain — Approx. 14 inches (355 mm)

Veg. — Scattered short *Combretum apiculatum*, a few *Grewia bicolor*, and a very few *Colophospermum mopane*.

P.M. — From siliceous or acid gneiss.

Description

0-7" — Yellowish brown (10YR5/4, 3/4) structureless medium grained sand. Soft consistence. Some gravel consisting partly of weathering gneiss fragments. Numerous roots. Changes gradually to :-

7-20" — Brown (7.5YR4/4, 3/4) similar sand with somewhat more gravel as above. Numerous roots. Changes fairly abruptly to :-

20-26" — Mainly sub-rounded quartz pebbles and gravel, loosely held. Some diffuse yellow lateritic mottling. Fairly numerous roots. Changes fairly sharply to :-

26-35" — Moderately hard pale weathering gneiss. Few roots.

Analytical data

Depth (inches)	0-6	12-18
C.S.%	22	21
M.S.%	32	31
F.S.%	36	36
Silt %	5	4
Clay %	5	8
pH (sat)	5.7	5.6
Cond (sat)	0.12	0.10
TEB	4.0	4.0
CEC	4.6	4.7
Ca	2.1	1.5
Mg	1.0	1.5
K	0.9	0.7
Na*	-	0.3
BS	85	87
E/C value	94	58
ESP	-	7

* Not corrected for water soluble sodium.

Remarks — No examination of the clay fraction was made.

Profile 13 — Sabi U.1 series, examined April, 1962. Upper horizons moist due to rain.

Site —  On high ground in very nearly flat topography just south of Mopani Block of Sabi Valley Experiment Station, about 2 miles east of Sabi river.

Ann. Rain — Approx. 17 inches (405 mm)

<u>Veg.</u> Tall <u>Colophospermum mopane</u> woodland. Sparse grass cover.

<u>P.M.</u> Granitic alluvium.

<u>Description</u>

0-7" Very dark greyish brown (10YR3/2 moist) coarse-grained sandy loam. Moist, friable consistence. No structure. Very numerous roots. Changes gradually to :-

7-15" Greyish brown (10YR5/2, 4/2) similar sandy loam. Slightly moist in upper part. Slightly hard consistence, structureless. Very numerous roots. Changes clearly to :-

15-20" Dark brown (about 8YR4/3, 3/4) sandy loam at first, becoming sandy clay loam with depth. Dry. Hard consistence becoming very hard with depth. Numerous roots. As a whole this horizon is intermediate in character between horizons 2 and 4. Changes clearly to :-

20-44" Dark brown (7.5YR3/4, 3/4) coarse grained sandy clay. Dry. Very hard consistence. Massive. Numerous roots. Changes fairly clearly to :-

44-70" Yellowish brown (10YR5/4, 7.5YR4/4) coarse to medium grained calcareous sandy clay loam. Dry. Very hard consistence at first, becoming hard with depth. Structureless. Numerous soft, mainly filamentous, carbonate deposits. Fairly numerous diffuse black ferro-manganese stains and some variegated brown and yellowish brown discolorations.

<u>Analytical data</u>

Depth (inches)	0-5	7-13	20-26	55-61
C.S.%	35	35	32	26
M.S.%	18	17	13	13
F.S.%	24	23	16	26
Silt %	13	13	8	22
Clay %	10	12	31	13?
pH (sat)	6.6	6.7	6.5	7.8
Cond (sat)	0.34	0.51	0.50	0.57
TEB	8.2	6.1	11.0	70.8
CEC	7.9	7.1	12.5	13.8
free CO"$_3$	0.3	nil	nil	57.0
Ca	5.7	3.5	6.8	61.3
Mg	2.0	2.0	3.2	8.7
K	0.5	0.6	0.5	0.3
Na*	-	-	0.5	0.5
BS	100	86	88	100
E/C value	79	59	40	106?
ESP	-	-	4	4

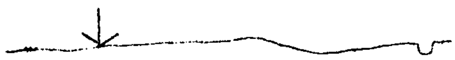
* Not corrected for water soluble sodium.

<u>Additional data</u>

Composite topsoil samples, 0-7" were taken in the virgin soil around profile 13 for carbon/nitrogen ratio and other determinations. Results were : Organic carbon 0.70%; total nitrogen 0.075%; C/N ratio 9.3; available P_2O_5 286 ppm; mineral nitrogen (initial) 2 ppm; mineral nitrogen (after incubation) 20 ppm.

Remarks — The clay fraction at the 20-26 inch level consists mainly of illite with a little kaolinite. The mechanical analysis at the 55-61 inch level is suspect owing to probable partial flocculation of the clay fraction. A hydraulic conductivity measurement (see Remarks - Profile 10) made in situ at the 20 inch level gave a result of 0.27 inches per hour over a 24 hour period.

Profile 14 — Sabi U.2 series, examined April 1962. Upper horizons moist due to rain.

Site —  On relatively low lying ground in very nearly flat topography just south of Mopani Block of Sabi Valley Experiment Station. About 360 yards east of Profile 13.

Ann. Rain — Approx. 17 inches (405 mm)

Veg. — *Colophospermum mopane* woodland which is shorter and less evenly spaced than at Profile 13. Some very young mopani thickets. Extremely sparse grass cover, mainly tufted *Aristida sp*.

P.M. — Granitic alluvium.

Description

0-4" — Brown (10YR5/3, 3/3) medium-grained sandy loam. Moist. Friable consistence, structureless. Very numerous roots. Changes fairly sharply to :-

4-7" — Greyish brown (10YR5/2, 3/2) medium-grained sandy clay. Slightly moist. Hard consistence when dry. Structureless. Very numerous roots. Changes fairly clearly to :-

7-17" — Dark greyish brown (10YR4/2, 3/2) clay. Dry. Very hard consistence, moderate coarse angular blocky structure. Numerous roots. Changes gradually to :-

17-36" — Dark brown (about 9YR4/3, 4/3) similar clay. Feeble coarse angular blocky structure. Fairly numerous roots. Changes gradually to :-

36-44" — Brown (about 8YR4/3, 4/3) clay. Very hard consistence becoming hard with depth. Massive. Isolated, mainly hard, carbonate concretions.

Analytical data

Depth (inches)	0-4	10-16	19-27	37-42
C.S.%	24	16	19	19
M.S.%	17	10	12	10
F.S.%	23	17	17	18
Silt %	21	13	12	11
Clay %	15	44	40	42
pH (sat)	6.1	6.5	6.9	7.6
Cond (sat)	0.30	0.31	0.32	0.38
TEB	12.9	22.2	20.2	30.8
CEC	11.8	22.2	18.6	17.7
free CO''_3	1.1	nil	1.6	13.1
Ca	7.5	13.3	12.5	23.5
Mg	3.9	7.0	5.9	5.8
K	1.2	1.1	1.0	0.8
Na*	0.3	0.8	0.8	0.7
BS	100	100	100	100
E/C value	79	50	47	42
ESP	3	4	4	4

* Not corrected for water soluble sodium.

Additional data

Composite surface samples 0-7" were taken in the virgin area around profile 14 for carbon/nitrogen ratio and other determinations. Results were :-
Organic carbon 0.76%; total nitrogen 0.079%; C/N ratio 9.6; available P_2O_5 355 ppm; mineral nitrogen (initial) 3 ppm; mineral nitrogen (after incubation) 16 ppm.

Remarks

The clay fraction at the 19-27 inch level consists very predominantly of mixed illite-montmorillonoid mixed layer minerals.

Hydraulic conductivity measurements were made *in situ* at the surface and at the 14 inch level. (see Remarks, Profile 10). The surface measurement was 0.36 inches per hour over a 24-hour period and, at the 14 inch level, the results were 0.03 inches per hour over the first 24 hours and nil, or practically so, over the following 24 hours.

Profile 15

Sabi C.1 series, examined May 1961. Topsoil moderately moist due to rain, soil below slightly moist.

Site

About 3 miles from base of hills on about 1% slope in Sabi Valley about 7 miles north-east of Sabi Valley Experiment Station.

Ann. Rain

Approx. 17 inches (405 mm)

Veg.

Acacia-Euphorbia veld with thick grass cover mainly *Urochloa sp.* Most of the Acacias are tall flat-topped *A. tortilis* and most of the Euphorbias are *E. ingens*.

P.M.

Colluvium originating from Umkondo sandstones and limestones of the high range of hills to the East.

Description

0-4"

Brown (7.5YR4/4, 3/4) fine-grained sandy loam. Moderately moist. Friable consistence, structureless. Very numerous roots. Changes gradually to :-

4-12"

Reddish brown (5YR4/4, 3/4) similar sandy clay loam. Slightly moist. Hard consistence. Feeble medium sub-angular blocky structure. Very numerous roots. Changes gradually to :-

12-26"

Dark reddish brown (5YR3/4, 3/4) sandy clay. Slightly moist. Hard to very hard consistence. Moderate medium sub-angular blocky structure. Very numerous roots. Changes clearly to :-

26-48"

Yellowish red (5YR4/6, 4/6) sandy clay. Slightly moist. Hard consistence, becoming slightly hard with depth. Calcareous, numerous roots. Changes gradually to :-

48-72"

Strong brown (7.5YR4/6, 4/6) similar calcareous sandy clay loam. Numerous roots.

Analytical data

Depth (inches)	0-3	6-10	13-19	30-36	60-66
C.S.%	9	8	8	8	8
M.S.%	13	10	9	9	12
F.S.%	44	40	37	38	41
Silt %	17	14	13	6	19
Clay %	17	28	33	39	20
pH (sat)	6.4	6.8	6.9	7.9	7.9
Cond (sat)	0.64	0.29	0.29	0.43	0.66
TEB	10.3	13.7	15.9	73.5	64.3
CEC	12.2	16.1	17.1	16.3	14.8
free CO''_3	nil	nil	nil	57.2	49.1
Ca	6.1	8.6	10.3	69.6	54.0
Mg	3.2	4.1	4.6	2.6	8.8
K	1.0	1.0	1.0	0.9	0.9
Na*	-	-	-	0.4	0.6
BS	84	85	93	100	100
E/C value	72	58	52	42	74
ESP	-	-	-	3	4

* Not corrected for water soluble sodium.

Additional data

Composite surface samples 0-7" were taken in the virgin area around Profile 15 for carbon/nitrogen ratio and other determinations. Results were :- Organic carbon 0.79%; total nitrogen 0.096%; C/N ratio 8.2; available P_2O_5 128 ppm; mineral nitrogen (initial) 4 ppm; mineral nitrogen (after incubation) 22 ppm.

Remarks — No examination of the clay fraction was made.

Profile 16 — Sabi C.2 series, examined May 1962. Soil slightly moist throughout profile.

