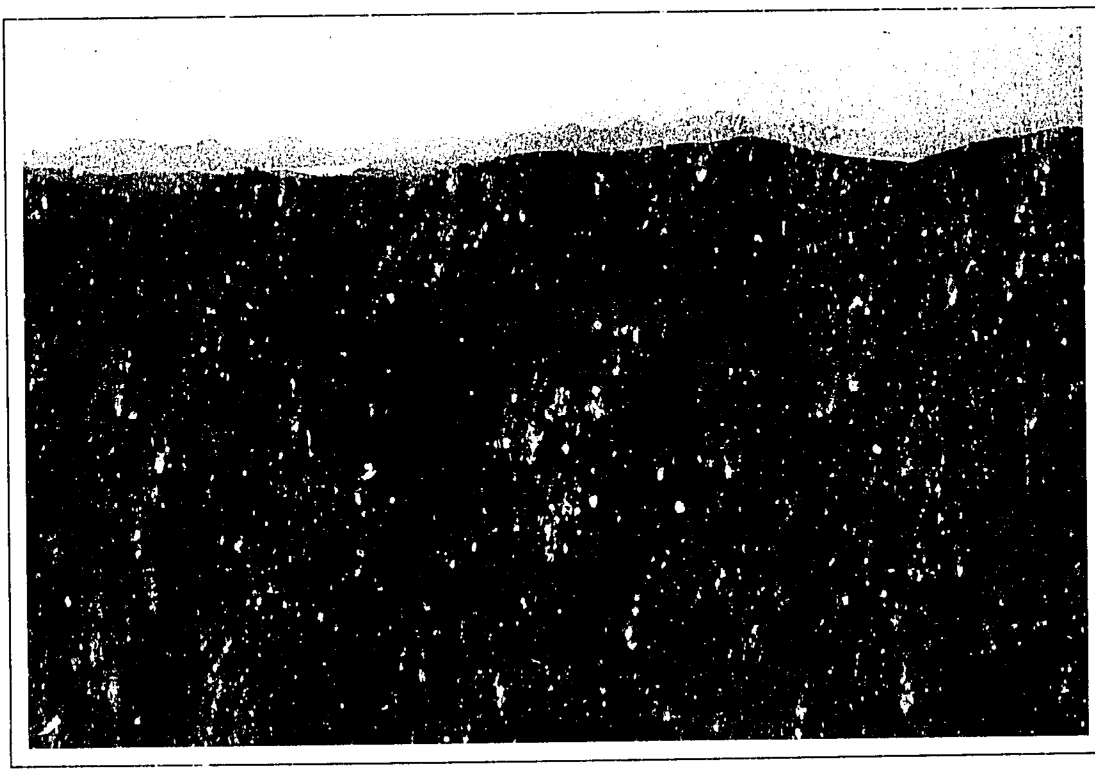
PROCEEDINGS OF THE

FOURTH INTERNATIONAL SOIL CLASSIFICATION WORKSHOP

RWANDA

2 to 12 June 1981

Part 2: FIELD TRIP AND BACKGROUND SOIL DATA



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Co-sponsored by

Institut des Sciences Agronomiques
du Rwanda (ISAR)
Rwanda

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Gent, Belgium

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FOURTH INTERNATIONAL SOIL CLASSIFICATION WORKSHOP
- RWANDA -

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INTRODUCTION

The 4th International Soil Classification Workshop is one of a series organized by the University of Puerto Rico. The 4th Workshop is also the first to be organized by the new Soil Management Support Services (SMSS) of the Soil Conservation Service (SCS) of the United States Department of Agriculture. The SMSS is a program of international technical assistance of SCS, funded by the United States Agency for International Development (AID). The Workshops form an integral part of the activities of SMSS. We place great emphasis on these Workshops as they provide a forum for scientists to meet, discuss, and provide solutions for our common goal of refining Soil Taxonomy for its better use as a vehicle for agro-technology transfer.

The tour guide for the Workshop is presented in two parts. The first part deals with information on the general physiographic situation in Rwanda and gives a detailed account of the geological, vegetational, and climatic setting of the soils to be studied during the tour. Part I of the tour guide is compiled by the host organizing committee.

Part II of the tour guide gives specific information on the physico-chemical, mineralogical, and micromorphological properties of the soil. Profile descriptions, as made by the host organizing committee, are also included.

This tour guide has been compiled with the assistance of several persons and organizations to whom we are most grateful. We greatly appreciate and cordially thank his excellency Mr. Frederick Nzamurambaho, the Minister of Agriculture, Rwanda, for his cooperation and assistance. The soils were sampled promptly by Mr. H. Neel, agricultural attache of the Belgian Embassy and by Mr. F. Iyamuremye, Director of the Institute de Science Agronomique, Rwanda and his efficient staff. Equally promptly, the samples were air freighted to the laboratories at Lincoln, Nebraska, by Mr. E.R. Chiavaroli, Director of the USAID Mission in Rwanda.

We would like to thank Dr. S. Holzhey, head of the National Soil Survey Laboratories at Lincoln, Nebraska, and his staff for performing all the analysis at so short a notice. The work was efficiently coordinated by Dr. J. Kimble, soil chemist of SMSS. Dr. Kimble also performed the arduous task of compiling all the information.

We are grateful to the Algemeen Bestuur voor Ontwikkelingssamenwerking for dispatching the undisturbed samples to the University of Gent, Belgium. The laboratories of Professor G. Stoops made the thin-sections and some clay analysis. Transmission and scanning electron microscopic work was done at the Electron Microscopic Centre of the University of Gent. We also would like to express our appreciation to Professor R. Tavernier for the computer analysis of the soil climatic data.

It is indeed a great pleasure to acknowledge the assistance and advice of Dr. Tej Gill of AID and of Dr. Klaus Flach, Associate Deputy Chief for Natural Resource Assessments of the Soil Conservation Service. Finally, and last but not the least, the tour guide would not have materialized if not for the initiative and enterprizing endeavours of Dr. Fred Beinroth of the University of Puerto Rico.

Dr. Hari Eswaran
Program Leader
Soil Management Support Services

AN OVERVIEW OF THE PHYSIOGRAPHY AND THE SOILS OF RWANDA

H. Neel

ABSTRACT

Rwanda, situated in the heart of Africa, just south of the equator without any direct access to the ocean, has a very high population density that is still increasing faster than the food production. Almost 95% of its population is engaged in agriculture.

The mild climate induced by the high elevation of the country is characterized by a regular alternation of dry and rainy seasons which make possible two crop seasons a year. The most important food crops are: bananas, cassava, sweet potatoes, beans, maize and sorghum. Coffee and tea are the main cash crops.

A wide range of different soils have developed in the old Precambrian rocks of shales, granite, and quartzite. Only in the northwest and the southwest occur soils which have developed in more recent parent material of volcanic origin. The succeeding erosion cycles induced by climatic changes and the tectonic movements have transformed Rwanda into the actual typical landscape of the 1000 hills. The many topographical positions which are possible in this landscape all influence the development of the soil profile.

According to actual knowledge only the Spodosols would be absent from Rwanda. The Ultisols are to be considered the most typical soil order in the high and medium elevation regions where the soil temperature regime is isothermic and the soil moisture regime udic or ustic.

In the low elevation regions the Oxisols are more common in an environment of an isohyperthermic soil temperature regime and an ustic soil moisture regime.

Among the pedogenetic particularities of the Rwandese soils may be noted the:

- sombric horizon
- stone-line

- double soil profile
- clay polyhydrons
- "socle" horizon
- "anthropic" soils

The first four particularities have probably something to do with soil displacement along the hillslopes. Very little is known about the genesis of the "socle" horizon. In a country with such a high rural population density the existence of "anthropic" soils could be expected.

RESUME

Le Rwanda, situé au coeur de l'Afrique, à peine quelques degrés en dessous de l'Equateur, sans accès direct à l'Océan, a une densité de population très élevée qui augmente plus vite que la production vivrière. A peu près 95% de la population est engagée dans l'agriculture. Suite à l'altitude, le climat du Rwanda est assez doux. Il est caractérisé par une alternance régulière de saisons de pluie et de saisons sèches, ce qui permet deux saisons culturales par an.

Les principales cultures vivrières sont: les bananes, le manioc, les patates douces, le haricot, le maïs et le sorgho. Le café et le thé sont les principales cultures industrielles.

Une grande gamme de sols différents se sont développés dans les vieilles roches précambriennes: schistes, granite, quartzite. Seulement dans le nord-ouest et le sud-ouest existent des sols qui se sont développés dans du matériel parental plus récent d'origine volcanique. Les cycles d'érosion qui se sont succédés ensemble avec les mouvements tectoniques ont donné naissance au paysage typique du Rwanda, celui des 1000 collines. Etant donnée l'influence de la position topographique sur le développement du profil pédologique, il est évident que dans un tel paysage ce facteur devient très important. A première vue seulement les Spodosols seraient absents du Rwanda. Les Ultisols doivent être considérés comme les sols les plus typiques des régions de haute et moyenne altitude où le régime thermique du sol est isothermique et le régime hydrique du sol est udique ou ustique.

Dans la région basse du pays les Oxisols sont plus communs. Le régime

thermique du sol y est isothermique, le régime hydrique y est ustique. Parmi les particularités pédogénétiques des sols Rwandais, nous pouvons citer:

- l'horizon sombre
- la nappe de gravats
- le profil double
- les polyèdres argileux
- l'horizon socle
- les sols anthropiques.

Les quatre premières de ces particularités ont probablement quelque chose à voir avec un déplacement du sol à l'échelle de la colline. Très peu est connu sur la genèse de l'horizon socle.

Il va de soi que dans un pays ayant une population rurale aussi dense, la présence de sols anthropiques est un phénomène normal.

PHYSICAL ENVIRONMENT

Location

The Republic of Rwanda is located centrally in the African continent, to the east of the African graben, and south of Lake Victoria, between 1°04' and 2°51' south latitude, and 28°53' and 30°53' east longitude (Fig. 1).

The total area of the country is 26,000 sq km, about the size of Burundi, a bit smaller than Belgium (± 29,000 sq km). The longest north-south span is almost the same as the longest north-east span: 220 km and 230 km.

Rwanda has common frontiers with Uganda on the north, with Tanzania on the east, with Burundi on the south, and with Zaire on the west. It has no ocean frontier. The distance from the Indian Ocean in the east is about 1200 km, from the Atlantic in the west, about 2200 km.

Population

The figures of the 1978 census indicated a population of 4,819,317 which increases by 3.1% per year. The population density is 185 per sq

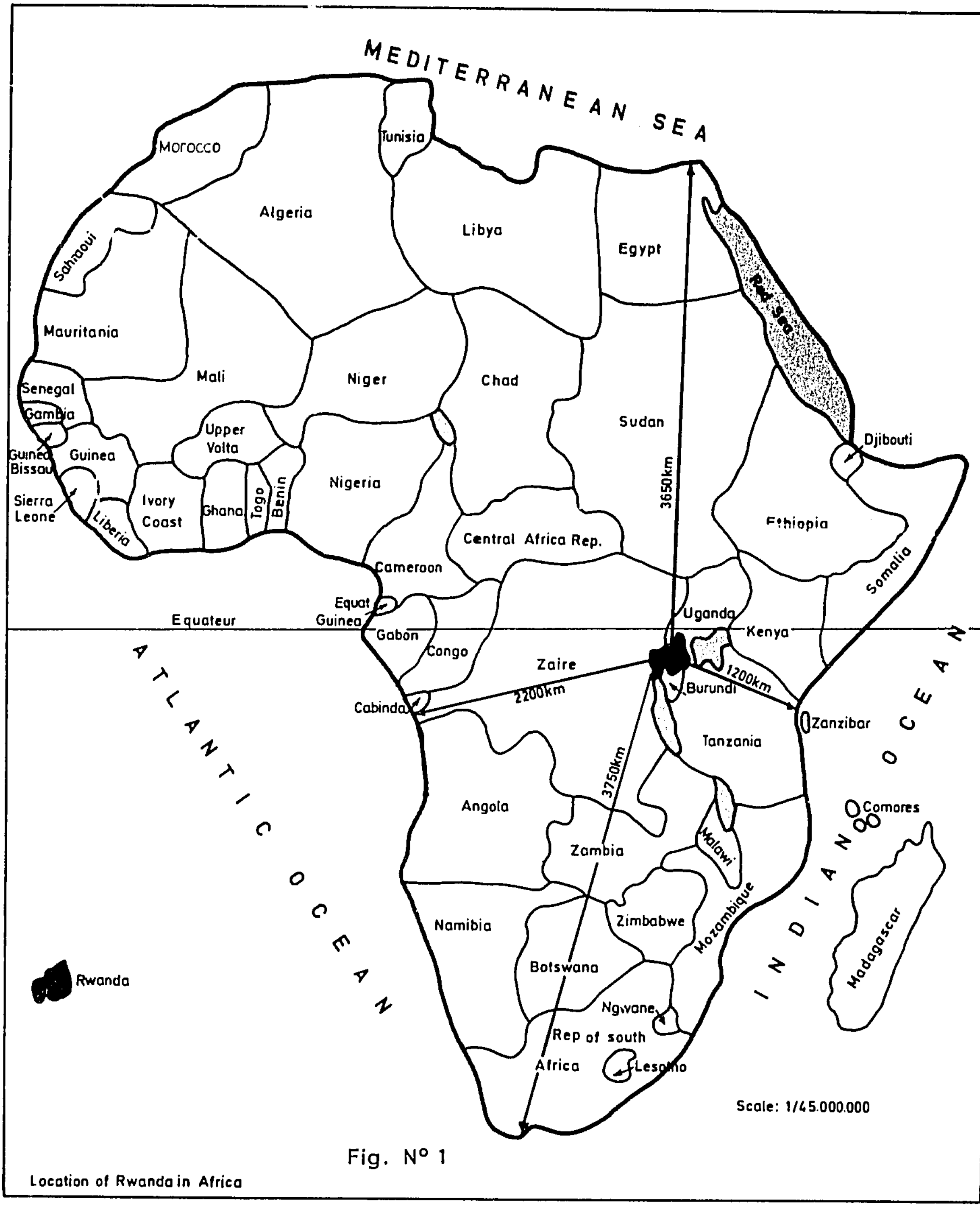


Fig. N° 1

Location of Rwanda in Africa

km or ± 350 per sq km of arable land. This means that Rwanda is the country with the highest population density in Africa.

About 95% of its population is engaged in agriculture, always on very small farms (± 1 ha.)

The gross national product per capita and per year does not exceed 100 dollars and increases very slowly.

Climate

The climate of Rwanda is quite different from what its geographic location would indicate (Figs. 2 and 3). Its average elevation moderates the figures expected from its latitude.

The lowest point in Rwanda goes down to 950 m, the highest reaches 4507 m. In spite of the influence of elevation, it still shows the annual rhythm of the low latitude climates: a regular alternation of dry and rainy seasons.

The climate of Rwanda includes two rainy seasons and two dry seasons:

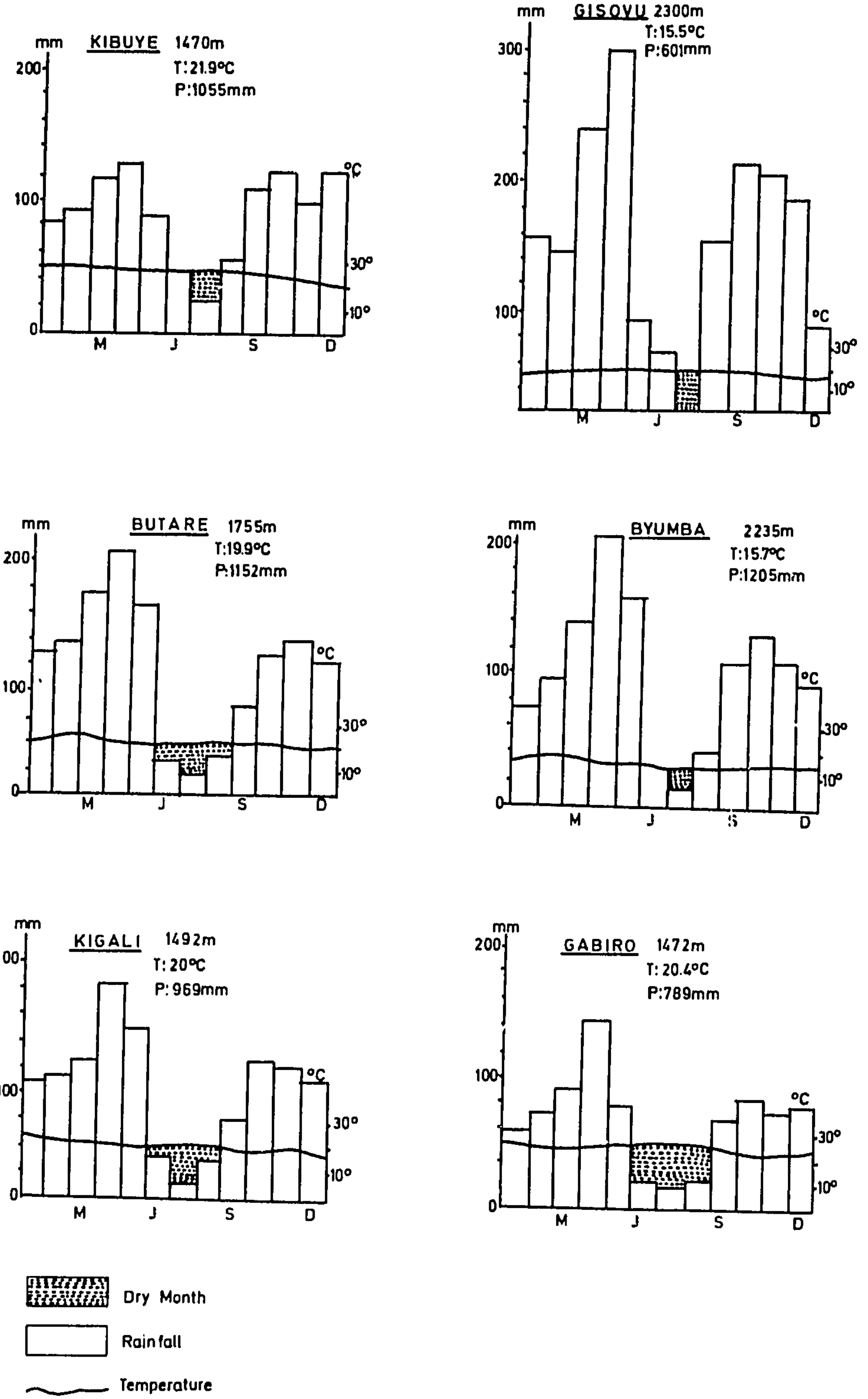
- the great rainy season from February to May;
- the great dry season from June to August;
- the small rainy season from September to November; and
- the small dry season from December to January.

Table 1. Climatic characteristics.

Region	Annual rainfall (mm)	Annual mean humidity (%)	Annual mean temperature (°C)	Annual ave. max. temp. (°C)	Annual ave. min. temp. (°C)
High elevation regions + 1800 m	1200-1800	70-80	15-18	19-22	10-12
Med. elevation regions 1500-1800 m	1000-1200	65-75	18-21	22-25	12-14
Low elevation regions - 1500 m	700-1000	60-70	21-24	25-28	14-16

According to the Köppen classification system:

- most of the high elevation regions belong to the CW-type with 2-3



Climatic diagrammes

Fig. 2

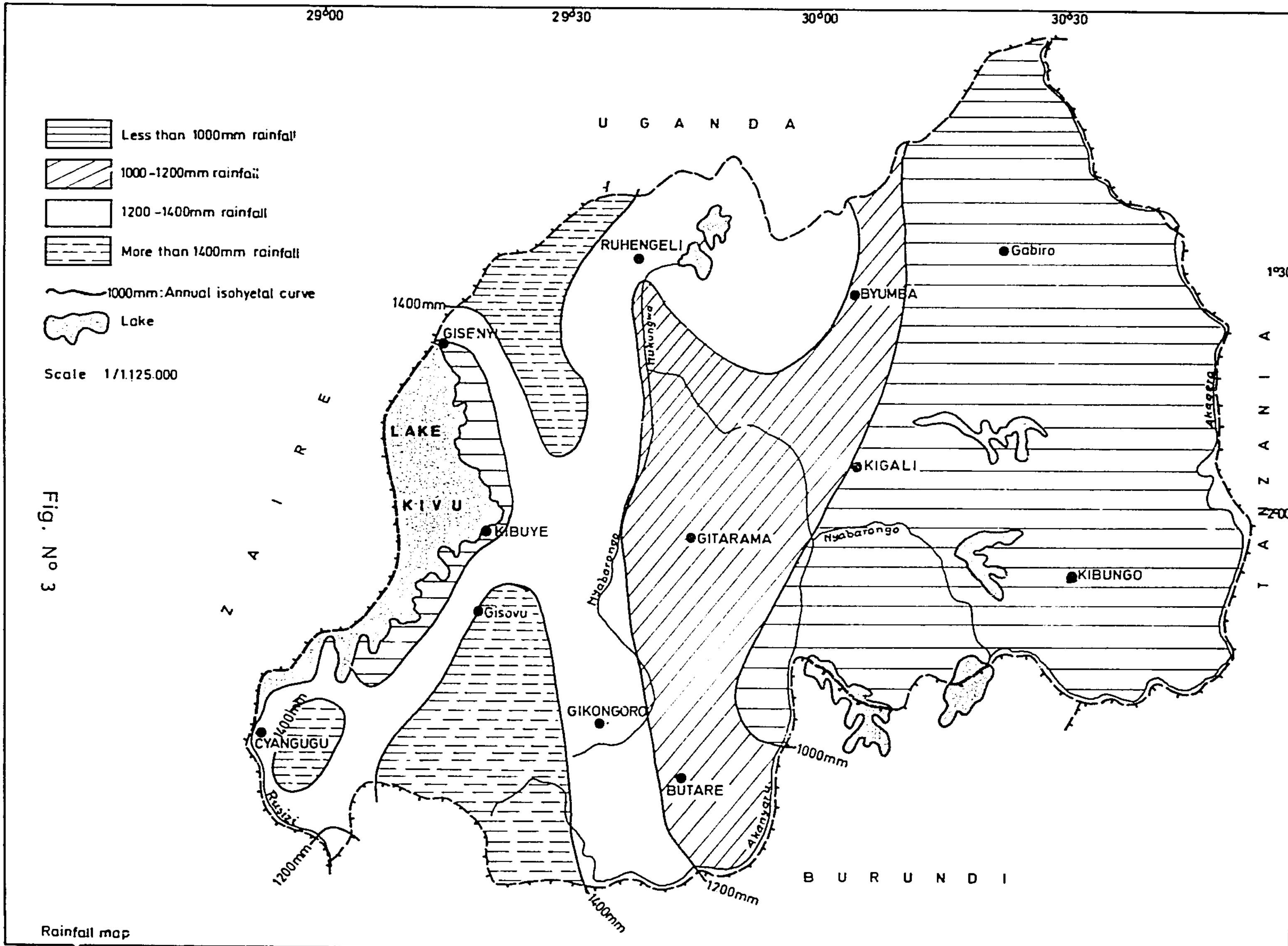


Fig. No 3

Rainfall map

months of rainfall under 60 mm, exceptionally to the Cf-type.

- most of the medium elevation regions belong to the Cw and Aw-type with 3 months of rainfall under 60 mm.
- most of the low elevation regions belong to the Aw-type with 3-4 months of rainfall under 60 mm.

Soil Climate

In spite of the significance of soil moisture and temperature regimes to soil classification, very little work on this subject has been done in Rwanda. The figures available about soil temperatures are shown in Table 2.

Table 2. Soil temperature.

	High elevation region ---	Medium elevation region Rubona--1706 m	Low elevation region Karama--1403 m
Annual mean soil temperature at 50 cm	---	22.2°C	25.1°C

An attempt is made to approach the soil moisture and temperature regimes by interpreting the data available on rainfall and air temperature. Based on these data, we may expect the following soil moisture and temperature regimes (Table 3).

Table 3. Soil moisture and temperature regime.

	High elevation region + 1800 m	Medium elevation region 1500-1800 m	Low elevation region - 1800 m
Soil moisture regime	udic-ustic	ustic	ustic
Soil temperature regime	isothermic	isothermic isohyperthermic	isohyperthermic

Geology

The rocks of the Rwandese basement complex all belong to the Precambrian era (Fig. 4). They can be subdivided in two series: the Rusizian, 2 billion years old, and the Burundian, 1.7 billion years old.

The Rusizian rocks are generally found in the western part of the country where they form the mountain ridges of Zaire-Nile and the western element of the central plateau.

They are composed of a wide range of shales locally pierced by synthectonic granitic batholiths. These granites give way to more rounded hills and larger valleys than the shales.

The Burundian series covers the rest of the country and spreads from Zaire to Uganda. It is less metamorphised and the granitic batholiths are not so frequent as in the Rusizian series (Bugesera-Mutara). It is mainly composed of relatively tender shales and harder quartzites which favor the formation of a differential erosion relief that resembles the appalachian type.

The Burundian series has indeed been strongly folded in the regions of Byumba and Kibungo where the whole relief and hydrography follows the succession of anticlines and synclines showing the quartzitic rocks on top between the corridors of shale. The granitic masses have often been lowered by erosion; their borders contain the most interesting mineral sites of Rwanda (cassiterite, tungsten).

During the Tertiary and Quaternary period, several impressive, actually inactive, volcanoes, located in the north- and southwestern part of the country, spread large amounts of volcanic material out on the landscape.

Geomorphology

The topographic forms of Rwanda are the result of the combined action of erosion and of tectonic movements: faulting, uplifting, subsiding, volcanism (Fig. 5). After the metamorphosis and folding of the sedimentary rocks that gave rise to the series of Rusizian and Burundian, the Rwandese socle has never been submerged again. This means that its evolution has been governed by the different erosion cycles induced by the climatic variations.

- After a cold climate during the Upper Carboniferous, several warmer, more or less humid climates followed during the Secondary and Tertiary periods. The corresponding erosion cycles, working upon different kinds of rocks, caused the peneplanation, the attenuation of

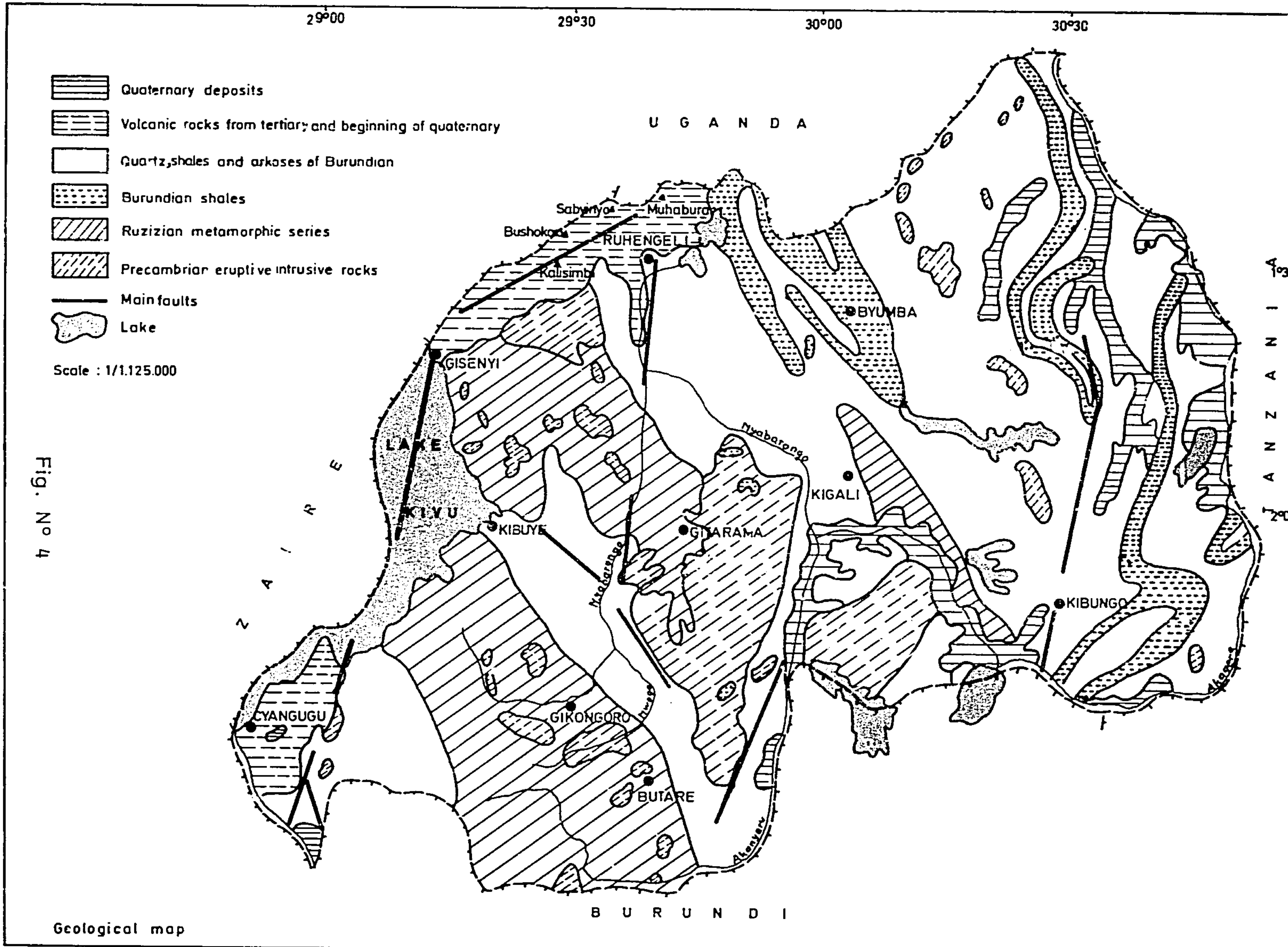
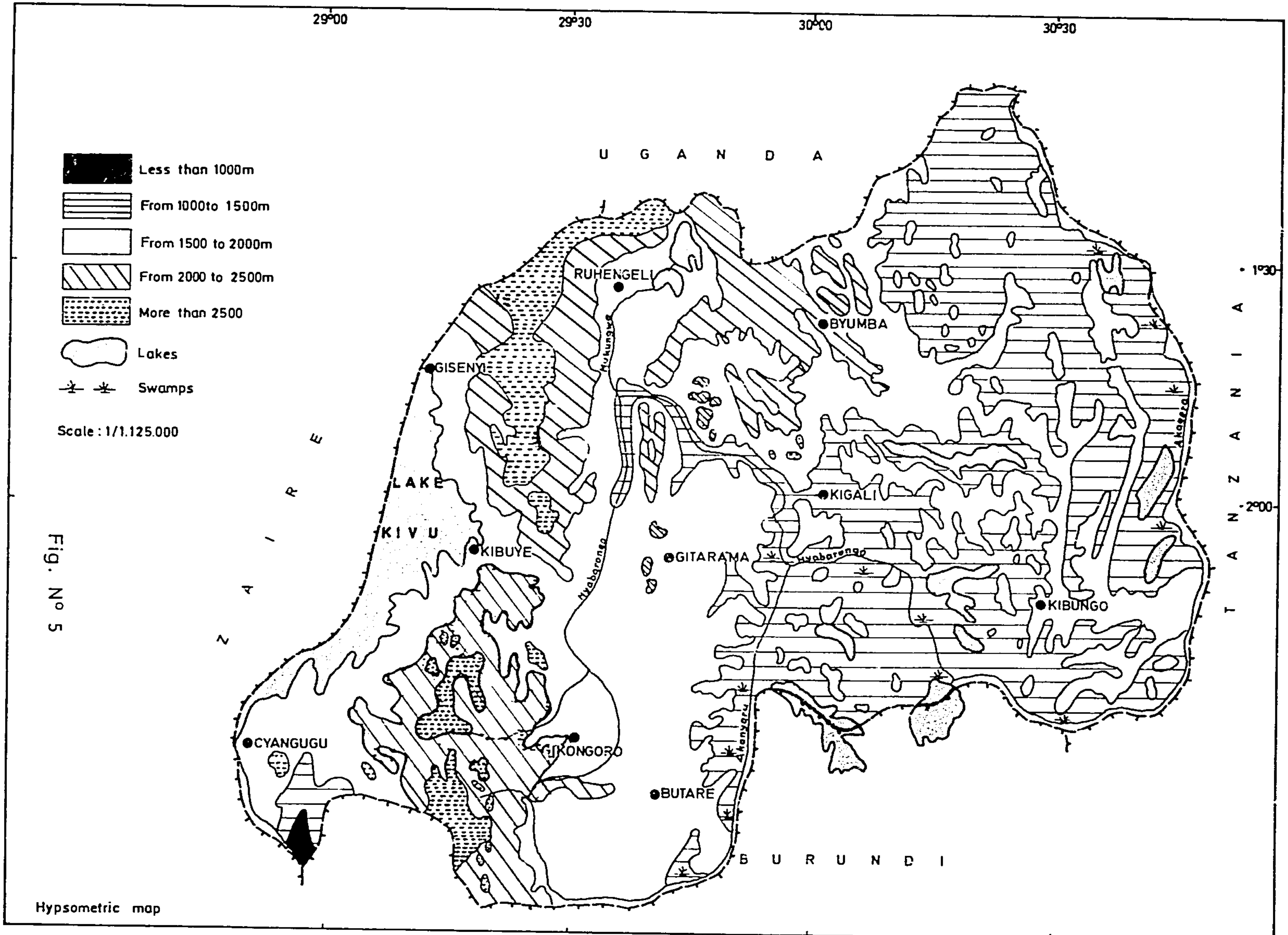

29°00
29°30
30°00
30°30
Quaternary deposits
Volcanic rocks from tertiary and beginning of quaternary
Quartz, shales and arkoses of Burundian
Burundian shales
Ruzizian metamorphic series
Precambrian eruptive intrusive rocks
Main faults
Lake
Scale : 1/1.125.000
U G A N D A
Sabyinyo
Muhabura
Bushokoro
RUHENGELI
Kalisimbi
BYUMBA
GISENYI
LAKE
KIVU
Z A I R E
KIBUYE
GITARAMA
Nyabarongo
KIGALI
KIBUNGO
T A N Z A N I A
1°30
2°00
CYANGUGU
GIKONGORO
BUTARE
Akanyaru
Akagera
B U R U N D I
Geological map

Fig. N° 4



Hypsometric map

Fig. N° 5

the appalachian relief and the lowering of the granitic batholiths.

- The tectonic movements which already started in the Paleozoic era, created during the Tertiary the "Rwandese" section of the famous African rift valley. This process induced the important volcanic effusions of the north- and southwest of the country. The Rwandese socle has been too intensively metamorphised to undergo the gigantic internal earth forces without being faulted, uplifted or subsided. The resulting section of the rock masses prepared the landscape of the 1000 hills.

Through the uplifting of the Zaire-Nile mountain ridges erosion activity increased, drainage directions were reversed, and several lakes were formed. Four-fifths of the rivers empty into Victoria Lake and the Nile; the remaining 1/5 empties into Kivu Lake, feeding in this way the Zaire River.

During the humid periods of the Quaternary, the water level of Victoria Lake was much higher than it is today. The lowering of the water level induced a new aggressive erosion cycle that is still active today.

In order to study the actual topographic forms of Rwanda resulting from this combined action of climate and tectonic movements, it is useful to distinguish three different regions:

- the Zaire-Nile mountain ridge (high elevation region);
- the central plateau (medium elevation region); and
- the low oriental peneplains (low elevation regions).

The Zaire-Nile mountain ridge. The Zaire-Nile mountain ridge, 20 to 50 km wide, traverses the country from north to south over a distance of 160 km. Its highest point reaches 3000 m. The abrupt slopes of the western side plunge into Lake Kivu at an elevation of 1460 m. The landscape is very rough with high-serried hills separated by small and deep valleys.

The central plateau. This topographic unit, situated between 1500 and 2000 m, 80 km wide, covers half of the country. The rivers that originated in the faulted socle have cut the landscape in a multitude of oblong hills of which the convex, often steep slopes, and the flat tops are characteristic.

The abundant alluvial material transformed the wider river valleys into flat marshlands.

In the Byumba and Kibungo region the appalachian relief does partially persist: long and small ridges, parallel rivers, transverse cuttings.

The low oriental peneplains. The rivers draining the higher altitude regions feed the numerous lakes situated in this landscape of large flat surfaces where the presence of ironstone crusts is something very common.

The larger rivers: Akanyaru, Nyabarongo, and Akagera are meandering through large papyrus-covered marshes.

We have already mentioned the existence of a 90 km long range of extinct volcanoes in the northwest of the country. The lowest, the Gahinga, has an altitude of 3474 m; the highest, the Karisimbi, reaches 4507 m.

Natural Vegetation

Owing to the high population density, only small islands of natural vegetation are left in Rwanda (Fig. 6). They are surrounded by anthropic vegetation. We may distinguish three zones:

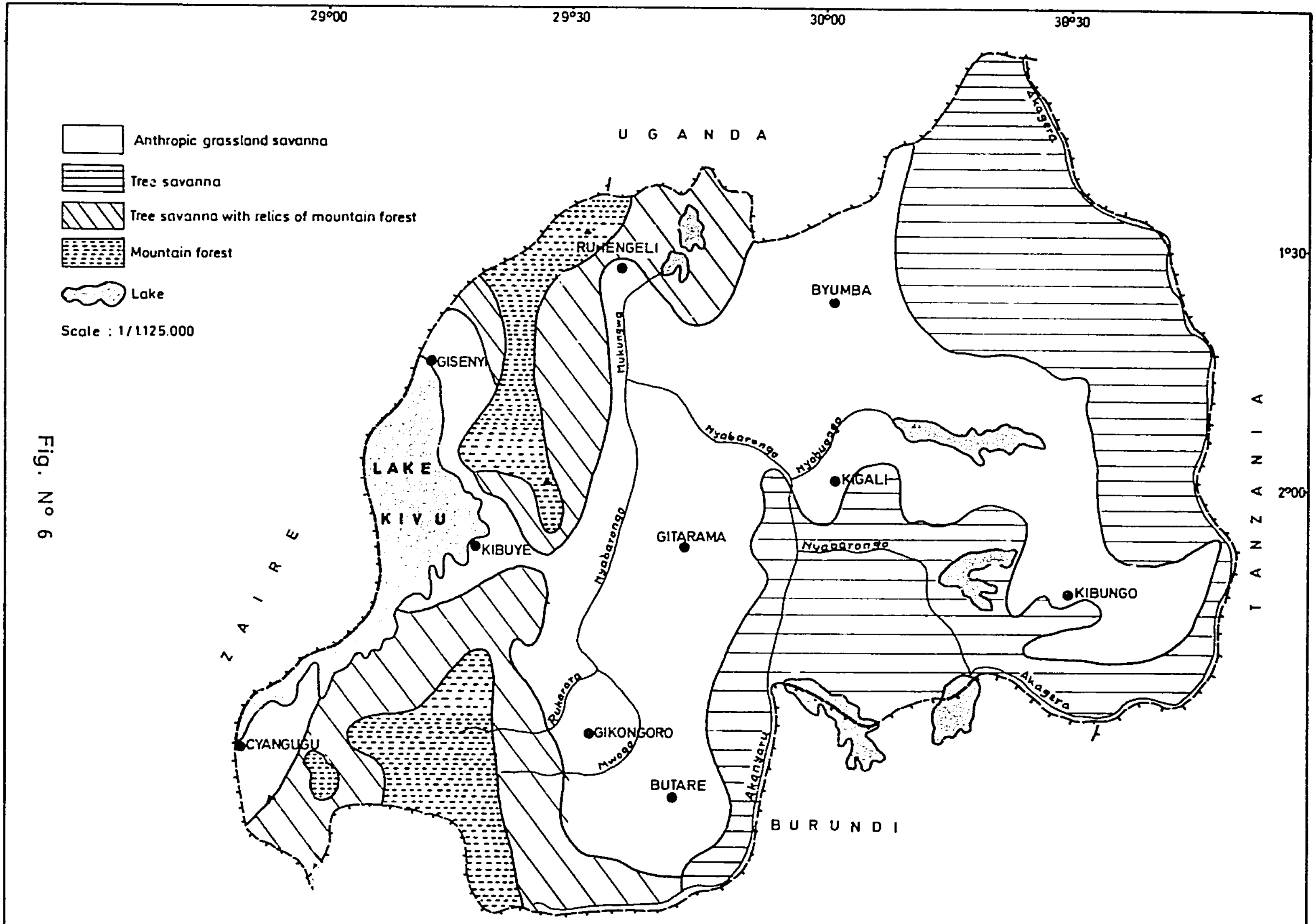
- the mountain forest and postforest regrowth (high elevation region);
- the anthropic savannah (medium elevation region); and
- the eastern savannah (low elevation region).

The mountain forest and postforest regrowth. Formerly, the whole region at an elevation of more than 1800 m (±1500 mm of rain) was covered by the mountain forest which presently only persists on the very steep slopes of the high mountain ridges (+ 100,000 ha). It is a forest with a rather low density of trees which never exceed 30 m. The luxurious herbaceous vegetation makes it difficult to penetrate. Among the more than 300 woody species, the most important trees are: *Carapa grandiflora, Cassipourea sp., Croton macrostachyus, Entandophragma excelsum, Ficalhoa laurifolia, Hagenia abyssinica, Harungana montana, Macaranga neomildbreadiana, Maesa lanceolata, Musanga leo-errerae, Myrianthus holstii, Newtonia buchananii, Podocarpus usambarensis, Polyscias fulva, Parinari excelsa, Syzygium parvifolium.*

Following human deforestation, bush fires, and cattle grazing, the vegetation evolved more or less quickly into a postforest regrowth or a grassland of *Pennisetum clandestinum* (Kikuyu grass), *Exotheca abyssinica* and/or *Eragrostis blepharoglumis.*

The flora of the postforest regrowth is very rich. Among the woody species (shrubs), we may mention as the most common species: *Hypericum lanceolatum, Dissotis sp., Polygala ruwenzoriensis, Vernonia sp., Pycnostachys sp., Rumex sp.,* .... Among the herbs we mention: *Erlangea cordi-*

Fig. No 6



Vegetation map

folia, Helichrysum setosum, Pteridium aquilinum var. africanum, Melinis minutiflora, Ageratum conyzoïdes, Acrocephalus galeopsifolius, Guizotia scabra,...

In contrast with the postforest regrowth, the flora of the grasslands is very poor. Only some typical herbs can be seen among the dominating grass species: *Buchnera ruwenzoriensis*, *Alectra communis*, and *Swertia sp.*

The anthropic savannah. In the medium elevation region, the natural vegetation has almost completely disappeared in favor of a man-induced flora. The most important grasses in the natural savannah are: *Brachyaria platynota* and *Hyparrhenia filipendula*. Many Acacia trees were always present.

