ERRATA

CONTENTS: 4.5 Andosols .... 34 should read: 32
p. 39: bottom line, delete first word (= of)
p. 83: INS-29, Hydric Dystrandept should read: Typic Hydrandept
p. 83: EC-9, 2Ca should read: 2Cg
p. 138: 6th line from top, Hydrandept should read: Hydrudand

Soil Monograph 2

Clay mineralogy and chemistry of soils formed in volcanic material in diverse climatic regions

C. Mizota[1] and L.P. van Reeuwijk[2]

[1] Department of Agricultural Chemistry, Kyushu University, Fukuoka, Japan
[2] ISRIC, Wageningen, The Netherlands

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

ISRIC, 1989

International Soil Reference and Information Centre (ISRIC)
P.O. Box 353
6700 AJ Wageningen
The Netherlands

CIP-GEGEVENS KONINKLIJKE BIBLIOTHEEK, DEN HAAG

Mizota, C. - Clay mineralogy and chemistry of soils formed in volcanic material in diverse climatic regions / C. Mizota and L.P. van Reeuwijk. - Wageningen : International Soil Reference and Information Centre, - (Monograph / International Soil Reference and Information Centre ; 2)
ISBN 90-6672-035-2 : f. 15.-
Doelgroep: bodemkundigen
SISO 631.2 UDC 631.4
Trefw.: bodemkunde.

Correct citation:
Mizota, C. and L.P. van Reeuwijk (1989)
Clay mineralogy and chemistry of soils formed in volcanic material in diverse climatic regions.
Soil Monograph 2, ISRIC, Wageningen.

PREFACE

This monograph originally was intended to be a report on an investigation into the chemical and mineralogical characteristics of soils on volcanic material in different climatic regions of the world. However, in the course of the preparation of the report, it was decided to expand its coverage. The main reasons for this were the appearance of a large number of publications with information related to the subject, the rapid progress in the revision of the classification of Ando soils and the recent acquisition by ISRIC of a considerable number of monoliths of soils on volcanic material. Although these monoliths were acquired after the original investigation was completed, the additional information obtained from them was considered useful enough to be included for reference purposes.

As a result, the present work now encompasses the following items: 1. A treatise on the present knowledge of the chemistry and mineralogy of soils on volcanic ash in general, and a review of case studies of soils from various regions of the world. 2. A discussion of the commonly used methods of chemical characterization of Ando soils. 3. A reproduction of the "andic soil properties" and the basic arrangement of the new Order of "Andisols" as prepared by ICOMAND for Soil Taxonomy, and of the Major Soil Grouping "Andosols" in the Revised Legend of the FAO-Unesco Soil Map of the World. 4. A report on the investigation into the composition of some sixty soil profiles developed in volcanic material in various regions of the world.

CONTENTS

1. INTRODUCTION 1

2. FORMATION AND COMPOSITION OF ANDO SOILS 5
   - 2.1 Introduction 5
   - 2.2 Chemical-mineralogical processes 6
   - 2.3 The binary composition 10
   - 2.4 The fate of Ando soils 12

3. THE COLLOIDAL FRACTION OF ANDO SOILS IN VARIOUS REGIONS OF THE WORLD 13
   - 3.1 Introduction 13
   - 3.2 West Indies, Central and South America 14
   - 3.3 Pacific Areas 15
   - 3.4 East Africa 17
   - 3.5 Europe 18
   - 3.6 North America 21
   - 3.7 China 22
   - 3.8 Arid Regions 22
   - 3.8 Summary 23

4. CLASSIFICATION AND THE ANDISOL PROPOSAL 25
   - 4.1 Introduction 25
   - 4.2 Definition of Andisols 26
   - 4.3 Andic soil properties 28
   - 4.4 Order, Suborders and Great Groups 29
   - 4.5 Andosols in FAO-Unesco Revised Legend 34

5. CHEMICAL CHARACTERIZATION OF ANDO SOILS 35
   - 5.1 Reactivity methods 35
   - 5.2 Selective dissolution methods 37
   - 5.3 Interpretation of dissolution data 39

6. MATERIALS AND METHODS 45
   - 6.1 Materials 45
   - 6.2 Methods 48

7. RESULTS AND DISCUSSION 53
7.1 Active Al and Fe 53
7.2 Crystalline clay minerals, oxides and primary constituents 58
7.3 Fluoride reaction, phosphate retention 62
7.4 Extractable aluminium 62
7.5 Physical properties 62
7.6 Summary 63

ACKNOWLEDGEMENTS 65

REFERENCES 67

APPENDIX 1. Soil characterization data 77

APPENDIX 2. Dissolution analysis of clays of selected horizons: acid oxalate-soluble constituents 91

APPENDIX 3. Dissolution analysis of clays of selected horizons: acid oxalate-insoluble constituents and mineral composition of the silt fraction (2-20μm) 97

APPENDIX 4. Soil profile descriptions 103

1. INTRODUCTION

Ando soils are relatively young soils with very distinctive properties usually (but not exclusively) developed in pyroclastic material, notably volcanic ash but also tuff, pumice, cinders, lahars, and other volcanic ejecta of all varieties of composition, the rare ultrabasic excepted (Neall, 1985). They are, therefore, confined to the volcanic regions of the world. Ando soils, being intrazonal soils, are found in a wide range of climates from the cool humid climates of Alaska or Hokkaido to subtropical Kyushu and tropical semi-arid parts of Hawaii (Mohr et al., 1972), The only prerequisites seem to be the availability of sufficient rain for rapid weathering of the parent material, production and accumulation of organic matter and good drainage. The total area of Ando soils is estimated at more than 124 million hectares or 0.84% of the world's land surface (Leamy et al., 1980). About 80% of the Ando soil area is potential crop land which corresponds with about 2% of the global potential crop land area. More than half of this is situated in the tropics (Buringh, 1979).

Ando, meaning "dark soil" in Japanese (Thorp & Smith, 1949) seems to have become the internationally accepted term (including the adjective "andic") for these types of soil which were previously known under various local names such as Humic Allophane soils and Kuroboku soils (Japan), Trumao soils (Chile), fresh or young volcanic ash soils and Brown Earth soils (Antilles), Black Dust soil or High Mountain soils (Indonesia), Soapy hill (West Indies) and Yellow Brown Loams (New Zealand). The FAO/Unesco Soil Map of the World (1974) recognizes Andosols as a Major Soil Group (Level I) whereas in Soil Taxonomy (USDA, 1975) they form a suborder of the Inceptisols: Andepts. Because of the vast increase in knowledge on the Ando soils since the conception of these classification systems, at present the classification in both systems is in a final stage of revision (see Chapter 4).

Some of the most typical characteristics of Ando soils were described by Mohr et al. (1972), Leamy et al. (1980), and Wada (1980, 1985) and are summarized as follows:

Morphology

- AC or ABC profile, the A-horizon ranging from 20 to 50 cm in thickness, but sometimes down to 100 cm or sometimes less than 20 cm.

- Dark colours dominating throughout the profile although there is a clear difference in colour between the topsoil and the subsoil. In cooler climates the colours are darker than in tropical climates where accumulation of organic matter is less prominent. The organic matter content averages about 8% but may range to 30% in the darkest profiles.
- Very porous, very friable, fluffy, non-plastic, non-sticky A-horizons merging clearly into the brown B or C-horizons.
- A-horizons with a crumb or granular structure.
- Soapy, smeary, slippery, greasy or unctuous feeling of the soil (in the field), becoming almost liquid when rubbed (thixotropy).
- Presence of identifiable ash layers.

Mineralogy

- Both the silt and sand fractions contain volcanic glass, the amount varying with the locality. Some of the mineral grains have a "coating" of volcanic glass.
- Ferromagnesian minerals (olivine, pyroxenes, amphiboles), feldspars and quartz are very common, the amount depending on the nature of the volcanic material.
- The mineral composition of the clay of Ando soils varies strongly, depending on several factors and conditions such as the stage of soil formation, the horizon, the composition of the volcanic parent material, the pH, the moisture regime, the thickness of overburden ash deposits, the accumulation of organic matter. The formation and transformation of clay minerals (or their precursors) by weathering of pyroclastic material are strongly affected by the accumulation of humus as this forms complexes with Al and, to a lesser extent, with Fe. The "amorphous materials" in the clay of Ando soils in most cases appear to consist of allophane and, less commonly, imogolite on the one hand and humus complexes of Al and Fe together with opaline silica on the other. They may occur together but there is an inverse relationship because the two groups have opposing conditions of formation (Shoji et al., 1982; Wada, 1977; Wada et al., 1986; this work, Chapter 2). Apart from primary minerals, among other components that are found in the clay to a greater or lesser extent, are ferrihydrite, (disordered) halloysite and kaolinite, gibbsite and various 2:1 or 2:1:1 layer silicates and intergrades.

Physico-chemical properties

- The ion exchange capacity is highly variable and pH-dependent: the CEC increases with pH whereas the AEC decreases and vice-versa.
- The base saturation is generally low (eutric types and very young soils excepted). When the clay consists dominantly of allophane and imogolite, the pH is relatively high (>5), whereas when the clay consists dominantly of humus-Al and -Fe complexes together with layer silicates, the pH is relatively low (<5) and exchangeable Al is then usually present, sometimes in plant-toxic amounts.
- Strong reaction with fluoride under the liberation of hydroxyl ions.
- Strong affinity for phosphate ions.
- The exchange complex and other reactive sites of Ando soils have been considered to consist dominantly of X-ray "amorphous" compounds of Al, Si and humus. Wada (1980) suggested, however, that it would be more appropriate to ascribe the chemical reactivity of these soils to the dominant presence of "active Al". The active Al may be present in various forms:
  1. Short-range-order or paracrystalline aluminosilicates such as allophane and imogolite;
  2. Interlayer hydroxy-Al ions in 2:1 and 2:1:1 layer silicates;
  3. Al-humus complexes;
  4. Exchangeable Al ions on layer silicates.

  The role of active Fe is generally considered inferior to that of active Al, but should not be neglected.
- The soils are difficult to disperse which gives problems in some analytical procedures, particularly the particle size distribution analysis is often highly unreliable (Van Reeuwijk, 1982; Wada, 1985; Shoji et al., 1988b) and therefore always suspect.
- The bulk density is low, usually less than 0.9 kg/l but values as low as 0.3 kg/l can be found.
- Unless the profiles are very young, the water content at 15 bar pressure is high: >20% (wt/wt) and values well in excess of 100% are not unusual (Flach, 1964).
- Air-drying of the soil material may cause several properties to change irreversibly, e.g. water uptake, ion exchange, volume, aggregation (Colmet-Daage, 1978; Andriesse et al., 1976).

More than half the area of soils derived from volcanic ash is located in tropical regions with widely varying climates. Only recently systematic and quantitative studies on the mineralogy and chemistry with the aim of modern classification and correlation have been initiated. Studies of soils in regions with a pronounced dry season (ustic, xeric, torric) are still rare and/or controversial.

The purpose of the present work is to contribute to an international soil data base the results of analysis of a number of ash-derived soils developed under diverse climatic conditions in various parts of the world.

In Chapter 2, the concept of the binary composition of the clay fraction of Ando soils is elaborated and subsequently, in Chapter 7, verified with the obtained data.

2. FORMATION AND COMPOSITION OF ANDO SOILS

2.1 Introduction

Ando soil formation essentially involves the rapid weathering of the porous permeable fine-grained parent material containing glass and microlites in the presence of organic matter. Depending on the moisture regime, the liberated basic cations are to a great extent washed out whereas Al and Fe ions are bound into stable complexes with humus. In addition, as long as soil conditions are not too acid, Al may also precipitate with Si to form allophane and often imogolite (Wada, 1977) while Fe precipitates as ferrihydrite[1]. Also, under certain environmental conditions, layer silicates of various types may be formed.

The organo-metallic complexes are protected against bio-degradation by the toxicity of Al (Tokashiki & Wada, 1975) as well as by the inaccessibility to enzymes (Tate & Theng, 1980). This protection exerted by Al is no less when it occurs in the form of allophane and imogolite (Wada, 1977). Apparently the activity of Al in these substances is sufficiently high to interact with organic molecules through ligand exchange and hydrogen bonding (Parfitt et al., 1977; Tate & Theng, 1980).

The mobility of the organo-metallic complexes is very limited since the rapid weathering yields sufficient Al and Fe to produce complexes with a high metal/organic ratio rendering them only sparingly soluble (Tate & Theng, 1980).

Humic and fulvic acids seem to play a major role in this process. The ratio HA/FA in Ando soils, although varying considerably, averages about unity. The proportion of fulvic acid tends to be higher in the younger, the wetter and the cooler types irrespective of parent material (Tokudome & Kanno, 1968; Wada & Aomine, 1973); Kononova, 1975: Colmet-Daage, 1978; Goh, 1980; Otowa, 1986). The ratio also tends to decrease with depth in the profile reflecting the somewhat lower stability of fulvic acid complexes as compared with those of humic acid (Kononova, 1975, Colmet-Daage, 1978).

---

[1]Ferrihydrite is the dominant iron oxide mineral in most volcanic ash soils and some of the properties ascribed to "allophane" may in part be due to ferrihydrite. Recent evidence suggests that much, if not all, of the organically bound Fe (as extracted by pyrophosphate) is ferrihydrite-Fe (Childs, 1985).

Clearly, such a combination of factors is pre-eminently suitable for strong accumulation of organic matter in the topsoil. By contrast, in podzols such complexation leads generally to metal-undersaturated complexes which are much more mobile (Tate & Theng, 1980).

The fate of the liberated Si depends largely on the extent to which Al is complexed by the humus. If most or all Al is complexed, the silica concentration of the soil solution increases and, while part of the silica may be leached, another part may precipitate as opaline silica when supersaturation occurs by evaporation (Shoji & Masui, 1971) or by freezing of the soil solution (Ping, 1988). Uncomplexed Al will combine with Si to form allophane and imogolite as well as layer silicates. The conditions for the formation of these minerals will be discussed in the ensuing paragraphs.

2.2 Chemical-mineralogical processes

2.2.1 *Allophane and imogolite vs. Fe- and Al-humus complexes*

In the above it is implied that the Al-humus complexes vs. allophane and imogolite are competitive in their formation and indeed they generally appear to occur in an inverse relationship. Hence, Ando soils may be looked at as having a *binary* chemical-mineralogical composition. It seems that allophane and imogolite are dominant under mildly acid to neutral conditions (pH > ca. 5) whereas Al-humus complexes are dominant under more acid conditions (pH < ca. 5) (Shoji et al., 1982; Shoji & Fujiwara, 1984; Parfitt & Saigusa, 1985; Shoji et al., 1985).

Ugolini and co-workers, studying soil solutions rather than soil solids of Podzols, Ando soils and intermediates, distinguish two types of weathering. As long as the activity of organic acids is relatively low, the pH and weathering is dominated by carbonic acid (pK = 6.3) whereas at relatively high organic acid activity the pH and weathering is dominated by fulvic and other organic acids with protonation constants (pK values) of 4.5-5. The former environment would favour the allophane/imogolite synthesis, the latter that of Fe- and Al-organic complexes (Ugolini et al., 1977; Ugolini & Dahlgren, 1987; Ugolini et al., 1988; Shoji et al., 1988a). Very recently, Gregor & Powell (1988) established four not too well-defined protonation constants of some fulvic acids: pK_1=6.5-6.7 (ca. 8% of total carboxyl acidity), pK_2=5.3-5.6 (ca. 15%), pK_3=3.9-4.8 (20-30%) and pK_4=2.6-2.7 (50-70%).

This would indicate that above pH 5 some complexation should well be possible.

The activity of organic acids in soils is determined by *a.* the content of organic matter and *b.* the supply of bases neutralizing the acid groups and thus controlling the pH.

a. *Content of organic matter*

When organic matter is abundant, its activity can be high unless and until this is reduced by a sufficient supply of bases. Obviously a low content in organic matter implies a low activity of organic acids so that Al and Fe liberated by carbonic acid and hydrolytic weathering cannot (all) be complexed. Therefore, Al-rich residues will be available for combining with Si to form allophane and imogolite and possibly layer silicates. The Fe may precipitate as ferrihydrite. Typical places of low organic matter contents where allophane and imogolite are often abundant are: (1) (very) young volcanic ash soils, (2) B and C-horizons of Ando soils as well as of Podzols and Brown Forest soils and (3) weathering ash and pumice beds with allophane commonly inside the fragments and imogolite as a gel film on the outside (Kanno et al., 1986; Wada & Matsubara, 1968: Wada et al., 1972: Tokashiki & Wada, 1975; Parfitt et al., 1980; 1983; 1984; Parfitt & Saigusa, 1985; Buurman & Van Reeuwijk, 1983; Ugolini et al., 1988; Veniale & Caucia, 1984; Loveland & Bullock, 1976).

b. *Supply of bases, pH*

Relatively high pH values prevail when sufficient bases, notably Ca and Mg, are present to neutralize the carboxyl groups of the organic acids thereby suppressing the formation of complexes with Al and Fe (Schnitzer & Skinner, 1963; Posner, 1964; Van Breemen & Wielemaker, 1974b). The main (natural) factors influencing the pH of the soil would be (1) the nature of parent material, (2) moisture regime and (3) vegetation:

(1) Mafic minerals exhibit a higher buffer capacity than felsic minerals (Van Breemen & Wielemaker, 1974a). The promotion of allophane and imogolite formation by basic parent ash and of Fe- and Al-humus complexes by acidic ash is well-documented (Tokashiki & Wada, 1975; Mizota, 1976; Shoji & Ono, 1978; Kirkman & McHardy, 1980; Shoji et al., 1982; Shoji & Fujiwara, 1984; Parfitt & Saigusa, 1985).

(2) The influence of the moisture regime seems obvious: the higher the leaching rate the lower the concentration of ions will be. The resulting mineralogy, however, is rather unpredictable as the effective rainfall may fluctuate and/or other factors may dominate, e.g. texture and composition

of parent material, stage of development (age) and possible rejuvenation by fresh ash (Wada, 1980; Parfitt et al., 1984; Parfitt & Wilson, 1985).

(3) The effect of vegetation on the weathering of volcanic ash has not been extensively investigated. Natural vegetation ranges widely from dense tropical forest to grasses and apart from producing the all-important organic matter, the vegetation probably influences pedogenesis strongly through interference with the precipitation and moisture regime and by the ion uptake and recycling possibilities of the root system. Ugolini et al. (1988) and Shoji et al. (1988a) studied podzolization under Abies mariesii (a conifer) and andosolization under Miscanthus sinensis (Japanese pampas grass) in the same volcanic ash in N.E. Japan. In view of the considerable difference in temperature and precipitation the striking differences in weathering processes in the A-horizon are difficult to ascribe to the biotic factor alone and a considerable climatic influence must be taken into account. This is supported by a subsequent similar study of soils in volcanic ash in Alaska where climatic differences were negligable. Differences in soil formation under forest and grass were here more subtle, yet indicating the same trend: grasses tend to foster andosolisation whereas forest promotes podzolisation. In fact, a reversal of podzolisation to andosolisation in one profile could be ascribed to a change in vegetation from forest to grass (Shoji et al., 1988b).

The pH of soils will gradually drop when the buffering by minerals (supply of bases) cannot keep pace with the production of organic acids so that part of the acid groups remain unneutralized. Under these conditions more Al and Fe has the opportunity to be complexed leaving less or no Al available for coprecipitation with silica. Under sufficiently acid conditions, previously formed allophane and imogolite may even be attacked since fulvic acids form stronger complexes with Al than silicic acid does (Farmer, 1981). Parfitt & Saigusa (1985) report that in some New Zealand volcanic ash soils (Spodosols and Andepts) allophane was only present when $(Fe_p + Al_p)/C_p$ values were higher than 0.1 (see Section 5.7), hence below this value the organic complexes can be considered undersaturated with Fe and Al. Inoue & Huang (1985, 1986, 1987) found for a number of organic acids that above a certain low concentration of acid the formation of allophane and imogolite is perturbed. It appeared that high molecular weight acids (tannic, fulvic, humic acid) are more effective in this than low molecular weight acids. There is evidence that the former can also form complexes with Si which the latter cannot (Inoue & Huang, 1986).

It is worth noting that the instability of allophane and imogolite does not result from a low pH as such: in the absence of complexing organic acids the optimum pH for imogolite synthesis is around 4.5 (Farmer et al., 1977; Wada, 1987), while acid dispersion at pH 3.5 gives good imogolite specimens (Farmer et al., 1978). That allophane and imogolite can also be formed at higher pH was shown by Farmer et al. (1978) in a volcanic ash soil in Italy with a pH around 6.5.

The experiments by Inoue & Huang (1985) showed that neutralization of the organic acids (by NaOH) reduced the perturbation effect. However, the pH of zero-perturbation was somewhat higher than pH 5, the value reported thusfar for the separation between "allophanic" and "non-allophanic" soils. This is most likely the result of the use of the non-complexed Na-ion. In soils, at higher pH values, Ca and Mg are ubiquitously present, particularly in parent materials that are basic ashes, and since these cations are complexed by organic acids (Schnitzer & Skinner, 1963) they compete much more effectively with Al and Fe for organic ligands than Na does. Perturbation experiments which include the effect of Ca and Mg seem to be indicated.

2.2.2 *Layer silicates of 2:1 and 2:1:1 types*

The acid, "non-allophanic" Ando soils usually contain a considerable amount of 2:1 and 2:1:1 clay minerals. Wada (1980) listed a number of possible sources of these minerals in Ando soils: 1. transformation of ferromagnesian minerals by weathering, 2. formation by crystallization from "amorphous" weathering products, 3. inclusion of layer silicates during eruption of the ash, 4. admixture from underlying paleosol when ash layer is thin, 5. addition of wind-blown materials.

Recent oxygen isotope studies indicated long-distance eolian transport of these layer silicates associated with fine-grained quartz (<50 μm) (Mizota, 1982, 1983; Mizota & Matsuhisa, 1985). Formation of 2:1 clay minerals from feldspars is well-documented (Tazaki, 1982; Tazaki & Fyfe, 1987a,b) while direct formation from volcanic glass (as distinct from indirect formation via allophane, imogolite and/or 1:1 clay minerals) was postulated by Trichet (as quoted by Hetier et al., 1977), Farmer et al. (1978), Shoji et al. (1982) and Shoji & Fujiwara (1984) to occur by a "solid-state alteration" of non-coloured (felsic) glass producing illite. The feasibility of such a process was not substantiated until just recently when Tazaki & Fyfe (1988), with the use of high-resolution TEM, observed rearrangements in natural and synthetic glass frameworks such as 3.3 Å domains and 10 and 14 Å clay precursors.

Chloritization in the soil is favoured by moderately acid conditions (Rich, 1968). This process is inhibited at very low pH since polymerization of Al will not occur then. Acid conditions may also lead to the adsorption of exchangeable Al on the layer lattice clay minerals which have a permanent negative charge; it is not found on allophane ("Alic" subgroups; ICOMAND, 1988).

2.3 The binary composition

The observed pH 5 boundary between allophane/imogolite on the one hand, and the Fe- and Al-humus complexes on the other, cannot be a sharp one by nature. The supplies of organic matter and moisture fluctuate to a greater or lesser extent, the formation and destruction of secondary compounds may show non-equilibrium or hysteresis and heterogeneity of the parent material results in different environments on microscale. Also, the protonation steps (pK-values) of fulvic acids are not well defined as they constitute a heterogeneous mixture of molecules (Gregor & Powell, 1988). In addition, rejuvenation of the profile with fresh ash may drastically change the prevailing conditions and pedogenesis. Small additions will increase the supply of weathereable minerals and glass and consequently the base status and pH. When the soil is buried under a thick overburden of ash, in the original A-horizon the supply of organic matter is virtually stopped and continued mineral weathering and enrichment by the leachate from the overburden may increase the base status and reverse the pH decrease. In the fresh top layer a new profile will start to develop (with an initial organic matter content of 0%).

All these factors and processes contribute to the co-existence of allophane/imogolite and Fe- and Al-humus complexes in most volcanic ash soils. Above pH 5, or thereabouts, the allophane/imogolite association will tend to dominate, below this it is the Fe- and Al-humus association.

In practice, this binary composition is expressed by a continuous range of composition of Ando soils between a pure allophane/imogolite association and a pure Fe- and Al-humus complexes association ("allophanic" vs. "non-allophanic") in which the pure end-members are rare. This composition, being a ratio of the two associations, varies both between and within soil profiles and may be an informative pedogenetic and soil chemical parameter.

The simplest estimation of the binary composition can be obtained by calculating the ratio Al_p/Al_o which ranges from 0 for the pure "allophanic" composition to 1 for the pure "non-allophanic" composition.

(Al_p = pyrophosphate-extractable Al, Al_o = oxalate-extractable Al. The former gives Al in Al-humus complexes whereas the latter includes Al in allophane/imogolite as well as in Al-humus complexes. See also Sections 5.2 and 5.3). This ratio is, in fact, the "active Al" in Al-humus complexes expressed as a fraction of the total active Al. A proper designation would be the "*binary ratio*" of the colloidal composition[1]. This term is, of course, not restricted to Ando soils but could be used for any soil (horizon) with such a binary composition.

In (very) young volcanic soils, the binary ratio can be expected to be close to 0 whereas in the topsoil of a strongly weathered or highly humic and acid volcanic soil the ratio could be close to 1. In well developed Ando soils, the binary ratio should decrease with depth and approaching 0 in the B and C-horizon because of the lower organic matter content, the higher pH and, therefore, the prevailing bicarbonate weathering (Wada, 1977, 1980; Parfitt & Saigusa, 1985; Shoji et al., 1988a,b). The binary composition is schematically represented in Figure 2-1.

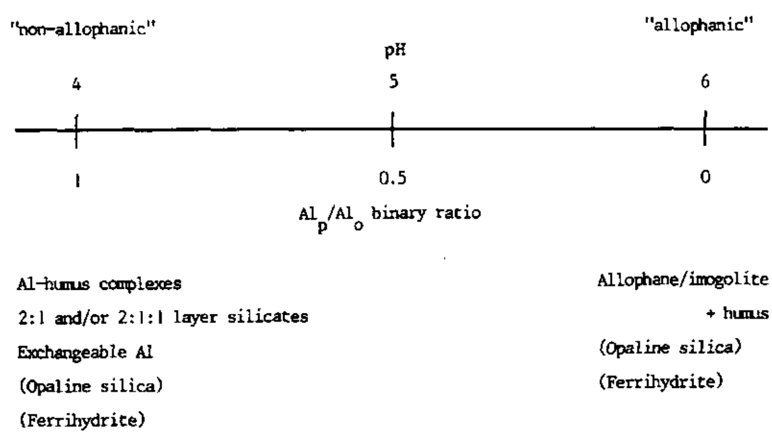

Fig. 2-1. Schematic representation of the binary composition of the clay fraction of Ando soils and the two "components" (associations) involved. Components between brackets may or may not be present.

---

[1]The complementary binary ratio could also be used and is expressed by $(Al_o\text{-}Al_p)Al_o$, i.e. the active Al in allophane as a fraction of the total active Al. The Al_p/Al_o ratio, however, is simpler and has already been reported by a few other workers (Parfitt & Saigusa, 1985; Ping et al. 1988; Shoji et al., 1985, 1988a,b).

The introduction of the concept of binary composition is no more than an expression of the recognition that the composition of the clay fraction of Ando (and related) soils constitutes a continuum between two end-members. It is a useful and necessary refinement of the thusfar employed terms "allophanic" and "non-allophanic" (the end-members) which, in many cases fail to do justice to the actual composition, soil properties, and soil forming processes that have taken place.

Since the binary composition is expressed as a ratio, it gives only a value for the relative proportion of the two components (or associations). For absolute contents these have to be determined individually. At present, this can most successfully be done for allophane (see Section 5.3).

2.4 The fate of Ando soils

When Ando soils mature and the easily weatherable primary minerals become depleted, the typical clay mineralogy throughout the profile changes. Allophane and imogolite may be transformed to halloysite, kaolinite or gibbsite as well as 2:1 type clay minerals depending on the silica potential of the soil solution (Wright, 1964). Also, the Al and Fe from the humus complexes will gradually become available and ferrihydrite will turn into goethite. Naturally, these processes are strongly influenced by the rate of rejuvenation, composition and texture of remaining material, depth and composition of overburden, moisture regime and bioclimatic factors. Eventually, Ando soils may intergrade to or become, for instance podzolic soils (Wright, 1964; Parfitt & Saigusa, 1985; Shoji et al., 1988a,b) or soils with oxic properties (Wada et al., 1986) or with argillization: Acrisols-Nitosols-Planosols/Ultisols (Kenya Soil Survey Staff, 1977, sites 6, 5 and 2 respectively; Naidu et al., 1987).

3. THE COLLOIDAL FRACTION OF ANDO SOILS IN VARIOUS REGIONS OF THE WORLD

3.1 Introduction

The formation and composition of soils in volcanic material, as described in the preceding chapter, apply to the "binary composition" concept Ando soils which are expected to develop under humid and perhnumid conditions. These include the Ando soils that are extensively found and described in many places in the world, regionally (e.g. the Pacific) as well as locally (e.g. Italy) and which fit the central concept of Andisols as given in the final ICOMAND (1988) proposal: "The central concept of an Andisol is that of a soil developing in volcanic ejecta (such as volcanic ash, pumice, cinders, lava), and/or in volcaniclastic materials, whose colloidal fraction is dominated by short-range-order minerals or Al-humus complexes[1]. Under some environmental conditions, weathering of primary alumino-silicates in parent materials of non-volcanic origin may also lead to the formation of short-range-order minerals; some of these are also included in Andisols".

Many older studies on Ando soils, roughly predating 1975, used only qualitative or less selective analytical techniques rather than the modern quantitative and much more selective techniques for the non-crystalline and para-crystalline clay components. A direct matching of the older results with the present central concept is, therefore, often difficult if not impossible. In addition, the occurrence of unusual volcanic ash soils under warmer climates with a dry period (ustic moisture regime) was reported recently. In this chapter, some of this geographical information will be summarized to see whether and under what conditions special features are of interest with reference to the influence of climate and parent ash on the mineralogy of the clay.

For a more general review of Ando soils in the world, the reader is referred to Leamy (1984).

---

[1]Note that Fe-humus complexes are not mentioned. All active Fe is apparently considered to occur as short-range-order ferrihydrite (see footnote p. 5).

3.2 West Indies, Central and South America

Warkentin & Maeda (1974) analysed the mineral composition of ash-derived "allophane" soils from Dominica and St. Vincent islands. Re-examination of the infra-red spectra and X-ray diffractograms of six clay samples from the soils indicated that five were characterized by a predominance of layer silicates associated with quartz. One clay sample from St. Vincent, which has a pronounced dry season, contained halloysite as a major clay constituent.

Extensive clay mineralogical studies have been conducted by ORSTOM on ash-derived soils in the French West Indies, Costa Rica, Nicaragua, Ecuador and Chile (Colmet-Daage, 1978, undated; Colmet-Daage & Lagache, 1965; Colmet-Daage et al., 1972a,b). From these studies a general trend emerged that in addition to varying amounts of allophane and imogolite the contents of 2:1 and 2:1:1 clays and fine-grained quartz increase with increasing rainfall and altitude. The reverse was found for halloysite. In Chile, the subsoils were clearly richer in halloysite and gibbsite than the topsoils and this was ascribed to greater age. In Ecuador, the occurrence of soils with conspicuous quartz and 2:1 type layer silicates in the clay with variable amounts of allophane is confined to the high rainfall areas (4000-5000 mm per annum), whereas those with halloysitic mineralogy are found in drier regions with annual rainfall of 500-1000 mm. More recently, Wada & Kakuto (1985) reported a unique clay mineral association in three Ecuadorian soils on andesitic ash. This consisted of more or less poorly ordered halloysite which they designated as "embryonic halloysite" and a 10 Å mineral which was not halloysite but rather showed similarities with illite. Allophane appeared to be absent. Though the soil moisture conditions were udic, the base saturation of the soils was high and rainfall was lower (1100-2200 mm p.a.) than with the soils with allophane. The formation of embryonic halloysite directly from ash was ascribed to the environment rich in bases and silica.

In Colombia, soils derived from volcanic ash in the Andes under humid to perhumid forest, contain dominantly allophane in the surface horizons which is transformed to halloysite in the subsurface horizons. Any 2:1 clay minerals present could be ascribed to inheritance or *in situ* formation from the ash parent material (Mejia et al., 1968).

In Nicaragua, soils derived from volcanic ash are situated in regions with annual rainfall of 500-2000 mm. The water balance shows the presence of a pronounced dry season of at least four months (ustic moisture regime) (Walter & Lieth, 1967). Out of eleven pedons examined by Colmet-Daage et al. (1970), only one pedon (N92) is characterized by a predominance of allophane, three by a mixed mineralogy of allophane and halloysite and the other seven by a halloysitic mineralogy.

Miehlich (1984) studied the soils derived from andesitic volcanic ash in the high-altitude areas of the Sierra Nevada, Mexico. In toposequences he found that as the climate became drier the amount of allophane decreased because of the lower weathering intensity; this was accompanied by a stronger crystallization of halloysite.

In El Salvador, Vertisols are found in quaternary pyroclastic deposits under an ustic moisture and isohyperthermic temperature regime (Yerima et al., 1987). The mean annual rainfall is ca. 1700 mm which falls mainly within half a year. The clay consists for 14-28% of "amorphous material" (as dissolved by 0.5 M NaOH). The question arises whether these soils are matured Ando soils or whether smectitic clay has predominated from the beginning under influence of the pronounced dry and wet seasons.

3.3 Pacific Areas

On the North Island of New Zealand, Parfitt and co-workers found an inverse relationship between allophane and halloysite depending upon the rate of leaching and amount of available silica (Parfitt, et al. 1983; Parfitt, et al., 1984; Parfitt & Wilson, 1985). At a high leaching rate (ann. prec. >2600 mm) in rhyolitic ash allophane is formed whereas a lower precipitation (<1200 mm ann.) resulted in halloysite. In an intermediate case, a mixed mineralogy of allophane/halloysite was found. In less acidic andesitic ash, allophane was formed even at relatively low leaching rates (<1200 mm ann.), halloysite appearing only at depth where coarser glass and pumice particles locally maintain a high silica concentration. They noticed that when the ratio halloysite/allophane increased the compositional ratio Al/Si of allophane decreased. In the absence of halloysite, under relatively Si-poor conditions, allophane has a high alumina content (imogolite-like allophane, atomic ratio Al/Si = 2 or molar ratio $SiO_2/Al_2O_3 = 1$); but with the appearance of halloysite allophane becomes richer in silica and its silica content may approach or even exceed that of halloysite (Al/Si = 1 or $SiO_2/Al_2O_3 = 2$).

Under seasonal moisture deficit and moderate rainfall (1200 mm per annum) in the Waikato region, New Zealand, Lowe (1986) noticed accumulation of Si in the form of cristobalite and the formation of halloysite.

Parfitt & Wilson (1985) found evidence that halloysite is not necessarily always formed by crystallization from allophane or imogolite but may also form directly from ash. Also in New Zealand, the occurrence of Al-humus complexes, opaline silica and 2:1/2:1:1 layer silicates, usually with only small amounts of fine-grained quartz, seems to be fairly widespread as can be inferred from analytical data of a number of profiles in ash (Parfitt et al., 1980).

Hassan et al. (1975) studied two Eutrandepts, a Dystrandept and a Hydrandept derived from basaltic volcanic ashes of Mauna Loa, Hawaii. They found only slight differences in the clay mineralogy among these Great Groups with allophane and kaolin (halloysite?) the common clay minerals. More recently, Wada et al. (1986) analyzed four soils from Maui, Hawaii: three Ustands and a Udand (ICOMAND, 1983). All three Ustands had allophane/imogolite and ferrihydrite as well as Al-humus (and Fe-) complexes in inverse amounts. They also contained some halloysite, but the least amount occurred in the most base-desaturated profile which also possessed the highest relative content of metal-humus complexes. Some active Al (Al_o) remained in the Udand but there was more active Fe (Fe_o) and, unusually, organically bound Fe (Fe_p) exceeded Fe_o (see also Chapter 5). In this profile where allophane was absent, the pH was significantly lower than in the Ustands with goethite and hematite present rather than ferrihydrite, and kaolinite had appeared at the expense of halloysite. This soil had the lowest base saturation of all four and clearly had oxic properties. Weatherable minerals in silt and fine sand had fallen in amount to less than 10% in the Udand and in two of the Ustands. All profiles contained 2:1/2:1:1 type layer silicates but the sharp X-ray reflections and the presence of fine-grained quartz suggested that they had, at least in part, an eolian origin.

Parfitt et al. (1988) found that rainfall and desilication is critical in mineral weathering on Hawaii. A perudic moisture regime and good drainage gave rise to a predominance of ferrihydrite with considerable amounts of allophane and gibbsite (Hilo and Akaka series, basaltic ash, good drainage), a udic moisture regime led to a predominance of allophane (Kukaiau series) whereas an ustic moisture regime resulted in mainly halloysite (Waimea series).

On Vanuatu (New Hebrides), Quantin et al. (1975) report on the pedogenesis of Ando soils in three different climatic zones. Under perhumid conditions bases are leached and ferralization occurs while silica is still available from young basic ash. This leads to abundant "amorphous" substances and, in the B-horizon, imogolite, gibbsite and boehmite. Halloysite was conspicuously present in the A-horizon. Under humid conditions a high base status was preserved which, together with the high silica supply, led to the formation of allophane and some halloysite in the A-horizon. In the B-horizon halloysite is increased at the expense of allophane while also some 2:1 type clay minerals appear. When the climate tends to ustic (with a dry period) the high base and silica concentrations results in the formation of smectites, particularly in the B-horizon, in addition to allophane. The smectites seem to form directly from basaltic glass. Halloysite is present in small amounts. All profiles contain opaline silica (diatoms) decreasing in amount with depth.

3.4 East Africa

Where conditions are favourable (volcanic ash, udic moisture regime) well-developed Ando soils, with and without exchangeable Al, occur in East Africa, e.g. in Tanzania on Mt. Kilimanjaro (National Soil Service Project, 1985) and in Kenya in Kimakia forest and Kiarutara, Muranga District (Kenya Soil Survey Staff, 1977).

In soils on the eastern slopes of the volcanic Aberdares mountain, Kenya, Theissen (1966a,b) found that quartz in the silt fraction and 2:1/2:1:1 type clay minerals together with "amorphous material" increased with increasing rainfall and altitude.

In Rwanda, in basic ash under udic to perudic conditions, central concept Ando soils are found (Mizota & Chapelle, 1988). The profiles showed a good correlation of the binary composition of horizons with pH. Halloysite was commonly found and increased in quantity with depth. Only the most acid topsoils contained 2:1:1 clay minerals.

By contrast, Wielemaker & Wakatsuki (1984) and Wakatsuki & Wielemaker (1985) describe Ando soils from the Great Rift Valley, Kenya which have the morphology of Andosols/Andepts but with too weakly developed properties to classify them as such: active-Al, pH-NaF and phosphate retention were all relatively low. Yet, the clay fractions were largely "X-amorphous" and were reported to consist of poorly ordered siliceous Fe-oxides rather than of allophane. All clays contained halloysite. Kaolinite increased with silt-size quartz (2-20 μm) and with decreasing amount of volcanic glass and hence with advancing stages of weathering. This particular clay mineralogy was attributed to the peralkaline siliceous nature of the trachytic ash and, in part, to the drier moisture regimes. Similar conditions may be responsible for the "immature" ash soils found in W. Sudan by White (1967) which contain kaolinite, illite, and clay-size quartz (and even some gibbsite and smectite) but no allophane.

Subsequently, by studying five other profiles in the same trachytic ash in Kenya, Wada et al. (1987) demonstrated the presence of embryonic halloysite in profiles of drier regions analogous to a situation found in Ecuador (Wada & Kakuto, 1985). In contrast to the profiles with embryonic halloysite, a related profile under more humid conditions had developed into a "true" Ando soil of the acid type with an association of Al-humus complexes + 2:1/2:1:1 layer silicates + kaolin + gibbsite + quartz in the clay. The conditions for the formation of embryonic halloysites may be summed up as semi-arid to sub-humid climate, high silica concentration of the soil moisture, high base status of the soil and a relatively high pH (>5.9). Such conditions could well occur during the dry season when through evaporation the soil solution becomes highly concentrated in dissolved components (seasonal resilication).

The present senior author and co-workers recently studied climosequences in volcanic ash of various compositions in Kenya and Tanzania. The picture that emerged largely coincides with that drawn above by Wada et al. (1987). Under wet conditions (perudic, udic) soils with relatively high active Al (Al-humus complexes and to a lesser extent allophane) and organic matter contents are formed. With decreasing rainfall (udic/ustic, ustic and aridic moisture regimes) contents of active Al and organic matter are reduced and the clay mineralogy becomes dominantly halloysitic/kaolinitic. The wetter types have lower pH and lower base saturation values than the drier types (Mizota, 1987; Mizota et al., 1988). At higher elevations (and therefore higher rainfall) the soils appeared to contain substantial amounts of 2:1 and 2:1:1 layer silicates covarying with fine-grained quartz of eolian origin. The specific influence of the petrological nature of the parent ash on weathering has yet to be established.

In the drier profiles, a particular type of smectite with a curly morphology was detected, displaying distinct (*hk*0) reflections but very weak basal reflections caused by poor layer stacking. At least in some of the profiles smectite seemed to be a major weathering product (Van der Gaast et al., 1986; Mizota, 1987). As yet, no possible link was made with embryonic halloysite which supposedly forms under similar conditions.

3.5 Europe

On basalts and in basaltic scoria deposits of the French Massif Central, Ando soils, in which allophane and imogolite predominate, prevail only in the areas where the monthly precipitation exceeds the monthly evapotranspiration in all months (perudic moisture regime), while "sols bruns" in which layer silicates predominate develop in the regions with a dry season (Hetier, 1975; Mizota, 1981).

Bech Borras et al. (1976a,b) analysed the clay minerals of three Ando soil pedons developed in basaltic scoria and lapilli near Olot, Spain, where the soil moisture regime is perudic. Contents of Al-vermiculite and kaolinite, associated with fine-grained quartz are high in the A-horizon but they are absent in B and C-horizons, while "allophane" (which dissolves in alternating treatments with 8 M HCl and 0.5 M NaOH) was a major clay constituent throughout the profile.

Also in Spain, Ando soils have developed on non-volcanic but easily weatherable parent rocks such as gabbros, amphibolites, and fine-grained schists rich in biotite (Garcia-Rodeja et al., 1987). The soils are well drained and formed under a udic moisture and mesic temperature regime. The colloidal fraction of all soils is dominated by Al-humus complexes and 2:1/2:1:1 phyllosilicates. In addition, they contain varying amounts of halloysite and gibbsite in an inverse relationship with the humus content. The soils have appreciable amounts of exchangeable Al, even at pH-H_2O values of 5.6. Allophane contents are low, also where pH values are well above 5. The Fe_o/Fe_d "activity ratios" are rather low (<0.4) indicating a lower weathering rate as compared with volcanic ash. This is also indicated by the absence of allophane in the subsurface horizons.

Violante & Tait (1979) and Violante & Wilson (1983) studied the clay mineralogy of Ando soils in central-southern Italy which has a temperate humid climate but with locally very variable (montane) conditions both in climate and in parent material. In soils in basic tephra (which is silica-undersaturated) allophane and (proto)imogolite are formed whereas in soils on basic and intermediate ignimbrites (some with quartz, and thus silica-oversaturated) well-developed imogolite is found associated with halloysite, gibbsite, and mica/illite as well as poorly crystalline vermiculite/smectite intergrades, but no allophane. They conclude that the "classical" processes occur (Wada, 1977): the weatherable minerals released silica and alumina which precipitate as imogolite or as proto-imogolite allophane. The latter gradually converts to halloysite particularly in the deeper horizons where silica tends to accumulate as a result of poorer drainage. Although halloysite is formed throughout the profile, dehydration near the surface may take place leading to formation of poorly crystalline kaolinite. Gibbsite is thought to form by local desilication of amorphous materials. The illite is likely to be inherited from the parent material whereas the 14 Å species is of pedogenetic origin.

Lulli et al. (1983) analysed the clay mineral composition of two Andic soils developed from pyroclastic materials in the same area in Italy. The major clay mineral of the Roccamonfina pedon (altitude: 750 m) formed in trachyandesitic scoria was halloysite with small amounts of allophane in the topsoil. In the Vulture pedon (altitude: 1250 m) in trachybasaltic ash under a colder and more humid climate, allophane was an abundant constituent. In the Roccamonfina pedon, micaceous minerals were observed in the surface horizons, in which quartz is an abundant silt-size mineral. A weak but distinct dry season occurs in summer at the lower altitude where the Roccamonfina pedon is situated (Lulli and Bindini, 1980).

Quantin et al. (1984) compared two Ando soils in the same region near Lake Vico, Italy. Both profiles are formed in trachytic ash. However, the ash of the one profile (Mte. Fogliano) is slightly more acidic than that of the other (Mte. Venere) while the former has a somewhat wetter and cooler exposure than the latter. This appeared to be sufficient for a significantly different pedogenesis. The Mte. Fogliano soil shows an accumulation of raw organic matter on the surface and deep penetration of humic and fulvic acids, without formation of a B-horizon. The soil is fairly acid and rich in Al- and Fe- organic complexes next to Al-rich allophane. Some podzolic features are present though not conspicuously. The Mte. Venere profile has no accumulation of raw organic matter on the surface, penetration of humic and fulvic acids is limited to the upper part of the soil, the pH is higher and allophane predominates over the organo-metallic complexes. The clear B-horizon contains small amounts of cryptocrystalline Fe-oxihydroxide (ferrihydrite?). The clays of both profiles contain only traces of halloysite and 2:1 layer silicates; only in the C-horizon of both, in the relative absence of organic substances, halloysite is abundantly formed by ageing.

A general description of Ando soils on Iceland is given by Gudmundsson & Dellé (1986). These soils are in an early stage of weathering and therefore have vitric properties (ICOMAND, 1983). They have 3-8% of organic matter, a high base saturation and only up to 6% clay. The weathering results in formation of allophane and an excess (opaline) silica.

3.6 North America

Klages (1978) analysed samples of 21 soils formed in volcanic materials of diverse age in the cold and humid climate of the Montana mountains. Since he used X-ray diffraction to determine the clay mineralogy, his information was limited to a characterization of the dominant clay minerals only. In recent ash: "amorphous" clays; Quaternary material: "amorphous" to poorly crystalline 2:1 clays; Tertiary: smectite clays; Cretaceous: mixed or interstratified 2:1 clays.

More recently, Baham & Simonson (1985) analysed 14 pedons from the uplands of coastal Oregon with a udic isomesic to mesic moisture and temperature regime. Seven of these pedons met the criteria of the Andisol proposal (ICOMAND, 1984) and the data indicated that they were true central concept Ando soils with Al-humus complexes dominating in the topsoil and decreasing in content with depth and inversely related to allophane content. They were found to be comparable with "nonallophanic" Ando soils of N.E. Japan (Shoji & Fujiwara, 1984). The pedons formed in basaltic material appeared to have high ferrihydrite contents (ca. 5%). Parfitt (1985) suggested that ferrihydrite should be taken into account in the classification of Andisols.

Hunter et al. (1987) report a non-volcanic Ando soil in the State of Washington. This soil has all the physical-chemical characteristics of an Ando soil but is formed in material containing only 10% glass. The clay fraction consists of various clay minerals but dominantly interstratified 2:1/2:1:1 types. Active Al amounts to about 2.5% in both the A and B-horizon and occurs mainly as Al-humus complexes. The Fe_o figures in all horizons are about 1.5 times higher than Al_o. The Fe_o/Fe_d "activity" ratio in the A and B-horizon is relatively low and ranges from 0.3-0.4. While pH-values are close to 5, exchangeable Al is present in significant amounts, particularly in the subsurface horizons. This peculiar situation was ascribed to alteration of inherited clay under predominantly moist conditions and a mild temperature in the presence of abundant of organic acids. This would lead to weathering of primary minerals and phyllosilicate clay to form metal-humus complexes and hydrous oxides of Fe, Al and Si.

In S. Alaska, Ando soils are widespread in volcanic ash parent materials. A general description of these soils, all formed under grass vegetation and a udic cryic moisture regime, was given by Simonson & Rieger (1967). More detailed information was obtained by two more recent studies. Ping et al. (1988) describe soils from the Aleutian Islands and Alaska Peninsula and found that the colloidal fraction of the topsoils has a mixed composition of Al-humus complexes and allophane with Al_p/Al_o binary ratios not exceeding 0.7. The corresponding pH values were all well above 5. Chloritized 2:1 clay minerals are abundant and a little exchangeable Al was noticed. Allophane contents increase with depth covarying with an increase in pH. Shoji et al. (1988b) describe Ando soils on the somewhat more northerly situated Kenai Peninsula with slightly lower temperatures and less precipitation. At these sites the topsoils are more acid and the colloidal fraction is dominated by Al-humus complexes (Al_p/Al_o = 1 or near to 1). A considerable amount of exchangeable Al is present and chloritization of the 2:1 clay minerals seems to be limited to the subsurface horizons. As mentioned earlier in Section 2.2.1, when the vegetation in this area is not grass but forest, these soils are considerably more acid and have developed into Podzols rather than Ando soils.

3.7 China

In China with its about 200 volcanoes which were active in recent geological periods, Ando soils occur locally but widespread in roughly the eastern half of the country including the island of Hainan. The soil forming conditions vary widely with elevations ranging from 15 to 2600 m, climatic conditions from tropic to temperate and eruptive periods from Miocene to 1720 A.D. Characterization of these soils has just begun and available data are therefore limited. This little information, however, indicates that the genetic characteristics of volcanic ash soils in China are similar to those in other regions of the world (Liu Chaod, 1985; Zhao Qi-guo, 1988).

3.8 Arid regions

Soils formed in pyroclastic material under relatively dry conditions have undergone only limited weathering and profile development. They may occur in locally dry conditions, such as in Kenya and Tanzania, or more extensive dry regions such as in the Middle East.

A well-described and analysed example of a soil formed under local aridic conditions and qualifying as Andisol (see Chapter 4) is the Guinate profile on the Canary Island of Lanzarote (Depto. Edafologia, Univ. de La Laguna, 1984; Parfitt, 1985). This profile developed under only 170 mm annual rainfall and contains about 3.5% allophane, 3% ferrihydrite and 3% organic matter and is several thousand years old. The base saturation is 100%

and the pH above 8 due to weak salinity. The A-horizon and the weakly developed B-horizon have positive NaF reactions (see Chapter 5).

Volcanic ash soils from a dry region in Syria were described by Osman et al. (1985). Two essentially AC profiles have developed under a torric (aridic) and xeric moisture regime respectively. Both qualified as Andept (Soil Survey Staff, 1975). Although the analyses for Andisol classification were not complete yet, active Al and organic matter appeared to be low. The torric profile was calcareous and gypsiferous whereas the xeric profile was only calcareous. The clay content of the A-horizon was in both cases about 13%, the clay mineralogy was not given however.

3.9 Summary

From the foregoing paragraphs the conclusion is drawn that under humid and perhumid conditions volcanic ash weathers mainly to allophane and imogolite when the soil environment is neutral to mildly acid and to Al-humus complexes in a more strongly acid conditions. Ferrihydrite and more or less poorly crystalline layer silicates are usually formed as well. From recent information it is evident that the composition of the colloidal fraction of Ando soils formed under humid and perhumid conditions is in fact a continuum between the pure allophane/imogolite association and the pure Al-humus complexes association. This we termed the "binary composition" of the colloidal fraction.

Under less humid conditions with the occurrence of a dry season only small amounts of Al-humus complexes and/or allophane and imogolite are accumulated while substantial amounts of halloysite and authigenic 2:1 clay minerals are formed by seasonal resilication.

4. CLASSIFICATION AND THE ANDISOL PROPOSAL

4.1 Introduction

The classification of Andosols on an international scale has been achieved mainly with the FAO-Unesco Soil Map of the World Legend (FAO-Unesco, 1974) or with Soil Taxonomy (Soil Survey Staff, 1975). Increased knowledge necessitated and facilitated considerable improvements in these systems and since about 1978 specialist working groups are operational in developing such improved systems. These groups are the "International Committee on the Classification of Andisols" (ICOMAND for Soil Taxonomy; ICOMAND, 1979) and the "International Reference Base for Soil Classification" Working Committee No. 11: Andic Soils (ISSS-IRB Working Committee) (Luzio-Leighton, 1985).