Site — About $1\frac{1}{2}$ miles from base of hills on very slight slope in Sabi Valley about 10 miles north-east of Sabi Valley Experiment Station.

Ann. Rain — Approx. 17 inches (405 mm)

Veg. — Numerous large flat-topped Acacias, mainly *A. tortilis*. Thick *Urochloa* grass cover.

P.M. — Colluvium from high range of hills to the East. In this part of the range, the hills are composed of Umkondo sandstones and limestones in which numerous dolerite dykes occur.

Description

0-3" — Yellowish red (5YR4/6, about 4YR3/4) sandy clay loam. Slightly hard consistence. Moderate medium granular micro-structure. Very numerous roots. Changes fairly clearly to :-

3-16" — Dark reddish brown (2.5YR3/4, 3/4) clay. Very hard consistence. Moderate coarse angular blocky structure. Very numerous roots. Changes gradually to :-

16-30"	Dark reddish brown (2.5YR2/4, 2/4) clay. Hard consistence. Feeble coarse angular blocky macro-structure, moderate medium granular micro-structure. Numerous roots. Changes clearly to :-
30-50"	Dark reddish brown (2.5YR3/4, 3/4) clay. Hard consistence becoming slightly hard with depth. Very feeble coarse angular blocky macro-structure, moderate medium granular micro-structure. Calcareous with numerous fine filamentous soft carbonate deposits. Numerous diffuse ferro-manganese stains and some small concretions. Fairly numerous roots. Changes gradually to :-
50-66"	Red (2.5YR4/6, 3/4) sandy clay loam. Slight hard consistence. Structureless. Calcareous with numerous soft filamentous carbonate deposits. Some isolated ferro-manganese stains. Some colluvially-borne weathering rock gravel some of which is basic in appearance. Fairly numerous roots. Some rounded stones and boulders appear at the bottom of the pit. These boulders are mostly Umkondo quartzite but a few appear to be dolerite.

<u>Analytical data</u>

Depth (inches)	0-3	7-13	19-25	35-41	54-61
C.S.%	16	15	14	14	18
M.S.%	14	11	10	11	11
F.S.%	33	24	25	26	24
Silt %	15	12	13	17	19
Clay %	22	38	38	32	28
pH (sat)	6.3	6.4	6.9	7.7	7.8
Cond. (sat)	0.42	0.21	0.24	0.34	0.55
TEB	11.8	18.7	21.6	48.8	60.8
CEC	14.5	22.0	25.0	21.6	20.7
free CO''_3	nil	nil	nil	27.2	40.1
Ca	7.4	12.2	15.4	41.0	48.2
Mg	3.6	5.8	5.6	6.8	11.4
K	0.8	0.7	0.6	0.6	0.6
Na*	-	-	-	0.4	0.6
BS	81	85	86	100	100
E/C value	66	58	66	68	74
ESP	-	-	-	2	3

* Not corrected for water soluble sodium.

<u>Remarks</u> The clay fraction at the 19-25 inch level consists very predominantly of illite-montmorillonoid mixed layer minerals.

FERSIALLITIC SOILS

Profile 17 — Salisbury E.2 series, examined September 1956. Topsoil dry, remainder of solum slightly moist.

Site — On level topography on normal upland in Salisbury environs.

Ann. Rain — Approx. 33 inches (840 mm)

Veg. — Tall *Hyparrhenia* grass. Original *Brachystegia spiciformis* - *Julbernardia globiflora* tree vegetation cleared years ago.

P.M. — From epidiorite.

Description

0-8" — Dark reddish brown (5YR3/4, 3/3) clay. Hard consistence. Well developed medium crumb structure. Numerous roots. Changes gradually to :-

8-25" — Dark reddish brown (2.5YR3/4 moist) clay. Hard consistence. Medium sub-angular blocky macro-structure, fine crumb to granular micro-structure. Shiny surfaces or clay coatings on peds visible to naked eye. Numerous small ferro-manganese stains and concretions. A few pores, numerous fine roots. Changes almost imperceptibly to :-

25-36" — Very similar horizon in all respects except that sub-angular blocky macro-structure and clay coatings on peds are slightly less well-developed. Consistence also, is slightly less hard and more pores are apparent. Changes gradually to :-

36-47" — Dark red (2.5YR3/6 moist) clay slightly hard consistence. Weakly developed sub-angular blocky macro-structure, fine crumb to granular micro-structure. Some ferro-manganese stains and concretions. Numerous pores. Changes very very gradually to :-

47-58" — Very similar horizon with only very feeble sub-angular blocky macro-structure. Clay coatings only discernible in some old root channels. Numerous pores. Changes very gradually to :-

58-66" — Slightly brighter red (10R to 2.5YR3/6 moist) clay. Little or no structure apart from fine crumb or granular. Numerous fragments of soft weathering epidiorite. Numerous pores.

Analytical data

Depth (inches)	0-7	9-15	17-24	27-34	38-45	48-56	59-65
C.S.%	3	2	3	3	3	2	2
M.S.%	4	3	2	2	2	1	1
F.S.%	15	8	8	6	8	9	16
Silt %	21	17	19	25	24	26	30
Clay %	47	70	68	64	63	62	51
pH (1 : 5)	6.1	6.3	6.5	6.7	6.5	6.5	6.6
TEB	13.1	12.8	14.2	12.1	12.5	16.6	22.9
CEC	17.7	17.1	17.1	15.2	15.0	19.1	22.9
BS	78	75	83	80	83	87	100
E/C value	31	24	25	24	24	31	45

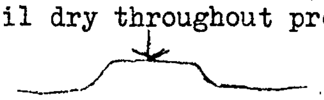
Remarks

No examination of the clay fraction from this particular profile has been made but later examinations of similar soils nearby show a predominance of kaolinite together with some illite-montmorillonoid mixed layer minerals. Although exchangeable calcium and magnesium were not estimated in this instance, numerous analyses on other soils of this series show that the calcium/magnesium ratio generally ranges from 2/1 to 3/1. A hydraulic conductivity measurement (see Remarks, Profile 10) made in situ at the 18" level gave a result of 0.6 inches per hour over a 24-hour period. Similar measurements on very similar red fersiallitic clays in the Salisbury area give results ranging from 0.5 to 1.0 inches per hour over 24-hour periods.

Profile 18

Darwendale X.1 series, examined July 1962. Soil dry throughout profile.

Site



On plateau remnant on top of Great Dyke near Darwendale. Numerous outcrops of hard laterite, probably from earlier cycle of erosion.

Ann. Rain

Approx. 33 inches (840 mm).

Veg.

Scattered *Diplorhynchus condylocarpon*, *Brachystegia boehmii* and *Julbernardia globiflora*.

P.M.

From ultrabasic rocks of Great Dyke, mainly monomineralic enstatite, and lateritic conglomerate.

Description

0-4"

Dark reddish brown (about 4YR3/4, 3/4) clay loam. Slightly hard to hard consistence. Feeble subangular blocky macro-structure, medium crumb to granular micro-structure. Numerous small round hard ferromanganese concretions (lateritic gravel). Numerous roots. Changes gradually to :-

4-17"

Dark red (2.5YR3/6, 3/4) clay. Slightly hard consistence. Similar structure to above. Somewhat more, loosely held laterite gravel as above. No clay coatings were visible to the naked eye. The soil mass contains numerous shiny very small particles which are probably heavy minerals. Numerous roots. Changes clearly to :-

17-36"

Laterite gravel, loosely packed, containing some subrounded quartz gravel and pebbles and some hard enstatite stones and boulders. The latter have about a $\frac{1}{4}$ inch thick orange weathering crust.

Analytical data

Depth (inches)	0-3½	9-16
Gravel %	4.6	16.4
C.S.%	12	14
M.S.%	13	11
F.S.%	25	21
Silt %	21	12
Clay %	29	42
pH (sat)	5.6	5.3
TEB	15.5	13.5
CEC	25.3	16.9
Ca	5.2	1.1
Mg	10.1	12.3
K	0.2	0.1
BS	61	80
E/C value	87	40

Remarks

The clay fraction at the 9-16 inch level contains a considerable amount of illite. According to the differential thermal analysis a small amount of goethite is also present. Due to the presence of appreciable illite in the clay fraction the E/C value of the subsoil is a little on the high side for a fersiallitic soil. The gravel percentage is a measure of the amount of lateritic gravel present.

Profile 19

Sinoia A.1 series, examined April 1962. Soil moist throughout profile due to recent rains.

Site

In flat part of valley about 10 miles north-west of Sinoia.

Ann. Rain

Approx. 32 inches (815 mm)

Veg.

Scattered Brachystegia boehmii, Piliostigma thonningii, Combretum ghasalense, and Diplorhynchus condylocarpon.

P.M.

From arkoses of the Lomagundi system.

Description

0-2½"

Dark greyish brown (10YR4/2 moist) fine-grained, relatively silty, sandy loam. Friable consistence, usually very hard when dry. Fine platy structure on surface of soil. Fairly numerous roots. Changes clearly to :-

2½-5"

Yellowish brown (10YR5/4 moist) similar sandy clay loam. Friable consistence. No structure. Fairly numerous pores. Fairly numerous roots. Changes gradually to :-

5-13"

Yellowish brown (10YR5/4 moist) similar sandy clay. Friable consistence. Numerous diffuse yellowish (10YR5/8 moist), and a few reddish (5YR5/8 moist) mottles. Numerous fine pores. Fairly numerous roots. Changes clearly to :-

13-19"

Mainly lateritic gravel, loosely held in a little soil-like material. Numerous soft, red (2.5YR4/8 moist) lateritic concretions. Few roots. Changes gradually to :-

19-30" Mainly lateritic gravel as above, loosely held in light greyish (10YR6/2 moist) soil-like material. The outer part of each lateritic concretion is coated with soft reddish (2.5YR4/8 moist) material, while the hard centres are a blue-black colour.

Analytical data

Depth (inches)	0-2	8-13	20-26
Gravel %	5.5	13.6	66.2
C.S.%	3	3	5
M.S.%	12	9	7
F.S.%	49	39	37
Silt %	17	16	19
Clay %	19	33	32
pH (sat)	5.5	5.2	5.7
TEB	4.8	5.2	5.3
CEC	5.9	7.9	8.0
Ca	2.8	3.1	3.2
Mg	1.8	2.0	2.0
K	0.2	0.1	0.1
BS	81	66	66
E/C value	31	24	25

Remarks — The clay fraction at the 20-26 inch level consists of kaolinite together with some illite. Although this soil is essentially fersiallitic, it shows some hydromorphic features. High water tables are of relatively short duration only, during periods of heavy rain. The gravel percentage is a measure of the amount of lateritic gravel present.

Profile 20 — Miami F.1 series, examined April 1962. Soil moist throughout profile due to recent rains.