In the secondary grasslands *Hyparrhenia bracteata, dissoluta, filipendula* and *diplandra* together with *Themeda triandra* dominate.

In the fallow land the grass *Digitaria vestita* is very common besides a multitude of other herbs such as *Galinsoga parviflora*, *Solanum nigrum*,...

The eastern savannah. In the eastern part of Rwanda exists the typical savannah of East Africa: an association of high grasses--*Themeda triandra*, *Hyparrhenia filipendula*, *Panicum maximum*, *Loudetia simplex*, Acacia trees and several shrubs. Here the annual bush-fire has become a normal ecologic factor. 250,000 hectares of this land belong to the National Akagera Park which is known for its game and beautiful scenery.

<u>Land Use</u> <u>(See Fig. 7.)</u>

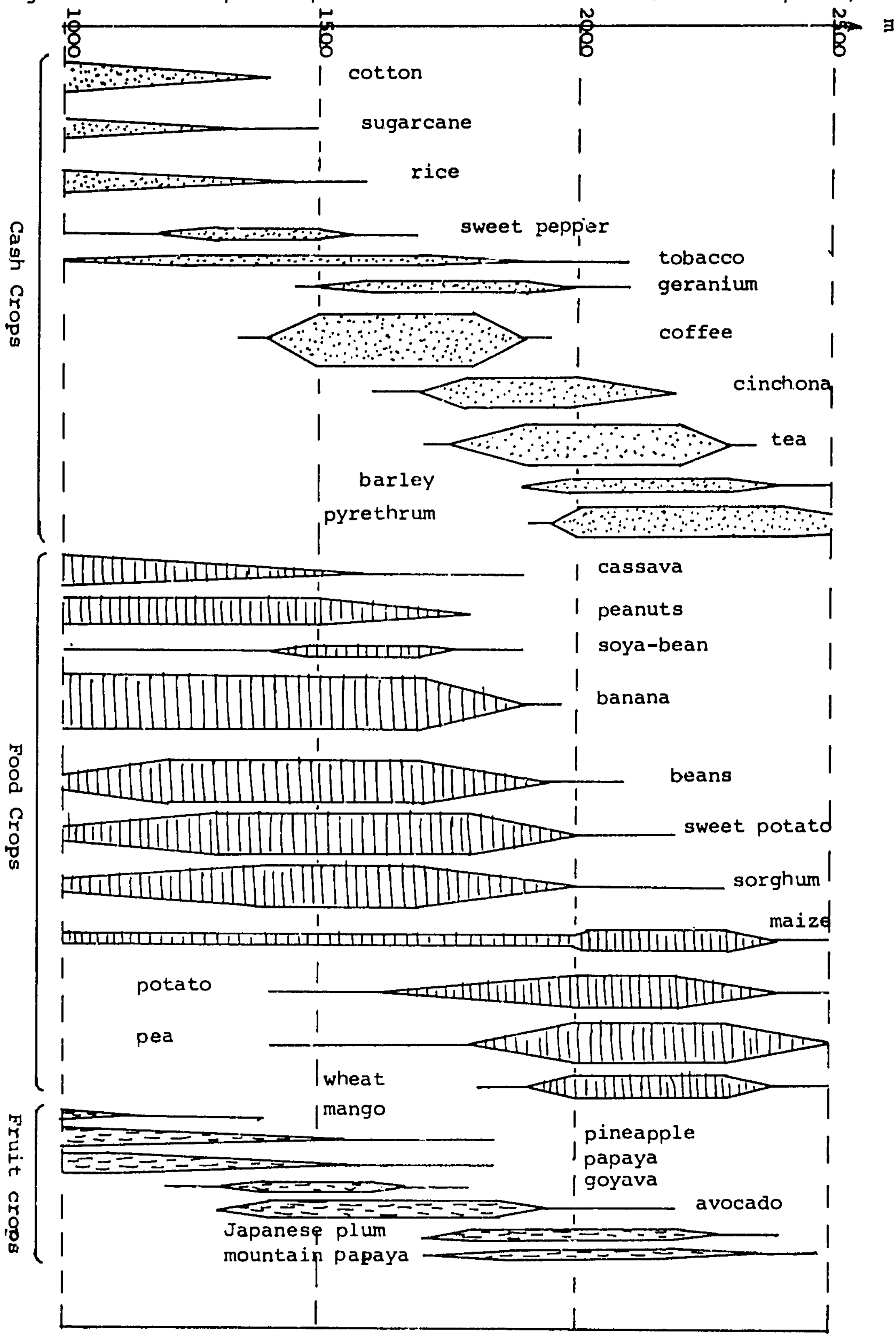
It has already been said that the population of Rwanda is mainly engaged in farming (95%) and lives in family units of about 5 people.

The country is remarkable for the way in which the people live in individual nuclear families, distributed over the hills, with only a very small number living in small trading centers or villages, or in towns (5%). Each family farms about a hectare of land.

The high population density is obviously leading to a shortage of farm land. It has been estimated that only 1,250,000 ha (47.5%) of the area of the country is suitable for farming.

Food crops. Food production is thought to increase on a yearly basis by 1.5%, population by 3.1%. This means that a food shortage in the near future is not excluded and can only be avoided by an intensification of

Figure 7. - Principal crops in relation to altitude (after Delepiere)



the agricultural production on the available land that can hardly be extended.

The mild climate making possible two yields a year, together with fairly good soils, are responsible for the high population density in Rwanda.

A classification of the major crops in relation to the range of altitude by which they are adapted has been made by Mr. Delepierre in Fig. 7. At the lowest elevations, cassava, bananas, beans, sweet potatoes, maize, sorghum, and peanuts are grown for food, with sugar cane, rice and a little cotton as cash crops. In the medium elevation zones, beans, bananas, sweet potatoes, sorghum, maize, peanuts, cassava, and some soybeans are grown for food, with coffee and tobacco as cash crops. At high altitudes, peas, potatoes, maize and wheat with some sorghum and some sweet potatoes on lower lying land, are the main food crops. Tea, pyrethrum, barley and chinchona are grown for cash crops.

In the next table the average yields of the major food crops are shown.

Table 4. Average yield of the major food crops.

Crop	Beans	Soybeans	Peas	Maize	Sorghum
Average yield kg/ha	825	760	800	1050	1040
Crop	**Wheat**	**Bananas**	**Sweet Potatoes**	**Potatoes**	**Cassava**
Average yield kg/ha	830	9300	6000	6000	4000

The yields shown in Table 4 are average yields for the country without taking into account the differences due to soil characteristics and without any use of fertilizers. Fertilizers are almost completely unknown in Rwanda.

Industrial crops. Along with the different trends in the production of food crops, a gradual increase has been noted in the area devoted to industrial crops, and in the production of coffee, tea, pyrethrum, sugarcane and chinchona. The only one of these with a substantial area planted is coffee with 35,000 ha.

In terms of value of exports, coffee is by far the most important, 60% of all exports; tea, pyrethrum, chinchona and livestock products account for another 15%.

In 1977 the area in industrial crops was as follows:

coffee	34,987 ha
tea	6,896 ha
pyrethrum	2,816 ha
chinchona	1,924 ha
cotton	392 ha
sugarcane	334 ha

Livestock. Actually, one counts about 600,000 local Ankole cattle, 600,000 goats, 250,000 sheep and less than 70,000 pigs. Owing to the lack of arable land, these numbers, especially the cattle number, are diminishing. Livestock productivity is very low.

SOILS OF RWANDA

For didactic reasons, we still maintain the subdivision of Rwanda in three major ecologic regions:

- the high elevation region (+ 1800 m);
- the medium elevation region (1500-1800 m); and
- the low elevation region (-1500 m).

In the preceding pages these regions have already been characterized from a climatic, geologic, geomorphologic and agricultural point of view. Now we will try to present a short inventory of the soils of these regions.

The High Elevation Region

The following soil orders exist in this region:

Entisols. They belong mainly to the suborders of Fluvents and Orthents and occupy the river valleys. They show little or no profile developments. Their texture is highly variable.

Inceptisols. In the zone covered by volcanic material and elsewhere on the steep hillslopes, the Inceptisols are an extensive soil unit. Many soils developed in the colluvium accumulated at the foot of the hillslopes belong to this order too. In the volcanic area they become Andepts (Dystrandepts, Eutrandepts and Hydrandepts), elsewhere Tropepts and Umbrepts.

Ultisols. Most of the well-drained soils of this region belong to the order of the Ultisols: Humults, Udults, and Ustults. In spite of the steep slopes, soils are generally deep and rich in organic matter.

Oxisols. It is not sure if there are any Oxisols in the high altitude region. Some of the soils show a structure which could make them considered as Oxisols. But generally their exchange capacity exceeds the value which is necessary for Oxisols.

Histosols. Histosols are very common in the poorly drained swamps. They are not typical for the region; they occur in any environment where drainage is impeded. The thickness of their paet layers may exceed 20 m.

The Medium Elevation Region

The soils of this region belong to the orders of:

Entisols. They occupy the same topographic sites as in the high altitude region. Because of a larger extent of broad river valleys, Fluvents are more frequent here.

Inceptisols. Inceptisols and Entisols are not linked to altitude. This is why they occur as well in the high elevation region as in the others. They are generally developed in accumulated colluvium and in parent material of recent origin (freshly weathered bedrock). For this last reason, Inceptisols are very common in the granitic area of Central Rwanda. In the same area, the presence of stone-lines is a very normal phenomenon in the soil profile. Often, they are associated with dark "horizons."

Mollisols. It happens that the colluvial material is sufficiently rich in cations and organic matter to induce the development of Mollisols. In any way, they are exceptional.

Alfisols. Alfisols are a bit less exceptional than Mollisols. In general, however, leaching is too intense to permit the development of Alfisols on a large scale.

Ultisols. In the medium elevation region Ultisols remain the most important soil order, especially the suborders of Humults and Ustults. Stonelines and dark "horizons" are common features.

Oxisols. On the less rejuvenated reliefs Oxisols are quite common: Humox, Orthox, and Ustox. Typical for many Oxisols, and this holds true also for the low elevation region, is the presence of oxic and argillic material in the same profile.

Histosols. See high elevation region.

The Low Elevation Region

The same soil orders as in the medium elevation region exist in the lowlands. In addition to these orders, Vertisols occupy the flat and dry valleybottoms: Usterts. The relative importance of the different soil orders is not the same: Inceptisols are less frequent; there are proportionally more Oxisols and less Ultisols than in the medium elevation region. They all belong to the isohyperthermic soil temperature regime and the ustic soil moisture regime.

For the country as a whole, we may say that the Ultisols are the most typical soils of Rwanda. According to current knowledge only the order of Spodosols would be absent from Rwanda. Speaking about soil fertility, we must stress that besides the classic pedogenetic factors, human activity did largely influence the soil fertility status. This human influence, together with relief, explain why there is such a wide range in crop yields over small distances, even in soils developed in the same parent material.

Some Pedogenetic Particularities

Sombric horizon.

Morphology. The existing sombric horizons may appear:

1. as a homogeneous carbon black layer much darker than the actual humic horizon;
2. as a collection of carbon black strikes and dots; or
3. as a homogeneous dark brown layer resembling the actual humic horizon.

Localization in Rwanda. Types (1) and (2) are mostly encountered in the medium-elevation region of Central Rwanda where peneplanation has been very streng. Type (3) belongs more to the high altitude regions of western Rwanda. No sombric horizon is found on very steep slopes. The best developed ones are found close to the hilltops.

Depth of appearance. The depth of appearance is very irregular. It may be found at the surface as well as at a depth of 1.50 m, on top, inside or under the stone-line when this is present.

Thickness. The thickness of the sombric horizon is very irregular too. It ranges from a few centimeters to more than a meter and may change very quickly with lateral distance. The horizon may disappear completely over a distance of some meters to appear again a bit farther away. Often it is much thicker than the actual humus horizon.

Chemical properties. In many instances the carbon content increases in the sombric horizon together with the carbon/nitrogen ratio. In other sombric horizons only this ratio increases. For the profiles R3, R4, R5 and R14, the carbon/nitrogen ratio in the sombric horizon is always higher than in the actual humic horizon. The sombric horizon of profile R3, for instance, has a carbon/nitrogen ratio of 19.6, the humic horizon of 13.3.

An increase of the Ca and Mg content in the sombric horizons, typical for the medium elevation regions (central plateau), is very common. See profiles R3, R5, and R14.

The pH measured in NaF of the sombric horizon in profiles R3 and R4 increases considerably. In R4 it attains a value of 10.6 for 8.6 in the humic horizon. Allophanic material should be present.

It often happens that at the depth of the sombric horizon a change in texture is noted. See profiles R3, R4, R5 and R14.

Genesis. See below.

Stone-line. Wherever a source of resistant material exists (quartz, quartzite, petroplinthite,...) a stone-line may be detected. That is the reason why it is more frequent in the soils of the granitic region than in those developed in shale rocks. Its thickness and depth of appearance is very irregular; the former depends mainly on the importance of the available source, the latter on the topographical position of the soil in the landscape. The thickness may range from a few centimeters to more than one meter; the depth of appearance from the surface to more than 1.5 m. Stones and gravel may be angular or may be rounded indicating a former river terrace. Often the stone-line marks a texture-break in the profile.

Clay-polyhydrons. In very many soils (profiles R4, R5, R14, R16), beside a stone-line or at the position where a stone-line could be expected if a source of sufficiently resistant material would be present, exists a layer of highly coherent, mostly rounded, polyhydrons which seem to be of the same origin as the stone-line, i.e. a clayey subsoil from which after exposure at the surface, the polyhydrons have been washed off. Afterwards they have been covered, as was the stone-line, by other soil material.

Argillic material and oxic material in the same profile It happens that oxic and argillic material can be found in the same profile. Mostly oxic material lies on argillic (see profiles R1, R2, R12, and R13) but the reverse is not impossible (see profile R11). A difference in texture between the oxic and argillic horizons is very common. In the profiles R1, R12, and R13, the Ca and Mg content increases in the argillic horizon.

Genesis of sombric horizons, stone-lines, clay polyhydrons and double profiles. We think that sombric horizons, stone-lines, clay polyhydrons, and the simultaneous presence of oxic and argillic horizons in the same soil profile all have something to do with the displacement of stones and soil material along the hillslopes. Most sombric horizons, without intending to exclude any migration of humus, would become buried organic surface horizons. The morphology, position, depth of appearance and thickness could be easier explained by considering them as buried horizons than by considering them as the result of humus migration.

How else can the increase of the carbon/nitrogen ratio, the increase in the Ca and Mg content and the allophanic material in the sombric horizons be explained? The textural change often noted at the level of the sombric horizon is another argument in favor of the "displacement theory."

"Socle" horizon. In the Eragrostis grasslands of the high altitude regions (see profile R4), the structure of the umbric epipedon or of a part of it is often massive. It looks like a "socle." In spite of this massive structure the bulk density is rather low (0.7-1 g/cm). A similar horizon may be found in the acid Andepts surrounding the Sabinyo volcano. Up to now, no satisfactory explanation was available. It seems to be linked to low bulk density and acid conditions.

Anthropic soils. Due to the high demographic pressure in Rwanda, human influence on soil characteristics is very important, especially in the high altitude regions where the Eragrostis grasslands are situated. Upon human intervention (tillage, manuring, erosion, ...) the morphology and chemistry of the soil may be completely changed. A soil without any coatings can be transformed in one that has plenty of them. It looks like if an oxic horizon can be transformed in an argillic one. The saturation of the exchange complex can be brought up from some percent to more than 50%.

DESCRIPTION OF THE FIELD TRIPS

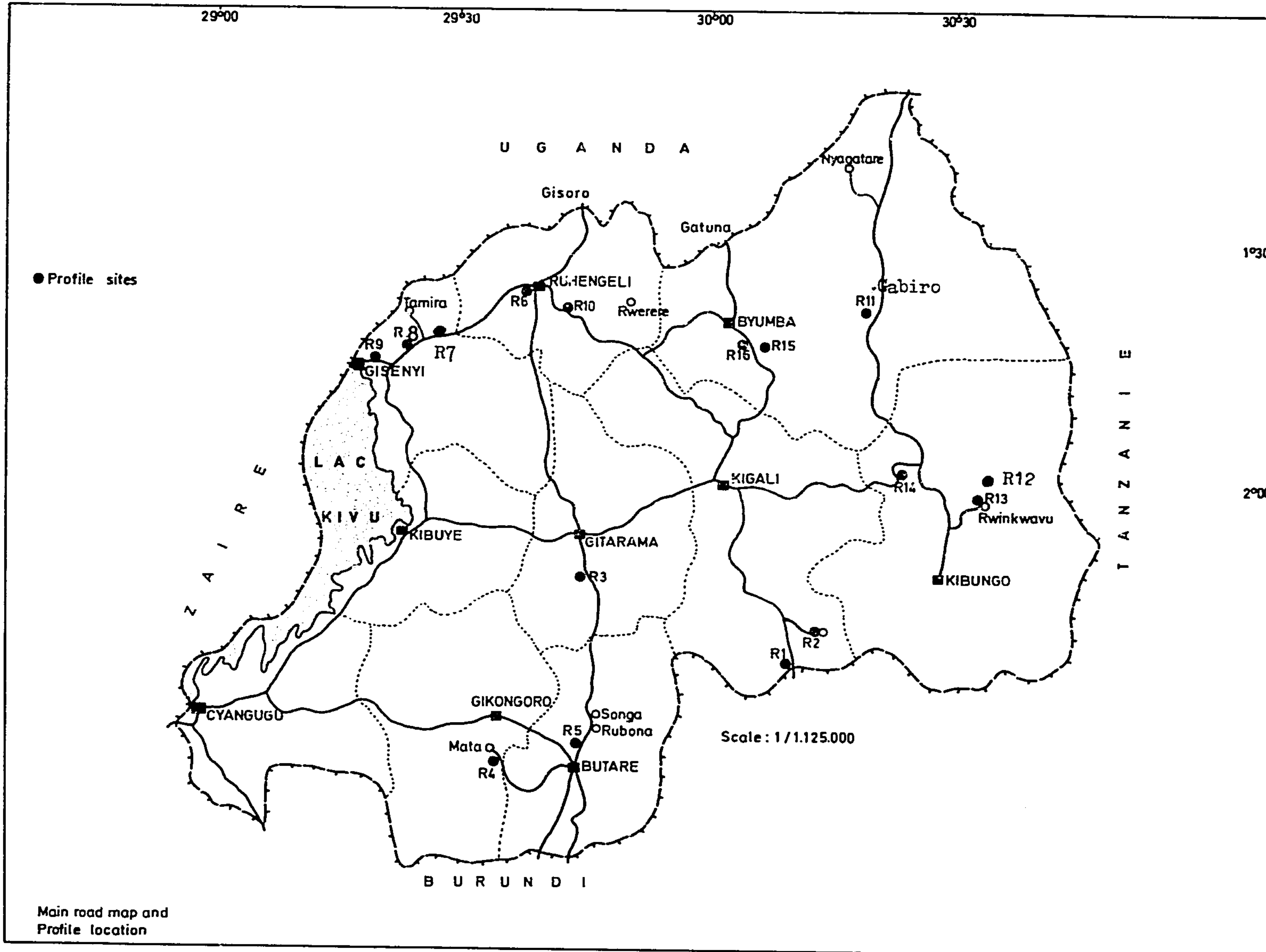
H. Neel

Field Trip No. 1

Date: Wednesday, 3 June 1981, pm
Visited area: Bugesera (1)
Place of departure: Kigali
Place of arrival: Kigali
Hour of departure: 1330 H
Distance: 134 Km
Duration of trip: 6H40'
Visited profiles: No. 1 and No. 2

Place	Time	Km	Observations
Kigali	1330	0	Altitude 1530 m
Nyabarongo River	1400	21	Second river of Rwanda--Altitude ± 1320 m (2)
Nyamata settlement	1405	25	Planned settlement of farmers on 2 ha plots (3)
Nyamata center	1430	33	---
Military camp of Gako	1455	50	---
Customs office	1520	62	Site of profile R1
	1630	departure from R1	
ISAR station of Karama	1650	74	Agricultural research station, site of profile R2 (4)
	1730	departure from R2	
Kigali	1910	134	---

(1) The natural region of the Bugesera, situated in the East of the country, is one of low agricultural potential: low and irregular rainfall (800-900 mm), and leached Oxisols in the well-drained sites. The large valleys are covered with Vertisols. The colluvial soils found on the foot



Main road map and
Profile location

of the hillslopes belong to the Inceptisols and Mollisols and are of good agricultural potential.

Ironstone crusts can often be seen on and along the road. Up to 1968, the area was infested by the tse-tse fly. Since then, due to the high demographic pressure in Rwanda, many people settled down in the Bugesera region in spite of the irregular rainfall and the poor quality of the soils.

(2) The Nyabarongo River flows into the Akagera River that ends in Victoria Lake. In this way, the source of the Nyabarongo, found in the mountain forest of Rwanda, is the most remote source of the Nile. The yellow color of its water is the result of erosion and of the waste waters of the cassiterite mines. The large papyrus swamp is typical for the valley bottoms of the large rivers in Rwanda.

(3) Several zones in Rwanda are organized in what is called here "paysannats," settlements of farmers on plots of 2 ha, based on an industrial crop, like coffee in this case. Non-agricultural soils are used for cattle grazing or reforestation.

(4) The agricultural research station of ISAR-Karama covers 2,700 ha used mainly as grazing lands. This means that the main activity of the station consists in cattle breeding. The trials of agricultural crops are mostly concentrated on the colluvial Inceptisols and Mollisols: peanuts, cowpea, common beans, cassava.... Cassava is the most important crop. Some irrigation research is done along the lake border.

Field Trip No. 2

Date: Thursday, 4 June 1981

Visited area:	Ruhengeri-Gisenyi, volcanic area (1)
Place of departure:	Kigali
Place of arrival:	Gisenyi
Hour of departure:	0800 H
Distance:	177 Km
Duration of trip:	8H45'
Visited profiles:	No. 6 and No. 7

Place	Time	Km	Observations
Kigali	0800	0	---
Gatsata	0810	8	Rice fields, sugar plant
Rutongo	0835	24	Cassiterite mining center--alt. 1920 m
Base, bridge	0935	60	Affluent of the Nyabarongo River
Mukungwa, bridge	1100	109	Hydroelectric power station under construction
Ruhengeri	1110	115	Center of "préfecture" entry in volcanic area--alt. 1850 m
- PNAP	1115	117	Potato research center; site of profile R6 (2)
	1230	departure from R6	
- Lunch	1235	118	---
	1400	departure from Ruhengeri	
Mutura	1445	150	Center for seed multiplication Alt. 2350 m (3); site of profile R7
	1615	departure from R7	
Pfunda	1635	168	Tea plant (4)
Gisenyi	1645	177	Center of the "préfecture" at the border of Kivu Lake (5), alt. 1450 m

(1) The trip from Kigali to Ruhengeri goes through a very mountainous region with a relief formed in a bedrock of shales. Most soils are clayey Ultisols.

(2) The potato research center has been operating for 2 years now. It is looking for well-adapted potato varieties which are resistant to bacterial and Phytophtora blight. From here, seed potatoes are spread to the farmers and other multiplication centers. Some research is done on potato storage.

(3) From the road Ruhengeri-Gisenyi, with clear weather, the chain of extinct volcanoes marking the border between Rwanda and Zaire can be seen. The highest, the Karisimbi, reaches 4507 m. At the foot of these volcanoes the pyrethrum crop is grown. The volcanoes themselves constitute

the last refuge of the mountain gorilla. The center of Mutura has been created mainly for the multiplication of high altitude crops: wheat, triticale, peas, potatoes.... It is run by the "Service for Selected Seeds" which owns several other centers where new varieties proposed by agricultural research are multiplicated for the benefit of the farmer.

(4) Rwanda has about ten tea factories, manufacturing the tea production of some 7000 ha. The Kitabi plantation situated at 2300 m in the south of the country produces one of the best teas in the world.

(5) In the past, Gisenyi was a well-known "lieu de villégiature" in Africa. Through the construction of a new hotel, the government tries to make it attractive again. Just at the other side of the border lies Goma, an important town in the Kivu region of Zaire.

Field Trip No. 3

Date:	Saturday, 6 June 1981
Visited area:	Gisenyi, back to Kigali
Place of departure:	Gisenyi
Place of arrival:	Kigali
Hour of departure:	0800
Distance:	212 Km
Duration of trip:	11H5'
Visited profiles:	No. 8, No. 9, and No. 10

Place	Time	Km	Observations
Gisenyi	0800	0	---
Kanzenze	0835	21	Site of profile R8
	1000	departure from R8	
Gisa	1020	39	Site of profile R9
	1150	departure from R9	
Gisenyi	1200	lunch	
	1330	departure from Gisenyi	
Ruhengeri	1445	101	---
Gahindo	1510	121	Site of profile R10
	1640	departure from R10	
Base, bridge	1750	156	---

Place	Time	Km	Observations
Rutongo	1830	188	Altitude 1920 m
Kigali	1905	212	---

Field Trip No. 4

Date: Sunday, 7 June 1981

Visited area: South of the country, Butare (1)

Place of departure: Kigali

Place of arrival: Kigali

Hour of departure: 0730 H

Distance: [illegible] Km

Duration of trip: 11H55'

Visited profiles: No. 3, No. 4 and No. 5

Place	Time	Km	Observations
Kigali	0730	0	---
Nyabarongo bridge	0740	6	Second river of Rwanda
Gitarama	0820	[illegible]8	Center of the "préfecture"
Munini	0845	68	Site of profile R3
	1000	departure from R3	
Ruhango	1005	71	Important local market
Nyabisindu	1030	89	Local center
ISAR-Songa	1040	96	Cattle breeding research station (2)
ISAR-Rubona	1055	109	Main agricultural research station (3)
Mbazi	1105	117	Site of profile R5
	1230	departure from R5	
Butare	1235	125	Second city of Rwanda; alt. 1750 m (4)
			Lunch
	1350	departure from Butare	
Kibeho	1430	149	Site of profile R4
	1550	departure from R4	

Place	Time	Km	Observations
	1605	160	Experimental field on soil fertility (5)
	1635		departure from Mata
Butare	1735	195	---
Kigali	1950	320	---

(1) The road Kigali-Butare crosses an area of mainly granitic bedrock that contains many quartz veins. The high hilltops are of quartzitic origin. The soils are in general gravelly, shallow and of light texture. Stone-lines are very common. Depth of the loose soil material is irregular. In the roadcut dark horizons can often be seen. It is an area of medium to low agricultural potential. In the neighbourhood of Butare, soils become much better, the bedrock changes in migmatite, shales with some intrusions of basic rocks. Around Butare, the highest population densities of Rwarda are noted: more than 700 people per sq km. Agriculture remains their principal subsistence source on very small plots (0.5 to 1.0 ha).

(2) The cattie-breeding ISAR-station of Songa has existed since 1930. Through selection in the local Ankole breed and through crosses with exotic races such as Jersey and Sahiwal, better milk and meat production performances are hopefully obtained. High productivity is hampered by shortage of adequate food and the existence of several diseases, among which the East coast fever causes the most damage. Some selection is also done on sheep and goats.

(3) The ISAR-station of Rubona is the most important of the agricultural research stations. It hosts all the laboratories, among them one for soil analysis. The research is especially concentrated on the crops of the mid-altitude areas (1500-1800 m): sorghum, common beans, soybeans, maize, sweet potatoes, coffee...

(4) Butare, the second city of Rwanda, is well known for the high concentration of educational institutions. It hosts the National University, and also an arboretum of high value: more than 150 different kinds of trees from everywhere in the world.

(5) Since 1972, ISAR controls an experimental field in the Mata region

where it is searching for methods for increasing the extremely low productivity of the soils under the *Eragrostis blepharoglumis* grassland. Spectacular results have been obtained with lime and fertilizers. Yields of the common crops have been increased from almost 0 kg to normal figures.

The basic problem turns out to be one of aluminum toxicity linked to the efficient fixation of the phosphorus. A wide program for increasing the agricultural production in the high-altitude areas has been based on the results achieved in this experimental field.

Field Trip No. 5

Date:	Monday, 8 June 1981
Visited area:	Akagera National Park
Place of departure:	Kigali
Place of arrival:	Akagera
Hour of departure:	0730 H
Distance:	220 Km
Duration of trip	10 H
Visited profiles:	No. 11

Place	Time	Km	Observations
Kigali	0730	0	---
Masaka	0745	19	Planned settlement of Icyanya on 2 ha plots based on coffee crop
Rwamagana	0835	62	Second center in the "préfecture" of Kibungo
Nsinda	0840	67	Site of profile R14
Kayonza	0855	76	Crossing of roads: to the right to Kibungo--Tanzania border, to the left to Gabiro--Uganda border
Muhazi lake	0910	81	Beautiful elongated lake
	1020	123	To the left road to Gatsibo--Byumba, typical savannah--landscape of east Rwanda
Nyakajage	1030	126	Site of profile R11
	1200		departure from R11

Place	Time	Km	Observations
Gabiro	1215	136	Guest-House, Lunch
	1300		departure from Gabiro
National Park	1330	139	Entry in the National Park (1)
Akagera Hotel	1730	220	Akagera Hotel

(1) The Akagera National Park was created in 1934 and occupies an area of 2500 sq km. In the east, the Akagera River, at an elevation of 1250 m, constitutes the border with Tanzania. It flows through large papyrus swamps interrupted by several lakes. We encounter a large variety of landscapes in the park: eroded hills with the highest point of 1825 m at Mount Mutumba, often covered with ironstone crusts, large valleys with Vertisols. Only these valley soils together with the humus-rich pediment soils could be used for agricultural purposes when enough rainfall would be available. In reality, rainfall is very low and irregular: 700-800 mm/year.

The flora depends on the quality of the soil and the amount of rainfall: grass savannah in the plains, Acacia wood on the pediments and xerophytic shrubs on the shallow soils About 28 species of big mammals can be seen in the park. It is well known for its large herds of buffalos, zebras, impalas and topis.

Field Trip No. 6

Date: Tuesday, 9 June 1981

Visited area:	South of the National Park, Rwinkwavu
Place of departure:	Hotel Akagera
Time of departure:	0800 H
Place of arrival:	Hotel Akagera
Distance:	34 Km
Duration of trip:	4H05'
Visited profiles:	No. 12 and No. 13

Place	Time	Km	Observations
Hotel Akagera	0800	0	---
Bishenyi	0815	8	Site of profile R12

Place	Time	Km	Observations
	0945	departure from R12	
Rwinkwavu	1005	17	Site of profile R13 (1)
	1135	departure from R13	
Hotel Akagera	1205	34	Lunch and presentation of papers

(1) Rwinkwavu is one of the important cassiterite mining centers in Rwanda.

Field Trip No. 7

Date: Wednesday, 10 June 1981

Visited area: Rwamagana area

Place of departure: Hotel Akagera

Place of arrival: Kigali

Hour of departure: 0800 H

Distance: 123 Km

Duration of trip: 4H10'

Visited profiles: No. 14

Place	Time	Km	Observations
Hotel Akagera	0800	0	---
Rwinkwavu	0835	18	Mining center
Kabarondo	0855	28	Crossing with the main road Kibungo-Kayonza
	0910	36	Craterlike depression (1)
	0925	departure from depression	
Kayonza	0935	45	Crossing of roads (see field trip No. 5)
Nsinda	0945	54	Site of profile R14
	1115	departure from R14	
Rwamagama	1120	61	Center of Rwamagana
Kigali	1210	123	Kigali, lunch

(1) Craterlike depressions are very numerous in Rwanda, especially in the regions covered with ironstone crust, where large plateau-like hill-tops are the common landscape feature. The origin of those craters is not known. Probably they have something to do with lateral transport of soil material under a former ironstone crust. They are generally found at the edge of a large hilltop.

Field Trip No. 8

Date: Thursday, 11 June 1981
Visited area: Byumba (1)
Place of departure: Kigali
Place of arrival: Kigali
Hour of departure: 0800 H
Distance: 134 Km
Duration of trip: 4H15'
Visited profiles: No. 15 and No. 16

Place	Time	Km	Observations
Kigali	0800	0	---
Gatsata	0810	8	Rice fields, sugar plant
	0815	16	Road crossing Kigali-Ruhengeri, Kigali-Byumba; sugarcane in the valley
	0900	59	Road crossing: to the right to Gatsibo, to the left to Byumba, straight on to the Ugandan border
Gitanwa	0905	63	Site of profile R15
	1010	departure from R15	
Kageyo	1025	71	Site of profile R16
	1110	departure from R16	
Kigali	1215	134	Lunch

(1) The very high mountains are typical for the region of Byu a. The highest tops reach 2400 m; the small valleys descend to 1800 m. In spite of the rough landscape, soils are in general deep even on the slopes of 50% and more. It is an area of good agricultural potential.

EXPLANATORY NOTES ON GRAPHS OF DEPTH FUNCTIONS OF FEATURES IN SOME SOILS FROM RWANDA

E. Schlichting

The graphs were prepared from data given in the Tour Guide of the 4th International Soil Classification Workshop held in Rwanda 2-12 June 1981 (only P-availability and PWP recalculated) in order to facilitate the comparison between depth functions of various features in one profile or of one feature in various profiles. The soil landscapes and their profiles were arranged in a slightly different way than in the Tour Guide in order to clarify certain trends. The classification of the profiles is that given by experts during the tour.

1. Soils From Ashes of the Northwestern Mountains

This landscape consists of lava plains (about 2200 m a.s.l.) with strong microrelief and several old volcanic mounds (up to 4500 m), made up of ashes and more coarse material, with very steep slopes (>50%). In the western and eastern fringe the volcanic materials are mixed with others. The soils were (partly are) covered by a medium mountain forest. From Fig. 1 it can be derived that with an increase in the proportion of volcanic material and in mm: °C (=rain factor, 50 to 100) and a decrease of erosion there are:

(a) increase in medium + fine silt rather than in measurable clay (of halloysitic to allophanic nature),

(b) increase first in free iron (Fe_d), then in extractable Al (Al_d), average $Fe_d:Al_d$ 7.2, 3.3, 1.6 in profiles 6, 8 and 7, respectively, (12.0 in 9),

(c) increase in organic matter with C:N near 10 (≈mull),

(d) first increase and then slight decrease in pH,

(e) parallel with (a) and--especially--(c) decrease in bulk density, increase in pH (NaF) and in CEC_p,
parallel with (d) some decrease in exchangeable bases without con-

siderable increase in Al, i.e. some decrease in the "real" CEC_r,

(f) parallel with (b) (especially Al) and (d) decrease in P availability.

In profile 9 from mS:fS of 0.5 above and of 1.0 below 7 dm depth a stratification can be derived which corresponds with higher mica contents and very high amounts of exchangeable K above that depth.

The soils are medium to very rich in N (1800, 2600, 4200 and 7700 gN/m^2 to 10 dm depth), more or less rich in Ca, Mg and K (except for profile 8 which is very poor) and have a good root penetrability. Available P was not determined and the air capacity and available water capacity cannot be calculated since data on pore volume and field capacity are lacking. Weight related 15-bar water data overemphasize the influence of allophane on the PWP since it decreases the bulk density.

2. Soils From Shales of the Northern Mountain Ridges

This very hilly landscape is a former erosion surface dissected into ridges (tops about 2000 m, partly covered with ironstone gravel) with steep slopes (average 50%) and deeply (≈200 m) incised small valleys. The soils were (but rarely are any longer) covered by forest. From Fig. 2 it can be derived that in this (presumed!) weathering sequence there are:

(a) decrease in medium + fine silt (high total silt contents in profile 10 due to the parent material!) and increase in clay; fine clay: clay-maximum only in the argillic horizon of the Alfisol,

(b) increase in free iron and extractable alumina, more than that in clay (especially Al, cf. Fig. 6), but in the profiles parallel with it (except for below 8 dm in profiles 15 with concretions + mottles and 16 with laterized shale fragments),

(c) increase in organic matter with an increasing C:N (extremely narrow C:N in the subsoils of the profiles 15 and 10 with mottling and with the highest content of 2:1 clay minerals of all profiles,

(d) decrease in pH,

(e) parallel with (c) decrease in bulk density and increase in CEC_p, parallel with (d) exchangeable bases decreasing and Al (more) increasing, i.e. an increase in the CEC_r (in profiles 15 and 16 CEC $NH_4OAc < NH_4Cl$!),

(f) parallel with (b) and (d) decrease in P availability, higher values in topsoils also parallel with (c).

In profile 16 from charcoal in the 3rd, sombric material (with wider C:N and higher pH in NaF) in the 4th and a discontinuity in the mS:fS values (cf. Fig. 6) between these horizons and a stone line below a stratification can be derived (unfortunately proof with gravel or stone contents not possible since not determined).

The soils are increasingly penetrable by roots physically (though the bulk densities in the subsoil of profile 15 were probably overestimated) but not physiologically (due to toxic amounts of Al), rich in N (1560, 1620 and 6600 gN/m^2 and poor in Ca, Mg (especially 10) and K (especially 16). Concerning available P, water and air capacity see 1.

3. Soils From Granites of the Southern Mountain Ridges

This hilly landscape differs from the preceding one insofar as the hilltops are about 1700 m, often plateau-like with smoother slopes (30-45%, often concave) and the valleys are less (≈ 100 m) incised and larger. From Fig. 3 it can be derived that with an increase in the thickness of the solum on the saprolithe and in the rain factor (60-80), but not in the slope, there are:

(a) decrease in weatherable sand minerals and (in the topsoil) in 2:1 clay minerals; a fine clay: clay-maximum only in the argillic horizon of the Alfisol,

(b) increase in free iron and extractable aluminum, more than that in clay (except for profile 3, which is the poorest in Fe_d, especially Al, cf. Fig. 6), but in the profiles parallel with it (except for 12-15 dm in profile 4 where also a $Fe_d:Al_d$-ratio like that in profile 8 is to be observed),

(c) increase in organic matter with an increasing C:N with less decrease or even an increase in the 4th, 5th or 6th horizon of profiles 3, 5 or 4, respectively (sombric horizons),

(d) decrease in pH,

(e) corresponding to (a) in spite of (c) (C:N increasing!) scarcely an increase in CEC_p and CEC_r, but of pH (NaF), parallel with (d) exchangeable bases decreasing and Al increasing; in the sombric horizons (cf. c) higher CEC_p and lower bulk densities,

(f) P availability less parallel with (b) and (d) than in landscapes 1 and 2.

Discontinuities in the mS:fS-ratios in profiles 3 and 4 (cf. Fig. 6, in 3 even a stone line) and charcoal in the horizons above the sombric show a stratification in all profiles. In profile 4 higher values for Al_d and pH (NaF) as well as CEC_r corresponding better to fine silt + clay than to clay alone point to an addition of ash in the depth 12-15 dm (cf. b).

The soils are medium in N (960, 1500 and 1520 gN/m^2 with probably decreasing availability, see C:N) and increasingly penetrable by roots (except for toxic amounts of Al, cf. 2), surprisingly poor in the sequence K > Mg > Ca. Concerning available P, water and air capacity see 1.

4. Soils From Granites (and Shale) of the South(east)ern Peneplains

This landscape differs from those described in sections 2 and 3 insofar as the hilltops are about 500-300 m lower and more often plateau-like with smoother slopes (30-20%). There is a frequent appearance of ironstone gravel. This tertiary peneplain is now under a rather dry climate and partly still covered by a savanna. From Fig. 4 it can be derived that with an increase in the thickness of the solum but a decrease in the rain factor (45 to 40) there are:

(a) rather a decrease than an increase in the content of clay (with similar minerals),

(b) decrease in free iron and extractable alumina, both between and in the profiles parallel with clay (cf. Fig. 6),

(c) decrease in organic matter with a decreasing C:N,

(d) only slight decrease in pH (increase in the topsoil),

(e) parallel with (c) and (d) decrease of CEC_p, CEC_r and of exchangeable bases (except for the topsoil) and--at least relatively--increase of exchangeable Al,

(f) parallel with (b) and (d) increase in P availability, especially in the topsoil.

These profiles can be linked with those in landscapes 2 and 3. Profile 14 shows CEC (NH_4OAc) < CEC (NH_4Cl) and a stratification similar to profile 16 (cf. Fig. 6, charcoal and sombric material--lesser decrease of C-- in the 4th horizon), but differs from 15, 10 and 16 by less silt and no illite, higher pH and contents in exchangeable bases, lower CEC_p and contents in C, N, Fe_d and Al_d (cf. Fig. 6). Accordingly, profiles 2 and 1 differ from 3-5 in lower contents in silt and weatherable minerals (no 2:1 minerals), C and N, free iron and exchangeable Al as well as lower CEC_p and in the topsoil higher pH and contents in exchangeable bases as well as higher P availability.

The soils are medium to low in N (1270, 660 and 590 gN/m^2 with probably increasing availability, see C:N), poor generally in K and increasingly in Ca (less in Mg). Concerning available P, water and air capacity see 1.

5. Soils From Metamorphites of the (North)eastern Peneplains

This landscape consists of strongly eroded hills (slopes 15-25%) with large pediments and moderately (70-80 m) incised large valleys. The soils in this dry region (rain factors below 40) are to a large extent still covered by a savanna. From Fig. 5 it can be derived that with a decrease of the proportion of shales in the pediment material and of the thickness of the solum above the C-horizon there are:

(a) decrease in clay and increase in the proportion of illites,

(b) decrease in free iron and extractable alumina, less than that in clay (especially Al, cf. Fig. 6),

(c) decrease in organic matter,

(d) only slight decrease of pH ($\pm$ increase in the topsoil),

(e) parallel with (a) and (c) decrease of CEC_p, with (d) decrease of exchangeable bases (less in the topsoil) and Al, i.e. decrease in CEC_r,

(f) parallel with (b) and (d) substantial increase in P availability (not only in topsoil).

These profiles can be linked with those in landscape 4. Profile 11 shows features (including a stratification in 9 dm depth, cf. Fig. 6) similar to those of profile 14, except for the different clay minerals and the higher topsoil-pH (this explains why Oxisol or Alfisol for profiles 11 and 14, respectively, were discussed as alternatives). Profiles 12 and 13 contain less total but more 2:1-clay and equal organic matter and, therefore, have a similar CEC_p as profiles 2 and 1, respectively, (consequently Paleustult was discussed for profiles 12 and 2), but contain more exchangeable bases and less exchangeable as well as extractable Al and have a higher P availability.