The emphasis in the classification criteria volcanic-ash derived soils has changed with time. Notably the concept "exchange complex dominated by amorphous materials" (ECDAM) in Ando soils, Andepts (Soil Survey Staff, 1975) and Andosols (FAO-Unesco, 1974) was increasingly criticized as the knowledge of clay mineralogy improved. It was therefore duly replaced by the "andic soil properties" concept (ICOMAND, 1983, and subsequent adaptations). An extensive account of the nature of Andic (and Vitric) materials was given by Parfitt (1984). Details of the development of the proposals will not be discussed here, the reader is referred to the respective Circular Letters of the working groups. At present, the ICOMAND proposal seems to have reached maturity and it is considered useful to reproduce here the essentials of the final proposal before publication of the new Order of Andisols (ICOMAND, 1988). The Revised Legend of the FAO-Unesco Soil Map of the World (FAO, 1988) also makes use of the definition of "andic soil properties" as developed by ICOMAND, to define "Andosols" on the Map.

For a good understanding of the background of the new Order of Andisols, its concept as well as that of andic soil properties is quoted in full. The key is given to Suborder Level. The Suborders and Great Groups are listed in Table 4-1.

After that, the soil units of the major soil grouping Andosols in the Revised Legend of the FAO-Unesco Soil Map of the World are described followed by the key.

4.2 Definition of Andisols

"The central concept of an Andisol is that of a soil developing in volcanic ejecta (such as volcanic ash, pumice, cinders, lava), and/or in volcaniclastic materials, whose colloidal fraction is dominated by short-range-order minerals of Al-humus complexes. Under some environmental conditions, weathering of primary alumino-silicates in parent materials of non-volcanic origin may also lead to the formation of short-range-order minerals; some of these soils are also included in Andisols.

The dominant process in most Andisols is one of weathering and mineral transformation. Translocation within the soil, and accumulation of the translocated compounds, are normally minimal. Nevertheless, accumulation of organic matter, complexed with aluminium, is characteristic of Andisols in some regimes.

Weathering of primary alumino-silicates has proceeded only to the point of formation of short-range-order minerals such as allophane, imogolite and ferrihydrite. Commonly, this state has been perceived as a stage in the transition from unweathered to more weathered volcanic material characteristic of some other soil orders. However, under some conditions the short-range-order minerals achieve a stability that allows them to persist with no or only very slow further alteration over long periods.

Andisols may have any diagnostic epipedon, provided the minimum requirements for the order are met in and/or below the epipedon. Andisols may also have any kind of soil moisture and temperature regime and as such may occupy any position in the landscape and at any elevation.

Andisols meet the requirements for mineral soils; this differentiates them from the Histosols which are organic soils by definition.

Andic soil properties are commonly exhibited within the top 60 cm of the mineral soil, in a layer at least 35 cm thick, except where a lithic or paralithic contact occurs at a depth shallower than 35 cm. The soil may have any kind of diagnostic horizon characteristic for other soils below the 35 cm layer. This is the minimum expression of andic soil properties required for the order. The soils are considered Andisols if the criteria for thickness and position of the Andic layer or layers are met, irrespective of the nature of the underlying material or horizons.

Cultivation of the soil, as in puddling of the surface 25 cm for paddy, may change some of the physical properties of the upper soil, such as bulk density. The presence, below this disturbed zone, of a layer at least 35 cm thick having andic soil properties will place the soil into Andisols. Many Andisols are stratified; to be considered as Andisols, the layers which meet the requirements for andic soil properties must have a cumulative thickness of at least 35 cm within the upper 60 cm. In many locations, materials of volcanic origin may be contaminated by other materials such as loess or alluvium; the minimum expression of andic soil properties again differentiates the Andisols.

In Spodosols, weathering in the surface horizons and release of iron and aluminium are accompanied by the subsequent translocation and accumulation of these elements in a lower (spodic) horizon, often accompanied by organic matter. Translocation of such compounds is minimal in Andisols, and Andisols are therefore differentiated from Spodosols by the absence of an albic horizon, or fragments of such a horizon, with an associated spodic horizon. Materials with andic soil properties may otherwise meet the requirements of spodic horizons.

Extreme weathering, as in Oxisols, may result in a product with some of the physico-chemical properties of materials with andic soil properties. However, oxic horizons are differentiated from horizons with andic soil properties in that the latter commonly contain an appreciable quantity of weatherable minerals such as glass, feldspars or ferro-magnesian minerals and the former do not commonly contain allophane or Al-humus in significant amounts.

Andisols are permitted to have an aridic soil moisture regime, and the soils are considered Andisols if the minimum expression requirements are met. Secondary accumulation of carbonates, gypsum and salts may be present in such Andisols.

Horizons with andic soil properties frequently meet the requirements for a cambic horizon and would otherwise be included in Inceptisols. Andisols are differentiated by the nature of the weathering product which is dominated by short-range-order materials rather than by crystalline clay minerals.

The minimum acceptable degree of weathering separates Andisols from the largely unaltered mineral soils included in Entisols. The minimum degree of weathering is expressed in chemical terms in the definition of andic soil properties and corresponds to the presence of a minimum amount of short-range-order material."

4.3 Andic soil properties

To have andic soil properties, the soil material must meet one or more of the following three requirements:

1. a. $Al_o + \frac{1}{2} Fe_o \geq$ 2.0% or more, *and*
   b. Bulk density of the < 2 mm fraction, measured at 1/3 bar water retention, $\leq$ 0.90 g/cm, *and*
   c. Phosphate retention > 85%; *or*

2. a. More than 60% by volume of the whole soil is volcaniclastic material > 2 mm, *and*
   b. $Al_o + \frac{1}{2} Fe_o \geq$ 0.4% in the < 2 mm fraction *and*
   c. Phosphate retention > 25%; *or*

3. The 0.02-2 mm fraction is at least 30% of the < 2 mm fraction and meets one of the following three requirements:
   a. If the < 2 mm fraction has:
   phosphate retention > 25% *and*
   $Al_o + \frac{1}{2} Fe_o \geq$ 0.4%
   there is at least 30% volcanic glass[1] in the 0.02-2 mm fraction, *or*
   b. If the < 2 mm fraction has:
   $Al_o + \frac{1}{2} Fe_o \geq$ 2.0%
   there is at least 5% volcanic glass in the 0.02-2 mm fraction, *or*
   c. If the < 2 mm fraction has:
   0.4% < $Al_o + \frac{1}{2} Fe_o$ < 2%
   there is at least a proportional content of volcanic glass in the 0.02-2 mm fraction between 30% and 5% (see figure 4-1)[2].

---

[1]Definition and assessment of volcanic glass is being developed.

[2]The content of glass in this requirement can also be expressed as: % glass > 35-15 (Al_o + ½ Fe_o)

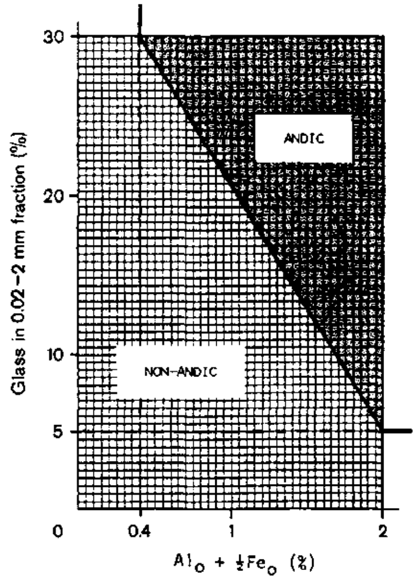

Fig. 4-1. Graphical representation of andic soil properties requirement 3c (from ICOMAND, 1987).

4.4 Order, Suborders and Great Groups

Key to Soil Orders

[Note: Andisols will key out after Histosols in the Key to Soil Orders]

A. Soils that .... (p. 91-92, USDA, 1975) HISTOSOLS

B. Other soils that
   1. Have andic soil properties
      a. Throughout all subhorizons, whether buried or not, which make up a thickness of 35 cm or more within 60 cm of the mineral soil surface, or
      b. Throughout 60% or more of the total soil thickness if a lithic or paralithic contact occurs within 60 cm of the mineral soil surface, and

   2. Do not have an albic horizon, or remnants of an albic horizon, with an associated spodic horizon, unless it occurs below the depth of the total thickness required in 1.

ANDISOLS

Key to Suborders

BA. Andisols that have experienced periods of saturation and reduction as evidenced by one or more of the following throughout a subhorizon with an upper boundary at less than 50 cm:
1. Two percent or more redox segregations[1]
2. Dominant chromas, moist, of 1 or less on ped faces, or in the matrix if peds are absent, other than in any horizon that has colour values, moist, of 3 or less.
3. Sufficient active ferrous iron to give a positive reaction to a, a'-dipyridyl[2] within 50 cm of the soil surface at some time of the year. AQUANDS

BB. Other Andisols that have a cryic or pergelic soil temperature regime. CRYANDS

BC. Other Andisols that have an aridic moisture regime. TORRANDS

BD. Other Andisols that have a xeric moisture regime. XERANDS

BE. Other andisols that have 1500 Pa water retention of less than 15% on air-dried samples and less than 30% on undried samples, as follows:
a. Throughout a thickness of 35 cm or more within 60 cm of the mineral soil surface, or
b. Throughout all subhorizons 60% or more of the total soil thickness if a lithic or paralithic contact occurs within 60 cm of the mineral soil surface. VITRANDS

BF. Other Andisols that have an ustic soil moisture regime. USTANDS

BG. Other Andisols. UDANDS

---

[1]Redox segregations, e.g., mottles and concretions, are formed as a result of the reduction and solubilisation of iron and/or manganese, their translocation, concentration, and their re-oxidation and precipitation in the form of oxides.

[2]A positive reaction to the dipyridyl field test for ferrous iron (Childs, 1981) may be used to confirm the existence of reducing conditions, and is especially useful in situations where, despite saturation, normal morphological indicators of such conditions are either absent or obscured (as by the dark colours characteristic of melanic great groups). A negative reaction, however, does not imply that reducing conditions are necessarily, or always, absent; this may merely mean that the level of free iron in the soil is below the sensitivity limit of the test or that the soil is in oxidised phase at the time of testing.

Table 4-1. Division and subdivision of Andisols (ICOMAND, 1988).

ORDER	ANDISOLS						
SUBORDERS	AQUANDS	CRYANDS	TORRANDS	XERANDS	VITRANDS	USTANDS	UDANDS
	Cryaquands	Gelicryands	Lithic Torrands	Vitrixerands	Ustivitrands	Durustands	Placudands
	Placaquands	Hydrocryands	Duric Torrands	Haploxerands	Udivitrands	Haplustands	Durudands
Great Groups	Duraquands	Vitricryands	Petrocalcic Torrands				Melanudands
	Vitraquands	Haplocryands	Aquic Torrands				Fulvudands
	Melanaquands		Calcic Torrands				Hydrudands
	Haplaquands		Typic Torrands				Hapludands

4.5 Andosols in the FAO-Unesco Revised Legend

The description of the major soil grouping Andosols and its soil units in the Revised Legend of FAO-Unesco Soil Map of the World (FAO, 1988, p. 40) has adopted the andic soil properties concept as used for Andisols and described in Section 4.3.

1. Description

ANDOSOLS (AN)

Soils showing andic properties to a depth of 35 cm or more from the surface and having a mollic or an umbric A horizon possibly overlying a cambic B horizon, or an ochric A horizon and a cambic B horizon; having no other diagnostic horizons; lacking gleyic properties within 50 cm of the surface; lacking the characteristics which are diagnostic for Vertisols; lacking salic properties.

Haplic Andosols (ANh)	Andosols having an ochric A horizon and a cambic B horizon; having a smeary consistence and having a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.
Mollic Andosols (ANm)	Andosols having a mollic A horizon; having a smeary consistence, and having a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.
Umbric Andosols (ANu)	Andosols having an umbric A horizon; having a smeary consistence and having a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.

Vitric Andosols (ANz)	Andosols lacking a smeary consistence or having a texture which is coarser than silt loam on the weighted average for all horizons within 100 cm of the surface, or both; lacking gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.
Gleyic Andosols (ANg)	Andosols showing gleyic properties within 100 cm of the surface; lacking permafrost within 200 cm of the surface.
Gelic Andosols (ANi)	Andosols having permafrost within 200 cm of the surface.

2. Key

Andosols key out after Histosols, Anthrosols, Leptosols, Vertisols, Fluvisols, Solonchaks and Gleysols respectively (FAO, 1988, p. 70):

ANDOSOLS (AN)

Andosols having permafrost within 200 cm of the surface.
Gelic Andosols (ANi)

Other Andosols showing gleyic properties within 100 cm of the surface.
Gleyic Andosols (ANg)

Other Andosols lacking a smeary consistence, or a texture which is silt loam or finer on the weighted average for all horizons within 100 cm of the surface, or both.
Vitric Andosols (ANz)

Other Andosols having a mollic A horizon.
Mollic Andosols (ANm)

Other Andosols having an umbric A horizon.
Umbric Andosols (ANu)

Other Andosols.
Haplic Andosols (ANh)

5. CHEMICAL CHARACTERIZATION OF ANDO SOILS

"Amorphous" constituents of soils have been shown to have a disproportionally strong influence on soil physico-chemical behaviour, both in volcanic ash soils and other soils, so many attempts have been made to develop methods for quantitative analysis of these materials. The usual instrumental analytical techniques such as X-ray diffraction, differential thermal and thermogravimetric analysis and infrared absorption are suitable only to a limited extent, particularly in multicomponent materials, which soil clays usually are. These techniques are, moreover, not always readily available for routine analysis. Consequently, chemical methods were used.

Chemical methods of analysis may be divided into *reactivity* and *dissolution* methods. Reactivity methods make use of a specific chemical or physical reaction upon addition of a reagent whereas dissolution methods are aimed at selectively dissolving one or more components and leaving other unaffected. A number of these methods with special reference to Ando soils will briefly be discussed.

5.1 Reactivity methods

CEC delta value. The highly pH-dependent charge has been used to characterize Ando soils by determining the CEC delta value, i.e. the difference in CEC determined at a low and high pH. Aomine & Jackson (1959) used this for calculation of the allophane content whereas Quantin (1982) and Van Reeuwijk & Van Oostrum (1986) proposed methods for this determination in order to employ the CEC delta value as a criterion in classification. The "variable charge ratio" was part of the abandoned ECDAM concept (ICOMAND, 1979) and it would seem that the determination of variable charge has more future as an agrotechnological parameter, as proposed by Gillman (1987) and Gillman & Sinclair (1987), than as a classification criterion although these two uses may well go together.

Fluoride reaction. The hydroxyl groups of the various components in Ando soils containing active Al react strongly with fluoride ions (ligand exchange). The release of OH can be employed in a field test with phenolphtalein-impregnated filter paper or in the laboratory by measurement with a pH meter (Fieldes & Perrot, 1966; Perrot et al., 1976). For a considerable time the pH-NaF has been used as part of the ECDAM concept (pH >9.4 when 1 g soil is stirred for 2 minutes with 50 ml 1 M NaF). Due to a number of shortcomings, notably the positive reaction with materials other than active Al (gibbsite, carbonates) the test was dropped as criterion for classification. However, it remains useful for monitoring purposes.

Phosphate retention. The high affinity of active Al and Fe components for phosphate is used to characterize Ando soils and to quantify this activity. Basically two procedures are being employed. The "Japanese" procedure in which the P-uptake is measured by 50 g soil from 100 ml 2.5% ammonium phosphate pH 7 (Wada, 1986, p. 119) and the method of Blakemore et al. (1981, 1987) in which is measured the proportion (in %) of phosphate withdrawn from 25 ml 1000 mg P/l solution of potassium dihydrogen phosphate (pH 4.6) by 5 g soil. The latter method was adopted for the phosphate retention criterion in "andic soil properties" of the ICOMAND proposal (see Chapter 4).

A weakness of the procedure would seem to be the omitting of a correction for the moisture content of the used air-dry sample material. Air-drying Ando soil samples may result in highly variable and often high moisture contents, particularly when not enough time is allowed. Therefore, for better accuracy and reproducibility the introduction of a moisture correction is suggested.

Note 1: The Blakemore method can be considered chemically the most sensitive of the two since at lower pH the active Al has a higher reactivity than at higher pH. It is unfortunate, however, that most "true" Ando soils have P-retention values well in excess of 90%, very often between 96 and 99% (asymptotic approach of 100%). Thus, the Blakemore method may be a good descriminator for classification purposes, but it gives little information about the real phosphate retention capacity of the high-retention soils (cf. Parfitt, 1984; Inoue, 1986; Garcia-Rodeja et al., 1987). The "Japanese" method is more sensitive in this respect as the 85% "Blakemore" boundary corresponds with a 1500 mg P_2O_5/100 g soil boundary and 99.9% Blakemore corresponds with about 2500 mg P_2O_5/100 g. The insensitivity of the Blakemore method can be improved by reducing the ratio soil/solution. The "Saunders" modified method employs half the ratio of the Blakemore method (i.e. 5 g soil/50 ml 1000 mg P/l KH_2PO_4 solution) and has been used for a large number of Japanese Ando soil samples. It appears that the 85% "Blakemore" boundary corresponds with a 55% "Saunders" boundary leaving a long haul to 100% for the high-retention soils (Inoue, 1986; Kurobokudo Co-operative Research Group, 1986).
It is proposed that the "Saunders" modification of the P-retention procedure be used for high-retention soil samples as a more informative alternative for the Blakemore procedure. For classification purposes the 85% boundary is then replaced by 55% P-retention.

Note 2: Because the "Saunders" P-retention data are considered to represent a discriminative response of Ando soils, such data of the Korubokudo Co-operative Research Groups (1986) were used to establish the relative activity of Al and Fe in P-retention. Multiple regression analysis with analysis of variance yielded the following equation (signif. at 1% probab. level):

$$\text{P-ret.} = (4.9 \pm 0.6)\,Al_o + (14.3 \pm 2.9)\,Fe_o + 33.3 \quad (R^2 = 0.62)$$

This suggests that Fe_o has a roughly 3 times higher specific activity than Al_o in phosphate retention which is largely in agreement with findings of Wada & Gunjigake (1979). Volcanic ash soils in Kenya also showed a high specific activity of Fe (Dr. W.G. Wielemaker, pers. comm.). It is noteworthy that there is a considerable contribution of factors other than Al_o and Fe_o individually. In contrast with this, for a number of soils in Nigeria on non-volcanic parent material, the opposite was found, i.e. a higher activity of Al_o as compared with Fe_o (Loganathan et al., 1987). Generally, Al-oxides are known to be more reactive than Fe-oxides of *similar specific surface area* (Cabrera et al., 1977). Therefore, similar data on other types of Ando soils are necessary to substantiate and perhaps differentiate these qualifications.

Ammonium oxalate reactivity (Ro). The hydroxyl reactivity of soil components can be assessed by measuring the release of OH upon reaction with oxalate. The procedure involves a pH-stat titration of a suspension of soil with a saturated ammonium oxalate solution pH 6.3 during 25 minutes at 20°C (Hernandez Moreno et al., 1985, 1987; Fernandez Caldas et al., 1985). The pH and reaction time were selected on basis of the kinetics observed. The results indicate that this reactivity (Ro) is a means of characterizing surfaces intermediate between selective dissolution and determination of strictly surface properties. Thus, there is a good correlation with Al_o (see Section 5.2) and even better with phosphate retention. There appears to be a considerable influence on Ro by the moisture content of the sample as well as by drying and heating, the extent of the influence depending on the composition of the material. Therefore, the difference in reactivity before and after drying or heating (ΔRo) may be used as a characteristic. Further testing of this approach seems to be warranted.

5.2 Selective dissolution methods

The "amorphous" or poorly ordered materials in soils have been and still are a very popular field for the application of selective dissolution techniques. The differences in type of bonding, bonding strength and degree of crystallinity of the various components can be used to differentiate between them by directed restrained chemical attack. The main problem is that because of the very nature of the constituents, the selectivity is often disappointing: there is no sharp boundary between crystalline and amorphous state; the bonding type and strength within one kind of component such as the organometallic complexes, may vary widely and/or the extractant may affect more than one component.

Boiling in 0.5 M NaOH (Hashimoto & Jackson, 1960) was for some time the favourite selective dissolution procedure to determine "allophane" in soils. It appeared, however, that also amorphous or poorly ordered (opaline) silica and often significant amounts of less ordered or finely grained kaolinite and halloysite were dissolved. This also goes, probably even more so, for the alternating HCl-NaOH (8x) dissolution treatment of Segalen (1968) which was subsequently modified by Quantin & Bouleau (1983). A field test using cold 4 M KOH to extract active Al proved to be highly correlated with the acid oxalate extraction and was adopted by ICOMAND as an alternative (ICOMAND, 1983). With the inclusion of oxalate extractable Fe (ferrihydrite and Fe-humus complexes) in the andic soil properties concept, the KOH extraction had to be dropped (ICOMAND, 1986).

At present, three selective extraction procedures are widely used to characterize the amorphous or poorly ordered constituents of the clay fraction of soils, particularly of Podzols and Ando soils: the pyrophosphate extraction, the acid oxalate extraction and the dithionite-citrate extraction.

Pyrophosphate extraction (Al_p, Fe_p, C_p). An extraction with 0.1 M sodium pyrophosphate solution (overnight, soil:solution ratio 1:100) selectively dissolves organic matter and associated Al and Fe from soils (McKeague, 1967; McKeague et al., 1971). There is virtually no reaction with poorly ordered iron oxides and silicates. A major drawback of the procedure is the strong peptizing effect of the phosphate: it is difficult to obtain clear supernatant solutions for analysis, and data for Al_p and Fe_p should be treated with some suspicion, particularly those for the latter (Schuppli et al., 1983).

Acid oxalate extraction (Al_o, Fe_o, Si_o). An extraction with acid (pH 3) 0.2 M ammonium oxalate solution (4 hrs, soil:solution ratio 1:50) extracts all "active Al" and "active Fe" components as well as the associated Si. This includes allophane, imogolite, Al- and Fe-humus complexes, "amorphous" or poorly ordered oxides such as ferrihydrite but not gibbsite, goethite, and hematite, nor layer silicates (Schwertmann, 1964; McKeague, 1967; Higashi & Ikeda, 1974; Fey & Le Roux, 1975; Wada, 1977).

Wada (1977, 1985) includes in the soil components containing active Al a phase with the somewhat vague term "allophane-like constituents". This phase has never been observed directly. Parfitt et al. (1980b) suggest that it may represent parts of allophane or other defective structures rather than representing an individual component. The active Fe components dissolved would be Fe-humus complexes and ferrihydrite. Childs (1985) and Parfitt (1985) observe that there is mounting evidence suggesting that monomeric iron complexes with organic matter would be rare in soils and that most "organic complexes of iron" probably involve ferrihydrite with intimately adsorbed organic matter. Hence Fe_o should be a good indicator of the ferrihydrite content in the soil.

Loveland & Bullock (1976) observed that sometimes oxalate failed to extract all organically bound Fe and Al. They considered that some of the Fe_o and Al_o is associated with humic acid rather than fulvic acid, the former being less soluble in acid solutions.

Wada et al. (1986) found Fe_p values in excess of Fe_o which could indicate either incomplete centrifugation of the pyrophosphate extract or incomplete extraction of humus-Fe and ferrihydrite by oxalate, or a combination of these two. Parfitt et al. (1988) report that the oxalate extraction did not recover all ferrihydrite from Hydrandepts on Hawaii as suggested by Mössbauer spectra after extraction. One would thus have to take into account a possible overestimation of Fe_p and an underestimation of Fe_o.

Dithionite/citrate extraction (Al_d, Fe_d). The extraction with a hot sodium dithionite + sodium citrate + sodium bicarbonate solution is widely used to determine the so-called "free iron oxide" content of soils (Mehra & Jackson, 1960). These free iron oxides consist of ferrihydrite and crystalline goethite and hematite particles up to about 50 μm in diameter. Above that size dissolution is incomplete (McKeague & Schuppli, 1985). The procedure was simplified by Holmgren (1967) who realized that citrate buffered sufficiently and sodium bicarbonate could be omitted. The latter procedure involves a more convenient overnight shaking at room temperature rather than repeated heating during 15-minute intervals. The two procedures are supposedly equivalent in their extracting power for free iron oxides and evidence is available that this is the case (Van Reeuwijk & Klamt, unpublished data). Other soil components dissolved by this extraction are Al- and Fe-humus complexes and poorly ordered Al-(oxy)hydroxides. Allophane and imogolite seem to be partly affected. The main merit of this extraction is probably that it facilitates an examination of the stage of weathering in a soil by comparing dithionite-extractable Fe with oxalate-extractable Fe ("activity ratio" Fe_o/Fe_d, see also Section 5.3). A summary of the dissolution characteristics of four reagents is given in Table 5-1.

5.3 Interpretation of dissolution data

The interpretation of analytical data for studies of soil genesis is generally less straightforward than their use for soil classification. In estimating contents of constituents or following genetical trends with the of ratios of extracted elements, basic assumptions and sources of error or

Table 5-1. Dissolution of Al, Fe and Si in various clay constituents by treatment with different reagents (modified after Wada, 1977; and Parfitt, 1980).

Element in specified component	Treatment with Pyro-phosphate	acid oxalate	dithionite /citrate	0.5 M NaOH
Al in:				
Organic complexes	good	good	good	good
Hydrous oxides				
non-crystalline	poor	good	good	good
crystalline (gibbsite)	no	no	poor	good
Fe in:				
Organic complexes	good	good	good	no
(Hydrous) oxides				
ferrihydrite	poor	good	good	no
goethite, hematite	no	no	good	no
Layer silicates	no	no	poor	no
Si in:				
Opaline silica	no	no	no	good
Crystalline silica	no	no	no	poor
Al and Si in:				
Allophane	poor	good	poor	good
Imogolite	poor	good/fair	poor	good
Layer silicates	no	no[1]	no/poor	poor/fair

[1]embryonic halloysite dissolves partly (Wada & Kakuto, 1985)

uncertainty should always be taken into account. Some of the most prominent of these will briefly be discussed here.

Al

The oxalate extraction dissolves "active Al" (Al_o). This includes allophane, (partly) imogolite, humus-Al, interlayer-Al and exchangeable Al. If the silica in this extract (Si_o) is considerable then allophane and imogolite are prominent and the other components usually are less significant particularly the latter two. When embryonic halloysite is present or suspected to be, i.e. under certain ustic and/or aquic conditions, Al_o will contain a contribution of this constituent as it is incongruently attacked by oxalate (Wada & Kakuto, 1985).

Pyrophosphate supposedly only dissolves humus-Al and by taking Al_o-Al_p the Al in allophane/imogolite is obtained. Parfitt & Henmi (1982) and Parfitt & Wilson (1985) consider the imogolite contribution in general is relatively small and suggest that the $(Al_o-Al_p)/Si_o$ ratio gives a good estimate of the composition of the allophane present (see below). Clearly, a number of uncertainties have accumulated, particularly when contents are low and consequently relative errors high (Parfitt et al., 1983), but in many cases a useful estimate may be obtained. The ratio Al_p/Al_o may be used to determine the position of an Ando soil in the binary composition concept (see Section 2.3). A low ratio, near 0, would suggest a soil high in allophane whereas a high ratio, near 1, indicates the predominance of Al-humus complexes. Intermediate values indicate a proportional mixture. A high ratio should be accompanied by a relatively low Si_o value and *vice-versa*, otherwise some error is implicated.

Fe

The ratio Fe_o/Fe_d or "activity ratio" has been widely used as an index for the degree of crystallinity or "age" of iron oxides. Values for (young) Ando soils are characteristically high (>0.75) whereas for older soils these are much lower (McKeague & Day, 1966; Blume & Schwertmann,1969). For Oxisols ratios less than 0.1 have been reported (Andriesse, 1978).

Wada et al. (1986) found Fe_p values in excess of Fe_o which would cast doubt on the effectiveness of oxalate to extract humus-Fe and ferrihydrite. However, in view of the earlier mentioned dispersion problems with the pyrophosphate extract, the source of uncertainty may lie here also. The earlier cited observation that Fe_o probably represents only ferrihydrite and that Fe-humus complexes do not play a significant role would make Fe_p an obsolete parameter and thus remove an important source of error and misunderstanding.

Childs (1985) proposed on the basis of the Fe content in ferrihydrite that the ferrihydrite content of soils may be estimated by

$$\%\ \text{ferrihydrite} = \%\ Fe_o * 1.7$$

because of uncertainties and errors he considers this a semi-quantitative estimate with a relative error of $\pm$ 25%.

Calculation of allophane content

Based on the dissolution data of a number of allophanes of various composition, Parfitt & Wilson (1985) proposed a method to estimate the allophane composition and content in soils. They established an almost linear relationship between the Al/Si compositional ratio and the Si content of allophanes. The Al/Si ratio can be obtained by using $(Al_o-Al_p)/Si_o$, and with the corresponding Si content of the allophane from the graph and the measured Si_o the allophane content can be calculated.

To facilitate computerized calculation of allophane contents we have approached the relationship (their Fig. 1) between the Al/Si ratio and the Si content of allophane with the equation:

$$y = -5.1x + 23.4$$

in which:

y = % Si in allophane
$x = (Al_o-Al_p)/Si_o$ atomic ratio

This relationship is graphically given in Fig. 5-1. The allophane content is then obtained by:

$$\text{\% allophane} = \frac{100}{y} * \%Si_o$$

Since allophanes have a limited range of composition and the ratio of extracted amounts of Al and Si may exceed this range due to lack of specificity of the extraction, limits have to be set in the Al/Si ratios used in the calculation. Based on the analysis of various allophanes, a reasonable range would seem to be between 1.0 and 2.5 (Parfitt, 1983; Parfitt & Henmi, 1982; Parfitt & Wilson, 1985). Any excess Al or Si would have to be allocated to an other phase such as hydroxy-Al (e.g. from Al-interlayers or poorly ordered gibbsite) and opaline silica respectively. Thus, a low Al/Si ratio (left-hand range of Fig. 5-1) is evidence of a relatively silica-rich environment (e.g. by limited leaching, drier conditions) whereas a high ratio (right-hand range of Fig. 5-1) suggests a silica-poor environment as would be expected under strongly leaching conditions. Clearly, allophanes are favoured by the intermediate situation.

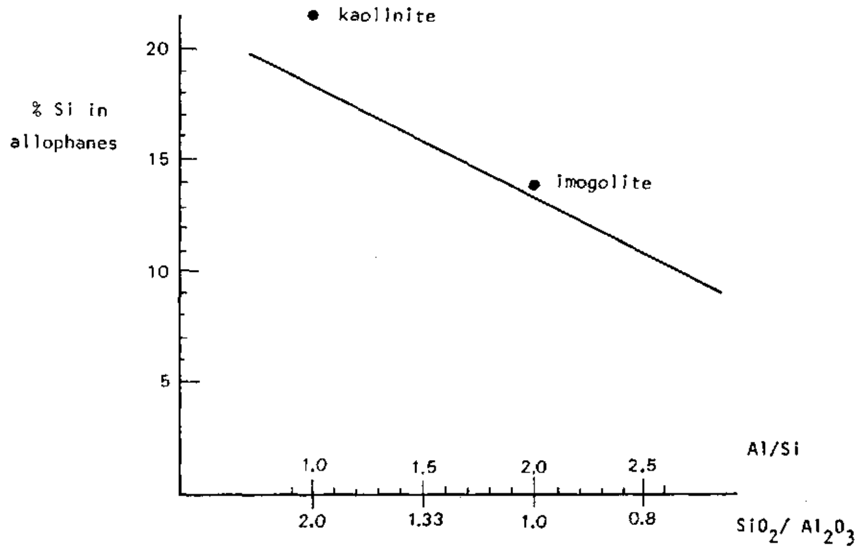

Fig. 5-1. Relation between Al/Si atomic ratio and Si content of allophanes of a range of composition (adapted from Parfitt & Wilson, 1985).

Al-humus complexes

No method is available to determine the Al-humus complexes quantitatively in any reliable way. This is mainly caused by the uncertain and variable composition of the organic component. Until such a composition can be determined (routinely), Al_p cannot be used as a basis for calculation. Organic carbon dissolved in the pyrophosphate extract (Cp) gives some indication but it may not be allocated to Al-humus only. A very indirect, but also uncertain estimation can perhaps be made by determining the weight loss upon acid oxalate treatment, which gives the total "amorphous" fraction, and subtracting from this the calculated allophane and ferrihydrite. Possibly dissolved interlayer-Al and exchangeable Al can be neglected.

6. MATERIALS AND METHODS

6.1 Materials

All profiles used in this study were formed in volcanic material. Most of the samples belong to soil monoliths of the ISRIC collection. They originate from Colombia (4), Indonesia (1), Italy (1), Kenya (7), Philippines (1), Rwanda (1), and USA (Hawaii) (3). In addition, samples were obtained from profiles (complete or in part) from various other parts of the world to expand the climatic coverage. These comprise: Costa Rica, Guadaloupe, Kenya, Mexico, Philippines, Tenerife, Syria, Tanzania, Vanuatu. Many of these latter samples were not analysed in full either because only a rapid characterization was considered necessary or because the samples were too small. Since the completion of the study a number of monoliths of Ando soils and intergrades to Ando soils from Indonesia and Ecuador were acquired by ISRIC and analysed for characterization. They have been included for data base and reference purposes in Appendix 1: INS 18-19-21-23-24-26-27-29-36-37, and EC 2-3-4-7-8-9-20 marked with *, but are not represented in Appendices 2 and 3 as the clay and silt fractions of these soils have not been studied in such detail as was done for the other. However, where possible and necessary, their data were used in the discussion (Chapter 7).

As a restriction, Ando soils from Japan and New Zealand have not been included in this study. Data and details of these soils are already easily accessible in the literature.

The profiles used in this study are listed in Table 6-1, and their descriptions are given in Appendix 4. The results of classification are provisional and tentative. This applies particularly for the classification according to the Andisol proposal (ICOMAND, 1988) which was applied only as an exercise (see App. 4). Some of the details of this proposal have not yet been finalized, e.g. the definition of volcanic glass, or are still under revision, e.g. melanic and fulvic epipedon. The division of the profiles into Group I and Group II is based on their content in active Al and Fe. The former have relatively high contents, the latter have relatively lower contents. This is further discussed in Section 7.1.

Table 6-1. Profiles of Ando soils and related soils used in this study.

GROUP I

Country or Area	Code or Name	Classification FAO/Unesco '74	Soil Taxonomy '75
Colombia	CO-11	Humic Andosol	Hydric Dystrandept/ Typic Hydrandept
Colombia	CO-12	Humic Andosol	Typic Dystrandept
Colombia	CO-13	Humic Andosol	Typic Hydrandept
Colombia	CO-14	Humic Andosol	Hydric Dystrandept/ Typic Hydrandept
Philippines	PHI-1	Humic Andosol	Hydric Dystrandept
Indonesia	INS-11	Humic Andosol	Hydric Dystrandept
Rwanda	RWA-1	Mollic Andosol	Udic Eutrandept
Italy	I-16	Humic Andosol	Typic Dystrandept
Italy	Roccamonfina	Humic Andosol	Typic Dystrandept
Hawaii (Kikoni)	USA-5	Mollic Andosol	Typic Eutrandept
Hawaii (Kukaiau)	USA-6	Humic Andosol	Hydric Dystrandept
Hawaii (Hilo)	USA-7	Humic Andosol	Typic Hydrandept
Kenya	EAK-5	Humic Andosol	Hydric Dystrandept
Kenya	EAK-34	Humic Andosol	Hydric Dystrandept
Guadeloupe	Chateauneuf	Humic Andosol	Hydric Dystrandept
Costa Rica	Paraiso	Humic Andosol	Hydric Dystrandept
Tenerife	Las Aves	Humic Andosol	Typic Dystrandept
Vanuatu (Aoba Isl.)	ORSTOM 243	Mollic Andosol	Udic Eutrandept
Vanuatu (Vanua-Lava Isl.)	ORSTOM 231	Humic Andosol	Oxic Dystrandept
Vanuatu (Sta. Maria Isl.)	ORSTOM 230	Mollic Andosol	Udic Eutrandept
Vanuatu (Sta. Maria Isl.)	ORSTOM 465	Humic Andosol	Typic Hydrandept
Mexico	Sierra Nevada no. 19	Humic Andosol	Hydric Dystrandept
* Indonesia	INS-3	Humic Andosol	Udic Eutrandept
* Indonesia	INS-18	Mollic Andosol	Udic Eutrandept
* Indonesia	INS-21	Humic Andosol	Hydric Dystrandept
* Indonesia	INS-23	Humic Andosol	Hydric Dystrandept
* Indonesia	INS-24	Mollic Andosol	Udic Eutrandept
* Indonesia	INS-27	Humic Andosol	Entic Dystrandept
* Indonesia	INS-29	Humic Andosol	Typic Hydrandept
* Indonesia	INS-36	Humic Andosol	Typic Dystrandept
* Ecuador	EC-3	Humic Andosol	Dystric Cryandept
* Ecuador	EC-9	Ochric Andosol	Entic Dystrandept

* See text Section 6.1.

Table 6-1. (cont'd)

GROUP II

Country or Area	Code or Name	Classification FAO/Unesco '74	Soil Taxonomy '75
Kenya	EAK-2	Mollic Andosol	Cumulic Hapludoll
Kenya	EAK-4	Vitric Andosol	Mollic Vitrandept
Kenya	EAK-35	Mollic Andosol	Mollic Vitrandept
Kenya	EAK-36	Mollic Andosol	Mollic Vitrandept
Kenya	EAK-37	Mollic Andosol	Mollic Vitrandept
Tanzania	Mukoma-1	Mollic Solonetz	Typic Natrustoll
Tanzania	SEK-NE	Mollic Andosol	Eutrandeptic Cumulic Haplustoll
Tanzania	Rhino-7	Luvic Chernozem	Typic Argiustoll
Tanzania	Dutwa-1	Mollic Solonetz	Typic Natriustoll
Tanzania	NaNo-S	Pellic Vertisol	Typic Pellustert
Tenerife	Birmagen	Chromic Cambisol	Andic Ustochrept
Vanuatu (Aoba Isl.)	ORSTOM 245	Mollic Andosol	Udic Eutrandept
Vanuatu (Aoba Isl.)	ORSTOM 247	Vitric Andosol	Mollic Vitrandept
Vanuatu (Aoba Isl.)	ORSTOM 253	Mollic Andosol	Andic Eutropept
Vanuatu (Sta. Maria Isl.)	ORSTOM 466	Mollic Andosol	Andic Eutropept
Mexico	Sierra Nevada no. 13	Humic Andosol	Hydric Dystrandept
Syria	R1	Vitric Andosol	Typic Vitrandept
Syria	R2	Vitric Andosol	Typic Vitrandept
Syria	R3	Vitric Andosol	Typic Camborthid/ Vitrandept
Syria	S3	Vitric Andosol	Typic Vitrandept
Philippines	Tagaytay	Haplic Pheozem	Cumulic Haplustoll
Kenya	1976/138-142	Eutric Planosol	Abruptic Tropaqualf
Kenya	134/7	Eutric Planosol	Abruptic Tropaqualf
Kenya	118/6	Eutric Planosol	Abruptic Tropaqualf
Kenya	145/5	Eutric Planosol	Abruptic Tropaqualf
Kenya	145/7	Eutric Planosol	Abruptic Tropaqualf
* Indonesia	INS-19	Dystric Cambisol	Oxic Humitropept
* Indonesia	INS-26	Eutric Cambisol	Andic Humitropept
* Indonesia	INS-37	Eutric Nitosol	Typic Paleudalf
* Ecuador	EC-2	Humic Cambisol	Andic Humitropept
* Ecuador	EC-4	Humic Acrisol	Orthoxic Tropohumult
* Ecuador	EC-7	Ferric Acrisol	Typic Tropaquult
* Ecuador	EC-8	Vitric Andosol	Typic Vitrandept
* Ecuador	EC-20	Vitric Andosol	Typic Vitrandept

* See text Section 6.1.

6.2 Methods

6.2.1 *Analysis of the soil*

Most analyses were done on air-dry fine earth. Where possible, field-moist fine earth samples were prepared by passing field-moist samples through a 2 mm sieve. The latter were used for particle size analysis, cation exchange properties and water retention at 15 bar. This is then indicated by the symbol # before the profile name (App. 1).

Clay content by routine procedure (ro in App. 1)
About 20 g of fine earth (air-dry or moist) was treated with 15% H_2O_2 to remove organic matter. Excess H_2O_2 was removed by boiling the suspension on a hot plate for 1 hr. Carbonate in some soils of Group II (App. 1) was removed with sodium acetate buffer pH 5. The suspensions were decanted until dispersion and then further dispersed with sodium hexametaphosphate and shaken overnight on a reciprocating shaker at ca. 125 str./min. The clay content was determined by the pipette method.

Clay content by special procedure (sp in App. 1)
Organic matter and carbonate removal as for routine procedure. Final dispersion by ultrasonic wave treatment (Sonicor probe, 20 kH at ca. 150 W for 15 mins.) and adjustment of pH of suspension to 4 or 10 (see App. 1) with some 1 M HCl or NaOH respectively. The clay was collected by repeated sedimentation and siphoning and the volume reduced by flocculation with some NaCl. The amounts of clay recovered were determined by drying an aliquot of the suspension after centrifuge-washing to remove NaCl.

pH
The pH-H_2O was measured in a 1:2.5 air-dry soil:water (wt/wt) suspension after 2 hrs. mechanical shaking.
The pH-KCl was measured similarly using a 1 M KCl solution instead of water.
The pH-NaF was measured in a suspension of 1 g soil in 50 ml 1 M NaF solution after 2 mins. stirring.

CEC and exchangeable bases
An ammonium acetate procedure using an automatic extractor was used (modified from USDA, 1972, 1982). Exchangeable bases were removed

by leaching with 1 M NH_4Ac pH 7 and determined in the leachate by AAS (Ca and Mg) and FES (Na and K). The soil was then saturated with 1 M NaAc pH 7, the excess Na was removed by leaching with 48% ethanol and adsorbed Na replaced by leaching with 1 M NH_4Ac pH 7. Na in the leachate was determined by FES.

Exchangeable Al

Exchangeable Al was determined by leaching the soil sample with 1 M KCl and determining the Al in the leachate by AAS.

Organic carbon

The Walkley-Black wet combustion method was used. Incomplete recovery was compensated for with a multiplier of 1.3 in the calculation.

Dithionite-citrate, oxalate and pyrophosphate extractions

The dithionite-citrate extraction was done by shaking overnight 1 g of soil with 60 ml of a solution consisting of 17% sodium citrate and 1.7% sodium dithionite (Holmgren, 1967). Al and Fe were determined in the extract by AAS (Al_d and Fe_d).

The oxalate extraction was done by shaking 1 g of soil with 100 ml 0.2 M acid ammonium oxalate (pH 3) for 4 hrs. in the dark (USDA, 1972). Al, Fe, and Si were determined in the extract by AAS (Al_o, Fe_o, and Si_o).

The pyrophosphate extraction was done by shaking 1 g of soil with 100 ml 0.1 M sodium pyrophosphate overnight. Al and Fe were determined in the extract by AAS (Al_p and Fe_p).

With all three extractions 3-4 drops of a 0.2 % "Superfloc" or "Kemflock" solution were used to promote flocculation and obtain a clear supernatant solution by centrifugation.

Calculation of the allophane content was done according to Parfitt & Wilson (1985) as set out in Section 5.3. Any Al or Si left over after allocation to allophane is reported as "excess" Al or Si. The binary ratio was obtained from Al_p/Al_o (see Section 2.3). Calculation of the ferrihydrite content was done with the relation: % ferrihydrite = 1.7 * Fe_o (see Section 5.3).

Phosphate retention

By Blakemore's procedure: a 5 g sample was shaken overnight with 25 ml of a 1000 mg P/l KH_2PO_4 solution of pH 4.6 and the amount of P left was determined colorimetrically.

Calcium carbonate equivalent

By the "rapid titration" method. The sample was shaken with dilute HCl and the residual acid titrated.

Water held at 15 bar

A fine earth sample (field-moist when available) was equilibrated in a pressure plate extractor.

Bulk density

By the oven-dry weight of a 100 ml core sample taken at field-moist conditions.

6.2.2 *Analysis of the clay fraction*

The clay fractions used for analysis were obtained as described in the previous section under "clay content by special procedure". The clays were stored as a flocculated suspension in a dilute NaCl solution in polythene bottles. Analytical results are reported in Appendices 2 and 3.

Oxalate extraction

Aliquots containing 100 mg clay were centrifuged and the sediments were shaken with 200 ml 0.2 M ammonium oxalate (pH 3) for 4 hrs. in the dark. The suspension was carefully centrifuged after adding four drops of 0.4% "Superfloc" or "Kemflock". Al and Fe were determined in the clear extract by AAS and Si by silico-molybdate colorimetry. Calculation of the allophane content was done according to Parfitt & Wilson (1985) as set out in Section 5.3 except that in the calculation of the Al/Si ratio for allophane Al_o need not be corrected with Al_p (organically bound Al was removed with H_2O_2). Any Al or Si left over after allocation to allophane is reported as "excess" Al or Si (App. 2).

Contents of oxalate-insoluble constituents in the clay (App. 3) were obtained with the following calculation: content (%) = 100 - Allophane - (Excess Al)*2.9 - Ferrihydrite. The figures used for the latter three terms are those reported in Appendix 2. The factor 2.9 is used to convert excess Al to gibbsite, the formula of which is taken to represent hydroxy-Al species.

X-ray diffraction
After the oxalate extraction, the clay residues were centrifuge-washed with 0.5 M NaCl and treated with 15% H_2O_2 in a small beaker on a hot plate to destroy the "Superfloc" used for centrifuging. The clays were peptized by decantation and an aliquot containing ca. 15 mg of clay was poured onto a porous plate (18 x 14 x 1.9 mm) under suction (Huting & Van Reeuwijk, 1986). Of each sample a Mg- and K-saturated specimen were prepared by percolation with a 0.5 M $MgCl_2$ and 1 M KCl solution respectively. After air-drying the specimens were analysed by X-ray diffraction using a Philips PW 180 assembly. Diffractograms were also made of glycerolated Mg-specimens, formamide-treated Mg-specimens and heated (to various temperatures) K-specimens. Relative abundance of minerals was estimated by measuring the peak height characteristic for the respective mineral species (App. 3).

Other instrumental analyses
Part of the oxalate treated suspension was dried by evaporation on a water-bath and the clay used for infrared spectroscopy on a Spectromaster (1.5 mg dry clay/300 mg KBr), electron microscopy on a JEM 100-B and differential thermal analysis on a DuPont 990.

Elemental or total chemical analysis (see Table 7.1)
An aliquot of the original clay suspension, containing about 1 g of clay was saturated with Ba to remove Na by centrifuge-washing with 0.5 M Ba-acetate. The sediment was then centrifuge-washed with water until peptization was obtained. After adding 2-3 drops of 0.5 M BaAc one more washing was given and the sediment freeze-dried. A bead was made with $Li_2B_4O_7$ at ca. 1200°C and analysed on a Philips PW 1404 X-ray fluorescence spectrometer.

6.2.3 Analysis of the silt fraction

The silt fractions (2-20μm) were separated by means of sedimentation and decantation from the residues after clay separation (see Section 6.2.2). Minerals in the silt fractions were identified by X-ray diffraction of randomly oriented powder specimens. Relative abundance of minerals was estimated by peak height measurement.

7. RESULTS AND DISCUSSION

The results of analysis are given in Appendices 1, 2 and 3. Appendix 1 contains the general soil characterization data, while in Appendices 2 and 3 the selective dissolution and mineralogical data of the clay fraction of a number of selected horizons are given respectively.

7.1 Active Al and Fe

Based on the amounts of Al and Fe extracted by acid oxalate (Al_o and Fe_o or "active" Al and Fe) as well as on the related phosphate retention figures (P-ret.), the profiles have been divided into two main groups. In Group I are placed all profiles with relatively high active Al and Fe contents whereas Group II contains the profiles with relatively low contents of active Al and Fe. Group I would thus contain the well-developed central concept of Ando soils whereas the soils in Group II are either very young (vitric) Ando soils or have developed, for one reason or the other, into a soil with weak andic properties or even without them present at all. Such reasons could, for instance, be an unsuitable climate, mineralogical composition, hydrological conditions or an advanced stage of development.

GROUP I

The "binary ratio" Al_p/Al_o at a glance gives information[1] about the relative composition of the colloidal fraction and the trend of this composition through the profile (see App. 1). As expected, there appears to be a clear general trend in the Group I Ando soils that the binary ratio is highest in the A-horizons and lower in the corresponding B and C-horizons. In other words, organically bound Al and Fe (see also Al_p and Fe_p, App. 1) is relatively highest in the A-horizons and decreases in the B and C-horizons whereas for allophane the reverse is true. Also in buried profiles this trend is often nicely preserved (e.g. profiles CO-14, INS-11, INS-24) although subsequent pedogenesis may have obscured the original trend (e.g. also in INS-11).

[1]Care should be taken with values of the binary ratio when contents of active Al are low: because of the large relative error the meaning of the ratio is then very limited. For this reason values are given in one decimal only.

A few A-horizons appear to have a (nearly) pure end-member composition. Those of profiles CO-13, CO-14, EAK-5 and EAK-34 are "non-allophanic", whereas profiles PHI-1 and INS-36 are "allophanic". Although the latter topsoils still seem to contain small amounts of humus-Al complexes, in view of the limited specificity of the selective dissolution procedures as discussed in Chapter 6, for all practical purposes these may be considered as "pure" end-members on the binary compostion scale.

About half of the analysed A-horizons appear to have intermediate binary ratios of composition, i.e. ranging from 0.2 to 0.8. For these soils a designation of either "allophanic" or "non-allophanic" would be inaccurate.

Almost all profiles have a considerable content of allophane in the B and C-horizons, including those with a non-allophanic A-horizon. Exceptions to this rule are found in CO-14 and EC-3 which have low contents of allophane as a result of the youthfulness or rejuvenation of the profiles. Profiles EAK-5 and INS-21 also have low allophane contents in the subsoil but this may, by contrast, be ascribed to old age as indicated by the high clay contents. Profile INS-21 seems to be an old buried profile which has been covered by a fresh layer of ash in which a new A-horizon has developed, but without a (clear) B-horizon.

It is noteworthy that a high binary ratio (dominance of Al-humus complexes) is always associated with a high organic matter content, but that the reverse is not necessarily true. There are several profiles with a substantial organic matter content and a low binary ratio (dominance of allophane) e.g. I-16, USA-5, USA-6, INS-11. This would illustrate the importance of the relative activity of organic matter and bases with respect to the composition of the colloidal fraction.

The relation between pH and binary ratio is illustrated in Fig. 7-1. It is clear that allophane predominates in general at pH values above 5 whereas Al-humus complexes do so below pH 5. This is in agreement with the findings of Shoji and co-workers (see Chapter 3). According to the regression line, the point of equal amounts of Al in allophane and in humus complexes (binary ratio = 0.5) would be exactly pH 5. However, in view of the wide scatter of the data and the consideration that a straight regression line is probably not the best fit of the data (a titration curve would be more likely) this value is fortuitous and the real value might be somewhat lower. Yet, for all practical purposes the pH value of 5 as a change-over point can be conveniently maintained.

The wide scatter of pH vs. binary ratio data may be ascribed largely to non-equilibrium conditions or hysteresis in response to pH changes. For this reason the deviations between profiles are much larger than those within profiles where the genetic relationship between horizons generally results in a gradual decrease of the Al_p/Al_o binary ratio with pH, i.e. an increase of allophane with depth (except when soil development has been interrupted by fresh ash layers). Analytical imperfections may also contribute to the scatter. The selective dissolution procedures and even a seemingly straightforward pH determination can be quite inaccurate or be considerably influenced by drying and storage of samples (Bartlett & James, 1980; Van Reeuwijk, 1984). With samples that were kept in a wet condition but which then inadvertently dried out gradually over periods in excess of a year, it was often impossible to reproduce the pH value originally determined. Nevertheless, it is felt that the occurrence of Al-humus complexes at higher pH values deserves further study.