Site

On locally level site in undulating country about 25 miles north-west of Miami.

Ann. Rain — Approx. 30 inches (760 mm)

Veg. — Numerous Julbernardia globiflora and Brachystegia boehmii.

P.M. — From highly micaceous formation running through gneissic country rock.

Description

0-2" Dark greyish brown (10YR4/2 moist) fine to medium grained loamy sand. Friable consistence, no structure. Contains much fine mica. Numerous roots. Changes clearly to :-

2-6" Brown (7.5YR4/4 moist) similar sandy loam, also highly micaceous. Numerous roots. Changes gradually to :-

6-18" Brown (7.5YR4/4 moist) similar sandy clay loam. Clay coatings were clearly discernible on fragment surfaces, even in the presence of much mica. Fairly numerous roots. Changes fairly sharply to :-

18-27" Mainly sub-rounded quartz stones and pebbles, loosely packed. Some micaceous and other more gneissic weathering rock fragments. Fairly numerous roots. Changes fairly sharply to :-

27-40" Highly micaceous very weathered rock with some soil-like material. Fairly numerous roots.

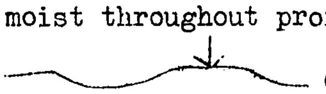
Analytical data

Depth (inches)	0-2	3-5	9-14	29-34
C.S.%	6	6	9	12
M.S.%	26	14	21	21
F.S.%	49	57	35	36
Silt %	9	8	7	7
Clay %	10	15	28	24
pH (sat)	6.0	6.0	5.8	6.2
TEB	3.0	3.4	4.9	5.2
CEC	4.0	4.3	6.1	6.0
Ca	1.8	1.8	2.8	3.7
Mg	0.8	1.2	1.6	1.1
K	0.4	0.4	0.5	0.4
BS	75	79	84	87
E/C value	40	29	22	25

Remarks

At the 29-34 inch level the clay fraction contains kaolinite together with an appreciable amount of illite. On carrying out the mechanical analysis it was noted that in addition to the mica that settled out in the sand and silt fractions, much remained in suspension even after 24 hours.

Profile 21 Karoi F.1 series, examined April 1962. Soil moist throughout profile due to rains.

Site  On locally level site in undulating country about 15 miles south-east of Karoi.

Ann. Rain Approx 34 inches (865 mm)

Veg. Mainly *Brachystegia boehmii* and some *Julbernardia globiflora*.

P.M. From phyllites and micaceous quartzites of the Piriwiri series.

Description

0-2½" Reddish brown (5YR4/4 moist) fine grained sandy loam. Friable consistence, no structure. Finely micaceous. Very numerous roots. Changes clearly to :-

2½-10" Red (about 3YR4/6 moist) similar, finely micaceous sandy clay loam. Very numerous roots. Changes gradually to :-

10-22" Dark red (2.5YR3/6 moist) similar sandy clay loam. Some shiny faces, other than mica, are discernible on fragments. These may be clay coatings. Numerous roots. Changes fairly sharply to :-

22-40" Sub-rounded quartz stones and pebbles, moderately loosely packed. Fairly numerous roots. Changes fairly sharply to :-

40-46" Red (10R4/6 moist) highly weathered soft micaceous phyllite with some soil-like material. Contains numerous sub-rounded quartz pebbles and stones as above. Fairly numerous roots.

Analytical data

Depth (inches)	0-2½	3-7	15-20
C.S.%	2	2	2
M.S.%	6	5	3
F.S.%	70	54	52
Silt %	8	13	16
Clay %	14	26	27
pH (sat)	6.1	5.5	5.2
TEB	4.3	3.1	3.2
CEC	5.6	4.4	4.1
Ca	3.0	1.9	1.4
Mg	1.0	1.0	1.5
K	0.3	0.2	0.2
BS	77	70	78
E/C value	40	17	15

Remarks At the 15-20 inch level the clay fraction contains kaolinite together with an appreciable amount of illite.

Profile 22 Karoi G.1 series, examined April 1962. Soil moist throughout profile due to rains.

Site On about 1% slope in undulating country, about 4 miles south of Karoi.

Ann. Rain Approx. 34 inches (865 mm)

Veg. Mixed Julbernardia globiflora, Piliostigma thonningii, Brachystegia spiciformis, and other trees.

P.M. From granite that appears to be somewhat more micaceous than in other areas.

Description

0-3" Very dark brown (10YR2/2 moist) fine to medium-grained sandy loam. Friable consistence, no structure. Very numerous roots. Changes clearly to :-

3-9" Brown (7.5YR4/4 moist) similar sandy clay loam. Isolated shiny minute particles which may be mica. Very numerous roots. Changes gradually to :-

9-25" Yellowish red (5YR4/6 moist) similar sandy clay. Scattered shiny particles as above. Fragments show surfaces which may be clay coatings. Numerous roots. Changes fairly sharply to :-

25-36" Moderately loosely packed, mainly sub-rounded, quartz stones and pebbles. Fairly numerous roots. Changes fairly sharply to :-

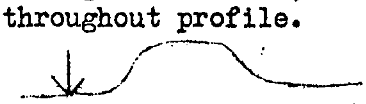
36-45" Reddish (2.5YR4/6 moist) soil-like material with much soft, weathering, relatively fine-grained granite which is slightly micaceous.

Analytical data

Depth (inches)	0-2½	3-7	17-23
C.S.%	5	5	6
M.S.%	14	14	12
F.S.%	57	50	41
Silt %	9	6	5
Clay %	15	25	36
pH (sat)	6.2	5.4	5.8
TEB	7.4	3.4	3.7
CEC	9.1	6.2	6.2
Ca	5.2	2.6	2.8
Mg	1.6	0.6	0.8
K	0.6	0.2	0.1
BS	81	55	60
E/C value	61	25	17

Remarks — At the 17-23 inch level the clay fraction consists of kaolinite together with some illite.

Profile 23 — Rutenga G.1 series, examined August 1962. Soil dry throughout profile.

Site —  On pediment with 3% slope below granite batholith near the confluence of the Nuanetsi and Msawe rivers, about 20 miles north-west of Rutenga.

Ann. Rain — Approx. 18 inches (405 mm)

Veg. — Mainly short Julbernardia globiflora.

P.M. — From granite.

Description

0-5" — Brown (7.5YR4/2, 3/2) medium to coarse-grained sand. Soft consistence, structureless. Very numerous roots. Changes gradually to :-

5-13" — Brown (7.5YR4/2, 3/2) very similar loamy sand. Soft to slightly hard consistence, structureless. Fairly numerous, mainly felspathic partially weathered and unweathered minerals clearly visible to the naked eye. Numerous roots. Changes gradually to :-

13-20" — Brown (7.5YR5/4, 4/4) very similar loamy sand. Slightly hard consistence, easily visible unweathered felspathic minerals as above. Numerous roots. Changes almost imperceptibly to :-

20-30" — Brown (7.5YR5/4, 5YR4/4) similar sandy loam with weatherable minerals as above. Slightly hard to hard consistence. Numerous roots. Changes gradually to :-

30-46" — Brown (about 6YR5/4, 5YR4/4) very similar slightly coarser grained sandy loam with slightly hard consistence. Numerous roots.

Analytical data

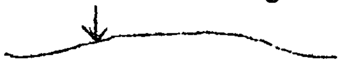
Depth (inches)	0-5	6-12	14-19	20-25	35-46
C.S.%	21	26	25	25	35
M.S.%	22	18	18	18	16
F.S.%	43	39	39	37	29
Silt %	8	8	7	7	6
Clay %	6	9	11	13	14
pH (sat)	6.2	5.8	4.4	4.5	4.5
TEB	4.0	2.7	2.1	2.5	2.6
CEC	4.8	4.1	4.2	4.1	3.8
Ca	2.7	1.5	1.0	1.4	1.5
Mg	1.1	1.0	1.0	1.0	1.0
K	0.2	0.2	0.1	0.1	0.1
BS	83	66	50	61	68
E/C value	80	46	38	32	27

Remarks

The clay minerals at the 20-25 inch level consist of kaolinite and illite, probably in about equal amounts. The tree vegetation is of a type normally found under higher mean annual rainfall than that received locally. This was attributed to appreciable run-off being received from the large bare granite batholith nearby. As a result the soils are probably more leached than normal for the area.

PARA-FERRALITIC SOILS

Profile 24 — Salisbury G.1 series, examined February 1962. Soil moist throughout profile due to rains.

Site —  On about 1% slope on side of broad ridge, in old reverted tobacco land, about 7 miles south of Salisbury.

Ann. Rain — Approx. 33 inches (840 mm)

Veg. — Mainly *Hyparrhenia* grass. Surrounding trees are mainly *Brachystegia spiciformis* and *Julbernardia globiflora*.

P.M. — From granite.

Description

0-6" — Dark yellowish brown (10YR3/4 moist) coarse-grained sand. Very friable consistence, no structure. Numerous roots. (This is an Ap horizon). Changes sharply to :-

6-18" — Dark yellowish brown (10YR4/4 moist) very similar loamy sand. Numerous roots. Changes gradually to :-

18-33" — Brown (7.5YR5/4 moist) similar sandy loam. Isolated felspathic particles discernible to the naked eye. Numerous roots. Changes gradually to :-

33-60" — Strong brown (7.5YR5/6 moist) similar sandy clay loam. Some felspathic particles as above. Fairly numerous roots.

Analytical data

Depth (inches)	0-5	8-14	20-26	48-54
C.S.%	35	29	28	28
M.S.%	30	27	24	22
F.S.%	24	26	25	24
Silt %	4	5	4	4
Clay %	7	13	19	22
pH (sat)	5.6	4.9	4.8	5.3
TEB	1.0	0.6	0.6	0.8
CEC	2.1	3.8	2.3	2.0
Ca	0.5	0.3	0.2	0.2
Mg	0.3	0.2	0.3	0.5
K	0.2	0.1	0.1	0.1
BS	48	16	26	40
E/C value	30	29	12	9

Remarks — The clay fraction at the 20-26 inch level consists entirely of kaolinite and amorphous free sesquioxides of iron and aluminium. The whole profile was highly porous. A hydraulic conductivity measurement (see Remarks, Profile 10) made *in situ* at the 20-inch level gave a highly empirical result of 18.6 inches per hour over a 2-hour period (the more porous the soil, the more empirical the result).
Although few felspathic particles could be discerned in the field there were many, in various stages of weathering, in the separated sand fractions in all horizons.

Profile 25 — Marandellas G.1 series, examined October 1958; upper horizons dry, subsoils slightly to moderately moist.

Site — On about ½% slope near top of broad crest on Grasslands Research Station, Marandellas.

Ann. Rain — Approx. 36 inches (915 mm)

Veg. — Mainly *Brachystegia spiciformis* woodland.