The soils are medium to low in N (1060, 810 and 440 gN/m^2), contain Ca, Mg and K in decreasing but, except for K in profile 13, still sufficient amounts and are not increasingly penetrable by roots as could be derived from the decreasing clay contents. Whether the decreasing PWP leads to a higher available water capacity cannot be judged (neither the available P, see 1.).

Hypotheses about soil genesis should be based on such relationships and then should be proved. It was not the intention of this article to discuss them in detail, but some examples shall be given:

(a) The profiles 15 and 10 are the only ones with "pseudogley"-morphology. On such steep slopes (35 and 40%) this could be caused by laterally moving water which might have imported NH_4 which, in turn, might be trapped by 2:1-clay minerals (cf. 2). This could be proved by comparing the nitrogen contents of these clay fractions with those of profile 16.

(b) The frequent appearance of signs for stratification (mS:fS-discontinuities, charcoal) over sombric horizons in profiles 3, 4, 5, 14 and 16 and their more distinct character with increasing inclination point to buried A- rather than to illuvial B-horizons. This could be proved by comparing the organic matter extractability in profiles with and without sombric horizons. The participation of volcanic material should be examined as well.

(c) The maximum of exchangeable bases, pH and P availability and minimum of exchangeable Al in the topsoil of profiles (14), 2, 1 and 11-13 in regions with rain factors below (45-)40 point to a prevalence of the biological pump over the leaching (burning alone would not explain the "S"-maximum and is shown by charcoal only in profile 11). This could be proved by comparing the depth functions of total P of these and soils from similar parent material in moister regions.

Abbreviations and Symbols Used in the Graphs

1. Section 1

(a) Size fractions: S=sand, U=silt, T=clay, +=cutanes, ( )=rare, indicated only in the uppermost horizon of appearance

(b) Minerals: Au=augite, Hbl=hornblende, Fsp =feldspar, All=allophane Chl=chlorite, Goe=goethite, Hall=halloysite, Hä=hematite, Ill=illite, Kao=kaolinite, Verm =vermiculite

2. Section 2

Fe_d = dithionite-citrate extractable iron (same Al_d in section 4)

3. Section 3

"S" = exchangeable Ca+Mg+K+Na

Al = exchangeable Al

H = CEC_p - ("S"+Al)

CEC_p = potential cation exchange capacity (NH_4OAc pH 7)

A = ash, Gr = granite, Mig = migmatites, Qu = quartzite, Sh = shales, all = alluvium, coll = colluvium

4. Section 4

P-AJ = P-availability index 1-c, c = P-adsorption coefficient

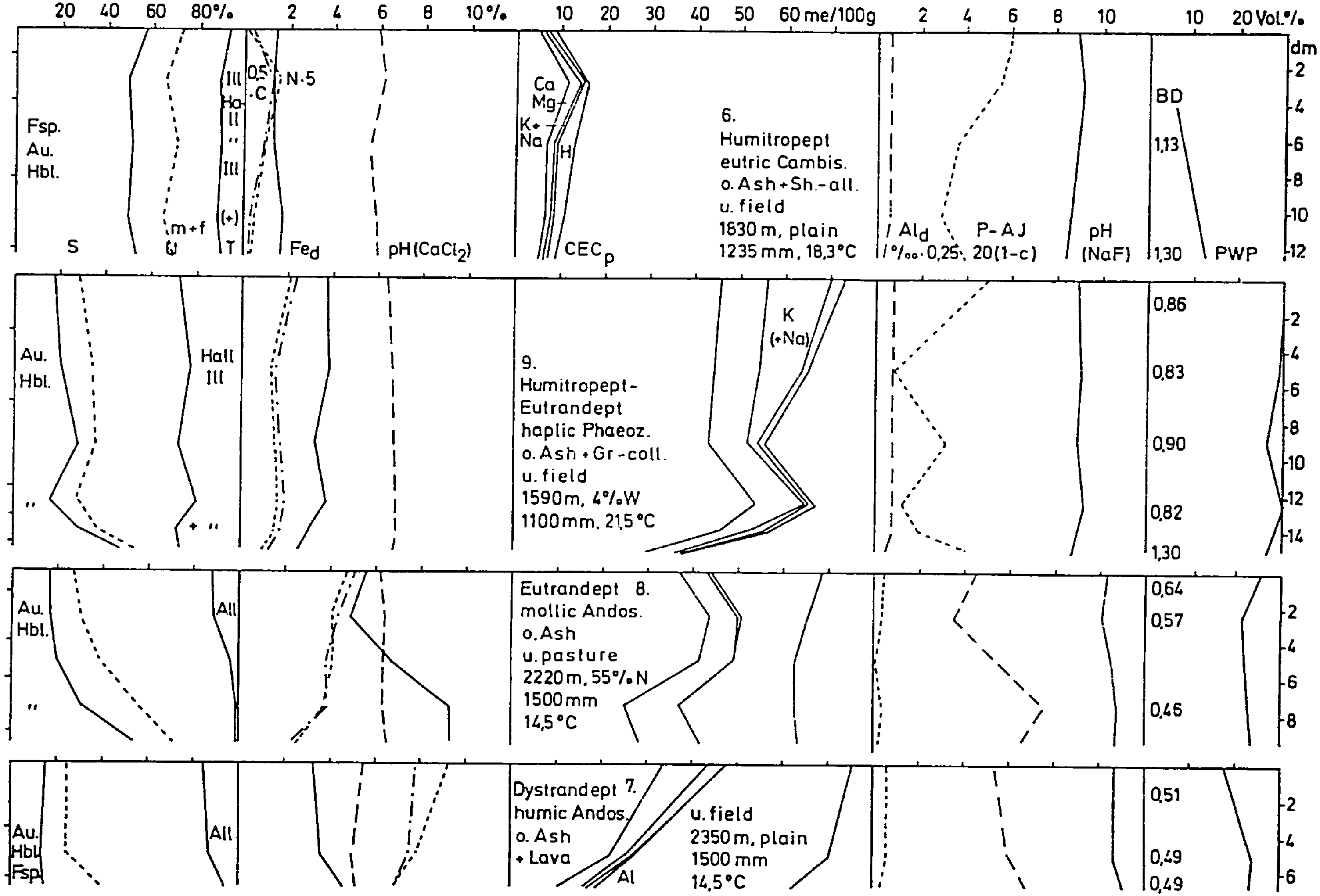
5. Section 5

BD = bulk density

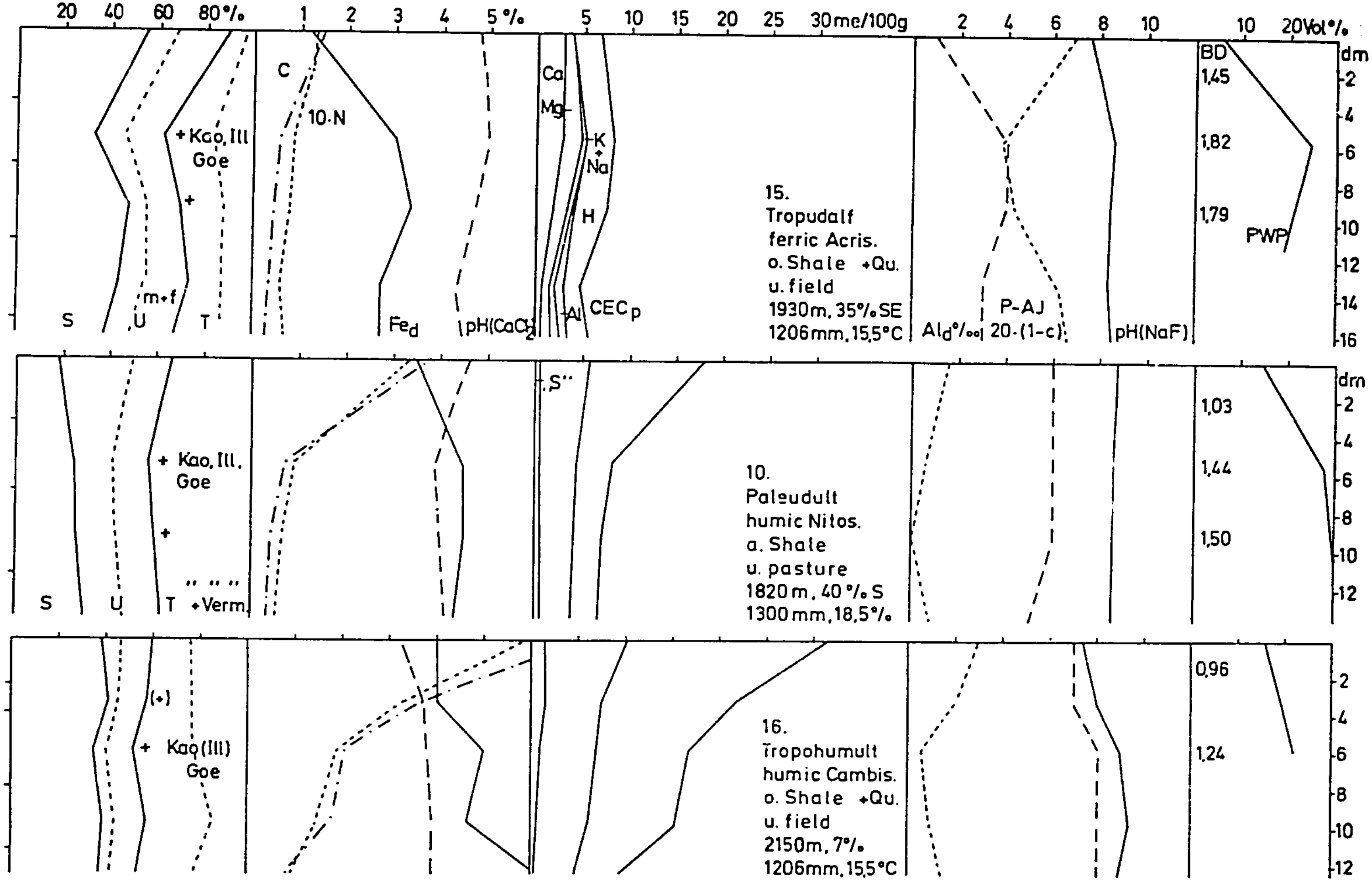
PWP = 15-bar water by weight·BD

General remark: In order to simplify the abscisses, some data were multiplied (e.g. by 0.5, 5 or 20); calculation of the real values, therefore, requires division of the numbers on the abscisses by these factors; factors for C and N are such that identical position of curves means C:N = 10. It should be noted that the scales for the sections 2 and 3 in graph 1 are two times smaller than in the other graphs.

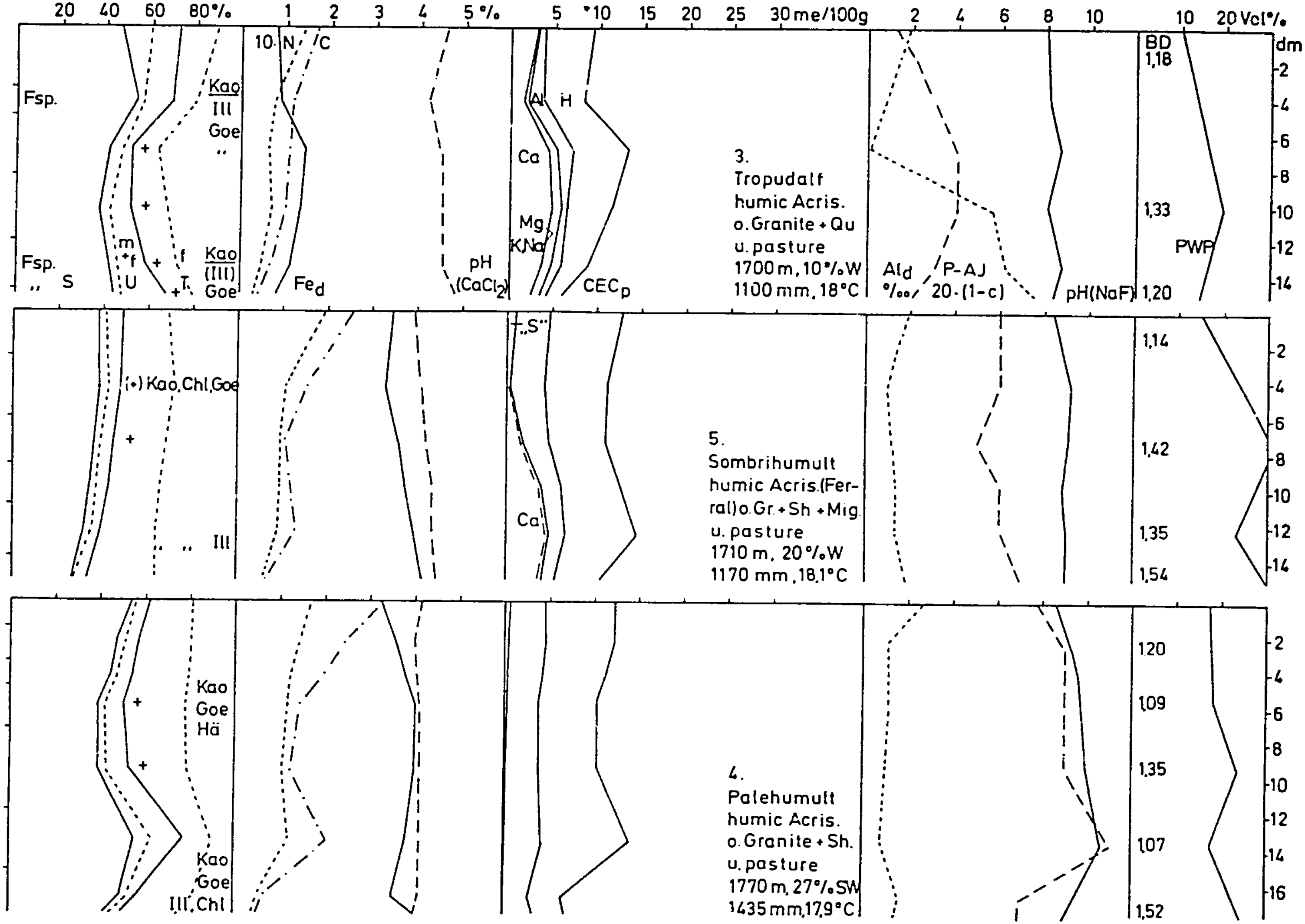
1. Soils from ashes of the northwestern mountains, Rwanda



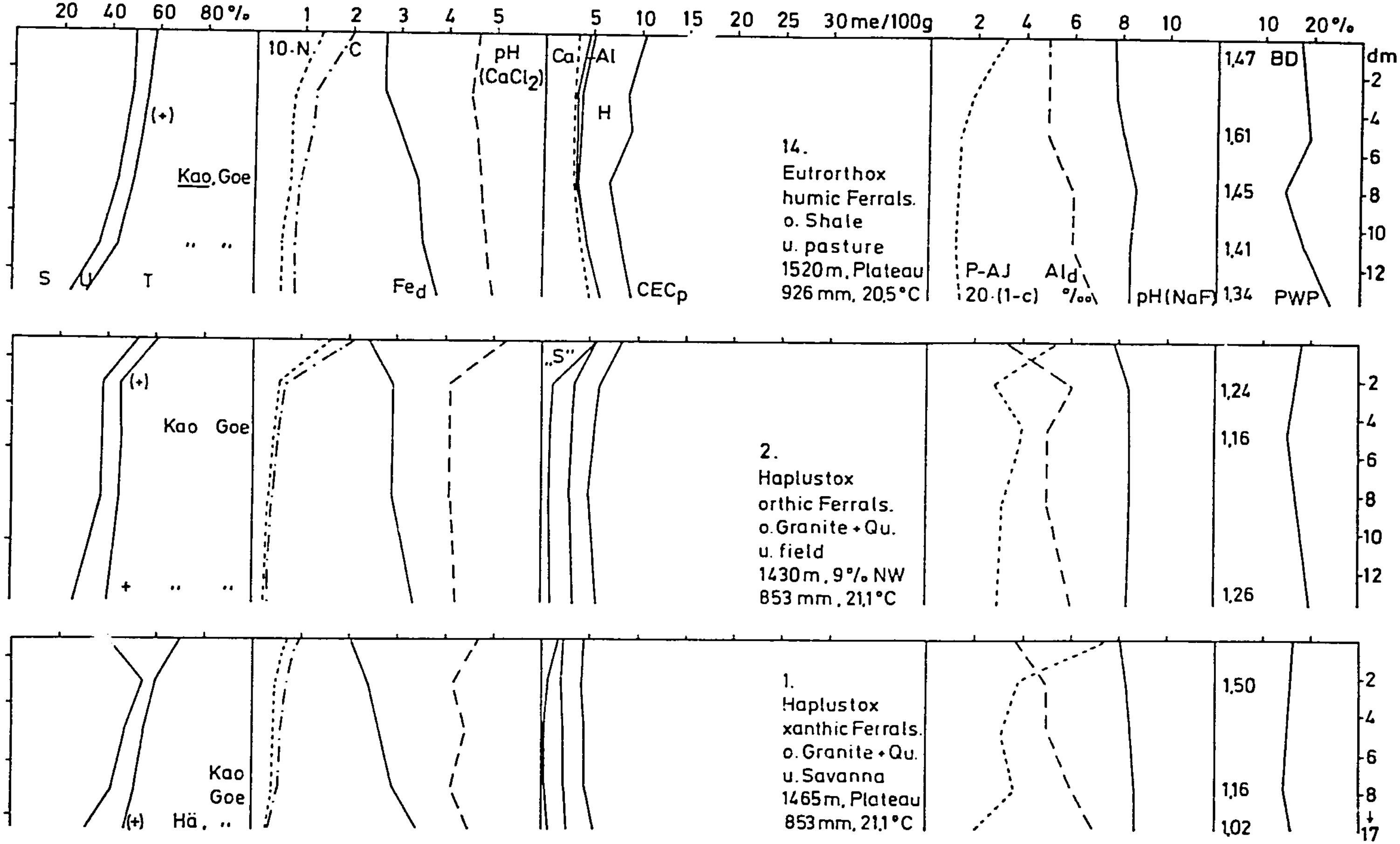
2. Soils from shales of the northern mountain-ridges, Rwanda



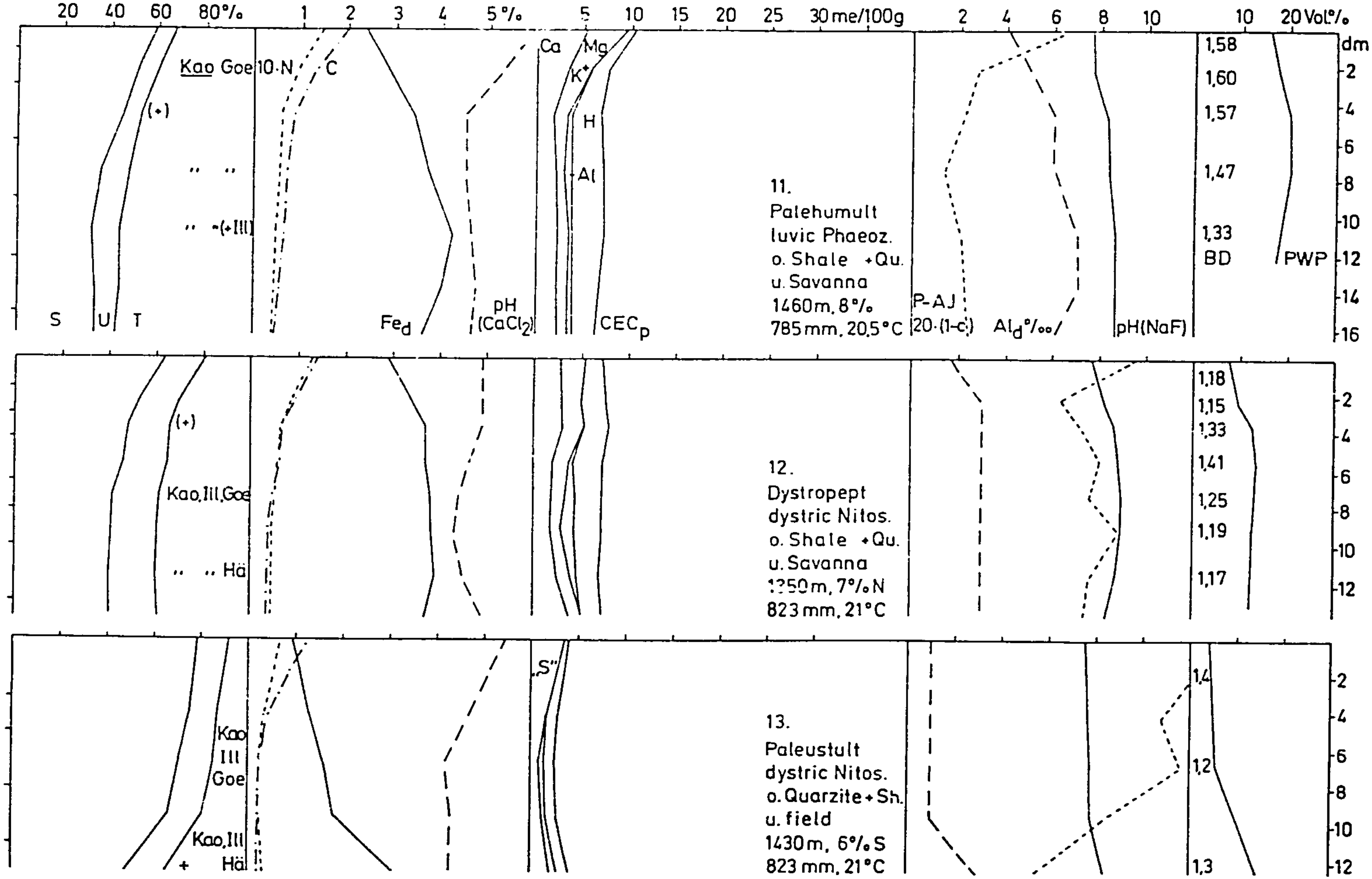
3. Soils from granites of the southern mountain-ridges, Rwanda



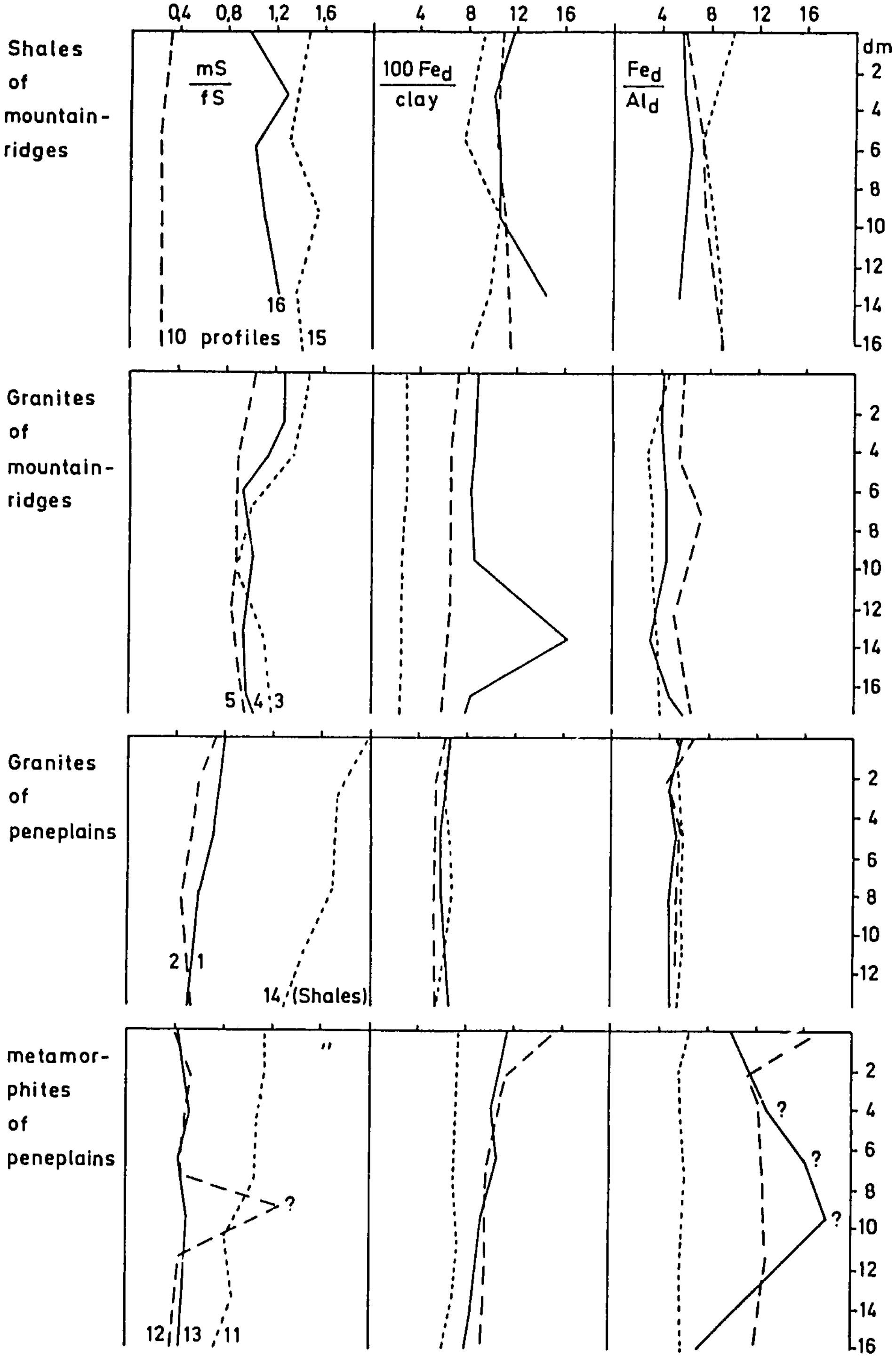
4. Soils from granites (and shale) of the southeastern peneplains, Rwanda



5. Soils from metamorphites of the northeastern peneplains, Rwanda



6. Ratios between various features in some soils from Rwanda



ANALYTICAL METHODS

The following is a brief description of the procedures and methodology used by the National Soil Survey Laboratory. If a more detailed description of any procedure is needed, the following report should be consulted: "Soil Survey Investigations Report No. 1, "oil Survey Laboratory Methods and Procedures for Collecting Soil Samples" USDA, SCS Revision 1981. For equivalent procedures of a less automated and instrumented nature, the 1972 revision should be consulted.

Method codes are included in the column headings on the data printouts and can be used as a key to the methods and procedures given in the above reports.

Some general comments on how the samples are handled:

All samples are air-dried and crushed using a wooden roller and sieved to remove fragments greater than 2 mm in diameter. All determinations are made on sieve samaples and reported on an oven-dry weight basis unless otherwise stated. The oven-dry weight basis is determined by oven-drying a sample at 105 degrees C.

Particle Size Distribution

Particle size distribution is determined on soil that has been treated with hydrogen peroxide for destruction of organic matter, washed to remove soluble salts with a filter candle system, dispersed with Calgon, and overnight shaking. Sand is separated from silt and clay by wet sieving. Clay is based on the weight of the clay in an aliquot taken by a pipette from a 1-liter suspension of the silt and clay. Silt is divided into coarse (.05 - .02 mm) and fine (.02 - .002 mm) silt. Fine silt is determined by pipette. Coarse silt is determined by the difference between 100 and the sum of sand and fine silt plus clay. Carbonate clay is determined by treating a clay aliquot with HCl and measuring the amount of CO_2 liberated with a digital electronic manometer.

15-Bar Water

The 15-bar water is determined by pressure membrane extraction. The water retained is expressed as a percent of the oven-dry weight of the soil.

Organic Carbon

Organic carbon is determined by the Walkley-Black procedure--oxidation with potassium dichromate and sulfuric acid. Excess dichromate is titrated with ferrous sulfate standardized against potassium dichromate on an automatic titrator. The laboratory uses a recovery factor of 0.77 as proposed by Walkley.

Nitrogen

Nitrogen is determined by Kjeldahl digestion with the ammonium being steam distilled into boric acid and titrated with HCl on an automatic titrator.

Dithionite-Citrate Extraction

Dithionite-citrate-extractable iron, aluminum, and manganese are determined by extracting a soil sample with an excess of sodium dithionite and sodium citrate in an 8-ounce bottle. Two grams of sodium dithionite and 20 grams of sodium citrate are added together with 4 ounces of water, and the sample is shaken overnight on a reciprocating shaker. Five drops of superfloc are added, the volume is made to 8 ounces, and the sample is shaken vigorously for 15 seconds and allowed to settle. An aliquot of the supernate is removed for the determination of iron, aluminum, and manganese by atomic absorption.

CEC and Extractable Bases (Ca, Mg, Na, K), pH 7

The soil is leached with normal ammonium acetate at pH 7 using an automatic extractor. Calcium, magnesium, sodium, and potassium are determined in the leachate by atomic absorption.

Excess ammonium acetate is leached from the sample with 95% ethanol, and the absorbed ammonium ion is steam distilled into boric acid and titrated with HCl to determine the ammonium acetate CEC at pH 7.

Extractable Acidity

Extractable acidity is measured by pH 8.2 triethanolamine and barium chloride replacement using an automatic extractor. The leachate is titrated with HCl.

Extractable Aluminum

The soil is leached with normal KCl using the automatic extractor. Aluminum is determined in the extract by atomic absorption.

CEC-Sum of Cations

Cation exchange capacity computed from the sum of ammonium acetate-extractable bases and extractable acidity.

CEC-Sum of Bases Plus Aluminum

Cation exchange capacity derived from the sum of ammonium acetate-extractable bases and the KCl-extractable aluminum.

CEC-NH_4Cl (Cation Retention Capacity by NH_4Cl, Unbuffered)

The soil is leached with normal ammonium chloride using an automatic extractor.

Excess ammonium chloride is leached from the sample with 95% ethanol, and the absorbed ammonium ion is steam distilled into boric acid and titrated with HCl to determine the ammonium chloride CEC.

pH-NaF

Fifty ml 1-N sodium flouride are added to 1 gram air-dry soil in a plastic beaker and stirred for 1 minute. The pH electrodes are immersed in the upper third of the suspension and the stirring continued for 1 minute longer. The pH of the suspension is read exactly 2 minutes after addition of the sodium flouride solution.

pH-Water

Twenty grams air-dry soil is weighed into a 4-ounce cup. Twenty ml distilled water is added and stirred. This is allowed to stand for 1 hour with occasional stirring. Cups are loaded into the sample changer of the automatic pH unit. Unit is programmed for number of samples involved and set for reading time of 60 seconds following cessation of stirring for both 1:1 water and 1:2 calcium chloride. Twenty ml of .02 M $CaCl_2$ are added after the water pH is taken, and after 60 seconds more, the $CaCl_2$ pH is measured.

pH-KCl

Same procedure as for pH-water except 1 N KCl is used.

Mineralogy

Both X-ray diffraction and differential thermal analysis are run using standard methodology.

Mineralogy

The clay, silt and sand fractions of selected horizons from each profile were analyzed to determine the mineralogical composition. The different techniques employed are briefly as follows:

(a) X-ray diffraction analysis (XRD). A Phillips diffractometer with a copper tube (at Lincoln) and a cobalt tube (in Ghent) were used. XRD was run on the untreated clays. A few of the clays showed weak peaks at low two theta values and so K and Mg saturation with associated heating or glycerol solvation, respectively, was done.

XRD analyses were also done on the silt and sand fractions.

(b) Differential thermal (DTA) and thermo-gravimetric analysis (TGA). These analyses were done only on the clay fractions. The instruments used were the Stone thermoanalyzer at Lincoln and the DuPont thermoanalyzer at Ghent. Semi-quantitative estimates were made using the data.

(c) Transmission electron microscopy. A Phillips electron microscope was used at Ghent. All pictures were taken at a magnification of x35,000.

Phosphate Retention Capacity (New Zealand)

This is the procedure suggested by L.C. Blakemore for soils having an exchange complex dominated by amorphous material in the proposal for the reclassification of "Andepts" by Dr. Guy Smith, 10 April, 1978.

Extraction.

Preparation of Reagent.

P-retention solution. Dissolve 8.80 g potassium dihydrogen phosphate (KH_2PO_4), A.R., and 32.8 g anhydrous sodium acetate (CH_3COONa), A.R., in distilled water, add 23 ml glacial acetic acid, A.R., and dilute to 2 liters in a volumetric flask. The pH of this solution should be between 4.55 and 4.65.

Procedure.

1. Weigh 5 g air-dry soil (<2 mm) into a stoppered 50 ml polypropylene centrifuge tube, and add 25 ml P-retention solution. Shake for 24 hr at about 20 degrees C.
2. Centrifuge at 2000 rpm for 15 min.
3. Determination of color.
   a. Color solution. To 4 liters of distilled water add 80 ml ascorbic acid and 160 ml molybdate solution and bring to 8 liters.
   b. Developing the color. Obtain 6 Erlenmeyer flasks (50 ml). To these flasks add as follows (these will be the standards for standard curve):

   Flask - (1) 2 ml extractant
   (2) 2 ml 2 ppm P
   (3) 2 ml 4 ppm P
   (4) 2 ml 6 ppm P
   (5) 2 ml 8 ppm P
   (6) 2 ml 10 ppm P

   Obtain 1 flask for each sample extracted. To these flasks add 2 ml of extract from sample in centrifuge tubes. To all of the flasks add 25 ml of color solution. Let stand for 15 minutes to allow color to develop fully. After color has developed transfer to colorimeter tubes. It may be necessary to dilute some samples.

c. Reading the color. Set the colorimeter at wavelength 880, using a red filter and red phototube. Read on transmittance scale. Zero colorimeter, set 100 using tube-1 of standards. Read remainder of standard curve. Read sample tubes. Calculate. Generally the standard curve is around the following values:

0	2	4	6	8	10	ppm
100	77	59	45	33	24	% transmittance

4. Calculation of results. Prepare a standard curve of % transmittance against % phosphate retention and reap off unknowns.

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Heilman, M.D., D.L. Carter, and C.L. Gonzalez. 1965. The ethylene glycol monoethyl ether (EGME) techniques for determining soil surface area. Soil Science 100:409-413.

Soil Survey Staff. 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. Agric. Handbook No. 436. Soil Conservation Service, U.S. Dept. Agric. U.S. Govt. Printing Office, Washington, D.C.

U.S. Department of Agriculture. 1972. Soil Survey Laboratory methods and procedures for collecting soil samples. Soil Survey Investigations Report No. 1. Soil Conservation Service, Washington, D.C.

RWANDA

Profile R 1

Classification:	Ferralsol (INEAC)
Location:	prefecture Kigali, sous-prefecture Bugesera, commune Gashora, secteur Nkanga, colline Rutete; custom-house at the Burundi frontier, 10 m west of the main road, 62 km from Kigali.
Physiography:	erosion surface, gently undulating landscape, with large plateaus, average slope 20%, difference between hilltops and valleys 130 m, presence of ironstone.
Topography:	plateau, slope west-facing 2%, altitude 1,465 m
Drainage:	well drained
Climate:	Aw4, 4 month dry season; annual rainfall 853 mm; mean temperature 21.1°C, mean soil temperature at 50 cm 25°C
Vegetation:	tropical savanna: Sclerophyllous shrubs, *Acacia hockii* grasses: *Brachyaria sp., Cymbobogon afronardus, Eragrostis sp., Hyparrhenia sp.;* many *Liliaceae*
Parent material:	granite associated with some quartzite
Limitations affecting plant growth:	low nutrient status, irregular rainfall

No. soil sample	Horizon	Depth (cm)	Horizon description
R1,1	A1	0-10	dark brown (10YR4/3); clay; dry; moderate medium crumb structure, slightly hard; many fine roots, several coarse roots of *Liliaceae;*

No. soil sample	Horizon	Depth (cm)	Horizon description
			gradual boundary,
R1,2	A3	10-34	dark brown (7.5YR4/4); clay, visible bleached sand grains; dry; moderate fine and medium subangular blocky, hard; many fine roots; gradual boundary,
R1,3	B21	34-65	strong brown (7.5YR4/5); clay; dry; moderate medium subangular blocky, slightly hard; common fine roots; clear regular boundary,
R1,4	B22	65-93	strong brown (7.5YR4.5/6); clay (more clayey than above); weak medium and fine subangular blocky, dry; soft; presence of some more stable peds (see R1,5); few fine roots; regular gradual boundary,
R1,5	IB2	93-170	strong brown (7.5YR4.5/6) is color of matrix, peds of 7.5YR4/6 (60%); clay for matrix, fine clay for strong blocks; moist; weak medium and fine subangular blocky, friable for matrix; with many (60%) strong medium and coarse angular blocky peds which show clay skins; firm; few fine roots.

-- Samples for micromorphology: R1,2 between 12 and 18 cm containing a large pore with cutans and ants

R1,4 between 68 and 74 cm

R1,5 between 100 and 106 cm

-- Sample for pot trials: R1

1

SAMPLED AS:

S 81FN-000 - R1 SAMPLE NOS. 81P1122 - 1126 DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- TOTAL CLAY LT .002	-2- TOTAL SILT .002-.05	-3- TOTAL SAND .05-2	-4- CLAY FINE LT .0002	-5- CLAY CO3 LT .002	-6- SILT FINE .002-.02	-7- SILT COARSE .02-.05	-8- SAND VF .05-.10	-9- SAND F .10-.25	-10- SAND M .25-.50	-11- SAND C .5-1	-12- SAND VC 1-2	-13- COARSE FRACTIONS (MM) WEIGHT 2-5	-14- 5-20	-15- 20-75	-16- .1-75	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM (3B1)			->	
811122	1S	0- 10	A1	32.4	24.2	43.4	16.4		2.1	22.1	9.3	16.2	13.0	4.5	0.4	--	--	--	34	--
811123	2S	10- 34	A3	40.1	5.9	54.0	25.0		1.6	4.3	5.0	18.9	14.1	9.2	6.8	--	--	--	49	--
811124	3S	34- 65	B21	45.8	7.1	47.1	26.6		2.9	4.2	5.6	17.2	11.8	7.5	5.0	--	--	--	41	--
811125	4S	65- 93	B22	49.1	9.3	41.6	28.3		4.1	5.2	5.8	14.3	8.5	7.2	5.8	--	--	--	36	--
811126	5S	93-170	IB2	53.5	15.7	30.8	33.0		8.2	7.5	8.5	10.9	5.5	3.1	2.8	--	--	--	22	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A10	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811122	1	0.85	0.062			2.1	0.4		0.13	0.26										8.4	
811123	2	0.72	0.049			2.4	0.5		0.10	0.26										10.5	
811124	3	0.58	0.041			2.6	0.5		0.09	0.25										11.4	
811125	4	0.52	0.039			2.9	0.6		0.09	0.26										12.7	
811126	5	0.31	0.029			3.4	0.7		0.10	0.29										15.3	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
811122	1	0.7	0.0	TR	0.4	1.9	4.2	0.4	6.1	4.3	2.3	17	31	44			4.2	8.1	4.6	5.5
811123	2	0.2	0.2	0.1	0.1	0.6	5.5	1.4	6.1	4.2	2.0	70	10	14			4.0	8.2	4.2	5.0
811124	3	0.1	0.1	--	0.1	0.3	6.4	1.8	6.7	4.3	2.1	86	4	7			3.9	8.4	4.4	4.9
811125	4	0.1	0.1	--	0.1	0.3	6.6	1.9	6.9	4.5	2.2	86	4	T			4.0	8.6	4.2	4.9
811126	5	0.4	0.2	TR	0.1	0.7	8.1	1.7	8.8	5.3	2.6	73	8	13			4.0	8.6	4.5	5.1

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY TOTAL ANALYSIS 7C3 K2O 6Q3A	Fe 6C7A	CLAY X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- PCT	->	<- RELATIVE AMOUNTS			->	<- PCT			->
811122	1	0.67		2.6										
811123	2	0.81		2.6										
811124	3	0.84		2.9										
811125	4	0.82		3.1	0.3	8.0	KK 4	GE 2			KK69			
811126	5	0.90		4.3	0.3	7.9	KK 4	GE 2	HE 1		KK60			

FAMILY CONTROL SECTION: DEPTH 0-110 PCT CLAY 47 PCT .1-75MM 36

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE GE GOETHITE HE HEMATITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE.

PROFILE 1

Sample 2. 10-34 cm. A3

The plasma is reddish brown in color and is aggregated into clumps of 1-5 cm diameter. Many of the clumps adhere to the angular, coarse sand size quartz grains. Most of the grains are quartz and there are traces of tourmaline, zircon, garnet, and a few glaucophanes.

Under polarized light the plasma is completely isotropic. Under higher magnifications and light intensities, the plasma has a waxy appearance. There is no evidence of any plasma separations or accumulation through translocation.

Runiquartz is frequent and some have very reddish plasma not only in the hair-line cracks but also in the external notches. The specific related distributions pattern (SRDP) is congelic.