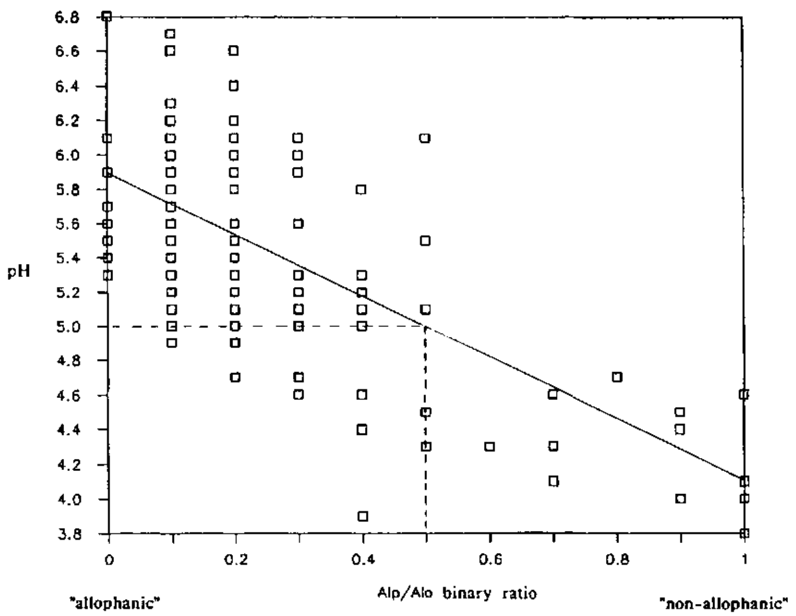

Fig. 7-1. A plot of the binary ratio of the clay composition vs. pH of the Group I soils (App. 1). The diagonal line is the regression line. Note that the squares may represent more than one pair of data.

The compositional Al/Si molar ratios for allophane calculated from $(Al_o-Al_p)/Si_o$ (Parfitt & Wilson, 1985) are generally within the range of allophane (1.0-2.5). Ratios above 2.5 are found particularly in some hydric Ando soils (e.g. PHI-1, USA-6, USA-7, INS-21). This excess of Al seems to be greatest where organic matter is the least (USA-7, Hilo series). The excess Al may be present as hydroxy-Al gels (short-range-order gibbsite) perhaps associated with humus (Higashi, 1983), but it may also be associated with allophane so that, in fact, an allophane species with a higher ratio Al/Si than 2.5 is present. This is allowed by the model for allophane of Van Reeuwijk & De Villiers (1970).

Many of the hydric-type Ando soils appear to have high contents of allophane and sometimes ferrihydrite (e.g. INS-11, 29 and USA-6, 7; see App. 1). However, this is not the rule since "non-allophanic" hydric types occur as well (e.g. CO-13, 14 and EAK-5, 34). Also, organic matter contents vary strongly and need not be particularly high: the Hydrandept USA-7 has only 6.5% C in the A-horizon. Thus, hydric properties may originate from various combinations and intensities of factors. The common prerequisites seem to be the volcanic nature of the parent material and a certain amount of humus associated with Al, either in allophane or in organic complexes.

Unlike profile USA-7 and 6 (Kukaiau series) from Hawaii, which have a perudic and udic moisture regime respectively, profile USA-5 from Hawaii (Kikoni series) has an ustic moisture regime. In spite of this, it appears to have a typical Group I composition as regards allophane and ferrihydrite (see App. 1). In contrast to the wetter Hilo and Kukaiau profiles, however, it has halloysite as the dominant crystalline clay mineral (see App. 3). This agrees with the findings of Parfitt et al. (1988) in another profile under ustic conditions on Hawaii (Waimea series), although this has lower allophane and ferrihydrite contents.

Allophane Al/Si molar ratios below 1.0 (as well as some extremely high ones) invariably result from insensitivity of the calculation when allophane contents are low. The present results, therefore, confirm that allophanes richer in Si than Al/Si = 1 do not occur and that any excess Si-phase such as opaline silica is not dissolved by acid oxalate treatment (see App. 1 and 2). A few negative values for the ratio Al/Si for allophanes (App. 1: EAK-5, EAK-34 and Tanzania Mukoma 1) result from a higher value for Al_p than Al_o and some error must be involved. In fact, there is always the risk of such errors but except in obvious cases such as these, they usually remain unnoticed.

When comparing the allophane content calculation of the clays (App. 2) with that of the corresponding whole soil (App. 1) it appears that the former yields in many cases a (much) higher Al/Si ratio, often in excess of 2.5. It is suspected that during pretreatment of the soil prior to clay separation, uncontrolled damage is inflicted on the clay (by hydrogen peroxide, and sometimes the acetate buffer) and that artefacts are produced. Such artefacts could be sparingly water-soluble complexes of Al with lower-molecular organic acids formed by the hydrogen peroxide treatment. These complexes are subsequently dissolved by the acid oxalate treatment. This observation may have serious consequences for past, present and future work in which a hydrogen peroxide treatment was or is involved.

GROUP II

In soils of Group II, the contents of Al-humus complexes, allophane and ferrihydrite are, by definition, generally low. Some may have limited amounts of these substances but the separation between Group I and II is, by nature, not a sharp one. The low content of active compounds is also expressed in the range of oxalate soluble contents of the clay (App. 2 and 3). In Group II soils much less clay is dissolved because of a higher content of (crystalline) layer silicates and/or unweathered primary constituents. Nearly all of Group I soils occur in at least udic moisture regimes whereas almost all of Group II soils are exposed to a pronounced period of dryness each year. With exception of the few Mollic Andosols or Eutrandepts in Group I, the difference in moisture regimes between the two soil groups is clearly reflected by the significantly higher base saturation of the Group II soils.

The exception to this general rule are the soils of Group II which are too young or too old for Group I, e.g. some soils from Ecuador (App. 1). Soil EC-7 is typically an "old" soil in alluvial volcanic material in an advanced stage of weathering although the sand still contains plenty of vitric material. It has a high clay content with little active Al and ferrihydrite. Although the soil moisture regime is perudic, the high clay content which has developed, now prevents strong leaching. Soil EC-8, by contrast, also under perudic conditions, is a very young soil. Yet, locally it is considered a "true" Andosol: a deep, black soil in volcanic ash. In the Andisol proposal (ICOMAND, 1988) the soil can be accommodated as a Thaptic Udivitrand.

Border-line cases between Group I and II are for instance profiles EAK-5 from Kenya which is marginal to Group I because of its age (App. 1) and INS-19 from Indonesia which is an old-age type of Group II but has a shallow clearly Group I A-horizon caused by rejuvenation (INS-21 is a similar profile but has a thicker A-horizon and is therefore a true Group I Ando soil).

The "Ando" soils from Kenya (EAK-2, 4, 35, 36, 37) are of the weakly developed types formed in peralkaline trachytic ash, as discussed in Section 3.4, and are included to further document the peculiar kind of pedogenesis in this parent material (and with an ustic soil moisture regime). It is noteworthy that profile EAK-34, by contrast, is a true Group I central concept Ando soil on this type of ash but it has a udic moisture regime. Thus Ando soils can be formed also in these peculiar acidic ashes provided the soil moisture regime is udic or wetter (Dr. W.G. Wielemaker, pers. comm.). The acidic character of the parent material is reflected by a binary ratio of 1 in the upper 50 cm (virtually no allophane; abundant 2:1 and 2:2 layer silicates; presence of exchangeable Al). The clay mineralogy of these profiles will be discussed in Section 7.2.

The activity ratio Fe_o/Fe_d, does not appear to be a very sensitive discriminator between Group I and II. In both groups a wide variation can be found (App. 1) which may only partly be ascribed to insensitivity due to low figures. Further investigation into the speciation of iron seems to be indicated.

7.2 Crystalline clay minerals, oxides and primary constituents

The contents of oxalate-insoluble constituents of the clay, consisting of layer silicate clay minerals, oxides and primary minerals, were estimated by simple subtraction of the fraction dissolved in oxalate from the total clay. The identity of the insoluble components was established by a combination of X-ray diffraction, infrared spectroscopy (IR), electron microscopy (EM) and differential thermal analysis (DTA).

Group I clays contain small to moderate amounts of insoluble constituents. Most of the residues of the Group I clays show well-defined X-ray diffraction characteristics and mainly consist of vermiculite-chlorite intergrades, mica, and illite as well as halloysite in some lower horizons (App. 3). The clay of profile CO-14 contains pyrophyllite and talc which may indicate the admixture of some metamorphic rock. There is a tendency that the contents of 2:1 and 2:1:1 clays in the Group I clays are higher in soils in which quartz predominates in the silt fraction (2-20 μm).

Group II clays consist dominantly of layer silicate clays (exceeding 80%). Some of them show well-defined sharp X-ray reflections (e.g. Tenerife-Birmagen and Vanuatu samples) and halloysite (7 and 10 Å reflections) is dominant.

Fig. 7-2. Electron micrograph of the clay separated from a Group II soil (EAK 35-3). Magn. 52000x.

Unusual clay minerals are found in the clays from Kenya and Tanzania. The X-ray diffraction patterns show very weak or no (00*l*) reflections but marked (*hk*0) reflections of layer silicates at 4.4-4.5 Å. They also show a strong low-angle scattering. During the experiments, clay specimens were seemingly well-oriented and no curling-off from the sample plates was observed. Dithionite-citrate treatment of the clays did not significantly improve the diffractogram. These observations indicate that the minerals are well-ordered along (*hk*0) but poorly along (00*l*) directions. Contents of these minerals were higher in the surface horizons than in the lower horizons. They are commonly found both in soils derived from acid peralkaline trachytic ash and from basaltic materials.

In Fig. 7-2, an electron micrograph of a specimen of such a clay is presented. The particles generally have a thin platy morphology. There are some tubular and spherical particles which are characteristic of halloysite. However, their contents are too low to give a discernable X-ray response. In the infrared spectra range (Fig. 7-3) weak but distinct absorption bands at

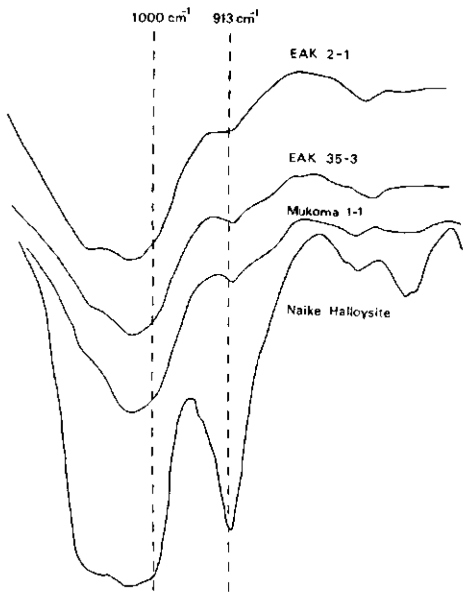

Fig. 7-3. Infra-red spectra of clays separated from three Group II soils and Naike halloysite.

913 cm^{-1}, characteristic for Al-OH of layer silicates are observed. The Naike halloysite from New Zealand is included as a reference with similar characteristics. In DTA (graphs not shown) a distinct endothermic peak was produced at about 450-480°C due to dehydroxylation. These temperatures are lower than those for typical halloysite formed by weathering of volcanic ash indicating a higher disordering. These findings strongly suggest that the clays from Kenya and Tanzania in the regions with a marked dry season are not "amorphous" as interpreted by De Wit (1978) and Jager (1982) but rather crystalline. During the dry season leaching is halted and a concentration of the soil solution occurs, apparently facilitating formation of layer silicates rather than allophane or Al-humus complexes (the production and accumulation of organic matter under such conditions is relatively restricted anyhow). In a separate study, the senior author discovered the presence of "curly smectite" in this type of clay (Van der Gaast et al., 1986; Mizota, 1987) whereas Wada et al. (1987) found evidence of "embryonic halloysite". The relatively high SiO_2/Al_2O_3 molar ratios of these clays (near to 4, the ratio found in 2:1 clay minerals) together with substantial amounts of K and Mg (see Table 7-1) and taking a certain influence of primary minerals into account, suggest that part of the clays must be of the 2:1 layer silicate type (mica, vermiculite, smectite, cf. App. 3).

There is little doubt that all these observations are connected. The details of the association still remain to be investigated.

Table 7-1. Chemical analysis of Ba-saturated clays of selected horizons of Group II soils.

	EAK	EAK	Mukoma	SEK-NE	Kenya		Rhino-7		Dutwa-1		Nano-S	
	2-4	35-3	1-4	4	1976/138	1976/142	1	4	1	4	1	4
SiO_2	45.27	52.47	50.9	50.9	42.5	51.7	52.7	55.6	53.2	50.5	43.5	43.0
Al_2O_3	18.30	17.09	20.3	18.0	14.4	18.0	19.9	18.7	23.4	22.3	17.1	17.5
Fe_2O_3	16.10	9.88	9.8	7.8	7.5	10.6	9.3	9.5	10.0	9.6	9.1	9.5
FeO	-.-	-.-	-.-	-.-	-.-	-.-	0.2	0.2	0.4	0.1	-.-	-.-
MnO	0.4	0.2	0.2	0.3	0.2	0.3	0.1	0.2	0.2	0.1	0.1	0.2
MgO	0.60	1.06	1.7	1.0	0.6	1.0	1.1	1.5	1.3	1.5	1.2	1.3
CaO	0.20	0.89	0.7	1.3	0.3	0.2	0.2	0.5	0.1	0.1	0.9	0.5
Na_2O	0.40	0.00	0.1	0.3	0.6	0.5	0.1	0.1	0.1	0.1	0.3	0.3
K_2O	1.42	1.12	2.1	2.0	1.2	1.6	2.4	2.0	2.4	2.1	2.7	2.9
TiO_2	1.27	0.85	1.2	0.8	0.9	0.9	1.2	1.0	1.7	1.4	1.1	1.1
BaO	2.46	4.79	-.-	4.8	16.0	6.4	-.-	-.-	-.-	-.-	4.2	4.1
P_2O_5	1.5	0.1	0.6	1.4	0.7	0.2	0.5	0.4	0.6	0.2	1.1	0.6
$H_2O(+)$	9.30	10.0	10.0	17.6	12.4	8.6	7.6	8.7	5.8	9.7	17.1	17.4
SiO_2/Al_2O_3*	4.20	5.21	4.3	4.0	5.0	4.9	4.5	5.0	3.9	3.8	4.3	4.2

*molar ratio

7.3 Fluoride reaction, phosphate retention

Although the pH-NaF has been dropped as a parameter for soil classification, it may still be used as an additional characteristic of Ando soils. It appears that all Group I soils show a strong positive reaction to fluoride (App. 1) whereas for Group II soils this is only the case in some of them. The positive reaction of carbonate in the soils with fluoride is evident.

Phosphate retention, also a reaction caused by active Al and Fe, largely follows the same pattern as the pH-NaF.

7.4 Extractable aluminium

Aluminium ions extracted by a 1 M KCl solution represent the exchangeable Al retained by the exchange complex. Considerable amounts are found in Group I soils with low pH (<5) and in which 2:1 and 2:1:1 clay minerals are present (App. 1 and 3). In a few cases exchangeable Al is found at pH values above 5 (e.g. INS-23, EC-3). This can be ascribed to the same scattering of data described in Section 7.1. With a few exceptions (mostly Ultisols), Group II soils with their relatively higher pH values, generally do not contain exchangeable Al.

7.5 Physical properties

A low bulk density and a high 15 bar water retention are associated with the predominance of non- and para-crystalline constituents in the clay fraction. Although undisturbed core samples were not available from all soils for the measurement of these parameters, it is evident that Group I soils, in which these constituents predominate, show lower bulk density figures than Group II soils. The threshold value of 0.9 kg/l as employed in the latest Andisol proposal (ICOMAND, 1988) seems to be realistic.

The employment of different procedures for particle size analysis reveals that in some cases a very good agreement in results exists whereas in other wide deviations occur. In several cases allophane contents are higher than clay contents so that incomplete dispersion and/or removal of clay during pretreatment must be inferred (e.g. I-16, RWA-1, INS-18, 21, 23). The message from this is clearly that particle size distribution data of volcanic ash soils should be treated with caution.

7.6 Summary

Samples of soils developed in volcanic ash were collected from various regions of the world and analysed for their clay mineralogy and chemistry. Samples were divided into two groups according to the content of active Al which is the Al soluble in acid oxalate solution and occurring in the form of non- and paracrystalline Al-hydroxides, organically complexed Al, allophane and imogolite.

Group I soils show a moderate to predominant presence of active Al, and meet the central concept of the Andisols characterized by low bulk density, high pH-NaF and P-retention.

The colloidal fraction of Ando soils have a "binary" composition as organically complexed Al seems to occur in an inverse relationship with allophane and imogolite. This colloidal fraction is dominated by allophane/imogolite under neutral to mildly acid conditions (pH >5) whereas Al-humus complexes dominate under acid conditions (pH <5). The binary composition can be quantified by the ratio or fraction Al_p/Al_o which is the fraction of the organically complexed Al of the total active Al and which ranges from 0 (all allophane) to 1 (all humus complexes). It is proposed that this ratio be used as an additional characterization parameter for soil horizons with andic properties.

By contrast, group II soils are low in active Al and consist mainly of halloysite, poorly ordered layer silicates with unknown structure and sometimes smectite.

The marked difference between these two groups of soils was interpreted as an indication of the different influences of climatic regime and petrological nature of the parent ash. Group I soils develop under typic udic and perudic moisture regimes and their ash parent materials are mainly basaltic to andesitic. Presence of a dry season (ustic and aridic moisture regimes), in which a seasonal concentration of soil solution in soils of Group II occurs, suppresses the development of the active Al, whilst the high silica content of acidic ash is favourable for the authigenic formation of layer silicates.

Some soils from old landscape areas with high rainfall in Colombia, Italy, Japan, Kenya, Hawaii and Canary Islands contain considerable amounts of 2:1 and 2:1:1 clays. The covariant relations with fine-grained quartz (2-20 μm) in their silt fractions indicate at least in part an eolian origin of the minerals. Similar relationships between the clay mineralogy and climatic regimes might also be found through the re-examination of the previous analytical data of soil development in volcanic ashes under diverse climatic regimes, particularly in the tropics.

ACKNOWLEDGEMENTS

The authors are greatly indebted to a large number of persons who have contributed material for this work, be it written information, soil samples or both. In the first place we refer to all authors of the profile descriptions who have been mentioned in Appendix 4. In addition to these (and including many of them) we should like to mention here the following colleagues who have been helpful: Mr. G.W. van Barneveld, Dr. P. Buurman, Dr. F. Colmet-Daage, Dr. Tj. Jager, Dr. H.A. de Wit, Dr. J. Gautheyrou, Dr. J.M. Hernandez Moreno, Dr. H. Ikawa, Mr. J.H. Kauffman, Dr. R. Miehlich, Dr. H. Ohtsuka, Dr. A. Osman, Mr. G. del Posso, Dr. P. Quantin, Dr. W. Siderius, Dr. O.C. Spaargaren, Mr. J.L. Tersteeg, Dr. R. Tavernier, Dr. W.G. Wielemaker.

Thanks are due to the laboratory staff of ISRIC for their cooperation in the analysis of soil samples, to Ms. Y. Karpes-Liem and Mr. B. van Lagen for typographical assistance in the final phase, and to Dr. E.M. Bridges for reading the manuscript and improving the English presentation.

The senior author is grateful for the financial support of the Japanese Ministry of Education and the International Agricultural Centre during his stay at ISRIC, Wageningen.

REFERENCES

Andriesse, J.P. (1978) A study into the mobility of iron in podzolized Serawak upland soils by means of selective iron extractions. Neth. J. Agric. Sci. 27:1-12.

Andriesse, J.P., H.A. van Rosmalen and A. Muller (1976) On the variability of amorphous materials in Andosols and their relationships to irreversible drying and P-retention. Geoderma 16:125-138.

Aomine, A. and M.L. Jackson (1959) Allophane determination in Ando soils by cation-exchange capacity delta value. Soil Sci. Soc. Amer. Proc. 23:210-214.

Baham, J. and G.H. Simonson (1985) Classification of soils with andic properties from the Oregon Coast. Soil Sci. Soc. Amer. J. 49:777-780.

Bartlett, R. and B. James (1980) Studying dried, stored soil samples - some pitfalls. Soil Sci. Soc. Am. J. 44:721-724.

Bech Borras, J., P. Quantin and P. Ségalen (1976a) Etude des andosols d'Olot (Gerona, Espagne). Ecologie, morphologie, caractéristiques physiques et chimiques. Cah. ORSTOM sér. Pédol. Vol. XIV;73-87.

Bech Borras, J., P. Quantin and P. Ségalen (1976b) Etude des andosols d'Olot (Gerona, Espagne). II: Caractéristiques minéralogiques, conclusion. Cah. ORSTOM. sér. Pédol., Vol. XIV:95-111.

Beinroth, F.H. W. Luzio L., F. Maldonado P. and H. Eswaran (1985) Proceedings Sixth International Soil Classification Workshop, Chile and Ecuador. Part III: Tour guide for Ecuador. Soc. Chilena de la Ciencia del Suelo, Casilla 6177, Santiago, Chile.

Blakemore, L.C., P.L. Searle and B.K. Daly (1981) Methods for chemical analysis of soils. N.Z. Soil Bur. Sci. Rep. 10A and (1987) revised ed.: Rep. 80. Soil Bureau, Lower Hutt, New Zealand.

Blakemore, L.C., P.L. Searle and B.K. Daly (1981) Methods for chemical analysis of soils. N.Z. Soil Bur. Sci. Rep. 80, Soil Bureau, Lower Hutt, New Zealand.

Blume, H.P. and U. Schwertmann (1969) Genetic evaluation of profile distribution of aluminium, iron and manganese oxides. Soil Sci. Soc. Amer. Proc. 33:438-444.

Buringh, P. (1979) Introduction to the study of soils in tropical regions. Pudoc, Wageningen, Netherlands.

Buurman, P. and L.P. van Reeuwijk (1984) Proto-imogolite and the process of podzol formation: a critical note. J. Soil Sci. 35:447-452.

Cabrera, F., L. Madrid and P. de Arambarri (1977) Adsorption of phosphate by various oxides: theoretical treatment of the adsorption envelope. J. Soil Sci. 28:306-313.

Childs, C.W. (1975) Towards understanding soil mineralogy. II. Notes on ferrihydrite. Laboratory Report CM7, Soil Bureau Lower Hutt, New Zealand.

Childs, C.W. (1981) Field tests for ferrous iron and ferric-organic complexes (on exchange sites or in water-soluble forms) in soils. Austr. J. Soil Res. 19:175-180.

Childs, C.W. (1985) Towards understanding soil mineralogy. II. Notes on ferrihydrite. Laboratory Report CM7, Soil Bureau, Lower Hutt, New Zealand.

Churchman, G.J., J.S. Whitton, G.G.C. Claridge and B.K.G. Theng (1983) A rapid test for halloysite. Soil Taxonomy News 5:10.

Colmet-Daage, F. (1978) Caractéristiques et propriétés hydriques de quelques sols dérivés de cendres volcaniques du Chili central. Publ. ORSTOM-Antilles no. 85 bis (3me ed.). ORSTOM Bondy, France.

Colmet-Daage, F. (ed.) (undated) Etude de quelques sols dérivés de cendre volcaniques du Costa Rica. Publ. ORSTOM-Antilles no. 80.

Colmet-Daage, F. et P. Lagache (1965) Caractéristiques de quelques groupes de sols dérivés de roches volcaniques aux Antilles françaises. Cah. ORSTOM, sér. Pédol. 1965, Vol. III no. 2:91-122.

Colmet-Daage, F., J. et M. Gautheyrou, C. de Kimpe and G. Fusil (1972,a) Dispersion et étude des fractions fines de sols à allophane des Antilles et d'Amérique Latine. I. La dispersion. Cah. ORSTOM, Sér. Pédol. Vol. X:169-191.

Colmet-Daage, F., J. et M. Gautheyrou, C. de Kimpe, G. Fusil and G. Sieffermann (1972,b) Dispersion et étude des fractions fines de sol à allophanes des Antilles et d'Amérique Latine. II. Modification de la nature et de la composition de la fraction inférieure à 2 microns selon la taille des particules. Cah. ORSTOM Sér. Pédol. Vol. X:219-241.

Colmet-Daage, F., J. et M. Gautheyrou, C. de Kimpe, G. Sieffermann, M. Delaune and G. Fusil (1970) Caractéristiques de quelques sols dérivés de cendres volcaniques de la côte Pacifique du Nicaragua. Cah. ORSTOM, sér. Pedol. 1970, Vol. VIII, no. 2:137-171.

De Wit, H.A. (1978) Soils and grassland types of the Serengeti Plain (Tanzania). Thesis, Agricultural Univ. Wageningen, Netherlands.

Depto. Edafologia, Universidad de la Laguna (1984) Tour Guide, Int. Conf. Volc. Soils, Tenerife, 1984, p. 270-275.

FAO (1988) FAO-Unesco Soil Map of the World, Revised Legend. World Resources Report 60, FAO, Rome.

FAO-Unesco Soil Map of the World (1974) Vol. I. Legend. Unesco, Paris, France.

Farmer, V.C. (1981) Possible roles of a mobile hydroxyaluminium orthosilicate complex (proto-imogolite) in podzolisation. In: Migrations organo-minérales dans les sols tempérés. Nancy. Sept. 1979. Colloques Internationales. Editions Centr. Nat. Rech. Scientifique, Paris, No. 303:275-279.

Farmer, V.C., A.R. Fraser and J.M. Tait (1977) Synthesis of imogolite: A tubular aluminium silicate polymer. J. Chem. Soc. Comm. 1977:462-463.

Farmer, V.C., A.R. Fraser, J.M. Tait, F. Palmieri, P. Violante, M. Nakai and N. Yoshinaga (1978) Imogolite and proto-imogolite in an Italian soil developed on volcanic ash. Clay Min. 13:271-274.

Fernandez Caldas, E., J.M. Hernandez Moreno, M.L. Tejedor Salguero, A. Gonzalez Batista and V. Cubas Garcia (1985) Behaviour of oxalate reactivity (Ro) in different types of Andosols II. In: E. Fernandez Caldas and D.H. Yaalon (eds.) Volcanic Soils. Catena Suppl. 7:25-33.

Fernandez Caldas, E., M.L. Tejedor Salguero and P. Quantin (1982) Suelos de Regiones Volcanicas. Tenerife, Islas Canarias. Colleccion viera y clavijo IV. Secretariado de publicaciones de la Universidad de la Laguna, Tenerife.

Fieldes, M. and K.W. Perrot (1966) Rapid field and laboratory test for allophane. N.Z. J. Sci. 9:623-629.

Flach, K.W. (1964) Genesis and morphology of ash-derived soils in the United States of America. FAO World Soil Resources Rep. 14:61-70.

Garcia-Rodeja, E., B.M. Silva and F. Macias (1987) Andosols developed from non-volcanic materials in Galicia, N.W. Spain. J. Soil Sci. 38:573-591.

Gillman, G.P. (1987) Fingerprint your soils for agrotechnology transfer. IBSRAM Newsletter 5:3-6.

Gillman, G.P. and D.F. Sinclair (1987) The grouping of soils with similar charge properties as a basis for agrotechnology transfer. Austr. J. Soil Res. 25:275-285.

Goh, K.M. (1980) Dynamics and stability of organic matter. In: B.K.G. Theng (ed.) Soils with variable charge: 373-393. Soil Bureau, Lower Hutt, New Zealand.

Gregor, J.E. and H.K.P. Powell (1988) Protonation reactions of fulvic acids. J. Soil Sci. 39:243-252.

Gudmundsson, T. and A. Dellé (1986) Development of Andosols in the highland of Iceland. Trans. 13th Int. Congr. Soil Sci. III:1133-1134.

Hashimoto, I. and M.L. Jackson (1960) Rapid dissolution of allophane and kaolinite halloysite after dehydration. Clays & Clay Minerals. 7th Conf. 102-103.

Hassan, T.S., H. Ikawa and L.D. Swindale (1975) The properties and genesis of four soils derived from basaltic ash, Mauna Loa, Hawaii. Pacific Sci. 29:301-308.

Hernandez Moreno, J.M., V. Cubas Garcia, A. Gonzales Batista and E. Fernandez Caldas (1985) *Study of ammonium oxalate reactivity at pH 6.3 (Ro) in different types of soils with* variable charge. I. In: E. Fernandez Caldas and D.H. Yaalon (eds.) Volcanic Soils. Catena Suppl. 7:9-23.

Hernandez Moreno, J.M., V.A. Cubas, J. Hernandez Brito, E. Fernandez Caldas and A. Herbillon (1987) Ammonium oxalate reactivity of synthetic hydroxides and silica-alumina gels. Proc. Int. Clay Conf. Denver, 1985:237-243.

Hétier, J.M. (1975) Formation et évolution des andosols en climat tempéré humide. Doct. thesis, Univ. Nancy.

Hétier, J.M., N. Yoshinaga and F. Weber (1977) Formation of clay minerals in Ando soils under temperate climate. Clay Min. 12:299-306.

Higashi, T. (1983) Characterization of Al/Fe-humus complexes in Dystrandepts through comparison with synthetic forms. Geoderma 31:277-288.

Holmgren, G.G.S. (1967) A rapid citrate-dithionite extractable iron procedure. Soil Sci. Soc. *Amer. Proc. 31:210-211.*

Hunter, C.R., B.E. Frazier and A.J. Busacca (1987) Lytell Series: A non-volcanic Andisol. Soil Sci. Soc. Am. J. 51:376-383.

Huting, J.R.M. and L.P. van Reeuwijk (1986) A simplified new suction apparatus for the preparation of small-size porous plate clay specimens for X-ray diffraction. Techn. Pap. 11, ISRIC, Wageningen, Netherlands.

ICOMAND (1979) Circular Letter no. 1. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

ICOMAND (1983) Circular Letter no. 5. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

ICOMAND (1984a) Circular Letter no. 6. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

ICOMAND (1984b) Circular Letter no. 7. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

ICOMAND (1986) Circular Letter no. 8. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

ICOMAND (1987) Circular Letter no. 9. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

ICOMAND (1988) Circular Letter no. 10. Int. Comm. Classif. of Andisols, c/o Soil Bureau, Lower Hutt, New Zealand.

Inoue, K. (1986) Chemical properties. Chapt. 4 in Wada (1986).

Inoue, K. and P.M. Huang (1985) *Influence of citric acid on the formation of short-range* ordered aluminosilicates. Clays & Clay Minerals 33:312-322.

Inoue, K. and P.M. Huang (1986) Influence of selected organic ligands on the formation of allophane and imogolite. Soil Sci. Soc. Am. J. 50:1623-1633.

Inoue, K. and P.M. Huang (1987) Effect of humic and fulvic acid on the formation of allophane. Proc. Int. Clay Conf. Denver, 1985:221-226.

Jager, Tj. (1982) Soils of the Serengeti Woodlands, Tanzania. Thesis, Agricultural Univ., Pudoc, Wageningen.

Kanno, I., Y. Onikura and T. Higashi (1968) Weathering and clay mineralogical characteristics of volcanic ashes and pumices. Trans. 9th Int. Congr. Soil Sci., Adelaide 3:111-122.

Kenya Soil Survey Staff (1977) Guide to the "standard" soil excursion in the Nairobi-Thika-Kindaruma area. Misc. Soil Pap. 7, Kenya Soil Survey, Nairobi.

Kirkman, J.H. and W.J. McHardy (1980) A comparative study of the morphology, chemical *composition and weathering of rhyolitic and andesitic glass. Clay Min. 15:165-173.*

Kononova, M.M. (1975) Humus of virgin and cultivated soils. In: J.E. Gieseking (ed.) Soil Components. 1. Organic components: 475-526. Springer Verlag Berlin, Heidelberg, New York.

Kurobokudo Co-operative Research Group (1986) Data Base in Wada (1986).

Leamy, M.L. (1984) Andisols of the world. Congr. Intern. Suelos Volcanicos, Comunicaciones, Secretariado de Publicaciones, Serie Informes no. 13, Univ. de La Laguna, Tenerife: 369-387.

Leamy, M.L., G.D. Smith, F. Colmet-Daage and M. Otowa (1980) The morphological characteristics of Andisols. In: B.K.G. Theng (ed.) Soils with variable charge: 17-34. Soil Bureau, Lower Hutt, New Zealand.

Liu Chaoduan (1985) Genetic characteristics of volcanic ash soil in Tengchong County, Yunnan Province. Acta Pedologica Sinica 22:377-389 (in Chin. with Eng. abstr.).

Loganathan, P., N.O. Isirimah and D.A. Nwachuku (1987) Phosphosrus sorption by Ultisols and Inceptisols of the Niger delta in southern Nigeria. Soil Sci. 144:330-338.

Loveland, P.J. and P. Bullock (1976) Chemical and mineralogical properties of Brown Podzolic soils in comparison with soils of other groups. J. Soil Sci. 27:523-540.

Lowe, D.J. (1986) Controls on the rates of weathering and clay mineral genesis in airfall tephras: a review and New Zealand case study. In: S.M. Colman and D.P. Dethier (eds.) Rates of chemical weathering of rocks and minerals. Academic Press Inc.

Lulli, L. and D. Bidini (1980) A climosequence of soils on slopes of an extinct volcano in southern Italy. Geoderma 24:129-142.

Lulli, L., D. Bidini, B. Dabin and P. Quantin (1983). Étude de deux sols andiques dérivés de roches volcaniques d'Italie du Sud (Monts Roccamonfina et Vulture) à caractère cryptopodzolique. 1. Environment, morphologie et caractères des constituants minéraux. Cah. ORSTOM, Sér. Pédol. XX:27-44.

Luzio-Leighton, W. (1985) Int. Ref. Base for Soil Classif., Working Comm. no. 11. Andic soils. Circular Letter 2.

McKeague, J.A. (1967) An evaluation of 0.1 M pyrophosphate and pyrophosphate-dithionite in comparison with oxalate as extractants of the accumulation products in podzols and some other soils. Can. J. Soil Sci. 47:95-99.

McKeague, J.A. and J.H. Day (1966) Dithionite and oxalate-extractable Fe and Al as aids in differentiating various classes of soils. Can. J. Soil Sci. 46:13-22.

McKeague, J.A., J.E. Brydon and N.M. Miles (1971) Differentiation of forms of extractable iron and aluminium in soils. Soil Sci. Soc. Amer. Proc. 35:33-38.

Mehra, O.P. and M.L. Jackson (1961) Iron oxide removal from soils and clays by a dithionite-citrate system buffered with sodium bicarbonate. Clays & Clay Minerals 7th Conf.:317-327.

Mejia, G., H. Konuke and J.L. White (1968) Clay mineralogy of certain soils of Colombia. Soil Sci. Soc. Am. Proc. 32:665-670.

Miehlich, G. (1980) The soils of the Sierra Nevada de Mexico. Data volume. Suplemento Comunicaciones, Proyecto Puebla-Tlaxcala VII. Fundacion Alemana para la Investigacion Cientifica, Priv. Calz. de los Fuertes 30-4, Puebla, Mexico.

Miehlich, G. (1984) Chronosequenzen und anthropogene Veränderungen andesitischen Vulkanaschböden in drei Klimastufen eines randtropisches Gebirges (Sierra Nevada de Mexico). Habilitationsschrift, Universität Hamburg, FRD.

Mizota, C. (1976) Relationships between the primary minerals and the clay mineral compositions of some recent Andosols. Soil Sci. Plant Nutr. 22:257-268.

Mizota, C. (1982) Tropospheric origin of quartz in Ando soils and Red-Yellow soils on basalts, Japan. Soil Sci. Plant Nutr. 28:517-522.

Mizota, C. (1983) Eolian origin of the micaceous minerals in an Ando soil from Kitakami, Japan. Soil Sci. Plant Nutr., 29:379-382.

Mizota, C. (1987) Chemical and mineralogical characterization of soils derived from volcanic ashes. In: S. Hirose (ed.) Agriculture and soils in Kenya - A case study of farming systems in the Embu District and characterization of volcanogenous soils. College of Agric. and Veterinary Medicine. Nihon Univ., Tokyo, Japan.

Mizota, C. and J. Chapelle (1988) Characterization of some Andepts and Andic soils in Rwanda, Central Africa. Geoderma 41:193-209.

Mizota, C. and T. Matsuhisa (1985) Eolian additions to soils and sediments of Japan. Soil Sci. Plant Nutr. 31:385-398.

Mizota, C., I. Kawasaki and T. Wakatsuki (1988) Clay mineralogy and chemistry of seven pedons formed in volcanic ash, Tanzania. Geoderma 43:131-141.

Mohr, E.C.J., F.A. van Baren and J. van Schuylenborgh (1972) Tropical Soils. Third ed. Mouton, Ichtiar Baru, Van Hoeve, The Hague, Paris, Djakarta.

Naidu, R., J.H. Kirkman and R.J. Morrison (1987) Mineralogy of soils from basaltic ash, Taveuni, Fiji. Geoderma 39:181-192.

National Soil Service Project (1985) Field Tour Guide, Kilimanjaro region, E. Afr. Soil Sci. Soc. Meeting, Arusha, Tanzania. N.S.S.P., Tanga, Tanzania.

Neall, V.E. (1985) Parent materials of Andisols. Proc. Sixth Int. Soil Classif. Workshop, Chile and Ecuador. Part 1. Papers:9-19.

Nelson, D.W. and L.E. Sommers (1982) Total carbon, organic carbon, and organic matter. In: A.L. Page (ed.) Methods of soil analysis. Part 2, 2nd ed., Agron. Ser. 9, ASA, SSSA, Madison, USA.

Osman, A., R. Tavernier, M. Ilaiwi and B. Kabbra (1985) Andisols in Syria. Proc. Sixth Int. Soil Classif. Workshop, Chile and Ecuador, Part 1. Papers: 321-336.

Otowa, M. (1986) Morphology and classification. In: K. Wada (ed.) Ando soils in Japan: 3-20. Kyushu University Press, Fukuoka, Japan.

Parfitt, R.L. (1984) The nature of Andic and Vitric materials. Congr. Intern. Suelos Volcanicos, Comunicaciones, Secretariado de Publicaciones, Serie Informes no. 13, Univ. de La Laguna, Tenerife: 413-435.

Parfitt, R.L. (1985) Allophane and ferrihydrite in some different Andisols from Overseas. N.Z. Soil News 33:196-202.

Parfitt, R.L. and M. Saigusa (1985) Allophane and humus-aluminium in Spodosols and Andepts formed from the same volcanic ash beds in New Zealand. Soil Sci. 139:149-155.

Parfitt, R.L. and A.D. Wilson (1985) Estimation of allophane and halloysite in three sequences of volcanic soils, New Zealand. In: E. Fernandez Caldas and D.H. Yaalon (eds.) Volcanic Soils. Catena Suppl. 7:1-8.

Parfitt, R.L., A.R. Fraser and V.C. Farmer (1977) Adsorption on hydrous oxides. III. Fulvic acid and humic acid on goethite, gibbsite and imogolite. J. Soil Sci. 28:289-296.

Parfitt, R.L., J.A. Pollok and R.J. Furkert (compilers) (1980a) Guide Book Tour I, North Island. Soils with variable charge conf., Soil Bureau, Lower Hutt, New Zealand.

Parfitt, R.L., R.J. Furkert and T. Henmi (1980b) Identification and structure of two types of allophane from volcanic ash soils and tephra. Clays & Clay Minerals 28:328-334.

Parfitt, R.L., M. Russel and G.E. Orbell (1983) Weathering sequence of soils from volcanic ash involving allophane and halloysite. Geoderma 29:41-57.

Parfitt, R.L., M. Saigusa and J.D. Cowie (1984) Allophane and halloysite formation in a volcanic ash bed under different moisture conditions. Soil Sci. 138:360-364.

Parfitt, R.L., C.W. Childs and D.N. Eden (1988) Ferrihydrite and allophane in four Andepts from Hawaii and implications for their classification. Geoderma 41:223-241.

Perrot, K.W., B.F.L. Smith and R.H.E. Inkson (1976) The reaction of fluoride with soils and soil minerals. J. Soil Sci. 27:58-67.

Ping, C.L., S. Shoji and T. Ito (1988) Properties and classification of three volcanic ash-derived pedons from Aleutian Islands and Alaska Peninsula, Alaska. Soil Sci. Soc. Am. J. 52:455-462.

Posner, A.M. (1964) Titration curves of humic acids. Trans. 8th Int. Congr. Soil Sci., Bucharest 3:161-173.

Quantin, P. (1982) Proposition du taux de capacité d'échange de cations dépendante du pH, comme critère de classification des andosols des Nouvelles-Hébrides (Vanuatu). Cah. ORSTOM, Sér. Pédol. XIX:369-380.

Quantin, P. (1985) Characteristics of the Vanuatu Andosols. In: E.Fernandez Caldaz and D.H. Yaalon (eds.) Volcanic Soils, Catena Suppl. 7:99-105.

Quantin, P. and A. Bouleau (1983) Détermination des constituants minéraux amorphes et crypto-cristallins d'andosols par l'analyse cinétique de leur dissolution par HCl et NaOH. Sci. du Sol - Bull. de l'A.F.E.S. no. 3/4-1983:217-234.

Quantin, P., D. Badaut-Trauth and F. Weber (1975) Mise en évidence de minéraux secondaires, argiles et hydroxides, dans les andosols des Nouvelles-Hébrides, apres la déferrification par la méthode de Endredy. Bull. Groupe franç. Argiles, 27:51-67.

Quantin, P., B. Dabin, A. Bouleau, L. Lulli and D. Bidini (1985) Characteristics and genesis of two Andosols in Central Italy. In: E. Fernandez Caldas and D.H. Yaalon (eds.) Volcanic Soils. Catena Suppl. 7:107-117.

Rich, C.I. (1968) Hydroxy-Al interlayers in expansible layer silicates. Clays & Clay Minerals 16:15-30.

Schnitzer, M. and S.I.M. Skinner (1963) Organo-metallic interactions in soils: 2. Reactions between different forms of iron and aluminium and the organic matter of a Podzol Bh horizon. Soil Sci. 96:181-186.

Schnitzer, M. and S.I.M. Skinner (1963) Organo-metallic interactions in soils: 1. Reactions between a number of metal ions in the organic matter of a podzol Bh horizon. Soil Sci. 96:86-93.

Schuppli, P.A., G.J. Ross and J.A. McKeague (1983) The effective removal of suspended materials from pyrophosphate extracts of soils from tropical and temperate regions. Soil Sci. Soc. Amer. J. 47:1026-1032.

Schwertmann, U. (1964) The differentiation of iron oxides in soil by extraction with ammonium oxalate solution. Zeitschr. Pflanzenern. Düngung, Bodenk. 105:194-202.

Schwertmann, U. (1985) The effect of pedogenic environments on iron oxide minerals. In: B.A. Stewart (ed.) Advances in soil science. Vol. 1:171-200. Springer-Verlag, New York.

Segalen, P. (1968) Note sur une méthode de détermination des produits minéraux amorphes dans certain sols à hydroxydes tropicaux. Cah. ORSTOM. Sér. Pédol. VI:105-126.

Shoji, S. and J. Masui (1971) Opaline silica of recent volcanic ash soils in Japan. J. Soil Sci. 22:101-108.

Shoji, S. and T. Ono (1978) Physical and chemical properties and clay mineralogy of Andosols from Kitakami, Japan. Soil Sci. 126:297-312.

Shoji, S. and Y. Fujiwara (1984) Active Al and Fe in the humus horizons of Andosols from northeastern Japan: Their forms, properties, and significance in clay weathering. Soil Sci. 137:216-226.

Shoji, S., I. Yamada and K. Kurashima (1981) Mobilities and related factors of chemical elements in the topsoils of Andosols in Tohoku, Japan: 2. Chemical and mineralogical compositions of size fractions and factors influencing the mobilities of major chemical elements. Soil Sci. 132:33-34.

Shoji, S., T. Ito, M. Saigusa and I. Yamada (1985) Properties of nonallophanic Andosols from Japan. Soil Sci. 140:264-277.

Shoji, S., Y. Fujiwara, I. Yamada and M. Saigusa (1982) Chemistry and clay mineralogy of Ando soils, Brown Forest soils, and Podzolic soils formed from recent Towada ashes, N.E. Japan. Soil Sci. 133:69-86.

Shoji, S., T. Takahashi, M. Saigusa, I. Yamada and F.C. Ugolini (1988a) Properties of Spodosols and Andisols showing climosequential and biosequential relations in S. Hakkoda, N.E. Japan. Soil Sci. 145:135-150.

Shoji, S., T. Takahashi, T. Ito and C.L. Ping (1988b) Properties and classification of selected volcanic ash soils from Kenai Peninsula, Alaska. Soil Sci. 145:396-413.

Simonson, R.W. and S. Rieger (1967) Soils of the Andept suborder in Alaska. Soil Sci. Soc. Am. Proc. 31:692-699.

Tate, K.R. and B.K.G. Theng (1980) Organic matter and its interactions with inorganic soil constituents. In: B.K.G. Theng (ed.) Soils with variable charge: 225-249. Soil Bureau, Lower Hutt, New Zealand.

Tazaki, K. (1986) Observation of primitive clay precursors during microcline weathering. Contrib. Mineral. Petrol. 92:86-88.

Tazaki, K. and W.S. Fyfe (1987a) Formation of primitive clay precursors on K-feldspar under extreme leaching conditions. Proc. Int. Clay Conf. Denver, 1985:53-58.

Tazaki, K. and W.S. Fyfe (1987b) Primitive clay precursors formed on feldspar. Can. J. Earth Sci. 24:506-527.

Tazaki, K. and W.S. Fyfe (1988) Glass-Amorphous? In: G.W. Bailey (ed.) Proc. 46th Ann. Meeting Electron Micro. Soc. Amer. p. 472. San Francisco Press, San Francisco.

Theisen, A.A. (1966a) Kristalline Bestandteile saurer tropischer Böden auf vulkanischem Ausgangsmaterial in Kenia. Zeitschr. Pflanzenern., Düngung, Bodenk. 115:173-181.

Theisen, A.A. (1966b) Röntgenamorphe Bestandteile saurer tropischer Böden auf vulkanischem Ausgangsmaterial in Kenia. Zeitschr. Pflanzenern., Düngung, Bodenk. 115:181-192.

Thorp, J. and G.D. Smith (1949) Higher categories of soil classification: Order, Suborder, and Great Soil Groups. Soil Sci. 67:117-126.

Tokashiki, Y. and K. Wada (1975) Weathering implications of the mineralogy of clay fractions of two Ando soils, Kyushu. Geoderma 14:47-62.

Tokudome, S. and I. Kanno (1968) Nature of humus in some Japanese soils. Trans. 9th Int. Congr. Soil Sci., Adelaide, 3:163-173.

Tour Guide 6th Int. Class. Workshop (1984). See Beinroth et al. (1985).

Ugolini, F.C. and R. Dahlgren (1987) The mechanism of podzolization as revealed by soil solution studies. In: D. Righi and A. Chauvel (eds.) Podzols et Podzolisation, Compt. Rend. Table Ronde Intern., AFES, INRA, Lab. de Pédologie, Univ. de Poitiers, France.

Ugolini, F.C., R. Dahlgren, S. Shoji and T. Ito (1988) An example of andosolization and podzolisation as revealed by soil solution studies, S. Hakkado, N.E. Japan. Soil Sci. 145:111-125.

Ugolini, F.C., R. Minden, H. Dawson and J. Zachara (1977) An example of soil processes in the Abies amabilis zone of Central Cascades, Washington. Soil Sci. 124:191-302.

USDA, Soil Conservation Service (1972, revised ed. 1982) Soil survey laboratory methods and procedures for collecting soil samples. Soil Survey Invest. Rep. no. 1.

USDA, Soil Survey Staff (1975) Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. USDA Handbook no. 436. USDA-SCS. U.S. Govt. Printing Office, Washington, D.C.

Van Breemen, N. and W.G. Wielemaker (1974a) Buffer intensities and equilibrium pH of minerals and soils: I. The contribution of minerals and aqueous carbonate to pH buffering. Soil Sci. Soc. Am. Proc. 38:55-60.

Van Breemen, N. and W.G. Wielemaker (1974b) Buffer intensities and equilibrium pH of minerals and soils: II. Theoretical and actual pH of minerals and soils. Soil Sci. Soc. Am. Proc. 38:61-66.

Van der Gaast, S.J., C. Mizota and J.H.F. Jansen (1986) Curved smectite in soils from volcanic ash in Kenya and Tanzania: A low angle X-ray powder diffraction study. Clays & Clay Minerals 34:665-671.

Van Reeuwijk, L.P. (1982) Laboratory methods and data exchange program for soil characterization. A report on the pilot round. Part I: CEC and texture. Techn. Pap. 6, ISRIC, Wageningen.

Van Reeuwijk, L.P. (1984a) On the way to improve international soil classification and correlation: the variability of analytical data. Ann. Rep. 1983 Intern. Soil Museum (now ISRIC), Wageningen.

Van Reeuwijk, L.P. (1984b) Laboratory methods and data exchange program for soil characterization. A report on the pilot round. Part II: Exchangeable bases, base saturation and pH. Techn. Pap. 8, ISRIC, Wageningen.

Van Reeuwijk, L.P. and A.J.M. van Oostrum (1986) A rapid method to determine a CEC delta value of soils. Poster Paper Int. Conf. Volc. Soils, Tenerife, 1984. Preprint and Working Paper 86/6, ISRIC, Wageningen, Netherlands.

Van Reeuwijk, L.P. and J.M. de Villiers (1970) A model system for allophane. Agrochemophysica 2:77-82.

Veniale, F. and F. Caucia (1984) Soils and weathering products from acidic volcanic rocks (Val Sesia, N. Italy). Congr. Intern. Suelos Volcanicos, Comunicaciones, Secretariado de Publicaciones, Serie Informes no. 13, Univ. de La Laguna, Tenerife: 689-690 (abstr.).

Violante, P. and J.M. Tait (1979) Identification of imogolite in some volcanic soils from Italy. Clay Min. 14:155-158.

Violante, P. and M.J. Wilson (1983) Mineralogy of some Italian Andosols with reference to the origin of the clay fraction. Geoderma 29:157-174.

Wada, K. (1977) Allophane and imogolite. In: J.B. Dixon and S.B. Weed (eds.) Minerals in soil environments: 603-638. Soil Sci. Soc. Amer., Madison, USA.

Wada, K. (1980) Mineralogical characteristics of Andisols. In: B.K.G. Theng (ed.) Soils with variable charge: 87-109. Soil Bureau, Lower Hutt, New Zealand.

Wada, K. (1985) The distinctive properties of Andosols. In: B.A. Stewart (ed.) Advances in soil science 2:173-229. Springer Verlag, New York.

Wada, K. (1986) (ed.) Ando soils in Japan. Kyushu Univ. Press, 7-1-146, Hakozaki, Higashi-ku, Fukuoka-shi, 812, Japan: 115-276.

Wada, K. and I. Matsubara (1968) Differential formation of allophane, imogolite and gibbsite in the Kitakami pumice bed. Trans. 9th Int. Congr. Soil Sci., Adelaide, 3:123-131.

Wada, K. and S. Aomine (1973) Soil development on volcanic materials during the Quaternary. Soil Sci. 116:170-177.

Wada, K. and S.-I. Wada (1976) Clay mineralogy of the B horizons of two Hydrandepts, a Torrox and a Humitropept in Hawaii. Geoderma 16:139-157.

Wada, K. and N. Gunjigake (1979) Active aluminum and iron and phosphate adsorption in Ando soils. Soil Sci. 128:331-336.

Wada, K. and Y. Kakuto (1985) Embryonic halloysites in Ecuadorian soils derived from volcanic ash. Soil Sci. Soc. Amer. J. 49:1309-1318.

Wada, K., Y. Kakuto and H. Ikawa (1986) Clay minerals, humus complexes, and classification of four "Andepts" of Maui, Hawaii. Soil Sci. Soc. Am. J. 50:1007-1013.

Wada K., T. Henmi, N. Yoshinaga and S.H. Patterson (1972) Imogolite and allophane formed in saprolite of basalt on Maui, Hawaii. Clays & Clay Minerals 20:375-380.

Wada, S.-I. (1987) Imogolite synthesis at 25 °C. Clays & Clay Minerals 35:379-384.

Wakatsuki, T. and W.G. Wielemaker (1985) Clay minderalogy of a soil formed in peralkaline volcanic ash from The Great Rift Valley in Kenya. Soil Sci. Plant Nutr. 31:475-480.

Walter, H. and H. Lieth (1967) Klimadiagramm-Weltatlas. Gustav Fisher, Jena.

Warkentin, B.P. and T. Maeda (1974) Physical properties of allophane soils from the West Indies and Japan. Soil Sci. Soc. Am. Proc. 38:372-377.

Wielemaker, W.G. and H.W. Boxem (eds.) (1982) Soils of the Kisii area, Kenya. Agric. Res. Rep. 922, Pudoc, Wageningen, Netherlands.

Wielemaker, W.G. and T. Wakatsuki (1984) Properties, weathering and classification of some soils formed in peralkaline volcanic ash in Kenya. Geoderma 32:21-44.

Wright, A.C.S. (1964) The Andosols or Humic Allophane soils of South America. FAO World Soil Resources Rep. 14:9-22.