P.M. — From granite.

Description

0-3" — Dark brown (10YR4/3, 3/3) coarse-grained sandy loam. Soft consistence, structureless. Numerous roots. Changes clearly to :-

3-8" — Brown (7.5YR5/4, 4/4) similar sandy clay loam. Numerous roots. Changes gradually to :-

8-30" — Reddish yellow (7.5YR6/6, 5/6) sandy clay. Slightly hard consistence. Very feeble medium crumb micro-structure. Numerous roots. Changes gradually to :-

30-40" — Reddish yellow (7.5YR6/6, 5/6) very similar sandy clay. Slightly gravelly with angular quartz grains larger than 2 mm. Changes almost imperceptibly to :-

40-66" — Very similar material which appears to be slightly more porous.

Analytical data

Depth (inches)	0-4	6-10	20-24	40-44
C.S.%	41	30	26	20
M.S.%	20	24	15	14
F.S.%	13	16	18	21
Silt %	8	7	5	5
Clay %	18	23	36	40
pH (1 : 5)	5.9	5.4	5.5	5.7
TEB	1.7	1.5	0.8	0.8
CEC	3.3	2.9	3.1	2.7
Ca	0.8	0.7	0.4	0.3
Mg	0.7	0.7	0.3	0.4
K	0.2	0.1	0.1	0.1
BS	52	52	26	30
E/C value	18	13	9	7

Remarks — The clay fraction at the 20-24 inch level consists mainly of kaolinite and free sesquioxides of iron and aluminium but a very small amount of gibbsite was also present, indicating a tendency to intergrade towards ortho-ferrallitic.

The whole profile is highly porous. A hydraulic conductivity measurement (see Remarks, Profile 10) made *in situ* at the 21 inch level gave an empirical result of 8.3 inches per hour over a 2-hour period (the more porous the soil, the more empirical the result).

Remarks continued

Although no felspars could be detected by the naked eye, a very rough mineral count made on the fine sand fraction at the 20-24" level indicated that it contains approximately 10% of felspathic remnants in various stages of weathering.

Profile 26

Featherstone M.1 series, examined September 1956. Soil dry in upper part of profile, slightly moist below.

Site

On gently sloping ground on broad crest about 10 miles north-east of Featherstone.

Ann. Rain

Approx. 32 inches (760 mm)

Veg.

Tall close-grown woodland of Brachystegia spiciformis, Julbernardia globiflora, Burkea africana and other trees.

P.M.

From Triassic sandstones (Forest sandstone).

Description

0-2"

Greyish brown (10YR5/2, 4/2) fine-grained sand. Loose and structureless. Very numerous roots. Changes fairly sharply to :-

2-19"

Yellowish brown (10YR5/4, 4/3) similar sand. Very numerous roots. Changes gradually to :-

19-32"

Brownish yellow (10YR6/6, 5/6) similar sand. Soft consistence. Very numerous roots. Changes gradually to :-

32-43"

Yellowish brown (10YR5/6 moist) sand with small amount of clay. Slightly moist. Slightly hard consistence. Numerous roots. Changes gradually to :-

43-59"

Similar (10YR5/6) slightly moist material. When moistened further it is mainly friable but has a certain brittleness. Some small whitish (10YR7/2 moist) and reddish (2.5YR5/6) pockets. This horizon may be slightly lateritised weathering sandstone. Changes gradually to :-

59-70"

Very similar horizon with less pronounced whitish and reddish pockets.

Analytical data

Depth (inches)	0-2	4-17	20-31	34-41	46-57	60-66
C.S.%	2	3	3	3	3	3
M.S.%	14	16	22	17	15	15
F.S.%	78	77	70	66	61	64
Silt %	2	1	1	1	1	1
Clay %	4	3	4	13	20	17
pH (1 : 5)	6.4	5.8	5.6	5.3	5.2	5.4
TEB	2.4	0.6	0.6	1.7	2.8	2.6
CEC	5.1	2.2	1.2	3.0	4.7	3.7
BS	47	27	50	57	60	70
E/C value	145	73	30	23	23	22

<u>Remarks</u>

The sand fractions consist practically entirely of quartz grains most of which are sub-rounded and transparent apart from some surface frosting. No weatherable minerals could be found. The clay fraction at the 34-41 inch level, however, consists mainly of kaolinite and free sesquioxides of iron and aluminium, together with a small amount of illitic minerals. This amount, though small, is sufficient to impart a fersiallitic character to the clay fraction, but the soil has been placed in the para-ferrallitic group on account of the absence of detectable weatherable minerals and the extremely low silt/clay ratio. These soils occur only in association with regosols.

ORTHO-FERRALLITIC SOILS

Profile 27 — Chipinga E.1 series (Red ortho-ferrallitic), examined June 1960. Soil moist throughout profile.

Site — On about 8% slope, east facing aspect, below Mount Selinda about 20 miles south-east of Chipinga.

Ann. Rain — Approx. 45 inches (1145 mm)

Veg. — Mainly grassland with some Veronica podocoma and Leonotis spp.

P.M. — From dolerite.

Description

0-4" — Dark reddish brown (5YR3/3 moist) clay. Friable consistence. Pronounced medium crumb to granular micro-structure. Numerous roots. Changes gradually to :-

4-10" — Dark reddish brown (2.5YR3/3 moist) very similar clay except that crumb structure is slightly coarser. Changes gradually to :-

10-17" — Dark reddish brown (2.5YR3/4 moist) very similar clay. Firm consistence. Very feeble medium sub-angular blocky macro-structure in addition to micro-structure as above. Changes gradually to :-

17-33" — Dark red (between 10 R and 2.5YR3/6 moist) similar clay. Changes almost imperceptibly to :-

33-55" — Dark red (nearer 10R3/6 than 2.5YR3/6 moist) very similar clay.

Analytical data

Depth (inches)	0-4	5-9	11-16	18-23	48-52
C.S.%	1	1	trace	trace	trace
M.S.%	4	3	2	2	1
F.S.%	26	18	13	12	12
Silt%	28	25	23	18	19
Clay%	41	53	62	68	68
pH (sat)	5.6	5.4	5.4	5.5	5.9
TEB	12.5	8.9	4.5	3.2	1.9
CEC	26.4	21.8	15.7	10.3	9.7
Ca	8.1	6.5	3.2	2.1	0.9
Mg	3.9	2.3	1.3	1.1	1.0
K	0.5	0.1	0.1	0.1	trace
BS	47	41	29	20	20
E/C value	64	41	25	15	14

Remarks — Although no examination of the clay fraction was carried out on samples from this profile, appreciable gibbsite in addition to kaolinite was found in a very similar soil derived from dolerite nearby.

Profile 28 — Melsetter M.1 series (Red ortho-ferrallitic), examined April 1960. Soil moist throughout profile.

Site — Cleaned up roadside cutting on about 4% slope on high ridge 10 miles south-west of Melsetter.

Ann. Rain — Approx. 60 inches (1525 mm)

Veg. — Short grass, about 20 yards from edge of wattle plantation.

P.M. — From quartzites and sandstones of the Umkondo system.

Description

0-8" — Dark brown (7.5YR3/2 moist) very fine-grained sandy loam. Very friable, no structure. Numerous roots. Changes clearly to :-

8-15" — Reddish brown (5YR4/4 moist) similar sandy loam. Changes gradually to :-

15-23" — Red (2.5YR5/6 moist) similar sandy clay loam. Changes gradually to :-

23-38" — Red (2.5YR4/6 moist) similar sandy clay loam. Changes very diffusively to :-

38-50" — Red (10R5/6) highly weathered quartzite which appears in every way to be like soil except for some fine filaments of sugary quartz which appear to have been quartz veins in the original quartzite.

Analytical data

Depth (inches)	0-7	9-14	17-22	29-35	43-49*
C.S.%	trace	trace	trace	trace	trace
M.S.%	1	1	1	1	1
F.S.%	68	67	63	61	66
Silt %	15	14	14	17	22
Clay %	16	18	22	21	11
pH (sat)	4.9	4.9	5.0	5.0	5.1
TEB	1.4	0.3	0.5	0.8	1.9
CEC	8.5	4.2	3.5	2.8	2.6
Ca	0.7	0.1	0.1	0.1	0.1
Mg	0.6	0.2	0.4	0.7	1.8
K	0.1	trace	trace	trace	trace
BS	16	7	14	29	73
E/C value	53	24	16	13	24

* Highly weathered rock.

Remarks — An examination of the clay fraction at the 29-34 inch level showed a small amount of gibbsite in addition to kaolinite.

Profile 29 — Chipinga S.1 series (Yellow ortho-ferallitic), examined June 1960. Soil moist throughout profile.

Site — On about 15% slope on edge of old cultivated land, on Southdown Tea Estates about 15 miles east-south-east of Chipinga.

Ann. Rain — Approx. 47 inches (1195 mm)

Veg. — Short grass

P.M. From shales of the Umkondo system.

Description

0-4" Dark brown (7.5 YR3/4 moist) clay with a relatively high silt content. Friable consistence. Moderate medium crumb micro-structure. Numerous roots. Changes clearly to :-

4-9" Reddish brown (5YR4/4 moist) similar clay. Friable to firm consistence. Weak medium crumb micro-structure. Changes gradually to :-

9-34" Yellowish red (5YR5/6 moist) similar clay. Firm consistence. Very feeble medium sub-angular blocky macro-structure, weak medium crumb micro-structure. Changes fairly clearly to :-

34-50" About equal proportions of purple-coloured, soft, weathering shale and soil-like material similar to that of horizon above. Changes fairly clearly to :-

50-60" Almost entirely soft purple shale as above with only a few pockets of soil-like material.

Analytical data

Depth (inches)	0-3½	5-8	18-24	53-59*
C.S.%	trace	trace	trace	trace
M.S.%	1	1	trace	trace
F.S.%	29	22	19	29
Silt %	30	30	24	50
Clay %	40	47	57	21
pH (sat)	4.5	4.6	5.0	5.0
TEB	2.5	1.3	0.9	0.9
CEC	10.7	9.1	6.8	3.5
Ca	1.0	0.3	0.2	0.2
Mg	1.3	0.9	0.6	0.7
K	0.2	0.1	0.1	trace
BS	23	14	13	26
E/C value	27	19	12	17

* Sample consists entirely of soft weathering shale.

Remarks An examination of the clay fraction at the 23-29 inch level, taken from a very similar soil nearby, showed some gibbsite in addition to kaolinite.

Profile 30 Bikita G.1 series (Yellow ortho-ferallitic), examined August 1962. Soil dry throughout solum.

Site On about 3% slope on Chisiana plateau about 7 miles west-south-west of Bikita, in cultivated land.

Ann. Rain Approx. 60 inches (1525 mm)

Veg. Nil (ploughed)

P.M. From granite.