Sample 4. 65-93 cm. B22

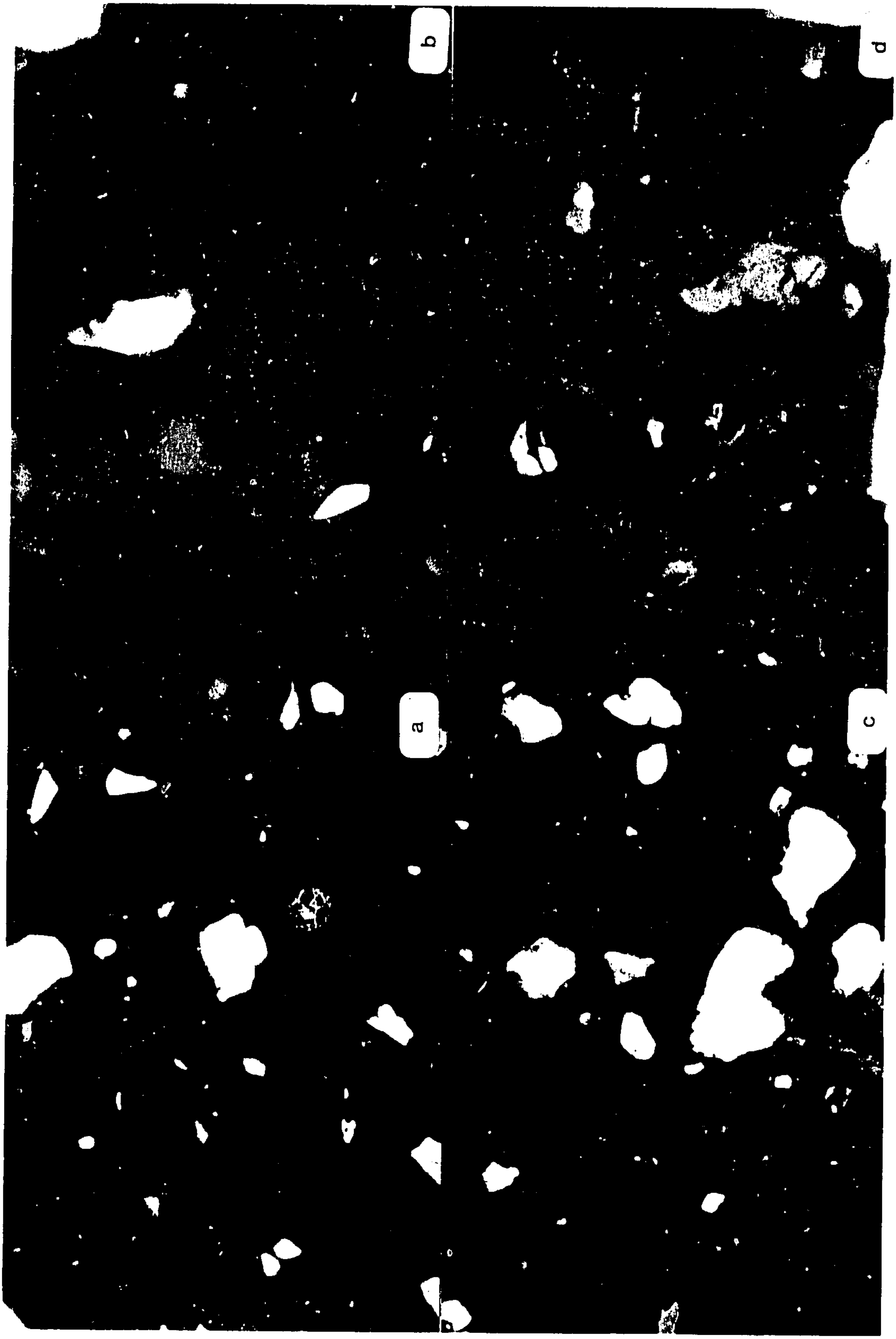
The s-matrix is more compact than the overlying horizon. There is little change in the color of the plasma and the plasma aggregates are fewer. The normal related distribution pattern is porphyric with localized congelic (Plate 1a). The sand grains are finer and there appears to be fewer runiquartz.

There is no change in the nature of the plasmic fabric which is very similar to the A3 horizon. The morphology of the runiquartz is also similar indicating similar origin. There is no evidence of clay translocation or other forms of stress features.

Sample R5. 93-107 cm. IIB2

There is a much higher amount of plasma and lesser amount of sand grains and the s-matrix appears more porous than the overlying horizons. The quartz grains are non-fractured and runiquartz is scarce. The plasma shows little or no change in color and the NRDP is prophyri-plasmic.

The plasmic fabric is isotic and only at higher magnifications is it argillasepic. The most striking feature of the sample is the presence of illuviation argillans (Plate 1b) which occupy about 8% of the area.


a
b
c
d

The argillans are thick and moderately well oriented. They have a grainy aspect indicating that they are in stages of degradation. Some of the argillans are also fragmented.

Illuviation of clay has been very intense in this horizon. Some of the finer voids are almost completely plugged up with translocated clay.

Interpretation

In the field description, no clay skins were observed up to a depth of 1 m. Clay skins were only evident in the IIB2 horizon and the micromorphological study confirms the field observations.

In the field, a lithological discontinuity was observed at a depth of about 1 m. In thin-sections, the presence of runiquartz in the top 1 m material and its absence deeper down the profile, and in addition the change in morphology of the quartz grains, shows this change in material. It may be concluded that the top 1 m is foreign, transported material.

The nature of the s-matrix in the top 1 m of the soil clearly indicates that it is oxic. The nature of the plasma and other features in the IIB2 horizon indicates that this is also oxic. However, translocated clay has accumulated in the latter oxic material. The morphology of the cutans clearly indicates that it is relict and cannot be related to current processes in the soil. The grainy aspect, the low birefringence, the fragmentation and all suggest the inherited nature of the feature. There is absolutely no indication of present-day clay translocation in the soil.

This is an example of a soil with an oxic horizon overlying the argillic horizon. The material is transported and probably preweathered.

Classifications (Chairman: F. Moormann)

1. Soil Taxonomy: Clayey, kaolinitic, isohyperthermic, Tropeptic Haplustox. With the current proposals of ICOMOX, it will be a Typic Kurustox.
2. FAO: Xanthic Ferralsol.

The discussions started with identification of clay skins in the field. Clay skins were identified both in the field and thin-sections at a depth of 93 cm. A possible explanation was that the soil was truncated up to a previous argillic horizon. The overlying material is preweathered and has all oxic properties.

Clay skins can be identified in the field by the slight difference in color with respect to the rest of the soil material. A well-defined clay skin on a void surface tends to be smooth and stands out at the edge where the soil material has been fractured. Thick coatings are easily identified but thin ones are more difficult.

The tropeptic subgroup was indicated because of the presence of the discernable structure in the oxic horizon. It was agreed that the term 'tropeptic' was inappropriate. The significance of the underlying horizon with clay skins and argillic properties--better structure and consistence--was emphasized. The 'kuric' great groups indicate the argillic property of clay increase in the profile. The presence of a subhorizon with clay skins, better structure and consistence could be implied by a 'leptic' subgroup instead of a typic.

These soils have several constraints to use. The first is soil moisture. We had tensiometers in the soil and after the heaviest shower, the soil moisture did not penetrate more than 75 cm. (This could also explain the absence of clay skins.) Groundwater is more than 40 or 50 m deep. Nutrient elements (Ca, Mg, N and P) are all deficient. The high aluminum at about 50 cm depth is a root-restricting zone and so roots do not grow much deeper to search for water.

The crop that does reasonably well is cassava. Cow-pea is grown during the wet seasons.

The INEAC classification (Sys) is:

Order: Kaolisols

Suborder: Hygro-xero Kaolisol

Group: Hygro-xero Ferralsol

Subgroup: Intergrade Ferrisol

Family: clayey

RWANDA

Profile R 2

Classification:	Ferralsol (INEAC)
Location:	prefecture Kigali, sous-prefecture Bugesera, commune Gashora, secteur Mwendo, colline Kayovu, agricultural station ISAR-Karama, plot B3.
Physiography:	gently undulating landscape with large plateaus, average slope 20%, average difference between tops and valleys 130 m; presence of ironstone.
Topography:	middle of northwest facing slope, concave, 9%; alt. 1,430 m
Climate:	Aw4; annual rainfall 853 mm; mean temperature 21.1°C, mean temperature of soil at 50 cm 25°C
Vegetation:	old cassava field, 25 ton/ha
Parent material:	granite associated with some quartzite
Limitations affecting plant growth:	low nutrient status, irregular rainfall

No. soil sample	Horizon	Depth (cm)	Horizon description
R2,1	Ap	0-10	dark brown (7.5YR4/3); clay; dry; moderate medium crumb structure, slightly hard; many fine roots, abrupt regular boundary
R2,2	B1	10-34	reddish-brown (5YR4/4); clay, moist; moderate medium subangular blocky, friable; some rare coatings; common

No. soil sample	Horizon	Depth (cm)	Horizon description
			fine roots; regular gradual transition,
R2,3	B21	34-58	yellowish-red (5YR4/6); clay; moist; weak medium subangular blocky; friable; few fine roots; regular gradual transition,
R2,4	B22	58-106	idem as R2,3 but very weak fine and medium subangular block structure, very friable,
R2,5	IIB2	106-176	yellowish-red (5YR4/6) for the matrix, reddish-brown (5YR4/4) for the hard peds (see profile R1); even some streaks of 5YR3/3 especially at the interior of the hard peds; clay to fine clay for the peds; matrix is of very weak fine and medium subangular blocky structure; hard peds have a strong medium and coarse angular blocky structure, coatings many, firm; few fine roots; increase of hard peds with depth forming a kind of pan.

P.S; oxic material upon argillic material

-- Samples for micromorphology: R2,2 between 22 and 29 cm
R2,3 between 45 and 52 cm
R2,5 between 115 and 121 cm

SAMPLED AS: FERRALSOL

S 81FN-C?? - R2 SAMPLE NOS. 81P1127 - 1131 DATE MAY 1981

RWANDA

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

GENERAL METHODS 1B1A, 2A1, 2B

-1-- -2-- -3-- -4-- -5-- -6-- -7-- -8-- -9-- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002-.05	TOTAL SAND .05-2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002-.02	SILT COARSE .02-.05	SAND VF .05-.10	SAND F .10-.25	SAND M .25-.50	SAND C .5-1	SAND VC 1-2	COARSE FRACTIONS (MM) WEIGHT 2-5	5-20	20-75	.1-75	(>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM (3B1)			->	
811127	1S	0- 10	AP	42.7	8.5	48.8	24.3		0.4	8.1	6.7	17.2	12.0	7.4	5.5	--	--	--	62	--
811128	2S	10- 34	B1	54.7	7.5	37.9	35.8		3.7	3.8	6.1	14.1	8.2	4.7	4.7	--	--	--	32	--
811129	3S	34- 58	B21	54.2	7.7	38.1	37.0		3.3	4.4	6.7	15.1	7.9	3.3	4.9	--	--	--	31	--
811130	4S	58-106	B22	55.7	7.9	36.4	39.8		4.1	3.8	7.5	14.9	6.6	3.2	4.2	--	--	--	29	--
811131	5S	106-176	IC2	60.2	13.7	26.1	39.8		8.2	5.5	8.0	9.1	4.9	1.9	2.3	--	--	--	18	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811127	1	1.78	0.134			2.5	0.4		0.19	0.27										11.5	
811128	2	0.70	0.057			2.9	0.6		0.11	0.25										13.5	
811129	3	0.52	0.049			2.9	0.5		0.10	0.25										13.3	
811130	4	0.41	0.035			2.7	0.5		0.09	0.24										13.1	
811131	5	0.35	0.027			3.3	0.6		0.09	0.26										15.8	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT				->				
811127	1	2.1	1.5	TR	1.0	4.6	6.4		11.0	7.9			42	58			4.4	7.9	5.0	5.6
811128	2	0.3	0.6	--	0.3	1.2	7.4	2.3	10.6	6.0	3.5	66	11	20			3.7	8.3	4.1	4.7
811129	3	0.1	0.7	--	0.1	0.9	7.2	2.3	8.1	5.5	3.2	72	11	16			3.7	8.4	4.1	4.6
811130	4	0.1	0.5	--	0.2	0.7	7.6	2.1	8.3	4.9	3.0	70	11	18			3.7	8.4	4.1	4.6
811131	5	0.1	0.6	TR	0.3	1.0	8.1	2.5	9.1	5.7	3.5	71	11	18			3.8	8.3	4.2	4.7

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY – CLAY – TOTAL ANALYSIS 7C3 K2O 6Q3A	FE 6C7A	X-RAY <2U 7A2I	7A2I	7A2I	7A2I	DTA <2U 7A3	7A3	TOTAL RES 7D1A	ODM WEATH 7B1A
					<- PCT	->	<- RELATIVE AMOUNTS			->	<- PCT			->
811127	1	0.77		5.4										
811128	2	0.86		4.0										
811129	3	0.80		3.9	0.4	6.9	KK 4	GE 1			KK65			
811130	4	0.84		3.4										
811131	5	0.85		4.3	0.4	7.0	KK 5	GE 2			KK58			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE.

PROFILE 2

Sample 2. 10-34 cm. B1

The s-matrix is very compact; the plasma fills up most of the spaces between the grains which are dominantly fine and medium sand-sized quartz. The color of the plasma is reddish-yellow.

The plasmic fabric is isotic with local argillasepic. The NRDP is plasmi-porphyric. There is a slight congelic tendency which is only locally expressed. As in Profile R1, the plasma has a waxy appearance.

Runiquartz and fractured quartz grains are common. There are also a few, fractured sesquioxidic concretions. There are very few remnants of roots or other forms of organic matter.

There is practically no plasma separation, but there are few illuviation argillans which occupy less than 1% of the area. The latter are generally thin and moderately well oriented. Many are fragmented.

Sample 3. 34-58 cm. B21

There is very little difference in the micromorphology of this horizon compared to the overlying horizon (Plate 1c). The only additional, distinct feature is pedotubules which are large and irregular. There is also no change in the amount of illuviation argillans.

Sample 5. 106-176 cm. IIB2

There is a considerable increase in plasma in this horizon with a corresponding decrease in fine and medium sand-size grains. The color and plasmic fabric of the plasma do not show any marked change. The plasmic fabric is still isotic, and the reddish-brown plasma has a waxy appearance. There are practically no runiquartz or fractured quartz grains in this horizon.

The horizon is characterized by a marked increase in the amount of illuviation argillans (Plate 1d) which occupy about 12% of the area. The argillans are thick, well oriented, but have a grainy aspect. Illuviation has been so intense that many of the finer voids have been plugged up with translocated clay. In some places, former illuviation argillans have been assimilated into the matrix of the soil material.

Interpretation

Profile R2 is very similar to R1 in practically all aspects. As in the previous profile, the horizon with illuvial clay occurs at a depth of 1 m. The top 1 m of the soil is different in some respects and shows evidence of being of transported origin.

This profile is another example of an oxic horizon overlying an argillic horizon. All the micromorphological evidences point to the fact that the argillic horizon is a relict feature, that the cutans are in stages of degradation and do not represent current illuviation features. The material of the IIB2 horizon wherein the argillans are present also have all the oxic properties.

Classifications

1. Soil Taxonomy: Clayey, kaolinitic, isohyperthermic, Tropeptic Haplustox. With the current proposal of ICOMOX, it will be a Leptic Kurustox.
2. FAO: Orthic Ferralsol.

Discussion (Chairman: M. Ali)

Dr. Schargel recognized the presence of an argillic horizon as the subsurface horizon meets the clay increase requirement. In addition, as the clay is kaolinitic, Soil Taxonomy only requires the argillic horizon to have some clay skins at depth and this requirement is also met. So the classification is an Oxic Paleustult. He, however, indicated that there was a degradation of the argillic horizon and that there was a distinct oxic horizon over the argillic. He would prefer the soil to be classified as a Haplustox but with the present definition it will be keyed out as a Paleustult. This view was supported by Comerma. He indicated that the clay increase is an important feature and should be brought out at the great group level as an Argiustox. The chairman of ICOMOX pointed out that the intent of the new great group--Kurustox--is the same and probably the term 'Argi' may be more appropriate than 'Kuric.'

Dr. Moormann explained that the soil does not fit the concept of the 'kandi' taxa and preferred the soil to be an Oxisol.

Dr. Tavernier disagreed with the reasons given by Schargel for his classification. He indicated that to classify the soil, one has to use the key and as the Oxisols are keyed out earlier, the soil is an Oxisol. Only if the argillic horizon lay over the oxic horizon, would the soil be keyed out as an Ultisol.

Dr. Van Wambeke pointed out that the definition of the oxic horizon reads, 'exclusive of an argillic horizon' which implies that a horizon cannot be an argillic and oxic at the same time. If you accept an argillic, you would have to indicate where it starts and if it starts at about 40 cm, you can forget the oxic horizon. Dr. Eswaran explained that this has really created difficulties in applying the system and for that reason, in the ICOMOX proposal, the phrase 'exclusive of an argillic horizon' has been dropped from the definition of the oxic horizon.

Dr. Frankart presented the geomorphic evolution of the landscape and added that the argillic horizon with clay skins in the lower part of the profile is relict. The profile has been truncated and new material added to the top. The 'polyedres or pedovites' in the lower part of the soil are indications that that material is transported. The pedovites may be fragments of saprolitic or argillic materials which have been compacted and rounded during transport. They act as stones in the soils where quartz or lateritic gravel is absent. Dr. Bennema thought that more attention must be given to termites and he preferred to attribute the origin of the surface mantle to biogenetic action.

The Rwandese colleagues considered that the potential of the soil is similar to that of Profile 1.

INEAC classification (Sys):

Order: Kaolisol

Suborder: Hygro-xero Kaolisol

Group: Hygro-xero Ferralsol

Subgroup: Intergrade Ferrisol

Family: clayey

RWANDA

Profile R 3

Classification:	Ferrisol/Sol Recent Tropicaux (INEAC)
Location:	prefecture Gitarama, commune Tambwe, secteur Munini, colline Nyinya, 50 m to the west of the main road Kigali-Butare, 68 km from Kigali.
Physiography:	hilly landscape, dissection of a former erosion surface, average slope 30%, average difference between tops and large valleys 1,100 m, presence of higher ridges of quartzite; many shallow soils with gravelly texture and stoneline and sombric horizon.
Topography:	convex slope of 10% west-facing, alt. 1,700 m
Drainage:	well drained
Climate:	Aw3, dry season of 3 months; annual rainfall 1,100 mm; mean temperature 18 °C.
Vegetation:	pastureland (fallow) with *Brachyaria sp.*, *Digitaria sp.*, *Sporobolus pyramidalis*, *Monechma subsessile*.
Parent material:	granite with frequent quartz and feldspar veins, some laterization.
Limitations affecting plant growth:	high gravel content, stone-lines, depth of soil, K-deficiency; crops in the neighborhood are of medium quality (cassave, maize, beans, sweet potato)

No. soil sample	Horizon	Depth (cm)	Horizon description
R3,1	A1	0-34	dark brown (7.5YR4/3); sandy clay; some quartz pebbles (F 10%), very small flakes

No. soil sample	Horizon	Depth (cm)	Horizon description
			of mica; moist; moderate fine and medium crumb structure, friable; many fine roots; clear regular transition,
R3,2	A3	34-50	dark reddish-brown (5YR2.5/2); clay, some quartz pebbles (F 15%), very small flakes of mica; moist; moderate medium subangular blocky, some coatings; firm; holes of termites; common fine roots; undulating abrupt transition,
R3,3	IIA11	50-84	heterogenous color, color of matrix dark reddish-brown (5YR2.5/2), large spots (F 5 cm) of black color (5YR2.5/1.5) covering 40% of the whole; stone-like very gravelly (quartz, feldspar) clay, some mica; moist; weak medium subangular blocky, firm; some coatings few fine roots; wavy clear boundary,
R3,4	IIA12	84-120	heterogenous color, matrix of black (5YR2.5/1.5), shots covering 20% of 5YR2.5/2 and others of weathered rock are yellowish-red (5YR4/6), coatings of 5YR2.5/1; gravelly clay, some mica; moderate medium angular and subangular blocky structure, moist; firm; many coatings; some irregular hard blocks from few mm to 5 cm are weathering granite fragments coated with very black skins; few fine roots; wavy gradual transition,
R3,5	IIC1	120-148	as R3,4 but with 50% weathered rock fragments

No. soil sample	Horizon	Depth (cm)	Horizon description
R3,6	IIC2	148-198	heterogenous color, soil is dark reddish-brown (5YR2.5/2) and weathered rock fragments are reddish-yellow (5YR6/6); clay between rock fragments; moist; many coatings on these fragments; few fine roots, one big root.

P.S. In R3,1 a pebble of 3 cm of quartz

In R3,2 some charcoal fragments

In R3,3 presence of crack filled in with R3,2 material where higher concentration of roots

-- Samples for micromorphology: R3,2 between 8 and 14 cm

R3,3 between 102 and 108 cm

R3,6 between 152 and 150 cm

-- Sample for pot trials: R3

SAMPLED AS: FERRISOL

S 81FN-CO? - 83 SAMPLE NOS. 81P1132 - 1137 DATE MAY 1981

PWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- CLAY LT .002	-2- SILT .002-.05	-3- SAND .05-2	-4- FINE CLAY LT .0002	-5- CO3 CLAY LT .002	-6- FINE SILT .002-.02	-7- COARSE SILT .02-.05	-8- VF SAND .05-.10	-9- F SAND .10-.25	-10- M SAND .25-.50	-11- C SAND .5-1	-12- VC SAND 1-2	-13- COARSE FRACTIONS 2-5	-14- 5-20	-15- 20-75	-16- .1-75 PCT OF <75MM (3B1)	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM (3B1) ->				
811132	1S	0- 34	A1	28.4	22.1	49.5	14.2		13.0	9.1	3.0	8.7	12.5	11.2	14.1	--	--	--	46	--
811133	2S	34- 56	A3	31.5	15.1	53.4	20.7		12.0	3.1	3.4	7.2	9.7	12.6	20.5	--	--	--	50	--
811134	3S	56- 84	2A11	48.7	10.9	40.4	36.7		7.2	3.7	2.7	4.8	4.9	5.6	22.4	--	--	--	35	--
811135	4S	84-120	2A12	48.5	15.0	36.5	32.2		10.5	4.5	3.6	5.3	4.7	7.6	15.3	--	--	--	33	--
811136	5S	120-143	2C1	42.7	16.3	41.0	29.5		11.6	4.7	4.1	6.0	6.6	10.2	14.1	--	--	--	37	--
811137	6S	143-199	2C2	33.6	22.8	43.6	20.9		19.2	3.6	6.1	10.0	11.6	10.8	5.1	--	--	--	37	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811132	1	1.47	0.111			0.8	0.2		0.31	0.34										9.6	
811133	2	1.12	0.075			0.9	0.3		0.26	0.33										10.4	
811134	3	1.07	0.060			1.4	0.4		0.27	0.29										14.0	
811135	4	1.00	0.051			1.3	0.4		0.24	0.30										14.4	
811136	5	0.68	0.046			1.1	0.3		0.20	0.31										13.1	
811137	6	0.38	0.029			0.8	0.2		0.18	0.37										12.3	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. CHMS /CM 8E1	PH KCL 1N 8C1G	NAF 8C1C	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
811132	1	2.1	0.5	TR	0.1	2.7	8.6	1.1	11.3	8.7	3.8	29	24	31			3.9	8.0	4.3	5.1
811133	2	1.5	0.3	--	0.1	1.9	9.8	1.8	11.7	8.1	3.7	49	16	23			3.8	8.2	4.2	5.0
811134	3	4.4	0.8	TR	0.1	5.3	12.8	1.7	18.1	13.3	7.0	24	29	40			3.9	8.6	4.4	5.2
811135	4	4.6	1.0	TR	0.1	5.7	9.6	0.9	15.3	11.4	6.6	14	37	50			4.0	8.9	4.5	5.4
811136	5	3.5	0.9	0.1	0.1	4.5	7.9	1.0	12.5	8.7	5.6	18	37	53			4.0	8.7	4.3	5.4
811137	6	2.4	1.0	TR	0.1	3.5	3.4	0.6	6.9	5.9	4.1	15	51	59			4.0	9.3	4.9	5.4

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	TOTAL ANALYSIS 7C3 K2O 6Q3A	Fe 6C7A	MINERALOGY CLAY X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7C1A	DOM WEATH 7B1A
					<- PCT	->	<- RELATIVE AMOUNTS ->				<- PCT			->
811132	1	0.93		5.7										
811133	2	0.72		6.8	1.1	4.0	KK 5	MI 2	GE 1		KK43			
811134	3	0.99		8.3	0.9	4.4	KK 4	MI 1	GE 1		KK55			
811135	4	0.72		8.2										
811136	5	0.69		6.5										
811137	6	0.63		4.9	0.8	3.6	KK 5	MI 1	GE 1		KK45			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MI MICA GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE.

PROFILE 3

Sample 1. 0-34 cm. A1

The organic matter stained, brownish colored plasma is present as aggregates between the many coarse and very coarse sand-sized grains of quartz. The other dominant minerals are plagioclases, microcline, and fine flakes of biotite and muscovites. The NRDP is grani-porphyric.

The plasmic fabric is argillasepic, skel-insepic. The feldspar grains are slightly altered. The quartz does not show any fracturing, and runiquartz is absent.

Sample 4. 86-120 cm. IIB2

The s-matrix differs from the previous sample in having a much higher amount of very coarse sand-size quartz grains and also a much higher amount of plasma. The color of the plasma is yellowish-brown, and the plasmic fabric is argillasepic, skel-omnisepic. There is a decrease in the amount of feldspars, but there is a marked increase in micas which are also larger in size.

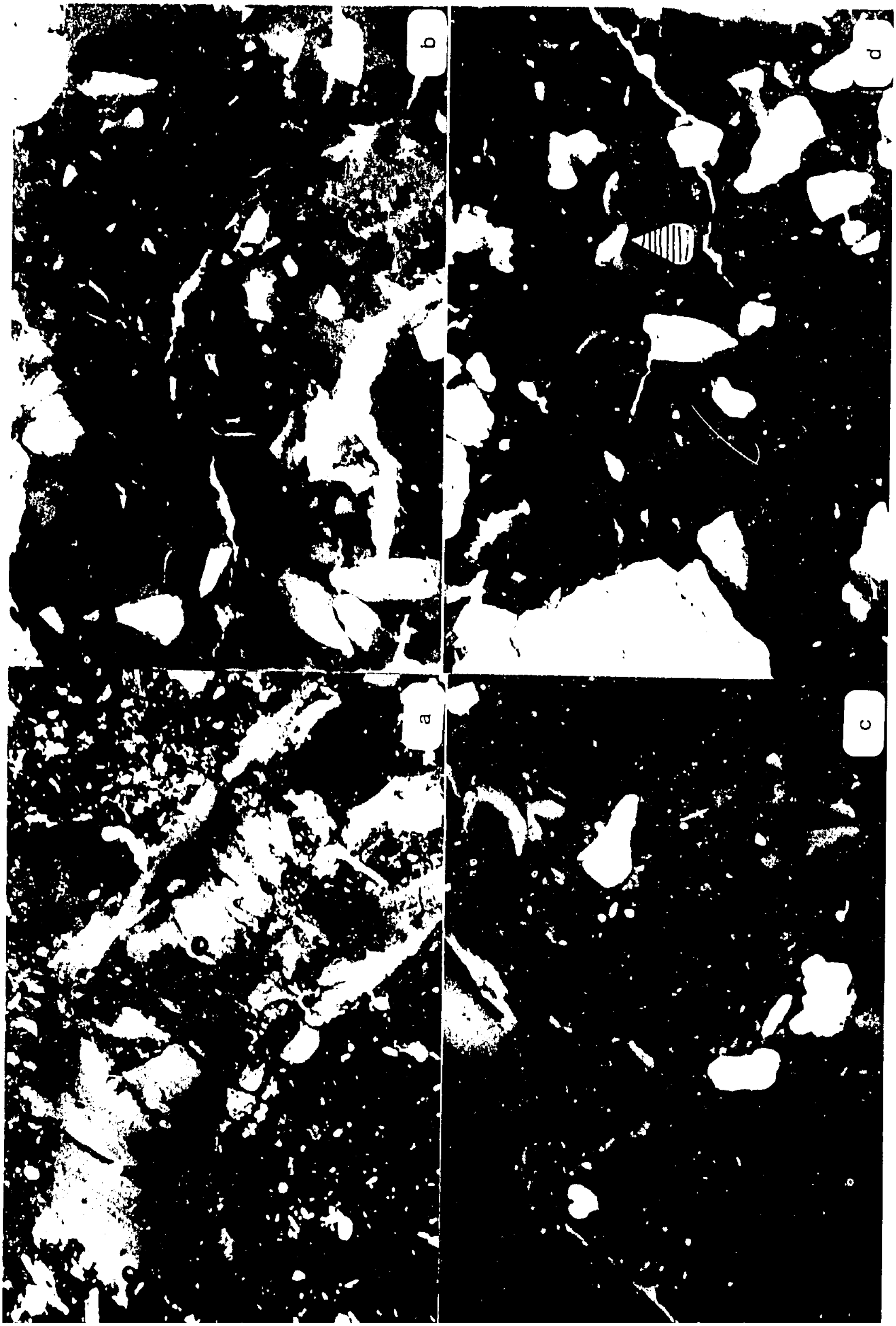
The horizon also differs in that it has a high amount of transloca-tion clay as argillans. The argillans, which are well oriented and thick (Plate 2a), occupy about 9% of the area. Some voids are completely filled in with translocated clay (Plate 2a) forming papules.

Sample 6. 148-198 cm. C&R

The s-matrix of this saprolite horizon is composed of coarse and very coarse sand size grains of quartz and feldspars with plasma filling the interstices. Much of the plasma is illuvial clays and occupies about 22% of the total area of the thin-section. The argillans are extremely well oriented and very thick.

Interpretation

The morphology of the quartz grains in the soil indicate a lithologic discontinuity at about 50 cm depth. The rest of the profile seems to have developed *in situ*.


a
b
c
d

Clay translocation is one of the most important processes taking place in the soil. The nature of the argillans clearly indicate that it is a current process. Much of the clay in the surface horizons has been translocated. The site of maximum accumulation is not the B horizon but rather the C horizon and even the saprolite. Though no evidence can be given to confirm it, it appears that both the A and B horizons are losing clay through eluviation which accumulates in the C horizon. The amount accumulating the B horizon is much less than in the C.

This profile illustrates:

(a) A soil with a well-developed argillic horizon

(b) A soil where clay translocation and accumulation are current processes.

Classifications

1. Soil Taxonomy: Fine-skeletal, kaolinitic, isothermic Ultic Tropudalf.
2. FAO: Humic Acrisol.

Discussion (Chairman: E. Schlichting)

The initial discussions centered around the climate. The soil moisture regime was considered to be udic marginal to ustic. The need for a good assessment of the SMR at the site was stressed. It was also indicated that the SMR will vary with the slope, with the soils on the steeper slopes having an ustic SMR while those on the more gentle slopes being udic. Dr. Arnold explained that this would be the correct way to spply SMR in Soil Taxonomy, though due to absence of data, this approach is not always followed.

There was good concurrence on the presence of the argillic and few disagreements to classifying the soil as an Alfisol. The sombric horizon, though evident in the field by the slightly spotted nature, could not be established with the analytical data. Presence of litho-logical dis-continuities and buried A horizons were speculated.

The chairman of ICOMLAC pointed out that the soil has a kandic horizon with the upper boundary at 40 cm. The soil could then be classified as a Kanhapludalf. The actual classification would depend on the presence of a sombric horizon. As the sombri- great groups key out earlier, the soil might be classified as a Sombriudalf and could belong to a kandic or orthoxic subgroup. Schargel felt that the sombric features, in this profile, could serve as a series criteria.

The INEAC classification (Sys) is:

Order:	Kaolisols
Suborder:	Xero Kaolisol (Humifere)
Group:	Xero Ferrisol with dark horizon
Great group:	intergrade to Brown Tropical Soil
Family:	clayey on shist

Dr. Sys added that he would like to classify the soil as a Sombrihumoxic Tropustalf. (There was some disagreement on the moisture regime. Dr. Sombroek insisted that actual measurements must be made.)

RWANDA

Profile R 4

Classification:	Ferralsol/Ferrisol (INEAC)
Location:	prefecture Gikongor, commune Mubuga, secteur Kiebeho, colline Munge, agricultural demonstration center, 5 m to the southwest of the road to Mata, 50 m from the intersection of that road with the road Butare-Kibeho, 24 km from Butare.
Physiography:	very hilly landscape, average slope 45%, average difference between small tops and valleys often with peat 150 m, many convex slopes.
Topography:	southwest facing slope of 27%; altitude 1,770 m
Drainage:	well drained
Climate:	Cw3, mean temperature 17.9°C; annual rainfall 1,435 mm
Vegetation:	grassland of *Eragrostis blepharoglumis* and *Exotheca abyssinica*.
Parent material:	granite associated with shales.
Limitations affecting plant growth:	high acidity and Al-content, low nutrient status.

No. soil sample	Horizon	Depth (cm)	Horizon description
R4,1	A11	0-15	dark reddish-brown (6YR3/3); clay; moist; weak fine crumb structure, very friable; very many fine roots; smooth gradual transition,

No. soil sample	Horizon	Depth (cm)	Horizon description
R4,2	A12	15-35	dark reddish-brown (6YR3/3); clay, moist; very weak fine crumb structure, very friable with some massive blocks up to 5 cm; many fine roots; smooth clear transition,
R4,3	A3	35-48	dark reddish-brown (5YR3/3), some streaks of 6YR3/3; clay, visible bleached sand grains; weak fine and medium subangular blocky, friable with some massive blocks; many fine roots; smooth clear boundary,
R4,4	B21	48-72	dark reddish-brown (5YR3/4), some streaks of 6YR3/3; clay; weak fine and medium subangular blocky structure, friable, some rare coatings in the pores made by termites; common fine roots; smooth gradual transition,
R4,5	I-IIB22	72-118	dark reddish-brown (5YR3/4), some streaks of (6YR3/3); clay; moderate fine and medium subangular blocky structure, some rare coatings, friable, presence of some charcoal and some hardened angular and subangular blocks of variable size and color of 2.5YR3/4; few fine roots; wavy clear boundary,
R4,6	IIA2	118-153	dark reddish-brown (5YR3/2), with hardened blocks of 2.5YR3/6 and streaks of 5YR3/4; clay; moist; weak fine and medium subangular blocky structure, friable, some rare coatings on the hardened blocks; few fine roots; smooth clear boundary,

No. soil sample	Horizon	Depth (cm)	Horizon description
R4,7	IIB2	153-180	dark reddish-brown (5YR3/6), some blocks of 2.5YR 3/6 and some streaks of 5YR3/2; clay; moist; weak fine and medium subangular blocky, friable, some rare coatings in the pores; few fine roots; smooth clear boundary,
R4,8	IIIC	180-230	dark reddish-brown (2.5YR3/4); fine clay; moist; moderate fine subangular and angular blocky structure, firm; presence of many subangular hardened blocks with heterogenous color at the inside (yellow and black streaks often in concentric rings); some coatings especially in the pores; some rare streaks of 5YR3/2); very few fine roots.

-- Samples for micromorphology:
R4,2 between 20 and 23 cm
R4,4 between 50 and 53 cm
R4,5 between 92 and 95 cm with hardened block
R4,6 between 132 and 135 cm
R4,8 between 210 and 213 cm

-- Sample for pot trials: R4

SAMPLED AS: FERRISOL

S 81RW-002 - 04 SAMPLE NOS. 81P1138 - 1145 DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1-- (- - -TOTAL CLAY LT .002	-2-- SILT .002 -.05	-3-- SAND .05 -2 - -)	-4-- (- -CLAY- -) FINE LT .0002	-5-- CO3 LT .002	-6-- (- -SILT- -) FINE .002 -.02	-7-- COARSE .02 -.05	-8-- (- - - -SAND- VF .05 -.10	-9-- F .10 -.25	-10- M .25 -.50	-11- C .5 -1	-12- VC 1 -2 - -)	-13- (-COARSE FRACTIONS(MM)- WEIGHT 2 -5	-14- 5 -20	-15- 20 -75	-16- .1- 75 -)	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - ->												<- PCT OF <75MM(3B1)->				
811138	1S	0- 15	A11	39.5	7.7	52.8	19.6		5.2	2.5	3.6	14.5	18.6	12.2	3.9	--	--	--	47	--
811139	2S	15- 35	A12	43.8	8.7	47.5	19.4		5.5	3.1	3.7	13.0	16.5	11.0	3.3	--	--	--	44	--
811140	3S	35- 48	A3	45.9	8.2	45.9	21.3		6.0	2.2	3.8	13.2	15.0	10.7	3.2	--	--	--	42	--
811141	4S	48- 72	B21	49.9	10.5	39.6	22.0		8.0	2.5	4.6	12.2	11.3	8.3	3.2	--	--	--	35	--
811142	5S	72-119	2B22	47.7	12.8	39.5	20.7		9.3	3.5	4.4	11.3	11.6	9.0	3.2	--	--	--	35	--
811143	6S	119-153	2A1	23.4	21.4	55.2	10.0		12.6	8.8	9.8	15.6	14.6	10.9	4.3	--	--	--	45	--
811144	7S	153-180	2B2	42.2	8.1	49.7	18.6		5.0	3.1	4.7	15.7	15.1	10.5	3.5	--	--	--	45	--
811145	8S	180-230	3C	50.2	7.4	42.4	25.1		4.5	2.9	4.2	12.1	12.5	9.5	4.1	--	--	--	38	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	(- - DITH-CIT - -) EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG - LIMITS - LL 4F1	PI 4F)	(- BULK DENSITY -) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(- - -WATER CONTENT - -) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - -PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
811138	1	3.08	0.167			3.3	0.8		0.31	0.37										14.5	
811139	2	2.42	0.140			3.6	0.9		0.28	0.34										15.0	
811140	3	1.99	0.123			3.8	0.9		0.25	0.31										15.0	
811141	4	1.43	0.117			4.0	0.9		0.20	0.34										16.8	
811142	5	1.21	0.103			4.0	0.9		0.21	0.37										17.5	
811143	6	2.05	0.129			3.8	1.1		0.61	0.70										16.4	
811144	7	0.67	0.053			3.5	0.7		0.15	0.32										13.6	
811145	8	0.53	0.047			4.0	0.7		0.14	0.33										16.7	

SAMPLE NO.	HZN NO.	(- NH4OAC EXTRACTABLE BASES -) CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	(- - - -CEC - - -) SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	-BASE SAT- SUM 5C3	NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	(- - - -PH - - -) KCL 1N 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - - - - - - - - - - -MEQ / 100 G - - - - - - - - - - - - ->										<- - - - -PCT - - - ->								
811138	1	0.3	0.1	TR	0.1	0.5	19.0	3.9	19.5	12.1	4.4	89	3	4			3.8	8.7	4.1	4.7
811139	2	0.3	TR	TR	0.1	0.4	20.3	4.1	20.7	12.2	4.5	91	2	3			3.8	9.3	4.0	4.5
811140	3	0.3	TR	TR	TR	0.3	18.3	3.8	18.6	11.3	4.1	93	2	3			3.8	9.6	4.1	4.7
811141	4	0.2	TR	TR	TR	0.2	17.1	3.6	17.3	10.1	3.8	95	1	2			3.9	9.7	4.1	4.7
811142	5	0.2	TR	TR	TR	0.2	18.3	3.6	18.5	10.2	3.8	95	1	2			3.9	7.7	4.1	4.6
811143	6	0.1	TR	--	TR	0.1	27.3	4.1	27.4	14.3	4.2	98	TR	1			4.0	10.6	4.1	4.7
811144	7	0.1	TR	--	TR	0.1	11.1	2.5	11.2	6.4	2.6	96	1	2			3.8	9.4	4.1	4.7
811145	8	TR	.3	--	TR	0.3	[illegible]	2.6	11.1	6.9	2.9	[illegible]	1	4			3.8	9.0	4.0	4.7

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	(- - MINERALOGY - - -) (- - CLAY - -) TOTAL ANALYSIS 7C3 K2O 6Q3A	Fe 6C7A	(- - X-RAY - - -) (- - <2U - - -) 7A21	7A21	7A21	7A21	(- -DTA - -) (- -<2U - -) 7A3	7A3	TOTAL DOM RES WEATH 7B1A	7B1A
					<- - - - -PCT- - - - ->		<- RELATIVE AMOUNTS ->						<- - - - -PCT - - - ->	
811138	1	0.89	46	6.1										
811139	2	0.94	55	6.4										
811140	3	0.94	52	6.0										
811141	4	0.94	52	5.6	0.4	7.5	KK 4	GE 1	HE 1		KK74			
811142	5	0.95	45	6.0										
811143	6	0.96	61	6.1										
811144	7	0.92	31	4.2										
811145	8	0.93	31	4.1	0.5	8.0	KK 4	MI 1	CL 1	GE 1	KK73			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE GE GOETHITE HE HEMATITE MI MICA CL CHLORITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE.

PROFILE 4

Sample 2. 15-35 cm. A12

The s-matrix is very porous and is generally reddish-brown in color. The plasma is packed into granular aggregates. Grains are mainly fine to medium sand-sized quartz with a few coarse sand-sized. A few weathered plagioclases are also present and there are few fine flakes of micas.

The NRDP is porphyric and the plasmic fabric is insepic, argillasepic. Runiquartz is abundant, and many of the larger quartz grains are fractured. There is a very high amount of phytoliths in this horizon.

Sample 4. 48-72 cm. B21

The s-matrix is more compact than the overlying horizon. The remaining features are similar except that there are markedly fewer coarse sand-sized quartz. There is a higher amount of plasma giving a plasmi-porphyric NRDP.

There is a slightly higher amount of mica flakes and about the same amount of feldspars. The additional feature is the presence of illuviation argillans. These are few (2%) and occur as very thin void coatings.

Sample 5. 72-118 cm. IIB22

The s-matrix differs from the previous, overlying horizon in two respects. One is the absence of feldspars, though the amount of micas remain the same. There is a slight increase in the amount of illuviation argillans (3%). The argillans are still thin but well oriented, and in addition there are a few papules. The latter are fine voids which are completely infilled with clay. Runiquartz is scarce in this horizon.

Sample 6. 118-153 cm. IIIA

The s-matrix of this horizon is completely different from the overlying horizons. The color of the plasma is brownish-yellow, and the plasma is arranged as rounded aggregates giving a congelic SRDP. The pellety structure resembles the microstructure of a spodic horizon and even that of andic soil material.

The plasmic fabric is argillasepic, insepic. There are practically no illuviation argillans in the thin-section and all the plasma appears to be in a flocculated state.

Although runiquartz is scarce in the previous, overlying horizon, it is frequent here. The plasma in the fissures of the runiquartz is bright red.

There are no remnants of organic materials in this horizon. Plant remains are scarce, and though the horizon is dark, the black color is due to staining by organic materials.

Sample 8. 180-250 cm. IIIC

The s-matrix of this horizon is distinctly different from that of sample 6. It is similar to sample 4. The quartz grains are fine to medium size and angular. The color of the s-matrix is reddish-yellow (Plate 2b) and plasmic fabric is argillasepic, omni-sepic. Void argillans are few and thin. Runiquartz formation is evident in this horizon.

Interpretation

This is a very complex soil; there are several materials lying one above the other and further complicated by several genetic processes.

The discontinuities in the material are evident both in the field and in the thin-sections. Clay translocation has taken place, but expression of the argillic horizon is very poor; the argillans are very thin. Clearly, the soil is a transitional one, showing micromorphological properties of an Inceptisol, Oxisol, and Ultisol.

The micromorphology of the sombric horizon complicates the picture. Due to the absence of detailed studies on other similar horizons, it is not evident if this is typical. The horizon shares micromorphological properties of spodic horizons and andic soil materials. There is no evidence to suggest that this is a buried A horizon, and it appears that the micromorphological properties indicate a genetic reorganization of the soil material. There is obviously a need for a more detailed evaluation. Although phytoliths were observed in the top horizon, these are absent in the sombric horizon. This perhaps points to the fact that it may not be a buried A horizon.