Yerima, B.P.K., L.P. Wilding, F.G. Calhoun and C.T. Hallmark (1987) Volcanic ash-influenced Vertisols and associated Mollisols of El Salvador: physical, chemical and morphological properties. Soil. Sci. Soc. Amer. J. 51:699-708.

Zhao Qi-guo (1988) Volcanic *ash soils in* China. *Soil Res.* Rep. *no.* 19, Inst. *of* Soil Sci., Acad. Sinica, Nanjing, China.

APPENDIX 1

Soil characterization data

App. 1. Soil data.

GROUP I

Depth (cm)	Hori-zon	Clay[1] ro	sp	pH	Org. C (%)	pH H2O	KCl	NaF	CEC (cmol(+)/kg)	Sum bases	Exch. Al	Al Pyr (%)	Al DC	Al Ox	Fe Pyr (%)	Fe DC	Fe Ox	Si Ox (%)	Al/Si[2] atom. ratio	Allo phane (%)	Excess[3] Al (%)	Excess Si	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)
# CO-11	COLOMBIA				Humic Andosol				Hydric Dystrandept/Typic Hydrandept																			
0-30	Ah1	23	17	4	15.4	4.3	4.2	10.6	68	7	2.5	1.9	2.1	3.0	0.9	1.3	1.2	0.8	1.4	5	-	-	0.6	2	0.92		58	98
30-57	Ah2	32			9.8	4.9	4.7	10.5	65	6	0.3	1.2	2.8	6.2	0.8	1.5	1.6	2.4	2.2	20	-	-	0.2	3	1.07		73	99
57-80	AC	36	32	4	6.3	5.4	4.9	10.3	62	3	0.2	0.9	6.4	6.2	0.6	3.6	1.5	2.7	2.0	21	-	-	0.1	3	0.42		71	99
80-130	C1	39			6.5	5.5	5.0	10.2	66	3	0.0	1.0	3.1	6.4	0.9	2.9	2.4	2.9	1.9	21	-	-	0.2	4	0.83		100	99
130-150	C2	42	41	4	3.5	5.7	5.4	10.0	74	6	0.0	1.4	1.6	10.3	0.2		2.6	5.7	1.6	38	-	-	0.1	4			90	99
# CO-12	COLOMBIA				Humic Andosol				Typic Dystrandept																			
0-30	Ah1	19	15	4	15.9	4.3	4.2	10.8	62	1	3.2	2.1	2.3	3.9	0.5	1.0	0.7	0.7	2.7	6	0.1	-	0.5	1	0.70	0.48	54	99
30-65	Ah2	19			9.3	5.1	4.7	10.9	47	2	0.6	1.3	1.7	4.0	0.3	0.8	0.6	1.2	2.3	10	-	-	0.3	1	0.75	0.72	48	99
65-88	AC	43	36	4	11.2	5.3	4.9	10.8	76	2	0.3	1.2	3.3	8.6	0.4	1.5	1.2	3.2	2.4	29	-	-	0.1	2	0.80	0.52	91	99
88-108	C1	40	45	4	1.9	5.6	5.4	10.6	47	2	0.1	0.3	2.1	9.7	0.0	2.2	1.6	5.5	1.8	39	-	-	0.0	3	0.73	0.48	85	99
108-150	C2	35			1.3	5.6	5.4	10.5	46	3	0.1	0.3	1.3	10.5	0.0	2.4	1.7	6.2	1.7	42	-	-	0.0	3	0.71			99
# CO-13	COLOMBIA				Humic Andosol				Typic Hydrandept																			
0-12	Ah1	20			46.2	4.1	3.4	6.9	179	10	6.5	0.5	0.7	0.7	0.3	0.4	0.4	0.1	2.1	<1	-	-	0.7	<1	1.00		150	56
12-30	Ah2	24			28.6	4.0	3.6	8.0	105	2	12.2	0.9	1.4	1.0	0.6	0.6	0.7	0.1	1.0	<1	-	-	0.9	1	1.17		114	82
30-51	AB	17	17	4	13.1	4.4	4.2	10.8	66	5	4.1	2.4	2.0	2.6	0.1	0.2	0.1	0.5	0.4	3	-	0.3	0.9	<1	0.50		67	99
51-78	Bh	32			15.9	4.4	4.2	10.9	122	0	4.5	2.7	5.7	7.1	0.4	0.5	0.5	1.6	2.9	15	0.6	-	0.4	<1	1.00		106	99
78-82	Bir	37	27	4	14.3	4.9	4.3	10.8	117	1	2.4	2.1	6.1	8.5	3.0	4.7	5.1	2.5	2.7	24	0.4	-	0.2	9	1.09		109	99
82-98	BC	28			8.5	5.1	4.7	10.9	77	0	0.8	1.3	4.1	8.0	0.5	1.4	1.1	2.8	2.5	26	-	-	0.2	2	0.79		92	99
98-120	C1	23	21	4	2.4	5.3	5.2	10.8	45	2	0.2	0.4	0.8	5.8	0.1	0.4	0.3	2.6	2.2	21	-	-	0.1	<1	0.75		50	99
120-150	C2	36			3.4	5.2	4.9	10.7	51	1	0.2	0.5	1.0	6.1	0.1	0.6	0.6	2.7	2.2	22	-	-	0.1	1	1.00		90	99
# CO-14	COLOMBIA				Humic Andosol				Hydric Dystrandept/Typic Hydrandept																			
0-30	Ah1	9	8	4	11.8	4.1	4.2	10.3	37	2	3.2	1.1	0.9	1.1	1.2	1.5	1.5	0.2	0.0	<1	-	-	1.0	3	1.00	0.49	106	93
30-50	Ah2	11			5.3	4.5	4.4	10.5	22	1	0.8	0.7	1.0	1.3	0.9	2.0	1.9	0.3	2.1	2	-	-	0.5	3	0.95		70	93
50-68	Ah3	17	30	4	7.9	4.6	4.5	10.6	35	2	0.7	0.8	1.5	2.2	1.0	2.0	2.0	0.7	2.1	6	-	-	0.4	3	1.00	0.66	103	99
68-98	C	15			2.6	5.4	5.0	10.5	17	1	0.2	0.4	1.3	1.8	0.2	2.2	2.0	0.8	1.8	6	-	-	0.2	3	0.91		60	96
98-150	2AB	20	17	4	6.5	5.5	4.8	10.5	32	5	0.4	0.8	1.1	1.6	0.9	1.9	1.8	0.6	1.4	4	-	-	0.5	3	0.95		86	96
# PHI-1	PHILIPPINES				Humic Andosol				Hydric Dystrandept																			
0-27	A1	42	29	4	11.0	4.9	4.6	10.8	94	2	0.3	1.4	2.7	9.4	0.5	2.3	1.4	3.2	2.6	30	0.3	-	0.1	2	0.61	0.54	74	99
27-52	B1	48			4.7	5.5	5.2	10.6	68	5	0.0	0.4	2.3	8.5	0.0	2.5	1.2	4.6	1.8	32	-	-	0.0	2	0.48			99
52-85	B21	41	39	4	2.3	5.6	5.2	10.3	67	5	0.0	0.3	2.3	10.9	0.0	2.3	1.2	4.5	2.4	40	-	-	0.0	2	0.52	0.53	105	99
85-121	B22	42			1.9	5.6	5.2	10.3	73	3	0.0	0.3	2.0	9.3	0.0	2.6	1.8	5.3	1.8	32	-	-	0.0	3	0.69			99
121-157	B23	41	43	4	1.9	5.6	5.2	10.2	77	3	0.0	0.3	1.6	9.7	0.0	2.9	1.5	5.7	1.7	39	-	-	0.0	3	0.52	0.45	113	99

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for dispersion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr = pyrophosphate
DC = dithionite-citrate
Ox = oxalate

App. 1. Soil data.

GROUP I

Depth (cm)	Horizon	Clay[1] ro -(%)-	Clay sp	Clay pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases	Exch. Al	Al Pyr -----(%)-----	Al DC	Al Ox	Fe Pyr -----(%)-----	Fe DC	Fe Ox	Si Ox (%)	Al/Si[2] atom. ratio	Allophane (%)	Excess[3] Al --(%)--	Excess Si	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)
# INS-11	INDONESIA				Humic Andosol		Hydric Dystrandept																					
0-12	Ap1	24	31	4	10.6	5.0	4.6	10.0	66	6	0.6	1.1	1.9	5.7	0.6	3.4	1.9	2.4	2.0	18	-	-	0.2	3	0.56	0.79	37	96
12-23	Ap2	20			6.9	4.7	4.4	10.1	64	2	1.6	1.2	2.0	6.0	0.6	3.4	2.0	2.6	1.9	19	-	-	0.2	3	0.59	0.79	38	98
23-40	B2	12	28	4	3.1	5.3	4.9	10.2	68	3	0.1	0.7	2.3	8.2	0.2	3.6	1.9	4.2	1.9	31	-	-	0.1	3	0.53	0.55	87	99
40-78	2A11	17	25	4	11.7	6.0	5.3	10.3	113	20	0.0	1.7	2.8	6.8	2.3	5.7	3.6	2.8	1.9	20	-	-	0.2	6	0.63	0.48	111	99
78-107	2A12	20			14.3	5.9	5.2	10.3	104	14	0.0	1.7	3.6	7.7	2.0	5.9	3.3	3.4	1.8	24	-	-	0.2	6	0.56	0.47	125	99
107-132	2A3	20			11.0	5.8	5.2	10.3	101	10	0.0	1.3	4.1	10.3	1.4	7.4	4.6	4.5	2.1	36	-	-	0.1	8	0.62	0.49	132	99
132-141	2B2	19	54	4	9.2	5.6	5.1	10.2	90	5	0.0	1.0	4.4	9.2	0.7	8.2	4.5	4.7	1.8	33	-	-	0.1	7	0.55	0.49	124	99
141-162	3A1	25	53	4	9.6	5.4	4.9	10.2	101	4	0.1	1.4	5.0	10.4	1.1	8.1	4.7	5.5	1.7	37	-	-	0.1	8	0.58	0.51	138	99
162-210	3B22	23	53	4	3.3	5.5	5.1	10.1	85	5	0.0	0.6	4.3	12.2	0.1	9.6	4.5	7.6	1.6	50	-	-	0.0	7	0.47	0.56	115	99
210-236	4A1	14	78	10	6.4	5.0	4.1	8.7	71	6	1.8	0.9	2.2	2.3	4.3	9.3	5.9	0.6	2.4	5	-	-	0.4	10	0.63		97	95
236-270	4B2	20	53	10	1.8	5.3	4.9	10.0	64	4	0.0	0.4	3.2	8.6	0.1	8.6	4.5	6.1	1.4	38	-	-	0.0	7	0.52		99	99
# RWA-1	RWANDA				Mollic Andosol		Udic Eutrandept																					
0-11	A11	25	27	4	9.9	5.8	5.4	9.8	80	34	0.0	0.8	1.8	4.3	0.5	5.7	3.1	2.4	1.5	15	-	-	0.2	5	0.54	0.61	62	96
11-40	A12	26			8.9	6.0	5.6	9.8	71	40	0.0	0.8	1.8	4.7	0.5	5.9	3.1	2.5	1.6	16	-	-	0.2	5	0.53	0.53	56	96
40-60	B1	16	31	4	5.4	6.6	5.8	9.8	64	38	0.0	1.1	2.4	6.7	1.1	4.8	5.4	3.3	1.8	23	-	-	0.2	9	1.13	0.50	74	99
60-90	B21	13			6.4	6.7	6.0	10.2	81	36	0.0	0.9	2.8	7.4	0.7	6.8	6.6	4.1	1.6	27	-	-	0.1	11	0.97	0.49	75	99
90-102	B22	4	7	4	3.0	6.8	6.0	10.1	74	29	0.0	0.4	2.9	8.1	0.1	10.9	8.7	5.4	1.5	34	-	-	0.0	15	0.80	0.55	56	99
# I-16	ITALY (La Palazzina)				Humic Andosol		Typic Dystrandept																					
0-4	Ah1	27	17	4	14.5	4.6	4.3	10.1	67	10	1.2	1.2	1.6	4.1	0.5	1.8	0.3	1.2	2.5	11	-	-	0.3	<1	0.17			96
4-29	Ah2	15			5.9	4.9	4.7	10.8	39	1	0.5	1.0	2.2	5.1	0.4	1.9	0.3	1.3	3.3	12	1.0	-	0.2	<1	0.16	0.50	42	99
29-47	Bu1	3	5	4	1.4	5.6	5.4	10.4	37	1	0.0	0.4	1.7	6.0	0.1	2.4	0.4	3.9	1.5	25	-	-	0.1	<1	0.17	0.58	51	99
47-66	Bu2	7			1.1	5.7	5.5	10.2	35	1	0.0	0.3	1.3	6.1	0.1	2.4	0.3	4.7	1.3	28	-	-	0.0	<1	0.12	0.57	51	99
66-85	BC1	4			0.5	5.9	5.4	9.7	33	1	0.0	0.2	0.9	5.1	0.1	1.9	0.3	3.8	1.3	23	-	-	0.0	<1	0.16	0.58	40	99
85-110	BC2	2	2	4	0.6	5.9	5.3	9.7	29	1	0.0	0.2	0.9	4.9	0.1	1.6	0.3	3.6	1.4	22	-	-	0.0	<1	0.19			99
ITALY	(Roccamonfina)				Humic Andosol		Typic Dystrandept																					
0-20	A11		22	4	16.9	6.1	5.3	10.0		48																0.58	25	95
20-45	A3		22	4	6.7	5.9	5.5	11.3		11																	21	98
45-110	B21		25	4	3.3	6.0	5.7	11.0		6																	22	99
110-150	2B22		24	4	1.1	6.0	5.4	11.6		6																	15	99
# USA-5	UNITED STATES (HAWAII, Kikoni)				Umbric Andosol		Typic Dystrandept																					
0-18	Ap	39	31	4	13.8	6.4	5.7	8.6	100	43		0.6	1.6	3.4	0.3	5.8	3.9	1.0	2.9	9	0.4	-	0.2	7	0.67		36*	92
18-40	B21	32			8.6	7.1	6.2	9.8	88	41		0.3	2.8	5.4	0.1	7.5	5.7	1.8	2.9	17	0.8	-	0.1	10	0.76	0.58	43	99
40-66	B22	34	51	4	7.6	7.3	6.4	10.3	91	39		0.3	3.5	8.6	0.1	8.3	7.0	3.5	2.5	33	-	-	0.0	12	0.84	0.59	48	99
66-107	B23	44			5.5	7.1	6.2	10.3	92	28		0.3	3.5	9.2	0.1	6.2	7.1	3.8	2.4	34	-	-	0.0	12	1.15	0.54	47	99
107-152	2B24	56	47	4	4.6	7.0	6.0	10.3	102	26		0.3	3.7	8.7	0.2	7.6	7.7	4.0	2.2	33	-	-	0.0	13	1.01		46	99

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for dispersion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

* dried, throughout

App. 1. Soil data.

GROUP I

Depth (cm)	Horizon	Clay[1] ro -(%)-	Clay[1] sp -(%)-	Clay[1] pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases (cmol(+)/kg)	Exch. Al (cmol(+)/kg)	Al Pyr -----(%)-----	Al DC -----(%)-----	Al Ox -----(%)-----	Fe Pyr -----(%)-----	Fe DC -----(%)-----	Fe Ox -----(%)-----	Si Ox (%)	Al/Si[2] atom. ratio	Allophane (%)	Excess[3] Al --(%)--	Excess[3] Si --(%)--	Binary ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)
# USA-6	UNITED STATES (HAWAII,Kukaiau) Humic Andosol Hydric Dystrandept																											
0-17	Ap1	41	53	4	9.2	5.1	4.8	10.3	60	1	0.3	1.9	4.6	6.0	1.8	8.0	7.1	0.9	4.7	9	1.9	-	0.3	12	0.89		35*	99
17-31	Ap2	45			8.9	5.2	5.0	10.4	58	0	0.1	1.9	5.1	5.5	2.5	9.4	7.2	1.0	3.7	9	1.2	-	0.3	12	0.77		42	99
31-49	B21	55	46	4	5.8	5.9	5.5	10.4	66	1	0.1	1.0	5.0	7.4	1.3	9.6	8.0	2.0	3.3	19	1.6	-	0.1	14	0.83		50	99
49-60	B22	57			6.0	6.1	5.6	10.5	70	1	0.0	0.9	5.5	9.7	0.8	9.9	8.1	2.9	3.2	27	1.8	-	0.1	14	0.82		55	99
60-76	B23	59	50	4	5.4	6.1	5.7	10.5	71	1	0.1	0.8	5.2	9.8	0.7	10.7	8.4	2.8	3.3	26	2.3	-	0.1	14	0.79		54	99
76-94	B24	57			4.8	6.2	5.7	10.4	60	1	0.1	0.8	5.6	8.2	1.1	10.6	9.3	2.1	3.7	20	2.4	-	0.1	16	0.88		53	99
94-113	B25	62	68	4	3.1	6.2	5.6	10.3	41	2	0.1	1.0	5.1	5.8	2.4	12.1	7.7	1.4	3.6	13	1.4	-	0.2	13	0.64		46	99
113-150	B26	66			4.4	6.1	5.6	10.4	67	2	0.1	0.8	5.3	8.6	1.0	9.7	7.5	2.6	3.1	25	1.5	-	0.1	13	0.77		53	99
# USA-7	UNITED STATES (HAWAII,Hilo) Humic Andosol Typic Hydrandept																											
0-23	Ap	39	44	4	6.5	5.8	5.5	10.1	46	5	0.0	0.9	5.5	4.9	1.5	5.0	6.8	1.2	3.5	11	1.1	-	0.2	12	1.36	0.74	74	99
23-56	B21	46			3.5	6.1	6.0	10.1	43	1	0.0	0.4	5.0	7.3	0.2	11.5	8.5	1.7	4.2	16	2.8	-	0.1	14	0.74	0.29	148	99
56-91	B22	48			3.1	6.3	6.1	10.1	47	1	0.0	0.4	5.6	7.0	0.4	13.0	9.3	1.6	4.3	15	2.8	-	0.1	16	0.72	0.30	160	99
91-102	B23	54	68	4	3.3	6.3	6.1	10.0	54	1	0.1	0.4	5.9	7.7	0.1	8.6	9.4	2.0	3.8	19	2.5	-	0.1	16	1.09	0.42	154	99
102-107	B24	38			2.2	6.1	6.1	9.9	35	0	0.0	0.3	5.1	5.6	0.2	11.9	9.9	1.3	4.2	12	2.2	-	0.1	17	0.83			99
107-165	B25	50	74	4	2.8	6.2	6.0	9.9	55	0	0.1	0.4	6.0	6.9	0.3	14.3	9.9	1.6	4.2	15	2.7	-	0.1	17	0.69	0.29	185	99
EAK-5	KENYA Humic Andosol Hydric Dystrandept																											
5-0	Ao	69	52	10	17.9	3.8	3.5	7.7	68	2	5.8	0.9	1.3	0.9	2.1	6.3	0.9	0.1	0.0	<1	-	-	1.0	2	0.14		41	81
0-22	A1	70			9.4	4.0	3.8	8.2	46	1	5.9	1.1	1.9	1.0	2.6	7.5	1.0	0.1	-1.0	<1			1.1	2	0.13	0.52	35	87
22-60	A3	55			7.6	4.5	4.0	10.3	48	0	4.3	1.3	2.1	1.5	2.6	7.6	1.2	0.1	2.0	<1	-	-	0.9	2	0.16	0.64	33	96
60-90	B21	57	71	10	4.0	4.6	4.1	9.9	34	1	3.0	1.0	2.0	1.0	2.4	8.6	1.2	0.1	0.0	<1	-	-	1.0	2	0.14		31	95
90-130	B22	56			3.7	4.7	4.1	10.3	69	1	2.4	1.1	2.2	1.3	2.6	8.8	1.4	0.3	0.7	2	-	0.1	0.8	2	0.16	0.53	31	97
110-123	ash	13			2.9	5.0	4.7	10.6	43	1	0.2	0.6	2.5	3.8	0.4	7.4	1.9	1.3	2.6	12	0.1	-	0.2	3	0.26		35	99
160-175	2A1	30	34	10	5.8	5.0	4.6	10.5	45	1	0.2	0.7	2.9	3.4	0.4	8.3	2.2	1.1	2.6	10	0.1	-	0.2	4	0.27		31	99
EAK-34	KENYA Humic Andosol Hydric Dystrandept																											
0-16	Ah1	30	31	10	13.1	4.4	4.1	10.2	62	0	4.9	1.9	2.5	2.2	2.5	9.4	2.1	0.3	1.0	2	-	-	0.9	4	0.22		50	99
16-28	Ah2	16	54	10	8.6	4.6	4.2	10.3	59	0	3.4	2.4	2.7	2.3	3.5	6.5	2.4	0.3	-0.3	<1			1.0	4	0.37		64	99
28-47	B1	30			7.5	4.6	4.4	10.5	44	0	2.2	2.5	3.4	2.6	3.3	11.1	2.5	0.5	0.2	3	-	0.4	1.0	4	0.23		56	99
47-130+	B2	12	45	10	5.4	4.7	4.6	10.5	45	1	0.7	1.2	3.6	4.0	1.9	5.2	2.4	1.3	2.2	11	-	-	0.3	4	0.46		70	99
GUADELOUPE	(Chateauneuf) Humic Andosol Hydric Dystrandept																											
?	B		42	4	6.0	3.9	4.1	9.8		1	4.5	1.1	1.0	2.5	1.9	2.3	1.5	0.4	3.6	4	0.4	-	0.4	3	0.65		68	96
COSTA RICA	(Paraiso) Humic Andosol Hydric Dystrandept																											
80-120	2B		30	4	0.3	6.6	5.3	9.9				0.4	1.8	6.4	0.1	5.2	6.4	4.6	1.3	27	-	-	0.1	5	0.52		105	98

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for dispersion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

* dried, throughout

GROUP I

Depth (cm)	Hori-zon	Clay[1] ro -(%)-	Clay[1] sp -(%)-	Clay[1] pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases (cmol(+)/kg)	Exch. Al (cmol(+)/kg)	Al Pyr (%)	Al DC (%)	Al Ox (%)	Fe Pyr (%)	Fe DC (%)	Fe Ox (%)	Si Ox (%)	Al/Si[2] atom. ratio	Allo phane (%)	Excess[3] Al (%)	Excess[3] Si (%)	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)
TENERIFE (Las Aves)						Humic Andosol			Typic Dystrandept																			
0-50	A11/2		30	4	4.0	6.7	5.6	10.9	45	13																	37	98
90-120+	2B		44	4	1.0	5.8	5.6	10.8	39	6																	66	99
VANUATU (Aoba Isl., ORSTOM 243)									Mollic Andosol			Udic Eutrandept																
0-10/15	A		13	10	7.8			9.4		48																0.80		55
15-30	AB		14	4	2.6			9.6		28																0.75		54
VANUATU (Vanua-Lava Isl., ORSTOM 231)									Humic Andosol			Oxic Dystrandept																
0-15	A		35	4	8.4			10.2																				95
50-70	Bw		24	4	1.0			10.4																				99
VANUATU (Santa Maria Isl., ORSTOM 230)									Mollic Andosol			Udic Eutrandept																
30-40	Bw		34	4	4.7	6.3				17																		99
VANUATU (Santa Maria Isl., ORSTOM 465)									Humic Andosol			Typic Hydrandept																
0-10	A		23	4	12.2			10.4																				97
40-70	Bw		35	4	4.4			10.3																				99
MEXICO (Sierra Nevada no.19)						Humic Andosol			Hydric Dystrandept																			
0-40	A1	22	13	4	6.5		5.6		39	14	0.1	0.7	0.9	2.9	0.3	1.1	0.7	1.3	1.7	9	-	-	0.2	1	0.64	0.64	20	90
40-110	A1	26	16	4	5.0		5.6		32	9	0.0	0.7	1.1	3.5	0.3	1.4	0.9	1.6	1.8	11	-	-	0.2	2	0.64	0.67	20	95
* INS-3	INDONESIA				Humic Andosol			Udic Eutrandept																				
0-20	Ap11	25			4.2	5.0	4.5	10.5	21	4		0.7	1.5	2.8	0.3	2.9	1.3	0.1	21.8	<1	1.9	-	0.3	2	0.45	0.46	28	96
20-44	Ap12	26			4.1	5.3	4.6	10.4	21	7		0.7	1.2	2.3	0.3	2.7	2.3	1.2	1.4	7	-	-	0.3	4	0.85	0.41	26	93
44-69	Ap2	34			1.8	5.9	4.9	10.0	22	12		0.4	1.6	1.6	0.4	4.9	1.7	0.9	1.4	6	-	-	0.3	3	0.35	0.39	31	94
69-85	B2	16			1.6	6.2	5.4	10.3	19	11		0.4	2.1	4.3	0.1	5.2	2.1	2.3	1.8	16	-	-	0.1	4	0.40			99
85-101	BC	23			1.1	6.1	5.1	10.1	22	14		0.4	1.7	2.6	0.1	5.2	2.1	1.5	1.5	10	-	-	0.2	4	0.40			97
101-126	2B2	15			1.0	5.9	5.1	10.1	23	12		0.4	2.1	3.9	0.1	5.5	1.9	2.2	1.7	15	-	-	0.1	3	0.35			98
126-150	3Ah	9			1.1	5.8	5.1	10.2	21	11		0.4	2.0	4.7	0.1	5.7	1.7	3.2	1.4	20	-	-	0.1	3	0.30			99
* # INS-18	INDONESIA				Mollic Andosol			Udic Eutrandept																				
0-30	Ah1		18	4	7.8	5.3	4.9	10.6	27	13		0.7	1.1	3.6	0.3	1.2	0.4	2.0	1.5	13	-	-	0.2	<1	0.33	0.60	28	93
30-37	Ah2		12	4	5.7	5.8	5.2	10.4	24	13		0.6	1.2	4.1	0.3	0.6	0.4	2.4	1.5	15	-	-	0.1	<1	0.67			96
37-48	2AB		17	4	4.8	5.8	5.3	8.7	20	11		0.5	1.5	7.2	0.2	2.2	0.5	4.6	1.5	29	-	-	0.1	<1	0.23	0.50	30	99
48-110	2Bw		20	4	2.9	5.5	5.0	9.6	14	4		0.4	1.4	7.5	0.0	2.5	0.5	5.4	1.4	33	-	-	0.1	<1	0.20	0.50	33	99
110+	3BC		20	4	1.4	5.5	5.4	9.7	0	1		0.3	1.3	8.8	0.0	3.0	0.1	6.1	1.4	38	-	-	0.0	<1	0.03			99

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for dispersion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

GROUP I

Depth (cm)	Horizon	Clay[1] ro (%)	Clay[1] sp (%)	Clay[1] pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases (cmol(+)/kg)	Exch. Al (cmol(+)/kg)	Al Pyr (%)	Al DC (%)	Al Ox (%)	Fe Pyr (%)	Fe DC (%)	Fe Ox (%)	Si Ox (%)	Al/Si[2] atom. ratio	Allophane (%)	Excess[3] Al (%)	Excess[3] Si (%)	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)
* INS-21	INDONESIA				Humic Andosol				Hydric Dystrandept																			
0-5	Ah1	27			9.2	5.2	4.6	10.6	19	2	0.5	0.9	1.7	2.4	0.4	1.5	0.7	0.6	2.6	6	0.1	-	0.4	1	0.47	0.74	30	92
5-15	Ah2	23			5.2	5.0	4.9	10.8	11	1	0.1	0.7	1.8	3.0	0.3	1.5	0.5	1.0	2.4	9	-	-	0.2	<1	0.33			97
15-25	Ah3	10			4.1	5.2	5.2	10.8	7	1	0.0	0.4	1.2	3.3	0.1	0.8	0.2	1.4	2.2	12	-	-	0.1	<1	0.25	0.70	20	97
25-30	AC	11			1.5	5.3	5.4	10.5	4	1	0.0	0.2	0.5	2.3	0.0	0.9	0.2	1.2	1.8	9	-	-	0.1	<1	0.22			88
30-80	2AB	74			0.7	5.1	4.7	9.6	12	5	0.0	0.2	1.2	0.5	0.1	3.7	0.7	0.1	3.1	<1	0.1	-	0.4	1	0.19	1.03	34	70
80-120+	2Bw	48			0.3	5.3	4.9	10.2	11	5	0.0	0.3	1.4	1.1	0.0	3.1	0.4	0.6	1.4	4	-	-	0.3	<1	0.13			85
* # INS-23	INDONESIA				Humic Andosol				Hydric Dystrandept																			
0-17	Ah		14	4	8.5	5.1	4.6	10.8	19	3		0.9	1.3	1.7	0.4	1.0	0.8	0.5	1.7	3	-	-	0.5	1	0.80	0.62	26	92
17-31	AC		10	4	3.6	5.6	5.2	10.8	6	0		0.5	1.1	2.3	0.1	0.8	0.6	0.9	2.1	7	-	-	0.2	1	0.75			94
31-54	C		4	4	0.7	5.6	5.6	10.4	14	4		0.3	0.9	4.5	0.0	1.5	0.8	1.9	2.3	16	-	-	0.1	1	0.53			96
54-70	2Ah		18	4	3.5	5.5	5.0	10.4	7	2		0.2	1.1	3.5	0.0	1.3	0.4	1.9	1.8	13	-	-	0.1	<1	0.31	0.63	26	96
70-88	2Bw		18	4	1.5	5.5	5.3	10.4	1	1		0.1	0.3	2.7	0.0	0.3	0.2	1.6	1.6	10	-	-	0.0	<1	0.67			96
88-125+	2C		5	4	0.1	5.6	5.3	9.6	4	1		0.1	0.2	1.9	0.0	0.2	0.1	1.7	1.1	10	-	-	0.1	<1	0.50			71
125-155	3Ah		27	4	0.6	5.5	4.9	9.8	11	5		0.2	0.9	2.3	0.0	2.2	0.3	0.7	3.1	7	0.4	-	0.1	<1	0.14			78
* # INS-24	INDONESIA				Mollic Andosol				Udic Eutrandept																			
0-11	Ah	24			7.7	5.6	5.2	9.6	37	27	0.0	0.5	1.2	2.9	0.2	3.0	1.5	1.7	1.5	11	-	-	0.2	3	0.50			86
11-26	BA	18			6.5	5.2	5.2	10.1	23	10	0.2	0.5	1.3	4.7	0.2	2.9	1.5	1.9	2.3	16	-	-	0.1	3	0.52	0.69	35	92
26-47	Bw1	28			4.0	5.4	4.8	10.0	24	11	0.0	0.4	2.1	6.1	0.1	5.6	2.1	4.4	1.3	26	-	-	0.1	4	0.38	0.61	76	98
47-78	Bw2	33			2.5	6.1	4.9	9.9	24	16	0.0	0.3	1.8	6.1	0.1	4.8	1.9	4.8	1.3	29	-	-	0.0	3	0.40	0.65	75	98
78-95	Bw3	33			1.9	6.2	5.0	9.6	34	25	0.0	0.2	1.2	3.5	0.1	5.3	2.0	2.8	1.2	16	-	-	0.1	3	0.38			98
95-107	2Ah1	63			2.7	6.1	5.0	8.9	40	30	0.0	0.2	0.7	1.0	0.5	5.7	2.0	0.7	1.2	4	-	-	0.2	3	0.35			76
107-138	2Ah2	60			4.8	6.1	5.1	9.2	43	32	0.0	0.7	1.6	2.0	0.9	5.0	2.2	1.6	0.8	9	-	0.2	0.3	4	0.44	0.70	75	89
138-180	2AB	53			3.4	6.1	5.1	9.4	37	30	0.0	0.4	1.6	2.4	0.4	4.5	2.4	2.3	0.9	13	-	0.2	0.2	4	0.53			91
* # INS-27	INDONESIA				Humic Andosol				Entic Dystrandept																			
8-0	Ao	10			48																							
0-12	Ah	10			31	4.3	3.9	10.1	160	1	9.6	1.8	1.9	2.5	0.8	0.8	0.9	0.5	1.4	3	-	-	0.7	2	1.13	0.28	136	94
12-50	Bw	11			3.4	5.2	5.2	11.1	68	0		0.9	1.5	4.4	0.5	1.4	1.3	1.7	2.1	13	-	-	0.2	2	0.93	0.47	72	99
50-125	C	14			0.9	5.1	5.2	10.8	55	0		0.3	0.0	5.9	0.0	0.2	0.2	4.0	1.4	25	-	-	0.1	<1	1.00	0.97	46	98
125-150	2C	18			0.4	5.4	5.4	10.5	29	0		0.3	0.3	5.5	0.0	0.2	0.2	3.6	1.4	22	-	-	0.1	<1	1.00			99

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for dispersion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr = pyrophosphate
DC = dithionite-citrate
Ox = oxalate

App. 1. Soil data.

GROUP I

Depth (cm)	Hori-zon	Clay[1] ro -(%)-	Clay[1] sp	Clay[1] pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases	Exch. Al	Al Pyr -----(%)-----	Al DC	Al Ox	Fe Pyr -----(%)-----	Fe DC	Fe Ox	Si Ox (%)	Al/Si[2] atom. ratio	Allo phane (%)	Excess[3] Al --(%)--	Excess[3] Si	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)
* # INS-29	INDONESIA				Humic Andosol		Hydric Dystrandept																					
0-16	Ah	28			19.5	4.6	4.4	11.2	84	1	4.6	2.7	2.8	4.1	4.6	5.8	4.5	0.5	2.8	5	0.1	-	0.7	8	0.78	0.35	120	99
16-35	BA	36			10.5	5.3	4.9	11.5	116	0	0.0	2.2	4.7	11.6	1.4	5.1	3.1	3.6	2.6	34	0.4	-	0.2	5	0.61			99
35-79	Bw	28			4.6	5.8	5.9	11.5	149	0		0.7	3.7	12.8	0.0	7.9	2.3	5.1	2.4	46	-	-	0.1	4	0.29	0.33	170	99
79-90	Bs	21			1.7	5.6	5.9	11.1	55	0		0.5	2.8	13.6	0.0	4.8	2.9	7.1	1.8	50	-	-	0.0	5	0.60			99
90-108	Bg(?)	12			1.2	5.4	5.7	10.9	56	0		0.3	1.0	5.8	0.0	1.1	0.6	2.9	1.9	21	-	-	0.1	1	0.55			99
108-135	C	16			0.5	5.2	5.5	10.7	37	0		0.3	0.3	4.6	0.0	0.3	0.2	2.6	1.7	18	-	-	0.1	<1	0.67			99
135-160	Cr	11			0.2	5.0	5.2	10.7	31	0		0.3	0.3	4.1	0.0	0.3	0.2	2.4	1.6	16	-	-	0.1	<1	0.67			97
* # INS-36	INDONESIA				Humic Andosol		Typic Dystrandept																					
0-30	A	14			2.5	5.7	5.5	10.7	40	4		0.3	0.9	4.9	0.0	1.7	0.8	2.9	1.6	19	-	-	0.1	1	0.47	0.73	71	99
30-44	C1	10			0.7	6.0	5.5	10.4	22	1		0.2	0.3	2.8	0.0	0.8	0.4	1.9	1.4	12	-	-	0.1	<1	0.50			87
44-100	B(?)	22			1.9	5.6	5.4	10.5	55	2		0.3	0.9	5.5	0.0	1.9	1.0	3.6	1.4	22	-	-	0.1	2	0.53	0.53	91	99
100-123	C2	10			0.4	5.6	5.2	10.2	26	1		0.1	0.3	3.5	0.0	0.6	0.4	2.5	1.4	15	-	-	0.0	<1	0.67			79
123-130	2A	28			2.4	5.4	5.2	10.3	64	5		0.8	1.5	6.2	0.3	3.6	1.9	3.9	1.4	24	-	-	0.1	3	0.53			99
130-170	2B	34			1.6	5.4	5.1	10.2	89	5		0.3	1.9	6.4	0.1	4.2	2.1	4.8	1.3	29	-	-	0.0	4	0.50	0.47	119	99
* # EC-3	ECUADOR				Humic Andosol		Dystric Cryandept																					
0-26	A1	8			6.1	5.2	4.5	10.1	13	3	0.7	0.4	0.6	0.9	0.3	0.7	0.5	0.3	1.7	2	-	-	0.4	<1	0.71	0.88	33	83
26-63	A2	10			5.7	5.6	4.7	10.5	11	3	0.2	0.4	0.6	1.3	0.4	0.9	0.7	0.7	1.3	4	-	-	0.3	1	0.78	0.97	35	89
63-92	A3	10			4.3	5.8	4.8	10.3	10	4	0.0	0.5	0.6	1.4	0.4	0.9	0.6	0.6	1.5	4	-	-	0.4	1	0.67			84
92-134	2C	1			0.2	6.1	5.0	8.4	1	0	0.0	0.1	0.1	0.2	0.0	0.3	0.1	0.1	1.0	<1	-	-	0.5	<1	0.33	0.84	6	20
134-182	3Ab	11			2.8	6.0	4.9	10.3	8	3	0.0	0.4	0.5	1.3	0.2	1.0	0.7	0.7	1.3	4	-	-	0.3	1	0.70			76
* # EC-9	ECUADOR				Ochric Andosol		Entic Dystrandept																					
0-7	A	16			3.4	5.3	4.8	10.1	12	7	0.2	0.6	0.5	1.5	0.4	0.7	0.5	0.7	1.3	4	-	-	0.4	<1	0.71	0.79	34	75
7-24	Bw1	16			2.9	5.6	4.9	10.2	12	6	0.0	0.5	0.5	1.5	0.4	0.8	0.5	0.7	1.4	4	-	-	0.3	<1	0.62			82
24-56	Bw2	17			2.2	5.5	5.0	10.4	9	2	0.0	0.4	0.5	1.7	0.2	0.8	0.4	1.0	1.3	6	-	-	0.2	<1	0.50			85
56-94	2Ab	19			1.6	5.5	5.2	10.1	11	1	0.0	0.4	0.5	2.5	0.1	1.0	0.4	1.7	1.2	10	-	-	0.2	<1	0.40	0.77	42	91
94-119	2C	22			1.1	5.6	4.9	9.5	15	1	0.0	0.3	0.8	2.4	0.1	1.6	0.3	1.6	1.3	10	-	-	0.1	<1	0.19			94
119-130	2Ca	23			0.7	5.7	4.8	9.2	17	3	0.0	0.2	1.0	2.0	0.1	2.5	0.4	1.5	1.2	9	-	-	0.1	<1	0.16	0.80	46	81
130-145	3Ab	29			0.5	5.7	4.8	8.8	16	5	0.0	0.2	0.9	2.1	0.1	2.1	0.2	1.5	1.3	9	-	-	0.1	<1	0.10	0.78	53	80

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for dispersion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

GROUP II

Depth (cm)	Horizon	Clay[1] ro -(%)-	Clay[1] sp	Clay[1] pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases	Exch. Al	Al Pyr -----(%)-----	Al DC	Al Ox	Fe Pyr -----(%)------	Fe DC	Fe Ox	Si Ox (%)	Al/Si[2] atom. ratio	Allophane (%)	Excess[3] Al --(%)--	Excess[3] Si	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)	CaCO3 (%)
EAK-2	KENYA	Mollic Andosol				Cumulic Hapludoll																							
0-17	A1	26	20	10	10.0	6.7	6.1	8.0	71	39		0.4	0.4	1.1	0.4	2.4	1.7	0.4	1.8	3	-	-	0.4	3	0.71	0.80	62	64	2.1
17-41	AB	19			4.3	7.1	6.2	8.5	36	24		0.3	0.4	1.0	0.4	2.2	1.6	0.4	1.8	3	-	-	0.3	3	0.73	0.90	51	63	1.5
41-49	B1	12			1.8	7.1	5.9	8.5	19	12		0.1	0.3	1.0	0.2	2.1	1.7	0.5	1.9	4	-	-	0.1	3	0.81		37	61	0.9
49-75	2A1	25	26	10	4.5	6.3	5.2	8.1	43	21		0.5	0.4	0.8	1.0	2.8	2.0	0.3	1.0	2	-	-	0.6	3	0.71	0.80	62	62	
75-105	2B1	14			4.0	6.3	5.3	9.3	51	23		0.7	1.2	2.6	1.0	4.2	2.7	1.1	1.8	8	-	-	0.3	5	0.64	0.80	58	89	
105-140	2B2	18	19	10	2.9	6.2	5.1	9.1	50	15		0.5	1.9	3.6	0.4	6.6	2.9	1.6	2.0	12	-	-	0.1	5	0.44	1.00	49	92	
EAK-4	KENYA	Mollic Andosol or Andic Regosol							Mollic Vitrandept																				
0-24	Ah	4	5	10	0.8	6.6	5.3	7.8	5	5		0.0	0.0	0.1	0.0	0.7	0.2	0.0		0				<1	0.29		6	18	0.2
24-44	Ah	3			0.7	6.9	5.5	7.8	6	5		0.0	0.1	0.1	0.0	0.7	0.2	0.0		0				<1	0.29	1.32		18	0.6
44-52	C	5			0.4	7.1	5.6	7.7	5	4		0.0	0.0	0.1	0.0	0.5	0.1	0.0		0				<1	0.20		5	14	0.4
52-75	C	3			0.3	7.2	5.8	7.7	4	4		0.0	0.0	0.0	0.0	0.4	0.1	0.0		0				<1	0.25	1.26		12	1.0
75-104	C	2	2	10	0.1	7.4	5.8	7.7	1	2		0.0	0.0	0.0	0.0	0.2	0.0	0.0		0				0	0.00	1.31	2	11	0.2
104-123	C2	5			0.2	8.8	6.1	7.7	9	10		0.0	0.0	0.1	0.0	0.4	0.1	0.0		0				<1	0.25	1.08		14	0.8
123-130	2Ah	2			0.0	8.9	5.9	7.7	1	2		0.0	0.0	0.0	0.0	0.1	0.0	0.0		0				0	0.00		2	11	
145-160	2B	15	22	10	0.7	9.8	8.9	8.1	33	32		0.0	0.1	0.2	0.0	1.9	0.2	0.0		0				<1	0.11	1.03	18	23	
# EAK-35	KENYA	Mollic Andosol				Mollic Vitrandept																							
0-20	A1	24	29	10	2.3	6.7	5.8	7.6	28	23	0.0	0.2	0.2	0.2	0.1	2.2	0.5	0.2	0.0	0	-	-	1.0	<1	0.23		21	31	2.1
20-60	B21	14			0.7	7.0	5.8	7.6	33	30	0.0	0.1	0.3	0.3	0.0	2.2	0.2	0.2	1.0	1	-	-	0.3	<1	0.09		25	28	2.5
60-90	2B22	6	16	10	0.4	7.3	6.3	7.6	37	33	0.0	0.0	0.2	0.2	0.0	1.7	0.1	0.3	0.7	2	-	0.1	0.0	<1	0.06		23	19	2.8
90-145	2B3	6	33	10	0.1	7.9	7.0	8.0	27	31	0.0	0.0	0.1	0.1	0.0	0.5	0.0	0.1	1.0	<1	-	-	0.0	0	0.00		17	22	4.4
EAK-36	KENYA	Mollic Andosol				Mollic Vitrandept																							
0-15	A1	8	15	10	3.1	6.7	5.9	7.9	35	26		0.1	0.2	1.0	0.1	1.9	1.6	0.8	1.2	5	-	-	0.1	3	0.84	1.14	18	40	0.1
15-28	A3	3			1.8	7.1	6.4	8.2	36	31		0.0	0.3	1.1	0.0	2.1	1.9	1.0	1.1	6	-	-	0.0	3	0.90	1.09	14	56	0.0
28-40	B1	5			1.5	7.2	6.5	8.7	46	39		0.0	0.4	1.2	0.0	3.0	2.1	0.7	1.8	5	-	-	0.0	4	0.70	1.06	19	66	0.1
40-60	B2	8	17	10	1.6	7.4	6.6	9.1	56	45		0.0	0.4	1.6	0.0	4.3	2.5	0.7	2.4	6	-	-	0.0	4	0.58	1.04	22	71	0.2
60-70	B3ca	10			1.4	7.9	7.2	9.8	63	69		0.0	0.5	2.1	0.0	4.5	3.5	1.1	2.0	8	-	-	0.0	6	0.78			74	0.0
90-180	C2cax	2	23	10	0.7	9.1	7.6	9.1	57	99		0.0	0.2	1.1	0.0	3.1	1.7	0.6	1.9	4	-	-	0.0	3	0.55			48	5.2
EAK-37	KENYA	Mollic Andosol				Mollic Vitrandept																							
0-30	Ap	20	16	10	7.0	6.7	6.1	8.3	49	34	0.0	0.2	0.3	0.5	0.1	1.8	0.9	0.2	1.6	1	-	-	0.4	2	0.50		26	30	3.0
30-120	A12/3	19	19	10	4.5	7.0	6.2	8.2	39	23	0.0	0.2	0.3	0.6	0.2	2.3	1.1	0.3	1.4	2	-	-	0.3	2	0.48		25	38	2.9
120-150	A14	19	25	10	2.4	7.0	6.0	8.3	33	22	0.0	0.1	0.5	0.8	0.2	3.4	1.6	0.5	1.5	3	-	-	0.1	3	0.47		34	39	1.5

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for disperion in special procedure
(see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e.
0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

App. 1. Soil data.

GROUP II

Depth (cm)	Hori-zon	Clay[1] ro	Clay[1] sp	Clay[1] pH -(%)-	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases (cmol(+)/kg)	Exch. Al (cmol(+)/kg)	Al Pyr -----(%)-----	Al DC	Al Ox	Fe Pyr -----(%)-----	Fe DC	Fe Ox	Si Ox (%)	Al/Si[2] atom. ratio	Allo phane (%)	Excess[3] Al --(%)--	Excess[3] Si	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)	CaCO3 (%)
TANZANIA (Mukoma-1) Mollic Solonetz Typic Natrustolt																													
0-15	A1	9	17	10	1.1	7.2	5.8	8.4	16	12		0.3	0.1	0.1	0.2	0.9	0.5	0.1	-2.1	<1	-	-	3.0	<1	0.56	1.57	6	24	0.5
15-30	B21ca	24			1.1	8.3	7.0	9.5	63	33		0.3	0.2	0.2	0.2	2.1	0.4	0.2	-0.5	<1	-	-	1.5	<1	0.19	1.41	19	40	0.8
30-45	B22ca	24			0.8	8.5	7.1	9.6	34	36		0.4	0.1	0.1	0.2	0.8	0.2	0.2	-1.6	<1	-	-	4.0	<1	0.25	1.41	19	31	8.0
45-60	B31ca	20			0.5	8.6	7.1	8.9	38	37		0.3	0.2	0.1	0.1	0.9	0.1	0.2	-1.0	<1	-	-	3.0	<1	0.11	1.34	20	28	7.5
60-90	B32ca	14			0.2	8.6	7.0	8.4	31	32		0.1	0.2	0.1	0.0	0.9	0.1	0.1	0.0	<1	-	-	1.0	<1	0.11	1.27	17	27	5.4
90-120	B33ca	19			0.2	9.1	6.9	8.3	38	37		0.2	0.3	0.2	0.1	1.2	0.1	0.2	0.0	<1	-	-	1.0	<1	0.08	1.22	23	27	1.7
120-150	B34ca	19	14	10	0.1	9.1	6.9	7.8	35	34		0.1	0.3	0.2	0.1	1.2	0.1	0.2	0.5	1	-	0.1	0.5	<1	0.08	1.18	22	28	1.6
TANZANIA (SEK-NE) Mollic Andosol Eutrandeptic Cumulic Haplustoll																													
0-16	A11	30	31	10	4.2	7.1	6.4	8.6	68	55		0.1	0.2	1.4	0.0	1.7	0.7	0.8	1.7	5	-	-	0.1	1	0.41	0.92	20	56	0.4
40-70	A13	30																								0.89	19		0.4
70-110	A14	31	39	10		8.5	7.1	9.7				0.0	0.2	0.6	0.0	1.4	0.4	0.3	2.1	2	-	-	0.0	<1	0.29	0.90	20		2.1
110-170	C	28			1.8	8.2	6.9	9.6	61	57		0.0	0.3	0.7	0.0	1.7	0.5	0.4	1.8	3	-	-	0.0	<1	0.29	0.86	21	55	2.9
TANZANIA (Rhino-7) Luvic Chernozem Typic Argiustoll																													
0-10	A1	14	10	10	1.3	6.4	5.2	8.2		9		0.0	0.0	0.0	0.0	0.2	0.1	0.0		0				<1	0.50	1.51	8	7	
10-55	B22t	31			0.8	8.3	6.6	7.9				0.0	0.1	0.1	0.0	0.3	0.1	0.1	1.0	<1	-	-	0.0	<1	0.33	1.60	16		
55-75	B23tc	29			0.5	7.0	5.2	7.6				0.0	0.1	0.1	0.0	0.3	0.1	0.1	1.0	<1	-	-	0.0	<1	0.33	1.47	14		
75-100	B31ca	37			0.4	8.6	7.0	9.0				0.0	0.1	0.1	0.0	0.2	0.1	0.1	1.0	<1	-	-	0.0	<1	0.50	1.28	18		1.2
100-150	B32ca	41	35	10	0.3	8.6	6.9	8.5		31		0.0	0.3	0.1	0.0	0.1	0.1	0.1	1.0	<1	-	-	0.0	<1	1.00	1.39	21	13	3.5
TANZANIA (Dutwa-1) Mollic Solonetz Typic Natriustoll																													
0-21	A1	17	12	10	2.3	7.1	5.4	8.0		8		0.1	0.1	0.1	0.0	0.4	0.1	0.0		0			1.0	<1	0.25	1.73	10	9	1.2
21-40	B21ca	39			0.9	7.7																				1.52	18		
62-80	B31ca				0.4	7.9																							0.5
80-100	B32ca	47	46	10	0.4	8.5	6.8	8.8		29		0.0	0.1	0.1	0.0	0.6	0.1	0.1	1.0	<1	-	-	0.0	<1	0.17			15	2.6
TANZANIA (NaNo-S) Pellic Vertisol Typic Pellustert																													
0-13	A11	50	27	10	8.3	7.0	5.9	8.4		39		0.0	0.2	0.4	0.0	1.1	0.3	0.3	1.4	2	-	-	0.0	<1	0.27	0.95	25	35	0.4
13-40	A12	63			4.5	8.1																				1.02	28		0.2
40-90	A13	62			2.2	8.0																				1.13	28		0.3
90-114	A14	59	49	10	2.2	7.7	6.0	8.7		41		0.1	0.2	0.3	0.0	1.0	0.2	0.4	0.5	2	-	0.2	0.3	<1	0.20			36	0.3
TENERIFE (Birmagen) Chromic Cambisol Andic Ustochrept																													
0-10	A11		48	10	1.8	6.3	5.0	9.9	27	13																	19	51	
35-85	B		54	10	0.3	6.1	4.9	9.9	30	18																	33	73	
VANUATU (Aoba Isl., ORSTOM 245) Mollic Andosol Udic Eutrandept																													
70-120	2B		29	10	1.4	7.7				27																	37	79	

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for disperion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

App. 1. Soil data.