Description

0-8" Dark greyish brown (10YR4/2, 2/2) medium to coarse grained sandy clay loam. Cloddy. Very numerous roots. Changes sharply to :-

8-21" Reddish yellow (5YR6/6, 5/6) clay. Slightly hard consistence, structureless. Numerous roots. Changes very gradually to :-

21-35" Reddish yellow (5YR5/6, 5/8) very similar clay. Slightly hard consistence in upper part becoming soft with depth. Numerous roots. Changes very gradually to :-

35-64" Very similar horizon with fewer roots.

Analytical data

Depth (inches)	1-6	11-17	26-32	49-55
C.S.%	22	19	17	15
M.S.%	18	10	11	8
F.S.%	24	16	17	19
Silt %	15	8	9	9
Clay %	21	47	46	49
pH (sat)	4.5	4.9	5.7	6.0
Org. C. %	1.26	-	-	-
T.N.%	0.120	-	-	-
C/N ratio	10.5	-	-	-
Available P_2O_5 ppm.	17	-	-	-
TEB	1.0	1.5	1.4	1.4
CEC	7.7	4.3	3.0	3.1
Ca	0.8	1.0	1.0	1.1
Mg	0.1	0.4	0.4	0.3
K	0.1	0.1	trace	trace
BS	13	35	47	45
E/C value	37	9	7	6

Remarks An examination of the clay fraction at the 26-32 inch level showed kaolinite with appreciable quantities of gibbsite. Base saturation in the subsoil is higher than normal for this type of soil but the extent to which fertilizer, manurial and lime applications have had an effect, is not known.

Profile 31 Inyangani G.1 series (Humic ortho-ferrallitic), examined June 1960. Soil moist throughout profile.

Site On east facing aspect on foothills below Inyangani mountain, on Eastern Highlands Tea Estate. About 10% slope.

Ann. Rain Approx. 100 inches (2540 mm)

Veg. Cleared ground about 20 yards from edge of tea plantation.

P.M. From granite.

Description

0-10" Very dark brown (10YR2/2 moist) medium to coarse grained sandy loam which is very rich in organic matter. Very friable and crumbly. Very numerous roots. Changes very gradually to :-

10-15" Very dark brown (10YR2/2 moist) very similar horizon in which there appears to be slightly less organic matter. Changes very gradually to :-

15-24" Very dark brown (10YR2/2 moist) very similar sandy clay loam in which, although still very appreciable, there appears to be slightly less organic matter than in the horizon above. Changes gradually to :-

24-32" Dark brown (7.5YR3/2 moist) similar horizon which contains some pockets of strong brown (7.5YR5/6 moist) soil which are far less rich in organic matter. Changes gradually to :-

32-42" Dark brown (7.5YR3/2 moist) organic rich material and strong brown (7.5YR5/6 moist) relatively less organic matter rich material, in about equal proportions. Feeble medium crumb micro-structure. Changes gradually to :-

42-58" Strong brown (7.5YR5/6 moist) clay with a pronounced medium to coarse grained sand fraction. Some darker organic matter stained pockets. Feeble crumb structure as above. Numerous roots. A three inch diameter auger hole was sunk in the bottom of the pit to a depth of 76 inches from the soil surface in order to obtain a sample (70-76") which to all intents and purposes, was free of organic matter. The colour of the material from the auger hole at the 70-76" level was a uniform strong brown colour (7.5YR5/6 moist).

Analytical data

Depth (inches)	0-10	18-24	34-40	44-50	70-76
C.S.%	18	20	17	18	16
M.S.%	22	16	14	14	13
F.S.%	35	27	21	20	19
Silt %	14	15	11	8	9
Clay %	11	22	37	40	44
pH (sat)	4.7	4.9	4.9	4.8	5.2
Org. C. %	3.09	2.05	-	-	-
T.N.	0.250	0.160	-	-	-
C/N ratio	12.4	12.8	-	-	-
TEB	0.6	0.5	0.1	0.2	0.1
CEC	17.8	12.2	7.9	6.3	5.6
Ca	-	-	0.1	0.1	0.1
Mg	-	-	trace	trace	trace
K	-	-	trace	0.1	trace
BS	3	4	2	4	2
E/C value	156	55	22	16	13

Remarks An examination of the clay fraction at the 70-76 inch level showed mainly gibbsite with a little kaolinite.

SODIC SOILS

Profile 32 Salisbury GS.3 series (weakly sodic-hydromorphic intergrade), examined March 1962, about a week after the pit had been dug. Soil mainly moist throughout profile due to rains.

Site On about 1% slope in low catenal position, in country which is mainly very flat and is underlain by solid unjointed granite. About 17 miles west of Salisbury on Atlantica Ecological Research Station.

Ann. Rain Approx. 33 inches (840 mm)

Veg. Grassveld with some Hyparrhenia spp.

P.M. Mainly from granite but some influence from metasediments of the Gold Belts.

Description

0-8" Very dark grey (N3/0 moist) medium to fine-grained sandy loam. Moist. Friable, no structure. Very numerous yellowish brown (10YR5/6 moist) iron stains in root channels. Changes gradually to :-

8-21" Dark grey (N4/0 moist) similar sandy loam. Very moist. Fairly numerous bleached (N6/0 moist) pockets. Iron stains as above. Sharp line change to :-

21-27" Dark grey (N4/0 moist) medium to fine grained sandy clay loam. Slightly moist at first becoming moderately moist with depth. Very hard consistence. Some bleaching (N6/0 moist) along upper horizon boundary. Some yellowish brown (10YR5/8 moist) mottles below about 23 inches. Changes gradually to :-

27-40" Very dark greyish brown (10YR3/2 moist) sandy clay. Moist becoming very moist with depth. Water table at 40 inches. Very numerous yellowish brown (10YR5/8 moist) mottles.

40-52" Below the water table the soil appears to be very similar to that of the horizon above it, except that it is slightly yellower. At 52" there is heterogeneous gravel which includes some shaly fragments. Below this again, weathering granite was encountered.

Analytical data

Depth (inches)	0-7	15-21	22-27	45-50
C.S.%	14	23	21	18
M.S.%	13	16	16	12
F.S.%	44	40	31	23
Silt %	19	15	10	6
Clay %	10	6	22	41
pH (sat)	5.1	5.8	5.2	5.1
TEB	4.1	1.8	8.4	10.5
CEC	6.4	2.8	8.6	11.9
Ca	2.7	1.3	4.9	5.6
Mg	1.3	0.5	2.8	4.3
K	0.1	trace	0.1	0.1
Na	-	-	0.6	0.5
BS	64	64	98	88
E/C value	64	47	39	29
w/s Na	-	-	trace	trace
ESP	-	-	7	5

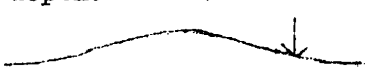
Remarks

The clay fraction at the 22-27 inch level consists mainly of illite with some kaolinite. Some free water has obviously moved along the upper boundary of the 21-27 inch horizon since the pit was excavated. After drying, the vertical surface of this horizon exposed in the profile showed a typical flaky appearance characteristic of soils in which there is some measure of deflocculation of the clay fraction.

Profile 33

Mondoro MG.1 series (strongly sodic soil, also with some hydromorphic features), examined October 1960. Soil dry to 20 inches, slightly moist at the 20-25 inch level, becoming progressively more moist with depth.

Site


On about ½% slope in relatively low-lying position in gently undulating country about 3 miles south of Mondoro.

Ann. Rain

Approx. 30 inches (760 mm)

Veg.

Mainly open grassland (Eragrostis, Tristachya and Hyparrhenia spp.) with a few scattered Protea sp. Julbernardia globiflora, and Brachystegia boehmii.

P.M.

Mainly from Triassic sands but with a significant influence of granite which underlies the Triassic formation at relatively shallow depth.

Description

0-5"

Brown (10YR5/3, 3/3) fine to medium-grained sand. Very soft consistence, structureless. Numerous roots. Changes gradually to :-

5-20"

Very pale brown (10YR7/3, 5/3) similar sand with a few isolated diffuse reddish mottles. Numerous roots. Sharp line change to :-

20-25"

Dark greyish brown (10YR4/2 moist) sand with a little clay. Slightly moist. Extremely hard consistence when dry. Very feebly columnar tops but massive below this. Tops of columns are bleached presumably due to lateral movement of water in the wet season. A few yellowish brown (10YR5/8 moist) mottles near 25 inches, a few fine roots. Changes gradually to :-

25-46" — Dark yellowish brown (10YR4/4 moist) similar sand with a little clay. Slightly moist. Extremely hard consistence when dry, massive. Numerous diffuse reddish (5YR5/6 moist) and yellowish brown (10YR5/8) mottles. A few very scattered hard carbonate concretions. Very occasional fine roots. Changes gradually to :-

46-60" — Yellowish brown (10YR5/4 moist) sand with a little clay. Slightly moist becoming moist with depth. Friable consistence, no structure. Numerous yellowish brown (10YR5/8 moist) mottles. No roots. Changes gradually to :-

60-70" — Very moist to wet yellow and grey gleyed similar material.

Analytical data

Depth (inches)	0-7	12-18	20-25	46-52
C.S.%	10	11	10	11
M.S.%	29	28	26	20
F.S.%	55	59	52	56
Silt %	3	1	2	1
Clay %	3	1	10	12
pH (sat)	5.8	7.2	7.8	7.7
Cond (sat)	0.14	0.20	0.42	0.37
TEB	0.9	0.4	3.6	3.4
CEC	1.7	0.5	3.4	3.5
free CO_3	nil	nil	0.2	nil
Na	-	-	2.01	0.60
w/s Na	-	-	0.07	0.06
BS	53	80	100	97
E/C value	57	50	34	29
ESP	-	-	59	17

Remarks — No examination of the clay fraction was made. Solid unjointed granite formations underlie all of the soils in this area at relatively shallow depth, and it crops out in water-courses in the area. Its influence on the soil is very evident, not only in the relative proportions of coarse, medium and fine sub-fractions of the total sand fraction (c.f. Profiles 1 and 26) but it is also primarily responsible for the hydromorphic as well as the sodic character of the soil.

Profile 34 — Enkeldoorn G.2 series (Strongly sodic), examined October 1960. Soil dry throughout profile.

Site — On about 3% slope in relatively low-lying area bordering water-course, about 7 miles north of Enkeldoorn.

Ann. Rain — Approx. 30 inches (760 mm)

Veg. — Mainly bare ground, with scattered small tufts of grass.

P.M. — From granite.