Classification

1. Soil Taxonomy: Fine, kaolinitic, isothermic, oxic Humitropept
2. FAO: Humic Acrisol

Discussions (Chairman: Dr. F. Colmet-Daage)

After a rather lengthy introduction by the chairman, Professor Sys elaborated on the classification of the soil according to Soil Taxonomy. He recognized the presence of 'broken cutans' and considered the presence of an argillic horizon. The low base saturation and relatively high organic matter places the soil in a Humult. He also indicated the presence of a sombric horizon and consequently, the soil belongs to the Sombrihumult. He then gave the INEAC classification as:

Order:	Kaolisols
Suborder:	Kaolisols humifere
Group:	Humiferous Ferrisol with dark horizon
Subgroup:	intergrade to Ferralsol
Family:	clayey on shale

Eswaran drew special attention to the sombric horizon. Two features which seem to distinguish the sombric horizon in this profile from the other soils are (a) the greasy, slimy feel in the field and also the loose fluffy consistence and (b) the microfabric which resembles an andic or spodic material. There seems to be some indication that this could be a buried andic material. The NaF pH is above 9.4 which excludes andic materials but the indications are that it was derived from andic materials. If we consider this horizon as a sombric horizon, we have to permit some of these field and laboratory properties.

Since there is no agreement on the sombric horizon, Moormann indicated that an alternative was to classify it as a Palehumult. He discounted the probability of the soil having a kandic horizon. He also considered the soil to be layered with buried horizons. As evidence of clay movement was poor, he preferred to discount the presence of an argillic horizon. Instead, he only considered the upper part of the soil and identified a cambic horizon, and classified it as an Oxic Humitropept. There was some agreement to this last classification.

INEAC classification (Sys):

Order: Kaolisol

Suborder: Kaolisol humifere

Group: with dark horizon

Subgroup: intergrade Ferralsol

Family: clayey

RWANDA

Profile R 5

Classification: Ferralsol/Ferrisol (INEAC)

Location: prefecture Butare, commune Mbazi, secteur Mbazi, colline Mbazi; 10 m to the west of the main road Kigali-Butare, 4 km from Butare.

Physiography: hilly landscape with large plateaus on which ironstone occurs, large valleys with hydromorphic soils sometimes peaty; average slope 30%; average difference between hilltops and valley bottoms 80 m.

Topography: west facing slope of 20%; altitude 1,710 m

Drainage: well drained

Climate: Aw3, mean annual temperature 11.1°C; mean annual rainfall, 1,171 mm; mean annual soil temperature at 50 cm 22.2°C.

Vegetation: grassland with some *Eucalyptus sp.*, *Digitaria sp.*, *Brachyaria sp.*; *Monechma subsessile*.

Parent material: granite associated with migmatite and shales.

Limitations affecting plant growth: low nutrient status.

No. soil sample	Horizon	Depth (cm)	Horizon description
R5,1	A1	0-25	dark reddish-brown (5YR3/4); clay; moist; weak medium crumb structure; friable; some massive blocks of variable size up to 5 cm; many chitinous grains of biologic origin; some rare coatings; many fine roots; smooth gradual boundary,

No. soil sample	Horizon	Depth (cm)	Horizon description
R5,2	B2	25-60	dark reddish-brown (5YR3/4); clay, some charcoal; moderate medium angular and sub-angular blocky structure, friable; some rare coatings; many fine roots; irregular clear boundary,
R5,3	B22	60-86	as R5,2 but dark red (4YR3/6),
R5,4	IIB	86-108	dark reddish-brown (4YR3/3); clay; weak fine and medium subangular blocky structure with some hardened angular and sub-angular blocks of variable size (F 2 cm) very dusky red (4YR2/2); friable; many fine roots; irregular gradual boundary,
R5,5	IIIA1	108-137	very dusky red (4YR2.5/3); clay, some charcoal; moist; moderate fine and medium angular blocky structure, firm; common fine roots; irregular gradual boundary,
R5,6	IIIC1	137-175	dusky red (2.5YR3/3), several streaks of 4YR2.5/3; (fine) clay; moist; strong fine and medium angular blocky structure, very firm; presence of many hardened blocks of 2.5YR3/6; many coatings; few fine roots; smooth gradual boundary.

-- Samples for micromorphology: R5,1 between 10 and 13 cm
R5,3 between 63 and 66 cm
R5,5 between 108 and 111 cm
R5,6 between 153 and 156 cm

-- Sample for pot trials: R5

SAMPLED AS:

S 81FN-00C - PS   SAMPLE NOS. 81P1146 - 1151   DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- TOTAL CLAY LT .002	-2- TOTAL SILT .002-.05	-3- TOTAL SAND .05-2	-4- CLAY FINE LT .0002	-5- CLAY CO3 LT .002	-6- SILT FINE .002-.02	-7- SILT COARSE .02-.05	-8- SAND VF .05-.10	-9- SAND F .10-.25	-10- SAND M .25-.50	-11- SAND C .5-1	-12- SAND VC 1-2	-13- COARSE FRACTIONS (MM) WEIGHT 2-5	-14- 5-20	-15- 20-75	-16- .1-75 PCT OF <75MM (3B1)	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->					
81P1146	1S	0- 25	A1	51.8	9.8	38.4	30.4		6.8	3.0	4.1	12.0	12.0	7.6	2.7	--	--	--	34	--
81P1147	2S	25- 60	B21	51.8	9.5	38.7	28.7		5.9	3.6	4.1	11.7	10.5	7.9	4.5	--	--	--	35	--
81P1148	3S	60- 96	B22	55.4	8.5	36.1	32.1		5.4	3.1	4.1	10.3	9.2	9.2	3.3	--	--	--	32	--
81P1149	4S	96-109	2B1	56.5	9.0	34.5	35.2		5.9	3.1	4.0	9.8	8.8	7.1	4.8	--	--	--	30	--
81P1150	5S	109-137	2B2	60.4	7.4	32.2	34.5		4.2	3.2	3.5	9.2	7.7	5.7	6.1	--	--	--	29	--
81P1151	6S	137-175	2C1	66.8	6.3	26.9	36.5		5.0	1.3	2.7	7.4	6.7	4.6	5.5	--	--	--	24	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
81P1146	1	2.24	0.162			3.4	0.6		0.24	0.30										15.6	
81P1147	2	1.58	0.109			3.3	0.6		0.22	0.29										14.9	
81P1148	3	1.35	0.098			3.6	0.5		0.20	0.28										15.3	
81P1149	4	1.17	0.076			3.7	0.6		0.22	0.29										16.1	
81P1150	5	1.27	0.070			3.9	0.6		0.24	0.28										16.8	
81P1151	6	0.69	0.060			4.1	0.7		0.16	0.29										19.5	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. CHPS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
81P1146	1	0.4	0.1	0.1	0.1	0.7	15.7	4.0	17.4	12.4	4.7	85	4	6			3.8	9.6	4.0	4.8
81P1147	2	0.4	TR	TR	TR	0.4	15.5	3.8	15.9	11.3	4.2	90	3	4			3.4	9.2	4.1	4.8
81P1148	3	1.9	TR	TR	TR	1.9	12.7	2.8	14.6	11.0	4.7	60	13	17			3.8	9.1	4.2	4.9
81P1149	4	3.9	0.1	TR	TR	4.0	12.9	2.1	16.9	12.7	6.1	34	24	31			3.8	8.8	4.3	4.8
81P1150	5	4.6	0.1	--	TR	4.7	11.5	1.9	16.2	14.6	6.6	29	26	32			3.9	9.0	4.3	5.1
81P1151	6	3.8	0.2	TR	TR	4.0	10.1	1.5	14.1	10.4	5.5	27	28	38			3.9	9.9	4.4	5.1

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY CLAY TOTAL ANALYSIS 7C3 K2O 6Q3A (PCT)	FE 6C7A (PCT)	X-RAY <2U 7A21 (RELATIVE AMOUNTS)	7A21	7A21	7A21	DTA <2U 7A3 (PCT)	7A3	TOTAL RSS 7C1A	DOM WEATH 7B1A
81P1146	1	0.92		7.8										
81P1147	2	0.95		6.9	0.9	6.7	KK 4	CL 1	GE 1		KK59			
81P1148	3	0.94		6.4										
81P1149	4	0.93		7.4										
81P1150	5	0.93		8.5										
81P1151	6	0.91		6.5	0.9	6.4	KK 5	MI 2	CL 2		KK56			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE   CL CHLORITE   GE GOETHITE   MI MICA

RELATIVE AMOUNT   6 INDETERMINATE   5 DOMINANT   4 ABUNDANT   3 MODERATE   2 SMALL   1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE.

PROFILE 5

Sample 1. 0-25 cm. A1 horizon

The s-matrix is very compact and has a grani-plasmic NRDP. The color of the plasma is brownish-yellow with heavy staining by organic matter. The plasmic fabric is insepic-argillasepic. Grains are mainly quartz with few, fine muscovite flakes. Voids are mainly root channels and are not interconnected.

Biological activity is high. There are a few aggro-tubules and faecal pellets. Few, undecomposed plant remains are also present. Phytoliths are rare. Other pedological features are not well expressed.

Sample 3. 60-86 cm. B22 horizon

There is practically no increase in the amount of plasma in this horizon and the NRDP is still grani-plasmic. The plasmic fabric is argillasepic-insepic, and there are fewer muscovite flakes. The most interesting feature of this horizon is the presence of illuviation argillans which occupy about 8% of the area. Plate 2c shows an example of a ped-argillan. The cutans are thick and well oriented. Clay illuviation has also filled up the finer voids to form papules and examples of this can be seen on the right hand side of Plate 2c.

Sample 5. 108-137 cm. IIA1 horizon

This is a sample of the sombric horizon. Plate 2d is a parallel light micrograph of this horizon. The plasma is dark brownish to black. The yellow parts of the micrograph (arrow) are the illuviation argillans.

The plasma is not uniformly black. In some places, it tends to appear diffuse, as for example around the quartz grains. Although enriched with organic matter, there is no modification of the s-matrix such as aggregation of the plasma. There are also no relicts of partially decomposed organic remains such as plant roots or phytoliths to suggest that this could be a buried A horizon.

The illuviation argillans are slightly enriched with organic matter. They are also not well oriented and have a waxy appearance. This suggests that the cutans in this horizon are relicts. This is evident when they are compared with the cutans in the B2 horizon.

Interpretation

This is a complex soil and the interpretation given below should be considered as a first approximation.

The sombric horizon does not show any property to indicate that it is a buried horizon. There are discontinuities in the material which complicates the genetic history of the soil. The irregular staining of the organic matter indicates or suggests that the organic colloid has diffused into the matrix. Simultaneously, there was illuviation of clay to form the waxy argillans. The staining of the argillans is not to the same extent as the matrix of the soil, indicating that the argillans were formed at the last phase of sombric horizon formation.

The maximum clay accumulation which can be attributed to the present-day clay illuviation is the zone between 50 and 100 cm. This is considered as a new generation of translocation. The argillans above the sombric are not stained with organic matter. Indirectly, it suggests that if the sombric horizon is a genetic horizon, it is not forming today in this profile.

Classifications

1. Soil Taxonomy: Fine, kaolinitic, isotheric, Humoxic Sombrihumult
2. FAO: Humic Ferralsol

Discussion (Chairman: Juan Comerma)

The first major item of discussion was the need and importance of correcting for CEC according to the content of organic matter. Dr. Bennema considered that the definition of the oxic horizon should be based on the CEC after correction for the contribution by organic matter. He offered his procedure for making such a correction. The Chairman of ICOMOX explained that the concept of the oxic horizon is one of low CEC, irrespective of the origin of CEC. Dr. Sys disagreed and indicated that the concept was one of weathering stage and this can be masked by the organic matter. Schargel pointed out that the CEC of organic matter is a function of several factors including humification stage and that no single value could be allocated to the contribution of organic matter for the correction. The chairman closed the discussion and requested members to put their ideas in writing and submit them to the respective ICOMS.

The origin of the sombric horizon was much debated. Dr. Frankart indicated that there was sufficient evidence to suggest an illuvial origin while Dr. Neel was convinced that many were depositional or buried A horizons. Dr. Neel also discussed the different forms of the horizon and indicated the possibility of a soil having multiple sombric horizons. It was agreed that there was a need for more detailed studies on such soils and it was recommended that SMSS explore such a project.

From the point of view of the use of the sombric horizon in Soil Taxonomy, there was also much debate. Many felt that there was sufficient morphological expression for it to be considered as a diagnostic horizon despite its origin and genesis. Others felt that it was a buried horizon and that the pedon should be classified according to the rules governing buried soils.

As in the other similar soils of the tour, everybody agreed that a geomorphic evaluation of the soils was necessary in order to explain the genesis of the soils. Dr. Arnold presented a hypothesis of at least three discontinuities in the pedon.

Finally Dr. Spain presented some ideas on the main soil management practices. He stressed the low base saturation which required liming and suggested deep liming to establish a good root proliferation. He pointed out the higher amount of roots in the sombric horizon and stated that this is trying to tell us something about the beneficial effects of this horizon.

The INEAC classification (Sys) is:

Order:	Kaolisol
Suborder:	Humiferous Kaolisol
Group:	Dark horizon humiferous Ferralsol
Great group:	intergrade to Ferrisol
Family:	clayey from shales and granite

RWANDA

Profile R 6

Classification: Sol Brun Tropicaux (INEAC)

Location: prefecture Ruhengeri, commune Kigombe, secteur Kabaya, colline Kabaya; PNAP center for potato selection in town of Ruhengeri.

Physiography: lava plain with strong microrelief dissected by intermittent rivers.

Topography: lava plain, at 30 m from a river; altitude 1,830 m

Drainage: well drained

Climate: Cw3, mean annual temperature 18.3°C; annual rainfall 1,235 mm

Vegetation: potato field

Parent material: volcanic ash and colluvium from shales

Limitations affecting plant growth: none

No. soil sample	Horizon	Depth (cm)	Horizon description
R6,1	Ap1	0-14	very dark grayish-brown (10YR3/2); clay; loam; moist; moderate fine crumb structure, very friable; very many fine roots; smooth clear boundary; probably soil brought in from elsewhere,
R6,2	Ap2	14-40	very dark grayish-brown (10YR3/2); clay, loam; moist; very weak fine crumb structure; loose; some rounded pebbles of 3 to

No. soil sample	Horizon	Depth (cm)	Horizon description
			5 cm of volcanic origin; very many fine roots; smooth gradual boundary,
R6,3	A3	40-82	very dark grayish-brown (10YR3/2); clay loam; some rounded pebbles, 1 stone of 10 cm of volcanic origin, slightly porous, brought in by the river; weak fine sub-angular blocky structure, very friable; common fine roots; irregular clear boundary,
R6,4	(B21)	82-122	dark brown (10YR3/2.5); clay; moist; mocerate medium subangular blocky structure, friable; presence of tongues of R6,3 materials; a few pebbles of 1 cm; some rare ccatings; few fine roots; smooth gradual boundary,
R6,5	(B22)	122-165	idem as R6,4 but without tongues of R6,3 material, presence of some hardened angular blocks, a few rounded pebbles of 1 to 5 cm of volcanic origin.

P.S. The soil lacks the low density of a typical Andept.

-- Samples for micromorphology: R6,3 between 50 and 57 cm
R6,5 between 130 and 137 cm

-- Sample for pot trials: R6

SAMPLED AS: SOL BRUN TROPICAL

S 81FN-CLC - R6 SAMPLE NOS. 81P1152 - 1156 DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1-- TOTAL CLAY LT .002	-2-- TOTAL SILT .002-.05	-3-- TOTAL SAND .05-2	-4-- CLAY FINE LT .0002	-5-- CLAY CO3 LT .002	-6-- SILT FINE .002-.02	-7-- SILT COARSE .02-.05	-8-- SAND VF .05-.10	-9-- SAND F .10-.25	-10- SAND M .25-.50	-11- SAND C .5-1	-12- SAND VC 1-2	-13- COARSE FRACTIONS (MM) WEIGHT 2-5	-14- 5-20	-15- 20-75	-16- .1-75	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)												<- PCT OF <75MM(3B1) ->				
811152	1S	0- 14	AP1	7.5	37.0	55.5			22.1	14.9	13.4	18.9	12.6	7.3	3.3	--	--	--	42	--
811153	2S	14- 40	AP2	10.7	40.3	49.0			23.6	16.7	12.6	15.0	10.8	6.8	3.8	--	--	--	36	--
811154	3S	40- 82	A3	10.1	39.5	51.4	2.9		19.4	19.1	9.6	17.2	12.1	7.9	4.6	--	--	--	42	--
811155	4S	82-122	B21	11.6	39.5	48.9			24.1	15.4	11.2	16.5	12.1	6.4	2.7	--	--	--	38	--
811156	5S	122-165	B22	9.5	39.3	52.2	3.3		22.3	16.0	12.4	15.8	12.0	7.5	4.5	--	--	--	40	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG LIMITS) LL 4F1	PI 4F	(BULK DENSITY) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(WATER CONTENT) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM ->									PCT <0.4MM		<- G/CC ->			CM/CM	<- PCT OF <2MM ->				CM/CM
811152	1	1.20	0.115			1.4	0.2		1.37	1.09										8.2	
811153	2	2.54	0.221			1.3	0.2		1.48	0.90										9.6	
811154	3	1.70	0.168			1.3	0.2		1.23	0.78										7.9	
811155	4	0.65	0.072			1.7	0.2		0.89	0.78										9.0	
811156	5	0.31	0.038			1.6	0.1		0.94	1.00										9.5	

SAMPLE NO.	HZN NO.	(NH4OAC EXTRACTABLE BASES) CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	(CEC) SUM CATS 5A3A	NH4OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	(BASE SAT) SUM 5C3	NH4OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	(PH) KCL 1N 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G ->										<- PCT ->								
811152	1	6.6	1.4	0.1	0.5	8.6	5.6		14.2	10.3			61	83			5.1	9.7	6.0	6.2
811153	2	11.8	2.2	0.1	0.7	15.0	7.2		22.2	15.8			68	95			5.7	9.1	6.2	6.8
811154	3	7.1	1.5	0.1	0.3	9.0	7.3		16.3	12.4			55	73			5.1	8.8	5.6	6.3
811155	4	6.5	1.4	0.2	0.2	8.3	5.7		14.0	10.3			59	81			5.2	9.5	5.8	6.5
811156	5	5.0	1.3	0.2	0.4	6.9	4.1		11.0	8.9			63	78			5.1	8.3	5.9	6.6

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	(MINERALOGY) TOTAL ANALYSIS 7C3 K2O 6Q3A	FE 6C7A	(CLAY) X-RAY <2U 7A2I	7A2I	7A2I	7A2I	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- PCT ->		<- RELATIVE AMOUNTS ->				<- PCT ->			
811152	1	0.71	25	8.9	1.3	7.2	MI 2	KH 1	FD 1		KH22			
811153	2	0.73	30	14.1										
811154	3	0.82	29	9.6	1.1	6.0	MI 1	KH 1	FD 1					
811155	4	0.86	41	9.2										
811156	5	0.82	25	8.4	1.0	7.6	KH 2	MI 2	FD 1		KH39			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL MI MICA KH HALLOYSITE FD FELDSPAR

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE.

PROFILE 6

Sample 3. 40-82 cm. A3 horizon

Under plain light, the s-matrix is dark brownish-black. Identifiable plant remains are few, and much of the organic matter is as complexes or as coatings on the clay. The plasmic fabric is isotic.

The NRDP is grani-plasmic. There is a relatively high amount of plasma which shows a weak tendency to aggregate. Although quartz dominates the grains, there is a significant amount of plagioclase feldspars and augite. In addition there are a few flakes of micas.

Sample 5. 122-165 cm. B22 horizon

There is practically no change in fabric characteristics as compared to the previous horizon. Plate 3a shows some of the more important features. The very high amounts of plagioclases and the few augites are evident. No olivines were detected. The plasmic fabric is isotic.

The tendency for the plasma to aggregate may be seen in the micrograph. There is a weak agglutinic SRDP associated with the basic grani-plasmic NRDP.

In addition to the single grains, there are also lithorelicts of basalt scattered all over the s-matrix.

Interpretation

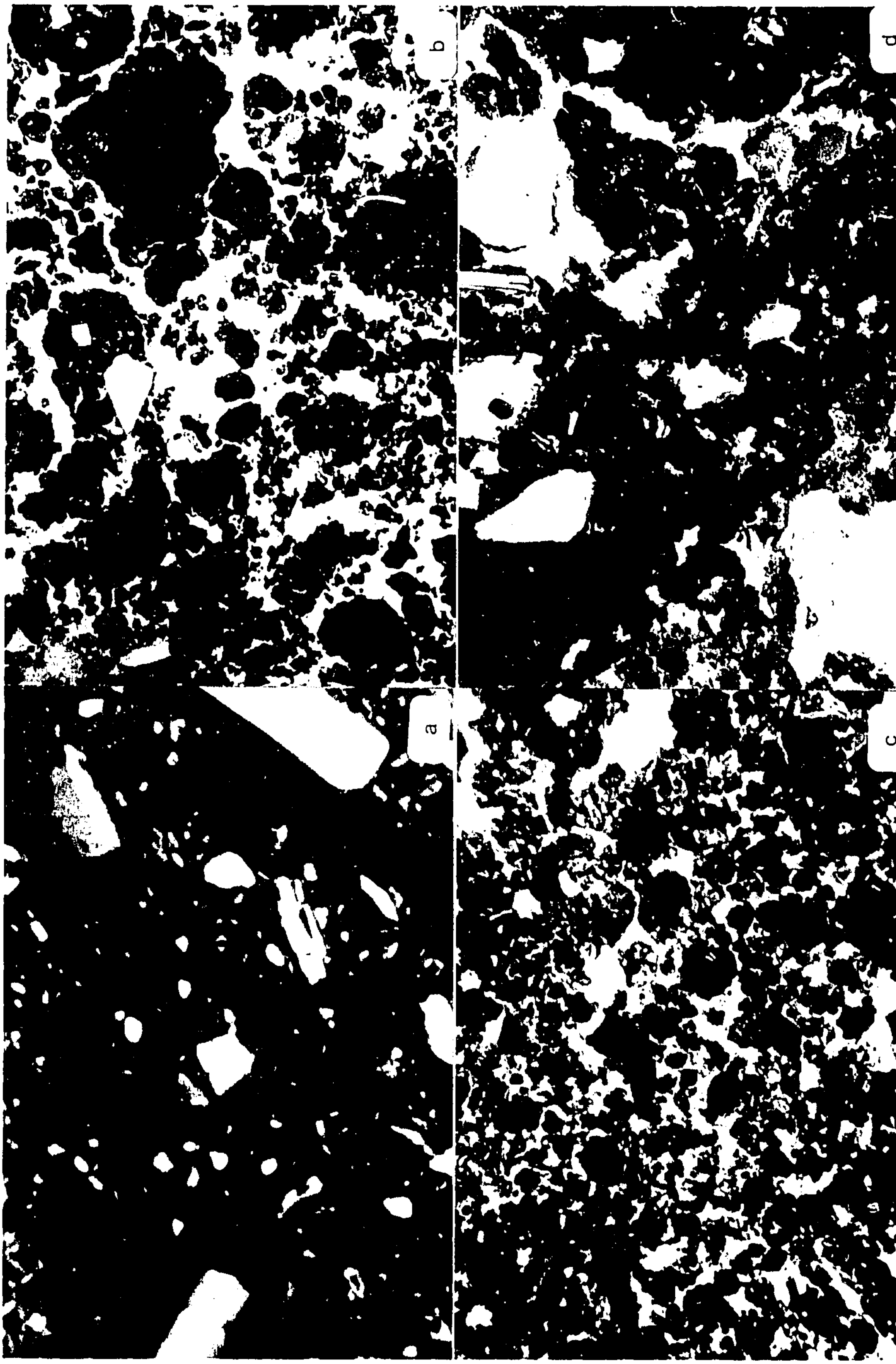
The soil has weak andic properties. The isotic plasmic fabric and the agglutinic SRDP, both of which are weakly expressed, suggest the andic characteristic.

The agglutinic tendency may be related to the very friable consistence of the soil material in the field. Both in the field and in thin-section, the plasma content was considered to be high. The particle-size data only gives 10% clay and this is clearly due to poor dispersion.

Classifications

1. Soil Taxonomy:

The soil keys out to an Inceptisol but does not meet the definition of a Tropept. There is an inconsistency between the key and definition.


a
b
c
d

If this is ignored, it can be classified as a Fluventic Eutropept.

The present key does not permit Mollisols in iso-temperature regimes. This has been amended and so the classification will be:

Coarse-loamy, mixed, isothermic, cumulic Hapludoll

The Chairman of ICOMAND did not consider that the soil will come out as an Andisol.

2. FAO: Eutric Cambisol

<u>Discussion</u> (Chairman E.M.T. Awa)

The first point for discussion was the origin of the soil material. Mr. Neel considered that the material is a mixture of riverine alluvium admixed with some ash. The river is just a few hundred meters from here and the presence of micas in the clay fraction points to the alluvial nature.

Dr. Eswaran suggested that the mineralogy class may be siliceous. For the mineralogy family class, it is necessary to consider the 0.02 to 2 mm fraction. The data that is presented refers only to the 0.02 to 0.2 mm fraction. We need to check this prior to the final classification.

Dr. Van der Zaag discussed the fertility aspects of the soil. There is virtually no response to P and in some places the S and Mg levels are low. In many places, the soil depth is shallow and the soil is rocky. This may also be a constraint to use of the soil. In order to have enough depth, bunds are made for potatoes. Yields are usually very good. Disease attack is common, mainly in the form of *Phytopthora*, which is less prevalent at higher elevations. Chemical spraying is not generally practiced.

With respect to P, the native P content is very high but much of it is not available. This is why both potatoes and beans show a good response to P.

INEAC classification (Sys):

Order:	Black Tropical soils
Suborder:	Non-hydromorphic
Group:	Melanic, eutrophic regosol
Subgroup:	typic
Family:	silty on reworked volcanic ash

RWANDA

Profile R 7

Classification:	Andosol (INEAC)
Location:	prefecture Gisenyi, commune Mutura, secteur Nkora, colline Nkora, center for multiplication of seed (SSS), 50 m west to the main road Gisenyi-Ruhengeri, 35 km from Ruhengeri.
Physiography:	lava plain with very irregular microrelief, generally shallow soils on lava flows.
Topography:	depression between lava flows; altitude 2,350 m
Drainage:	moderately well drained
Climate:	Cw2, mean annual temperature 14.5°C; annual rainfall appr. 1,500 mm
Vegatation:	fallow of elephant grass: *Pennisetum purpureum*
Parent material:	volcanic ash and lava.
Limitations affecting plant growth:	depth of loose material, P-status.

No. soil sample	Horizon	Depth (cm)	Horizon description
R7,1	Ap	0-36	very dark brown (10YR2/2); clay loam, bit smeary; low bulk density; very weak fine crumb structure, loose; moist; many fine roots; smooth gradual boundary,
R7,2	A12	36-64	black (10YR2/1); clay loam, bit smeary; low bulk density; weak fine crumb structure, moist, very friable; a few fine subangular, more firm blocks; many fine roots; irregular gradual boundary,

No. soil sample	Horizon	Depth (cm)	Horizon description
R7,3	A13	64-100	black (10YR2/1); clay loam; smeary; moist; weak medium subangular blocky structure; friable; low bulk density; several massive blocks and some angular firm blocks, a few volcanic fragments; many fine roots; smooth abrupt boundary.
100--			lava stones of 10 to 50 cm

-- Samples for micromorphology: R7,1 between 10 and 16 cm
R7,2 between 46 and 52 cm
R7,3 between 94 and 100 cm

-- Sample for pot trials: R7

SAMPLED AS: ANDCSCL

S 81FN-00C - 87 SAMPLE NOS. 81P1157 - 1159 DATE MAY 1981

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

-1-- -2-- -3-- -4-- -5-- -6-- -7-- -8-- -9-- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002 -.05	TOTAL SAND .05 -2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002 -.02	SILT COARSE .02 -.05	SAND VF .05 -.10	SAND F .10 -.25	SAND M .25 -.50	SAND C .5 -1	SAND VC 1 -2	COARSE FRACTIONS(MM) WEIGHT 2 -5	WEIGHT 5 -20	WEIGHT 20 -75	.1- 75	(>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM(3B1)->				
811157	1S	0- 36	AP	14.5	71.4	14.1			60.0	11.4	5.6	4.3	1.7	1.3	1.2	--	--	--	8	--
811158	2S	36- 64	A12	12.8	73.7	13.5			62.7	11.0	3.7	3.8	1.8	2.0	2.2	--	--	--	10	--
811159	3S	64-100	A13	6.0	79.9	14.1			64.3	15.6	4.9	4.4	2.0	1.4	1.4	--	--	--	9	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG LIMITS) LL 4F1	PI 4F	(BULK DENSITY) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(WATER CONTENT) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811157	1	15.4	1.750			3.4	2.2		5.04	2.68										38.9	
811158	2	15.9	1.563			3.7	2.4		5.53	3.82										49.7	
811159	3	13.7	1.174			4.5	2.7		10.40	7.93										47.6	

SAMPLE NO.	HZN NO.	(NH4OAC EXTRACTABLE BASES) CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G7A	(CEC) SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	(PH) KCL 1N 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
811157	1	29.6	7.9	0.3	2.5	40.3	61.1		101.4	73.1			40	55			4.3	10.6	5.3	5.7
811158	2	21.3	4.6	0.1	0.9	26.9	64.6	0.5	91.5	70.9	27.4	2	27	30			4.7	10.6	5.0	5.5
811159	3	10.1	5.9	0.5	0.2	16.7	72.1	1.9	88.8	62.4	18.5	10	19	27			4.5	11.0	5.1	5.4

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	(MINERALOGY – CLAY) TOTAL ANALYSIS 7C3 K2O 6Q3A	Fe 6C7A	X-RAY <2U 7A21	7A21	7A21	7A21	DTA 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- PCT	->	<- RELATIVE AMOUNTS			->			<- PCT	->
811157	1	0.97	96	44.3										
811158	2	0.97	96	35.4	0.5	A.7	NX 6							
811159	3	0.98	98	24.6										

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KINC F MINERAL NX AMORPHOUS

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 7

Thin-sections were made of all the three horizons (Ap, A12, A13), and as there are only minor variations in the samples, description is only given for the third horizon. Plate 3b shows a micrograph taken under parallel light of the fabric of the A13 horizon. Under plane polarized light, the whole s-matrix is isotropic. There is so much organic matter and so few grains that nothing can be seen. The isotropic nature of the plasma is also due to the presence of large amounts of amorphous materials.

Although the soil material has about 15% organic carbon, with the exception of the Ap horizon, there are very few recognizable remains of organic matter. Most of the organic matter is plasmafied and exists as coatings around particles or as complexes with the mineral colloid.

Due both to the organic matter and the amorphous colloids, the plasma is aggregated, giving rise to a specific related distribution pattern called agglutinic. This is very characteristic of the fabric of Andepts and is seen in Plate 3b. The fabric arises as a result of drying out of the colloids which shrink and form micro-granules.

The result is to give a very friable and fluffy consistence to the soil. The micro-granules are not stable entities as they crush easily between the fingers, and as the particles are not platy, they smear the fingers. However, under gentle pressure, they can regain their form and this is called thixotropy.

As stated earlier, any other micromorphological feature which may be present is masked by the colloid. This, however, is a property of Andisols.

Classifications

1. Soil Taxonomy (by Dr. G. Uehara): Medial, isothermic, Typic Dystrandept.

Dr. Tavernier commented that the distinction between an Eutrandept and Dystrandept is that the former has a base saturation of 50% or more in some subhorizon between a depth of 25 and 75 cm. As the pedon has such a subhorizon, it should be classified as an Udic Eutrandept.

2. FAO (Dr. A. Pécrot): Humic Andosol.

Discussion (Chairman: Dr. H. Ikawa)

Dr. Leamy discussed the formation of ICOMAND. In the development of Soil Taxonomy, the data base was from Hawaii, Alaska and the western U.S. In 1978, when Dr. Guy Smith concluded his visit in New Zealand, he submitted a proposal based on his experience in New Zealand, the West Indies, and the U.S. His proposal was to elevate the Andepts and Andaquepts to an order level and to call the new order Andisols. Though a proposal was submitted, he recognized the fact that much more needed to be known about the Andisols of Africa, South America and the Middle East before a comprehensive proposal could be made.

There are two main points in the definition of Andisols. First, the exchange complex must be dominated by amorphous materials. Abbreviated as ECDAM, the conditions to be met are:

(a) must have a bulk density of less than 0.85 per cc;

(b) a pH in NaF of 9.4 or more;

(c) a phosphate retention of more than 90%; and

(d) the amount of variable charge is also specified.

The second point relates to the coarse-textured materials which must have 60% or more vitric volcanic material and a pH in NaF of 9.2 or more.

In the Andisols, suborders are defined on moisture and temperature regimes--Aquands, Borands, Xerands, Ustands, Tropands and Udands. The characteristics used for the determination of the great groups include: hydric, vitric, placic, melanic.

With respect to profile 7 and as the proposal stands, it is a Haplotropand. The melanic great group was established for the Udands on the basis of the Japanese experience where the classic Ando soil is present. The requirements are that they must be thicker than 30 cm, with a value and chroma of 2 or less and 8% or more organic carbon. Having seen this profile, we would consider a Melanotropand. Dr. Eswaran inquired if a Humitropand would not be preferable in order to be consistent with Soil Taxonomy. The reason why Dr. Smith selected melano--instead of humi--was because of the special nature of the humic allophonic complexes.

Management of the soil. Dr. Van der Zaag gave an account of the management properties of soils similar to profile 7. In general the P levels are very high in these soils. They had conducted P trials ranging from 0 to 2000 kg/ha and found no response. There are, however, some responses to sulfur but we have not tested it on field trials.

The socle horizon. Mr. H. Neel brought a sample of the socle horizon from near Sabinjo volcano. This firm layer forms at the soil surface (and resembles a sod layer). The vegetation in the area is patchy and wherever there is a very poor growth, one can find the socle horizon. (Compilor's note: This may correspond to the derno layer of the Russians.)

INEAC classification (Sys):

Order: recent tropical soils

Suborder: non-hydromorphe

Group: Humiferous

Subgroup: Eutrophic

Family: on volcanic ash

RWANDA

Profile R 8

Classification: Andosol (INEAC)

Location: prefecture Gisenyi, commune Mutura, secteur Kanzenze, colline Kirerema, 10 m north of the road to the Isar-station of Tamira, 2 km from the main road Gisenyi-Ruhengeri, 21 km from Gisenyi.

Physiography: large lava plain with several old volcanic mounds made up of ashes and more coarse material, strong microrelief in the plain.

Topography: slope north-facing of an old volcano mount 55%, altitude 2,220 m, altitude of top 2,340 m

Drainage: well drained

Climate: Cw2, mean annual temperature 14.5°C; annual rainfall 1,500 mm

Vegetation: grassland of *Pennisetum clandestinum, Digitaria sp., Poa sp.,* some Eucalyptus trees.

Parent material: volcanic ash

Limitations affecting plant growth: depth of loose material

No. soil sample	Horizon	Depth (cm)	Horizon description
	Ao	3-0	organic litter
R8,1	A11	0-11	dark brown (7.5YR3/2) silty clay loam, moist; bit smeary; low bulk density; massive structure; very many fine roots;

No. soil sample	Horizon	Depth (cm)	Horizon description
			friable; smooth abrupt boundary; presence of some rare small spots of 2.5YR4/6 being weathered volcanic ash,
R8,2	A12	11-40	dark brown (7.5YR3/2), some very rare dots of 2.5YR4/6; silty clay loam, bit smeary, low bulk density; moist, very weak fine and medium granular and subangular blocky structure, very friable; many fine roots; smooth and abrupt boundary,
R8,3	B1	40-60	dark brown (7.5YR3/3.5), some very rare, red spots; silty clay loam, bit smeary, low bulk density; moist; very weak fine crumb and subangular blocky structure, very friable; smooth and gradual boundary; many fine roots,
R8,4	B21	60-90	dark reddish-brown (6YR3/3); silty clay loam, smeary (light thixotropy), low bulk density; moist; weak medium sub-angular block structure, friable, presence of some massive blocks, some very rare coatings in pores; common fine roots; smooth clear boundary,
R8,5	B22	90-102	dark reddish-brown (5YR3/3); gravelly silty clay loam, pebbles of volcanic material, some mm in diameter, red at the outside (2.5YR4/6) and black at the inside; low bulk density; moist, weak medium sub-angular block structure, friable, common fine roots; smooth and abrupt boundary,
R8,6	C	102-	pure volcanic material of variable size

No. soil sample	Horizon	Depth (cm)	Horizon description
			(mms), or irregular shape, porous, low density, heterogenous color, red and black (7.5YR2/0), lightly coherent.

-- Samples for micromorphology: R8,1 between 4 and 11 cm
R8,2 between 32 and 39 cm
R8,4 between 73 and 80 cm

-- Sample for pot trials: R8

SAMPLED AS: ANDOSOL

S 81FN-200 - 008 SAMPLE NOS. 81P1160 - 1165 DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- CLAY LT .002	-2- SILT .002-.05	-3- SAND .05-2	-4- FINE CLAY LT .0002	-5- CO3 CLAY LT .002	-6- FINE SILT .002-.02	-7- COARSE SILT .02-.05	-8- VF SAND .05-.10	-9- F SAND .10-.25	-10- M SAND .25-.50	-11- C SAND .5-1	-12- VC SAND 1-2	-13- WEIGHT 2-5	-14- WEIGHT 5-20	-15- WEIGHT 20-75	-16- WEIGHT .1-75	-17- >2MM WT PCT OF WHOLE SOIL
				<- - PCT OF <2MM (3A1) - ->												<- PCT OF <75MM(3B1)->				
81P1160	1S	0- 11	A11	11.4	71.2	17.4			59.2	12.0	7.2	4.9	2.5	1.5	1.3	--	--	--	10	--
81P1161	2S	11- 40	A12	10.1	72.8	17.1	--		58.7	14.1	8.5	4.3	2.3	1.2	0.8	--	--	--	9	--
81P1162	3S	40- 66	B11	3.3	76.4	20.3			57.7	18.7	11.6	5.2	2.4	0.8	0.3	--	--	--	9	--
81P1163	4S	66- 90	B21	0.6	67.5	31.9	--		43.7	23.8	16.8	9.2	3.3	1.8	0.8	--	--	--	15	--
81P1164	5S	90-102	B22	3.5	44.6	53.8			26.9	17.7	19.9	16.4	6.9	4.8	5.8	--	--	--	34	--
81P1165	6S	102- [illegible]	C													--	--	--		--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG LIMITS) LL 4F1	PI 4F	(BULK DENSITY) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(WATER CONTENT) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - PCT OF <2MM - ->									PCT <0.4MM		<- - G/CC - ->			CM/CM	<- - PCT OF <2MM - ->				CM/CM
81P1160	1	3.75	0.396			5.4	1.7		5.98	3.41										38.9	
81P1161	2	8.62	0.720			5.0	1.4		6.46	3.68										37.2	
81P1162	3	7.62	[illegible]			6.7	2.2		18.97	13.42										44.3	
81P1163	4	7.62	0.750			9.3	3.0		103.50	98.67										59.2	
81P1164	5	4.55	0.497			9.3	2.6		39.69	30.31										48.5	
81P1165	6					3.6	0.5													24.5	

SAMPLE NO.	HZN NO.	(NH4OAC EXTRACTABLE BASES) CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACID-ITY 6H5A	EXTR AL 6G9A	(CEC) SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	(BASE SAT) SUM 5C3	NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	(PH) KCL 1N 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - MEQ / 100 G - - ->										<- - PCT - ->								
81P1160	1	38.4	6.3	0.1	0.3	45.1	38.9		84.0	68.2			54	66			5.2	10.2	6.2	6.5
81P1161	2	43.7	6.5	0.1	0.2	50.5	37.5		88.0	65.2			57	77			5.5	10.1	6.4	6.6
81P1162	3	41.2	7.8	0.2	0.1	49.3	44.3		93.6	62.6			53	79	--		5.7	10.5	6.3	6.9
81P1163	4	25.1	11.4	0.4	0.1	37.0	52.8		89.8	62.1			41	60			5.8	10.8	6.3	6.8
81P1164	5	29.1	12.0	0.3	0.2	41.6	45.2		86.8	53.5			48	66	--		6.0	10.7	6.5	7.2
81P1165	6																			

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	(MINERALOGY) (CLAY) TOTAL ANALYSIS 7C3 K2O 6Q3A	FE 6C7A	X-RAY (<2U) 7A21	7A21	7A21	7A21	DTA 7A3	7A3	TOTAL RES 7B1A	OOM WEATH 7B1A
					<- - PCT - ->		<- RELATIVE AMOUNTS ->				<- - PCT - ->			
81P1160	1	0.98	96	46.0										
81P1161	2	0.98	94	48.9	0.3	6.6	NX 6							
81P1162	3	1.00	98	47.5										
81P1163	4	0.98	99	37.6	0.6	6.7	NX 6							
81P1164	5	0.99	99	43.7	0.5	9.0	NX 6							
81P1165	6													

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL NX AMORPHOUS

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 8

Three samples (A11, B21, B22) were taken for thin-sections, and due to the uniformity of the material, only the B22 horizon is described here.

Plate 3c shows the fabric of this horizon and the effect of organic matter may be seen by comparing this with Plate 3b. This soil has only about 7 to 8% organic carbon. The s-matrix is more brownish, but the plasmic fabric is still isotic. Under plane polarized light, everything is black and only the few grains can be seen. There is very little quartz but a relatively high amount of augite and plagioclases. A few glass shards are also present. These, psideromelane, are yellowish in color showing evidence of alteration.

Although particle size analysis only gives about 0.6% clay, it is evident from Plate 3c that there is as much as 60% clay in the material. The aggregation leading to an agglutinic SRDP is evident. These aggregates do not disperse with sodium hexa-metaphosphate, and this accounts for the very low measured clay. A similar feature may be seen in spodic horizons, and previous workers have called them faecal pellets. This is clearly a misinterpretation. As stated in Profile 7, the agglutinic SRDP and isotic plasmic fabric are the diagnostic properties of Andisols--they show the andic syndrome.