GROUP II

Depth	Hori-	Clay[1]			Org.	pH			CEC	Sum	Exch.	Al			Fe			Si	Al/Si[2]	Allo	Excess[3]		Binary[4]	Ferri	Activ.	Bulk	15 bar	P-	CaCO3
	zon	ro	sp	pH	C	H2O	KCl	NaF		bases	Al	Pyr	DC	Ox	Pyr	DC	Ox	Ox	atom.	phane	Al	Si	ratio	hydr.	ratio	dens.	water	ret.	
(cm)		-(%)-			(%)				(cmol(+)/kg)			-----(%)-----			-----(%)-----			(%)	ratio	(%)	--(%)--		Al_p/Al_o	(%)	Fe_o/Fe_d	(kg/l)	(wt%)	(%)	(%)
VANUATU (Aoba Isl., ORSTOM 247) Vitric Andosol Mollic Vitrandept																													
0-15	A		24	10	3.2			8.9																				34	
VANUATU (Aoba Isl., ORSTOM 253) Mollic Andosol Andic Eutropept																													
70-100	2B-C		31	10	0.5	6.5				30																	40	79	
VANUATU (Santa Maria Isl., ORSTOM 466) Mollic Andosol Andic Eutropept																													
0-15	A		33	10	4.5			9.2																				62	
15-80	Bw		27	10				9.2																				55	
MEXICO (Sierra Nevada no.13) Humic Andosol Hydric Dystrandept																													
0-15	A11		16	10	3.6		5.3		36	14	0.0	0.2	0.4	0.9	0.1	1.5	0.5	0.4	1.8	3	-	-	0.2	<1	0.33			57	
15-70	A12		14	10	1.0		5.3		35	11	0.0	0.1	0.3	1.1	0.0	1.7	0.6	0.6	1.7	4	-	-	0.1	1	0.35	0.84	18	57	
SYRIA R1 Vitric Andosol Typic Vitrandept																													
0-5	A1		12	10	0.3	8.4		10.4	19	19																	9	17	17.0
5-17	C1		16	10	0.6	8.5		10.8																			10	19	13.0
SYRIA R2 Vitric Andosol Typic Vitrandept																													
0-3	A1		12	10	1.0	8.3																					8	21	10.0
3-16	C1		11	10	0.7	9.2																					10	15	10.0
SYRIA R3 Vitric Andosol Typic Camborthid/Typic Vitrandept																													
0-20	A1		15	10	0.3	7.6																					9	17	13.0
20-50	C1		18	10	0.2	8.9																					9	20	13.0
SYRIA S3 Vitric Andosol Typic Vitrandept																													
0-40	AC		5	10	0.3	8.5		11.5				0.0	0.0	0.7	0.0	0.9	1.1	0.9	0.8	5	-	0.1	0.0	2	1.22		14	32	5.0
PHILIPPINES (Tagaytay) Haplic Pheozem Cumulic Haplustoll																													
0-12	A1		54	10	2.6	6.1	4.6	9.5		25	0.1															1.21	23	59	
12-27	2A1		48	10	3.9	6.3	4.7	9.4		38	0.1															1.17	23	56	
27-35	3A1		41	10	4.8	6.2	4.9	9.4		38	0.0															1.13	31	52	
35-44	4A12		42	10	3.7	6.3	4.9	9.7		36	0.0															1.08	32	54	
44-51	4A1		47	10	2.8	6.3	4.8	9.5		33	0.0															1.14	31	57	
51-136	4B2		64	10	1.3	6.3	4.6	9.6		47	0.0															1.20	38	57	
136-166	5C1		70	10	0.6	6.4	4.4	9.6		53	0.1															1.21	41	58	

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for disperion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

GROUP II

Depth (cm)	Hori-zon	Clay[1] ro	Clay sp -(%)-	pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC	Sum bases	Exch. Al (cmol(+)/kg)	Al Pyr	Al DC -----(%)-----	Al Ox	Fe Pyr	Fe DC -----(%)-----	Fe Ox	Si Ox (%)	Al/Si[2] atom. ratio	Allo phane (%)	Excess[3] Al	Excess Si --(%)--	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)	CaCO3 (%)
KENYA 1976/138-142					Eutric Planosol				Abruptic Tropaqualf																				
0-7	A1	26	10		1.9					19		0.1	0.1	0.2	0.2	0.9	0.7	0.1	1.0	<1	-	-	0.5	1	0.78			32	
7-23	A2	24	10			6.2	4.2	8.1		12		0.1	0.1	0.1	0.2	1.5	0.5	0.0		0			1.0	<1	0.33				
23-34	B21t	48	10							28		0.1	0.1	0.2	0.1	1.6	0.5	0.1	1.0	<1	-	-	0.5	<1	0.31				
34-86	B22t	61	10		1.0	7.5	5.6	8.5		44		0.3	0.1	0.2	0.2	0.6	0.2	0.4	-0.5	<1			1.5	<1	0.33	1.40			
86-160	B23ca	53	10		0.3					37		0.0	0.1	0.1	0.0	0.6	0.2	0.2	0.5	1	-	0.1	0.0	<1	0.33			23	
KENYA 134/7					Eutric Planosol				Abruptic Tropaqualf																				
25-35	A22	13	10		1.0	6.5	4.5	7.9	9	6		0.1	0.2	0.1	0.1	4.6	0.5	0.1	0.0	<1	-	-	1.0	<1	0.11			10	0.0
50-60	B22	65	10		0.9	7.7	4.2	7.8	45	33		0.3	0.1	0.2	0.1	0.8	0.2	0.1	-1.0	<1			1.5	<1	0.25				1.3
80-92	2B	61	10		0.5	7.6	4.2	7.8	43	39		0.1	0.2	0.2	0.1	1.3	0.2	0.1	1.0	<1	-	-	0.5	<1	0.15			28	1.5
KENYA 118/6					Eutric Planosol				Abruptic Tropaqualf																				
150-200	2B31	51	10			7.8	5.4	8.5	34	37																			2.4
250-300	2B32	34	10			8.1	5.9	7.8	25	28		0.0	0.1	0.1	0.0	0.9	0.1	0.2	0.5	1	-	0.1	0.0	<1	0.11			19	2.2
KENYA 145/5					Eutric Planosol				Abruptic Tropaqualf																				
10-20	A2	19	10		1.6	5.6	4.6		14	10		0.1	0.1	0.1	0.1	1.5	0.4	0.0		0			1.0	<1	0.27	1.16		18	
40-50	B2t	41	10		1.0	7.0	5.5		23	25		0.1	0.1	0.2	0.0	1.2	0.2	0.2	0.5	1	-	0.1	0.5	<1	0.17	1.29			1.7
150-200	C2	29	10		0.2	7.6	5.7		43	42		0.0	0.1	0.2	0.0	0.6	0.1	0.1	2.0	<1	-	-	0.0	<1	0.17			13	2.3
KENYA 145/7					Eutric Planosol				Abruptic Tropaqualf																				
10-20	B2	65	10			7.0	6.2	7.5	35	23		0.0	0.2	0.2	0.1	0.9	0.3	0.2	1.0	1	-	-	0.0	<1	0.33			33	0.0
40-50	B31	57	10			7.6	6.8		54	50																			
80-90	B32	37	10			8.0	7.0	8.6	52	48		0.0	0.1	0.2	0.0	0.7	0.1	0.2	1.0	1	-	-	0.0	<1	0.14			17	4.7
110-120	Ccam	40	10			8.2	7.1		49	48																			
* # INS-19 INDONESIA					Dystric Cambisol				Oxic Humitropept																				
0-16	Ah1	29	4		9.3	5.1	4.5	10.2	17	1		1.0	1.6	2.6	0.6	1.9	0.9	0.6	2.8	6	0.2	-	0.4	2	0.47	0.75	33	95	
16-23	Ah2	29	4		3.2	5.0	4.7	10.5	7	0		0.5	1.4	1.0	0.4	2.7	0.4	0.3	1.7	2	-	-	0.5	<1	0.15			84	
23-29	2AB	67	4		1.3	5.0	4.9	10.5	5	1		0.4	1.3	0.4	0.5	4.3	0.2	0.1	0.0	<1	-	-	1.0	<1	0.05			73	
29-85	2Bw1	62	4		0.5	5.1	5.6	10.5	3	2		0.2	1.4	0.3	0.1	4.3	0.2	0.1	1.0	<1	-	-	0.7	<1	0.05	1.05	27	75	
85-110+	2Bw2	55	4		0.4	5.0	5.0	10.2	5	1		0.3	1.3	0.3	0.2	4.2	0.2	0.1	0.0	<1	-	-	1.0	<1	0.05			68	

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for disperion in special procedure
(see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e.
0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

App. 1. Soil data.

GROUP II

Depth (cm)	Hori-zon	Clay[1] ro -(%)-	Clay[1] sp	Clay[1] pH	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases (cmol(+)/kg)	Exch. Al (cmol(+)/kg)	Al Pyr (%)	Al DC (%)	Al Ox (%)	Fe Pyr (%)	Fe DC (%)	Fe Ox (%)	Si Ox (%)	Al/Si[2] atom. ratio	Allophane (%)	Excess[3] Al (%)	Excess[3] Si (%)	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)	CaCO3 (%)
* # INS-26	INDONESIA				Eutric Cambisol	Andic Humitropept																							
0-16	Ap	27			2.8	4.6	4.1	9.4	24	13	1.4	0.3	0.8	1.2	0.2	4.1	1.3	0.6	1.5	4	-	-	0.2	2	0.32	0.92	28	74	
16-29	AB	24			3.5	4.6	4.0	9.3	24	11	2.1	0.3	0.8	1.1	0.2	4.0	1.2	0.6	1.3	4	-	-	0.3	2	0.30			77	
29-45	Ahb	31			4.2	5.2	4.6	9.4	28	18	0.0	0.3	0.8	1.2	0.3	3.7	1.3	0.5	1.8	4	-	-	0.2	3	0.35	0.72	47	75	
45-77	Bw1	35			3.2	5.3	4.6	9.4	25	18	0.0	0.3	0.8	1.3	0.4	4.5	1.6	0.6	1.7	4	-	-	0.2	3	0.36			82	
77-101	Bw2	32			1.9	5.7	4.7	9.2	23	18	0.0	0.2	0.6	1.1	0.2	4.7	1.6	0.6	1.5	4	-	-	0.2	3	0.34	0.97	30	73	
101-115	Bw3	30			1.5	5.8	4.7	9.2	23	18	0.0	0.1	0.6	1.0	0.1	4.4	1.4	0.5	1.8	4	-	-	0.1	2	0.32			70	
115-150	BC	31			1.5	5.7	4.6	9.0	22	17	0.0	0.1	0.6	0.9	0.1	4.5	1.4	0.5	1.6	3	-	-	0.1	2	0.31	1.11	29	68	
* INS-37	INDONESIA				Eutric Nitosol	Typic Paleudalf																							
0-30	A	55			1.7	5.4	4.3	8.4	21	11	0.2	0.1	0.5	0.5	0.3	4.2	1.3	0.2	2.0	2	-	-	0.2	2	0.31	1.07	32	55	
30-70	Bw1	67			0.7	5.1	3.9	8.6	20	11	1.5	0.1	0.5	0.5	0.2	5.0	1.3	0.2	2.0	2	-	-	0.2	2	0.26	0.78	40	66	
70-127	Bw2	63			0.4	5.5	4.4	9.1	21	13	0.3	0.1	0.6	0.6	0.1	5.0	1.6	0.4	1.3	2	-	-	0.2	3	0.32	0.85	43	72	
127-150	Bw3	52			0.2	5.8	4.7	9.2	19	12	0.0	0.1	0.7	0.7	0.1	4.6	1.3	0.5	1.2	3	-	-	0.1	2	0.28			71	
160-280	-	27			0.2	6.0	5.1	9.3	20	14		0.2	1.2	1.5	0.1	4.4	1.3	1.0	1.3	6	-	-	0.1	2	0.30			85	
* # EC-2	ECUADOR				Humic Cambisol	Andic Humitropept																							
0-15	Ah1	12			6.2	5.3	4.6	10.1	13	4	0.5	0.5	0.6	1.0	0.4	0.7	0.6	0.3	1.7	2	-	-	0.5	1	0.86			73	
10-55	Ah2	13			4.9	5.5	4.7	10.2	13	4	0.0	0.5	0.5	1.1	0.3	0.7	0.5	0.4	1.5	3	-	-	0.5	<1	0.71	1.04	26	73	
55-79	Ah3	13			5.2	5.7	4.9	10.2	15	7	0.0	0.4	0.5	1.3	0.3	0.7	0.5	0.6	1.5	4	-	-	0.3	<1	0.71			79	
79-96	2Ab1	14			4.6	5.8	4.9	10.1	14	7	0.0	0.4	0.5	1.4	0.3	0.7	0.5	0.8	1.3	5	-	-	0.3	<1	0.71	1.02	32	77	
96-165	2Ab2	15			3.9	5.8	4.9	9.8	14	8	0.0	0.3	0.4	1.4	0.3	0.9	0.5	0.8	1.4	5	-	-	0.2	<1	0.56			68	
165-200	2Ab3	22			3.9	6.0	4.9	8.5	19	15	0.0	0.2	0.5	1.0	0.4	1.2	0.7	0.6	1.3	4	-	-	0.2	1	0.58			52	
* EC-4	ECUADOR				Humic Acrisol	Orthoxic Tropohumult																							
0-12	Ah	37			5.1	4.4	3.9	9.0	31	1	3.9	1.0	2.3	0.8	3.4	15.4	3.9	0.0		0			1.3	7	0.25	0.96	34	83	
12-50	Bw1	50			1.4	4.8	4.1	9.7	20	0	2.9	1.0	2.2	1.2	2.7	14.5	3.3	0.0		0			0.8	6	0.23			77	
50-95	Bw2	50			0.6	4.8	4.1	9.9	16	0	2.6	0.9	2.3	1.3	1.7	13.3	2.6	0.0		0			0.7	4	0.20	1.08	36	73	
95-142	B(C)	35			0.4	4.7	4.1	10.5	20	0	3.4	1.1	1.9	1.2	1.3	10.5	1.2	0.0		0			0.9	<1	0.02	1.06	44	80	
142-200	C	13			0.2	4.8	4.0	11.2	29	1	4.2	1.7	1.6	2.8	0.5	6.1	0.7	0.1	11.0	1	0.8	-	0.6	1	0.11			87	

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for disperion in special procedure
(see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e.
0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

GROUP II

Depth (cm)	Hori-zon	Clay[1] ro sp pH -(%)-	Org. C (%)	pH H2O	pH KCl	pH NaF	CEC (cmol(+)/kg)	Sum bases (cmol(+)/kg)	Exch. Al (cmol(+)/kg)	Al Pyr (%)	Al DC (%)	Al Ox (%)	Fe Pyr (%)	Fe DC (%)	Fe Ox (%)	Si Ox (%)	Al/Si[2] atom. ratio	Allophane (%)	Excess[3] Al (%)	Excess[3] Si (%)	Binary[4] ratio Al_p/Al_o	Ferri hydr. (%)	Activ. ratio Fe_o/Fe_d	Bulk dens. (kg/l)	15 bar water (wt%)	P-ret. (%)	CaCO3 (%)
* # EC-7	ECUADOR		Ferric Acrisol		Typic Tropaquult																						
0-8	A	53	3.2	4.6	4.2	8.4	16	5	1.9	0.3	0.9	0.7	0.7	3.4	0.8	0.1	4.0	3	0.1	-	0.4	1	0.24			72	
8-38	AB	62	1.3	4.8	4.1	8.9	13	2	3.3	0.3	0.9	0.6	0.4	4.6	0.8	0.1	4.0	3	0.1	-	0.5	1	0.17	0.91	28	73	
38-92	Bt	80	0.4	5.0	3.9	9.2	16	3	6.4	0.2	0.9	0.6	0.2	4.3	0.6	0.1	4.0	3	0.1	-	0.3	1	0.14	0.90	36	81	
92-150	2C	20	0.1	5.4	4.7	10.0	9	1	0.5	0.2	0.4	4.1	0.0	1.6	0.2	2.3	1.7	16	-	-	0.0	<1	0.12			93	
* # EC-8	ECUADOR		Vitric Andosol		Typic Vitrandept																						
0-25	A1	12	5.1	5.8	5.0	10.3	14	11	0.0	0.6	0.5	0.9	0.5	0.7	0.5	0.3	1.0	2	-	-	0.7	<1	0.71			71	
25-57	A2	9	2.7	6.4	5.0	10.3	9	4	0.0	0.4	0.4	0.9	0.2	0.6	0.4	0.4	1.3	3	-	-	0.4	<1	0.67	0.99	21	68	
57-84	A3	11	3.1	6.8	5.2	10.3	10	5	0.0	0.4	0.5	1.6	0.1	0.8	0.5	0.9	1.3	5	-	-	0.2	<1	0.62			78	3.4
84-120	2C1	1	0.2	6.8	5.2	8.4	2	1	0.0	0.1	0.1	0.3	0.0	0.2	0.1	0.2	1.0	1	-	-	0.3	<1	0.50	1.14	5	21	2.7
120-133	3Ab1	8	1.2	6.7	5.0	9.8	6	3	0.0	0.2	0.2	1.1	0.0	0.5	0.2	0.7	1.3	4	-	-	0.2	<1	0.40			49	
* # EC-20	ECUADOR		Vitric Andosol		Typic Vitrandept																						
0-25	Ah	10	4.3	5.8	5.0	10.5	11	5	0.0	0.5	0.6	1.2	0.5	0.8	0.6	0.5	1.4	3	-	-	0.4	1	0.75	1.04	24	84	
25-47	AC	7	2.3	5.9	5.0	10.5	7	3	0.0	0.4	0.5	1.1	0.3	0.7	0.5	0.5	1.4	3	-	-	0.4	<1	0.71			76	
47-65	2C1	1	0.5	6.0	5.1	9.8	2	1	0.0	0.1	0.1	0.4	0.0	0.2	0.1	0.2	1.5	1	-	-	0.2	<1	0.50	0.93	7	27	
65-85	2C2	1	0.1	6.2	5.2	8.1	2	1	0.0	0.1	0.0	0.2	0.0	0.3	0.1	0.1	1.0	<1	-	-	0.5	<1	0.33			16	
85-147	2C3	0	0.1	6.3	5.2	7.8	1	1	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.1	1.0	<1	-	-	0.0	<1	0.50			9	
147-170	3Ab	12	0.8	6.1	4.9	8.9	6	4	0.0	0.1	0.2	0.4	0.2	0.8	0.5	0.3	1.0	2	-	-	0.2	<1	0.62			37	

1 ro = according to routine procedure
sp = according to special procedure
pH = pH for disperion in special procedure (see 6.2 Methods)

2 $(Al_o-Al_p)/Si_o$ used for allophane
3 after calculation of allophane
4 ranging from 0 to 1; i.e. 0 = all allophane; 1 = all humus-Al

Pyr= pyrophosphate
DC = dithionite-citrate
Ox = oxalate

APPENDIX 2

Dissolution analysis of clays of selected horizons:
acid oxalate-soluble constituents

App. 2. Oxalate dissolution analysis of clays.

GROUP I

Depth (cm)	Hori-zon	Fe	Al	Si	Total (as oxide)	Al_o/Si_o atomic ratio	Allo-phane	Excess[1] Al	Excess[1] Si	Ferri-hydrite
		(%)					(%)			
CO-11	COLOMBIA		Humic Andosol			Hydric Dystrandept/Typic Hydrandept				
0-30	Ah1	5.7	9.8	3.5	34.2	2.9	33	1.4	-	10
57-80	AC	4.9	15.9	7.1	52.3	2.3	61	-	-	8
130-150	C2	3.6	16.5	8.8	55.0	2.0	67	-	-	6
CO-12	COLOMBIA		Humic Andosol			Typic Dystrandept				
0-30	Ah1	4.3	10.2	3.6	33.2	2.9	34	1.5	-	7
65-88	AC	3.0	17.1	6.9	51.4	2.6	65	0.5	-	5
88-108	C1	3.2	13.5	6.7	44.5	2.1	53	-	-	5
CO-13	COLOMBIA		Humic Andosol			Typic Hydrandept				
30-51	AB	1.4	9.4	2.0	23.9	4.9	19	4.6	-	2
78-82	Bir	12.0	13.1	5.0	52.7	2.7	47	1.1	-	20
98-120	C1	1.8	22.8	9.9	66.8	2.4	89	-	-	3
CO-14	COLOMBIA		Humic Andosol			Hydric Dystrandept/Typic Hydrandept				
0-30	Ah1	12.7	4.3	0.1	26.4	44.8	1	4.1	-	22
50-68	Ah3	10.3	9.8	4.3	42.6	2.4	39	-	-	18
98-150	2AB	7.0	6.8	2.8	28.9	2.5	26	-	-	12
PHI-1	PHILIPPINES		Humic Andosol			Hydric Dystrandept				
0-27	A1	4.5	17.2	8.3	56.7	2.2	68	-	-	8
52-85	B21	3.8	15.2	8.6	52.8	1.8	61	-	-	7
121-157	B23	2.7	16.1	9.3	54.2	1.8	65	-	-	5
INS-11	INDONESIA		Humic Andosol			Hydric Dystrandept				
0-12	Ap1	5.7	13.7	4.8	44.2	3.0	45	2.2	-	10
23-40	B2	5.7	16.5	7.9	56.1	2.2	65	-	-	10
40-78	2A11	8.9	14.1	5.1	50.4	2.9	48	1.8	-	15
132-141	2B2	8.5	13.5	5.2	48.9	2.7	49	1.0	-	14
141-162	3A1	8.5	15.4	5.2	52.5	3.1	49	2.9	-	14
162-210	3B22	6.9	17.6	6.6	57.1	2.8	62	1.7	-	12
210-236	4A1	7.8	2.5	0.6	17.1	4.3	6	1.1	-	13
236-270	4B2	7.5	12.0	5.1	44.4	2.4	46	-	-	13
RWA-1	RWANDA		Mollic Andosol			Udic Eutrandept				
0-11	A11	9.6	9.8	3.5	39.7	2.9	33	1.4	-	16
40-60	B1	12.7	11.5	4.6	49.8	2.6	43	0.4	-	22
90-120	B22	11.5	12.4	4.6	49.7	2.8	43	1.3	-	20
I-16	ITALY (La Palazzina)				Humic Andosol	Typic Dystrandept				
0-4	Ah1	4.2	8.3	2.3	26.6	3.8	22	2.8	-	7
29-47	Bu1	6.9	17.8	8.2	61.1	2.3	70	-	-	12
85-110	BC2	5.9	17.9	7.3	58.1	2.6	69	0.3	-	10
ITALY	(Roccamonfina)				Humic Andosol	Typic Dystrandept				
0-20	A11	2.8	9.5	3.5	29.5	2.8	33	1.1	-	5
20-45	A3	3.4	12.3	5.0	38.8	2.6	47	0.3	-	6
45-110	B21	3.5	12.8	5.7	41.5	2.3	49	-	-	6
110-155	2B22	3.4	14.3	6.9	46.8	2.2	57	-	-	6

1 after calculation of allophane

App. 2. Oxalate dissolution analysis of clays.

GROUP I

Depth (cm)	Hori-zon	Fe (%)	Al (%)	Si (%)	Total (as oxide) (%)	Al_o/Si_o atomic ratio	Allo-phane (%)	Excess[1] Al (%)	Excess[1] Si (%)	Ferri-hydrite (%)
USA-5 UNITED STATES (HAWAII,Kikoni) Umbric Andosol Typic Dystrandept										
0-18	Ap	7.9	5.8	0.8	23.9	7.5	8	3.9	-	13
40-66	B22	11.3	11.1	2.6	42.6	4.4	24	4.8	-	19
107-152	2B24	9.9	8.9	3.4	38.2	2.7	32	0.7	-	17
USA-6 UNITED STATES (HAWAII,Kukaiau) Humic Andosol Hydric Dystrandept										
0-17	Ap1	13.2	6.3	0.7	32.4	9.4	7	4.6	-	22
31-49	B21	10.7	10.0	1.7	37.8	6.1	16	5.9	-	18
60-76	B23	11.4	12.5	2.2	44.8	5.9	21	7.2	-	19
94-113	B25	8.9	4.9	1.1	24.4	4.6	10	2.3	-	15
USA-7 UNITED STATES (HAWAII,Hilo) Humic Andosol Typic Hydrandept										
0-23	Ap	10.6	6.7	1.2	30.5	5.8	11	3.8	-	18
91-102	B23	12.7	10.7	2.1	42.9	5.3	20	5.6	-	22
107-165	B25	11.8	8.6	1.7	36.9	5.3	16	4.5	-	20
EAK-5 KENYA Humic Andosol Hydric Dystrandept										
5-0	Ao	2.9	1.4	0.2	7.2	7.3	2	0.9	-	5
60-90	B21	3.0	1.9	0.1	8.2	19.8	1	1.7	-	5
160-175	2A1	4.2	6.5	1.6	21.6	4.2	15	2.6	-	7
EAK-34 KENYA Humic Andosol Hydric Dystrandept										
0-16	Ah1	5.4	2.9	0.4	13.9	7.5	4	1.9	-	9
16-28	Ah2	6.4	3.4	1.3	18.5	2.7	12	0.3	-	11
47-130+	B2	5.1	6.1	1.4	22.0	4.5	13	2.7	-	9
GUADELOUPE (Chateauneuf) Humic Andosol Hydric Dystrandept										
?	B	3.7	4.3	1.1	15.7	4.1	10	1.7	-	6
COSTA RICA (Paraiso) Humic Andosol Typic Dystrandept										
80	B	5.2	8.8	2.4	29.1	3.8	23	3.0	-	9
TENERIFE (Las Aves) Humic Andosol Typic Dystrandept										
0-50	A11/2	3.7	15.6	4.1	43.6	4.0	39	5.7	-	6
90-120+	2B	3.4	12.4	4.1	37.0	3.1	39	2.5	-	6
VANUATU (Aoba Isl., ORSTOM 243) Mollic Andosol Udic Eutrandept										
0-10/15	A11	11.5	11.0	3.0	43.6	3.8	28	3.8	-	20
15-30	A12	9.8	11.1	3.2	41.7	3.6	30	3.4	-	17
VANUATU (Vanua-Lava Isl., ORSTOM 231) Humic Andosol Oxic Dystrandept										
0-15	A11	4.2	13.4	4.0	39.9	3.5	38	3.8	-	7
50-70	(B)	2.4	11.8	4.1	34.5	3.0	39	1.9	-	4
VANUATU (Santa Maria Isl., ORSTOM 230) Mollic Andosol Udic Eutrandept										
30-40	A12(B	10.5	19.6	8.2	69.5	2.5	77	-	-	18
VANUATU (Santa Maria Isl., ORSTOM 465) Humic Andosol Typic Hydrandept										
0-10	A11	14.5	14.7	1.2	51.0	12.8	11	11.8	-	25
40-70	(B)	8.5	20.4	5.9	63.5	3.6	55	6.2	-	14
MEXICO (Sierra Nevada no.19) Humic Andosol Hydric Dystrandept										
0-40	A1	5.1	17.4	5.5	51.8	3.3	52	4.2	-	9
40-110	B1	5.2	17.2	5.2	51.2	3.4	49	4.7	-	9

1 after calculation of allophane

App. 2. Oxalate dissolution analysis of clays.

GROUP II

Depth (cm)	Hori-zon	Fe	Al	Si	Total (as oxide)	Al_o/Si_o atomic ratio	Allo-phane	Excess[1] Al	Excess[1] Si	Ferri-hydrite
		(%)					(%)			
EAK-2 KENYA Mollic Andosol Cumulic Hapludoll										
0-17	A1	7.3	4.4	0.6	20.1	7.6	6	3.0	-	12
49-75	2A1	7.7	2.7	0.7	17.6	4.0	7	1.0	-	13
105-140	2B2	6.9	8.4	3.0	32.1	2.9	28	1.2	-	12
EAK-4 KENYA Mollic Andosol or Andic Regosol Mollic Vitrandept										
0-24	Ah	5.3	1.4	0.4	11.1	3.6	4	0.4	-	9
75-104	C	1.0	0.3	0.0	1.9		0	-	-	2
145-160	2B	1.2	0.7	0.2	3.5	3.6	2	0.2	-	2
EAK-35 KENYA Mollic Andosol Mollic Vitrandept										
0-20	A1	1.8	0.6	0.2	4.3	3.1	2	0.1	-	3
60-90	2B22	0.6	0.6	0.5	3.1	1.2	3	0.0	-	1
90-145	2B3	0.1	0.4	0.1	1.1	4.2	1	0.2	-	0
EAK-36 KENYA Mollic Andosol Mollic Vitrandept										
0-15	A1	6.6	3.4	0.7	17.3	5.1	7	1.7	-	11
40-60	B2	6.8	4.2	1.1	20.0	4.0	10	1.6	-	12
90-180	C2cax	3.2	3.1	0.7	12.0	4.6	7	1.4	-	5
EAK-37 KENYA Mollic Andosol Mollic Vitrandept										
0-30	Ap	6.9	2.2	0.3	14.8	7.6	3	1.5	-	12
30-120	A12/3	6.8	2.5	0.4	15.3	6.5	4	1.5	-	12
120-150	A14	6.3	2.5	0.5	14.8	5.2	5	1.3	-	11
TANZANIA (Mukoma-1) Mollic Solonetz Typic Natrustoll										
0-15	A1	1.4	1.0	0.5	4.8	2.1	4	0.0	-	2
120-150	B34ca	0.4	0.7	0.5	2.9	1.5	3	0.0	-	1
TANZANIA (SEK-NE) Mollic Andosol Eutrandeptic Cumulic Haplustoll										
0-16	A11	1.6	2.4	0.3	7.5	8.3	3	1.7	-	3
70-110	A14	1.2	1.3	0.3	4.9	4.5	3	0.6	-	2
TANZANIA (Rhino-7) Luvic Chernozem Typic Agriustoll										
0-10	A1	0.6	0.5	0.2	2.3	2.6	2	0.0	-	1
100-150	B32ca	0.2	0.2	0.1	1.0	2.1	1	0.0	-	0
TANZANIA (Dutwa-1) Mollic Solonetz Typic Natrustoll										
0-21	A1	0.6	0.5	0.1	2.1	5.2	1	0.3	-	1
80-100	B32ca	0.1	0.2	0.1	0.8	2.1	1	0.0	-	0
TANZANIA (NaNo-S) Pellic Vertisol Typic Pellustert										
0-13	A11	0.6	0.6	0.2	2.4	3.1	2	0.1	-	1
90-114	A14	0.3	0.5	0.2	1.9	2.6	2	0.0	-	1
TENERIFE (Birmagen) Chromic Cambisol Andic Ustochrept										
0-10	A11	1.8	0.9	0.1	4.5	9.4	1	0.7	-	3
35-85	B	4.5	0.8	0.2	8.3	4.2	2	0.3	-	8
VANUATU (Aoba Isl., ORSTOM 245) Mollic Andosol Udic Eutrandept										
70-120	2B	9.4	5.8	1.9	28.4	3.2	18	1.2	-	16
VANUATU (Aoba Isl., ORSTOM 247) Vitric Andosol Mollic Vitrandept										
0-15	A11	3.6	2.4	0.3	10.4	8.3	3	1.7	-	6
VANUATU (Aoba Isl., ORSTOM 253) Mollic Andosol Andic Eutropept										
70-100	2B-C	6.9	3.1	0.7	17.2	4.6	7	1.4	-	12
VANUATU (Santa Maria Isl., ORSTOM 466) Mollic Andosol Andic Eutropept										
0-15	A11	3.7	2.4	0.3	10.5	8.3	3	1.7	-	6
15-80	B	2.4	1.2	0.2	6.0	6.2	2	0.7	-	4

1 after calculation of allophane

App. 2. Oxalate dissolution analysis of clays.

GROUP II

Depth (cm)	Hori-zon	Fe	Al	Si	Total (as oxide)	Al_o/Si_o atomic ratio	Allo-phane	Excess[1] Al	Excess[1] Si	Ferri-hydrite
		-----------	(%)	-----------			-----------	(%)	-----------	
MEXICO (Sierra Nevada no.13)				Humic Andosol		Hydric Dystrandept				
0-15	A11	4.0	4.8	0.9	16.7	5.5	9	2.6	-	7
15-70	A12	4.2	5.7	1.5	20.0	4.0	14	2.1	-	7
SYRIA R1		Vitric Andosol			Typic Vitrandept					
0-5	A1	0.8	1.7	0.3	5.1	5.9	3	1.0	-	1
5-17	C1	0.8	1.7	0.3	5.1	5.9	3	1.0	-	1
SYRIA R2		Vitric Andosol			Typic Vitrandept					
0-3	A1	0.7	1.7	0.2	4.8	8.8	2	1.2	-	1
3-16	C1	0.5	1.7	0.2	4.5	8.8	2	1.2	-	1
SYRIA R3		Vitric Andosol			Typic Camborthid/Typic Vitrandept					
0-20	A1	0.5	1.7	0.2	4.4	8.8	2	1.2	-	1
20-50	C1	0.4	1.7	0.1	4.1	17.7	1	1.5	-	1
SYRIA S3		Vitric Andosol			Typic Vitrandept					
0-40	AC	2.6	1.1	0.0	5.8		0	-	-	4
PHILIPPINES (Tagaytay)				Haplic Pheozem		Cumulic Haplustoll				
0-12	A1	5.6	1.2	0.3	10.9	4.2	3	0.5	-	10
12-27	2A1	5.8	1.4	0.5	12.0	2.9	5	0.2	-	10
27-35	3A1	6.2	1.5	0.4	12.6	3.9	4	0.5	-	11
35-44	4A12	6.2	1.4	0.2	12.1	7.3	2	0.9	-	11
44-51	4A1	5.9	1.3	0.3	11.5	4.5	3	0.6	-	10
51-136	4B2	4.1	1.1	0.4	8.7	2.9	4	0.1	-	7
136-166	5C1	3.8	1.0	0.3	7.8	3.5	3	0.3	-	7
KENYA 1976/138-142			Eutric Planosol			Abruptic Tropaqualf				
0-7	A1	1.2	0.5	0.0	2.7		0	-	-	2
7-23	A2	1.0	0.6	0.0	2.7		0	-	-	2
23-34	B21t	0.5	0.4	0.0	1.4		0	-	-	1
34-86	B22t	0.2	0.3	0.0	0.9		0	-	-	0
86-160	B23ca	0.3	0.2	0.1	1.0	2.1	1	0.0	-	1
KENYA 134/7			Eutric Planosol			Abruptic Tropaqualf				
25-35	A22	1.0	0.4	0.0	2.2		0	-	-	2
50-60	B22	0.1	0.3	0.0	0.9		0	-	-	0
80-92	2B	0.2	0.3	0.0	0.9		0	-	-	0
KENYA 118/6			Eutric Planosol			Abruptic Tropaqualf				
150-200	2B31	0.1	0.2	0.1	0.7	2.1	1	0.0	-	0
250-300	2B32	0.2	0.3	0.1	1.0	3.1	1	0.1	-	0
KENYA 145/5			Eutric Planosol			Abruptic Tropaqualf				
10-20	A2	1.6	0.5	0.1	3.4	5.2	1	0.3	-	3
40-50	B2t	0.3	0.4	0.1	1.4	4.2	1	0.2	-	1
150-200	C2	0.2	0.4	0.0	1.2		0	-	-	0
KENYA 145/7			Eutric Planosol			Abruptic Tropaqualf				
10-20	B2	0.4	0.3	0.0	1.2		0	-	-	1
40-50	B31	0.2	0.3	0.0	0.9		0	-	-	0
80-90	B32	0.2	0.2	0.0	0.7		0	-	-	0
110-120	Ccam	0.1	0.3	0.0	0.9		0	-	-	0

[1] after calculation of allophane

APPENDIX 3

Dissolution analysis of clays of selected horizons: acid oxalate-insoluble constituents and mineral composition of the silt fraction (2-20μm)

Abbreviations used:

Cb	= cristobalite
Fd	= feldspar
Gb	= gibbsite
Goe	= goethite
Ht	= halloysite
Ht/Sm-Vt	= randomly interstratified halloysite with smectite-vermiculite
Kt	= kaolinite
LS	= layer silicates
Mc	= mica
Mc-Vt	= intergrade mica and vermiculite
Mc-Pyro/talc	= intergrade mica and pyrophyllite/talc
MH	= metahalloysite
Mc/Sm(LC)-Vt	= intergrade mica and low-charge smectite-vermiculite
Mc-Vt/Ch	= intergrade mica and vermiculite/chlorite
Pyro	= pyrophyllite
Ps	= palygorskite
Qz	= quartz
Sm	= smectite
Sm(LC)	= low-charge smectite
Talc-Pyro/Vt	= intergrade talc and pyrophyllite/vermiculite
Vt-Ch	= intergrade vermiculite and chlorite

App. 3. Oxalate-insoluble constituents.

GROUP I

Depth	Hori-zon	Con-tent	Relative abundance of minerals in CLAY		Relative abundance of minerals in SILT				
(cm)		(%)	Clay minerals	Primary minerals	Qz	Fd	Cb	Gb	LS
CO-11 COLOMBIA			Humic Andosol Hydric Dystrandept/Typic Hydrandept						
0-30	Ah1	53	Vt-Ch>>>Kt	Cb>>Qz,Fd	+	+	+	-	-
57-80	AC	31	Vt-Ch>Mc-Vt/Ch,Ht,Kt	Cb>Fd,Amp	++	++	++	-	++)*
130-150	C2	27	Vt-Ch>Mc-Vt/Ch,Ht,Kt	Cb,Amp>>Qz,Fd	+	+	++	-	-
CO-12 COLOMBIA			Humic Andosol Typic Dystrandept						
0-30	Ah1	55	Vt-Ch>>Kt,Gb	Cb	++	+	++	+	++)*
65-88	AC	29	Vt-Ch>Mc/Vt-Ch,Kt,Gb	Cb>Qz	++	+	++	-	+)*
88-108	C1	42	Vt-Ch>>Mc/Vt-Ch,Kt,Gb	Cb	++	+	++	-	++)*
CO-13 COLOMBIA			Humic Andosol Typic Hydrandept						
30-51	AB	66	Vt-Ch>>Kt	Cb>>Qz	++	+	+	-	-
78-82	Bir	30	Vt-Ch>>Mc/Vt-Ch,Kt,Gb	Cb>Qz	++	+	-	-	++)*
98-120	C1	8	Vt-Ch,Gb>Kt	Qz,Fd,Cb	+	+	+-	-	+
CO-14 COLOMBIA			Humic Andosol Hydric Dystrandept/Typic Hydrandept						
0-30	Ah1	65	Sm,Vt-Ch>Talc,Pyro,Kt,Gb	Cb>>Fd	+	++	++	+	-
50-68	Ah3	43	Mc-Pyro/Talc>Sm,Pyro,Kt	Cb>Fd	+-	++	+++	-	+-
98-150	2AB	62	Sm,Vt-Ch>Kt>Ch,Talc-Pyro/Vt,Gb	Cb>>Fd	+	+	+++	+	+)*
PHI-1 PHILIPPINES			Humic Andosol Hydric Dystrandept						
0-27	A1	34	Vt-Ch,Ht,Kt,Gb	Cb	+-	+-	++	+	-
52-85	B21	32	Ht,MH	Cb	+-	+	+++	+	-
121-157	B23	30	Ht>Vt-Ch,Kt,Gb	Cb	+-	+-	++	+	-
INS-11 INDONESIA			Humic Andosol Hydric Dystrandept						
0-12	Ap1	39	Kt,MH(?)>Vt-Ch,Ht	Cb,Fd	+	+	++	-	-
23-40	B2	25	Ht>Vt-Ch,Kt	Cb	+	+-	+	-	-
40-78	2A11	32	Ht>Vt-Ch,Kt	cB	+-	+-	+	-	-
132-141	2B2	34	Ht,Kt	Cb	+	+	+++	-	-
141-162	3A1	29	Ht>>Kt	Cb	+-	+	+++	-	-
162-210	3B22	21	Ht>>>Kt	Cb>Fd	+-	++	+++	+	-
210-236	4A1	78	Ht>>>Kt	Cb	+	+	+++	-	++
236-270	4B2	41	Ht>>>Kt	Cb	+	+	++	-	+
RWA-1 RWANDA			Mollic Andosol Udic Eutrandept						
0-11	A11	47	Ht>Gb,Vt-Ch(?)	Qz,Fd	+	+	-	-	-
40-60	B1	34	Ht>Gb>Vt-Ch	Fd	+-	+	-	-	-
90-120	B22	33	Gb,Ht>Vt-Ch(?)	Fd	-	+	-	-	-
I-16 ITALY (La Palazzina)			Humic Andosol Typic Dystrandept						
0-4	Ah1	63	Mc-Vt,Vt-Ch,Kt>Mc	Qz>>Fd	+++	+	-	-	++
29-47	Bu1	18	Ht,Kt(?)	Qz	+-	-	-	-	-
85-110	BC2	20	Ht,Kt	Qz>Fd	+-	-	-	-	-
ITALY (Roccamonfina)			Humic Andosol Typic Dystrandept						
0-20	A11	59	Vt-Ch,Mc>Ht,Kt	Fd>>Qz	++	++	-	-	+
20-45	A3	46	Vt-Ch,Mc>Ht,Kt	Fd>Qz	+	++	-	-	+
45-110	B21	45	Vt,Ht>Mc,Kt	Fd>>Qz	+	++	-	-	+
110-155	2B22	41	Ht,Vt>Mc,Kt	Fd>>Qz	+	+++	-	-	+

+-: questionable, +: present, ++: moderate, +++: abundant
)* mainly chloritic materials

App. 3. Oxalate-insoluble constituents.

GROUP I

Depth (cm)	Horizon	Content (%)	Relative abundance of minerals in CLAY: Clay minerals	Relative abundance of minerals in CLAY: Primary minerals	Relative abundance of minerals in SILT: Qz	Fd	Cb	Gb	LS
USA-5 UNITED STATES (HAWAII,Kikoni) Umbric Andosol Typic Dystrandept									
0-18	Ap	69	Ht>Mc,Kt,Vt-Ch	Qz>>Fd	+	+-	-	-	+++
40-66	B22	43	Ht>Mc(?),Vt-Ch,Kt	Qz	+	+-	-	+-	++
107-152	2B24	49	Ht>Vt-Ch,Kt>Ch(?)	Fd>Qz	+-	+-	-	-	++
USA-6 UNITED STATES (HAWAII,Kukaiau) Humic Andosol Hydric Dystrandept									
0-17	Ap1	58	Gb>Vt-Ch,Mc,Kt,Mc/Vt-Ch	Qz	+++	-	-	++	+
31-49	B21	49	Gb>>Vt-Ch,Mc,Kt	Qz	+++	-	-	+	+
60-76	B23	39	Gb>>Vt-Ch,Mc,Kt	Qz	++	-	-	++	+
94-113	B25	68	Vt-Ch,Mc>Gb>Mc/VtCh,Kt	Qz	+++	+-	-	++	+
USA-7 UNITED STATES (HAWAII,Hilo) Humic Andosol Typic Hydrandept									
0-23	Ap	60	Gb>Kt,Vt-Ch(?)	Qz>Fd	++	-	+	++	+-
91-102	B23	42	Gb>Kt,Vt-Ch(?)	Qz>Fd	++	-	+-	+++	+-
107-165	B25	51	Gb>Kt,Vt-Ch(?)	Qz>Fd	++	-	+	+++	+-
EAK-5 KENYA Humic Andosol Hydric Dystrandept									
5-0	Ao	90	MH,Gb,Kt>Vt-Ch,Goe	Qz	+++	+	-	+	++
60-90	B21	89	MH,Kt>Gb>Vt-Ch	Qz	+++	+	-	++	+++
160-175	2A1	70	Gb>Kt>Ht,MH,Vt-Ch(?)	Qz	+++	+	-	++	++
EAK-34 KENYA Humic Andosol Hydric Dystrandept									
0-16	Ah1	82	Vt-Ch,Kt>Gb>Ht(?)	Qz,Fd	+++	+-	-	+	+++
16-28	Ah2	76	Vt-Ch,Gb>Kt	Qz	++	+-	-	++	++
47-130+	B2	70	Vt-Ch,Kt,Gb>Ht(?)	Fd	++	+-	-	+	++
GUADELOUPE (Chateauneuf) Humic Andosol Hydric Dystrandept									
?	B	79	Gb>Vt-Ch,Mc/Vt-Ch,Ht,Kt	Cb,Qz	+++	-	+++	++	-
COSTA RICA (Paraiso) Humic Andosol Typic Dystrandept									
80	B	59	Ht>>MH	Cb	+-	-	+	-	++ (Ht?)
TENERIFE (Las Aves) Humic Andosol Typic Dystrandept									
0-50	A11/2	39	Vt-Mc>Kt,Gb	Qz	+++	+	-	+-	+
90-120+	2B	48	Gb>Vt-Mc,Kt	-	++	+	-	+	+
VANUATU (Aoba Isl., ORSTOM 243) Mollic Andosol Udic Eutrandept									
0-10/15	A11	41	Sm(?)	Fd	-	++	-	-	+
15-30	A12	43	Sm(?)	-	-	++	-	-	+
VANUATU (Vanua-Lava Isl., ORSTOM 231) Humic Andosol Oxic Dystrandept									
0-15	A11	44	Gb>>>Ht(?)	-	+-	-	-	+++	-
50-70	(B)	52	Gb>>>Kt(?)	-	+-	-	-	+++	-
VANUATU (Santa Maria Isl., ORSTOM 230) Mollic Andosol Udic Eutrandept									
30-40	A12(B	5	-	glass	-	+	-	-	-
VANUATU (Santa Maria Isl., ORSTOM 465) Humic Andosol Typic Hydrandept									
0-10	A11	30	Sm(?)	Cb	-	-	-	-	+-
40-70	(B)	13	-	Cb	-	-	-	-	+-
MEXICO (Sierra Nevada no.19) Humic Andosol Hydric Dystrandept									
0-40	A1	27	MH	Cb>>Fd	+-	++	++	-	++
40-110	B1	28	MH>Ch	Cb>>Fd	+-	++	++	-	++

+-: questionable, +: present, ++: moderate, +++: abundant

App. 3. Oxalate-insoluble constituents.

GROUP II

Depth (cm)	Horizon	Content (%)	Relative abundance of minerals in CLAY: Clay minerals	Relative abundance of minerals in CLAY: Primary minerals	Relative abundance of minerals in SILT: Qz	Fd	Cb	Gb	LS
EAK-2 KENYA			Mollic Andosol Cumulic Hapludoll						
0-17	A1	73	Ht,MH(?)	Fd	+-	+++	-	-	-
49-75	2A1	77	Ht>>MH(?)	Fd	+-	+++	-	-	-
105-140	2B2	44	Ht>Kt>Gb,Vt-Ch(?),MH(?)	Fd>Qz	+	+++	-	-	++
EAK-4 KENYA			Mollic Andosol or Andic Regosol	Mollic Vitrandept					
0-24	Ah	86	Ht(?)	Fd	+-	+++	-	-	-
75-104	C	98	-	Fd	+-	+++	-	-	-
145-160	2B	95	Ht~MH(?)	Fd	-	+++	+-	-	++
EAK-35 KENYA			Mollic Andosol Mollic Vitrandept						
0-20	A1	95	Ht(?),Mc(?) **	Fd	+-	+++	-	-	++
60-90	2B22	96	Ht(?),Mc(?) ***	Fd	+-	++	-	-	++
90-145	2B3	99	Ht(?) **	Fd	+-	+++	-	-	++
EAK-36 KENYA			Mollic Andosol Mollic Vitrandept						
0-15	A1	77	Ht(?) **	-	-	+-	-	-	++
40-60	B2	73	Ht(?) **	-	-	+	-	-	++
90-180	C2cax	84	Ht(?) **	-	+-	+	-	-	++
EAK-37 KENYA			Mollic Andosol Mollic Vitrandept						
0-30	Ap	81	MH(?) **	Fd	-	+++	-	-	-
30-120	A12/3	80	Ht(?) **	Fd	-	+++	-	-	-
120-150	A14	80	Ht	Fd	-	+++	-	-	-
TANZANIA (Mukoma-1)			Mollic Solonetz Typic Natrustoll						
0-15	A1	94	polycompon. interstratif.(?) ***	Fd	+++#	++	+-	-	+
120-150	B34ca	96	Ht(?) **	Fd	++ #	+	-	-	+++
TANZANIA (SEK-NE)			Mollic Andosol Eutrandeptic Cumulic Haplustoll						
0-16	A11	89	Mc(?),Ht(?)_ **	-	+	++	+-	-	++
70-110	A14	93	Mc(?),Ht(?) **	-	++	+-	-	-	++
TANZANIA (Rhino-7)			Luvic Chernozem Typic Agriustoll						
0-10	A1	97	Sm(LC)>>Mc,Kt	Qz>Fd	+++#	++	-	-	-
100-150	B32ca	99	Sm(LC)>>Mc,Kt	Qz>Fd	+++#	++	-	-	-
TANZANIA (Dutwa-1)			Mollic Solonetz Typic Natrustoll						
0-21	A1	97	Mc/Sm(LC)-Vt,Ht/Sm-Vt	Qz	+++#	++	-	-	-
80-100	B32ca	99	Mc/Sm(LC)-Vt,Ht/Sm-Vt	Qz	+++#	+	-	-	+
TANZANIA (NaNo-S)			Pellic Vertisol Typic Pellustert						
0-13	A11	97	Mc(?),Ht(?) **	Fd	+-	+-	-	-	+++
90-114	A14	97	Mc(?),Ht(?)	Fd	+	+-	-	-	+++
TENERIFE (Birmagen)			Chromic Cambisol Andic Ustochrept						
0-10	A11	96	MH>>Kt,Vt-Ch(?),Mc(?)	-	+++	++	-	-	++
35-85	B	90	Ht-MH>>Mc	-	+	+	-	-	++
VANUATU (Aoba Isl., ORSTOM 245)			Mollic Andosol	Udic Eutrandept					
70-120	2B	63	Ht>>>Sm(?)	Fd	-	+++	-	-	-
VANUATU (Aoba Isl., ORSTOM 247)			Vitric Andosol	Mollic Vitrandept					
0-15	A11	86	Sm>>Vt-Ch	Fd	-	++	-	-	++
VANUATU (Aoba Isl., ORSTOM 253)			Mollic Andosol	Andic Eutropept					
70-100	2B-C	77	Ht>>>Sm(?)	-	-	+	-	-	+++
VANUATU (Santa Maria Isl., ORSTOM 466)			Mollic Andosol	Andic Eutropept					
0-15	A11	86	MH>Ht	Fd	-	++	-	-	+++
15-80	B	92	Ht-MH	Fd	-	++	-	-	+++

+-: questionable, +: present, ++: moderate, +++: abundant

** very poorly ordered minerals with well-marked (hk0) but without (001) reflections

*** possibly random interstratification of vermiculite, smectite and mica

mainly derived from underlying weathered granitic and/or gneissic rock (very coarse grained)

App. 3. Oxalate-insoluble constituents.