Description

0-2½" — Greyish brown (10YR5/2, 3/2) medium to coarse-grained sand. Soft to slightly hard consistence, structureless. Numerous fine roots in parts. Changes very abruptly to :-

$2\frac{1}{2}$-8"	Greyish brown (2.5Y5/2, 4/2) medium to coarse-grained sandy clay loam. Very hard consistence. Rounded columnar tops which are bleached due to lateral water movement, thin vertical cracks below. A few fine roots. Changes very gradually to :-
8-16"	Greyish brown (2.5Y5/3, 4/2) similar sandy clay loam. Very hard consistence. Feeble coarse angular blocky structure. Fairly numerous hard carbonate concretions and some softer deposits. Fairly numerous yellowish brown (10YR5/6) diffuse mottles. Changes very gradually to :-
16-26"	Very similar horizon but with some dark grey discolorations. Some weathering granitic gravel. Changes gradually to :-
26-48"	Mainly weathering gneissic granite with some soil-like material similar to that in horizon above.

Analytical data

Depth (inches)	0-2	5-7	9-14
C.S.%	25	22	22
M.S.%	34	24	26
F.S.%	28	24	25
Silt %	8	7	6
Clay %	5	23	21
pH (sat)	6.4	8.0	8.7
Cond (sat)	0.58	1.13	1.53
TEB	3.2	13.4	14.9
CEC	4.1	11.7	8.8
free CO''_3	nil	1.7	6.1
Na	0.45	6.20	6.16
w/s Na	0.09	0.33	0.53
BS	78	100	100
E/C value	82	51	42
ESP	11	53	70

Remarks

No examination of the clay fraction was made. Water which had evaporated in a water-course nearby left a white efflorvescence in places. This efflorvescence consisted almost entirely of sodium carbonate and bi-carbonate. Some of the weathering gneissic granite in the water-course effervesced with acid presumably due to impregnation with such salts as the water evaporated. Freshly broken unweathered rock, however, showed no such reaction. Most of the granites in Southern Rhodesia are soda-granites and the main felspathic constituents are albitic plagioclases. There can be little doubt that the sodium which gives rise to sodic soils originates from weathering of these felspars. Were this not the case, highly soluble salts such as sodium carbonate would have been removed long ago under the prevailing rainfall.
The A horizons of the profile have been largely removed by erosion.

Profile 35 — Salisbury GS.4 series (Strongly sodic) examined March 1962. Frist inch or so moist due to rains, remainder of profile dry except in vicinity of water which had collected in the bottom pit from run-off.

Site — In a bare patch on nearly level ground in relatively low-lying position flanking a water-course on Atlantica Ecological Research Station about 17 miles west of Salisbury.

Ann. Rain — Approx. 33 inches (840 mm)

Veg. — Nil

P.M. — Mainly from granite but with an appreciable influence of inter-bedded sediments of the Gold Belts.

Description

0-1" — Greyish brown (10YR5/2, 4/2) fine to medium grained sandy loam. Moist. Friable consistence, no structure. Some sub-rounded quartz pebbles on surface. Changes very abruptly to :-

1-7" — Dark greyish brown (10YR4/2, 3/2) clay. Slightly moist in first ½ to 1 inch, dry below. Very hard consistence. Upper surface has rounded columnar tops, thin irregular, mainly vertical, cracks below. Very isolated minute hard carbonate concretions. Changes very gradually to :-

7-23" — Similar heavy clay with strong medium angular blocky structure. Slightly more numerous carbonate concretions.

23-43" — Very similar heavy clay which is calcareous as well as sodic. Numerous large hard carbonate concretions which show a finely crystalline structure when broken. The level of run-off water in the pit was 43 inches and the soil becomes moist about 2 inches above this level. The water had become a slightly viscous gel due to suspended deflocculated clay.

Analytical data

Depth (inches)	0-1	2-7	14-20	29-35
C.S.%	12	6	5	7
M.S.%	17	9	6	7
F.S.%	49	30	21	23
Silt %	13	17	14	12
Clay %	9	38	54	51
pH (sat)	6.1	8.5	8.7	8.9
Cond (sat)	0.70	1.06	1.00	0.82
TEB	3.7	34.1	54.9	80.5
CEC	5.5	24.0	30.9	27.8
free CO''_3	nil	10.1	24.0	52.7
Ca	1.1	12.9	21.5	40.4
Mg	2.5	11.1	17.5	25.4
K	0.1	0.2	0.2	0.2
Na	-	9.9	15.7	14.5
w/s Na	-	0.7	1.0	1.6
BS	67	100	100	100
E/C value	61	63	57	55
ESP	-	41	51	52

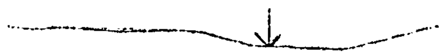
Remarks

The Atlantica Ecological Research Station is on the edge of an extensive very flat area underlain by solid unjointed granite. As a result most of the soils over this tract are characterised by high water-tables but in places sodium released from the weathering of albitic plagioclases in the granite, has accumulated in the soils to give rise to small areas in which the soils are either strongly sodic as in the profile just described, or weakly sodic as in Profile 32.

Profile 36

Sabi U.4 series (Saline sodic soil), examined August 1963. Soil dry throughout profile.

Site



About half-way down bare sloping ground flanking the lowest part of the Dagati pan in the lower Sabi Valley.

Ann. Rain

Approx. 16 inches (405 mm)

Veg.

Nil

P.M.

Mainly granitic alluvium.

Description

0-4"

Greyish brown (10YR5/2, 4/2) very coarse-grained sandy loam. Hard consistence, massive. Surface veneer of coarse sand about 1 mm thick. Below this, pale (10YR7/2) very thin skin or coating. Soil mass effervesces gently with acid. Some organic (black-alkali) stains in places. No roots. Changes fairly clearly to :-

4-14"

Yellowish brown (10YR5/4, 4/4) very coarse-grained sandy clay loam. Very hard consistence, massive. Much white flecking due to sand and gravel fracture caused by digging implements. Soil mass effervesces vigorously with acid. Some large very hard, very irregular-shaped carbonate concretions which occlude sand grains. Changes gradually to :-

14-24+"

Brown (7.5YR5/4, 4/4) similar sandy clay. Very hard to extremely hard consistence, massive. White flecking as above. Soil mass effervesces less vigorously with acid than horizon above. Numerous hard concretions as above. Some reddish and blue-black ferromanganese stains in places. Very gravelly.

Analytical data

Depth (inches)	0-4	7-13	18-24
C.S.%	33	37	28
M.S.%	10	14	13
F.S.%	20	18	18
Silt %	21	9	8
Clay %	16	22	33
pH (sat)	10.1	10.3	10.0
Cond (sat)	15 +	15 +	± 12
TEB	41.9	15.3	28.0
CEC	20.4	9.6	14.0
free CO_3''	21.5	5.7	14.0
Ca	17.0	2.5	10.0
Mg	3.7	1.3	4.5
K	0.8	0.7	1.1
Na	20.4	10.8	12.4
BS	100	100	100
E/C value	127	44	42
ESP	100	100	89

Composition of the saturation extracts in milligram equivalents per litre

Depth (inches)	0-4	7-13	18-24
Ca	1.1	2.1	0.9
Mg	3.6	2.0	5.3
Na	282.1 (6.3m.e.%)	289.2 (6.0m.e.%)	150.4 (4.3m.e.%)
K	0.3	0.4	0.3
CO''_3	91.8	108.0	47.9
HCO'_3	24.4	24.6	19.1
Cl'	109.5	109.3	62.1
SO''_4	35.7	22.2	12.2
PO'''_4	3.1	6.9	4.0
Total cations	287.1	293.7	156.9
Total anions	264.5	270.0	145.3

Remarks

No examination of the clay fraction was made. The water-soluble sodium figures in the saturation extracts correspond to 6.3, 6.0, and 4.3 m.e.% respectively, in the soil. In spite of making allowance for them, the derived exchangeable sodium figure for the 7-13 inch level is greater than the cation exchange capacity. It would appear, therefore, that owing to solubility product and other effects, the amount of sodium measured in the saturation extract is not a true indication of the water soluble sodium content of at least some highly saline sodic soils.

CALCIC HYDROMORPHIC SOILS

Profile 37 Salisbury E.4 series (Calcic hydromorphic vertisol), examined September 1955. Soil dry at surface, becoming progressively moist with depth.

Site In low catenal position near edge of very wet area flanking a water-course in the Salisbury environs, near site of Profile 17 (red fersiallitic clay).

Ann. Rain Approx. 33 inches (840 mm)

Veg. Hygrophilous grasses and herbs.

P.M. From epidiorite.

Description

0-1" Black (N2/0, 2/0) heavy clay. Strong medium to coarse granular structure. The granules themselves are very hard. Some wide vertical cracks. Very numerous roots. Changes clearly to :-

1-6" Black (N2/0 moist) similar clay. Slightly moist. Fine to medium angular blocky structure, some wide vertical cracks. Very numerous roots. Changes gradually to :-

6-13" Black (N2/0 moist) similar clay. Moist. Irregular coarse angular blocky structure, fairly numerous slickenslide surfaces. Extremely firm consistence. Some patches containing numerous small hard carbonate concretions. Numerous roots. Changes gradually to :-

13-27" Very dark grey (N3/0 moist) heavy clay. Very moist. Pronounced slickenslides, some very large. Fairly numerous hard carbonate concretions as above. Fairly numerous fine roots. Changes gradually to :-

27-45" Very dark grey (5Y3/1 moist) similar clay. Very moist. Pronounced slickenslides as above. Some diffuse yellowish brown (10YR5/8 moist) mottles near 45 inches. Numerous sub-rounded quartz stones and more angular unweathered epidiorite fragments, also at this depth. Carbonate concretions diminish with depth. Few fine roots. Changes gradually to :-

45-53" Olive grey (5Y4/2 moist) similar clay. Wet. Some large slickenslides. Numerous yellowish brown (10YR5/8 moist) mottles, becoming more numerous with depth. Numerous quartz and epidiorite stones as above.

Analytical data

Depth (inches)	0-1	2-5	15-23	30-38
M.S. + C.S.%	9	7	9	9
F.S.%	19	13	18	10
Silt %	16	12	10	9
Clay %	56	68	63	72
pH (1 : 5)	6.7	6.9	8.6	7.8
TEB	58.5	66.9	102.7	59.7
CEC	60.6	69.7	54.0	58.6
Free CO''_3	nil	nil	48.7	1.1
BS	97	96	100	100
E/C value	108	103	86	81

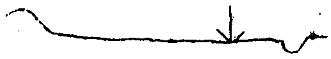
Remarks

The clay fraction at the 15-23 inch level consists practically entirely of montmorillonite.
The mechanical analyses at this level and to a lesser extent at the 30-38 inch level, are not very accurate since both samples showed thixotropic properties.
In order to obtain an approximate mechanical analysis of the sample from the 15-23 inch level, only 25 grams of soil, instead of the normal 50 grams, had to be taken for mechanical analysis by the hydrometer method.