Classifications (Chairman: Dr. M.L. Leamy)

1. Soil Taxonomy: Medial, thixotropic, Udic Eutrandept
2. FAO: Mollic Andosol

RWANDA

Profile R 9

Classification:	Sol Brun Tropicaux (INEAC)
Location:	prefecture Gisenyi, commune Rubavu, secteur Gisa, colline Gisa, 10 m east of the main road Gisenyi-Ruhengeri, 4 km from Gisenyi.
Physiography:	landscape of granite and shale hills between which are large concavities filled in with colluvium.
Topography:	concavity with west-facing slope of 4%, altitude 1,590 m
Drainage:	well drained
Climate:	Aw3, mean annual temperature app. 21.5°C; annual rainfall 1,100 mm
Vegetation:	plot of coffee Arabica
Parent material:	colluvium of granitic origin, with admixture of shales and volcanic ash
Limitations affecting plant growth:	none

No. soil sample	Horizon	Depth (cm)	Horizon description
R9,1	Ap1	0-30	very dark grayish-brown (10YR3/2) fine clay, some mica; moist; plastic; sticky; strong medium crumb structure, very firm; coatings; many fine roots; smooth and gradual boundary,
R9,2	Ap2	30-70	very dark grayish-brown (10YR3/2), clay; moist; plastic, sticky; some mica;

No. soil sample	Horizon	Depth (cm)	Horizon description
			moderate medium subangular blocky structure, friable, many pores of biologic origin, coatings; common roots; smooth clear boundary,
R9,3	A13	70-116	very dark grayish-brown (10YR3/1.5); clay, much mica, some dots of weathered granite; moist; weak fine and medium subangular block structure, very friable; strong biologic activity; coatings; few fine roots; smooth and clear boundary,
R9,4	A14	116-132	very dark grayish-brown (10YR3/2); clay, some mica, some dots of weathered granite; strong medium angular blocky structure, firm, some massive blocks; many coatings; fine roots; smooth and clear boundary,
R9,5	A15	132-147	very dark gray (10YR3/1); fine clay, much mica; moist; weak medium subangular blocky structure; friable; coatings in pores; few fine roots; smooth and abrupt boundary,
R9,6	A16	147-160	very dark grayish-brown (10YR3/2); clay, much mica; moist strong angular and subangular medium blocky structure firm; coatings; few fine roots.

-- Samples for micromorphology: R9,1 between 15 and 21 cm
R9,2 between 40 and 46 cm
R9,3 between 81 and 87 cm
R9,4 between 117 and 123 cm
R9,6 between 146 and 152 cm

-- Sample for pot trials: R9

SAMPLED AS: SOL BRUN TROPICAL

5 BIFM-SOC - 39 SAMPLE NOS. 81P1166 - 1171 DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

				-1--	-2--	-3--	-4--	-5--	-6--	-7--	-8--	-9--	-10-	-11-	-12-	-13-	-14-	-15-	-16-	-17-
				(- - -TOTAL - - -)			(- -CLAY- -)		(- -SILT- -)		(- - - - - -SAND- - - - - -)					(-COARSE FRACTIONS(MM)-)				(>2MM)
				CLAY	SILT	SAND	FINE	CO3	FINE	COARSE	VF	F	M	C	VC	- - - WEIGHT - - -				WT
SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	LT .002	.002 -.05	.05 -2	LT .0002	LT .002	.002 -.02	.02 -.05	.05 -.10	.10 -.25	.25 -.50	.5 -1	1 -2	2 -5	5 -20	20 -75	.1- 75	PCT OF WHOLE SOIL
				<- - - - - - - - - PCT OF <2MM (3A1) - - - - - - - - - - ->												<- PCT OF <75MM(3B1)->				
811166	1S	0- 30	AP1	26.1	55.5	18.4			43.7	11.8	8.1	5.6	2.7	1.2	0.8	--	--	--	10	--
811167	2S	30- 70	AP2	22.6	56.6	20.8			42.4	14.2	9.2	6.0	3.2	1.5	0.9	--	--	--	12	--
811168	3S	70-116	A13	28.0	43.6	28.4			34.5	9.1	6.0	8.9	8.0	3.6	1.9	--	--	--	22	--
811169	4S	116-132	A14	19.8	64.0	16.2			51.2	12.8	5.2	4.1	3.3	2.1	1.5	--	--	--	11	--
811170	5S	132-147	A15	28.3	41.0	29.7			34.4	8.6	4.7	8.6	8.5	4.6	2.3	--	--	--	24	--
811171	6S	147-150	A16	26.9	26.6	46.5			19.4	7.2	5.7	13.8	14.1	8.4	4.5	--	--	--	41	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - - - - - -PCT OF <2MM - - - - - - ->									PCT <0.4MM		<- - G/CC - - ->			CM/CM	<- - -PCT OF <2MM - ->				CM/CM
811166	1	4.32	0.370			3.8	0.3		2.72	1.38										36.0	
811167	2	3.03	0.263			3.9	0.3		2.98	1.59										35.9	
811168	3	3.51	0.281			3.3	0.3		1.98	1.05										29.4	
811169	4	3.78	0.316			3.8	0.3		3.39	1.84										36.5	
811170	5	3.32	0.306			3.0	0.3		1.96	0.95										27.6	
811171	6	2.03	0.184			2.5	0.2		1.39	0.75										20.3	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 5B3A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- - - - - - - - - - - - -MEQ / 100 G - - - - - - - - - - - - ->										<- - - - -PCT - - - ->								
811166	1	45.3	10.5	0.1	12.4	68.3	12.7		81.2	70.7			84	96			5.8	9.0	6.5	6.8
811167	2	44.4	9.7	0.1	9.4	63.6	11.1		74.7	65.1			85	98	--		5.8	9.1	6.6	7.2
811168	3	43.0	8.6	0.1	2.6	54.3	11.6		65.9	55.5			82	98	--		5.9	8.9	6.7	7.3
811169	4	54.2	11.3	0.2	1.0	66.7	13.5		80.2	67.1			83	99	--		5.4	9.2	6.8	7.2
811170	5	46.0	9.2	0.1	0.8	56.1	11.5		67.6	55.4			83	100	--		5.9	8.9	6.8	7.2
811171	6	29.5	6.1	0.1	1.2	35.9	11.0	--	46.9	37.4			77	96			6.0	8.7	6.7	7.1

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY < 2mm TOTAL ANALYSIS 7C3 K2O 6Q3A	< 2mm Fe 6C7A	< 0.002mm K2O 6Q3A	< 0.002mm Fe 6C7A	CLAY X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	WEATH 7B1A
					<- - - - - - - - - - PCT - - - - - - - - - ->				<- RELATIVE AMOUNTS ->				<- - - - -PCT - - - ->			
811166	1	0.81	52	60.0												
811167	2	0.96	52	59.4			1.3	8.1	KH 1	MI 1			KH19			
811168	3	0.84	50	51.5												
811169	4	0.94	66	63.7	0.9	6.7										
811170	5	0.91	85	50.6												
811171	6	0.80	38	33.9	1.2	5.3	1.1	8.2	KH 2	MI 1			KH29			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KH HALLOYSITE MI MICA

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 9

Thin-sections of the A1, B21 and B22 horizons were made of this profile, and due to the uniformity of the material, only the B22 horizon is described. The profile is derived from volcanic ash materials admixed with alluvium. Due to its physiographic position, it is at a more advanced stage of soil formation than Profiles 7 or 8.

Plate 3d shows the fabric of the B22 horizon, and for an appreciation of soil genesis, may be compared with plates 3b,c. The normal related distribution is grani-plasmic, and the agglutinic SRDP of Profiles 7 and 8 is only very weakly expressed. The plasma is still very heavily stained with organic matter and so is brownish-black.

There is a very high amount of fine sand-sized, angular quartz grains. Few large flakes of muscovite and few plagioclases are also present. The plasmic fabric is essentially isotic, but insepic features are also present. The clay mineralogical study shows that the dominant clay mineral is halloysite, and this mineral can also give rise to an isotic plasmic fabric.

The micromorphology of the B horizon clearly indicates transitional properties between andic materials and cambic horizon. The weak development of the agglutinic SRDP and the isotic plasmic fabric points to weak andic properties. On the other hand, the grani-plasmic NRDP and insepic plasmic fabric are evidence of weak cambic characteristics.

The profile is clearly transitional between an Andisol and Inceptisol. Micromorphologically, it will not be incorrect to place it in either order.

Classifications

1. Soil Taxonomy:

The soil is a borderline case for several classes. The pH NaF is just below the requirement for the definition of 'dominance by amorphous materials.' The soil meets all other requirements and may be classified as medial, isotherm .c, Udic Eutrandept. The most appropriate classification is as a Mollisol. If the amendment to the definition of the order is accepted, the soil is classified as fine loamy, mixed, isothermic, Camulic Hapludoll.

2. FAO: Mollic Andosol.

Discussion (Dr. J. Kimble)

The presence or absence of a cambic horizon was discussed. Dr. Van Wambeke pointed out that the definition of a cambic horizon excludes the characteristics of a mollic epipedon.

Dr. Leamy indicated that with the new proposals of ICOMAND, the soil will not be keyed out as an Andisol and he considered the classification as a Mollisol most appropriate. Dr. Pécrot stated that in the FAO classification, the soil would not classify as Andosol. In the FAO classification, the soil does not have a mollic horizon and so a cambic horizon is recognized; the soil is a Cambisol. Drs. Bennema and Tavernier pointed out that the restrictions on the cambic horizon are the same as in Soil Taxonomy. The discussion then became bogged down in interpretation of the definition in the FAO legend.

Mr. Gahamani then presented the Russian approach to classification. There are several schools of thought and these were presented.

INEAC classification (Sys):

Order:	Black Tropical soil
Suborder:	non-hydromorphic
Group:	melanic, eutric Regosol
Subgroup:	typic
Family:	silty on reworked volcanic ash

RWANDA

Profile R 10

Classification:	Ferrisol/Sol Recent Tropicaux (INEAC)
Location:	prefecture Ruhengeri, commune Nshabingo, secteur Bushoka, colline Bushoka, 20 m to the northeast of the main road Kigali-Ruhengeri, 20 km from Ruhengeri.
Physiography:	very hilly landscape, average slope of 50%, average difference of altitude between the tops and the small valley 200 m.
Topography:	convex slope of 40%, altitude 1,820 m
Drainage:	well drained
Climate:	Cw3, mean annual temperature app. 18.5°C; annual rainfall app. 1,300 mm
Vegetation:	grassland of *Digitaria sp.*, ferns, *Helichrysum sp.*, *Melastomataceae*, some young Eucalyptus trees, fallow of several years.
Parent material:	shales
Limitations affecting plant growth:	low nutrient status

No. soil sample	Horizon	Depth (cm)	Horizon description
R10,1	A1	0-33	dark reddish-gray (6YR4/2), 20% of reddish-brown (5YR4/4) polyhydrons; clay, some mica; moist, moderate medium subangular blocky structure, firm; common fine roots; some charcoal; smooth and clear boundary,

No. soil sample	Horizon	Depth (cm)	Horizon description
R10,2	B21	33-71	reddish-brown (5YR4/4); fine clay, some mica; very strong medium and coarse angular blocky structure, very firm; moist; many colored coatings of 5YR3/4; few fine roots; smooth and gradual boundary,
R10,3	B22	71-115	reddish-brown (5YR4/4), some rare polyhedrons of 2.5YR4/6; fine clay, 1 angular quartz pebble of 3 cm; strong fine and medium angular blocky structure, very firm; moist; many colored coatings, less than in R10,2; few fine roots; smooth and gradual boundary,
R10,4	C	115-165	yellowish-red (5YR4/6); fine clay, some mica; moist; strong fine and medium angular blocky structure; firm; many less colored coatings; few fine roots.

-- Samples for micromorphology: R10,1 between 20 and 26 cm
R10,2 between 45 and 51 cm
R10,3 between 91 and 97 cm

-- Sample for pot trials: R10

SAMPLED AS: FERRISOL

S 81FN-CCP -S10 SAMPLE NOS. 81P1172 - 1175 DATE MAY 1981

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002-.05	TOTAL SAND .05-2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002-.02	SILT COARSE .02-.05	SAND VF .05-.10	SAND F .10-.25	SAND M .25-.50	SAND C .5-1	SAND VC 1-2	COARSE FRACTIONS (MM) WEIGHT 2-5	5-20	20-75	.1-75 PCT OF WHOLE SOIL	(>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM(3B1)			->	
811172	1S	0- 33	A1	37.8	34.2	28.0			15.6	18.6	17.7	7.2	2.2	0.7	0.2	--	--	--	10	--
811173	2S	33- 71	B21	43.9	31.3	24.8			15.3	16.0	16.6	6.1	1.5	0.5	0.1	--	--	--	8	--
811174	3S	71-115	B22	41.1	33.3	25.6			16.9	16.4	16.8	6.4	1.7	0.5	0.2	--	--	--	9	--
811175	4S	115-165	C	37.1	33.3	29.6			16.0	17.3	19.1	6.9	1.8	0.6	0.2	--	--	--	9	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG LIMITS) LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811172	1	2.81	0.251			3.8	0.6		0.38	0.50										18.8	
811173	2	1.73	0.189			4.5	0.6		0.19	0.44										19.3	
811174	3	0.47	0.065			4.5	0.6		0.17	0.47										19.5	
811175	4	0.36	0.052			4.3	0.5		0.18	0.46										17.7	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2E	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G7A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT			->					
811172	1	0.1	0.1	--	0.3	0.5	23.5		24.0	14.4			2	3	--		3.7	9.7	4.3	4.4
811173	2	0.2	TR	0.2	0.1	0.5	15.7	4.0	16.2	8.3	4.5	89	3	6			3.6	8.6	3.9	4.6
811174	3	0.2	0.1	TR	0.3	0.6	14.4	3.5	15.0	7.1	4.1	85	4	8			3.7	8.6	4.0	4.8
811175	4	0.2	0.1	TR	0.3	0.6	12.0	3.2	12.6	6.7	3.8	84	5	9			3.7	8.6	4.1	4.7

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY < 2mm TOTAL ANALYSIS 7C3 K2O 6Q3A	< 2mm Fe 6C7A	CLAY TOTAL ANALYSIS K2O 6Q3A	CLAY Fe 6C7A	CLAY X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- PCT			->	<- RELATIVE AMOUNTS			->	<- PCT			->
811172	1	0.94	56	8.3	1.7	4.7										
811173	2	0.97	58	6.2	1.9	5.6	2.4	9.8	KK 4	MI 2	GE 1		KK55			
811174	3	1.00	60	6.0												
811175	4	0.96	29	6.1	1.7	5.3	2.3	10.1	KK 4	MI 2	GE 1		KK52			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MI MICA GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 10

Sample 1. 0-33 cm. A1 horizon

The NRDP of the s-matrix is grani-plasmic and is characterized by a high amount of silt and fine sand grains. The grains are mostly quartz and are generally angular. Muscovite flakes are common and are generally fine, silt-sized. The plasma is brownish-yellow and heavily stained with organic matter.

Plasmic fabric is weakly developed, insepic-argillasepic. There are few, fine, reddish sesquioxidic nodules, generally diffuse. Illuviation argillans are few and generally confined to the finer voids.

Sample 2. 33-71 cm. B21 horizon

Compared to the overlying horizon there is a marked increase in the plasma. The plasma is pale yellow in color and there is much less organic matter. The plasmic fabric is also better developed and also has a much higher amount of the very fine muscovite flakes.

Accumulation of plasma through translocation is very intense, and well-oriented illuviation argillans occupy about 20% of the area. Small voids are also filled up by the translocated clay to form papules.

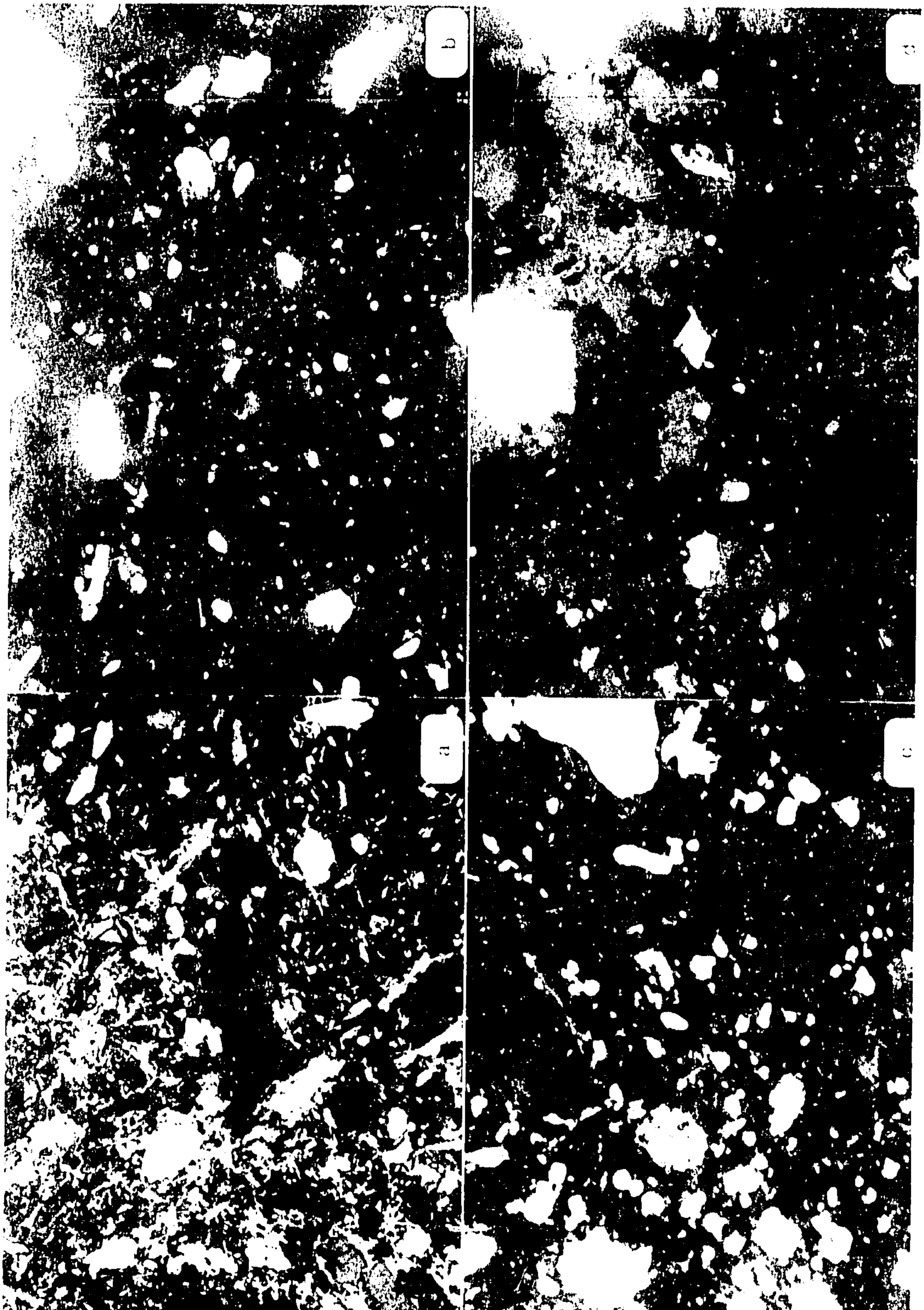
Sample 3. 71-115 cm. B22 horizon

The horizon is similar to the B21 horizon except that there are much fewer illuviation argillans. The argillans are thick and well oriented (Plate 4a) but occupy only about 12% of the area. Papules are also common. The muscovite flakes can also be seen in Plate 4a.

An additional feature in this profile is the presence of sesquioxidic nodules which are bright red in color. The fabric of these clearly indicate that they are not inherited. This suggests some moisture saturation during some part of the year.

Interpretation

Clay translocation is an important current process in the soil. In addition, particularly in the lower horizon, there seems to be some segre-



gation of iron leading to formation of the nodules. This may be attributed to a low hydraulic conductivity of the material.

Classification

1. Soil Taxonomy: Clayey, kaolinitic, isothermic, Orthoxic Palehumult
2. FAO: Dystric Nitosol

Discussion (Chairman: Mr. L. Monchaeron)

The discussions were commenced with a classification of the soil according to Soil Taxonomy by Paramananthan. The first point of discussion was the concept of the 'Pale.' Paramananthan suggested that the physiographic location of the profile and other features such as the good structures indicated a more recent stage in the genesis of the soil. He would prefer to classify it as a Tropohumult (conceptually), though following the key, he has to classify it as a Palehumult. Tavernier concurred with this problem and referred to an early suggestion of Dr. Guy Smith to include the increase of clay skins with depth for the Pale. Herbillon considered that the presence of 2:1 clays showed that the soil is much younger and suggested that the Pale great groups be confined to those soils with a CEC NH_4OAc of less than 16 meq.

Isbell questioned the use of low organic carbon requirement for the Humult. He believes that upon cultivation, the carbon will be lost and this will affect the classification.

Moormann then classified the soil with the ICOMLAC proposal as a Kandihumult. Moormann and Bennema also suggested a revision of the definition of Humults.

The INEAC classification by Sys is:

Order:	Kaolisols
Suborder:	Hygro-xero Kaolisols
Group:	Hygro-xero Ferrisols
Subgroup:	Intergrade to Sols Bruns Tropicaux
Family:	Clayey on shale.

RWANDA

Profile R 11

Classification: Ferralsol/Ferrisol

Location: prefecture Byumba, commune Gitusa, secteur Nyakajage, colline Kabarole, 10 m to the west of the main road Kayonza-Kakitumba, 50 km from Kayonza.

Physiography: landscape of large pediments leaning against hills of rather low elevation, average slope of 15%, average difference between the hilltops and the large valleys 70 m.

Topography: pediment with slope of 8%, altitude 1,460 m

Drainage: well drained

Climate: Aw4, mean annual temperature 20.5°C; annual rainfall 785 mm

Vegetation: savanna, has been cultivated 7 years ago, presence of *Cymbombogon* and *Acacia hockii*.

Parent material: shales associated with quartzite.

Limitations affecting plant growth: rainfall, low nutrient status.

No. soil sample	Horizon	Depth (cm)	Horizon description
R11,1	A11	0-10	dark brown (83YR/2); clay; moist; moderate fine and medium crumb structure, friable; some charcoal; many fine roots; smooth and clear boundary,
R11,2	A12	10-30	dark brown (8YR3/3); clay; weak medium crumb structure, friable; moist; many fine roots; smooth and clear boundary,

No. soil sample	Horizon	Depth (cm)	Horizon description
R11,3	B1	30-60	dark reddish-brown (6YR3/3); clay; moist; some burned fine roots; weak medium subangular blocky structure, friable; some coatings in pores; few fine roots; at 60 cm presence of 1 stone of quartz of 15 cm and other angular, of 10 cm,
R11,4	B21	60-90	dark reddish-brown (5YR3/4); clay, still some burned grass roots; weak, fine and medium subangular blocky structure, friable; moist; some rare coatings, few fine roots; smooth and gradual boundary,
R11,5	IIB22	90-122	dark reddish-brown (5YR3/4), some rare spots of 5YR3/3 clay; very weak medium subangular block structure, very friable; coatings very rare; moist; some burned grass roots; few fine roots; smooth gradual boundary,
R11,6	IIC1	122-150	yellowish-red (5YR4/6), some spots of 5YR3/3 corresponding to subangular lightly hardened polyhedrons of variable size, less than 0.5 cm; clay; very weak fine and medium subangular blocky structure, very friable; moist; few fine roots; smooth and clear boundary,
R11,7	IIC2	150-200+	idem to R11,6 but even less structure and loose.

-- Samples for micromorphology: R11,2 between 15 and 18 cm
R11,3 between 38 and 41 cm
R11,4 between 76 and 79 cm
R11,5 between 110 and 113 cm

R11,6 between 140 and 143 cm

-- Sample for pot trials: R11

P.S. argillic horizon on an Oxic horizon

SAMPLED AS: FERRISOL

S 81FN-OOC -R11 SAMPLE NOS. 81P1176 - 1182 DATE MAY 1981

RWANDA

GENERAL METHODS 1E1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- CLAY LT .002	-2- SILT .002-.05	-3- SAND .05-2	-4- FINE CLAY LT .0002	-5- CO3 CLAY LT .002	-6- FINE SILT .002-.02	-7- COARSE SILT .02-.05	-8- VF SAND .05-.10	-9- F SAND .10-.25	-10- M SAND .25-.50	-11- C SAND .5-1	-12- VC SAND 1-2	-13- WEIGHT 2-5	-14- WEIGHT 5-20	-15- WEIGHT 20-75	-16- WEIGHT .1-75	-17- >2MM WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)												<- PCT OF <75MM (3B1)				
811176	1S	0- 10	A11	34.4	8.8	36.8			4.2	4.6	5.5	18.5	21.3	10.2	1.3	--	--	--	51	--
811177	2S	10- 30	A12	39.4	7.0	31.6	26.9		5.0	4.1	4.9	16.7	19.1	9.3	1.6	--	--	--	47	--
811178	3S	30- 60	B1	47.9	7.9	44.2			4.1	3.8	4.8	14.1	15.2	8.4	1.7	--	--	--	39	--
811179	4S	60- 90	B21	52.9	11.9	35.2	33.5		5.8	6.1	5.8	11.1	11.6	5.3	1.4	--	--	--	29	--
811180	5S	90-122	IB22	57.7	10.5	31.8	38.3		5.8	4.7	5.6	10.9	8.9	4.7	1.7	--	--	--	26	--
811181	6S	122-152	IC1	57.0	10.2	32.8			4.9	5.3	5.4	10.7	8.8	4.5	3.2	--	--	--	27	--
811182	7S	150- [illegible]	IC2	58.4	9.5	32.1			5.4	4.1	5.8	11.1	8.0	4.2	3.0	--	--	--	25	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	RATIO/CLAY 15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM									PCT <0.4MM		<- G/CC ->			CM/CM	<- PCT OF <2MM				CM/CM
811176	1	1.87	0.127			2.5	0.4		0.28	0.28										9.7	
811177	2	1.31	0.085			2.8	0.5		0.19	0.26										10.[illegible]	
811178	3	0.85	0.056			3.4	0.5		0.14	0.25										11.9	
811179	4	0.71	0.053			3.7	0.6		0.13	0.24										12.8	
811180	5	0.62	0.047			4.2	0.7		0.13	0.24										13.9	
811181	6	0.53	0.042			4.0	0.7		0.12	0.24										13.6	
811182	7	0.46	0.038			3.6	0.6		0.11	0.23										13.7	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2C	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G										<- PCT								
811176	1	4.9	2.7	--	[illegible]	[illegible]	[illegible]		15.2	7.6			55	86			5.4	7.7	5.8	6.5
811177	2	3.2	1.7	--	[illegible]	5.7	[illegible]		14.0	7.6			41	75			4.9	7.7	5.3	6.1
811178	3	1.7	[illegible]	--	[illegible]	3.2	[illegible]	[illegible]	13.5	6.7	3.0	16	24	48			4.2	[illegible]	4.5	5.3
811179	4	2.0	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]	12.9	7.0	3.8	21	23	43			4.2	8.4	4.5	5.3
811180	5	2.3	1.0	[illegible]	[illegible]	3.4	[illegible]	[illegible]	13.7	7.3	3.8	11	25	47			4.3	8.6	4.6	5.4
811181	6	2.2	[illegible]	[illegible]	[illegible]	3.2	[illegible]	[illegible]	11.3	6.5	3.5	9	24	48			4.4	8.6	4.7	5.5
811182	7	2.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.7	6.2	3.7	9	25	55			4.4	9.0	4.6	5.5

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY CLAY TOTAL ANALYSIS 7C3 K2O 6Q3A PCT	Fe 6C7A PCT	X-RAY <2U 7A2L 7A2I 7A2L 7A2I (RELATIVE AMOUNTS)	DTA <2U 7A3 7A3 PCT	TOTAL RES 7D1A PCT	OOM HEATH 7B1A PCT
811176	1	0.72		8.5						
811177	2	0.86		7.0	0.5	7.7	KK 4 GE 2	KK55		
811178	3	0.89		4.8						
811179	4	0.93		4.6	0.5	7.8	KK 4 GE 1	KK65		
811180	5	0.90		4.6	0.5	8.1	KK 4 MI 1 GE 1	KK61		
811181	6	0.89		4.4						
811182	7	0.88		4.3						

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE GE GOETHITE MI MICA

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 11

Sample 2. 10-30 cm. A12 horizon

The s-matrix appears slightly porous with a grani-plasmic NRDP. The grains are all of fine and medium sand-sized quartz, and there are no other minerals in the sample. There is a slight tendency for the brownish-yellow plasma to aggregate to form a congelic SRDP. Plasmic fabric is very poorly expressed and is dominantly argillasepic. Most of the voids are ortho-vughs and none show any coating of clay.

Sample 4. 60-90 cm. B21 horizon

There is a marked increase in the amount of plasma in the horizon and the s-matrix is compact (Plate 4b). There is also an increase in the amount of silt and a decrease in the amount of fine and medium sand. These indicate a discontinuity in the material. The plasma is brownish-yellow and the plasmic fabric is typically argillasepic. Voids are ortho-vughs and, as can be seen in Plate 4b, they are devoid of argillans. There are no other micromorphological features of any significance.

Sample 5. 90-122 cm. II B22 horizon

There is a marked decrease in medium-sized sand grains with a corresponding increase in the amount of plasma, suggesting another discontinuity. The plasma color is still brownish-yellow, although there are patches which are more black. There are also a few fine streaks of black material.

The NRDP is plasmic, but there is a tendency for the plasma to aggregate. It is not as strongly expressed as the sombric horizon in Profile 4. The black plasma also penetrates some of the cracks in the larger quartz grains.

A few illuviation argillans are present and occupy about 2% of the area. They are thin and poorly oriented.

Interpretation

The profile shows a marked clay increase with depth, but to a depth of about 1.25 cm the increase cannot be attributed to clay translocation. The profile is stratified as seen by the size and shape of the quartz grains. Illuviation argillans are only present in the lower part of the profile and their morphology suggests that they are relict.

The underlying sombric horizon is also not very well expressed. It has a few features which differentiate it from the overlying material, but nothing spectacular.

The major part of the soil, below the A1 horizons, has oxic properties. Classification of the soil may present problems as the soil has also some argillic characteristics. From a micromorphological point of view, it is considered an Oxisol.

Classification

Soil Taxonomy: Clayey, kaolinitic, isohyperthermic
Ustoxic Palehumult

FAO: Dystric Nitosol (Luvic Phaeozem)

Discussion (Chairman: Dr. S. Paramananthan)

Arnold opened the discussion by referring to the discontinuities in the profile. He illustrated the method of calculation based on the clay-free sand.

Schargel noted: a change in chroma and value between the top 30 cm and deeper layers which is not indicated in the profile description. He considered the soil to have a mollic epipedon. Based on the clay increase and though the clay cutans are very poorly expressed, he identified the presence of an argillic horizon. He then proceeded to classify the soil as an Ustoxic Palehumult.

The new Chairman of ICOMOX (Buol) agreed with the classification and preferred to have the soil in the Ultisol order. The former chairman of ICOMOX (Eswaran) then explained the concepts which ICOMOX had attempted to develop. This profile illustrated a recurring situation where a soil has a textural increase with an upper horizon having all properties of an oxic horizon, underlain by a horizon with clay skins. The clay increase in the soil and the clay skins at depth will cause some to classify the soil as an Ultisol. The soil is clearly a transitional case with both Ultisolic and Oxisolic properties and our problem is to make a choice. The contention of ICOMOX is to give priority to the nature of the horizon closer to the surface (and which is the zone critical to plant roots) and so give preference to the oxic horizon. The constraints presented by the oxic nature of the surface horizon are more serious than the advantages of a clay increase. So the soil is considered as an Oxisol and because of the soil moisture regime, an Ustox. The clay increase in the soil is important and differentiates this Oxisol from others and so a new great group is proposed--the Kurustox.

The chairman of ICOMLAC (Moormann) determined that there is no kandic horizon within 125 cm with a probability of 95%. He further stressed the transitional nature of the soil and concurred with the previous chairman of ICOMOX that it should be classified as Kurustox.

Sombroek remarked on the low porosity of the soil and proposed to the Chairman of ICOMLAC to modify his definitions so that the soil would belong to a Kandi taxa.

The INEAC classification (Sys) is:

Order:	Kaolisols
Suborder:	Humiferous Hygro-xero Kaolisol
Great group:	Humiferous Hygro-xero Ferrisol
Subgroup:	intergrade to Ferralsol
Family:	clay on shales.

RWANDA

Profile R 12

Classification: Ferralsol (INEAC)

Location: prefecture Kibungo, commune Kayonza, secteur Rwinkwavu, colline Bishenyi; 500 m from the border of the national Akagera Park, 10 m to the north of the road Rwinkwavu-Akagera-hotel, 128 km from Kigali.

Physiography: hilly landscape with strongly eroded hills and large valleys, average slope 25%, average difference between hilltops and valley bottom 80 m, presence of large pediments.

Topography: pediment, slope north-facing 7%, elevation 1,350 m

Drainage: well drained

Climate: Aw4, mean annual temperature 21°C; annual rainfall 823 mm

Vegetation: savanna, wood vegetation: *Acacia sp.*, *Euphorbia candelabrum*, *xerophyllous* thickets
grass vegetation: *Brachyaria sp.*, *Panicum maximum*, many *Liliaceae*.

Parent material: shales associated with quartzite.

Limitations affecting plant growth: irregular rainfall, low nutrient status

No. soil sample	Horizon	Depth (cm)	Horizon description
R12,1	A11	0-16	dusky red (4YR3/2.5); clay; moist; moderate fine and medium crumb structure, friable; many fine roots; smooth and gradual boundary
R12,2	A12	16-30	dark reddish-brown (2.5YR3/3); clay; moderate fine and medium subangular blocky

No. soil sample	Horizon	Depth (cm)	Horizon description
			structure, friable; moist; many fine roots; smooth and gradual boundary,
R12,3	B1	30-43	dark reddish-brown (2.5YR3/3); clay; weak medium subangular blocky structure, friable; some very rare coatings in pores of biologic origin, common fine roots; smooth and clear boundary,
R12,4	B21	43-66	dark reddish-brown (2.5YR3/4); clay; dry; weak medium subangular blocky structure, soft; some very rare coatings in pores; common fine roots; smooth and gradual boundary,
R12,5	B22	66-80	dark reddish-brown (2.5YR3/4); clay; cfr. R12,4 but of slightly hard consistence,
R12,6	B23	80-100	idem to R12,4,
R12,7	C1	150-	dark reddish-brown (2.5YR3/4); clay; dry; moderate medium subangular and angular blocky structure, hard, some coatings; few fine roots; smooth gradual boundary,
R12,8	C2	130-160	dark reddish-brown (2.5YR3/4), some spots of 5YR3/2 corresponding to lightly hardened rounded polyhedrons; dry; moderate medium subangular and angular blocky structure, hard, some coatings; few fine roots.

-- Samples for micromorphology: R12,1 between 5 and 8 cm
R12,2 between 14 and 17 cm
R12,3 between 30 and 33 cm

R12,4 between 43 and 46 cm

R12,5 between 66 and 69 cm

R12,6 between 81 and 84 cm

R12,7 between 117 and 120 cm

-- Sample for pot trials: R12

SAMPLED AS: FERRASOL

S 81FN-[illegible]-712 SAMPLE NOS. 81P1183 - 1190 DATE MAY 1981

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
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NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

-1- -2- -3- -4- -5- -6- -7- -8- -9- -10- -11- -12- -13- -14- -15- -16- -17- -18- -19- -20-

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002-.05	TOTAL SAND .05-2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002-.02	SILT COARSE .02-.05	SAND VF .05-.10	SAND F .10-.25	SAND M .25-.50	SAND C .5-1	SAND VC 1-2	COARSE FRACTIONS (MM) WEIGHT 2-5	5-20	20-75	.1-75 PCT OF LT75MM(3B1)	>2MM WT PCT OF WHOLE SOIL
				<- - - PCT OF <2MM (3A1) - - ->																
81P1183	1S	0- 15	A11	22.7	16.5	60.9			7.3	3.5	13.6	29.1	12.9	2.7	2.6	--	--	--	57	--
81P1184	2S	15- 30	A12	30.1	17.2	52.7	23.5		9.2	9.0	12.3	23.2	12.4	3.2	1.6	--	--	--	43	--
81P1185	3S	30- 43	B1	34.1	17.3	48.6			7.0	10.9	10.1	22.1	10.8	2.7	2.3	--	--	--	18	--
81P1186	4S	43- 66	B21	35.7	17.8	46.5	28.9		7.4	10.0	11.1	20.8	9.5	3.2	1.3	--	--	--	35	--
81P1187	5S	66- 90	B22	38.7	19.5	41.5	3		8.2	11.4	9.6	17.2	9.3	2.6	1.6	--	--	--	32	--
81P1188	6S	90-110	B23	39.4	19.0	41.6	31.9		9.0	10.0	23.4	5.3	4.0	2.6	1.5	--	--	--	18	--
81P1189	7S	110-130	C1	40.1	19.8	40.1	31.5		9.0	10.4	11.6	17.6	7.6	2.1	1.6	--	--	--	29	--
81P1190	8S	130-147	C2	39.3	20.6	40.3			9.0	11.4	12.4	17.5	7.2	2.0	0.9	--	--	--	29	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- - PCT OF <2MM - ->									PCT <0.4MM		<- - G/CC - ->			CM/CM	<- - PCT OF <2MM - ->				CM/CM
81P1183	1	1.29	0.113			3.1	0.2		0.33	0.31										7.1	
81P1184	2	0.91	0.094			3.6	0.3		0.25	0.24										9.6	
81P1185	3	0.67	0.066			3.7	0.3		0.23	0.29										9.5	
81P1186	4	0.52	0.052			3.7	0.3		0.20	0.27										9.8	
81P1187	5	0.41	0.047			3.8	0.3		0.18	0.23										10.7	
81P1188	6	0.37	0.042			3.9	0.3		0.19	0.27										10.7	
81P1189	7	0.36	0.041			3.7	0.3		0.17	0.26										10.6	
81P1190	8	0.35	0.040			3.7	0.3		0.19	0.27										10.8	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	AL BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL IN 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- - - MEQ / 100 G - - ->										<- - PCT - ->								
81P1183	1	3.7	1.5	--	0.3	5.1	7.4	TR	12.9	7.6			40	67			4.6	7.3	4.7	5.7
81P1184	2	2.7	1.7	TR	0.5	4.3	7.3		11.2	7.5			37	55			4.5	7.2	4.7	5.6
81P1185	3	3.[illegible]	1.4	0.1	0.3	5.2	8.7		13.9	7.3			37	67			4.4	7.6	4.7	5.7
81P1186	4	2.[illegible]	1.4	TR	0.2	3.6	9.1	0.5	12.7	7.2	4.1	12	28	49			4.2	9.4	4.6	5.5
81P1187	5	1.[illegible]	1.[illegible]	0.1	[illegible]	3.2	8.0	1.2	11.3	7.1	4.4	27	25	45			4.3	9.3	4.4	5.6
81P1188	6	1.7	0.9	0.1	0.2	2.[illegible]	9.1	1.3	12.1	7.2	4.1	32	23	39			4.0	9.1	4.3	5.3
81P1189	7	2.5	0.[illegible]	0.1	0.1	3.7	8.2	0.[illegible]	11.9	6.[illegible]	4.5	18	31	54			4.1	9.7	4.5	5.4
81P1190	8	3.7	0.3	0.1	[illegible]	[illegible]	[illegible]		12.[illegible]	7.2			42	71			4.5	9.1	4.3	5.8

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL SATD MEQ/100G	MINERALOGY CLAY TOTAL ANALYSIS PCT K2O 6Q3A	FE 6C7A	X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- - PCT - ->		<- RELATIVE AMOUNTS ->						<- - PCT - ->	
81P1183	1	0.57		5.7										
81P1184	2	0.58		5.8										
81P1185	3	0.54		6.7										
81P1186	4	0.50		5.5										
81P1187	5	0.52		4.3	1.6	8.5	KK 3	MI 2	GE 1		KK41			
81P1188	6	0.55		4.3										
81P1189	7	0.62		5.3	1.6	8.6	KK 3	MI 2	HE 1		KK52			
81P1190	8	0.53		6.0										

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MI MICA GE GOETHITE HE HEMATITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 12

Sample 3. 30-43 cm. B1 horizon

The s-matrix is quite porous with about equal amounts of fine, medium, and coarse sand grains of quartz. There is no sorting of the sands in this horizon. The plasma is yellowish-red and does not show any staining with organic matter. The NRDP is grani-plasmic, and there is no tendency for the plasma to aggregate.

The few voids that are present are ortho-vughs and have a thin lining of argillans (Plate 4c). Some of the finer voids are filled up with argillans, forming papules, and these are more frequent. However, the total amount of illuvial features does not occupy more than 1% of the area.

The plasmic fabric is essentially argillasepic. A few fine muscovite flakes give the plasma a flecked appearance. There are no other pedological features in this horizon.

Sample 4,5. 43-66 and 66-80 cm. B21 and B22 horizons

Both of these horizons have similar micromorphological features. They are, however, different from the overlying horizons. There is a better sorting of the sand grains in these horizons. There is a marked decrease in the coarse fraction, and most of the sand grains are fine sand sized or silt sized. There is no significant change in the amount or type of plasma, or in the nature of the plasmic fabric.

Illuviation argillans are also very scarce in this horizon. They are present as a thin lining on some of the voids and occupy less than 1% of the area of the thin-section.

Interpretation

This is a complicated profile. It is highly stratified indicating relatively recent depositional material. Apparently, insufficient time has lapsed since deposition, for homogenization of the material and even for clay translocation. Illuviation argillans are very poorly developed. The profile presents a real problem for classification.

Classification

Soil Taxonomy: Fine, mixed, isohyperthermic Ustoxic Dystropept

FAO: Dystric Nitosol

Discussion (Chairman: Mr. F. Muchena)

In his introduction, the chairman remarked on the complexity of the profile and drew attention to the physiographic position of the soil. This was elaborated upon by Dr. Arnold who stressed that in order to have an appreciation of the genesis of the soil, it is necessary to know the evolution of the landscape. The profile is developed on a pediment. Employing the clay-free sand ratios, one could establish several layers. The uppermost layer extends to a depth of 30 cm and meets all the requirements of a mollic epipedon. The second layer, from 30 to 60 cm, has all the properties of a cambic horizon; the third layer, from 60 to 120 cm, has no cutans and in fact has oxic properties while below this is a layer with cutans. No stone-line is present as the original material has few stones. So basically there are four (or more) contrasting materials on which soil processes have operated. Classification of the multi-layered profile is difficult and requires an additional step in the reasoning. There is a horizon which has clay skins and meets the requirements of an argillic but both the field and micromorphological study indicates that it is buried. So for the present we can ignore it. The uppermost horizon below the mollic epipedon is a cambic horizon and as this horizon is desaturated, the soil is not a mollisol but an inceptisol; therefore we can classify the soil as an Ustoxic Dystropept. Dr. Arnold stated that he was sure many would disagree with him, but he felt this was the only way to classify the soil according to Soil Taxonomy.