GROUP II

Depth (cm)	Hori-zon	Con-tent (%)	Relative abundance of minerals in CLAY: Clay minerals	Relative abundance of minerals in CLAY: Primary minerals	Relative abundance of minerals in SILT: Qz	Fd	Cb	Gb	LS
MEXICO (Sierra Nevada no.13)			Humic Andosol	Hydric Dystrandept					
0-15	A11	76	MH	Fd	+-	+++	+	-	++
15-70	A12	73	MH	Fd	+-	+++	+	-	++
SYRIA R1			Vitric Andosol	Typic Vitrandept					
0-5	A1	93	Sm,Vt>Ps,Mc,Kt	Qz	++	+	-	-	++
5-17	C1	93	Sm,Vt>Ps,Mc,Kt	Qz	++	+	-	-	++
SYRIA R2			Vitric Andosol	Typic Vitrandept					
0-3	A1	94	Sm,Vt>Ps,Mc,Kt	Qz	++	+	-	-	++
3-16	C1	94	Sm,Vt>Ps,Mc,Kt	Qz	++	+	-	-	++
SYRIA R3			Vitric Andosol	Typic Camborthid/Typic Vitrandept					
0-20	A1	94	Sm,Vt>Ps,Mc,Kt	Qz	++	+	-	-	++
20-50	C1	94	Sm,Vt>Ps,Mc,Kt	Qz	++	+	-	-	++
SYRIA S3			Vitric Andosol	Typic Vitrandept					
0-40	AC	96	Poorly crystallized 2:1>>Kt	Qz	+	+	-	-	+++
PHILIPPINES (Tagaytay)			Haplic Pheozem	Cumulic Haplustoll					
0-12	A1	86	MH>>Ht	-	+-	+	-	-	+++
12-27	2A1	84	MH>>Ht	-	+-	++	-	-	+++
27-35	3A1	84	MH>>Ht	-	+-	++	-	-	+++
35-44	4A12	84	Ht>>MH	-	+-	+	-	-	+++
44-51	4A1	85	Ht	-	+-	+	-	-	+++
51-136	4B2	89	Ht	-	+	+	-	-	+++
136-166	5C1	88	Ht	-	+	+	-	-	+++
KENYA 1976/138-142			Eutric Planosol	Abruptic Tropaqualf					
0-7	A1	98	Sm(LC)>>Mc>Kt	Fd,Qz	+++	+++	-	-	-
7-23	A2	98	Sm(LC)>>Mc>Kt	Fd,Qz	+++	+++	-	-	-
23-34	B21t	99	Sm(LC)>>Mc,Kt>Ht/Sm-Vt	Fd,Qz	+++	+++	-	-	-
34-86	B22t	100	Sm(LC)>>Mc,Kt>Ht/Sm-Vt	Fd,Qz	+++	+++	-	-	-
86-160	B23ca	98	Sm(LC)>>Mc,Kt>Ht/Sm-Vt	Fd,Qz	++	+++	-	-	+-
KENYA 134/7			Eutric Planosol	Abruptic Tropaqualf					
25-35	A22	98	Ht(?) **	Qz>Fd	+++	+++	-	-	-
50-60	B22	100	Sm-Vt/Kt-Ht	Qz,Fd	++	+++	-	-	-
80-92	2B	100	Sm-Vt/Kt-Ht	Qz,Fd	++	+++	-	-	-
KENYA 118/6			Eutric Planosol	Abruptic Tropaqualf					
150-200	2B31	99	Sm(LC)>>Mc,Ht/Sm-Vt	Fd	+	+++	-	-	+
250-300	2B32	99	Sm(LC)>>Mc,Ht/Sm-Vt	Fd	+-	+++	-	-	+
KENYA 145/5			Eutric Planosol	Abruptic Tropaqualf					
10-20	A2	95	Mc(?) ***	Fd	+-	+++	-	-	-
40-50	B2t	97	Mc(?) ***	Fd	+-	+++	-	-	+
150-200	C2	100	Mc(?) ***	Fd	+-	+	-	-	++
KENYA 145/7			Eutric Planosol	Abruptic Tropaqualf					
10-20	B2	99	Mc-Sm-Vt (Mc-rich phase)	Fd	++	+++	-	-	+
40-50	B31	100	Mc-Sm-Vt (Mc-rich phase)	Fd	++	+++	-	-	++
80-90	B32	100	Mc-SmVt (Mc-rich phase)	Fd	+-	+	-	-	++
110-120	Ccam	100	Mc-Sm-Vt (Mc-rich phase)	Fd	+-	+	-	-	++

+-: questionable, +: present, ++: moderate, +++: abundant
** very poorly ordered minerals with well-marked (hk0) but without (00l) reflections
*** possibly random interstratification of vermiculite, smectite and mica

APPENDIX 4

Soil profile descriptions

GROUP I

Profile: CO 11

Classification:	
FAO/Unesco (1974)	: *Humic Andosol*
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept/Typic Hydrandept
ICOMAND (1988)	: Hydric Pachic Fulvudand
Location	: 15 km S. of Pasto (Narino), Colombia Latitude: 1°07'N Longitude: 77°22'W Altitude: 3100 m
Described by	: W. Siderius
Physiography	: Undulating volcanic plain
Slope	: 8%
Parent material	: Andesitic volcanic ash
Vegetation	: Original forest cleared for cultivation
Land use	: Pasture; in immediate vicinity also maize, potatoes, beans, Eucalyptus and Pinus
Soil climate	: Udic, isomesic
Ecological zone	: Humid montane forest
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah1	0-30	Black (10YR 2.5/1) moist, loam; strong fine and medium granular; soft dry, friable moist, non sticky and non plastic wet; smeary; many fine medium and coarse pores; many fine and medium roots; gradual smooth boundary to
Ah2	30-57	black (10YR 2.5/1) moist, silt loam; moderate fine and medium subangular blocky; slightly hard dry, friable moist, non sticky and non plastic wet; smeary; few moderately thick organans; few to common small charcoal fragments; many fine medium and coarse tubular pores; common fine and medium roots; gradual smooth boundary to
AC	57-80	very dark greyish brown (10YR 3/2) moist, clay loam; weak fine to medium subangular blocky; slightly hard dry, friable to firm moist, slightly sticky and non plastic wet; common moderately thick organans and cutans; common charcoal fragments; common krotovina ϕ 3 cm ellipsoidal; some whitish biological mottles; common fine, medium and coarse pores; common fine and medium roots; gradual smooth boundary to
C1	80-130	dark brown (10YR 3/3) moist, loam; weak medium to fine subangular blocky; soft dry; friable to firm moist, slightly sticky and non plastic wet; few krotovina's (ϕ 3 cm); common fine, medium and coarse pores; common fine and medium roots; gradual smooth boundary to
C2	130-150+	brown (7.5YR 4/4) moist, loam; porous massive, consistence and pores as C1; few fine roots.

Remarks: thin Fe fibres occur at 150 cm; but are too deep to be diagnostic for the placic horizon; common earthworm activity from 0-80 cm, but especially from 0-50 cm; burrows and krotovinas are common from 50-80 cm; few occur between 80-130 cm.

Profile: CO 12

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Typic Dystrandept
ICOMAND (1988)	: Pachic Fulvudand
Location	: 2.5 km N. of Narino, Colombia Latitude: 1°20'N; Longitude: 77°20'W; Altitude: 2350 m
Described by	: W. Siderius
Physiography	: Dissected footslopes of Galeras volcano
Slope	: 5%
Parent material	: Andesitic ash and tuff
Vegetation	: Original forest cleared for cultivation
Land Use	: Sisal; in immediate vicinity also maize, potatoes, onions, Eucalyptus and Pinus
Soil climate	: Udic, isomesic
Ecological zone	: Humid lower montane forest
Drainage	: Well drained

Profile description

Horizon	Depth (cm)	Description
Ah1	0-30	Dark brown (7.5YR 3/2) moist, loam, weak fine to medium granular; slightly hard dry, friable moist, non sticky and non plastic wet; few volcanic glass; many fine, medium and coarse tubular pores; many fine medium and coarse roots; gradual smooth boundary to
Ah2	30-65	black (7.5YR 2.5/0), with few fine faint diffuse dark reddish brown (5YR 3/4) mottles along root channels; sandy loam; weak fine to very friable moist, slightly sticky and non plastic wet; many volcanic glass; roots and pores as Ah1; gradual smooth boundary to
AC	65-88	very dark grey (10YR 3/1) moist, sandy loam; weak medium to fine subangular blocky; slightly hard dry, very friable moist, slightly sticky and non plastic wet; common volcanic glass; many fine, medium and coarse pores; few fine and medium roots; reaction to NaF = 0; pH is 5.5; gradual smooth boundary to
C1	88-108	yellowish brown (10YR 5/6) moist, clay loam; porous massive; slightly hard dry, very friable moist, slightly sticky and non plastic

		wet; few volcanic glass; common pores; very few roots; gradual smooth boundary to
C2	108-150	yellowish brown (10YR 5/8) moist, sandy loam; porous massive; soft dry, very friable moist, non sticky and non plastic wet; few volcanic glass, some rock fragments; pores and roots as C1.

Remarks:

Depth of the C2 may attain 15 m, little evidence of fauna activity in the soil, some tubules; pH relatively high because of lower elevation, less rain, higher temperature.

Profile: CO 13

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Typic Hydrandept
ICOMAND (1988)	: Alic Fulvudand
Location	: 14 km E. of Pasto (Narino), Colombia Latitude: 1°10'N; Longitude: 77°11'W; Altitude: 3240 m
Described by	: W. Siderius
Physiography	: Strongly dissected volcanic upland
Slope	: 9%
Parent material	: Andesitic ash
Vegetation	: Humid montane forest
Soil climate	: Udic, isomesic. Influence of cold wet winds from "Laguna la Cocha"
Ecological zone	: Montane rain forest
Drainage	: Moderately well drained

Profile description

Horizon	Depth (cm)	Description
Ah1	0-12	Dark reddish brown (5YR 2.5/2) moist, loam; very weak fine subangular blocky to massive; very friable moist, non sticky, non plastic wet; smeary; many fine and medium tubular pores; common fine and medium roots; gradual wavy boundary to
Ah2	12-30	black (5YR 2.5/1) moist, loam; very weak fine subangular blocky to massive; consistence, pores and roots as Ah1; gradual wavy boundary to
AB	30-51	dark brown (7.5YR 3/2) moist, loam; very weak fine subangular blocky to massive; very friable moist, non sticky non plastic wet; smeary; common fine and medium pores; common fine and medium roots; gradual wavy boundary to

Bh	51-78	very dark grey (10YR 3/1) moist, loam; very weak fine subangular blocky to massive; very friable moist, non sticky and non plastic wet; smeary; common fine and medium pores; many fine and medium roots; abrupt wavy boundary to
Bir	78-82	reddish brown (5YR 4/3) moist, loam; strong medium platy; firm moist, non sticky non plastic wet; no roots; no pores; abrupt wavy boundary to
BC	82-98	very dark grey (10YR 3/1) moist, with few medium, faint, diffuse yellowish brown (10YR 5/6) mottles along root channels; loam; massive; very friable moist, non sticky and non plastic wet; smeary; few fine pores; few fine and medium roots; abrupt broken boundary to
C1	98-120	brownish yellow (10YR 6/6) moist with common medium distinct yellowish red (5YR 5/8) mottles; loam; massive; very friable moist, non sticky and non plastic wet; smeary; few fine and medium roots; abrupt wavy boundary to
C2	120-150	yellowish brown (10YR 5/4) moist, with few medium distinct yellowish red (5YR 5/8) mottles; loam; massive; consistence as C1.

Remarks:
Apart from the Ah1 horizon, a major occurrence of roots from 51-78 cm just above the placic horizon. The latter acts as a pan and upholds water, resulting in seepage just above the Bir.

Profile: CO 14

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept/Typic Hydrandept
ICOMAND (1988)	: Thaptic Haplocryand/Thaptic Hydrocryand
Location	: 18 km W. of Pasto along road to summit of Galeras volcano (Narino), Colombia Latitude: 1° 10'N; Longitude: 77° 22'W; Altitude: 3810 m
Described by	: W. Siderius
Physiography	: North slope of Galeras volcano
Slope	: 38%
Parent material	: Partly consolidated volcanic ash, tuff and cinders
Vegetation	: Montane grassland
Soil climate	: Udic, cryic
Ecological zone	: Sub-alpine grassland
Drainage	: Well drained

Profile description

Horizon	Depth in cm	Description
Ah1	0-30	Very dark grey (7.5YR 3/1) moist, slightly gravelly sandy loam; weak fine granular; slightly hard dry, friable moist, non sticky and non plastic wet; few fine rocky fragments; many fine medium and coarse pores; many fine and medium roots; gradual wavy boundary to
Ah2	30-50	dark brown (7.5YR 3/2) moist; slightly gravelly sandy clay loam; weak fine granular; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; pores and roots as Ah1; gradual wavy boundary to
Ahb	50-68	very dark grey (10YR 3/1) moist with common medium, distinct dark yellowish brown (10YR 4/4) "mottles"; loam; porous massive; slightly hard dry, friable moist, slightly sticky and slightly plastic wet; slightly smeary; common fine and medium pores; many fine and medium roots; clear wavy boundary to
C	68-98	yellowish brown (10YR 5/6) moist; sandy clay loam; porous massive; slightly hard dry, friable moist, slightly plastic wet; common fine and medium pores; common fine and medium roots; clear wavy boundary to
2AB	98-150	black (10YR 2.5/1) moist; loam; porous massive; soft dry, very friable moist, slightly sticky and plastic wet; smeary; common fine and medium pores; common fine and medium roots.

Profile: PHI 1

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Hydric Thaptic Fulvudand
Local	: Pili series
Location	: Philippine Union College, Panicuason, Naga City, Luzon, Phillipines Latitude: 13°40'00"N; Longitude: 123°17'11"E; Altitude: 140 m
Described by	: M. Raymundo and A. Dayot
Physiography	: Upper piedmont plain
Position of site	: Upper slope of piedmont plain of Mt. Isarog
Slope	: 2-5%
Parent material	: Slightly compacted friable volcanic ash
Vegetation	: Grasses, shrubs, various crops (coconut, sugar cane, maize, sorghum)
Land use	: Research area, diverse crops
Climate	: Humid equatorial, MAT 27°C, MAR 3500 mm
Soil climate	: Udic, isohyperthermic (MAT soil: 29°C)
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A	0-27	Black (10YR 2/1), silt loam; non sticky, non plastic, very friable; massive in place, breaking to weak medium prismatic and fine granular; many fine grass roots, clear smooth boundary to
B1	27-52	dark yellowish brown (10YR 3/4) silt loam; non sticky, non plastic; friable; strong fine and medium subangular blocky; few fine roots, few fine random pores, few fine worm holes; presence of illuviated organic matter and clay material on some root holes and ped faces, diffuse wavy boundary to
B21	52-85	dark brown (7.5YR 4/4) silt loam; very slightly sticky, very slightly plastic, friable, strong fine and medium subangular blocky structure; few fine roots, few fine random pores, few fine worm holes; presence of illuviated organic matter and clay material on connected root pores from upper horizon and on some ped faces; diffuse wavy boundary to
B22	85-121	dark brown (7.5YR 4/4) silt loam; slightly sticky and slightly plastic, friable; moderate fine and medium angular and subangular blocky structure; very few very fine roots, few fine pores; presence of illuviated organic matter and clay material on connected root pores from upper horizon and on weak ped faces; diffuse wavy boundary to
B23	121-157	brown (7.5YR 4/4) silt loam; slightly sticky and slightly plastic, friable; moderate fine and medium subangular blocky structure.

Profile: INS 11

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept, thixotropic
ICOMAND (1988)	: Hydric Thaptic Fulvudand
Location	: Benchmark Soil site at ITKA, Lembang, Bandung, W. Java, Indonesia Latitude: 6°48'S; Longitude: 107°38'E; Altitude: 120 m
Described by	: D.L. Gallup, H. van Reuler and R.G. Manuelpillai
Physiography	: lower slope of volcano
Position of site	: S.E. facing
Slope	: 3-4%, convex
Parent material	: Andesitic ash
Vegetation	: Grass
Land use	: In area: intensive vegetable production
Climate	: Humid tropical
Soil climate	: Udic, isothermic

Drainage : Well drained

Profile Description (all colours when moist)

Horizon	Depth (cm)	Description
Ap1	0-12	Very dark brown (10YR 2/2) silt loam; weak fine subangular blocky breaking to moderate fine granular structure; friable, non-sticky and slightly plastic; abundant fine and common medium roots; abundant fine interstitial pores; gradual smooth boundary to
Ap2	12-23/30	very dark greyish brown (10YR 3/2) silt loam; weak fine subangular blocky breaking to weak fine granular structure; friable non sticky and slightly plastic; common fine and few medium roots; abundant fine interstitial pores; clear wavy boundary to
B2	23/30-40	dark brown (7.5YR 3/3) heavy silt loam; moderate fine subangular blocky structure; slightly firm, slightly sticky and sligthly plastic; common fine roots, common fine and very fine tubular and many fine interstitial pores; slightly darker coloured cutans on peds; slightly smeary; clear wavy boundary to
2A11	40-78	black (N 2/0) silt loam; moderate fine subangular blocky breaking to moderate fine granular structure; friable, slightly sticky, slightly plastic; few fine roots; few medium and many fine tubular and many fine interstitial pores; common fine nodules that can be crushed that appear to be organic matter; gradual smooth boundary to
2A12	78-107	black (N 2/0) light silty clay loam; moderate medium subangular blocky breaking to moderate fine angular blocky strucutre; slightly firm; slightly sticky; slightly plastic; few fine roots; few medium and many fine tubular and many fine interstitial pores; slightly smeary; many fine (1 to 2 mm) black nodules that can be crushed, apparently organic matter; clear smooth boundary to
2A3	107-132	black (10YR 2/1) light silty clay loam; moderate fine angular subangular blocky structure; firm; slightly sticky and slightly plastic; few fine roots; many fine and medium tubular and many fine interstitial pores; slightly smeary; shiny cutans on most ped faces; many fine (1 to 2 mm) black nodules; clear smooth boundary to
2B2	132-141	very dark brown (10YR 2/2) silty clay loam; weak medium subangular blocky breaking to moderate fine angular and subangular blocky structure; firm slightly sticky and plastic; very few fine roots; few medium and many fine tubular and many fine interstitial pores; few red (2.5YR 4/6) weathered rock fragments about 5 mm diameter; many fine black nodules; clear smooth boundary to
3A1	141-162	black (10YR 2/1) light silty clay loam; moderate medium subangular blocky breaking to moderate fine angular blocky structure; firm, slightly sticky and slightly plastic; very few fine roots; common fine

		tubular and many fine interstitial pores; few fine weathered rock fragments, shiny cutans on most ped faces; many fine black nodules; clear smooth boundary to
3B22	161-210	dark yellowish brown (10YR 3/4) silty clay loam; moderate fine subangular blocky structure; friable; slightly sticky and slightly plastic; very few fine roots; common fine interstitial pores; many fine (1 to 2 mm) brown nodules that can be crushed, few fine weathered red/yellow gravel; clear smooth boundary to
4A1	210-236	very dark grey (10YR 3/1) silty clay loam; moderate fine angular blocky structure; friable, slightly sticky and slightly plastic; few fine interstitial pores; few black nodules that can be crushed; few fine multicoloured weathered gravel; clear smooth boundary to
4B2	236-270	dark yellowish brown (10YR 3.5/4) silty clay loam; moderate medium angular blocky strucutre; firm to friable; slightly sticky and slightly plastic; few fine interstitial pores.

Profile: RWA 1

Classification:
- FAO/Unesco (1974) : Mollic Andosol
- FAO (1988) : Mollic Andosol
- Soil Taxonomy (1975) : Udic Eutrandept
- ICOMAND (1988) : Pachic Fulvudand

Location : Prefect. Gisenyi, commune Mutura, sect. Kauzeuze, colline Kirerema, 10 m N. of main road to Isar-station of Tamira, 2 km from main road Gisenyi-Ruhengeri, 21 km from Gisenyi
Latitude: 1°38'S; Longitude: 29°23'E; Altitude: 2220 m

Described by : Tour guide, Fourth Int. Soil Class. Workshop, Rwanda 1981, SMSS, USDA, SCS, Box 2890, Washington DC, 20013 USA (Profile R8)

Physiography : Large lava plain with several old volcanic mounds of ashes and coarser material; strong microrelief

Position of site : N. facing slope of old volcano, ca. 100 m below top

Parent material : Basic volcanic ash

Vegetation : Pennisetum clandestinum; Digitaria sp.; Poa sp., some Eucalyptus trees

Land use : Grassland

Climate : Cw2, MAT 14.5°, MAR 1500 mm

Soil climate : Udic, isothermic

Drainage : Well drained

Profile Description

Horizon	Depth (cm)	Description
Ao	3-0	Organic litter.
A11	0-11	Dark brown (7.5YR 3/2) silty clay loam, moist; bit smeary; low bulk density; massive structure; very many fine roots; friable; smooth abrupt boundary; presence of some rare small spots of 2.5YR 4/6 being weathered volcanic ash to
A12	11-40	dark brown (7.5YR 3/2), some very rare dots of 2.5YR 4/6; 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 to
B1	40-60	dark brown (7.5YR 3/3.5), 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 to
B21	60-90	dark reddish brown (6YR 3/3); silty clay loam, smeary (litht thixotropy); low bulk density; moist; weak medium subangular blocky structure, friable, presence of some massive blocks, some very rare coatings in pores; common fine roots; smooth clear boundary to
B22	90-102	dark reddish brown (5YR 3/3) gravelly silty clay loam, pebbles of volcanic material, some mm in diameter, red at the outside (2.5YR 4/6) and black at the inside; low bulk density; moist, weak medium subangular block structure, friable; common fine roots; smooth and abrupt boundary to
C	102+	pure volcanic material of variable size (mms) and irregular shape, porous, low density; heterogenous colour, red and black (7.5YR 2/0), slightly coherent

Profile: I 16

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Typic Dystrandept
ICOMAND (1988)	: Typic Hapludand/Typic Melanudand
Location	: near "La Palazzina", S.W. of Lago del Matese, ca. 60 km N. of Napoli Latitude: 41° 24'30"N; Longitude: 14° 25'00"; Altitude: 1150 m
Described by	: O.C. Spaargaren
Physiography	: Concave slope in steeply dissected limestone mountains
Slope	: 19%

Parent material	: Coarse tuff or pumice (less than 12000 yrs old) overlying hard limestone
Vegetation	: Beech forest with some undergrowth of herbs
Land use	: Semi-controlled fire-wood production
Climate	: Mediterranean (but high altitude) MAR 1350 mm, MAT 7.7 °C
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Brief description of the soil: A black to very dark brown topsoil overlies at about 30 cm a weakly structured strong brown, clay loam to sandy loam subsoil, developed in coarse tuff deposits.

Horizon	Depth (cm)	Description
0	3-0	Undecomposed and partly decomposed leaf litter; abrupt and smooth boundary to
Ah1	0-4	black (10YR 2/1, moist) to very dark grayish brown (10YR 3/2, dry) silty clay loam; weak fine and medium crumb; slightly sticky and slightly plastic when wet, very friable when moist; many very fine and fine discontinuous exped interstitial pores; non calcareous; few animal burrows; common very fine and fine roots; 5.0; abrupt and smooth boundary to
Ah2	4-29	very dark brown (10YR 2/2, moist) to greyish brown (10YR 5/2, dry) clay loam; porous massive; slightly sticky and non-plastic when wet, very friable when moist; common very fine and fine discontinuous interstitial and random tubular pores; non calcareous; few charcoal fragments; few animal burrows; common to many very fine, fine and medium roots and few coarse roots; clear and irregular boundary to
Bu1	29-47	strong brown (7.5YR 5/6, moist) to yellow (10YR 7/6, dry) gravelly clay loam; weak medium and coarse angular blocky; non-sticky and non-plastic when wet, very friable when moist; broken moderately thick clay-iron cutans on main ped faces; common very fine and fine discontinuous intertitial pores; few animal burrows; non calcareous; common very fine and fine and few medium roots; many rounded strongly weathered volcanic ash particles; clear and smooth boundary to
Bu2	47-66	strong brwon (7.5YR 4/6, moist) to yellow (10YR 7/6, dry) gravelly sandy loam; very weak coarse subangular blocky; non-sticky and non-plastic when wet, loose to very friable when moist; patchy thin clay-iron cutans on some single grains; many very fine and fine discontinuous interstitial pores; non calcareous; common very fine and fine roots; very many rounded weathered volcanic ash particles; clear and smooth boundary to
BC	66-120	strong brown (7.5YR 4/6, moist) to yellow (10YR 7/6, dry) gravelly sandy loam; very weak coarse subangular blocky; non-sticky and

non-plastic when wet, loose when moist; patchy thin clay-iron cutans on some single grains; many very fine and fine discontinuous interstitial pores; non calcareous; few very fine and fine roots; very many rounded weathered volcanic ash particles.

Profile: Italy Roccamonfina

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Typic Dystrandept
ICOMAND (1988)	: Thaptic Fulvudand
Location	: Monte La Frascara, Roccamonfina (Caserta), Italy Latitude: 41°17'N; Longitude: 13°59'E; Altitude: 865 m
Physiography	: Inner slope of Somma's caldera
Parent material	: Leucitic tephritic pyroclastics on leucitic lava
Vegetation	: Chestnut (Castanea sativa) coppice
Climate	: Mediterranean (at higher altitude); MAR 1525 mm; MAT 11°C
Soil climate	: Udic (small rain deficit for about 6 weeks)
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A11	0-20	Black (5YR 2.5/1) loam; moderate medium crumb; moist, loose (very porous), few small volcanic rock fragments; abundant small roots; clear smooth boundary to
A3	20-45	very dark greyish brown (10YR 3/2) loam; moderate medium granual going to medium crumb; moist, very friable; frequent roots; few weathered leucite-rich volcanic rock fragments; gradual irregular lower boundary to
B21	45-110	reddish brown (5YR 4/4) loam; very coarse granular going to medium subangular blocky structure; abundant small pores; moist, very friable; frequent roots; few weathered leucite-rich volcanic rock fragments; diffuse lower boundary to
2B22	110-155	yellowish brown (10YR 5/6) loam; very coarse granular going to medium angular and subangular blocky structure; abundant small pores; moist, very friable; some fine and medium roots; frequent to very frequent weathered leucite-rich lava fragments to
2B3	155-220	strong brown (7.5YR 5/6) loam; very fine angular blocky structure; few small pores; moist, very friable; rare small roots in fissures.

Profile: USA 5

Classification:	
FAO/Unesco (1974)	: Mollic Andosol
FAO (1988)	: Umbric/Mollic Andosol
Soil Taxonomy (1975)	: Typic Dystrandept/Eutrandept, medial, isothermic
ICOMAND (1988)	: Pachic Haplustand
Local	: Kikoni series
Location	: Waimea, Island of Hawaii, approx. 1.6 km E. of Waimea Town Latitude: 20° 01'30"N; Longitude: 155° 39'33"W; Altitude: 840 m
Described by	: S. Nakamura
Physiography	: Nearly level to moderately sloping Waimea Plain
Position of site	: N. face of drainage ditch
Slope	: 2%
Parent material	: Andesitic ash
Vegetation	: Kikuyu grass, castor bean, thistle, joee
Land use	: Pasture, truck crops, wildlife habitat
Climate	: MAR 760 mm, MAT 18° C
Soil climate	: Ustic
Drainage	: Well drained
Moisture	: Dry

Profile Description

Horizon	Depth (cm)	Description
Ap	0-18	Very dark brown (10YR 2/2) silt loam; strong very fine subangular blocky structure; hard, sticky, plastic; many roots; many pores; clear smooth boundary to
B21	18-40	dark brown (7.5YR 3/3) very fine sandy loam; massive; very friable, non-sticky, non-plastic; many roots; many very fine pores; gradual smooth boundary to
B22	40-66	dark brown (7.5YR 3/4) very fine sandy loam; weak medium subangular blocky structure; very friable, non-sticky, non-plastic; many roots; many very fine pores; clear wavy boundary to
B23	66-107	dark brown (7.5YR 3/4) very fine sandy loam; weak medium subangular blocky structure; very friable, non-sticky, non-plastic; pockets of very dark grayish brown (7.5YR 3/2) soil that has strong fine subangular blocky structure; many roots; many pores; clear wavy boundary to
2B24b	107-152	very dark grayish brown (7.5YR 3/2) silty clay (gritty); strong fine and medium subangular blocky and blocky structure; common roots; many pores; 5 to 10% lava fragments.

Profile: USA 6

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept, isothermic, thixotropic
ICOMAND (1988)	: Pachic Fulvudand/Hydric Thaptic Fulvudand
Local	: Kukaiau series
Location	: Honokaa, Island of Hawaii. Approx. 2.5 km SE of Honokaa Town, University of Hawaii Benchmark Soils Proj. exp. site Latitude: 20°04'06"N; Longitude: 155°26'56"W; Altitude: 395 m
Described by	: H. Ikawa and Soekardi
Physiography	: Gently sloping to steep uplands
Slope	: 6-7%
Parent material	: Andesitic ash
Vegetation	: Formerly sugarcane, presently in experimental maize and vegetable crops
Climate	: MAR 1800-2500 mm, MAT 19-21°C
Soil climate	: Udic
Drainage	: Well drained
Moisture	: Moist

Profile Description

Horizon	Depth (cm)	Description
Ap1	0-17	Dark reddish brown (5YR 3/3) silty clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many very fine roots; many very fine pores; clear smooth boundary to
Ap2	17-31	dark reddish brown (5YR 3/3, 3/4) silty clay loam; weak fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic; many very fine roots; many very fine pores; abrupt smooth boundary to
B21	31-49	dark reddish brown (5YR 3/3) silty clay loam; weak fine and medium subangular blocky structure; friable, sticky, plastic, weakly smeary; common very fine roots; many very fine pores, few fine and medium pores coated with dark-colored material; gradual smooth boundary to
B22	49-60	dark reddisbh brown (5YR 3/3) silty clay loam; moderate fine and medium subangular blocky structure; friable, slightly sticky, plastic, weakly smeary; few very fine roots; many very fine pores, few fine and medium pores coated with dark-colored material; few weathered cinders 1-4 cm diameter; clear smooth boundary to
B23	60-76	dark reddish brown (5YR 3/3, 3/4) silty clay loam; moderate fine and medium subangular blocky structure; friable, sticky, plastic, weakly

		smeary; few very fine roots; many very fine pores, few fine pores coated with dark-colored material; clear smooth boundary.
B24	76-94	dark reddish brown (5YR 3/4) and reddish brown (5YR 4/4) silty clay loam; moderate fine, medium, and coarse subangular blocky structure; friable, sticky, plastic, weakly smeary; few very few roots; many very fine pores, few fine pores coated with dark-colored material; clear smooth boundary to
B25	94-113	dark reddish brown (5YR 3/3, 3/4) silty clay loam; moderate fine and medium subangular blocky structure; friable, sticky, plastic, weakly smeary; few very fine roots; many very fine pores, few fine pores coated with dark-colored material; clear smooth boundary to
B26	113-150	yellowish red (5YR 4/6) silt loam; moderate fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic, moderately smeary; few very fine roots; many very fine pores; few fine pores; gel-like coatings ped faces: gradual smooth boundary to
B3	150-163	dark reddish brwon (5YR 3/3, 3/4) and reddish brown (5YR 4/4) silt loam; moderate fine and medium subangular blocky structure; friable, slightly sticky, slightly plastic, weakly smeary; many very fine pores, few fine pores with decomposed roots; some weathered rocks with vesicles containing dark-colored material as well as light-colored gel-like material.

Profile: USA 7

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Typic Hydrandept, isohyperthermic, thixotropic
ICOMAND (1988)	: Thaptic Hydrudand
Local	: Hilo Series
Location	: Wainaku, Island of Hawaii. Approx. 18 km NNW of mouth of Waikuku River in Hilo Bay. Roadbank in sugarcane field of Mauna Kea Sugar Company Latitude: 19°44'39"N; Longitude: 155°6'2"W; Altitude: 93 m
Described by	: S. Nakamura
Physiography	: Gently sloping to steep uplands
Slope	: 5%
Parent material	: Andesitic volcanic ash
Vegetation	: Sugar cane, hilograss, california grass
Climate	: MAR 3800 mm, MAT ca. 22.5°C
Soil climate	: Perudic
Drainage	: Well drained
Moisture	: Moist

Profile Description

Horizon	Depth (cm)	Description
Ap	0-23	Dark brown (7.5YR 3/4) silty clay loam (gritty due to irreversible drying); moderate very fine and fine subangular blocky structure; friable, slightly sticky, plastic; common roots; many pores; there is mixture of redder material from below; at the base of this horizon is a 1 to 5 cm thick discontinuous dark red ash band that rubs down to a sandy clay loam; clear smooth boundary to
B21	23-56	dark brown (7.5YR 3/4) silty clay loam; weak medium prismatic structure parting to moderate fine subangular blocky; friable, sticky, plastic, moderately smeary; common roots; many very fine and few fine pores; horizon appears stratified due to ash deposits; the lower 5 cm is dark reddish brown (5YR 3/4); gradual smooth boundary to
B22	56-91	dark reddish brown (5YR 3/4) and yellowish red (5YR 4/6) silty clay loam; moderate medium prismatic structure parting to strong fine and very fine subangular blocky; friable, sticky, plastic, moderately smeary; few roots; many very fine and common fine pores; horizon appears stratified due to ash deposits; clear smooth boundary to
B23	91-102	dark brown (7.5YR 3/2) silty clay loam; moderate medium prismatic structure parting to strong fine subangular blocky; friable, sticky, plastic, moderately smeary; few roots; many very fine and common fine pores; clear smooth boundary to
B24	102-107	dark reddish brown (5YR 3/4) silty clay loam: moderate medium prismatic structure parting to strong, fine subangular blocky; friable, sticky, plastic, moderately smeary; few roots; many very fine and common fine pores; clear smooth boundary to
B25	107-165	dark brown (7.5YR 3/4) silty clay loam; strong medium prismatic structure parting to strong fine subangular blocky; friable, sticky, plastic, moderately smeary; few roots; many very fine and common fine pores.

Profile: EAK 5

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Alic Hapludand
Location	: Kimakia forest, Muranga distr., Kenya (Excursion site 3, Kenya Soil Surv. Staff, 1977; Misc. Soil Paper 7) Latitude: N 9904.4; Longitude: E 250.0 (local); Altitude: 2290 m
Physiography	: Foothills of Aberdares Mts., hilly to mountainous
Slope	: 40%

Parent material	: Volcanic ash (trachitic?)
Vegetation	: Mixed bamboo forest
Climate	: Subhumic, MAT 14-16 °C, MAR ±1000-1600 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ao	5-0	Undecomposed organic matter.
A1	0-17	Dusky red (5YR 3/3 dry, 2.5YR 3/2 moist); silty clay; weak to moderate, fine to medium, subangular blocky structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; many, very fine, common, fine and medium pores; many fine, medium and coarse roots; gradual and smooth transition to
A3	17-55	reddish brown (5YR 4/3 moist); clay; weak, medium, subangular blocky structure; very friable when moist, slightly sticky and slightly plastic when wet; common, very fine and few, medium pores; common, fine medium and coarse roots; gradual and smooth transition to
B21	55-83	reddish brown (5YR 4/4 moist); clay; porous massive to weak, medium and coarse subangular blocky structure; very friable when moist, slightly sticky and slightly plastic when wet; common, very fine, fine and medium pores; few fine, medium and coarse roots; diffuse and smooth transition to
B22	83-166	dark reddish brwon (5YR 3/3 moist); clay; porous massive structure; very friable when moist, slightly sticky and slightly plastic when wet; common fine and medium pores; few, fine and medium roots; gradual and smooth transition to
2A1b	166-220	dark brown (7.5YR 3/2 moist); clay; moderate, medium and coarse angular blocky structure; firm when moist, slightly sticky and slightly plastic when wet; common, fine and many medium roots; many filled up insect holes; clear and wavy transition to
2B2b	220-240+	yellowish red (5YR 4/6 moist); clay; moderate, fine and medium, angular blocky structure; firm when moist; slightly sticky and slightly plastic when wet; common, moderate clay cutans; common, very fine and fine pores.

Profile: EAK 34

Classification:
FAO/Unesco (1974) : Humic Andosol

FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Alic Fulvudand
Location	: N. part of Gituamba Agric. Sta., Muranga Distr. Kenya Latitude: 0°45'S; Longitude: 36°51'E; Altitude: 2180 m
Described by	: D.N. Mungai & A. Weeda
Physiography	: Footslope ridges
Position of site	: Upper part of slope
Slope	: 10%
Parent material	: Pyroclastic rocks with intercalated basalts covered by trachytic volcanic ash
Vegetation	: Bracken vegetation
Land use	: Cattle grazing area
Climate	: Subhumid, MAT 14-16°C, MAR 1000-1600 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah	0-16	Very dark greyish brown (10YR 3/2, moist); sandy clay loam; coarse, weak, subangular blocky, composed of fine weak subangular blocks; friable when moist, non-plastic and non-sticky when wet; very frequent fine and few medium roots; slight reaction to NaF; abrupt smooth boundary to
BA	16-28	very dark brown (7.5YR 2/4, moist); sandy loam; coarse, very weak, subangular blocky; friable when moist, non-plastic and non-sticky when wet; frequent fine and common medium roots; slight reaction to NaF; gradual smooth boundary to
B1	28-47	dark reddish brown (5YR 3/3, moist); sandy clay loam; coarse, moderate, subangular blocky, composed of fine, weak, subangular blocks; friable when moist, non-plastic and slightly sticky when wet; common fine and medium, and few coarse roots; moderate reaction to NaF; diffuse smooth boundary to
B2	47-130+	dark reddish brown (5YR 3/4, moist); sandy clay loam; coarse, moderate subangular blocky, composed of medium, weak, subangular blocks; very few, thin clay-cutans; friable when moist, non-plastic and slightly sticky when wet; few fine and medium roots; strong reaction to NaF.

Profile: Guadeloupe Chateauneuf

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol

Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Alic Fulvudand ?

Description not available

Profile: Costa Rica: Paraiso

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Typic Dystrandept
ICOMAND (1988)	: Hydric Pachic Melanudand (?)
Local	: Birrisito series
Location	: Between Cervabes and Paraíso, N. of highway in field of Mr. Irola; 205.8 km N. and 554.4 km E, Irazú topographic sheet (3445 IV); Costa Rica. Panel sobre Suelos Derivados de Cenizas Volcanicas de América Latina, 6-13 Julio, 1969. Turrialba, Costa Rica. Profile 2. Altitude: 1500 m.
Physiography	: Long regular side slope of volcano
Slope	: 10%
Parent material	: Volcanic ash
Vegetation	: Very weedy, unimproved pasture
Land use	: Not cultivated since last crop of sugar cane two year ago
Climate	: MAT 19 °C; MAR ca. 2000 mm/yr, with mild dry season
Soil climate	: Udic (?)
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ap	0-30	Black (10YR 2/1) loam; moderate very fine granular structure; friable, slightly sticky, slightly plastic; many very fine interstitial pores, few tubular; many very fine roots; clear and smooth boundary to
A12	30-80	black (10YR 2/1 or 1/1) loam; moderate fine subangular blocky breaking to strong very fine granular structure; friable, slightly sticky, slightly plastic; many very fine interstitial and tubular pores; many krotovinas; many very fine roots; one angular pebble and one fragment of pottery near the lower boundary; abrupt, clear and irregular boundary to
2B1	80-120	dark brown (10YR 4/3, with variations to 4/4 and 3/3) silty clay; weak fine and very fine subangular blocky breaking to moderate very fine granular structure; friable, sticky, plastic; many very fine tubular pores; few nearly white, common black, few reddish grains less than 1 mm diameter; very variable; 35 percent inclusions, from 10 to 15

		cm across, of material like that of horizons above and (to a lesser extent) below; clear, gradual and wavy boundary to
2B21	120-160	strong brown (7.5YR 4/6) silty clay; moderate very fine subangular blocky structure; friable, sticky, plastic; many very fine tubular pores; few soft reddish concretions, from 2 to 5 mm diameter; few nearly white grains less than 1 mm diameter; few black sand grains; inclusions, from 5 to 15 cm across, of material like that of B1 and A12; many roots; gradual boundary to
2B22	160-195	strong brown (7.5YR 4/6) silty clay; weak medium breaking moderate fine and very fine subangular blocky structure; friable, sticky, plastic; many very fine tubular pores; few nearly white grains less than 1 mm diameter; few black sand grains; few roots; clear and smooth boundary to
3B23tb	195-210+	brown (7.5YR 4/4) silty clay; moderate medium subangular blocky strucutre; firm sticky, plastic; common very fine tubular pores; common coatings (clay film?) on peds, some reddish; few small black coatings; few reddish concretions, from 2 to 5 mm diameter; few roots.

Profile: Tenerife (Las Aves)

Classification:
- FAO/Unesco (1974) : Humic Andosol
- FAO (1988) : Umbric Andosol
- Soil Taxonomy (1975) : Typic Dystrandept
- ICOMAND (1988) : Thaptic Fulvudand
- Local : Andosol desaturado crómico

Location : Mt. Agua Garcia, Tenerife, Canary Islands, Spain. Ref.: Fernandez Caldas et al. (1982)
Latitude: 28° 26'40"N; Longitude: 16° 22'47"W; Altitude: 1100 m

Position of site : Along N. facing slope
Parent material : Basaltic ash and lapilli
Vegetation : Pinus canariensis
Climate : Temperate perhumid; foggy zone, MAT ca. 15° C
Soil climate : Udic

Profile Description

Horizon	Depth (cm)	Description
A11-A12	0-50	Very dark brown-grey to dark brown (7.5YR 2/3); very humic loamy sand; fine granular; very friable; very low bulk density and strongly microporous; many fine roots; clear boundary to

B/C	50-70/90	dark reddish brown (deep red) (2.5YR 3/4) with dark brown lateral layer; gravelly (lapilli) and fine loamy; loose; few coarse and fine roots; irregular wavy boundary to
2B	90-120+	brown (7.5YR 4/5) loamy clay; massive, friable, microporous; low bulk density, weakly plastic, moist and sticky, weakly thixotropic, few roots.

N.B.: throughout the profile a strong reaction with NaF, the strongest in the B/C horizon.

Profile: Vanuatu, Aoba Isl., ORSTOM no. 243

Classification:
FAO/Unesco (1974) : Mollic Andosol
FAO (1988) : Mollic Andosol
Soil Taxonomy (1975) : Udic Eutrandept
ICOMAND (1988) : Typic/Eutric Hapludand
intergrade to Mollic Vitrandept in depth
Location : Vanuatu-Aoba Island, near Vureas and Loloway
Latitude: 15° 17'30"S; Longitude: 167° 57'E;
Altitude: 100 m
Described by : P. Quantin (ORSTOM, France)
Physiography : Plateau of lava flows
Position of site : North-East, windward
Slope : Weak, < 5%
Parent material : Basaltic ashes over cinders and flows of basalt*
Vegetation : Rainforest
Land use : Shifting cultivation of rain-fed crops, or coconut plantations
Climate : Wet tropical, of windward type, MAR ca. 3000 mm, MAT ca. 26 °C
Soil climate : Udic,isohyperthermic
Drainage : Well drained; very rapid permeability

* the ash deposits are ca. 500 to 1500 years old from the topsoil to the buried soils in depth.

Profile Description

Horizon	Depth (cm)	Description
A	0-10/15	Very dark reddish brown (5YR 2/2) sandy loam and very humiferous; finely granular; very friable; very porous and permeable; low bulk density; very dense fine roots to
AB	10/15-30	dark reddish brown (5YR 3/2) sandy loam and humiferous; finely crumb; slightly coherent wet; but very friable, like flour often drying; very porous and permeable; low bulk density; dense fine roots to

Bw	30-120	lightly reddish brown (7.5YR 4/3) loamy sand and some weathered cinders (lapilli of basalt); slightly humiferous; finely crumb; very friable; very porous and permeable; low bulk density; less numerous roots, rather scarce to
	120-400	5 buried shallow Andosols made of dark brown loamy A horizons and of weathered cinders or tuffs beds.

Remarks:
- We note a weak reaction to the FIELDES (NaF) test in the whole soil profile.
- The <2 μm fraction contains a ferriferous allophane of hisingerite type, and few spherical halloysite, some ferrihydrite and very few opal.
- The parent material is a basalt very rich in Mg and Fe.

Profile: Vanuatu, Vanua-Lava Isl., ORSTOM no. 231

Classification:
FAO/Unesco (1974) : Mollic Andosol/Dystri-Mollic Andosol
FAO (1988) : Mollic/Umbric Andosol
Soil Taxonomy (1975) : Oxic Dystrandept
ICOMAND (1988) : -
Location : Vanuatu-Vanua Lava Island, SW Coast, near Vureas
Latitude: 13°54'S; Longitude: 167°27'E; Altitude: 100 m
Described by : P. Quantin (ORSTOM, France)
Physiography : Plateau of volcanic tuff
Position of site : Middle of the plateau, SW of the Island
Slope : Weak, < 10%
Parent material : Basaltic ash over a volcaniclastic tuff (andesitic basalt)*
Vegetation : Rainforest
Land use : Coconut plantation and gardens
Climate : Wet tropical, MAR ca. 4000 mm, MAT ca. 26°C
Soil climate : Udic Isohyperthermic
Drainage : Well drained, rapid permeability

* the ash deposits are recent in the topsoil (100-2000 years) and older (>2000 years) in depth

Profile Description

Horizon	Depth (cm)	Description
A	0-15	Dark reddish brown (5YR 3/3) loam, very humiferous; medium sized granular structure; friable; smeary; very porous and very permeable; very low bulk density; abundant fine roots to
AB	15-30	dark reddish brown (5YR 3/3.5) loam, less humiferous; finely crumb; very friable; very porous; moderately abundant fine roots, transition gradual to

Bw	30-70	reddish brown (5YR 4/4) mottled with fine ochre spots (of weathered basaltic cinders); clay loam, slightly humiferous; very fine crumb structure, like flour; very friable; non sticky; very important microporosity; very low bulk density; scarce roots to
2B	70-180+	dark reddish brown (5YR 3/4) loam, slightly humiferous; fine crumb structure; more firm; friable; non sticky; very important microporosity; few scarce roots.

Remarks:
- The <2 μm fraction contains mostly Al-rich allophane of imogolite type (fibrous) in 2B, or spherical in Bw, and some ferrihydrite. In 2B, it contains also much gibbsite and few halloysite (tubular) and few fine goethite.
- The reaction to the FIELDES (NaF) test is rapid and strong in the whole soil profile; but a little lower in depth (2B).
- The parent material is an andesitic basalt, rich in Al and Ca.

Profile: Vanuatu, Santa Maria Isl., ORSTOM no. 230

Classification:

FAO/Unesco (1974)	: Mollic Andosol/Eutri-Mollic Andosol
FAO (1988)	: Mollic(/Umbric?) Andosol
Soil Taxonomy (1975)	: Udic Eutrandept
ICOMAND (1988)	: Typic Hapludand or Thaptic Fulvudand
Location	: Vanuatu-Santa Maria Island, NE Coast, near Lemara village, Tarasag Bay Latitude: 14°15'S; Longitude: 167°35'E; Altitude: 15 m
Described by	: P. Quantin (ORSTOM, France)
Physiography	: Plateau of Lava flows
Position of site	: North-East of the Island, near the Coast, windward
Slope	: Weak, <5%
Parent material	: Basaltic ashes over an olivine-basalt flow*
Vegetation	: Rainforest
Land use	: Coconut plantation
Climate	: Wet tropical, MAR ca. 4000 mm, MAT ca. 26°C
Soil climate	: Udic,isohyperthermic
Drainage	: Well drained, rapid permeability

* the ash deposits are recent in the topsoil

Profile Description

Horizon	Depth (cm)	Description
A	0-10/15	Dark reddish brown (5YR 3/2) sandy loam, very humiferous; medium to fine sized granular structure; friable; very porous and very permeable; low bulk density; abundant roots to
AB	15-30	dark reddish brown (5YR 3/3) loam, humiferous; transitional to

Bw	30-50/60	dark reddish brown (5YR 3/3.5) loam, humiferous; finely crumb; friable; very porous and permeable; low bulk density; slightly moist; moderately abundant roots to
R*	>60	weakly weathered hard olivine-basalt. * designated D by Quantin.

Remarks:
- The <2μm contains mainly spherical allophane and few spherical halloysite, and some ferrihydrite.
- The reaction to the FIELDES (NaF) test is rapid and strong.
- The parent material is a basalt rich in Mg and Fe.

Profile: Vanuatu, Santa Maria Isl., ORSTOM no. 465

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Typic Hydrandept
ICOMAND (1988)	: Aquic Hydrudand
Location	: Vanuatu, Santa Maria Island, Western Summit of the Caldera, near Mt. Lilgirip and Mt. Makenwouin Latitude: 14° 16'S; Longitude: 167° 28'E; Altitude: 640 m.
Described by	: P. Quantin (ORSTOM, France)
Physiography	: Flate dome of shield volcano
Position of site	: West facing summit of the dome, near the W. Caldera wall
Slope	: Smooth, 10-20%
Parent material	: Basaltic ashes, over volcanic tuff and basaltic breccia*
Vegetation	: Low height 'perhumid' rainforest, rich in treeferns and epiphytes
Land use	: None
Climate	: 'Perhumid' wet tropical, MAR ca. 5000 mm (?), MAT ca. 22° C
Soil climate	: Perudic,isohyperthermic, transition to isothermic
Drainage	: Well drained, rather slow permeability in depth

* the ash deposit are very recent in the topsoil, older in depth

Profile Description

Horizon	Depth (cm)	Description
A	0-10	Dark reddish brown (5YR 3/3) loam, very humiferous; finely crumb, fluffy; very friable; wet; smeary; very low bulk density; fairly abundant fine roots; rapid transition to
Bw	10-70	dark reddish brown (5YR 3/4) loam, humiferous; rather continuous and massive structure; smeary; friable; slightly plastic; slightly 'thixotropic'; very low bulk density; very important micro-porosity, but poor macro-porosity and slow permeability; few scarce root.

C	70-80	mottled; weathering of tuff or of basaltic breccia.
R*	80+	weakly weathered basaltic breccias.
		* designated D by Quantin.

Remark:
- The reaction to the FIELDES (NaF) test is very strong and rapid in the whole soil profile
- The <2 μm fraction contains mostly Al-rich allophane of imogolite type, and some ferrihydrite.

Profile: Mexico, Sierra Nevada No. 19

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Pachic Melanudand
Local	: Andosol humandos
Location	: Ca. 15 km N.E. of Amecameca and ca. 55 km S.E. of Mexico City. Ref.: Miehlich, 1984 (1980, p. 28, profile 19) Latitude: 19° 17'N; Longitude: 98° 39'W; Altitude: 3400 m
Physiography	: Slope of Iztaccihuatl volcano
Position of site	: W. slope
Slope	: 25%
Parent material	: Andesitic volcanic ash
Vegetation	: Pinus sp., grasses
Land use	: Forestry, forest grazing
Climate	: Cold, humid, MAT 8° C, MAR 1100-1300 mm
Soil climate	: Udic, isomesic

Profile Description

Horizon	Depth (cm)	Description
Ao	5-0	Undecomposed organic matter.
A1	0-110	Black (7.5YR 2/0) clay loam (in ash layer 3C; see ref.) fine crumb, very soft to soft, thixotropic; from 0-40 many roots, from 40-110 few roots; clear boundary to
2R	110+	stony moraine.

Remark:
The given horizon designations were interpreted from the original diagnostic horizon designation by Miehlich (1980). these are respectively: macorg, a3um, 2lit.

Profile: INS 3

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Udic Eutrandept
ICOMAND (1988)	: Thaptic Hapludand
Location	: Pasir Area, Cikopo Selaten, W. Java, Indonesia Latitude: 6°42'36"S; Longitude: 106°54'33"E; Altitude: 900 m
Described by	: Subardja and P. Buurman
Physiography	: Volcanic slope
Slope	: 15%
Parent material	: Intermediate tuff
Vegetation	: Tea
Land use	: Tea estate
Climate	: Köppen: Afa.
Soil climate	: Udic, isothermic, MAR 3344 mm
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ap1	0-44	Dark brown (10YR 3/3, moist), clay; massive fine crumb; many fine and very fine pores; very friable when moist, slightly sticky and slightly plastic when wet; gradual smooth to
Ap2	44-69	dark brown (10YR 3/3, moist), clay; massive fine crumb to weak coarse subangular blocky; many fine and very fine pores; very friable when moist, slightly sticky and slightly plastic when wet; clear smooth to
B2	69-81/85	dark brown to brown (7.5YR 4/4, moist), clay; weak coarse subangular blocky; many fine and very fine pores; friable when moist, slightly sticky and slightly plastic when wet; about 20% rounded rock fragments; clear wavy to
BC	81/85-101	strong brown (7.5YR 4/6, moist), silty loam; weak coarse subangular blocky; many fine and very fine pores; friable when moist, slightly sticky and slightly plastic when wet; clear smooth to
2B2	101-126	strong brown (7.5YR 5/6, moist), silty loam; weak coarse subangular blocky; many fine and very fine pores; friable when moist, slightly sticky and slightly plastic when wet, clear smooth to
3Ah	126-150+	dark brown to brown (7.5YR 4/4, moist), clay; weak coarse subangular blocky; many fine and very fine pores; friable when moist, slightly sticky and slightly plastic when wet.

Profile: INS 18

Classification:	
FAO/Unesco (1974)	: Mollic Andosol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Udic Eutrandept
ICOMAND (1988)	: Thaptic Melanudand
Location	: Central Aceh, N. Sumatra, Indonesia, 5 km WSW of Takengon along road to Tebes Luwes Latitude: 4°36'18"N; Longitude: 96°47'24"E; Altitude: 1395 m
Described by	: P. Buurman
Physiography	: lower volcanic slope of Salak Nama volcano
Position of site	: Southern exposure
Slope	: 2-6%
Parent material	: Andesitic ash
Vegetation	: Coffee
Land use	: Coffee plantation
Climate	: MAT 18.8°C, MAR 1700 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description (all colours for moist soil)

Horizon	Depth (cm)	Description
Ah1	0-30	Black (10YR 2/1, moist) loam; moderate fine subangular blocky; friable, thixotropic; common roots; few coarse and medium, common fine and many very fine pores; gradual wavy boundary to
Ah2	30-37	very dark brown (10YR 2/2 moist) loam; moderate fine angular blocky; friable, thixotropic; few coarse and medium, common fine roots; few coarse, common medium and many fine and very fine pores; clear smooth boundary to
A/B	37-48	dark yellowish brown (10YR 4/4 moist); loam to clay loam; moderate medium-coarse subangular blocky; friable to firm, thixotropic; few roots; few medium and many fine and very fine pores; clear and smooth boundary to
B	48-110	yellowish brown (10YR 5/6 moist) clay loam to silty clay loam, 2-5% stoniness; weak medium to coarse subangular blocky; firm, thixotropic; few roots; few coarse and medium, many fine and very fine pores; clear and smooth boundary to
B/Cg	110-120/130	brownish yellow (10YR 6/8 moist) loam to silt loam, 15-20% stoniness increasing with depth; firm, thixotropic; coarse and medium yellow (7.5YR 6/8) mottles; gradual smooth boundary to
C	130+	andesite, 15-20% saprolite.