Profile 38

Mazoe S.3 series (Calcic hydromorphic clay), examined June 1964. Soil dry at surface becoming moist with depth, water table at 54 inches.

Site


On flat ground in low catenal position about 4 miles south-east of Mazoe.

Ann. Rain Approx. 30 inches (760 mm)

Veg. Sedges and reeds.

P.M. From interbedded metasediments of the Gold Belts.

Description

0-8" Black (N2/0 moist), relatively silty clay. Hard consistence. Moderate, medium sub-angular blocky structure. Numerous rust-like stains in root channels. Changes clearly to :-

8-20" Black (N2/0 moist) heavy clay. Very slightly moist. Very hard to extremely hard consistence. Moderate, coarse prismatic structure with shiny pressure faces between the peds. Numerous rust-like stains in root channels in upper part of this horizon. A few small yellow (2.5Y5/6) mottles. Changes fairly clearly to :-

20-34" Very dark grey (N3/0 moist) similar clay. Moist. Very firm consistence. Very coarse angular blocky cracking pattern on surface. Some pressure faces evident. Prominent yellow (2.5Y5/6) mottles. Changes clearly to :-

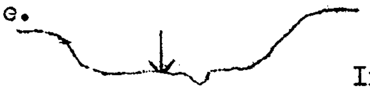
34-54" Mottled gley horizon, matrix N3/0, mottles (2.5Y5/6) Moist. Very firm consistence. Water table at 54 inches.

Analytical data

Depth (inches)	0-6	12-18	24-30	40-46
C.S.%	2	2	3	2
M.S.%	2	2	2	2
F.S.%	29	20	24	28
Silt %	34	25	23	18
Clay %	33	51	48	50
pH (sat)	5.6	6.5	6.9	6.7
Cond (sat)	0.21	0.20	0.11	0.10
TEB	22.2	26.6	18.9	15.8
CEC	31.4	29.6	21.9	20.7
Ca	12.8	14.8	10.2	8.5
Mg	9.0	11.4	8.5	7.1
K	0.4	0.4	0.2	0.2
BS	71	90	86	76
E/C value	95	58	46	41

Remarks No examination of the clay fraction has been made.

Profile 39 Mazoe C.2 series (Humic calcic hydromorphic clay), examined February 1964. Soil moist to wet throughout profile.

Site  In low lying area at base of hills, flanking the Marodzi river, about 5 miles south of Mazoe.

Ann. Rain Approx. 30 inches (760 mm)

Veg. Sedges and reeds.

P.M. Colluvial material off epidiorite.

Description

0-11" Very dark brown (10YR2/2 moist) clay, very rich in organic matter. Very moist. Crumbly. Numerous rust-like stains along root channels. Some orange (7.5YR4/4) discolorations or mottles. Changes fairly sharply to :-

11-17" Mainly non-sticky, crumbly, black (N2/0 moist) organic matter with many occlusions of material similar to horizon above. Numerous stainings as above. Very moist. Changes clearly to :-

17-28 +" Dark grey (5Y4/1 moist) clay, very rich in organic matter. Some orange (7.5YR4/4) mottles and some more neutral grey (N4/0) pockets. Some pockets or occlusions of black (N2/0) organic matter as in horizon above.

Analytical data

Depth (inches)	0-8	$11\frac{1}{2}$-15	19-26
C.S.%	trace	1	trace
M.S.%	trace	5	1
F.S.%	21	27	15
Silt %	43	37	40
Clay %	36	30	44
pH (sat)	6.3	6.3	6.3
Org. C. %	4.30	14.92	5.04
T.N.%	0.351	1.080	0.416
C/N ratio	12.2	13.8	12.1
Available P_2O_5 ppm.	27	22	6
Cond (sat)	4.2	0.6	0.4
TEB	61.0	106.0	47.2
CEC	55.9	95.3	48.3
free CO''_3	5.1	10.7	nil
Ca	46.4	86.1	36.2
Mg	13.1	19.8	10.9
K	1.5	0.1	0.1
BS	100	100	98
E/C value	156	317	111

Remarks No investigation of the clay minerals was possible. Since organic matter was not destroyed mechanical analyses and the E/C values are meaningless as a measure of the activity of the clay fractions but they correlate, very roughly, with the amounts of organic matter present. The high electrical conductivity in the surface horizon may be due largely to calcium and magnesium bi-carbonates.

NON-CALCIC HYDROMORPHIC SOILS

Profile 40 — Salisbury G.3 series (non-calcic hydromorphic soil), examined August 1955. Soil dry at surface, slightly moist below becoming very moist with depth.

Site — On very nearly level ground near Lydiate (about 35 miles west of Salisbury).

Ann. Rain — Approx. 32 inches (815 mm)

Veg. — Mainly open grassland (*Hyparrhenia spp.*) with scattered *Parinari curatellaefolia* and *Protea sp.*

P.M. — From granite.

Description

0-4" — Greyish brown (2.5Y5/2, 4/2) medium to coarse-grained sand. Soft consistence, structureless. Very numerous roots. Changes gradually to :-

4-10" — Pale brown (10YR6/3, 5/3) similar sand. Slightly moist. Numerous roots. Changes gradually to :-

10-31" — Light yellowish brown (10YR6/4 moist) similar loamy sand. Moist. Very friable consistence, no structure. Pronounced diffuse yellowish brown (10YR5/6 moist) stains. Numerous roots. Changes gradually to :-

31-47" — Light grey (10YR7/2 moist) similar loamy sand. Very moist to wet. Much yellowish red (5YR5/8 moist) iron-rich, moderately hard lateritic concretionary material. Water table at 47 inches.

Analytical data

Depth (inches)	0-3	19-24	40-44
C.S.%	29	22	24
M.S.%	32	27	27
F.S.%	29	35	31
Silt %	5	4	6
Clay %	5	12	12
pH (1 : 5)	5.6	4.7	5.1
TEB	1.5	0.5	0.6
CEC	2.3	2.3	3.0
BS	65	22	20
E/C value	46	19	25

Remarks — No examination of the clay fraction was made. Hydromorphic soils extend even up to the tops of the very slight crests in this relatively flat country. The reason for the hydromorphic conditions is the solid unjointed granite which underlies the whole area. It crops out on the surface in places and its unjointed solid nature is clearly shown in a disused quarry some miles away, which was about 100 yards long, 40 yards wide, and about 70 feet deep. It was abandoned because of water which flowed into the workings along the top of the granite.

Profile 41 — Umvuma K.1 series (Humic non-calcic hydromorphic soil), examined August 1962. Top 3 inches dry, moderately moist below becoming very moist with depth.

Site — On edge of relatively steep-sided depression (vlei) about 7 miles south of Umvuma.

Ann. Rain — Approx. 28 inches (710 mm)

Veg. — Some bracken and ferns, in patches.

P.M. — Kalahari sand, possibly with a little influence of granite which underlies the Kalahari sand at relatively shallow depth.

Description

0-3" — Dark grey (N4/0, 2/0) very light, loose material which appears to be mainly organic matter. On very close examination however it is seen to contain much fine sand. Moistens only with difficulty. Changes very gradually to :-

3-9" — Black (N2/0 moist) similar material with more sand. Moderately moist. Very numerous sedge-like roots coated with yellowish brown (10YR5/8) stains. Changes almost imperceptibly to :-

9-19" — Black (N2/0 moist) very similar material. Moist. Changes abruptly to :-

19-65" — White (N8/0, 10YR7/2) medium to coarse-grained sand. Moist becoming very moist with depth. Very numerous roots with yellowish brown (10YR5/8 moist) stains as above. Also some diffuse stains between roots. The roots decrease with depth. Water table at 65 inches. Some coarse granitic-looking particles discernible in these sands.

Analytical data

Depth (inches)	0-3	4-8	10-16	20-26
C.S.%	11	19	15	25
M.S.%	13	20	19	34
F.S.%	54	40	45	37
Silt %	16	14	14	2
Clay %	6	7	7	2
pH (sat)	3.7	3.8	3.6	4.3
Org. C. %	9.22	3.69	5.48	-
T.N.%	0.58	0.22	0.31	-
C/N ratio	15.9	16.8	17.5	-
Available P_2O_5 ppm.	27.0	5	7	-
TEB	0.7	0.2	0.2	0.2
CEC	30.6	14.4	19.2	1.0
Ca	0.4	0.2	0.2	0.1
Mg	0.2	trace	trace	0.1
K	0.1	trace	trace	trace
BS	2	1	1	20
E/C value	510	206	274	50

Remarks — Since organic matter was not destroyed the mechanical analyses and the E/C values are meaningless as measures of the activity of the clay fractions but they correlate, very roughly, with the amounts of organic carbon present. In addition, the E/C value at the 20-26 inch level is only very approximate due to the extremely low clay content. The soils about 30 yards up the slope are regosols, typical of Kalahari sands.

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INDEX

TYPICAL SOIL SERIES DESCRIBED IN APPENDIX A.