Sombroek did not agree with the classification. He agreed with Arnold that the second and third horizons have cambic and oxic properties respectively. The fact, however, remains that there is a clay increase and that there is a subsurface horizon with clay skins. If the key is followed, the soil is an Alfisol. This is a similar situation to Arenic and Grossarenic soils with an argillic horizon. If we base our classification on interpretations, the soil should be a Psamment but we have to follow the key and so it will belong to an Ultisol or Alfisol, even though the argillic only begins at 1.5 m.

Moormann stated that the CEC requirements for the Kanditaxa are met and his computer calculations showed that the soil has a kandic horizon with a probability of 95%. With the current proposals of ICOMLAC, the soil will be classified as a Kandiustalf and he suggested a Rhodic subgroup.

The INEAC classification (Sys) is:

Order: Kaolisols

Suborder: Hygro-xero Kaolisol

Group: Hygro-xero Ferrisol

Subgroup: intergrade to Brown Tropical soil with eutrophic A

Family: clayey associated with shales and quartzites.

RWANDA

Profile R 13

Classification: Arenoferralsol (INEAC)

Location: prefecture Kibungo, commune Kayonza, secteur Rwinkwavu, colline Rwinkwavu; mining center of Rwinkwavu (cassiterite), 20 m north of the road Rwinkwavu-hotel Akagera, 2 km from the office.

Physiography: hilly landscape with strongly eroded hills and large valleys, average slope 25%, average difference between hilltops and valley bottoms 80 m, presence of large pediments.

Topography: pediment, slope south-facing 6%, elevation 1,430 m

Drainage: well drained

Climate: Aw4, mean annual temperature 21°C; annual rainfall 823 mm

Vegetation: fallow with *Hyparrhenia sp.*, *Eragrostis sp.*

Parent material: quartzite associated with shales.

Limitations affecting plant growth: soil texture, low nutrient status, irregular rainfall.

No. soil sample	Horizon	Depth (cm)	Horizon description
R13,1	A1	0-30	dark reddish-brown (5YR3/3); sandy clay loam; moist; weak medium crumb structure, friable; many fine roots; smooth and clear boundary,
R13,2	B1	30-50	dark reddish-brown (5YR3/4); sandy clay loam; moist; structureless massive, some lightly hardened subangular medium poly-

No. soil sample	Horizon	Depth (cm)	Horizon description
			hedrons; few fine roots; smooth and gradual boundary,
R13,3	B21	50-80	yellowish-red (5YR3/6); moist; sandy clay loam; structureless massive, some lightly hardened subangular medium polyhedrons, firm; few fine roots; smooth and gradual boundary,
R13,4	B22	80-110	yellowish-red (5YR3/6); sandy clay loam; dry; structureless massive, some lightly hardened subangular polyhedrons, slightly hard; few fine roots; smooth and clear boundary,
R13,5	IC	110-170	dark red (2.5YR3/6); clay; moist; moderate medium angular blocky structure, firm; matrix is of sandy clay loam in which occur lightly hardened angular medium polyhedrons with colored coatings (2.5YR3/3) on the ped faces; few fine roots.

-- Samples for micromorphology: R13,1 between 5 and 8 cm
R13,3 between 60 and 63 cm
R13,5 between 120 and 123 cm

-- Sample for pot trials: R13

P.S. Oxic horizon on argillic horizon

SAMPLED AS: ARENCFERRAL

S 81FN-0CG -R13 SAMPLE NOS. 81P1191 - 1195 DATE APRIL 1982

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1- CLAY LT .002	-2- SILT .002-.05	-3- SAND .05-2	-4- FINE CLAY LT .0002	-5- CO3 CLAY LT .002	-6- FINE SILT .002-.02	-7- COARSE SILT .02-.05	-8- VF SAND .05-.10	-9- F SAND .10-.25	-10- M SAND .25-.50	-11- C SAND .5-1	-12- VC SAND 1-2	-13- WEIGHT 2-5	-14- WEIGHT 5-20	-15- WEIGHT 20-75	-16- WEIGHT .1-75	-17- >2MM WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM(3B1)			->	SOIL
811191	1S	0- 30	A1	10.2	13.6	76.2	7.8		4.1	9.5	11.0	43.8	20.0	1.3	0.1	--	--	--	65	--
811192	2S	30- 50	B1	12.6	12.5	74.9			4.9	7.6	9.8	42.2	21.3	1.4	0.2	--	--	--	65	--
811193	3S	50- 80	B21	15.0	14.9	70.1	14.2		5.3	9.6	11.5	40.2	17.1	1.2	0.1	--	--	--	59	--
811194	4S	80-110	B22	19.0	15.1	65.9	15.4		6.1	9.0	11.6	35.1	17.6	1.3	0.3	--	--	--	54	--
811195	5S	110-172	IC	35.8	16.5	47.7	28.5		5.3	11.2	10.1	24.9	11.5	1.0	0.2	--	--	--	38	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 3D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811191	1	0.84	0.054			1.1	0.1		0.34	0.33										3.4	
811192	2	0.43	0.032			1.3	0.1		0.24	0.33										4.1	
811193	3	0.25	0.022			1.6	0.1		0.17	0.30										4.5	
811194	4	0.21	0.021			1.8	0.1		0.15	0.27										5.2	
811195	5	0.20	0.027			3.1	0.3		0.14	0.30										10.7	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
811191	1	1.6	1.0	--	0.2	2.8	4.3		7.1	3.5			39	60			4.9	7.6	5.1	6.0
811192	2	0.6	0.9	--	0.2	1.7	4.6	0.1	6.3	3.0	1.8	6	27	57			4.4	7.7	4.7	5.5
811193	3	0.2	0.4	TR	0.3	0.9	5.3	0.6	6.2	2.6	1.5	40	15	35			4.0	7.8	4.2	5.0
811194	4	0.3	0.8	--	0.1	1.2	5.2	0.4	6.4	2.8	1.6	25	19	43			4.0	7.8	4.3	5.0
811195	5	0.5	1.4	0.1	0.1	2.1	4.3	0.8	6.4	4.9	2.9	28	33	43			4.0	8.3	4.3	5.1

SAMPLE NO.	HZN NO.	ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY CLAY TOTAL ANALYSIS 7C3 K2O 6Q3A	Fe 6C7A	X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	OOM WEATH 7B1A
					<- PCT	->	<- RELATIVE AMOUNTS			->	<- PCT			->
811191	1	0.38		3.4										
811192	2	0.46		2.4										
811193	3	0.42		3.0	1.7	9.2	KK 3	MI 2	GE 1		KK45			
811194	4	0.57		2.4										
811195	5	0.73		3.6	1.6	8.8	KK 3	MI 2	HE 1	GE 1	KK50			

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MI MICA GE GOETHITE HE HEMATITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE R13

Sample 1

The NRDP is prophyri-granic. The reddish-brown plasma adheres to the grains forming coatings as in a spodic horizon. In certain places, the inter-granular voids are all filled up with the plasma. The plasmic fabric is isotic, argillasepic. Although the plasma coats the grains, there is no evidence of orientation due to stress. The fabric is very porous and this corresponds to the very friable consistence in the field. The plasma, in the intergranular voids, is aggregated, and this also contributes to the very friable consistence.

There is a remarkably high amount of runiquartz. A few plagioclase feldspars and some micas are also present.

Sample 3

The s-matrix shows a slightly higher amount of plasma. The other aspects of the s-matrix are similar (Plate 4d). Some of the voids have a very thin lining of illuviation argillans, occupying less than 1% of the area. Much of the plasma is inherited with the sediment. The plasmic fabric is argillasepic and in some places it is isotic. A few plagioclases are present but micas are rare.

Sample 5

There is a small increase of plasma in this horizon, and the NRDP is porphyric, unlike the porphyri-granic of the overlying horizons. The nature of the quartz grains and plasma indicate similarities with the overlying horizon. There is no evidence to suggest a discontinuity. The basic difference with the overlying horizons is the increased amounts of illuviation argillans which occupy about 2% of the area. They are generally thin and moderately well oriented. They do suggest current illuviation.

Interpretation

The soil has some basic properties of an Oxisol. The plasma indicates several attributes of the plasma of Oxisols. However, the presence of the weatherable minerals, though in small amounts, will take it out of the Oxisols. The interesting feature of the weatherable minerals is that they seem to decrease with depth. The surface horizon has detectable amounts, while in the last horizon they have to be searched for.

Clay illuviation has taken place, but by any measure this is a minor process and does not contribute to the clay increase in the soil. The increase in clay content with depth is a sedimentological feature and not related to weathering or clay migration.

Classification

1. Soil Taxonomy: Coarse-loamy, silicieous, isohyperthermic, Ustoxic
   Dystropept
2. FAO: Dystric Nitosol

Discussion (Chairman: J.K. Samki)

Buol gave a brief summary of the properties of the soil and then classified it. He indicated that though the surface horizon was dark, the low organic carbon required the epipedon to be termed as ochric. The 1.2 increase in clay content was sufficient to identify an argillic horizon. Although the micromorphology shows only very small amounts of clay skins; I would not place emphasis on that to define an argillic horizon. The profile is classified as a Paleustult. At the family level, the soil would be classified as coarse-loamy, siliceous, isohyperthermic, Typic Paleustult.

Birasa questioned the presence of an argillic horizon and its significance in this soil. As far as the plant roots were concerned, it is the top meter which is of importance and the relatively uniform coarse-loamy particle size is the important feature. The deep argillic is of little significance even from the point of view of moisture storage. He would prefer to classify the soil as a Haplustox.

Gahamani indicated the soil was weathered before transport and that the top 110 cm is reworked oxic material sitting on an old argillic or saprolitic material. The position in the landscape clearly indicates this and consequently the modern-day profile is an Oxisol.

Arnold agreed that there was deposition of more recent material on an older argillic horizon. The angular "polyhedrons" described in the profile description are fragments of saprolite rounded during transport and in this soil behave like a stone-line. Consequently, we are dealing with a soil having a buried argillic horizon and following the rules of Soil Taxonomy, we have to classify the upper strata. Due to the high CEC, we have to recognize a cambic horizon and the soil is classified as a Ustoxic Dystropept.

The chairman of ICOMLAC indicated that the profile meets the CEC requirements for a Kandi taxon. There is a textural argillic horizon with the top at 80 cm but there is no clear evidence in the field or in thin-sections for clay skins. There is, however, a kandic horizon, the top of which starts at 110 cm and so with the new proposals, the soil will be classified as a kandiustult. This might resolve some of the problems highlighted in the previous discussions and particularly in situations like this where we are dealing with stratified materials.

Comerma indicated that similar textural materials in Venezuela were always a constant source of problem for classification. In Venezuela, we have an ochric epipedon underlain by an oxic followed by an argillic horizon. We have called this a Psammentic Haplustox and we have never been satisfied. The proposal of ICOMLAC solves this problem.

Sombroek indicated that the decrease of base saturation with depth is an important feature for agronomic purposes and proposed that we find a means to bring this into Soil Taxonomy. He also proposed an oxic subgroup in the Paleustult. He also concurred with the kandi concept and said it was most appropriate here.

Spain, considering the agronomic properties, stated that this soil would have fewer problems with P fixation. He indicated the need for N and suggested the inclusion of a legume in the rotation. He also suspected that there would be response to K. The most important management feature is moisture conservation and suggested mulching and minimum tillage. Zero tillage would result in surface sealing due to the extreme wet/dry conditions and so he recommended minimum tillage.

INEAC classification (Sys) is:

Order: Kaolisol

Suborder: Hygro-xero Kaolisol

Group: Hygro-xero Ferrisol

Subgroup: intergrade Brown Tropical Soil

Family: Loamy from quartzite and shales.

RWANDA

Profile R 14

Classification:	Ferralsol/Ferrisol (INEAC)
Location:	prefecture Kibungo, commune Rutonde, secteur Nsinda, colline Nsinda; 20 m to the southeast of the main road Kigali-Kayonza, 80 km from Kigali, 7 km from Rwamagana.
Physiography:	landscape with large plateaus and abrupt slopes to sometimes very small valleys, presence of ironstone at the border of the plateaus; average slope 30%; average difference between hilltops and valley bottoms 150 m.
Topography:	plateau; elevation 1,520 m
Drainage:	moderately well drained
Climate:	Aw4, mean annual temperature 20.5°C; annual rainfall 926 mm
Vegetation:	grassland with *Brachyaria sp., Sporobolus phyamidalis.*
Parent material:	shales
Limitations affecting plant growth:	low nutrient status

No. soil sample	Horizon	Depth (cm)	Horizon description
R14,1	A11	0-20	dark reddish-brown (5YR3/2); clay, some bleached sand grains; moist; weak medium crumb and subangular blocky structure, friable; many fine roots; smooth and gradual boundary,
R14,2	A12	20-40	dark reddish-brown (5YR3/2.5); clay, some bleached sand grains; moist; weak medium

No. soil sample	Horizon	Depth (cm)	Horizon description
			subangular blocky structure, friable; many fine roots; smooth and clear boundary,
R14,3	B1	40-57	dark reddish-brown (5YR3/3.5); clay; moist; still some bleached sand grains; weak medium subangular blocky structure, firm; some rare coatings in pores; few fine roots smooth and gradual boundary,
R14,4	B2	57-95	dark reddish-brown (5YR3/4); clay, still some bleached sand grains; weak subangular and angular medium blocky structure, friable; some coatings in pores which are mostly filled up with 5YR3/3 material; few fine roots; irregular gradual boundary,
R14,5	IIA/B	95-124	dark reddish-brown (5YR3/3); clay; still some bleached sand grains; some charcoal; dry; matrix of weak medium angular blocky structure, hard; presence of approximately 10% mottles of 5YR3/2 corresponding to hardened rounded polyhedrons with streaks of 5YR3/4 at the inside, of variable size (F 1 cm), some have angular faces, with coatings, the interior has hardly any pores; few fine roots, irregular gradual boundary,
R14,6	IIC	124-150	heterogenous color: matrix of 5YR3/4, approximately 40% of 5YR3/2 (see R14,5) and approximately 40% of 5YR4/6 corresponding to hardened rounded polyhedrons with coatings; clay; dry; strong

No. soil sample	Horizon	Depth (cm)	Horizon description
			medium angular blocky structure, firm, coatings; 5YR3/4 material surrounds the polyhedrons of 5YR4/6 and of 5YR3/2; presence of some laterized shale fragments and of some quartz fragments (F 2 cm); few fine roots.

-- Samples for micromorphology: R14,1 between 10 and 13 cm
R14,3 between 42 and 45 cm
R14,4 between 74 and 77 cm
R14,5 between 108 and 111 cm
R14,6 between 140 and 143 cm

-- Sample for pot trials: R14

P.S. Oxic material on argillic material

SAMPLED AS: FERRISOL

S 81FN-OCC -014 SAMPLE NOS. 81P1196 - 1201 DATE APRIL 1982

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-4- CLAY LT .002	-5- SILT .002 -.05	-6- SAND .05 -2	-7- FINE CLAY LT .0002	-8- CO3 CLAY LT .002	-9- FINE SILT .002 -.02	-10- COARSE SILT .02 -.05	-11- VF SAND .05 -.10	-12- F SAND .10 -.25	-13- M SAND .25 -.50	-14- C SAND .5 -1	-15- VC SAND 1 -2	-16- COARSE FRACTIONS (MM) WEIGHT 2 -5	-17- 5 -20	-18- 20 -75	-19- .1- 75	-20- (>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM(3B1)			->	
81I196	1S	0- 20	A11	43.3	6.9	49.8	25.6		3.4	3.5	2.2	11.5	21.9	12.9	1.3	--	--	--	48	--
81I197	2S	20- 40	A12	44.2	6.4	49.4	25.9		3.3	3.1	2.1	11.9	20.7	13.3	1.4	--	--	--	47	--
81I198	3S	40- 57	B1	46.7	6.6	46.7			3.8	2.8	2.4	12.2	21.0	10.5	0.6	--	--	--	44	--
81I199	4S	57- 95	B2	50.0	7.0	43.0	28.5		4.5	2.5	2.4	10.9	18.6	10.0	1.1	--	--	--	41	--
81I200	5S	95-124	2A/B	56.3	7.5	36.2	31.5		4.1	3.4	2.0	10.3	14.8	8.0	1.1	--	--	--	34	--
81I201	6S	124-150	2C	69.8	5.9	24.3	36.4		3.8	2.1	1.9	6.9	8.9	5.8	0.8	--	--	--	22	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
81I196	1	1.75	0.114			2.7	0.5		0.23	0.28										12.3	
81I197	2	1.29	0.083			2.7	0.5		0.19	0.27										11.8	
81I198	3	1.19	0.079			3.0	0.5		0.17	0.26										12.3	
81I199	4	0.95	0.076			3.4	0.6		0.14	0.27										13.4	
81I200	5	0.90	0.059			3.5	0.6		0.14	0.25										13.9	
81I201	6	0.97	0.059			3.8	0.7		0.13	0.25										17.4	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
81I196	1	3.3	0.9	TR	0.1	4.3	8.9	0.3	13.2	9.8	4.6	7	33	44			4.3	7.7	4.6	5.3
81I197	2	3.1	0.3	TR	TR	3.4	8.6	0.4	12.0	8.6	3.8	11	28	40			4.2	7.8	4.5	5.4
81I198	3	3.3	0.2	TR	TR	3.5	7.4	0.2	10.9	8.0	3.7	5	32	44			4.3	8.1	4.6	5.4
81I199	4	3.1	0.2	--	TR	3.3	6.8	0.1	10.1	6.8	3.4	3	33	49			4.5	8.6	4.7	5.5
81I200	5	3.8	0.5	0.2	TR	4.5	6.8		11.3	8.0			40	56			4.6	8.4	4.8	5.6
81I201	6	5.0	1.0	TR	TR	6.0	6.9		12.9	9.1			47	66			4.8	8.4	5.0	5.8

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY TOTAL ANALYSIS 7C3 (< 2mm) K2O 6Q3A	Fe 6C7A	(< 0.002) K2O 6Q3A	Fe 6C7A	(< 0.0002mm CLAY) K2O 6Q3A	Fe 6C7A	X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- PCT					->	<- RELATIVE AMOUNTS			->	<- PCT			->
81I196	1	0.86		6.1	0.1	3.6												
81I197	2	0.91		5.1														
81I198	3	0.93		4.9														
81I199	4	0.94		4.2	0.2	4.1	0.3	7.5	0.3	6.3	KK 4	GE 1			KK77			
81I200	5	0.94		5.3	0.2	4.8	0.2	7.3	0.3	6.2	KK 4	GE 1			KK59			
81I201	6	0.93		6.7	0.2	5.5												

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 14

Sample 1

The s-matrix is very compact and the NRDP is plasmi-porphyric. The grains are medium to coarse sand-sized quartz, heavily fractured, and angular. Runiquartz is abundant in this horizon. The plasma is reddish-brown being heavily stained with organic matter. The plasmic fabric is typically argillasepic.

Apart from a few tourmaline grains, few other weatherable minerals could be detected. The tourmalines are medium sand-sized and well rounded. There are very few phytoliths in this horizon.

Sample 3

Apart from a brightening of the color, there is very little change in the s-matrix as compared to the overlying horizon. The quartz grains are also heavily fractured.

Sample 4

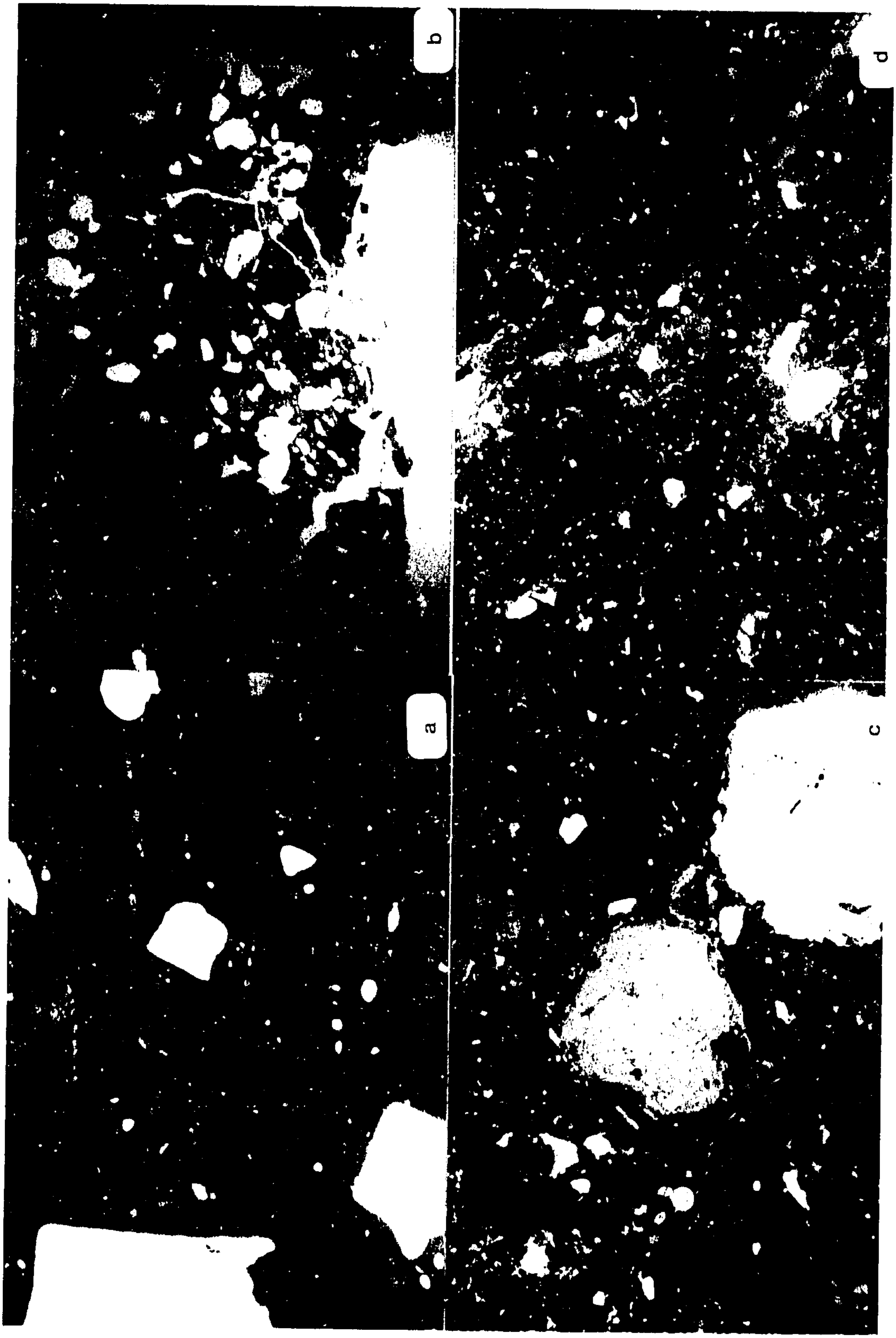
The s-matrix appears more compact (Plate 5a); there is a slight increase in the proportions of plasma. The NRDP is porphyri-plasmic, and the plasmic fabric is argillasepic. The plasma is yellowish-red and seems to be locally stained with organic matter.

There is no evidence of clay illuviation. All the voids are clean and not coated with translocated clay. The section was also scanned for the presence of phytoliths but none was found.

Sample 5

This horizon is very similar to sample 4. There is very little change in the micromorphology, except that the plasma is more brownish.

A thin lining of illuviation argillans are present, coating some of the larger voids. This does not suggest clay migration of any significance. Phytoliths are also rare and, searching the section, only one could be detected.


a
b
c
d

Sample 6

This horizon shows some basic differences with the overlying horizons. The basic s-matrix features are, however, similar. The NRDP is porphyri-plasmic and the plasmic fabric is argillasepic. The grains are composed of angular, medium sand-sized quartz which are generally not fractured. Runiquartz is also scarce, and no phytoliths could be detected.

The most interesting feature is the very high amount of illuviation ferri-argillans. These occupy about 12% of the area, are thick, but are poorly oriented and have a grainy aspect. Some of the argillans are incorporated in the s-matrix, forming papules.

A few large pedovites are also present. These are reddish-yellow (Plate 5b), and very compact. The NRDP is porphyri-plasmic but with much fewer grains. The voids in the pedovites also have argillans which are more yellow and thinner. These argillans are different from the argillans of the s-matrix of the soil material. In some instances, the argillans of the pedovites end abruptly at the boundary of the body, indicating that the pedovite is of different origin.

Classifications

1. Soil Taxonomy: Clayey, kaolinitic, isohyperthermic, Sombrihumic Eutrorthox
2. FAO: Humic Ferralsol

Discussion (Chairman: E.C. Sousa)

Eswaran explained the presence of several geomorphic surfaces and indicated that the profile is most probably sited on an end Tertiary surface. Soils on these old geomorphic surfaces are frequently characterized by the presence of stone-lines if there is a supply of stones. When there are no quartzitic or other resistant gravels, the stone-line may sometimes take other forms which hitherto have not been described in literature but which Neel and Frankart have studied in detail. In this area, the parent material is shales and during transport, the shale fragments are rounded and these gravel-size elements may be recognized in the present-day profile. Neel and Frankart call them 'polyerders' but Eswaran prefers to refer to them as 'Pedovites'. The pedovites may also be fragments of an argillic horizon. You see such features very well in this soil where there are distinct argillans in the pedovites but there are practically no cutans in the soil material around them.

In this profile you have a sombric horizon in which there are pedovites of saprolite. The pedovites are redder or less dark in color. In the horizon below the sombric, there are other kinds of pedovites--those derived from an argillic horizon and containing cutans. These pedovites are trying to tell us the geomorphic evolution of the landscape and the genesis of the soil. We need to appreciate this before trying to classify the soil.

Arnold concurred that there are several layers in the soil and also pointed out the presence of some angular fragments which indicated a discontinuity at 40 cm. Based on his clay-free sand, he showed the presence of another discontinuity at 95 cm where the pedovites occur. Arnold recognized the presence of an oxic horizon but as the base saturation was low, the soil cannot be keyed out as a Humox but as a Sombrihumic Eutrorthox.

Van Wambeke then explored the different ways the soil could be classified depending on what concepts one wishes to follow. He indicated that a diagnostic horizon should have the main features in all parts to be more helpful in applying the criteria. He concluded that since the definition of Oxisols states that they must have an oxic horizon exclusive of an argillic horizon, he is forced to go to the Alfisols and classify the soil as an Oxic Tropudalf. He concluded that in applying Soil Taxonomy, one should not proceed intuitively but follow the key rather rigidly.

The Chairman of ICOMOX (Buol) said that in the new proposals, if the top 18 cm after mixing has more than 40% clays and meets the requirements of an oxic horizon, the soil is an Oxisol. He then asked the Chairman of ICOMLAC to comment.

Moormann indicated that ICOMOX and ICOMLAC were interphasing beautifully and also that the soil did not have a kandic horizon. He requested the previous Chairman of ICOMOX to comment.

Eswaran stated that in the current proposals of ICOMOX, the troublesome reference to the argillic horizon in the definition of Oxisols was eliminated. He concurred with Moormann and Buol that this was an Oxisol. At the suborder level, he indicated that the Humox definition was changed and now requires a mollic or umbric epipedon, without any reference to temperature regime or base saturation. So the soil is a Humox and a Sombrihumox. The clay increase suggests properties grading to an Ultisol or Alfisol and so it is a Kuric Sombrihumox.

INEAC classification (Sys):

Order:	Kaolisols
Suborder:	Hygro-xero Kaolisol
Group:	Hygro-xero Ferralsol, humiferous and with dark horizon
Great group:	typic and eutrophic in A
Family:	clayey from shales.

RWANDA

Profile R 15

Classification:	Ferrisol/Sol Recent Tropicaux (INEAC)
Location:	prefecture Byumba, commune Kibare, secteur Mukarange, colline Gitanwa; 10 m west of the main road Kigali-Gatuna, 57 km from Kigali, 4 km from the crossing of the roads Kigali-Gatuna, Byumba, and Gatsibe.
Physiography:	very hilly landscape with ironstone gravel on the hilltops; average slope 50%, average difference between the hilltops and the small valleys 200 m.
Topography:	convex slope of 35% on a piedmont adjacent to a big hill; elevation of 1,930 m
Drainage:	well drained
Climate:	Cw3, annual rainfall 1,206 mm; mean annual temperature 15.5°C,
Vegetation:	farmers' fields: sorghum, beans, peas, maize, sweet potatoes
Parent material:	shales associated with some quartzite
Limitations affecting plant growth:	soil structure, nutrient status

No. soil sample	Horizon	Depth (cm)	Horizon description
R15,1	Ap	0-37	dark brown (8YR3/3); clay, some charcoal and shale fragments; moist; moderate medium crumb structure, firm; many fine roots; smooth and abrupt boundary,

No. soil sample	Horizon	Depth (cm)	Horizon description
R15,2	B21	37-72	dark brown (7.5YR4/4); clay; wet; presence of approximately 10% rock fragments (pebbles) of shale and quartz of irregular shape and variable size (F 6 cm), some charcoal; plastic and very sticky; very strong coarse columnar structure; full of colored coatings (7.5YR5/6) on the faces especially in the cracks which attain 5 mm; common fine roots; smooth and gradual boundary,
R15,3	B22	72-113	heterogenous color: strong brown matrix (7.5YR5/6), mottles (20%) of 7.5YR4/4 due to hydromorphy, streaks (30%) of 7.5YR5/4 corresponding to sandy material; matrix is of fine clay texture; moist; weak coarse angular blocky structure to massive; sticky and plastic, many coatings; sandy streaks are of moderate fine and medium angular blocky structure, slightly sticky and nonplastic; many coatings; presence of some shale fragments and of many porous black concretions (5YR2.5/1) of variable size (1-5 cm), friable, probably hematite, manganese containing halloysite?; few fine roots; smooth and gradual boundary,
R15,4	C	113-155	heterogenous color: matrix of strong brown color (7.5YR5/6), mottles (10%) of 7.5YR4/4, 20% sandy streaks of 7.5YR5/4; texture of matrix fine clay; moist strong medium and coarse angular blocky structure, sticky and plastic, full of colored coatings, for sandy material see R15,3;

No. soil sample	Horizon	Depth (cm)	Horizon description
			few fine roots, some shale fragments; smooth and clear boundary,
		155-	platelike laterized shale fragments of variable size (F 5 cm).

-- Samples for micromorphology: R15,1 between 10 and 17 cm
R15,3 between 50 and 57 cm
R15,4 between 75 and 81 cm

-- Sample for pot trials: R15

P.S. R15,3a contains a large amount of the black concretions taken between 72 and 85 cm.

SAMPLED AS: FERRISOL

S 81FN-0UO -R15 SAMPLE NOS. 81P1202 - 1206 DATE APRIL 1982

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	-1-- TOTAL CLAY LT .002	-2-- TOTAL SILT .002 -.05	-3-- TOTAL SAND .05 -2	-4-- CLAY FINE LT .0002	-5-- CLAY CO3 LT .002	-6-- SILT FINE .002 -.02	-7-- SILT COARSE .02 -.05	-8-- SAND VF .05 -.10	-9-- SAND F .10 -.25	-10- SAND M .25 -.50	-11- SAND C .5 -1	-12- SAND VC 1 -2	-13- COARSE FRACTIONS(MM) WEIGHT 2 -5	-14- WEIGHT 5 -20	-15- WEIGHT 20 -75	-16- WEIGHT .1- 75	-17- (>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM(3B1)			->	
811202	1S	0- 37	AP	21.1	31.1	47.8	8.3		19.4	11.7	8.1	12.8	18.1	7.1	1.7	--	--	--	40	--
811203	2S	37- 72	B21	38.8	28.4	32.8	16.5		17.3	11.1	6.4	8.7	11.5	4.4	1.8	--	--	--	26	--
811204	3S	72-113	B22	30.9	22.4	46.7	12.4		14.8	7.6	6.0	9.7	15.0	10.2	5.8	--	--	--	41	--
811205	4S	113-155	C	27.7	29.8	42.5	13.9		17.9	11.9	7.8	10.3	14.2	7.2	3.0	--	--	--	35	--
811206	5S	155-	SHALE	33.5	29.7	36.8			18.8	10.9	7.0	8.8	12.6	6.3	2.1	--	--	--	30	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	RATIO/CLAY CEC 8D1	15 BAR 8D1	ATTERBERG LIMITS LL 4F1	PI 4F	BULK DENSITY FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	WATER CONTENT FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811202	1	1.11	0.119			1.8	0.2		0.34	0.39										8.2	
811203	2	0.56	0.094			3.0	0.4		0.21	0.36										13.9	
811204	3	0.47	0.078			3.3	0.4		0.24	0.38										11.6	
811205	4	0.30	0.057			2.7	0.3		0.18	0.36										10.0	
811206	5	0.29	0.061			2.7	0.3		0.17	0.36										12.2	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	NH4-OAC 5A8B	BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	NAF 8C1D	CACL2 .01M 8C1F 1:2	H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT			->					
811202	1	2.3	1.0	TR	0.8	4.1	5.1		9.2	7.1			45	58			4.6	7.8	4.9	5.7
811203	2	2.6	2.2	TR	0.6	5.4	6.8		12.2	8.2			44	66			4.5	8.5	5.0	5.8
811204	3	1.7	1.5	--	0.5	3.7	6.1	0.3	9.8	7.5	4.0	7	38	49			4.3	8.3	4.7	5.5
811205	4	0.6	0.8	--	0.5	1.9	4.7	1.1	6.6	4.9	3.0	37	29	39			3.9	8.4	4.3	5.2
811206	5	0.6	0.7	TR	1.3	2.6	4.9	0.8	7.5	5.6	3.4	24	35	46			4.0	8.4	4.4	5.4

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G	MINERALOGY TOTAL ANALYSIS 7C3 < 2mm K2O 6Q3A	< 2mm Fe 6C7A	< 0.002mm K2O 6Q3A	< 0.002mm Fe 6C7A	< 0.0002mm K2O 6Q3A	< 0.0002mm Fe 6C7A	CLAY X-RAY <2U 7A21	7A21	7A21	7A21	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
					<- PCT		PCT			->	<- RELATIVE AMOUNTS			->	<- PCT			->
11202	1	0.71		4.9	1.2	2.2												
11203	2	0.81		6.1	1.8	3.6	3.0	7.7	2.4	7.9	KK 4	MI 3	GE 1		KK40			
11204	3	0.78		4.7														
11205	4	0.69		3.[illegible]	1.6	3.4												
11206	5	0.67		3.6	1.8	3.9												

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MI MICA GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 15

Sample 2 and 3. 37-72 and 72-113 cm. B21 and B22 horizon

Both these samples are similar in their micromorphological properties, and so are discussed as one. The NRDP is grani-plasmic and the soil material is quite porous. The plasma is pale yellow and the plasmic fabric is insepic, omnisepic. Stress oriented features are moderately well developed.

Illuviation argillans are present in both horizons and occupy about 7% of the area. They are well developed and well oriented. Plate 5c shows these argillans and some papules.

The grains are dominantly quartz and are generally rounded. Few fine plagioclases and fine flakes of muscovite are also present.

Interpretation

This is one of the profiles where illuviation of clay is a dominant, current, pedogenic process. There is some stratification in the profile, but argillic horizon formation transcends the stratification. The soil also seems to have some shrink-swell potential. The low amount of stress-oriented clay observed in the thin-section points to this.

Classifications

1. Soil Taxonomy: Fine, mixed isothermic
   Orthoxic Tropudult
2. FAO: Ferric Acrisol
3. INEAC:

Order: Kaolisol
Suborder: Humiferous hygrokaolisol
Group: Humiferous hygroferrisol
Subgroup: intergrade brown tropical soil
Family: clayey.

4. ICOMLAC: The chairman indicated that although the CEC 7 is slightly high, the ECEC is low enough for a kandic horizon. The soil is classified as a Kanhapludult.

RWANDA

Profile R 16

Classification:	Ferralsol/Ferrisol
Location:	prefecture Byumba, commune Kibare, secteur Mukarange, colline Kageyo; main road to Byumba, 10 m to the south of it, 4 km from the crossing with the road to Gatsibe, 57 km from Kigali, 4 km from Byumba center.
Physiography:	very hilly landscape with ironstone gravel on the hill-tops; average slope 50%; average difference in elevation between the tops and the small valleys 200 m.
Topography:	near hilltop, slope 7%; altitude 2,150 m.
Drainage:	well drained
Climate:	Cw3, mean annual temperature 15.5°C; annual rainfall 1,206 mm
Vegetation:	fallow: *Digitaria sp.*, *Carex sp.*, *Borreria princea.*
Parent material:	shales associated with some quartzite
Limitations affecting plant growth:	low nutrient status

No. soil sample	Horizon	Depth (cm)	Horizon description
R16,1	Ap	0-25	dark brown (7.5YR3/2); clay, moist; many bleached sand grains; weak fine crumb structure, very friable, some massive blocks, low bulk density; many fine roots; irregular and clear boundary,
R16,2	A3	25-40	dark reddish-brown (5YR3/2.5; clay, many bleached sand grains; moist; moderate

No. soil sample	Horizon	Depth (cm)	Horizon description
			fine and medium subangular block structure, friable, some rare coatings in pores; tongues of R16,1 material are going down to R16,3; many fine roots; irregular and gradual boundary,
R16,3	B2	40-80	dark reddish-brown (5YR3/4), tongues of 7.5YR3/2; clay, some charcoal; moderate medium subangular blocky structure, friable; some rare coatings; common and medium fine roots; irregular and gradual boundary,
R16,4	IIA/B	80-112	dark reddish-brown (5YR3/3.5); clay, some quartzite stones of 10 to 20 cm just above the stone-line; some rare platelike laterized shale fragments; moist; weak fine and medium subangular blocky structure, friable, some rare coatings; presence of some hardened rounded polyhedrons of variable size (F 3 cm); common fine and medium roots, smooth and abrupt boundary,
R16,5	IIIC?	112-135	stone-line, matrix yellowish-red (5YR4/6); clay; moist; ironstone gravels with heterogenous color inside, often 10YR3/6, rounded, some mm to more than 1 cm, many platelike laterized shale fragments; few fine and medium roots.

-- Samples for micromorphology: R16,1 between 8 and 15 cm
R16,3 between 45 and 52 cm

-- Sample for pot trials: R16

SAMPLED AS: FERRISOL

S 81FN-OOC -616 SAMPLE NOS. 81P1207 - 1211 DATE APRIL 1982

RWANDA

GENERAL METHODS 1B1A, 2A1, 2B

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
NATIONAL SOIL SURVEY LABORATORY
LINCOLN, NEBRASKA

SAMPLE NO.	HZN NO.	DEPTH (CM)	HORIZON	TOTAL CLAY LT .002	TOTAL SILT .002-.05	TOTAL SAND .05-2	CLAY FINE LT .0002	CLAY CO3 LT .002	SILT FINE .002-.02	SILT COARSE .02-.05	SAND VF .05-.10	SAND F .10-.25	SAND M .25-.50	SAND C .5-1	SAND VC 1-2	COARSE FRACTIONS (MM) WEIGHT 2-5	5-20	20-75	.1-75	(>2MM) WT PCT OF WHOLE SOIL
				<- PCT OF <2MM (3A1)											->	<- PCT OF <75MM (3B1)			->	
811207	1S	0-25	AP	41.4	19.3	39.3	24.1		13.5	5.8	4.2	13.1	14.4	5.7	1.9	--	--	--	35	--
811208	2S	25-40	A3	42.7	16.7	40.6			12.6	4.1	4.0	12.3	15.9	6.6	1.8	--	--	--	37	--
811209	3S	40-80	B2	48.9	16.6	34.5	23.6		11.4	5.2	3.8	11.8	12.2	4.7	2.0	--	--	--	31	--
811210	4S	80-112	2A/B	43.3	18.3	38.4	14.7		13.4	4.9	4.2	11.5	12.7	6.3	3.7	--	--	--	34	--
811211	5S	112-135	C	47.2	15.6	37.2	22.1		10.9	4.7	3.8	9.3	11.1	5.9	7.1	--	--	--	33	--

SAMPLE NO.	HZN NO.	ORGN C 6A1C	TOTAL N 6B3A	EXTR P	TOTAL S 6R3A	DITH-CIT EXTRACTABLE FE 6C2B	AL 6G7A	MN 6D2A	(RATIO/CLAY) CEC 8D1	15 BAR 8D1	(ATTERBERG - LIMITS -) LL 4F1	PI 4F	(BULK DENSITY) FIELD MOIST 4A3A	1/3 BAR 4A1D	OVEN DRY 4A1H	COLE WHOLE SOIL 4D1	(WATER CONTENT) FIELD MOIST 4B4	1/10 BAR 4B1C	1/3 BAR 4B1C	15 BAR 4B2A	WRD WHOLE SOIL 4C1
		<- PCT OF <2MM						->			PCT <0.4MM		<- G/CC		->	CM/CM	<- PCT OF <2MM			->	CM/CM
811207	1	5.39	0.492			4.0	0.7		0.67	0.43										17.9	
811208	2	3.68	0.321			4.0	0.7		0.51	0.42										17.9	
811209	3	2.06	0.186			5.0	0.8		0.34	0.36										17.5	
811210	4	1.75	0.146			4.6	0.8		0.35	0.41										17.9	
811211	5	0.82	0.088			6.2	0.8		0.20	0.36										16.9	

SAMPLE NO.	HZN NO.	NH4OAC EXTRACTABLE BASES CA 5B5A 6N2E	MG 5B5A 6O2D	NA 5B5A 6P2B	K 5B5A 6Q2B	SUM BASES	ACIDITY 6H5A	EXTR AL 6G9A	CEC SUM CATS 5A3A	CEC NH4-OAC 5A8B	CEC BASES + AL 5A3B	AL SAT 5G1	BASE SAT SUM 5C3	BASE SAT NH4 OAC 5C1	CO3 AS CACO3 <2MM 6E1G	RES. OHMS /CM 8E1	PH KCL 1N 8C1G	PH NAF 8C1D	PH CACL2 .01M 8C1F 1:2	PH H2O 8C1F 1:1
		<- MEQ / 100 G									->	<- PCT		->						
811207	1	0.7	0.5	TR	0.2	1.4	36.7	7.9	38.1	27.8	9.3	85	4	5			3.3	7.6	3.4	4.0
811208	2	0.7	0.7	TR	0.1	1.5	26.6	6.0	28.1	21.6	7.5	80	5	7			3.5	9.0	3.7	4.4
811209	3	0.1	0.8	TR	0.1	1.0	25.2	6.0	26.2	16.8	7.0	86	4	6			3.7	9.0	3.8	4.5
811210	4	TR	0.5	--	0.1	0.6	22.4	5.5	23.0	15.2	6.1	90	3	4			3.7	9.3	3.9	4.5
811211	5	0.1	0.3	--	0.1	0.5	13.8	4.1	14.3	9.4	4.6	89	3	5			3.7	8.9	3.9	4.5

SAMPLE NO.	HZN NO.	P-ADSORP COEFF 6S2	P-RETENT CAPCTY (*) PCT	CEC NH4CL 5A9B MEQ/100G (<2mm)	K2O 6Q3A (<2mm)	Fe 6C7A (<2mm)	K2O 6Q3A (<0.002mm)	Fe 6C7A (<0.002mm)	K2O 6Q3A (<0.0002mm)	Fe 6C7A (<0.0002mm)	CLAY X-RAY <2U 7A2I	7A2I	7A2I	7A2I	DTA <2U 7A3	7A3	TOTAL RES 7B1A	DOM WEATH 7B1A
				<- TOTAL ANALYSIS 7C3 - PCT						->	<- RELATIVE AMOUNTS			->	<- PCT			->
811207	1	0.87		15.6	1.1	5.6												
811208	2	0.90		10.3														
811209	3	0.97		9.6	1.2	6.7	1.6	11.1	1.4	11.2	KK 3	MI 1	GE 1		KK40			
811210	4	0.95		8.9	1.3	7.1												
811211	5	0.93		6.0	1.3	8.9												

ANALYSES: S= ALL ON SIEVED <2MM BASIS

MINERALOGY: KIND OF MINERAL KK KAOLINITE MI MICA GE GOETHITE

RELATIVE AMOUNT 6 INDETERMINATE 5 DOMINANT 4 ABUNDANT 3 MODERATE 2 SMALL 1 TRACE

(*) NEW ZEALAND SOILS BUREAU PROCEDURE

PROFILE 16

Sample 3. 40-80 cm. B2 horizon

Only one sample of this profile was available, as the other samples were spoiled during thin-section preparation. The NRDP of the s-matrix is plasmic. Grains are mainly fine and medium sand-sized quartz and a few fine flakes of muscovite. Plasma is reddish-yellow and plasmic fabric is well developed omni-skelesepic.