Profile: INS 21

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Alfic Hapludand
Location	: Central Aceh, N. Sumatra, Indonesia, Alur Gading, 500 in W of km 56 along road Biruen-Takengon Latitude: 4° 51'55"N; Longitude: 96° 44'05"E; Altitude: 700 m
Described by	: P. Buurman
Physiography	: Rolling landscape
Position of site	: Lower par of volcanic slope, exposure: west
Slope	: 2-6%
Parent material	: Andesitic ash over old ash
Vegetation	: Imperata cylindrica
Land use	: Abandoned, infrequently burned
Climate	: MAT 22° C, MAR 3100 mm
Soil climate	: Udic (to perudic?)
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah1	0-5	Black (5YR 2.5/1 moist); loam; strong very fine crumb; very friable; thixotropic; common fine and medium roots; many pores of all sizes; clear and smooth boundary to
Ah2	5-15	very dark grey (5YR 3/1 moist) loam, moderate coarse subangular blocky; friable thixotropic; common fine and few medium roots; many fine and very fine, few medium and coarse pores; clear and smooth boundary to
Ah3	15-25	very dark grey (5YR 3/1 moist) loam, weak coarse subangular blocky; friable; thixotropic; common fine roots; common fine to very fine, few medium and coarse pores; clear smooth boundary to
AC	25-30/35	brown to dark brown (7.5YR 4/4 moist) sandy loam; weak coarse subangular blocky to structureless, friable; few fine roots; many fine and very fine pores; few Fe and Mn mottles on rock fragments; many partly weathered andesite fragments of ca. 1 cm diameter; gradual smooth boundary to
2AB	30/35-80	dark brown (7.5YR 3/2 moist) clay; strong fine subangular blocky; friable, non-sticky, plastic, thixotropic; many fine and very fine pores; gradual smooth boundary to
2Bw	80-120+	brown (7.5YR 5/4 moist) silty clay loam; moderate fine subangular blocky, very friable, non sticky, plastic, thixotropic, common fine and very fine pores.

Profile: INS 23

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Thaptic Udivitrand
Location	: Central Aceh, N. Sumatra, Indonesia, Timanggajah, 25 m E. of road at km 60 on road Biruen-Takengon Latitude: 4°51'55"N; Longitude: 96°44'05"E; Altitude: 950 m
Described by	: P. Buurman
Physiography	: lower volcanic slope; rolling
Slope	: 2-6%
Parent material	: Andesitic flow on ash layers
Vegetation	: Domestic garden
Land use	: See vegetation
Climate	: MAT ca. 20°C, MAR ca. 2100 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah	0-17	Very dark brown (10YR 2/2 moist); sandy loam to loam; weak fine to medium subangular blocky; friable, thixotropic; many roots of various sites; few medium, common fine and many very fine pores; clear smooth boundary to
A/C	17-31	dark brown (10YR 3/3-3/3 moist); loam to clay loam; weak medium subangular blocky; firm, thixotropic; many fine and very fine roots, common medium and coarse roots; few medium and common fine and very fine pores; clear smooth boundary to
C	31-54	brownish yellow and light grey (10YR 6/6 and 2.5Y 7/2 moist) gravelly sand to loamy sand (tuffaceous gravel and volcanic ash and sand); no structure; loose; few fine roots; common medium and many fine and very fine pores; abrupt smooth boundary to
2A	54-70	dark brown (10YR 3/3 moist) clay loam; firm, strongly thixotropic; moderate medium angular blocky; few fine and medium roots; few medium, common fine and many very fine pores; clear smooth boundary to
2B	70-88	yellowish brown to light yellowish brown (10YR 5/4 to 6/4 moist) clay loam to clay; moderate medium to coarse angular blocky; extremely firm, thixotropic; few medium and coarse roots; few medium, common fine and many very fine pores; abrupt smooth boundary to

2C	88-125/130	brownish yellow and light yellowish brown (10YR 6/8 and 2.5Y 7/3-6/4 moist) gravelly sand to laomy sand (tuffaceous gravel and volcanic ash and sand) no structure; loose; no roots; common coarse and medium pores, many fine and very fine pores; abrupt irregular boundary to
3AB	125/130-155	yellowish brown (10YR 5/6 moist) sandy loam; weak coarse angular blocky; friable, plastic, non-sticky, strongly thixotropic; no roots; many fine and very fine pores.

Profile: INS 24

Classification:

FAO/Unesco (1974)	: Mollic Andosol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Udic Eutrandept
ICOMAND (1988)	: Typic Hapludand
Location	: Ca. 1 km S. of Desa Sebaluh, Kecamatan Pudjon, Kabupaten Malang, E. Java, Indonesia Latitude: 7°51'S; Longitude: 112°30'E; Altitude: 1260 m
Described by	: G.W. van Barneveld and J.L. Tersteeg
Physiography	: Piedmont landform at lower N.E. slopes of Kawi-Butak volcano
Position of site	: Slightly convex plateau
Slope	: 6-13%
Parent material	: Intermediate and basic ash
Vegetation	: Pinus merkusii, infested by Kirinyu shrubs (Eupatorium and Lanatana)
Land use	: Timber plantation
Climate	: MAT 19°C, MAR 2300 mm, evapotransp. 1300 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah	0-11/18	Very dark brown (10YR 2/2) when moist and dark greyish brown (10YR 4/2) when dry; loam; moderate to strong medium and coarse crumb structure; non-sticky; non-plastic; non-thixotropic, friable when moist; very porous; many fine and medium roots; clear and wavy boundary to
AC	11/18-26	dark brown (7.5YR 3/4) when moist and brown (10YR 4/3) when dry; loam; weak medium and coarse granular and subangular blocky structure; non-sticky, non-plastic, non-thixotropic, friable when moist; few small (<0.5 cm) semi-cemented rounded volcanic ash noduels; very porous; many fine roots; abrupt and smooth boundary to

2Bw1	26-47	strong brown (7.5YR 4/6) when moist and brown (10YR 5/3) when dry, faintly mottled with dark grayish brown (10YR 4/2.5) when dry; silty clay loam; moderate medium and coarse irregular angular blocky structure; slightly sticky, slightly plastic, friable when moist; few small (<0.5 cm) semi-cemented rounded volcanic ash nodules; many fine and medium pores; common fine roots; gradual and wavy boundary to
2Bw2	47-78	strong brown (7.5YR 4/6) when moist and yellowish brown (10YR 5/4) when dry, faintly mottled with dark greyish brown (10YR 4/2.5) when dry; silty clay loam; moderate medium irregular angular blocky structure; slightly sticky, slightly plastic, slightly thixotropic, friable when moist; few small (<0.5 cm) semi-cemented rounded volcanic ash nodules; many fine and common medium pores; few fine roots; gradual and smooth boundary to
2Bw3	78-95	strong brown (7.5YR 4/6) when moist and yellowish brown (10YR 5/4) when dry, distinctly mottled with dark grayish brown (10YR 4/2) and brownish yellow (10YR 6/6) when dry; silty clay loam; moderate medium granual and irregular angular blocky structure; slightly sticky, slightly plastic, slightly thixotropic, friable when moist; few small (<0.5 cm) semi-cemented rounded volcanic ash nodules; common fine and medium pores; few fine roots; clear and wavy boundary to
3Ah1	95-107	black (10YR 2/1) when moist and very dark grey (10YR 3/1) when dry, faintly mottled with dark greyish brown (10YR 4/2) when dry: clay; moderate medium subangular and irregular angular blocky structure; sticky, plastic, non-thixotropic, friable when moist; common fine and medium pores; very few fine roots; clear and smooth boundary to
3Ah2	107-138	black (7.5YR 2/0) when moist and very dark grey (7.5YR 3/0) when dry; clay; moderate medium subangular and irregular angular blocky structure; sticky, plastic, non-thixotropic, friable when moist; common fine and medium pores; no roots; gradual and smooth boundary to
3AB	138-150+	very dark gray (10YR 3/1) when moist and dark greyish brown (10YR 4/2) when dry; clay; moderate medium subangular and irregular angular blocky structure; sticky, plastic, non-thixotropic, friable when moist; common fine and medium pores; no roots.

Profile: INS 27

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Dystrandept entic, loamy
ICOMAND (1988)	: Acric Hapludand

Location	: Indonesia, Sumatra, Taput, 12 km W. of Doloksanggul along road to Pusuk Latitude: 2 · 16'N; Longitude: 98 · 40'E; Altitude: 1450 m
Described by	: S. Kauffman and Soedewo
Physiography	: Undulating landscape, low hill
Position of site	: Middle slope
Slope	: 7%
Parent material	: Acidic tuff ("Toba" tuff)
Vegetation	: General: evergreen woodland, perennial "Kemenyan"
Land use	: Low level arable farming
Climate	: Köppen: Af, MAT 18-19C ·, MAR 2040 m
Soil climate	: Udic
Drainage	: Moderately well to well drained

Profile Description

Horizon	Depth (cm)	Description
Ao	8-0	Black (5YR 2.5/1, moist); leaves, decomposed; abrupt wavy boundary to
Ah	0-12	black (10YR 2/1, moist); silt loam; organic matter, moderately decomposed; weakly coherent porous massive; non sticky non plastic very friable weakly smeary; many fine roots throughout and many medium roots throughout; clear wavy boundary to
Bw	12-50	yellowish brown (10YR 5/6, moist); fine weak subangular blocky; slightly sticky slightly plastic firm; many fine random tubular pores; many very fine roots throughout and common fine roots throughout; few coarse weathered and few coarse Toba tuff fragments; clear wavy boundary to
C	50-125	yellow (10YR 7/6, moist); medium loamy sand; strongly coherent porous massive; non sticky non plastic firm; few micro interstitial pores; slightly porous; few very fine roots clear wavy boundary to
2C	125-150	brownish yellow (10YR 6/6, moist); fine loamy sand; strongly coherent massive; non sticky non plastic very firm; nil roots.

Remarks:
- After heavy rain water stagnates on the soil surface in isolated spots.
- The Kemenyan tree (resin collection) has been planted 15 to 20 years ago.
- The thickness of C material and has about 15% of the surface stained by organic matter.
- The C horizon contains thin iron fibres.
- Depending on the thickness of the solum the soil classifies as well as Andic Cambisol (FAO) and Andic Dystropept (ST). Toba tuff originates from an ash flow. It has a sandy texture, the sand consists for larger part of translucent fragments, probably mainly volcanic glass.

Profile: INS 29

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Dystrandept Hydric, clayey
ICOMAND (1988)	: Aquic Hydrandept
Location	: Indonesia, N. Sumatra, Taput, Harian Boho, 2.1 km W. of Tele (west side bridge, to left) Latitude: 2 • 34'N; Longitude: 98 • 37'E; Altitude: 1800 m
Described by	: Kauffman and Soedewo
Physiography	: Plateau
Slope	: 1%
Parent material	: Acidic tuff ("Toba" tuff)
Vegetation	: Evergreen woodland, semi-natural
Land use	: Nearby: low level arable farming
Climate	: Köppen: Af, MAT 15-16 • C, MAR 2440 mm
Soil climate	: Perudic
Drainage	: Moderately well

Profile Description

Horizon	Depth (cm)	Description
Ah	0-16	Black (5YR 2.5/1, moist); leaves, highly decomposed; non sticky non plastic friable; many fine roots throughout and many medium roots throughout; pH (field): 5.0; clear smooth boundary to
BA	16-35	Dark yellowish brown (10YR 4/4, moist); sandy clay loam; fine weak subangular blocky; slightly sticky slightly plastic friable; many fine random tubular pores and many medium random tubular pores; many fine roots throughout and common medium roots throughout; pH (field): 5.5; gradual smooth boundary to
BW	35-79	dark yellowish brown (10YR 4/6, moist); clay loam; fine to medium moderate subangular blocky; slightly sticky slightly plastic friable; broken thin cutans on pedfaces; many fine/medium random slightly sticky slightly plastic friable; broken thin cutans on pedfaces; many fine/medium random tubular pores and few coarse random tubular pores; common fine roots throughout and few medium roots throughout; pH (field): 5.5; abrupt wavy boundary to
Bs	79-90	red (2.5YR 4/8, moist); sandy clay loam; moderately coherent porous massive; non sticky non plastic friable; common very fine random tubular pores and few fine random tubular pores; common fine roots throughout; pH (field): 5.5; abrupt wavy boundary to
Bg?	90-108	weakly coherent porous massive; non sticky non plastic friable; common fine pores and few medium pores; few fine roots throughout; pH (field): 5.0; clear wavy boundary to

C	108-135	brownish yellow (10YR 6/8, moist); loamy sand; weakly coherent porous massive; non sticky non plastic friable; common fine pores and common medium pores; few fine roots throughout; pH (field): 5.0; clear wavy boundary to
Cr	135-160	yellow (10YR 7/6, moist); loamy sand; weakly coherent massive; non sticky non plastic firm; few fine pores; pH (field): 5.0.

Remarks:
- The original forest has been cleared, at present fallow land with abundant ferns. At some distance of site low level arable farming, mainly horticulture.
- All horizons have clearly a low bulk density.
- In the BA horizon the colours change gradually from the colours of the A and the B horizon.
- From 80 to 108 the profile consists of a series of thin horizons which are influenced by redox processes. It has been described as Bs (80-90) and Bg? (90-108) horizons. The Bg? itself can be subdivided in very thin layers: Bg (90-100) 10YR 4/4, clay loam, Bh (100-103) 5YR 2.5/2, loamy sand (buried A horizon?) and Bs (103-108) 2.5YR 4/8, loamy sand.
- The sequence of these thin layers varies locally, its genesis is not clear. Roots are concentrated in coarse channels in the Bg and C horizons.
- The C horizons have a sandy texture, the sand consists mainly of translucent fragments, probably volcanic glass.

Profile: INS 36

Classification:

FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Dystrandept typic, clayey
ICOMAND (1988)	: Acric Hydric Hapludand
Location	: Indonesia, W. Sumatra, Merapi footslope, 4 km NNE of Padang Panjang Latitude: 0°24'S; Longitude: 100°26'E; Altitude: 1050 m
Described by	: Kauffman and Soedewo
Physiography	: Volcano footslope
Position of site	: Lower slope
Slope	: 16%
Parent material	: Basic volcanic ash, sandy
Vegetation	: Wooded fallow land with few crops e.g. banana
Land use	: Nearby: sawah
Climate	: Köppen: Af, MAT 22°C, MAR 3250 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A	0-30	Dark brown (10YR 3/3, moist); silt loam; medium moderate subangular blocky into fine weak subangular blocky; slightly sticky non plastic friable weakly smeary; common fine distinct (2.5R 4/8)

		mottles; many fine pores; many fine roots throughout and common medium roots throughout; abrupt wavy boundary to
C1	30-44	light brownish grey (10YR 6/2, moist); loamy sand; weakly coherent porous massive; non sticky non plastic friable; many very fine/fine pores; many fine roots; abrupt wavy boundary to
B?	44-100	dark brown (10YR 3/3, moist); silt loam; fine weak subangular blocky; slightly sticky non plastic friable; many fine random tubular pores; common fine roots throughout; few fine fresh Lapilli fragments; clear wavy boundary to
C2	100-123	strong brown (7.5YR 5/8, moist); sand; structureless single grain; non sticky non plastic loose; many fine interstitial pores; few fine roots throughout; abrupt wavy boundary to
2A	123-130	black (10YR 2/1, moist); fine weak subangular blocky; slightly sticky non plastic friable; many fine random tubular pores; few fine roots throughout; clear wavy boundary to
2B	130-170	strong brown (7.5YR 4/6, moist); silt loam; medium moderate subangular blocky fine moderate subangular blocky; slightly sticky non plastic friable weakly smeary; many fine/fine/medium/coarse pores; few fine roots throughout; few medium fresh basalt fragments.

Remarks:
- The soil parent material is an ash/lapilli layer of about 1 to 1.5 metre deposited on a man-made terrace.

Profile: EC 3

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol
Soil Taxonomy (1975)	: Dystrandept Andic, loamy, mixed, isomesic
ICOMAND (1988)	: Pachic, Melanudand
Location	: Ecuador, Pinchiucha, Quito, El Corazon volcano Latitude: 0°31'S; Longitude: 78°38'40W; Altitude: 4000 m
Described by	: T. Cook and G. del Posso
Physiography	: Mountainous (El Corazon volcano)
Position of site	: Upper slope
Slope	: 45%, NE facing
Parent material	: Volcanic ash
Vegetation	: Semi-natural shortland grass
Land use	: Paramo grass
Climate	: MAT 11.5°C, MAR 1000 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-26	Black (10YR 2/1, moist); loam; medium weak subangular blocky; slightly sticky slightly plastic very friable weakly smeary; many very fine/fine tubular pores and few medium tubular pores; many very fine roots throughout and many fine roots throughout; diffuse wavy boundary to
A2	26-63	black (10YR 2/1, moist); loam fine to medium weak subangular blocky; slightly sticky slightly plastic friable weakly smeary; many very fine/fine tubular pores; many very fine roots throughout and many fine roots throughout; diffuse wavy boundary to
A3	63-92	black (10YR 2/0, moist); medium weak subangular blocky; slightly sticky slightly plastic friable weakly smeary; many very fine/fine tubular pores; common very fine roots throughout and common fine roots throughout; few medium pumice fragments; abrupt wavy boundary to
2C	92-134	yellowish brown (10YR 5/4, moist); coarse sand, gravelly; structureless single grain; non sticky non plastic loose loose; many very fine/medium interstitial pores; few very fine roots; frequent medium pumice fragments; abrupt wavy boundary to
3Ab	134-182	black (10YR 2/1, moist); loam; moderately coherent porous massive; sticky plastic friable; many very fine/fine tubular pores and common medium tubular pores; few very fine roots.

Remarks:
- EC 03 is comparable to profile Ecuador 8 in Part III: Tour Guide for Ecuador of the Sixth International Soil Classification Workshop (1984).
- There are not sufficient temperature data available at the altitude of the site. When a correction of 6 degrees celsius per 1000 metre is applied on the data of Izobamba meteo station, the average annual temperature is around the limit of 8 degree celsius, hence mesic to frigid. If the frigid temperature regime is rejected the soil will key out as Dystrandept.
- The soil is a true volcanic ash soil except for the bulk density, which is slightly too high. If the bulk density criterion is strictly applied the soil will classify as Andic Humitropept (ST) and as humic Cambisol (FAO).

Profile: EC 9

Classification:	
FAO/Unesco (1974)	: Ochric Andosol
FAO (1988)	: Haplic Andosol
Soil Taxonomy (1975)	: Dystrandept entic, medial, isohyperthermic
ICOMAND (1988)	: Acric Hapludand
Location	: Ecuador, Esmeraldas, Quininde, INIAP Sta. St. Domingo Latitude: 00 · 01'30"N; LongitudeA: 79 · 22'00"W; Altitude: 280 m
Described by	: T. Cook and G. del Posso
Physiography	: Broad low interfluve
Position of site	: Crest
Slope	: 1%
Parent material	: Volcanic ash
Vegetation	: Evergreen forest
Land use	: Forest cleared, now oil palm and pasture
Climate	: MAT 24 · C, MAR 3300 mm
Soil climate	: Udic
Drainage	: Moderately drained (gr.w. table at 200 cm)

Profile Description

Horizon	Depth (cm)	Description
A	0-7	Dark brown (10YR 3/3, moist); coarse weak subangular blocky; non sticky non plastic friable; common very fine/ fine tubular pores; common very fine roots and few fine roots; clear irregular boundary to
Bw1	7-24	dark brown (10YR 4/3, moist); silt loam; medium weak subangular blocky; slightly sticky slightly plastic very friable; many very fine/fine tubular pores and many very fine interstitial pores; few very fine roots and few fine roots; gradual wavy boundary to
Bw2	24-56	dark brown (10YR 4/3, moist); silt loam; coarse weak angular blocky into medium weak subangular blocky; non sticky non plastic friable; common very fine/fine tubular pores; few very fine roots and few fine roots; gradual wavy boundary to
2Ab	56-94	very dark greyish brown (10YR 3/2, moist); loam; coarse weak angular blocky into medium weak subangular blocky; non sticky non plastic friable; common very fine/fine tubular pores and many very fine interstitial pores; few very fine roots; gradual wavy boundary to
2C	94-119	dark brown (10YR 4/3, moist); loam; coarse weak angular blocky into medium weak subangular blocky; slightly sticky slightly plastic friable; common very fine/fine tubular pores and many very fine interstitial pores; few very fine roots; clear wavy boundary to
2Cg	119-130	grey to greyish brown (10YR 5/1.5, moist); fine sandy loam; weakly coherent porous massive; non sticky non plastic friable; common fine

		distinct (10YR 4/4) and common medium prominent (2.5Y 4/2) mottles; common very fine tubular pores and many very fine interstitial pores; few very fine roots; abrupt irregular boundary to
3Ab	130-145	very dark greyish brown (10YR 3/2, moist); silt loam; weakly coherent porous massive; non sticky non plastic friable; many very fine tubular pores and many very fine interstitial pores; few very fine roots.

Remarks:
- EC 9 is comparable to profile Ecuador No. 5 in Part III: Tour guide for Ecuador of the Sixth International Soil Classification Workshop (1984).
- Down to a depth of 110 cm medium and coarse decayed roots are present.
- The A horizon includes also the 10YR 2/1 colour. About 1% fragments of brick and artifacts are present in the first half metre.
- Twenty years ago the area was frequently flooded by the rio Blanco (and rio Quininde), now the area is protected against flooding.

GROUP II

Profile: EAK 2

Classification:	
FAO/Unesco (1974)	: Mollic Andosol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Cumulic Hapludoll
ICOMAND (1988)	: Hydric Thaptic Fulvudand
Location	: Kiambu District, Excursion site 1, Kenya Soil Survey Staff (1977) Latitude: 9898.4 N (local); Longitude: 234.0 E (local); Altitude: 2550 m
Physiography	: Dissected upland
Slope	: 4%
Parent material	: Peralkaline trachytic ash
Vegetation	: Mixed bamboo forest; at spot cypress and pine forest
Climate	: Cool humid, MAT 12-14 °C, MAR 1000-1600 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-17	Black (10YR 4/4 dry, 2.5YR 2.5/1 moist); silt loam moderate, medium granular structure; soft when dry, very friable when moist, non sticky and non plastic when wet; few, very fine pores; many fine roots; clear and smooth transition to
AB	17-40	black (10YR 4/2 dry, 10YR 2.5/1 moist); silt loam; porous massive to weak subangular blocky structure; soft when dry, very friable when moist, non sticky and non plastic when wet; common, very fine pores; common fine and few medium roots; clear and smooth transition to
B1	41-49	brownish grey (10YR 6/2 dry, 10YR 4/2 moist) loam; massive to weak columnar structure; slightly hard when dry, very friable when moist; non sticky and non plastic when wet; few medium roots; few medium pores, gradual and smooth transition to
2A1	49-75	black (7.5YR 3/2 dry, 5YR 2/1 moist); silty clay loam; moderate, fine and medium subangular blocky structure; slightly hard when dry, very friable when moist, non sticky and non plastic when wet; common very fine and fine pores; few medium roots; clear and smooth transition to
2B1	75-105	dark brown (7.5YR 4/4 dry, 7.5YR 3/2 moist); silty clay loam; porous massive to weak subangular blocky structure; soft when dry, very friable when moist, non sticky and non plastic when wet; common very fine and fine pores; few fine and medium roots; gradual and smooth transition to
2B2	105-106+	dark reddish brown (7.5YR 4/4 dry, 5YR 4/3 moist); silty clay loam, moderate, medium, subangular blocky to moderate, fine angular

blocky structure; slightly hard when dry, friable when moist, non sticky and non plastic when wet; few, thin clay cutans, common very fine and fine pores; few roots.

Profile: EAK 4

Classification:	
FAO/Unesco (1974)	: Mollic Andosol or Andic Regosol
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Mollic Vitrandept
ICOMAND (1988)	: no Andisol
Location	: Near Suswa, Kenya, along Rd. B3 to Suswa and Narok, 5 km past Longonot Satellite Station Latitude: 9886.7N (local); Longitude: 216.9E (local); Altitude: 2020 m
Physiography	: Plain, gently undulating
Slope	: Almost level
Parent material	: Recent volcanic ash (trachytic?)
Vegetation	: Grasses, herbs and thornbushes
Land use	: Extensive grazing
Climate	: MAT 18-20 °C; MAR 450-900 mm
Soil climate	: Ustic
Drainage	: Somewhat excessively drained

Profile Description

Horizon	Depth (cm)	Description
Ah	0-35	Very dark greyish brown (2.5YR 3/2) moist, and dark greyish brown (2.5Y 4/2) dry, the lowest 2-5 cm pumiceous gravel, sandy loam; structureless to weak subangular blocky; non-sticky, non-plastic, very friable moist, soft dry; somewhat stratified at places; many fine to very fine pores, many fine to very fine roots, especially in the upper 10 cm; abrupt wavy boundary to
2C	35-110	very dark greyish brown (2.5YR 3/2) in upper part to very dark grey (2.5YR 3/0) in lower part moist, sandy loam; porous massive; non-sticky, non-plastic, very firm moist, hard dry; the lowest 20 cm with small volcanic glass fragments; few gravel throughout; upper part stratified; very porous throughout; very few very fine roots, concentrated in cracks and above the layer with glass; abrupt wavy boundary to
3C	110-120	gravel layer of pumice; abrupt wavy boundary to
4Ah	120-145+	dark brown (7.5YR 4/4) moist, sandy loam; moderate medium crumb, common very fine and fine pores; many very fine and fine roots (consistence not recorded).

Profile: EAK 35

Classification:	
FAO/Unesco (1974)	: Mollic Andosol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Mollic Vitrandept
ICOMAND (1988)	: Calcic Haplustand
Location	: 3 km W. of Narok town along road to Masai Maru Latitude: 1°07'S; Longitude: 35°52'E; Altitude: 1950 m
Described by	: Kenya Soil Survey (Observ. 146/2-4)
Physiography	: Flat to very gently undulating volcanic plain
Slope	: 1-3%
Parent material	: Volcanic ash (peralkaline trachytic?)
Vegetation	: Short grass with bushes
Climate	: MAT 16-18°C, MAR 450-1100 mm
Soil climate	: Ustic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-20	Dark brown (7.5YR 3/2 moist), clay loam; massive, falling apart to weak very fine to fine subangular blocky structure; friable when moist, sticky and plastic when wet; slightly calcareous, clear smooth boundary to
B21	20-60	dark brown (7.5YR 3/2 moist) sandy clay; massive falling apart to weak very fine crumby structure; friable when moist, sticky and plastic when wet; slightly calcareous; diffuse smooth boundary to
2B22	60-90	dark brown (7.5YR 3/2 moist), clay loam; massive falling apart to weak fine to medium subangular blocky structure; firm when moist, sticky and plastic when wet; moderately calcareous, diffuse smooth boundary to
2B3	90-145	horizon composed of concretionary mass of weathering tuff, calcareous to
2C	145-170	horizon composed of weathering tuff which feels loose when moist and gritty when wet as if containing sand grains.

Profile: EAK 36

Classification:	
FAO/Unesco (1974)	: Mollic Andosol, sodic phase
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Mollic Vitrandept
ICOMAND (1988)	: Vitric Haploxerand

Location	: Chyulu Range, Kajiado District, just S.E. of El Mau Hill Latitude: 2° 31'S; Longitude: 37° 42'E; Altitude: 1170 m
Described by	: Kenya Soil Survey (observ. 182/1-44)
Physiography	: Very gently undulating plain
Slope	: 1-2%
Parent material	: Recent volcanic ash
Vegetation	: Grassland
Land use	: Semi-nomadic grazing
Climate	: MAT ca. 22°, MAR 500-750 mm
Soil climate	: Xeric
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-15	Black (10YR 4/2.5 dry, 10YR 2/1.5 moist); loam; weakly coherent porous massive structure; slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; many, very fine and fine pores; many, fine roots; clear and smooth boundary to
A3	15-28	very dark brown (10YR 3.5/3 dry, 10YR 2/2 moist); sandy loam, very weakly coherent porous massive structure; soft to loose when dry, very friable to loose when moist, non-sticky and non-plastic when wet, many, very fine and fine pores; many to common, fine roots; gradual and smooth boundary to
B1	28-40	very dark greyish brown (10YR 5/4 dry, 10YR 3/2 moist), sandy clay loam; weakly coherent porous massive to loose granular structure; soft to loose when dry, very friable to loose when moist, non-sticky and non-plastic when wet; many, very fine and fine pores; common, fine roots; gradual and smooth boundary to
B2	40-60	very dark greyish brown (10YR 5/4 dry, 10YR 3/2 moist), sandy clay loam; weakly coherent porous massive to very weak, fine, subangular blocky structure; soft when dry, very friable to loose when moist, non-sticky and non-plastic when wet; many very fine and fine pores; common, fine roots; clear and smooth boundary to
B3ca	60-70	dark brown (10YR 5.5/4 dry, 10YR 3/3 moist); gravelly sandy clay loam; weakly coherent porous massive to very weak, fine, subangular blocky structure; soft to slightly hard when dry, very friable when moist, non-sticky and non-plastic when wet; many, very fine and fine pores; strongly calcareous; pseudomycelium of calcium carbonate; common, fine roots; abrupt and smooth boundary to

C1ca	70-90	dark yellowish brown (10YR 7/4 dry, 10YR 4/4 moist); sandy clay laom; strongly coherent porous massive structure; (fragipan); hard when dry, "brittle" when moist and wet; many, very fine and fine pores; strongly calcareous; pseudomycelium of calcium carbonate; very few, fine roots; abrupt and wavy boundary to
C2ca,x	90-180	dark yellowish brown (10YR 7/4 dry, 10YR 4/4 moist) and various other colours; stratified, gravelly, sandy clay loam;, porous massive structure, in places fragipan; hard or loose when dry, "brittle" or loose when moist and wet; many, very fine and fine pores; strongly calcareous; moderately sodic; pseudomycelium of calcium carbonate; very few, fine roots.

Profile: EAK 37

Classification:	
FAO/Unesco (1974)	: Mollic Andosol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Mollic Vitrandept
ICOMAND (1988)	: Pachic Melanudand or Pachic Haplustand
Location	: 8 km N. of Nairagie Engare along road to Mau-Narok (Narok District) Latitude: 0°59'S; Longitude: 36°08'E; Altitude: 2640 m.
Described by	: Kenya Soil Survey (observ. no. 133/3/188)
Physiography	: Footslope ridges
Position of site	: Upper side slope
Slope	: 20%
Parent material	: Peralkaline trachytic volcanic ash
Land use	: Crop land: maize/potatoes/beans
Climate	: MAT 12-14°C, MAR 800-1300 mm
Soil climate	: Udic/ustic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ap	0-30	Black (10YR 2/1 moist); clay loam; very fine to fine, moderate crumb; very friable when moist, plastic and sticky when wet; many very fine, fine and medium roots; many fine and medium pores; gradual smooth boundary to
A12/A13	30-120	black to very dark brown (10YR 2/1.5 moist); clay loam; fine, medium, coarse moderate subangular blocky; very friable when moist, plastic and sticky when wet; common very fine and fine roots; few medium roots; many fine and medium pores; gradual smooth boundary to

A14	120-150+	very dark brown (10YR 2/2 moist); clay loam; medium and coarse moderate subangular blocky; very friable when moist, plastic and sticky when wet; few very fine and fine roots; many fine and medium pores.

Profile: Tanzania Mukoma-1

Classification:

FAO/Unesco (1974)	: Mollic Solonetz
Soil Taxonomy (1975)	: Typic Natrustoll
Location	: Mukoma Hill Latitude: 2°29'S; Longitude: 34°45'E; Altitude: 1550 m.
Described by	: Tj. Jager (1982, his profile B1)
Physiography	: Upper pediment
Slope	: 4%
Parent material	: Granitic rocks and volcanic (trachytic) deposits
Vegetation	: Themeda trianda, Panicum coloratum, Eustachus paspaloïdes, Acacia tortilis, Balanites egyptiaca
Climate	: MAT ca. 21°C, MAR ca. 700 mm
Soil climate	: Ustic, isohyperthermic (mean ann. soil temp. ca. 25°C)
Drainage	: Moderately well drained
Moistness	: Moist

Profile Description

Horizon	Depth (cm)	Description
A1	0-15	Very dark brown (10YR 2.5/2 when moist) sandy loam; weak fine subangular blocky; hard, very friable, slightly sticky and slithly plastic; many fine and few medium biopores; many small and medium roots; much coarse quartz sand; abrupt and smooth boundary to
B21t	15-30	very dark greyish brown (10YR 3/2 when moist) clay; moderately weak very coarse prismatic, consisting of moderately strong medium angular blocky elements; friable, slightly sticky and plastic; common fine and few medium biopores; many small and medium roots; common coarse quartz sand; many continuous clay and pressure cutans; effervescent carbonate reaction of the soil material starting at 22 cm; clear and smooth boundary to
B22t	30-45	very dark grey (10YR 3/1 when moist) clay; moderate medium angular blocky; very friable, slightly sticky and slightly plastic; common fine and few medium biopores; few small roots; much coarse quartz sand; common small distinct white carbonate powder spots; effervescent carbonate reaction of the soil material; clear and smooth boundary to
B31	45-60	dark grey (10YR 3.5/1 when moist) clay; moderately weak fine subangular blocky; very friable, slightly sticky and slightly plastic;

		common fine and few medium biopores; few small roots; much coarse quartz sand; common small distinct white carbonate powder spots; effervescent carbonate reaction of the soil material; clear and undulating boundary to
B32	60-90	reddish dark brown (5YR 3/3, 10YR 3/2 (20%) and 7.5YR 5/6 (20% when moist) clay-loam; moderately weak fine angular blocky; very friable, slightly sticky and slithly plastic; common fine and medium biopores; few small roots; few coarse quartz sand; many large prominent white hard carbonate concretions; effervescent carbonate reaction of the material; gradual and smooth boundary to
B33	90-120	yellowish red, black and brown (5YR 4/6, 10YR 2/1 (15%) and 10YR 3/4 (15%) when moist) clay-loam; moderately weak fine angular blocky; friable, slightly sticky and slightly plastic; many fine and common medium biopores; few small roots; few coarse quartz sand; few carbonate mycelium; few small to large prominent white hard carbonate concretions; many medium distinct soft Fe-concretions 5YR 3/2; effervescent carbonate reaction of the soil material; gradual and smooth boundary to
B34	ca. 120-150	reddish brown, dark yellowish brown (5YR 4/4 and 10YR 3/4 (10%) when moist) silt loam; moderately weak fine angular blocky; friable, slightly sticky and slightly plastic; many fine and common medium biopores; no roots; few coarse quartz sand; few small to large distinct white hard carbonate concretions; many medium distinct soft Fe-concretions 5YR 3/2; moderate carbonate reaction of the soil material.

Root distribution: Many small and medium roots to 30 cm.
Biological activity: Termite activity below 90 cm.

Profile: Tanzania SEK-NE

Classification:
FAO/Unesco (1974) : Mollic Andosol
Soil Taxonomy (1975) : Eutrandeptic Cumulic Haplustoll
Location : 2.5 km N.E. of the "S.E. kopjes" in Lemuta area, Serengeti plain
Latitude: 2°47'S; Longitude: 35°12'E; Altitude: 1600 m.
Described by : H.A. de Wit (1978, his profile no. 45)
Physiography/Position of site : Valley bottom
Slope : Level
Parent material : Trachytic (nephelinite) ash (originally with Na_2CO_3)
Vegetation : Grass
Land use : National Park for over 10 years
Climate : MAT ca. 21.5°C, MAR 400-700 mm with dry and wet season
Soil climate : Ustic, isohyperthermic
Drainage : Well drained

Salinity : Non-saline 0-170 cm; slightly saline 170-190 cm; moderately saline 190+ cm

Profile Description

Horizon	Depth (cm)	Description
A11	0-16	Dark greyish brown (10YR 4.5/2.5 when dry, 10YR 3/2 when moist) silty clay loam; moderate medium and coarse subangular blocky often attached to roots, locally medium and thick platy near the surface, thin surface crust always present; soft to slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; few large, common meso and fine biopores, many micropores; common medium, many fine roots; few shells or shell fragments; lower boundary clear and wavy to
A12	16-40	dark greyish brown (10YR 4-4.5/2 when dry, 10YR 3/1 when moist) (silty) clay loam; almost structureless, massive, falling apart into moderately weak medium and coarse clods with much unaggregated material, soft when dry, very friable when moist, alsmot non-sticky and slightly plastic when wet; common fine biopores, many micropores; few old dung beetle balls with weakly cemented walls; lower boundary gradual and smooth to
A13	40-70	dark greyish brown (10YR 4-4.5/2 when dry, 10YR 2.5-3/2 when moist) calcareous silty clay loma; moderately weak very coarse prismatic, falling apart into moderate very coarse subangular clods; soft to slightly hard when dry, very friable when moist; non-sticky (above) to slightly sticky (below) and slightly plastic; few large and meso, common fine biopores, many micropores; common fine roots; common fresh and old dung beetle balls, few shell fragments; few white coatings, non-calcareous, on inner walls of biopores, becoming more common below; lower boundary gradual and smooth to
A14	70-110	brown (10YR 4.5/2.5 when dry, 10YR 3/2.5 when moist) silty clay loam; moderately weak very coarse prismatic, localy slightly tilted, especially near the lower boundary; very weakly cemented fine clods, increasing in number downwards to
C	110-170	brown (10YR 5/3 when dry, 10YR 3/3 when moist) calcareous silty clay loam; weak very coarse prismatic, elements tending to be slightly tilted below, falling apart in few angular clods and little unaggregated material; slightly hard when dry, (very) friable when moist, sticky and plastic when wet, stickiness and plasticity increasing downwards; few large and few meso biopores, common fine biopores, many macropores; common fine roots but less frequent than in overlying horizon, locally accumulating on the peds surfaces; common fine and medium non-calcareous white veins; common fine weakly cemented soil aggregates, becoming more frequent towards the bottom of the pit.

By auger:

170-190	Soil material becomes more yellow, 10YR 5.5-6/3 when dry, 10YR 3.5/3 when moist; many fine, weakly cemented soil aggregates, concretion-like; slightly sticky and plastic when wet, slightly saline.
190-210	10YR 6/3.5 when dry, 10YR 4/3 when moist, slightly sticky and slightly plastic when wet, moderately saline.
210-250	10YR 6/3.5-4 when dry, 10YR 4/4 when moist; slightly sticky and non to slightly plastic when wet; moderately saline; many fine weakly cemented soil aggregates.

Profile: Tanzania Rhino-7

Classification:

FAO/Unesco (1974)	: Luvic Chernozem
Soil Taxonomy (1975)	: Typic Argiustoll
Location	: Rhino-Mbali Pali Area; Serengeti National Park Latitude: 1°45'S; Longitude: 34°57'E; Altitude 1655 m
Described by	: Tj. Jager (1982, his profile B51)
Physiography	: Ridge slope
Slope	: 4%
Parent material	: Gneissic rocks and volcanic (trachytic) deposits
Vegetation	: Themeda triandra
Land use	: National Park
Climate	: Dry sub-humid, with 3 months dry period. MAT ca. 21°C, MAR ca. 1000 mm
Soil climate	: Ustic, isohyperthermic
Drainage	: Imperfectly drained
Moistness	: Moist throughout profile
Biological activity	: *Termite activity below 75 cm*

Profile Description

Horizon	Depth (cm)	Description
A1	0-10	Black (10YR 2/1, moist) sandy loam; weak fine to medium subangular blocky; very friable, slightly sticky and slightly plastic; common fine and medium biopores; many small and medium roots; much coarse quartz sand; clear and smooth boundary to
B22t	10-55	very dark grey (10YR 3/1, moist) sandy clay-loam; very coarse strong prismatic, consisting of strong coarse angular blocky elements; friable, sticky and very plastic; few fine and medium biopores, many small and common medium roots; common coarse quartz sand; prisms have coatings of white sand; many continuous clay and pressure cutans; clear and smooth boundary to

B23tca	55-75	very dark grey (10YR 3/1.5, moist) sandy clay-loam; moderate medium angular blocky; friable, sticky and plastic; few fine and medium biopores; common medium and small roots; common coarse quartz sand; common continuous clay and pressure cutans; few distinct white carbonate mycelium; clear carbonate reaction of the soil material; gradual and smooth boundary to
B31ca	75-100	dark to very dark greyish brown (10YR 3.5/2, moist) sandy clay; moderate medium angular blocky; friable, sticky and plastic; common fine and few medium biopores; very few small and medium roots; common coarse quartz sand; few patchy cly and/or pressure cutans; few distinct white carbonate mycelium; few small distinct white hard carbonate concretions; clear carbonate reaction of the soil material; few termite channels filled with fungus; clear and smooth boundary to
B32ca	100-150	brown (10YR 5/3, moist) clay; weak medium angular blocky; friable, very sticky and plastic; few fine and medium distinct white hard carbonate concretions; effervescent carbonate reaction of the soil material; common termite channels filled with fungus and darker topsoil (10YR 2/1).
	Below 150	Yellowish brown Fe mottles (10YR 5/8) and black mottles as well as concretions appear; also somewhat rounded small quartz gravel is present and coarse sand content increase.

Remark: This pit is located on a termite mound line.

Profile: Tanzania Dutwa-1

Classification:	
FAO/Unesco (1974)	: Mollic Solonetz
Soil Taxonomy (1975)	: Typic Natriustoll
Location	: Dutwa Plain, Kirawira area, Serengeti National Park Latitude: 2°17'S; Longitude: 34°11'E; Altitude: 1220 m
Described by	: Tj. Jager (1982, his profile B27)
Physiography	: Plain
Slope	: 1%
Parent material	: Granitic rocks and volcanic (trachytic) deposits
Vegetation	: Chrysochloa orientalis, Microchloa kunthii, Balanites egyptiaca
Land use	: National Park
Climate	: Semi arid, MAT ca. 22°C, MAR 850 mm
Soil climate	: Ustic, isohyperthermic
Drainage	: Imperfectly drained
Moisture	: Dry
Biological activity	: No evidence

Profile Description

Horizon	Depth (cm)	Description
A1	0-21	Very dark grey (10YR 3/1 when moist, 10YR 5/1 when dry) sandy loam; weak fine subangular blocky; slightly hard, very friable, slightly sticky and non plastic; few fine and medium biopores; common small roots; much coarse quartz sand; clear and smooth boundary to
B21ca	21-40	dark brown (10YR 3/3 when moist, 10YR 4/3 when dry) sandy clay; moderate fine to medium subangular blocky; slightly hard, very friable, sticky and plastic; few fine and medium biopores; common small roots; much coarse quartz sand; very few small faint white hard carbonate concretions; clear and smooth boundary to
B22ca	40-62	brown (10YR 4/3 when moist, 10YR 4.5/3 when dry) clay; moderately weak very fine subangular blocky; slightly hard, very friable, sticky and slightly plastic; common fine, few medium and few large biopores; few small roots; much coarse quartz sand; common small distinct white hard carbonate concretions; clear and smooth boundary to
B31ca	62-80	brown (10YR 5/3 when moist, 10YR 6/3 when dry) clay; moderately weak very fine to fine subangular blocky; slightly hard, very friable, sticky and slightly plastic; many fine and common medium biopores; very few small roots; common coarse quartz sand; few small faint white hard carbonate concretions; clear and smooth boundary to
B32ca	80-100	pale brown (10YR 6/3 when moist and dry) clay; moderately weak very fine to fine subangular blocky; slightly hard, very friable, sticky and slightly plastic; common fine and medium biopores; much coarse quartz sand and both angular and well rounded gravel to 6 cm; few small faint white hard carbonate concretions.

Profile: Tanzania NaNo-S

Classification:	
FAO/Unesco (1974)	: Pellic Vertisol
Soil Taxonomy (1975)	: Typic Pellustert
Location	: Girtasho area, Serengeti Plain, About 7.5 km NW of Naabi Hill, 1.75 km W of main road Latitude: 2° 45'58"S; Longitude: 34° 57'24"E; Altitude: 1645 m
Described by	: H.A. de Wit (1978, his profile no. 47)
Physiography	: Valley bottom
Slope	: Level
Parent material	: Clayey deposit of volcanic ash
Vegetation	: Grasses and herbs
Land use	: National Park
Climate	: Semi-arid, MAT ca. 21° C, MAR 600-700 mm
Soil climate	: Ustic, hyperthermic

Drainage	: Well drained, in wet season probably somewhat poorly drained
Moisture	: Moist throughout
Groundwater	: Very deep or absent
Salinity	: Non-saline throughout

Profile Description

Horizon	Depth (cm)	Description
A11	0-13	Very dark grey (10YR 4/1.5 when dry, 10YR 3/1 when moist, 2/1 when wet) silty clay; moderately weak compound very coarse blocky structure, falling apart into strong very fine and fine (sub)angular blocky when drying out, often attached to roots, with a medium and thick platy surface crust, locally some coarse blocky elements just below the surface; hard when dry, friable when moist, sticky and plastic when wet; few large, common meso bio-pores, common fine biopores, many micropores (in and between the very fine aggregates); few large and medium roots, common to many fine roots; few fine holes with plastered walls; common larvae; many fine cracks between the fine aggregates; lower boundary clear and slightly wavy to
A12	13-40	very dark grey (10YR 3/1 when dry, 10YR 2/1 when moist) clay; moderate coarse and very coarse prismatic falling apart into strong (above) to moderate (below) medium to very fine angular blocky (almost granular) aggregates; hard when dry, firm when moist, plastic and sticky when wet; few large, common fine, few to common meso biopores, many(?) micropores; few large and medium roots, common fine roots, becoming less common towards lower boundary; common recent medium dungbeetle balls with brown walls peeling off; few cracks up to 5 mm wide near lower boundary; common darker coloured coatings on aggregate surfaces; lower boundary gradual and smooth to
A13	40-90	black to very dark grey (10YR 2-2.5/1 when dry, 10YR 2/1 when wet) clay; (moderately) strong coarse and very coarse prismatic, rather massive, which can be broken into coarse prismatic and sharply edged angular clods with much very fine blocky above and little very fine blocky and granular material below; very hard when dry, very firm when moist, very sticky and very plastic when wet, especially below; few meso, few to common (above) fine biopores, common(?) micropores; few medium roots, common (above) to few (below) fine roots, often along the surfaces of the structural elements; common darker coloured coatings, especially on faces of smaller aggregates; locally pockets in which very fine sandgrains are common; a single krotovina-like element, running vertically, more brownish than the surrounding material (10YR 3-3.5/2 when dry) about 3 inches in diameter was found; few fine rounded lime concretions at 67 cm; between the structural elements cracks up to 15 mm wide were recorded; lower boundary gradual and wavy to

A14	90-114	very dark grey to greyish brown (10YR 3/1-2 when dry, 10YR 2/1-2 when moist) clay; moderately strong very coarse prismatic which can be broken into sharply edged coarse and very coarse angular elements; very hard when dry, very firm when moist, very sticky and very plastic when wet; few meso and fine biopores, common(?) micropores; few medium and few fine roots; common medium and coarse slickensides (intersecting) locally common fine sandgrains; few fine powdery lime veins and pockets; common lighter coloured parts (mottles?), 10YR 3/2 when dry; few above, below common fine and medium rounded lime concretions, 10YR 7/2 when dry, indurated; lower boundary clear, almost abrupt and smooth to
C	114-130	(bottom of pit) greyish brown to brown (10YR 5/2.5-3 when dry, 10YR 3.5-2.5 when moist) calcareous silty clay loam; almost structureless; firm when moist above, more loose below, sticky and plastic when wet; many (above) to abundant indurated lime concretions, fine and medium above, rather rounded, medium and coarse, irregularly shaped below with sandgrains included; concretions form over 50% of the volume.

Remarks:
- The very fine aggregates in the 0-13 and 13-40 horisons proved to be very stable during infiltration experiments, whereas the hard prisms at lower depth tended to turn into soft mud (much swelling too) when wetted.
- The 40-90 cm horison might be subdivided into an upper (40-70 cm) and a lower part (70-90 cm).

Profile: Tenerife, Birmagen

Classification:

FAO/Unesco (1974)	: Chromic Cambisol
Soil Taxonomy (1975)	: Andic Ustochrept
Local	: Suelo pardo eutrofico rubificado
Location	: Llano del Moro, Tenerife, Canary Islands, Spain Ref.: Fernandez Caldas et al. (1982) Latitude: 28°26'30"N; Longitude: 16°21'08"W; Altitude: 750 m.
Physiography	: Footslope of recent volcano. S. facing, strong insolation
Parent material	: Basaltic ash and lapilli
Land use	: Cultivated terrace
Climate	: Intergrade between mediterranean and subtropical with two contrasting seasons
Soil climate	: Ustic

Profile Description

Horizon	Depth (cm)	Description
A11	0-10	Dark reddish brown (5YR 3/4) clay loam rich in organic matter; fine and medium granular structure, very friable; many macro-pores; many fine roots; irregular boundary to
A12	10-35	reddish brown (5YR 4/4) clay loam with fine sand of weatherable minerals and some organic matter; structure more coherent and larger elements subangular blocky; less friable and less porous; many roots; clear boundary to
(B)	35-85	brown-red (5YR 4/7) clay loam with weatherable minerals; medium blocky with strong cohesion, deep brown coatings; lower porosity; fewer roots,
(B)C	85-110	brown clay loam with many reddish spots of altered lapilli (darker inside); very weakly developed blocky structure; lower porosity; few roots,
C1g	110-140	light brown gravel and clay loam with greenish mottles and rubified fine lapilli; massive structure, plastic; weakly permeable; moist and sticky; no roots,
C2R	140-160	dark grey lapilli, little altered, cemented by white clay (halloysite).

Remark: The NaF-test is negative throughout the profile.

Profile: Vanuatu (Aoba Isl.) ORSTOM 245

Classification:
FAO/Unesco (1974) : Mollic Andosol
Soil Taxonomy (1975) : Udic Eutrandept
Location : Vanuatu-Aoba Island, near Lolopuepue and Lolosori
Latitude: 15°18'S; Longitude: 167°54'E; Altitude: ca. 190 m.
Described by : P. Quantin (ORSTOM, France)
Physiography : Lava flow
Position of site : N.E., low slope of lava flow near the coast; transition to leeward
Slope : weak, 5-10%
Parent material : ca. 500-1500 years old, ashes and cinders deposits of basaltic composition over basaltic lavas
Vegetation : Rain forest
Land use : Coconut plantation
Climate : Wet tropical, transition to with a very short dry season (ca. 2 months); MAT ca. 26°C, MAR ca. 2800 mm/y.
Soil climate : Udic, isohyperthermic
Drainage : Well drained, very rapid permeability

Profile Description

Horizon	Depth (cm)	Description
A1	0-5	Very dark reddish brown (5YR 2/1.5); sandy loam, very humiferous; medium to coarse sized granular structure, friable; very permeable, very abundant fine roots, to
A2	5 to 15-20	dark reddish brown (5YR 2/2); sandy loam, very humiferous, fine to medium sized crumb structure; very friable; very porous and permeable; low bulk density; abundant fine roots, to
BA	20-50	dark reddish brown (5YR 3/2); sandy clay loam, humiferous; fine crumb structure; very friable; very porous and permeable; low bulk density; fairly abundant fine roots, to
BwC	50-110	dark brown (7.5YR 3/2) with fine reddish mottles of weathered cinders; sandy loam and some gravels of cinders; slightly humiferous; fine to medium crumb structure; very friable; very porous and permeable; low bulk density; more scarce roots, to
2C	110-≥130	reddish brown weathered cinders; particular; friable; very permeable; scarce roots.

Remarks:
- Reaction to the FIELDES (NaF) test: Null or very weak in the top soil, weak in depth.
- Mineralogy of <2 μm fraction:
  A: mostly allophane; traces of spherical halloysite and of smectite-vermiculite clay mineral; ferrihydrite and few opal.
  BwC: mostly allophane; few but more obvious spherical halloysite; ferrihydrite; traces of 14 Å clay minerals.
- Mineralogy of parent material: ankaramite-basalt, very rich in Mg and Fe; with labradorite and augite, few olivine.