APPENDIX B

METEOROLOGICAL DATA

(Per)iod used for (ra)infall	PLACE		RAINFALL July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Year		Mean °F Max.	Mean °F Min.	Mean R.H. % 0600	Mean R.H. % 1400	Period Used Extremes	Period Used R.H.
(19)31-1961	FORT VICTORIA	1	0.09	0.09	0.18	0.80	2.94	5.36	5.30	4.76	3.24	0.71	0.23	0.39	24.09	Jul.	70.9	41.7	85	33	1931-61	1951-61
(18)98-1961	Lat. 20°04'S. Long. 30°52'E.	2	0.59	0.79	1.78	3.90	6.97	19.14	20.75	15.79	11.36	3.68	1.74	1.76	54.61	Oct.	85.8	59.2	76	32		
	Altitude 3595'	3	0.00	0.00	0.00	0.00	0.17	0.53	0.22	0.11	0.03	0.00	0.00	0.00	9.60	Jan.	81.9	62.8	94	59		
(19)31-1961	GATOOMA	1	0.00	0.01	0.13	1.18	3.52	7.09	7.26	6.27	3.65	1.19	0.17	0.07	30.54	Jul.	74.7	46.1	74	29	1931-61	1951-61
(18)98-1961	Lat. 18°19' S. Long. 30°54'E.	2	0.25	0.13	1.51	3.96	8.24	16.68	17.00	17.13	11.92	4.36	1.70	0.80	52.39	Oct.	89.8	61.6	65	25		
	Altitude 3790'	3	0.00	0.00	0.00	0.00	0.14	1.89	0.52	0.09	0.04	0.00	0.00	0.00	17.16	Jan.	82.3	63.2	91	58		
	SALISBURY	1	0.04	0.06	0.21	1.16	3.72	6.81	7.97	7.10	4.24	1.20	0.35	0.18	33.04	Jul.	69.9	43.6	78	30	1951-61	1951-61
(18)96-1956	Lat. 17°50'S. Long. 31°01'E.	2	0.48	1.78	3.08	3.43	9.29	16.82	18.84	18.79	11.98	3.95	1.95	0.99	50.84	Oct.	83.2	58.2	70	30		
	Altitude 4831'	3	0.00	0.00	0.00	0.00	0.63	1.03	0.70	1.15	0.32	0.00	0.00	0.00	17.76	Jan.	78.1	60.3	93	60		
(19)01-1956	MARANDELLAS	1	0.07	0.10	0.29	1.33	4.37	7.72	8.44	7.05	5.46	1.38	0.49	0.14	36.84	Jul.	66.5	42.7	86	33	1933-61	1953-61
(19)00-1961	Lat. 18°10'S. Long. 31°30'E.	2	1.01	1.44	4.93	7.52	11.21	23.31	19.53	14.12	16.83	5.12	7.04	1.30	71.53	Oct.	80.4	55.5	78	30		
	Altitude 5400'	3	0.00	0.00	0.00	0.00	0.42	2.08	1.65	0.37	0.15	0.00	0.00	0.00	18.21	Jan.	75.5	58.1	95	60		
(19)31-1961	SABI	1	0.08	0.09	0.19	0.70	2.55	3.39	3.83	3.14	2.50	0.49	0.30	0.31	17.57	Jul.	78.7	45.4	87	35	1951-61	1951-61
(19)27-1961	Lat. 20°21'S. Long. 32°20'E.	2	0.60	0.98	1.82	2.82	4.72	10.38	17.15	8.57	10.24	2.24	1.85	1.75	36.89	Oct.	92.8	63.0	78	30		
	Altitude 1465'	3	0.00	0.00	0.00	0.00	0.00	0.55	0.44	0.00	0.00	0.00	0.00	0.00	8.43	Jan.	88.4	67.7	90	53		
(19)26-1956	TRIANGLE	1	0.22	0.14	0.33	0.73	3.04	4.59	5.53	4.16	3.92	1.12	0.29	0.42	24.49	Jul.	79.4	42.8	89	34	1944-60	1951-60
(19)21-1959	Lat. 21°01'S. Long. 31°24'E.	2	3.01	0.76	2.01	4.43	7.00	12.95	15.92	11.00	12.70	5.70	1.69	3.70	45.08	Oct.	92.5	62.2	81	30		
	Altitude 1380'	3	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.07	0.00	0.00	0.00	0.00	5.93	Jan.	89.6	67.8	94	55		
	TULI	1	0.04	0.06	0.13	1.09	2.62	3.39	3.81	3.14	2.54	0.80	0.13	0.17	17.92	Jul.	75.8	41.9	81	35	1954-61	1954-61
(19)33-1961	Lat. 21°23'S. Long. 28°59'E.	2	0.41	0.30	1.43	4.81	6.27	9.12	12.73	9.19	8.70	4.72	1.00	1.42	32.51	Oct.	89.8	61.2	73	32		
	Altitude 2510'	3	0.00	0.00	0.00	0.00	0.15	0.00	0.14	0.00	0.00	0.00	0.00	0.00	5.67	Jan.	86.4	64.3	92	51		
	BULAWAYO	1	0.03	0.03	0.16	0.92	3.34	5.06	5.64	4.24	3.11	0.78	0.36	0.07	23.74	Jul.	69.8	44.6	71	29	1936-56	1936-56
(18)96-1956	Lat. 20°09'S. Long. 28°37'E.	2	0.86	0.47	1.91	4.57	9.48	13.37	12.72	14.47	9.94	4.62	3.54	1.27	47.33	Oct.	85.1	59.6	68	28		
	Altitude 4405'	3	0.00	0.00	0.00	0.00	0.16	0.12	0.00	0.00	0.05	0.00	0.00	0.00	7.85	Jan.	80.1	61.2	90	55		
24	CHIRUNDU	1	0.00	0.00	0.00	0.47	2.79	5.84	6.95	5.75	3.28	0.63	0.00	0.07	25.78	Jul.	82.7	51.8	80	34	1951-61	1951-61
years	Lat. 16°00'S. Long. 28°54'E.	2	0.04	0.05	0.01	3.57	7.12	9.90	11.67	11.20	11.85	2.75	0.06	0.95	–	Oct.	98.9	73.0	55	25		
	Altitude 1295'	3	0.00	0.00	0.00	0.00	0.65	0.84	1.72	0.29	0.00	0.00	0.00	0.00	–	Jan.	88.4	71.1	95	62		
(19)55-1960	INYANGANI "B"	1	1.60	1.71	2.77	6.01	11.11	23.85	22.79	20.72	11.12	9.00	2.09	3.01	115.78	Jul.	72.1	51.1	Not Recorded		1953-61	–
(19)53-1964	Lat. 18°20'S. Long. 32°55'E.	2	2.85	4.53	7.46	10.92	19.11	32.78	39.26	33.38	27.26	17.90	5.24	5.64	160.83	Oct.	83.3	59.9				
	Altitude 3450'	3	0.03	0.42	0.00	0.30	4.08	11.39	4.13	12.28	3.64	1.43	0.15	0.72	70.48	Jan.	81.4	64.0	–			
(1)931-1960	BEIT BRIDGE	1	0.07	0.03	0.27	0.81	1.65	2.51	3.36	1.99	1.57	0.67	0.16	0.18	13.27	Jul.	77.9	46.1	77	33	1951-61	1951-61
(1)921-1963	Lat. 22°13'S. Long. 30°00'E.	2	1.23	0.64	3.03	4.20	6.78	8.31	17.80	5.41	6.18	4.04	2.30	1.50	25.19	Oct.	90.3	66.4	68	33		
	Altitude 1500'	3	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	4.32	Jan.	89.7	69.8	83	46		

Sheet 2.

Period used for Rainfall	PLACE		July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Apr.	May	June	Year		Mean Max. °F	Mean Min. °F	Mean R.H. % 0600	Mean R.H. % 1400	Period Used Extremes	Period Used R.H.
1925–1955	BIKITA	1	0.69	0.55	0.51	1.16	4.25	7.26	8.59	7.64	7.16	1.79	0.76	1.05	41.41	Jul.	69.6	49.4	Not Recorded		1933–49	–
(1925–1963	Lat. 20°08'S. Long. 31°00'E.	2	2.06	2.24	2.17	5.75	11.08	21.38	27.31	23.47	15.73	5.08	2.70	6.71	75.45	Oct.	84.4	62.0				
(	Altitude 3190'	3	0.00	0.00	0.00	0.00	0.39	0.11	2.01	0.00	0.70	0.00	0.00	0.00	26.31	Jan.	81.5	64.3	–			
1955–1961	CHISENGU	1	1.13	1.36	1.54	2.16	4.23	11.37	8.23	9.49	7.29	3.00	0.91	3.18	53.89	Jul.	62.3	46.7	76	57	1955–61	1955–61
–	Lat. 19°54'S. Long. 32°53'E.							NOT		AVAILABLE						Oct.	74.7	56.4	70	56		
–	Altitude 4865'															Jan.	72.7	58.2	89	75		
1926–1955	DETT	1	0.00	0.01	0.07	0.79	2.63	5.26	6.82	5.49	3.32	0.99	0.22	0.01	25.61	Jul.	75.8	38.3	76	28	1951–61	1951–61
(1926–1963	Lat. 18°43'S. Long. 26°56 E.	2	0.02	0.32	1.26	4.10	6.31	14.82	21.23	16.38	11.06	4.52	1.65	0.17	39.01	Oct.	91.6	61.6	64	26		
(	Altitude 3532'	3	0.00	0.00	0.00	0.00	0.54	0.24	2.20	0.39	0.00	0.00	0.00	0.00	14.21	Jan.	82.9	63.9	92	59		
1904–1955	ENKELDOORN	1	0.07	0.06	0.22	1.26	3.81	6.33	7.62	5.38	3.72	0.77	0.21	0.12	29.57	Jul.	67.6	43.2	88	37	1957–61	1957–61
(1904–1962	Lat. 19°02'S. Long. 30°53'E.	2	0.53	0.63	1.23	7.66	9.74	15.39	23.42	12.12	13.94	3.48	1.65	1.17	60.02	Oct.	82.5	56.1	79	33		
(	Altitude 4830'	3	0.00	0.00	0.00	0.00	0.24	0.00	0.29	0.09	0.02	0.00	0.00	0.00	13.61	Jan.	78.3	59.6	92	56		
1898–1953	GWELO	1	0.03	0.05	0.20	0.85	3.80	5.99	5.92	5.46	3.42	0.75	0.29	0.10	26.86	Jul.	68.2	39.2	81	33	1951–61	1951–61
(1898–1963	Lat. 19°27'S. Long. 29°51'E.	2	0.17	1.79	1.56	5.51	9.80	15.58	13.55	13.26	14.17	3.85	2.16	2.42	47.21	Oct.	83.4	56.2	75	32		
(	Altitude 4688'	3	0.00	0.00	0.00	0.00	0.18	0.25	0.46	0.07	0.16	0.00	0.00	0.00	11.61	Jan.	77.8	59.3	93	59		
(	MELSETTER	1	0.76	0.48	0.49	1.26	4.50	7.80	10.85	8.26	7.26	1.93	1.03	0.84	45.46	Jul.)					–	–
(1899–1955	Lat. 19°49'S. Long. 32°52'E.	2	3.00	3.38	3.21	4.53	10.64	20.91	35.07	29.39	18.89	6.48	3.25	3.68	102.08	Oct.)	Not Recorded					
(	Altitude 4820'	3	0.00	0.00	0.00	0.00	0.22	0.85	1.83	0.69	0.70	0.00	0.02	0.00	23.72	Jan.)						
(	UMVUKWES	1	0.03	0.04	0.11	0.57	4.00	7.88	8.02	6.60	5.97	1.06	0.19	0.03	34.50	Jul.	68.3	43.2	87	38	1962 –	1964
(1926–1956	Lat. 17°00'S. Long. 30°53 'E.	2	0.21	1.16	0.75	4.70	9.11	14.79	14.10	15.52	14.04	3.67	1.13	0.19	53.37	Oct.	83.8	57.1	73	29	only	
(	Altitude 4820'	3	0.00	0.00	0.00	0.00	1.48	0.00	1.51	0.68	0.07	0.00	0.00	0.00	17.86	Jan.	75.6	59.9	98	68		

NOTES : (a) 1 = Mean monthly and mean annual rainfall

2 = Highest rainfall in any one month and highest total rainfall in any one year.

3 = Lowest rainfall in any one month and lowest total rainfall in any one year.

(b) R.H. = Relative humidity.

(c) Rainfall given in inches.