The section has about 5% of illuviation argillans, thick and moderately well oriented (Plate 5d). However, the argillans in many of the larger voids are disrupted and assimilated into the s-matrix, as can be seen in the lower right-hand corner of Plate 5d.

Interpretation

Clay illuviation is a strong current process. The shrinking and swelling causes fragmentation of the argillans and their subsequent incorporation into the matrix of the soil. The process is, however, not very intense, and so the argillic horizon is still intact.

Classifications (Chairman: A. Pécrot)

1. Soil Taxonomy: Fine, mixed, isothermic, Typic Humitropept
2. FAO: Humic Cambisol
3. INEAC:

Order:	Kaolisol
Suborder:	Humiferous hygro-kaolisol
Group:	Humiferous hygro-ferrisol
Great group:	intergrade Ferralsol
Family:	clayey

APPENDIX I

Results of Soil Moisture and Temperature Regimes

The following contains computed moisture and temperature regimes from available climatic data. The moisture and temperatures regimes were computed using F. Newhall's model.

* * *

Profiles No: 1, 2 Station Name: Karama

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	80.0	20.0	80.3
February	86.0	21.1	74.8
March	106.0	21.7	88.0
April	141.0	20.1	71.1
May	89.0	21.0	80.8
June	16.0	21.3	81.1
July	4.0	20.3	74.6
August	12.0	21.9	89.5
September	39.0	21.9	87.0
October	81.0	22.3	94.2
November	125.0	21.5	84.3
December	74.0	20.3	75.5
	Total 853.0	Average 23.7	Total 981.4

Soil Moisture Regime: Ustic Soil Temperature Regime: Isohyperthermic

* * *

Profile No.: 3 Station Name: Byimana

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	30.7	18.6	72.4
February	164.5	18.5	64.6
March	163.0	18.5	71.1
April	179.8	18.3	67.4
May	61.9	18.2	68.4
June	22.7	17.6	62.3
July	0.0	18.3	69.1
August	100.8	18.6	71.5
September	72.2	18.2	66.7
October	65.2	18.6	72.1
November	136.4	18.2	67.5
December	65.2	18.1	68.8
	Total 1062.4	Average 20.8	Total 821.9

Soil Moisture Regime: Udic Soil Temperature Regime: Isohyperthermic

* * *

Profile No.: 4 Station Name: Mata-Rwanda

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	123.0	18.1	69.7
February	159.0	18.0	62.1
March	171.0	18.5	71.9
April	226.0	18.3	68.1
May	152.0	17.7	65.6
June	22.0	17.9	65.0
July	7.0	16.5	57.5
August	37.0	17.9	67.3
September	94.0	19.7	78.0
October	135.0	18.5	72.2
November	167.0	18.5	70.5
December	142.0	17.4	64.8
	Total 1435.0	Average 20.6	Total 812.5

Soil Moisture Regime: Udic Soil Temperature Regime: Isothermic

Profile No.: 5

Station Name: Rubona

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	113.0	19.0	72.7
February	121.0	19.4	68.2
March	142.0	19.9	79.0
April	188.0	19.2	71.0
May	152.0	19.1	72.0
June	24.0	18.8	66.8
July	6.0	17.7	61.8
August	26.0	19.1	72.4
September	66.0	19.3	71.8
October	110.0	20.3	82.6
November	129.0	19.3	72.8
December	94.0	18.3	67.4
	Total 1171.0	Average 21.6	Total 859.3

Soil Moisture Regime: Udic

Soil Temperature Regime: Isothermic

* * *

Profile No.: 6

Station Name: Ruhengeri

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	70.7	19.0	74.9
February	93.1	18.4	63.5
March	142.2	18.3	69.3
April	175.1	18.0	65.0
May	152.3	17.9	66.1
June	50.0	17.5	61.5
July	20.5	18.8	72.5
August	48.4	19.0	74.2
September	107.8	18.5	68.5
October	149.1	18.5	71.0
November	131.4	18.3	67.7
December	95.1	18.7	72.6
	Total 1235.7	Average 21.2	Total 826.7

Soil Moisture Regime: Udic

Soil Temperature Regime: Isothermic

Profiles No.: 7, 8, 9, 10 Station Name: Tamira

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	91.7	12.7	53.9
February	74.6	13.1	50.6
March	85.2	13.5	58.0
April	230.3	13.3	55.1
May	66.0	12.6	52.7
June	139.6	12.7	51.7
July	116.3	12.9	54.3
August	10.4	13.7	59.0
September	107.1	13.4	55.6
October	112.0	14.1	61.6
November	133.8	13.5	56.7
December	67.9	12.7	53.9
	Total 1234.9	Average 15.7	Total 663.3

Soil Moisture Regime: Udic Soil Temperature Regime: Isothermic

* * *

Profiles No.: 11, 12, 13 Station Name: Rwinkwavu

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	100.0	21.1	83.3
February	54.7	20.2	67.7
March	89.4	21.0	81.7
April	177.1	21.1	79.9
May	102.6	21.3	83.8
June	1.1	21.1	79.6
July	2.0	21.7	87.5
August	14.1	22.1	91.7
September	54.6	21.3	81.7
October	66.3	20.9	81.1
November	44.5	20.8	78.2
December	116.6	20.7	79.6
	Total 823.0	Average 23.6	Total 976.0

Soil Moisture Regime: Ustic Soil Temperature Regime: Isohyperthermic

Profile No.: 14 Station Name: Rwamagana

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	56.4	19.7	75.8
February	86.1	19.5	66.9
March	119.8	20.0	77.7
April	168.9	19.8	73.6
May	109.0	20.1	77.9
June	12.6	18.9	66.5
July	9.7	20.0	77.1
August	23.0	20.3	79.9
September	55.2	19.7	72.8
October	88.7	19.4	73.2
November	106.4	19.8	74.4
December	90.3	19.7	75.8
	Total 926.1	Average 22.2	Total 891.6

Soil Moisture Regime: Udic Soil Temperature Regime: Isohyperthermic

* * *

Profiles No.: 15, 16 Station Name: Byumba

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	77.2	15.4	61.1
February	96.2	15.3	54.6
March	138.4	15.4	60.8
April	203.7	15.8	61.2
May	161.4	15.4	60.4
June	30.9	15.3	58.0
July	17.0	15.8	62.8
August	39.8	15.4	60.6
September	106.9	15.5	59.4
October	130.4	15.4	60.9
November	111.1	15.6	60.6
December	92.8	15.5	61.7
	Total 1205.8	Average 18.0	Total 722.1

Soil Moisture Regime: Udic Soil Temperature Regime: Isothermic

Station Name: Kibuye

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	79.3	21.5	85.6
February	91.9	21.3	75.4
March	115.5	21.7	84.0
April	121.7	21.7	84.0
May	85.6	22.1	84.0
June	45.9	21.5	81.9
July	21.3	21.6	85.3
August	49.9	21.7	86.6
September	106.7	21.4	81.3
October	118.6	21.3	83.4
November	96.0	21.3	81.3
December	121.7	21.3	83.7
	Total 1054.1	Average 24.0	Total 1005.5

Soil Moisture Regime: Udic Soil Temperature Regime: Isohyperthermic

* * *

Station Name: Gabiro

Month	Precipitation (mm)	Temperature (°C)	Evapotranspiration (mm)
January	57.1	20.3	79.1
February	70.4	20.4	72.1
March	90.1	20.3	78.6
April	143.0	20.6	78.6
May	73.2	20.7	81.6
June	18.2	20.4	76.7
July	14.2	22.1	94.0
August	19.0	21.6	89.7
September	66.9	19.9	72.9
October	79.3	19.7	73.9
November	75.3	18.5	62.8
December	78.4	17.7	58.7
	Total 785.1	Average 22.7	Total 918.8

Soil Moisture Regime: Ustic Soil Temperature Regime: Isohyperthermic

Station Name: Rusumu

Month	Precipitation (mm)		Temperature (°C)		Evapotranspiration (mm)
January	100.0		21.1		83.4
February	54.7		20.2		67.8
March	89.4		21.0		81.7
April	177.1		21.1		79.9
May	102.6		21.3		83.7
June	1.1		21.1		79.5
July	2.0		21.7		87.4
August	14.1		22.1		91.6
September	54.6		21.3		81.6
October	66.3		20.9		81.2
November	44.5		20.8		78.3
December	116.6		20.7		79.7
Total	823.0	Average	23.6	Total	975.9

Soil Moisture Regime: Ustic   Soil Temperature Regime: Isohyperthermic

* * *

Station Name: Kigali

Month	Precipitation (mm)		Temperature (°C)		Evapotranspiration (mm)
January	56.4		19.7		75.8
February	86.1		19.5		66.9
March	119.8		20.0		77.7
April	168.9		19.8		73.6
May	109.0		20.1		77.9
June	12.6		18.9		66.5
July	9.7		20.0		77.1
August	23.0		20.3		79.9
September	55.2		19.7		72.8
October	88.7		19.4		73.2
November	106.4		19.8		74.4
December	90.3		19.7		75.8
Total	926.1	Average	22.2	Total	891.6

Soil Moisture Regime: Udic   Soil Temperature Regime: Isohyperthermic

APPENDIX II

Results of Mineralogical Analyses

Estimates of the dominant minerals in the clay fraction are given in the summaries of the physico-chemical and mineralogical properties, listed after each profile description. The intent here is to discuss briefly the TEM studies of the clays.

Profile 2

Kaolinite is the dominant mineral in this soil with about 66-70% in all horizons. Fig. 1a shows a sample of the B_{21} horizon. The kaolinite crystals are subrounded and of varying sizes. Some are opaque due to heavy coating with iron while most are speckled.

Profile 3

The sample taken at 120 cm depth in the profile has about 65% kaolinite. The kaolinite crystals are rounded (Fig. 1b). The speckled appearance of kaolinite is an artifact caused by beam damage.

Profile 6

Figs. 1c,d and Fig. 2a are samples from Ap1, A3 and B22 horizons. The Ap1 horizon has an exceptionally high amount of micas. The other samples have some micas.

In the subsurface horizons, the dominant clay mineral is halloysite. These occur as either fine tubes or as spherical particles. Small clusters of amorphous aggregates are also present and are probably allophane.

Profile 7

Fig. 2b shows a network of immogolite strands in the A13 horizon. In the lower part of the micrograph, the strands are so thick that they appear opaque. An example of a spherical halloysite can also be seen in the centre of the micrographs. Aggregates of allophane are also abundant in the sample.

Fig. 1

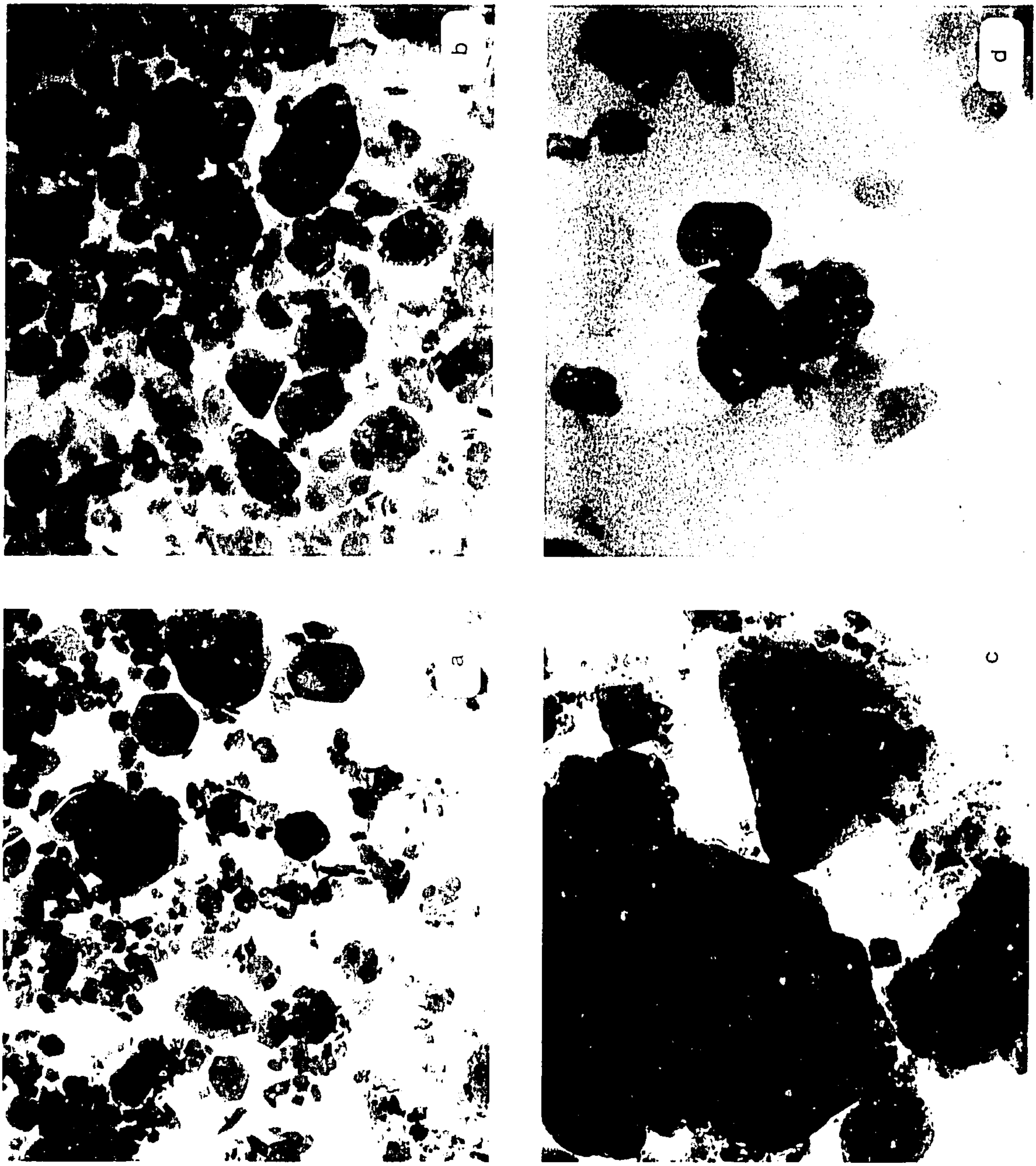
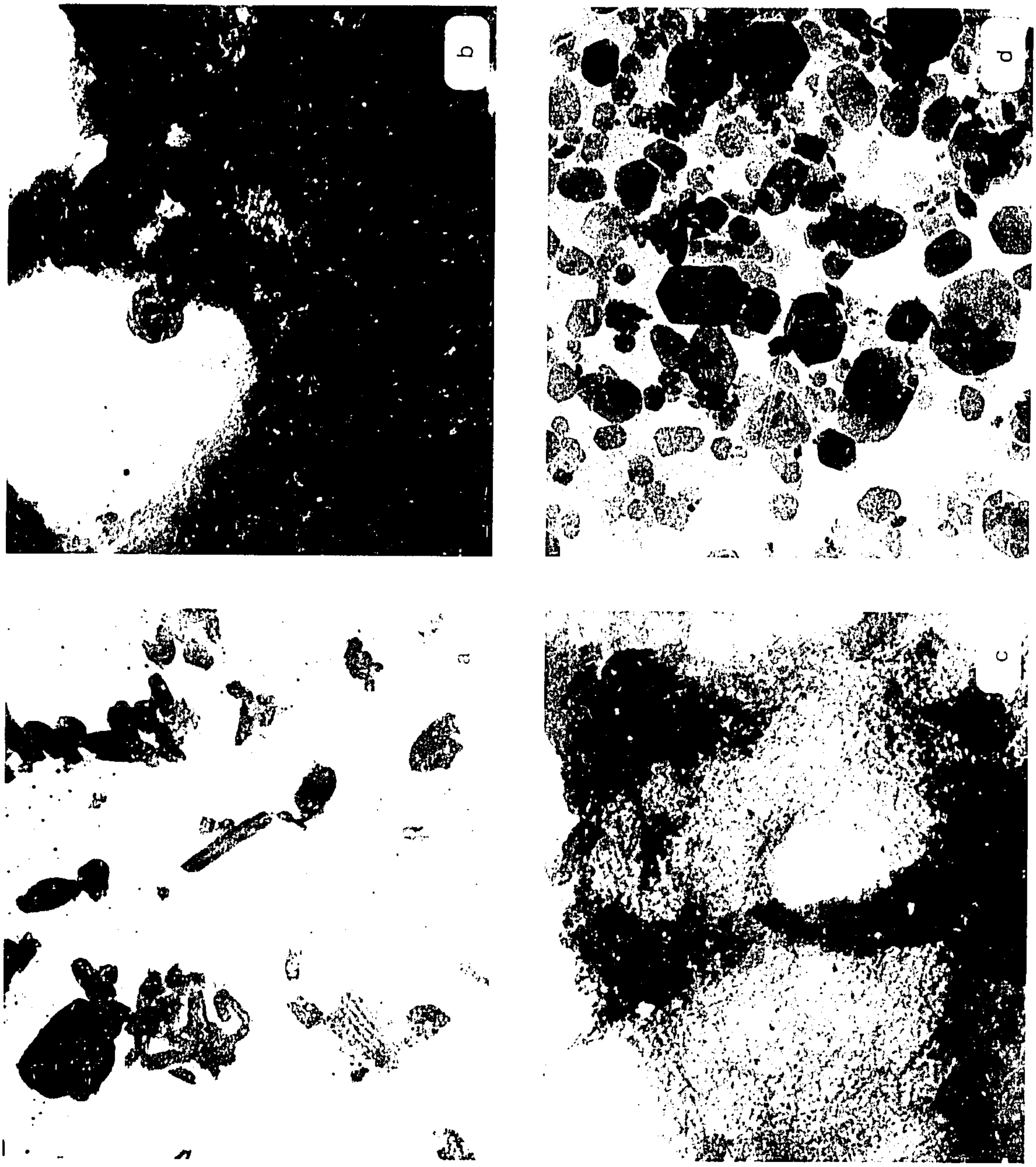


Fig. 2



Profile 8

A better example of immogolite is seen in Fig. 1c. The strands are extremely fine. Associated with the immogolite also are aggregates of allophane.

Profile 11

The kaolinite crystals in the A12 horizon (Fig. 2d) are extremely well crystallized. Most of them are hexagonal and very thin. Rounding of the kaolinite may be due to pedogenesis or transport. It appears that this sample has suffered a minimum of both.

Profile 12

The B22 horizon has a mixture of kaolinite and illite. In Fig. 3a, only the kaolinite crystals are readily seen. The illite occurs as fine comminuted flakes intermixed with the kaolinite.

Profile 16

The B2 horizon of this sample has about equal amounts of kaolinite and illite. In Fig. 3b, only the large illite flakes are readily visible. The kaolinite is present as small crystals and is masked by the illite. The illite is also heavily altered.

APPENDIX III

Results of Optical Observations

Grain counts were not made because of time constraints. Rapid optical scans were made by Dr. Holzhey with the assistance of Dr. Kimble. The results of these scans follow by profile. The percentages are estimated from the observations and not from actual counts.

Profile R1

811122-vfs: Quartz estimated 80-90%; tourmaline estimated 10%; iron oxide < 5%; unidentified resistant < 5%; plant opal-trace; one possible pyroxene. Some quartz has rhombohedral secondary growth.

811125-vfs: Similar to 1122 but one feldspar, < 1% pyroxene, and several zircon (< 1%).

-fs: Similar suite; greater proportion quartz.

811126-vfs: Quartz about 50%; 40-50% opaque and semi-opaque, reddish hue aggregates of clay and iron oxides; tourmaline < 5%; other resistant < 1%; 0.1% feldspar with edges slightly irregular (etched), glass, plant opal and possible pyroxene all < 0.1%.

Profile 3

811133-vfs: Feldspar, about 30-50%; no twinning visible; many ragged edges; sillimanite, andalusite < 5%; opaques, zircon, unident resistant < 5%; muscovite < 1%; < 1% plant opal; and < 0.1% possible pyroxene, possible biotite or chlorite < 0.1%.

811136-fs: Dominantly feldspar, 60-75%; quartz about 15%; biotite maybe 10-15% by numbers, less by weight; and muscovite < 1%; 1 possible tremolite; and no heavy minerals. Grains dominantly angular to irregular. Some etched edges on some feldspars.

-vfs: Similar to vfs with a few sillimanite; 1 possible tremolite; and 1 plant opal.

811137-vfs: 50-65% feldspar; < 50% quartz; < 10% biotite; 1 zircon; < 1% sillimanite; < 1% possible monazite; < 1% muscovite; and < 1% possible pyroxene. Grains irregular to angular to subrounded. Feldspars roughly half dirty, many etched edges.

fs: Similar to vfs with more quartz--75-80%; less feldspar; much less biotite; < 1% opaque iron oxides; and < 1% zircon and sillimanite.

Profile 4

811138-vfs: Quartz $\geq$ 90%; feldspar < 5%; ferromagnesian < 3% (pyroxene and possibly amphibole); biotite < 1%; sillimanite < 1%; muscovite < 1%; plant opal < 0.1%; opaque 1-2%; and one possible garnet. Grains mostly subrounded to angular. Many of the feldspars dirty (> ½). Other weatherables clean.

811141-vfs: Quartz about 85-90%; ferromagnesian (mostly pyroxene) < 5%; other resistant < 5%; feldspar < 1%, possibly some with index of mounting medium that were missed; biotite < 1%; muscovite < 1%; opaque $\leq$ 5%; other resistant < 1%; and 1 plant opal.

811144-vfs: Quartz 85-90%; feldspar < 1% possibly some at index of mounting medium; muscovite < 1%; biotites, other weatherable (mostly pyroxene--some probably sillimanite) < 5%; opaque $\leq$ 5%; other resistant < 1% including tourmaline, probably rutile; and 1 plant opal.

Profile 5

811147-vfs: Quartz 80-85%; feldspar < 1%; muscovite < 1%; biotite < 1%; other weatherable < 1% (pyroxene dominant); opaque ≤ 5%; tourmaline ≤ 5%; plant opal < 1% mostly prismatic, some teardrop; possible rutile and other resistant < 1%.

811149-vfs: Similar to 1147.

811150-vfs: Similar to 1147. Still some plant opal, but less than 1147.

811151-vfs: Similar to 1150 with slight increase in feldspar (still < 1%), and some muscovite (still < 1%).

Profile 6

811154-vfs: Quartz probably 25-30%; feldspar probably > 50%; with 1/5-1/6 having index > mounting medium (calcium-rich). Roughly half identified as feldspar coated with isotropic brown alteration products, resembling jumbles of small pieces cemented by altered glass. Perhaps these were glass-coated pieces containing small growing crystals when the ash cooled. The glass may have subsequently divitrified. 10-20% ferromagnesian (dominant pyroxene); 10-20% opaque; ≤ 5% rounded, yellow-brown flakes resembling biotite, but possibly alteration products or aggregates of other clay minerals; and one clean glass.

811156-vfs: Differs from 1154 in: higher proportion of feldspar is clean, shows plagioclase and microperthite twinning, small proportion of feldspar has jumbles of feldspar laths (some microperthite) with isotropic brown coatings; 1 zircon; more yellow-brown aggregates, still < 5%; and < 1% clean glass.

Profile 7

811158-fs: Opaque aggregates ≥ 50%; ferromagnesians ≤ 25%; feldspar

≤ 15%; quartz ≤ 10%; plant opal < 1%; muscovite < 1%; carbonates < 1%; isotropic brown flakes of clay < 1%; tourmaline < 1%.

Profile 8

811161-vfs: Predominantly opaque aggregates; < 10% isotropic, yellowish red aggregates resembling crusts from PSDA; plant opal, some resembling sponge spicules < 1%; remainder dominantly ferromagnesian > 25%; feldspar < 5%, some covered by alteration products; quartz < 5%; and zircon < 1%.

811163-vfs: Similar to 1161 with less feldspar, quartz and no plant opal observed; > 75% opaque aggregates; 1 carbonate; and some possible sillimanite.

Profile 9

811167-vfs: Dominantly opaque and semi-opaque aggregates ≥ 75%; ferromagnesians 10-15% (pyroxene dominant, some biotite, possible amphibole); quartz < 10%; feldspar < 5%; muscovite < 1%; possible sillimanite and wollastonite, both tentative; plant opal < 1%; zircon < 1%; and other resistant < 1%.

811169-vfs: Similar to 1167 except, quartz about equal to ferromagnesians; still some plant opal; and 1 glass.

811171-vfs: Quartz about 40-60%; opaque aggregates < 25%; red-yellow clay aggregates < 5%; ferromagnesian about 25%; glass < 1%; muscovite < 1%; feldspar < 1%; tourmaline < 5%; and other resistant < 1%.

Profile 10

811172-vfs: Quartz ≥ 90%, subrounded to angular; opaque < 5%; muscovite < 1%; ferromagnesian (dominant pyroxene) < 1%; tourmaline < 1%; 1 biotite; glass < 1%; brown aggregates < 1%; and feldspar < 1%.

811173-vfs: Similar to 1172 but quartz probably > 95%; and fewer aggregates plus opaques--< 5%.

811175-vfs: Similar to 1175, but fewer aggregates plus opaques < 10%.

Profile R11

811177-vfs: Quartz > 90%--dominantly subrounded to rounded; opaques < 1%; feldspar < 1%; glass < 1%; rutile < 1%; tourmaline < 1%; ferromagnesian (pyroxene, possible amphiboles) < 1%; and plant opal < 1%.

811179-vfs: Quartz ≥ 90%, dominantly subrounded with rounded and angular present; opaques < 5%; zircon possibly 1%; 1 brown glass; 1 clear glass or opal; muscovite < 1%; feldspar < 1%; tourmaline < 1%; high index mineral resembling aegerine but without pleochroism possibly 1%; and rutile < 1%.

811180: Similar to 1179 but quartz > 95%; less zircon, possible staurolite < 1%, no feldspar seen; and no muscovite seen.

Profile R12

811184-vfs: Quartz > 90% subrounded to rounded; opaques < 10%; plant opal < 1%; 2 high relief greenish grains, non-pleochroic, anhedral, resembling aegerine; 1 hornblende; and tourmaline < 1%.

811187-vfs: Similar to 1184; plus feldspar < 1%; augite < 1%; and no hornblende.

811189-vfs: Mostly subangular quartz ≥ 95%; opaques ≤ 5%; 1 possible rutile; and 1 feldspar.

Profile R13

811191-vfs: Mostly subangular to subrounded; quartz ≥ 95%; opaques < 5%; tourmaline < 1%; zircon < 1%; and plant opal < 1%.

811193-vfs: Similar to 1191 with a few angular quartz and one possible pyroxene; and 1 panicoid shaped (as thumb bone, 2nd joint) plant opal as occurs in veins of *Zea Mays*.

811195-vfs: Similar to 1191 with semi-panicoid plant opal; and one possible garnet.

Profile R14

811196-vfs: Subrounded to angular quartz ≥ 75%; tourmaline ≤ 15%; opaques < 10%; zircon < 1%; feldspar < 1%; glass < 1%; pyroxene < 1% (some of tourmaline rounded, oriented for minimal pleochroism and birefringence, difficult to distinguish from pyroxene); and plant opal < 1%.

811199-vfs: Similar to 1196 with a few more angular quartz; small increase in feldspar (still < 1%), and possible sphene < 1%.

811200-vfs: Quartz angular to subrounded ≥ 90%; opaques < 2%; tourmaline < 5%; reddish-brown, rounded clay aggregates < 1%; garnet < 1%; ferromagnesians ≤ 5% (resemble diopside, hypersthene, augite); feldspar, glass and muscovite together < 1%; 1 possible plant opal; possible monazite < 1%; possible sphene < 1%; and possible kyanite < 1%.

811201-vfs: Similar to 1200 except several definite plant opal; and fewer weatherable mineral grains by perhaps 1/3.

Profile R15

811203-vfs: Angular to subrounded quartz > 90%; opaques < 5%; brown aggregates ≤ 1%; tourmaline < 1%; zircon < 1%; rutile < 1%; ferromagnesian < 1%; glass < 1%; plant opal < 1%; and feldspar not seen.

811204-vfs: Similar to 1203, but some feldspar (< 1%); possible chlorite (< 1%); and no glass or opal seen.

811205-vfs: Similar to 1203, except quartz > 95%; no feldspar seen, garnet < 1%, and one grain of opal or glass seen.

Profile R16

811207-vfs: Subrounded with some angular quartz $\geq$ 75%; opaques $\leq$ 20%; tourmaline < 1%; zircon < 1%; ferromagnesian $\leq$ 1%; feldspar < 1%; plant opal $\leq$ 1%; and yellow-red rounded flakes $\leq$ 1%, possibly clay crusts from PSDA.

811209-vfs: Similar to 1210, plus garnet < 1%; and no feldspar seen.

811210-vfs: Subrounded to angular quartz $\geq$ 75%; opaque $\leq$ 25%; zircon < 1%; tourmaline < 1%; yellow-red to red-brown rounded clay flakes < 1%; plant opal $\leq$ 1%; feldspar < 1%; ferromagnesian < 1%; and sphene < 1%.

811211-vfs: Subrounded quartz $\geq$ 75%; opaques $\leq$ 25%; zircon < 1%; tourmaline < 1%; yellow-red to red-brown rounded clay flakes < 1% (could be clay crusts from particle size analysis); garnet < 1%; and sphene < 1%.

Legend: Opaques--principally iron-oxide rich or iron oxide coated grains and aggregates.

Ferromagnesians--principally pyroxenes and amphiboles. All weatherable by Soil Taxonomy definition.

Plant opal--grains inherited from cellular silica deposits in plants. Most observed opals were prismatic except as otherwise described.

Feldspar--generally not the high-Ca representatives unless specified as having index near or above the mounting medium. Mostly not twinned.

APPENDIX IV

Supplemental Analytical Data

The following computer-generated table contains some extra data that does not appear on the standard NSSL data printout. The table contains 12 columns. A brief explanation of each column follows:

Col. 1. NSSL laboratory number used to identify the samples.

Col. 2. Series designation--R1 through R16.

Col. 3. Horizon for field description.

Col. 4. Surface area (mg/g soil) determined with ethylene glycol monoethyl ether (EGME). Procedure is described in companion papers by Carter, et al. (1965) and Heilman, et al. (1965), and in SSIR No. 1 rev. 1980, code number 7D2.

Col. 5. Surface area (mg/g clay) based on % clay. To calculate, divide values in Col. 4 (SA/EGME) by percent clay and multiply by 100.

Col. 6. Surface area (M^2/g soil) calculated by multiplying mg/g of EGME adsorbed by 3.496503 (Heilman, et al. 1965).

Col. 7. Surface charge density (esu x 10^4/cm^2) for CEC measured by ammonium acetate pH 7. To calculate, divide CEC by surface area (M^2/g soil) and multiply by 28.9 x 10^4. Derivation can be found in Surface and Colloid Chemistry (Cast, R.G. 1977).

Col. 8. Variable charge (meq/100 g soil) calculated by subtracting the effective CEC (sum of bases plus KCl-Al) from CEC by sum of cations plus extractable acidity.

Col. 9. Ratio of variable charge to CEC by sum of cations.

Col. 10. CEC7 (meq/100 g clay) ammonium acetate pH 7 CEC divided by percent clay and multiplied by 100.

Col. 11. ECEC (meq/100 g clay) effective CEC divided by percent clay and multiplied by 100.

Col. 12. CEC-NH_4Cl (meq/100 g clay) CEC measured using NH_4Cl divided by percent clay and multiplied by 100.

1	2	3	4	5	6	7	8	9	10	11	12
NSSL	SERIES	HOR	SA ECME	SA CLAY	SA M2/G	CD7 ESU	VAR CHAR	VAR /SUM	CEC7 /CLAY	ECEC /CLAY	CECN /CLAY
811122	R1	A1	15	46	52	2.39	3.8	.62	13.2	7.09	8.02
811123	R1	A3	17	42	59	2.06	4.1	.67	10.4	4.98	6.48
811124	R1	B21	19	41	66	1.88	4.6	.69	9.38	4.58	6.33
811125	R1	B22	21	43	73	1.78	4.7	.68	9.16	4.48	6.31
811126	R1	I B2	25	47	87	1.76	6.2	.7	9.90	4.85	8.03
811127	R2	AP	20	47	69	3.31	6.4	.58	18.5	10.7	12.6
811128	R2	B1	22	40	76	2.28	7.1	.67	10.9	6.39	7.31
811129	R2	B21	22	41	76	2.09	4.9	.6	10.1	5.90	7.19
811130	R2	B22	21	38	73	1.94	5.3	.64	8.79	5.38	6.10
811131	R2	I B2	25	42	87	1.89	5.6	.62	9.46	5.81	7.14
811132	R3	A1	18	63	62	4.06	7.5	.66	30.6	13.3	20.0
811133	R3	A3	18	57	62	3.78	8	.68	25.7	11.7	21.5
811134	R3	II A11	32	66	111	3.46	11.1	.61	27.3	14.3	17.0
811135	R3	II A12	31	64	108	3.05	8.7	.57	23.5	13.6	16.9
811136	R3	II C1	25	59	87	2.89	6.9	.55	20.3	13.1	15.2
811137	R3	II C2	21	63	73	2.34	2.8	.41	17.5	12.2	14.5
811138	R4	A11	29	73	101	3.46	15.1	.77	30.6	11.1	15.4
811139	R4	A12	31	71	108	3.26	16.2	.78	27.8	10.2	14.6
811140	R4	A3	31	68	108	3.02	14.5	.78	24.6	8.93	13.0
811141	R4	B21	32	64	111	2.63	13.5	.78	20.2	7.61	11.2
811142	R4	II B22	33	69	115	2.56	14.7	.79	21.3	7.96	12.5
811143	R4	II A1	37	158	129	3.2	23.2	.85	61.1	17.9	26.0
811144	R4	II B2	25	59	87	2.13	8.6	.77	15.1	6.16	9.95
811145	R4	III C	25	50	87	2.26	8.2	.74	13.5	5.77	8.16
811146	R5	A1	29	56	101	3.55	12.7	.73	23.9	9.07	15.0
811147	R5	B21	27	52	94	3.47	11.7	.74	21.8	8.10	13.3
811148	R5	B22	29	52	101	3.15	9.9	.68	19.8	8.48	11.5
811149	R5	II B1	31	55	108	3.4	10.8	.64	22.4	10.7	13.0
811150	R5	II A1	32	53	111	3.8	11.6	.64	24.1	10.9	14.0
811151	R5	II C1	32	48	111	2.71	8.6	.61	15.5	8.23	9.73
811152	R6	AP1	18	240	62	4.8	5.6	.39	137.	114.	118.
811153	R6	AP2	20	187	69	6.62	7.2	.32	147.	140.	131.
811154	R6	A3	18	178	62	5.78	7.3	.45	122.	89.1	95.0
811155	R6	B21	24	207	83	3.59	5.7	.41	88.7	71.5	79.3
811156	R6	B22	22	232	76	3.38	4.1	.37	93.6	72.6	88.4
811157	R7	AP	50	345	174	12.14	61.1	.6	504.	277.	305.
811158	R7	A12	52	406	181	11.3	64.1	.7	553.	214.	276.
811159	R7	A13	54	900	188	9.59	70.3	.79	1040	308.	410
811160	R8	A11	67	587	234	8.42	38.9	.46	598.	395.	403.
811161	R8	A12	64	634	223	8.45	37.5	.43	645.	500	484.
811162	R8	B1	74	2242	258	7.01	44.3	.47	1896	1493	1439
811163	R8	B21	89	14833	311	5.77	52.8	.59	1035	6166	6266
811164	R8	B22	112	7000	391	4.69	45.2	.52	3968	2600	2731
811165	R8	C	0.0	0.0							

1	2	3	4	5	6	7	8	9	10	11	12
NSSL	SERIES	HOR	SA EGME	SA CLAY	SA N2/G	CD7 ESU	VAR CHAR	VAR /SUM	CEC7 /CLAY	ECEC /CLAY	CECN /CLAY
811167	R9	AP2	81	358	283	6.65	11.1	.15	288.	281.	262.
811168	R9	A13	72	257	251	6.39	11.6	.18	198.	193.	183.
811169	R9	A14	88	444	307	6.32	13.5	.17	338.	336.	321.
811170	R9	A15	73	258	255	6.28	11.5	.17	195.	198.	178.
811171	R9	A16	48	178	167	6.47	11	.23	139.	133.	126.
811172	R10	A1	26	69	90	4.62	23.5	.98	38.0	1.32	21.9
811173	R10	B21	24	55	83	2.89	11.7	.72	18.9	10.2	14.1
811174	R10	B22	24	58	83	2.47	10.9	.73	17.2	9.97	14.5
811175	R10	C	21	55	73	2.65	8.8	.7	17.5	9.97	16.0
811176	R11	A11	22	64	76	3.65	14.4	.95	27.9	2.32	24.7
811177	R11	A12	23	58	80	2.75	13.2	.94	19.2	2.03	17.7
811178	R11	B1	27	56	94	2.06	9.7	.72	13.9	7.93	10.0
811179	R11	B21	29	55	101	2	9.1	.71	13.2	7.18	8.69
811180	R11	B22	32	55	111	1.9	9.9	.72	12.6	6.58	7.97
811181	R11	C1	34	60	118	1.62	9.8	.74	11.5	6.14	7.71
811182	R11	C2	31	53	108	1.66	10	.73	10.6	6.33	7.36
811183	R12	A11	21	93	73	2.93	12	.93	32.5	3.96	25.1
811184	R12	A12	25	83	87	2.49	12.8	.97	24.9	1.32	19.2
811185	R12	B1	26	76	90	2.5	13.6	.98	22.8	.879	19.6
811186	R12	B21	26	73	90	2.31	8.8	.68	20.1	11.4	15.4
811187	R12	B22	27	69	94	2.18	8.6	.66	18.2	11.3	12.3
811188	R12	B23	28	71	97	2.15	8	.66	18.2	10.4	12.4
811189	R12	C1	29	72	101	1.97	7.4	.62	17.2	11.2	13.2
811190	R12	C2	29	74	101	2.06	11.7	.97	18.3	1.01	15.2
811191	R13	A1	13	127	45	2.25	4.3	.61	34.3	27.4	33.3
811192	R13	B1	11	87	38	2.28	4.5	.71	23.8	14.2	19.0
811193	R13	B21	11	73	38	1.98	4.7	.76	17.3	10	20
811194	R13	B22	14	74	48	1.69	4.8	.75	14.7	8.42	12.6
811195	R13	C	24	67	83	1.71	3.5	.55	13.6	8.10	25.4
811196	R14	A11	27	62	94	3.01	8.6	.65	22.6	10.6	34.8
811197	R14	A12	27	61	94	2.64	8.2	.68	19.4	8.59	28.7
811198	R14	B1	29	62	101	2.29	7.2	.66	17.1	7.92	26.1
811199	R14	B2	28	56	97	2.03	6.7	.66	13.6	6.8	21
811200	R14	A/B	32	57	111	2.08	6.8	.6	14.2	7.99	22.3
811201	R14	C	36	52	125	2.1	6.9	.53	13.0	8.59	23.4
811202	R15	AP	16	76	55	3.73	9	.98	33.6	.947	57.3
811203	R15	B21	27	70	94	2.52	11.6	.95	21.1	1.54	39.1
811204	R15	B22	22	71	76	2.85	5.0	.59	24.2	12.9	37.8
811205	R15	C	18	65	62	2.28	3.6	.55	17.6	10.8	30.3
811206	R15	SHALE	20	60	69	2.35	4.1	.55	16.7	10.1	26.5
811207	R16	AP	40	97	139	5.78	28.8	.76	67.1	22.4	77.0
811208	R16	A3	35	82	122	5.12	20.6	.73	50.5	17.5	60.4
811209	R16	B2	36	74	125	3.88	19.2	.73	34.3	14.3	48.2
811210	R16	A/B	36	83	125	3.51	16.9	.73	35.1	14.0	43.4
811211	R16	C	30	64	104	2.61	9.7	.68	19.9	9.74	31.7

OTHER EDITIONS

— Les principaux ennemis des cultures maraîchères au Sénégal.

— Principaux ennemis des cultures de région des grands lacs d'Afrique centrale.

— Cultures maraîchères au SAHEL TUNISIEN.

— Traité pratique de l'irrigation sous pression.

1. Belgian development cooperation in the republic of Zambia project:

   Mount Makulu central agricultural Research Station plant protection section — Summary of Research progress for the period 14.12.1976 - 13.12.1981.

2. Comment tailler mes caféiers?

   How to prune coffee? (in preparation).

3. Plaquette de présentation de l'Institut des Sciences agronomiques du Burundi (ISABU).

4. Proceedings of the Fourth International Soil Classification workshop:

   Rwanda, 2 to 12 June 1981.

   Part I: Papers.

   Part II: Field trip and background soil data.