Profile: Vanuatu, Aoba Isl., ORSTOM no. 247

Classification:	
FAO/Unesco (1974)	: Vitric Andosol, intergrade to Mollic Andosol
Soil Taxonomy (1975)	: Mollic Vitrandept
Location	: Vanuatu, Aoba Island, near Ambore Latitude: 15°22'30"S; Longitude: 167°44'E; Altitude: 30 m.
Described by	: P. Quantin
Physiography	: Lava flows
Position of site	: W. Coast; lower slope of lava flow, near the coast; leeward
Slope	: Weak, 5-10%
Parent material	: Basaltic ashes and cinders beds over basaltic lava flow*
Vegetation	: Rain forest
Land use	: Coconut plantation
Climate	: Wet tropical with a short dry season (ca. 3 months), of leeward type, MAR ca. 2500 mm, MAT 26-27°C

Soil climate : Ustic, isohyperthermic
Drainage : Well drained, very rapid permeability

*the ash deposits are ca. 500 to 1500 years old from the topsoil to the buried soil at depth

Profile Description

Horizon	Depth (cm)	Description
A	15-20	Very dark brown, almost black (10YR 3/1.5) loam, humiferous; medium to fine sized crumb structure; fairly strong cohesion; very porous and permeable; very abundant fine roots,
BA	20-50	dark brown (10YR 4/2) sandy loam, slightly humiferous; very fine crumb structure; very fraible like flour; very porous and permeable, almost dry; low bulk density; moderately abundant roots,
Bw	50-60	dark brown (10YR 4/3) loamy sand, slightly humiferous; very permeable, dry; low bulk density; rather few roots,
C	60-90	dark grey (10YR 4/1); sand of weathered ash-sand cinders; very permeable and dry; very few roots,
2BwA	90-135	dark brown (10YR 4/2) loamy sand, slightly humiferous; finely crumb; very friable; very permeable and dry; scarce roots,
3ABw	135-145	dark brown (10YR 4/3) loamy sand and humiferous; finely crumb; moderately coherent; friable; very porous and permeable, but lightly moist; few roots,
3BwC	145-160	dark brown (10YR 4/3.5) loamy sand, slightly humiferous, finely crumb; friable; very porous and permeable, but lightly moist; few roots.

Remarks:
- We note a weak reaction to the Fields (NaF) test in the whole soil profile;
- The <2 μm fraction contains hisingerite-allophane and ferriferous (badly crystalline) beidellite, and some ferrihydrite and traces of opal;
- the parent material is a basalt very rich in Mg en Fe.

Profile: Vanuatu (Aoba Isl.) ORSTOM 253

Classification:
FAO/Unesco (1974) : Mollic Andosol
Soil Taxonomy (1975) : Udic Eutrandept intergrade to Andic Eutropept
Location : Vanuatu-Aoba Island, Natarimbow near Red Cliff
Latitude: 15°28'S; Longitude: 167°49'E; Altitude: ca. 150 m.
Described by : P. Quantin

Physiography	: Rolling slope of shield volcano; ancient surface superficially dissected by erosion; rejuvenated by ash and cinder deposits
Position of site	: South, lower slope windward facing
Slope	: Moderate, 10-20%
Parent material	: Recent basaltic ashes over older basaltic tuff
Vegetation	: Secondary rain forest and bush; fallow
Land use	: Shifting cultivation of rain-fed crops, and some small coconut plantations
Climate	: Wet tropical of windward type: MAT ca. 26 °C, MAR ca. 3000 mm
Soil climate	: Udic, isohyperthermic
Drainage	: Well drained; very great permeability in the topsoil, but lower at depth

Profile Description

Horizon	Depth (cm)	Description
A	0 to 15-20	Very dark reddish brown (5YR 3/2); sandy loam, very humiferous; medium granular structure; fairly firm, friable; low bulk density; very porous and permeable; very abundant roots, to
AB	20-40	dark reddish brown (5YR 3/3); sandy loam; humiferous; fine to medium granular structure; friable; low bulk density; very permeable; abundant roots, to
2BwC	50-120+	dark brown with fine reddish and grey mottles of weathered cinders; sandy loam (more sandy, with some gravels of weathered cinders; very slightly humiferous; massive and coarse blocky structure; fairly firm, but friable and a little plastic; a little higher bulk density; less permeable; fairly abundant fine roots.

Remarks:

- Reaction to the FIELDES (NaF) test: is weak in the whole soil profile.
- Mineralogy of <2 μm fraction:
  A: mostly allophane and few spherical halloysite and probably some ferrihydrite and very few opal.
  2BwC: mostly spherical and tubular halloysite; a few allophane and ill-crystallized goethite; traces of smectites.
- Mineralogy of parent material: olivine basalt, very rich in Mg and Fe, with labradorite, augite and few olivine.

Profile: Vanuatu (Sta. Maria Isl.), ORSTOM no. 466

Classification:	
FAO/Unesco (1974)	: Molli-Andic Cambisol or Mollic Andosol/Eutric Cambisol
Soil Taxonomy (1975)	: Andic Eutropept
Location	: Vanuatu-Santa Maria Island; midslope between the W. summit Latitude: 14 ° 17'30"S; Longitude: 167 ° 27'E; Altitude: ca. 300 m

Described by	: P. Quantin
Physiography	: Rolling slope of a shield volcano
Position of site	: Westward-mid slope, interfluve
Slope	: 20-30%
Parent material	: Basaltic ash over basaltic breccias*
Vegetation	: Rain forest
Land use	: Shifting agriculture of rainfed subsistence crops
Climate	: Wet tropical, with a very short dry season, of leeward type, MAT 24-25 °C, MAR 3000-2500 mm (?)
Soil climate	: Udic, intergrade to ustic, isohyperthermic
Drainage	: Well drained, rapid permeability

*the ash deposits are recent in the topsoil, older in depth.

Profile Description

Horizon	Depth (cm)	Description
A	0-15	Dark brown (7.5YR 3/2) clay loam, humiferous; medium sized crumb structure; friable; low bulk density; very permeable; abundant roots; good biological activity; gradual transition to
Bw	15-80	brown (7.5YR 4/2) loam; slightly humiferous; rather continuous massive structure; weakly coherent, very friable; very porous and permeable; low bulk density; scarce roots,
C	80-120+	dark brown (7.5YR 4/2) mottled with grey, ochre and white spots; massive structure; loamy sand; friable; deriving from a basaltic breccia.

Remarks:
- The <2 µm fraction contains mostly 7 and 10 Å halloysite, and little allophane (ca. 2%) and some interstratified 2:1 clay minerals, as well as a little goethite and lepidocrocite.
- The reaction to the FIELDES (NaF) test is slow and rather weak in depth.

Profile: Mexico, Sierra Nevada no. 13

Classification:	
FAO/Unesco (1974)	: Humic Andosol
FAO (1988)	: Umbric Andosol (?)
Soil Taxonomy (1975)	: Hydric Dystrandept
ICOMAND (1988)	: Mollic Haplustand (?)
Local	: Cambandos Andosol
Location	: Ca. 15 km NE of Amecameca and ca. 55 km SE of Mexico City. Ref.: Miehlich (1980; p. 28, profile 13) Latitude: 19 ° 17'N; Longitude: 98 ° 39'W; Altitude: 2650 m.
Described by	: G. Miehlich
Physiography	: Lower slope of Istaccihuatl volcano
Position of site	: Exposition West, about 18 km from crater

Slope	: 25%
Parent material	: Andesitic volcanic ash
Vegetation	: Pinus teocote; Pinus sp., Quercus sp.
Land use	: Forest grazing
Climate	: Cool "dry" (climate A, see ref.), MAR 1050 mm, MAT 13 °C
Soil climate	: Ustic, isomesic

Profile Description

Horizon	Depth (cm)	Description
A0	5-0	Undecomposed organic matter.
A11	0-15	Ash layer 3C (see ref.), very dark greyish-brown (10YR 3/2) clay loam; crumb; soft; allophane (+) thyxotropy (+); penetrated by roots, marked transition to
Bw	15-70	dark brown (10YR 3/3) sandy clay loam, below 40 cm sandy loam; fine crumb; allophane (+); thixotropy (+); weakly penetrated by roots; marked transition to
2C	70-90	pumice layer P (see ref.)
3A11	90-115	old volcanic Toba sediments; dark brown (10YR 3/3) clay loam; subangular blocky, firm; gradual transition to
3A12	115-200	very dark grey brown (10YR 3/2) clay loam; subangular blocky; firm; no allophane; thixotropy (+); weakly penetrated by roots.

Remarks:
- This profile is comparable to profile Sierra Nevada no. 19 but is lower situated and has dryer conditions. It is, therefore, less developed: *less* weathering, *less* allophane or humus complexes, less dark colours.
- The given horizon designations were interpreted from the original diagnostic horizon designation by Miehlich (1980). They are respectively: macorg, a3och, a3cam, 2lit, 3fthixcam, 3fsilthixcam.

Profile: Syria R1

Classification:	
FAO/Unesco (1974)	: Vitric Andosol
Soil Taxonomy (1975)	: Typic Vitrandept
ICOMAND	: Calcic-Gypsic Vitritorrand (Osman et al., 1985)
Location	: Ca. 20 km E. of Raqqa, 1.5 km S.E. of Minkher Carbi volcano, Syria Latitude: 35 ° 54'N; Longitude: 39 ° 14'E; Altitude: 290 m.
Described by	: O. Mukhtar, M. Ilaiwi and N. Khatib
Physiography	: Undulating piedmont plain of volcanic hill
Slope	: Almost flat

Parent material	: Volcanic ash and lapilli, dark coloured basaltic, scoriae originating from Minkher W. (Gharbi) and E. (Sharqui) volcanoes. Upper Quaternary age
Vegetation	: Sparse winter grass
Climate	: Arid, MAR 209 mm; MAT (soil) 21 °C
Soil climate	: Aridic, thermic

Profile Description

Horizon	Depth (cm)	Description
A	0-5	Pale brown (10YR 6/2, dry) dark brown (10YR 3/3, moist) loam, weak fine to medium subangular blocky, slightly hard dry, friable moist, slightly sticky, slightly plastic wet, calcareous, ca. 25% lapilli (1-2 mm diameter), many fine and very fine roots, common very fine tubular pores, clear smooth boundary to
C1	5-17	pale brown (10YR 6/3, dry) brown (10YR 4/3, moist) loam, weak fine to medium subangular blocky, slightly hard dry, friable moist, sticky, slightly plastic wet, calcareous, lapilli as above partly coated by lime, active macrofauna, common very fine roots, common very fine tubular pores, merging boundary to
C2	17-35	pale brown (10YR 6/3, dry) brown (10YR 4/3, moist) loamy coarse sand, very weak fine subangular blocky, soft dry, very friable moist, sticky, slightly plastic wet, calcareous, lapilli as above but larger size mostly coated by lime, active macrofauna, few very fine roots, few very fine tubular pores, clear smooth boundary to
2C3	35-54	accumulation of lapilli, completely coated by $CaCO_3$ (+ gypsum) ranging in size from 1-7 mm, clear smooth boundary to
2C4	54-79	accumulation of lapilli partly coated by lime (+ gypsum) abrupt smooth boundary to
2C5	79-155	repeated sequences of layers of weakly/strongly cemented crust of lapilli cemented by lime (+ gypsum) followed by loose accumulation of partly coated lapilli.

Profile: Syria R2

Classification:	
FAO/Unesco (1974)	: Vitric Andosol (?)
Soil Taxonomy (1975)	: Typic Vitrandept
Location	: Ca. 20 km E. of Raqqa, 3.5 km S.E. of Minkher Garbi volcano, Syria Latitude: 35 ° 53'; Longitude: 39 ° 13'; Altitude: 285 m.
Described by	: O. Mukhtar, M. Ilaiwi and N. Khatib
Physiography	: Euphrates river, third terrace

Slope	: Almost flat
Parent material	: Calcareous alluvial material covered by basic volcanic material (ash and lapilli)
Vegetation	: Winter grass
Climate	: Arid, MAR 209 mm; MAT (soil) 21 °C
Soil climate	: Aridic, thermic

Profile Description

Horizon	Depth (cm)	Description
Surface		Black layer of lapilli as single grains (1 cm thick)
A	0-3	Light brownish grey (10YR 6/2, dry) brown (10YR 4/3, moist) sandy loam, weakly developed fine to medium platy, slightly hard dry, friable moist, sticky, slightly plastic wet, calcareous, ca. 35% lapilli (ca. 2 mm diameter), common very fine roots mostly concentrated at the lower limit of the horizon, common very fine tubular pores, clear smooth boundary to
C1	3-16	very pale brown (10YR 7/3, dry) dark brown (10YR 3/3, moist) sandy loam, weakly developed fine to medium subangular blocky, slightly hard dry, friable moist, sticky, plaistic, calcareous, lapilli as above very few very fine pores, merging boundary to
C2	16-30	very pale brown (10YR 7/3, dry) dark brown (10YR 3/3, moist) sandy laom, weakly developed fine to medium subangular blocky, slightly hard dry, friable moist, sticky and plastic wet, calcareous, lapilli as above, very few very fine roots, many very fine pores, merging boundary to
2C3	30-62	pale brown (10YR 7/3, dry) yellowish brown (10YR 5/4, moist) sandy loam, very weak fine to medium subangular blocky, soft dry, very friable moist, slightly sticky, slightly plastic wet, ca. 55% lapilli, common bioactivity, very few very fine roots, many very fine tubular pores, merging boundary to
2C4	62-87	light grey (10YR 7/2) brown (10YR 5/3, moist) loamy sand, very weak fine to medium subangular blocky, soft dry, friable moist, slightly sticky, non plastic (wet), calcareous, lapilli 70-80% by volume (1-4 mm diameter) with increasing number of larger size with depth, many very fine tubular pores, merging boundary to
2C5	87-140	accumulation of lapilli as single grains partly coated by lime (+ gypsum), irregular strongly cemented crust ranging in thickness from 2 to 8 cm formed by lapilli cemented by lime (gypsum).

Profile: Syria R3

Classification:	
FAO/Unesco (1974)	: Vitric Andosol (?)
Soil Taxonomy (1975)	: Typic Vitrandept
Location	: Ca. 20 km E. of Raqqa, 1 km E. of Mohamadia, Syria Latitude: 35 ° 52'N; Longitude: 39'12"E; Altitude: 280 m.
Described by	: O. Mukhtar, M. Ilaiwi and N. Khatib
Physiography	: Euphrates river, third terrace
Slope	: Almost flat
Parent material	: Calcareous alluvial material covered by basic volcanic material (ash and lapilli)
Vegetation	: Irrigated wheat
Climate	: Arid, MAR 209 mm; MAT (soil) 21 ° C
Soil climate	: Aridic, thermic

Profile Description

Horizon	Depth (cm)	Description
Ap	0-20	Pale brown (10YR 6/3, dry) dark brown (10YR 3/3, moist) sand, moderately developed medium subangular blocky, slightly hard dry, friable moist, slightly sticky, slightly plastic wet, calcareous, ca. 25% lapilli (ca. 2 mm diameter) partly coated by $CaCO_3$, very few small soft concretions of $CaCO_3$, common bioactivity, few fine and medium roots, common fine and very fine tubular pores, clear smooth boundary to
A12	20-55	light yellowish brown (10YR 6/4, dry) dark yellowish brown (10YR 4.5/4, moist) coarse sandy loam, weak fine to medium subangular blocky, soft dry, very friable moist, slightly sticky slightly plastic wet, calcareous, lapilli as above, common bioactivity, few very fine roots, common fine and very fine tubular pores, gradual wavy boundary to
2C1	55-100	non homogeneous horizon due to tonguing from the upper horizon, accumulation of lapilli (60-70%), average size 1-2 mm partly coated by lime, tongues (30-40%) pale brown (10YR 6/3), loamy coarse sand to
2C2	100-115	light grey (10YR 7/9, dry) grey (10YR 5/1, moist) loamy coarse sand, very weak fine to medium subangular blocky, soft when slightly moist, very friable moist, non sticky, non plastic wet calcareous, 70-80% fine lapilli, no roots in the lower parts of the horizon continuous crust (1-2 cm thick) formed by very fine lapilli cemented by $CaCO_3$, few white pseudo-mycelia.

Profile: Syria S3

Classification:	
FAO/Unesco (1974)	: Vitric Andosol
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Typic Vitrandept
ICOMAND (1988)	: Typic Vitrixerand
Location	: 1 km N. of Shehba, S.W. Syria. Ref. Osman et al (1985) Latitude: 32°54'N; Longitude: 36°38'E; Altitude: 1000 m.
Described by	: A. Osman
Physiography	: Hilly volcanic piedmont
Parent material	: Volcanic ash on lapilli (basaltic)
Vegetation	: Shrubs
Climate	: Semi-arid; MAR 335 mm
Soil climate	: Xeric, thermic

Profile Description

Horizon	Depth (cm)	Description
A11	0-2	Volcanic material (2-5 mm of diameter),
A12	2-7	light yellowish brown (10YR 6/4, dry) dark yellowish brown (10YR 3/6, moist) sandy loam, platy fine at the top, fine subangular blocky underneath, slightly hard dry, very friable moist, non sticky, non plastic, non calcareous, very fine lapilli (20%), common very fine roots, abrupt irregular boundary,
C1	7-50	soil pockets from the upper horizon (15 cm diameter) at the top. Lapilli (95%) of 2-10 mm diameter, cemented by lime with increased in the depth. 5% of soil, same as above,
C2	50-150	lapilli cemented by lime.

Profile: Philippines Tagaytay

Classification:	
FAO/Unesco (1974)	: Haplic Pheozem
Soil Taxonomy (1975)	: Cumulic Haplustoll
Location	: Near Vista Lodge, Tagaytay City Latitude: 14°06'N; Longitude: 120°56'E; Altitude: 600 m.
Described by	: T. Adachi and H. Otsuka
Physiography	: Undulating pyroclastic flow land, top of volcano footslope
Parent material	: Volcanic ash
Vegetation	: Grass
Land use	: Uncultivated
Climate	: Monsoon, MAR 2320 mm (5 months low rainfall); MAT 23°C
Soil climate	: Ustic

Profile Description

Horizon	Depth (cm)	Description
A1	0-12	Brownish black (5YR 2/1, moist) clay loam, fine granular blocky, sticky and plastic, very friable moist, very abundant humus, clean, smooth boundary to
2A1	12-27	black (5YR 1.7/1, moist) clay loam, fine granular blocky, sticky and plastic, very friable moist, abundant humus, clear, smooth boundary to
3A11	27-35	black (5YR 1.7/1, moist) light clay, sticky and plastic, friable moist, very abundant humus, gradual, smooth boundary to
3A12	35-44	very similar to horizon above acept for abundant humus, clear, smooth boundary to
4A1	44-51	brownish black (5YR 2/1, moist) light clay, angular blocky, sticky and plastic, slightly firm moist, few scoria, abundant humus, gradual, smooth boundary to
4B2	51-136	dark reddish brown (5YR 3/2, moist) light clay, slightly firm moist, sticky and plastic to very plastic, common reddish brown (5YR 4/8) scoria (2-3 mm), common humus, clear, smooth boundary to
5C1	136-166	dark reddish brown (5YR 3/3) and bright brown (7.5YR 5/8, moist) light clay, slightly firm, moist, sticky and plastic to very plastic, common scoria, gradual, smooth boundary to
5C2	166-230	dark brown (7.5YR 3/4) and bright brown (7.5YR 5/8) light clay, moist, firm, moist, abundant pisolites (10-30 mm), clear, smooth boundary to
6C3	230-270	yellowish brown (10YR 5/6), light clay, moist, very firm moist, abundant gravel (2-3 mm), sticky and plastic, clear, smooth boundary.
7R	270+	"Adove" mud flow bed.

Profile: Kenya 1976/138-142

Classification:
- FAO/Unesco (1974) : Eutric Planosol
- Soil Taxonomy (1975) : Abruptic Tropaqualf

Location : Narok District, W. Kenya
Latitude: 0°58'22"W; Longitude: 34°57'23"E; Altitude: 1740 m.

Described by : W.G. Wielemaker and H.W. Boxem (1982). Their obs. 130/4-Ex.9

Physiography : Plain

Slope : 1-2%

Parent material	: Quaternary volcanic ash (peralkaline trachytic)
Vegetation	: 20% grass, 80% shrubs
Land use	: Extensive grazing
Climate	: MAR 1500 mm, MAT ca. 19 °C
Soil climate	: Udic (with 3-4 drier months)
Drainage	: Poorly drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-7	Black (5YR 2.5/1, moist) loam; strong, fine, subangular blocky; few to common very fine biopores; slightly hard, slightly sticky and slightly plastic; clear and smooth transition to
A2	7-23	dark brown to dark greyish brown (7.5-10YR 4/2, moist) pinkish grey (7.5YR 7/2, dry) clay loam; few, very fine distinct reddish yellow (7.5YR 6/8) mottles; loam; strong, medium prismatic; few to common, very fine biopores; hard, slightly sticky and slightly plastic; abrupt and wavy transition to
B21t	23-34	black (10YR 2.5/1, moist) clay loam; strong, coarse prismatic; cutans of clay and organic matter, thick and continuous; few very fine biopores; very hard, very firm sticky and plastic; gradual and smooth transition to
B22t	34-86	black (10YR 2.5/1, moist) clay; strong, fine angular blocky; slicken-sides in lower part of the horizon; few very fine biopores; very hard, very firm, sticky and plastic; few lime concretions; clear and smooth transition to
B23ca	86-160	dark brown (10YR 4/3-3/3, moist), common, fine, distinct reddish yellow (7.5YR 6/8) mottles; clay; moderate, fine angular blocky; common, very fine biopores; hard, firm, sticky and plastic; few small iron-manganese concretions; lime concretions; clear and smooth transition to
B31ca	160-175	dark brown (10YR 4/3-3/3, moist); many, distinct, reddish yellow (7.5YR 6/8) mottles; clay; strong fine angular blocky; few, very fine biopores; very hard, firm sticky and plastic; common, small iron managanese concretions; few lime-concretions; gradual and wavy transition to
B32g	175-225	very mottled, yellowish and black material (ash); silt; compact; few biopores; very hard; many iron-manganese concretions; positive reaction with HCl.

Profile: Kenya 134/7

Classification:	
FAO/Unesco (1974)	: Eutric Planosol
Soil Taxonomy (1975)	: Abruptic Tropaqualf
Location	: Ca. 7.5 km W. of Kingangop, Kenya Latitude: 0°36'S; Longitude: 36°30'E; Altitude: 2430 m.
Described by	: W.G. Wielemaker
Physiography	: Plain, gently undulating
Slope	: Almost flat (1-2%)
Parent material	: Quaternary volcanic ash (peralkaline trachytic)
Land use	: Pasture
Climate	: Semi-humid, MAR 800-1400 mm, MAT 12-14°
Soil climate	: Udic (-ustic?)
Drainage	: Imperfectly drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-17	Grey (10YR 3/1, moist) common distinct very fine orange brown mottles; loam; moderate very fine angular blocky; friable, slightly sticky, slightly plastic; many pores; clear and smooth transition to
A21	17-27	light brownish grey (10YR 6/2, moist) mottling as above; loam; weak fine angular blocky; strong, common iron and maybe clay cutans; very friable, slightly sticky, slightly plastic; many pores; abrupt and wavy transition to
A22	27-27/38	light grey (10YR 7/1, moist) few faint very fine orange brown mottles; loam; 50% hard iron manganese concretions; weak fine angular blocky; common weak to moderate clay cutans; friable, slightly sticky, slightly plastic; abrupt and broken transition to
B21	27/38-47	very dark brown (10YR 2.5/2, moist) clay; 10% hard Fe/Mn concretions; moderate fine angular blocky; very firm, slightly sticky, slightly plastic; few very fine pores; abrupt and wavy transition to
B22	47-60	very dark brown (10YR 2.5/2, moist) clay; moderate to strong fine angular blocky; very firm, slightly sticky slightly plastic; few very fine pores; gradual and smooth transition to
B23	60-83	dark yellowish brown (10YR 4/4) and very dark brown (10YR 2.5/2, moist) clay; strong moderate angular blocky; firm, slightly sticky, slightly plastic; few very fine pores; clear and smooth transition to
2B	83+	very dark greyish brown (10YR 3/2, moist) few diffuse very fine greyish white mottles; clay; moderate fine angular blocky; common moderate clay cutans; friable, slightly sticky, slightly plastic; 50% Fe/Mn concretions of 3-8 mm diameter.

Profile: Kenya 118/6

Classification:	
FAO/Unesco (1974)	: Eutric Planosol
Soil Taxonomy (1975)	: Abruptic Tropaqualf
Location	: Ca. 2 km ESE of Londiani, along C35 road Latitude: 0°10'S; Longitude: 35°35'E; Altitude: 2300 m.
Described by	: W.G. Wielemaker
Physiography	: Hilly plains
Slope	: Nearly flat (1%)
Parent material	: Quaternary volcanic ash (peralkaline trachytic)
Land use	: Pasture and maize
Climate	: Sub-humid, MAR 1000-1600 mm, MAT 14-16°C
Soil climate	: Udic (-ustic?)
Drainage	: Imperfectly drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-10	Dark grey (10YR 4/1, moist) few faint very fine orange brown mottles; silty clay loam; moderate very fine subangular blocky; slightly sticky, slightly plastic; common very fine and fine pores; clear and smooth transition to
A3	10-30/40	grey (10YR 5/1, moist) few faint very fine orange brown mottles, silty clay loam; moderate fine angular blocky; non sticky, non plastic; 5-10% iron concretions of 3-5 mm diameter; few and very fine pores; abrupt and irregular transition to
B2t	30/40-55	very dark grey (10YR 3/1, moist) clay; strucutre?; firm slightly sticky and plastic; nil to few very fine pores; some yellowish mottles of less decomposed volcanic ash,
2A2 + B2t	55-72	20% grey (10YR 5/1) and 80% very dark grey (10YR 3/1, moist) clay; structure?; 80% black and yellow manganese and iron concretions of 5-20 mm diameter,
2B2t	72+	at 90 cm depth, some slickensides.

Profile: Kenya 145/5

Classification:	
FAO/Unesco (1974)	: Eutric Planosol
Soil Taxonomy (1975)	: Abruptic Tropaqualf
Location	: ca. 45 km W. of Narok, just W. of Ngore Ngore Police Post along B7/3 road from Narok to Bomet Latitude: 1°02'S; Longitude: 35°29'E; Altitude: 2200 m.
Described by	: W.G. Wielemaker

Physiography : Very gently undulating plain
Slope : ½%
Parent material : Quaternary volcanic ashes (peralkaline trachytic)
Vegetation : 60% grasses, 30% shrubs, 8% herbs
Climate : Semi-humid to semi-arid, MAR 700-1200 mm, MAT 10-18 °C
Soil climate : Ustic
Drainage : Imperfectly drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-13	Light brownish grey (10YR 6/2, dry) and dark greyish brown (10YR 4/2, moist) common faint very fine orange brown rust mottles; silt loam; moderate fine angular to subangular blocky; slightly hard, friable, slightly sticky, slightly plastic; many micro and very fine, common fine pores,
A2	13-40	light grey (10YR 7/1, dry) and greyish brown (10YR 5/2, moist) common faint very fine rust mottles; silt loam; weak fine angular blocky; common moderate clay and manganese cutans; soft friable, slightly sticky, slightly plastic; many micro and very fine, few fine pores,
B2t	40-51	very dark grey (10YR 3/1, moist) common clear very fine rust mottles; silty clay loam; strong, fine angular blocky; firm, slightly sticky and plastic; pores as above; few Fe concretions of 3-4 mm diameter,
B3sim	51-65	40% colour as above, 60% dark yellowish brown (10YR 4/4, moist) silt loam; strong fine angular blocky and porous massive; firm, slightly sticky, slightly plastic; many micro and very fine pores, silica pan, does not react with HCl,
C	65+	dark yellowish brown (10YR 4/4, moist) silt loam; porous massive; common strong manganese and or clay cutans; pores as above; 1%, 3 mm large $CaCO_3$ concretions, increasing with depth.

Profile: Kenya 145/7

Classification:
FAO/Unesco (1974) : Eutric Planosol
Soil Taxonomy (1975) : Abruptic Tropaqualf
Location : Ca. 1 km S of road C340 from Narok/Ewaso Ngiro to Keekorok Game Lodge, about 60 km S.W. of Narok, just across river Gisheramuruak
Latitude: 1 °24'S; Longitude: 35 °29'E; Altitude: 2000 m.
Described by : W.G. Wielemaker
Physiography : Flat plain

Slope	: 0-½%
Parent material	: Quaternary volcanic ashes (peralkaline trachytic)
Vegetation	: 100% grasses
Land use	: Extensive grazing
Climate	: Semi-arid, MAR 450-900 mm, MAT 16-18 °C
Soil climate	: Ustic
Drainage	: Imperfectly drained

Profile Description

Horizon	Depth (cm)	Description
A1/2	0-9	Light brownish grey (10YR 6/2, dry) dark grey (10YR 4/1, moist) silty clay loam; moderate fine angular to subangular blocky; very hard, slightly sticky, slightly plastic; common micro and very fine, few fine pores; less than 1 percent 2 mm large iron, manganese concretions; abrupt and smooth transition to
B2	9-40	very dark grey to black (7.5YR 2.5/0, moist) clay; strong, medium angular blocky; extra hard, extra firm, slightly sticky, plastic; few micro and very fine pores; clear and smooth transition to
B3	40-110	brown to dark brown (10YR 4/2, moist) mottles and mycelium of $CaCO_3$; silt loam; moderate, very fine angular blocky; friable, slightly sticky, slightly plastic; locally strong reaction to HCl,
Ccam	110+	pale yellow (2.5Y 7/4, dry; 2.5Y 4/4, moist) $CaCO_3$ with concretions.

Profile: INS-19

Classification:	
FAO/Unesco (1974)	: Dystric Cambisol
Soil Taxonomy (1975)	: Oxic Humitropept
Location	: 1 km SSE of Blangrakal, km 43 on the road Biruen-Takengon, Central Aceh, N. Sumatra, Indonesia Latitude: 4°52'18"N; Longitude: 96°42'45"E; Altitude: 750 m.
Described by	: P. Buurman
Physiography	: Volcanic lower slope
Position of site	: Middle part of slope, facing N.W.
Slope	: 2-6%
Parent material	: Andesitic/dacitic ash (upper 23 cm, Lampahan eruption) overlying old (Geureudong) andesitic ash
Vegetation	: Grass
Land use	: Extensive grazing
Climate	: Humid equatorial, MAR ca. 3000 mm, MAT ca. 21 °C
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah	0-16	Very dark brown (10YR 2/2-2/3, moist) loam (mixed with <5% andesitic gravel diam. <5 mm); moderate medium subangular blocky to granular; friable moist, hard dry; many coarse and medium, common fine and very fine pores; common coarse and medium, many fine and very fine roots; clear and smooth transition to
A	16-23	dark yellowish brown to brown (10YR 4/4-5/3, moist) loam (mixed with <5% andesitic gravel, diameter <5 mm); moderate medium subangular blocky; firm; many coarse and medium, common fine and very fine pores; common coarse, many medium, fine and very fine roots; abrupt and smooth transition to
2AB	23-29	yellowish brown (10YR 5/4-5/6, moist) loam to clay loam; moderate medium to coarse angular blocky; firm, slightly thixotropic; common medium, fine and very fine pores; few coarse and medium, common fine and very fine roots; clear and smooth boundary to
2Bw1	29-85	yellowish brown (10YR 5/8, moist) clay loam to clay; strong coarse to very coarse subangular blocky; firm to friable, thixotropic; few medium and fine, common very fine pores; few fine and very fine roots; gradual and wavy transition to
2Bw2	85-110+	yellowish brown (10YR 5/8, moist) clay; strong coarse to very coarse subangular blocky; friable, thixotropic; few medium, fine and very fine pores; few very fine roots.

Profile: INS-26

Classification:	
FAO/Unesco (1974)	: Andic/Mollic Cambisol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Andic Humitropept
ICOMAND (1988)	: Thaptic Haplustand
Location	: US Army (1944): Sheet 53/XLII-D, false coordinates: 136N215E; western valley side slope of one of the smaller tributaries of the Kali Konto, approximately 1.2 km west-southwest from Desa Sebaluh, Kecamatan Pudjon, Kabupaten Malang, East Java, Indonesia. Altitude: 1210 m.
Described by	: M. Prabowo, L. Rayes, G.W. van Barneveld, H. van Reuler and J.H. Tersteeg
Physiography	: Piedmont landform at the lower N.E. slopes of Kawi-Butak
Slope	: 10% (concave valley side slope)
Parent material	: Colluvially reworked volcanic material, derived from intermediate and basic volcanic ash
Land use	: Rainfed annual food crops and vegetables on graded benched fields
Climate	: MAR 2200 mm, MAT 20 °C, pronounced dry and wet season
Soil climate	: Ustic

Drainage : Well drained

Profile Description

Horizon	Depth (cm)	Description
Ap	0-16	Very dark grayish brown (10YR 3/2) when moist and dark grayish brown (10YR 4/2) when dry; clay loam; moderate medium granular and subangular blocky structure; slightly sticky, slightly plastic and very friable when moist; many fine, medium and coarse pores, many fine roots; clear and smooth boundary to
AB	16-29	very dark grayish brown (10YR 3/2) when moist and dark grayish brown (10YR 4/2) when dry; clay loam; moderate medium granular and subangular blocky structure; slightly sticky, slightly plastic and very friable when moist; many fine, medium and coarse pores; common fine roots; clear and wavy boundary to
Ahb	29-45	black (10YR 2/1) when moist and very dark gray (10YR 3/1) when dry, faintly mottled with dark grayish brown (10YR 4/2) when dry; clay loam with very few very coarse sand particles of semi-weathered tuff; moderate medium subangular blocky structure; patchy thin coatings of clay with organic matter on ped faces; slightly sticky, slightly plastic and friable when moist; common fine and medium pores; few fine roots; clear and smooth boundary to
Bw1	45-77	dark yellowish brown (10YR 3/4) when moist and grayish brown (10YR 5/2) when dry, faintly mottled with dark grayish brown (10YR 4/2) when dry; clay loam with few very coarse sand particles of semi-weathered tuff; moderate medium irregular angular blocky structure; patchy thin coatings on ped faces and some large complete channel infillings of clay with organic matter; sticky, plastic and friable when moist; common fine, medium and coarse pores; few fine roots; clear and smooth boundary to
Bw2	77-101	dark yellowish brown (10YR 3/4) when moist and brown (10YR 5/3) when dry, faintly mottled with dark grayish brown (10YR 4/2) when dry; clay loam with few very coarse sand particles of semi-weathered tuff; moderate medium irregular angular blocky structure; patchy thin coatings of clay with organic matter on ped faces; sticky, plastic and friable when moist; common fine, medium and coarse pores; few fine roots; clear and smooth boundary to
Bw3	101-139	dark yellowish brown (10YR 3/4) when moist and brown (10YR 5/3) when dry, faintly mottled with dark grayish brown (10YR 4/2) when dry; clay loam with few very coarse sand particles of semi-weathered tuff; moderate medium irregular angular blocky structure; patchy thin coatings of clay with organic matter on ped faces; sticky, plastic and friable when moist; common fine and medium and many coarse pores; very few fine roots; clear and smooth boundary to

BC	139-150+	dark brown (10YR 3/3) when moist and brown (10YR5/3) when dry; clay loam with common very coarse sand particles and gravels (<0.3 cm) of semi-weathered tuff; weak to moderate, medium irregular angular blocky structure; slightly sticky, slightly plastic and friable when moist; many fine and coarse and few medium pores; very few fine roots.

Remark: This soil is intermediate between the upland Andosols and the Cambisols of the intervolcanic plain. It resembles an Andosol but has lost some characteristic properties. Transport and redeposition of volcanic material has resulted in higher bulk densities and lower content of amorphous constituents. They are intensely reworked by biological activity and have high organic matter throughout.

Profile: INS 37

Classification:

FAO/Unesco (1974)	: Eutric Nitosol
Soil Taxonomy (1975)	: Paleudalf typic
Location	: W. Sumatra, Indonesia. Foothill of Merapi volcano, 7 km E. of Padang Pajang Latitude: 0 • 27'S; Longitude: 100 • 27'E; Altitude: 600 m
Described by	: Kauffman and Soedewo
Physiography	: Lower foothill of volcano, hilly topography
Position of site	: Middle slope
Slope	: 30%
Parent material	: Basic volcanic ash over residual intermediate igneous material
Land use	: Low level arable farming, banana. Home yards
Climate	: Köppen: Af, MAT ca. 22 • C, MAR ca. 2600 mm
Soil climate	: Udic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A	0-30	Black (7.5YR 2/2, moist); clay; fine moderate subangular blocky and fine weak crumb; slightly sticky slightly plastic friable; many fine/medium pores; many fine roots throughout and many medium roots throughout; gradual smooth boundary to
Bw1	30-70	dark brown (7.5YR 3/2, moist); clay fine to medium moderate subangular blocky; slightly sticky slightly plastic friable; many fine/medium pores; many fine roots throughout and many medium roots throughout; gradual smooth boundary to
Bw2	70-127	dark brown (7.5YR 3/3, moist); clay; fine to medium moderate subangular blocky; slightly sticky slightly plastic friable; continuous moderately thick cutans on pedfaces; many very fine/fine random tubular pores a few medium random tubular pores; common fine roots

		throughout and few fine roots throughout; few medium fresh and few medium weathered andesite fragments; frequent termite channels; gradual smooth boundary to
Bw3	127-160	dark brown (7.5YR 3.5/4, moist); clay; fine to medium weak subangular blocky; slightly sticky slightly plastic very friable; many very fine/fine random tubular pores; common fine roots throughout.
Auger	160-280	dark brown (7.5YR 4/5, moist); clay.

Remark: The prominent subangular to angular blocky structure with shiny pedfaces points to a Nitosol.

Profile: EC 2

Classification:
- FAO/Unesco (1974) : Humic Cambisol
- FAO (1988) : Umbric Andosol
- Soil Taxonomy (1975) : Humitropept Andic
- ICOMAND (1988) : Pachic Melanudand

Location : Ecuador, Pinchincha, Quito. INIAP Exp. Sta. St. Catalina
Latitude: 0°20'15"S; Longitude: 78°33'45"W; Altitude: 3140 m
Described by : S. Kauffman and G. del Posso
Physiography : Footslopes of volcano range
Position of site : Middle slope
Slope : 12%
Parent material : Volcanic ash
Land use : High level mixed farming, cereals, crop-grass rotation
Climate : Köppen: Cs? MAT 11-12°C, MAR 1430 mm
Soil climate : Udic, isomesic
Drainage : Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah1	0-10	Black (10YR 2/1, moist); loam; medium to coarse moderate granular; non sticky non plastic friable; many very fine interstitial pores; many very fine roots throughout and common medium roots throughout; diffuse smooth boundary to
Ah2	10-55	black (10YR 2/0, moist); fine moderate subangular blocky; slightly sticky slightly plastic friable; many very fine tubular pores and few fine tubular pores; common very fine roots throughout and common fine roots throughout; diffuse boundary to
Ah3	55-79	black (10YR 2/1, moist); loam; fine moderate subangular blocky; slightly sticky slightly plastic friable; many very fine tubular pores

		and few fine tubular pores; common very fine roots throughout and few fine roots throughout; very few medium weathered pumice gravel fragments; gradual wavy boundary to
2Ab1	79-96	black (10YR 2/1, moist); loam, gravelly; fine weak subangular blocky; slightly sticky slightly plastic friable; many very fine tubular pores and few fine tubular pores; few very fine roots throughout and few fine roots throughout; frequent medium weathered pumice gravel fragments; clear wavy boundary to
2Ab2	96-165	black (10YR 2/1, moist); loam; fine weak subangular blocky; slightly sticky slightly plastic friable; many very fine tubular pores and few fine tubular pores; few very fine roots throughout and few fine roots throughout; clear wavy boundary to
2Ab3	165-185	black (10YR 2/0, moist); silt loam, slightly gravelly; fine weak subangular blocky; slightly sticky slightly plastic friable; many very fine tubular pores and few fine tubular pores; few very fine roots throughout and few fine roots throughout; very few medium weathered pumice gravel fragments.

Remarks:
- EC 2 is comparable to profile Ecuador 6 in: Part III - Tour Guide for Ecuador of the Sixth International Soil Classification Workshop (1984). The soil is a true volcanic ash soil, however the bulk density is too high for the required criteria of Soil Taxonomy and FAO.

Profile: EC 4

Classification:	
FAO/Unesco (1974)	: Humic Acrisol
Soil Taxonomy (1975)	: Tropohumult Orthoxic
Location	: Ecuador, Galapagos, St. Cristobal Island, St. Joacim volcano Latitude: 0°53'S; Longitude: 89°30'W; Altitude: 500 m
Described by	: Kauffman and del Posso
Physiography	: West slope of volcano
Position of site	: Middle slope
Slope	: 25%, W. facing
Parent material	: Fine-grained basic rock
Vegetation	: Lantana accumulata, Mora, Guajabe, firns
Land use	: Degraded deciduous shrub
Climate	: Köppen: Aw, MAT 21°C, MAR 1300 mm
Soil climate	: Ustic, isohyperthermic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
Ah	0-12	Dark reddish brown (5YR 3/4, moist); clay; fine to medium moderate and fine to medium moderate subangular blocky; slightly sticky slightly plastic; many very fine/fine tubular pores and few medium tubular pores; many very fine roots throughout and common medium roots throughout; clear smooth boundary to
Bw1	12-95	dark yellowish red (3.7YR 3/6, moist); silty clay; fine to medium moderate subangular blocky; slightly sticky slightly plastic very friable; patchy thin clay and sesquioxides cutans; many very fine tubular pores and few medium tubular pores; many very fine roots throughout; diffuse smooth boundary to
Bw2	95-142	dark yellowish red (3.7YR 3/6, moist); silty clay; fine to medium moderate subangular blocky; slightly sticky slightly plastic very friable; continuous moderately thick clay and sesquioxides cutans; many very fine tubular pores; common very fine roots throughout; diffuse smooth boundary to
C	142-200	reddish brown (5YR 4/4, moist; 7.5YR 5/6, dry); silt loam; medium to coarse weak subangular blocky moderately coherent porous massive; very friable; many very fine tubular pores; few very fine roots throughout; very few medium strongly weathered basalt/pumice fragments.

Remarks:
- Natural vegetation is nearly completely overtaken by introduced species. Dominant species are Lantana accumulata, introduced 2 years ago and Guajaba introduced about 20 years ago (verbal information).
- The weather station El Progreso at an altitude of 200 metre is connected to this site. Source of data is FAO (1985) Plant Production and Protection Series no. 24 "Agroclimatological data for Latin America". An altitude correction of about 300 metre should be applied. Note that the meteo station of Puerto Baquerizo localized at sea level is not representative.
- According to an approximate precipitation-altitude correlation for San Cristobal island the precipitation at an altitude of 500 meter is in the range of 1500 to 2000 mm.
- It is assumed that the soil was frequently enriched with volcanic ash.
- The soil has many chemical properties of an Andosol, and would be classified as Oxic Dystrandept, however the bulk density is too high.

Profile: EC 7

Classification:
FAO/Unesco (1974) : Ferric Acrisol
Soil Taxonomy (1975) : Tropaquult typic
Location : Ecuador, Napo, Francisco de Orellana, La Joya de los Sachas, INIAP Sta. S. Carlos

Latitude: 0 • 19'S; Longitude: 76 • 50'W; Altitude: 260 m

Described by	: Kauffman and del Posso
Physiography	: Alluvial terrace "Llanura"
Position of site	: Flat
Slope	: 0-1%
Parent material	: Tuff
Vegetation	: Semi-natural vegetation, evergreen forest
Land use	: Cocoa (nearby exp. sta.)
Climate	: Köppen: Af, MAT 24-25 • C, MAR 3150 mm
Soil climate	: Perudic, isohyperthermic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A	0-8	Dark yellowish brown (10YR 3/6, moist); very fine moderate crumb and very fine moderate granular; sticky plastic friable; many very fine/fine interstitial pores; many very fine roots and many medium roots in cracks; gradual smooth boundary to
AB	8-38	dark yellowish brown (10YR 3/6, moist); clay; fine to medium moderate subangular blocky; sticky plastic friable; many very fine/fine random continuous inped tubular pores; common very fine roots and many medium roots in cracks; gradual smooth boundary to
B	38-92	dark yellowish brown (10YR 4/6, moist); medium moderate subangular blocky; sticky plastic friable; broken moderately thick clay cutans on pedfaces; few very fine/fine random continuous inped tubular pores; common very fine roots throughout and few coarse roots throughout; very few medium fresh C horizon fragments; abrupt wavy boundary to
2C	92-150	brown to dark brown (10YR 4/3, moist); strongly coherent porous massive; non sticky non plastic very firm; few very fine random continuous inped tubular pores and common very fine/fineinterstitial pores; weakly cemented continuous platy petroferric.

Remarks:
- The soil parent material probably consists of two layers. From 0 to 92 cm quaternary alluvium, probably mixed with little volcanic ash. From 92 cm starts abruptly a very hard layer, consisting of sandy ash, probably transported and deposited by the river. The genesis of the cementation and hardness of this layer is not yet understood. The very hard layer could only be broken with a pick-axe.
- The hard layer blocks root development and permeability for water is low. No water table has been observed, however it is assumed that excess of water runs laterally to depressions.

Profile: EC 8

Classification:	
FAO/Unesco (1974)	: Vitric Andosol
FAO (1988)	: Mollic Andosol
Soil Taxonomy (1975)	: Typic Vitrandept
ICOMAND (1988)	: Thaptic Udivitrand
Location	: Ecuador, Pichancha, St. Domingo, 20 km E. of Allutiquin (near Tandapi) Latitude: 0°25'00"S; Longitude: 79°02'20"W; Altitude:
Described by	: T. Cook and G. del Posso
Physiography	: Hill slope
Position of site	: Slope, NE facing
Slope	: 45%
Parent material	: Volcanic ash
Vegetation	: General: evergreen forest
Land use	: Cultivated pasture
Climate	: MAT 16-17°C, MAR 2130 mm
Soil climate	: Perudic, isohyperthermic
Drainage	: Well drained

Profile Description

Horizon	Depth (cm)	Description
A1	0-25	Black (10YR 2/1, moist); loam; medium to coarse moderate subangular blocky into moderate granular; non sticky non plastic friable; many very fine tubular pores and common very fine tubular pores; many very fine roots and few coarse roots; very few fine pumice fragments; gradual wavy boundary to
A2	25-57	black (10YR 2/1, moist); loam; medium to coarse weak subangular blocky into coarse weak granular; non sticky non plastic friable; many very fine tubular pores and common fine interstitial pores; common very fine roots and common fine roots; very few fine pumice fragments; diffuse wavy boundary to
A3	57-84	black (10YR 2/0, moist); loam; coarse weak subangular blocky; non sticky non plastic friable; patchy thin humus cutans on pedfaces; many very fine tubular pores and few fine interstitial pores; few very fine roots and few fine roots; few very fine pumice fragments; clear wavy boundary to
2C1	84-120	brown to dark brown (10YR 4/3, moist); coarse sand, gravelly; single grain; non sticky non plastic loose; many very fine interstitial pores; few very fine roots; frequent very fine pumice fragments; clear wavy boundary to
3AB1	120-133	very dark greyish brown (10YR 3/2, moist); loam; coarse weak subangular blocky; non sticky non plastic friable; many very fine

tubular pores and common very fine interstitial pores; few very fine roots; very fine fine pumice fragments.

Remarks:
- See also information of profile Ecuador 11 in Part II: Tour Guide for Ecuador of the Sixth International Soil Classification Workshop (1984).
- In the A1 and A2 horizons about 1% fragments of brick, stone, artefact and charcoal are present. The upper part of the 2C1 horizon has been stained black (10YR 2/1).

Profile: EC 20

Classification:	
FAO/Unesco (1974)	: Vitric Andosol
FAO (1988)	: Vitric Andosol
Soil Taxonomy (1975)	: Vitrandept typic
ICOMAND (1988)	: Typic Udivitrand
Location	: Ecuador, Pichincha, Machachi, ca. 15 km W. of Aloag on the Aurora farm Latitude: 0•28'0"S; Longitude: 78•42'40"W; Altitude 2780 m
Described by	: T. Cook and G. del Posso
Physiography	: Mountainous
Position of site	: Upper slope
Slope	: 25%, N. facing
Parent material	: Acidic volcanic ash
Vegetation	: Kikuyu grass, Pinus radiata
Land use	: Medium level mixed farming, perennial crops
Climate	: Köppen: Cw, MAT 9-10•C, MAR 1280 mm
Soil climate	: Udic, isomesic
Drainage	: Somewhat excessive

Profile Description

Horizon	Depth (cm)	Description
Ah	0-25	Very dark brown (10YR 2/2, moist); loam; medium weak subangular blocky and medium moderate granular; slightly sticky slightly plastic friable; few very fine/medium tubular pores; common very fine roots throughout and few fine roots throughout; gradual wavy boundary to
AC	25-47	very dark brown (10YR 2/3, moist); sandy loam, slightly gravelly; medium weak subangular blocky; slightly sticky non plastic very friable; many very fine interstitial pores and common fine tubular pores; few very fine roots throughout and few medium roots throughout; clear wavy boundary to
2C1	47-65	brown to dark brown (10YR 4/3, moist); coarse sand, gravelly; structureless single grain; non sticky non plastic loose; many medium

		interstitial pores; few very fine roots throughout and few fine roots throughout; clear wavy boundary to
2C2	65-85	very light reddish brown (2.5Y 7/4, moist); coarse sand, gravelly; structureless single grain; loose; many very fine/medium interstitial pores; few fine roots throughout and few medium roots throughout; clear wavy boundary to
2C3	85-147	light grey (10YR 7/2, moist); very gravelly; structureless single grain; loose; many very fine/medium interstitial pores; few very fine roots throughout; abrupt wavy boundary to
3Ab	170-170	very dark greyish brown (10YR 3/2.5, moist); silt loam, slightly gravelly; weak subangular blocky; slightly sticky slightly plastic friable moderately smeary; few fine prominent clear (2.5YR 3/4) and common fine prominent diffuse (5.0YR 3/3) mottles; common very fine tubular pores; few very fine roots in mat at top of horizon.

Remarks:

EC 20 is similar to profile Ecuador 4 in: Part III - Tour Guide for Ecuador of the Sixth International Soil Classification Workshop (1984).

PUBLICATIONS

Soil Monolith Papers

1. Thionic Fluvisol (Sulfic Tropaquept) Thailand, 1981
2. Orthic Ferralsol (Typic Haplustox) Zambia, in prep.
3. Placic Podzol (Placaquod) Ireland, in prep.
4. Humic Nitosol (Oxic Paleustalf) Kenya, in prep.
5. Humic Acrisol (Orthoxic Palehumult) Jamaica, 1982
6. Acri-Orthic Ferralsol (Haplic Acrorthox) Jamaica, 1982
7. Chernozem calcique (Vermustoll Typique) Romania, 1986
8. Ferric Luvisol (Oxic Paleustalf) Nigeria, in prep.

Technical Papers

1. Procedures for the collection and preservation of soil profiles, 1979
2. The photography of soils and associated landscapes, 1981
3. A new suction apparatus for mounting clay specimens on small-size porous plates for X-ray diffraction, 1979 (exhausted, superseded by TP 11)
4. Field extract of "Soil Taxonomy", 1980, 4th printing 1986
5. The flat wetlands of the world, 1982
6. Laboratory methods and data exchange program for soil characterization. A report on the pilot round. Part I: CEC and Texture, 1982; 3rd printing 1984
7. Field extract of "classification des sols", 1984
8. Laboratory methods and data exchange program for soil characterization. A report on the pilot round. Part II: Exchangeable bases, base saturation and pH, 1984
9. Procedures for soil analysis, 1986; 2nd edition, 1987
10. Aspects of the exhibition of soil monoliths and relevant information (provisional edition, 1985)
11. A simplified new suction apparatus for the preparation of small-size porous plate clay specimens for X-ray diffraction, 1986
12. Problem soils: their reclamation and management (copied from ILRI Publication 27, 1980, p. 43-72), 1986
13. Proceedings of an international workshop on the Laboratory Methods and Data Exchange Programme: 25-29 August 1986, Wageningen, the Netherlands, 1987
14. Guidelines for the description and coding of soil data, revised edition, 1988
15. ISRIC Soil Information System - user and technical manuals, with computer programme, 1988
16. Comparative classification of some deep, well-drained red clay soils of Mozambique, 1987
17. Soil horizon designation and classification, 1988
18. Historical highlights of soil survey and soil classification with emphasis on the United States, 1899-1970, 1988

Soil Monographs

1. Podzols and podzolization in temperate regions, 1982
   with wall chart: Podzols and related soils, 1983
2. Clay mineralogy and chemistry of soils formed in volcanic material in diverse climatic regions, 1989
3. Ferralsols and similar soils; characteristics, classification and limitations for land use, in prep.

Wall charts

- Podzols and related soils, 67 x 97 cm, 1983 (see Soil Monograph 1)
- Soils of the World, 85 x 135 cm, 1987 (Elsevier Publ. Company, in cooperation with ISRIC, FAO and Unesco)