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1988

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ABSTRACT

Otsuka, H., Briones, A.A., Daquiado, N. P., and Evangelio, F.A. 1988

Characteristics and genesis of volcanic ash soils in the Philippines

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The Philippine islands are part of a circum-Pacific volcanic belt. There are many volcanoes and volcanic ash soils including 'Kuroboku-do', 'Andosols', 'Andepts' and 'Andisols', are widely distributed in this country.

The objective of this study is to investigate the distribution of volcanic ash soils including their morphological characteristics, physico-chemical properties and characteristics of organic matter in relation to clay mineralogy for the purpose of comparing these parameters with those of corresponding soils in Japan.

Tagaytay soils are found on the northwestern slope of Taal volcano. Organic matter content decreases with decreasing elevation. They also show a high base saturation. The young volcanic ash and pumice have high total phosphorus contents. The buried humic layers and the A horizon were developed 1170 ± 70 yrs.B.P. and 710 ± 100 yrs.B.P., respectively.

Caliraya soil derived from Mt. Banahaw ejecta has a very low pH, high exchangeable aluminum content, low base saturation, low phosphate absorption and high peak of halloysite in the X-ray diffraction pattern. The soil may represent a transition from Andisols to Ultisols.

Isarog soil showed the highest soil organic matter contents, high pH (NaF), high phosphate absorption and water contents but low exchangeable cation contents and bulk density. A similar behavior was observed for the Kuroboku soils with amorphous X-ray patterns in Japan. The age of the humic layers ranged from 580 ± 90 yrs.B.P. to 610 ± 90 yrs.B.P.

Iriga soil in the Bicol area has a high pH, high exchangeable cation contents and base saturation.

There were two types of soils from Mayon volcanic ash: one consisting of relatively old ash with a fine texture, high phosphate absorption and water content while the other consisted of young ash with a coarse texture and low phosphate absorption. Both of them display high exchangeable cation contents.

Bulusan soil in Sorsogon has a low pH, high exchangeable aluminum content and low base saturation.

Zambales soils derived from Mt. Pinutubo, Zambales province have a high pH, phosphate absorption, and coarse texture but low C.E.C. and water contents.

Negros soils found at high elevations of Mt. Canlaon, Negros Occidental, have a high pH, high organic matter content and phosphate absorption but low exchangeable cation content with indications of the presence of amorphous clay minerals.

From the relationships established between the phosphate absorption coefficients and base saturation of the samples, volcanic ash soils in the Philippines and those from Japan may be classified into two groups according to varying combinations in the range of these two properties.

Eighteen profiles were classified as Udoll, 2 profiles; Ochrept, 5 profiles, Andept, 9 profiles and Udult, one profile based on the Soil Taxonomy. Using ICOMAND, 10 of them were classified as Udand and Ustand. It was considered that the volcanic ash soils in the Philippines have undergone a transition through two types:

(1) Vitric Hapluudand ➔ Pachic Hapluudand ➔ Eutrochrept ➔ Distrochrept ➔ Hapludult, and (2) Udivitrand, Vitric Hapludand, or Vitric Hapluustand ➔ Pachic Hapludand ➔ Hydric Melanudand.

Index words: volcanic ash soil, age of humic layers, transition of andisal genesis, classification characteristics, phosphate, humus, clay mineralogy.

PREFACE

Total land area of the Philippines is about 30.00 million hectares. Agricultural land is subclassified into land area fully utilized (11.6 million hectares or 38.7% against the total area) and land area idle or under-utilized with a potential for agricultural development (3.13 million hectares or 10.4% against total area).

The entire population of the country in 1985, was 56 million including a total labor force of 21.6 million. The aggregate agricultural labor force which is estimated at 10 million or 46.3% is composed of share tenants, agricultural lease holders, and regular and seasonal farm workers.

Gross national product (GNP) contributed by the agricultural sector of the Philippines accounts for 1/4 of the total GNP and the agricultural exports account for about 40% of the total amount. However, there are many problems such as low agricultural productivity, depleted forests and low income, etc. in the agricultural sector.

As described above, the agricultural sector is very important for the development of the social and economic conditions in the Philippines. Thus the new government of the Philippines is focusing its attention on the development of agriculture though long- and medium-term economic development programs with a comprehensive agrarian reform.

To implement the programs, the soil resources for agricultural development must be surveyed and evaluated. It is also important to understand the characteristics, genesis, and classification of the Philippine soils in order to obtain basic information for soil utilization, soil management, and soil evaluation.

The current studies dealt with volcanic ash soils, which are important for agriculture in the tropical area due to their fertility, during the senior author's stay at the Department of Soil Science, College of Agriculture, University of the Philippines, Los Banos (UPLB) for a period of 4 years. This report is the result of the cooperative research program between the Tropical Agriculture Research Center (TARC) and UPLB.

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It is difficult to name all the persons who have collaborated with the authors in the implementation of those studies. However they would like to express their sincere appreciation to those people and herewith note that the studies might not have been implemented successfully without their cooperation.

I. INTRODUCTION

I. 1. Agricultural Conditions

Gross value added in agriculture (GNV), total production value, yield and harvest area in 1986 are shown in Table 1 according to the Bureau of Soils and Water Management (1988a, 1988b, and 1988c).

Table 1. Gross value added in agriculture (GRV), total production value, yield and harvest area in 1986

Crops	GVA (Million pesos)	(%)	Production (Metric ton)	Yield (Ton/ha)	Harvest area (Thousand ha)
Agri. Crops	17,063	100			
Rice	4,973	29	9,248	2.67	3,465
Corn	1,847	11	4,090	1.14	3,590
Coconut	1,680	10	3,210	0.96	3,335
Sugarcane	781	5	1,520	4.27	356
Banana	935	5			
Other Crops	6,847	40			

Gross value added in agriculture per one person, 1706.3 pesos, can be estimated from the 10 million people employed in agriculture including the 5.5 million share tenants, agricultural leaseholders, regular and seasonal farmworkers as labor force.

Agricultural area was subclassified into 11.61 million hectares of active area and 3.13 million hectares of expansion area in 1983. Agricultural population estimated by NEDA, 1983, numbered 51,956 thousand in 1983, 54,378 thousand in 1985 and may reach 69,885 thousand in 2000, so thus the man-land ratio is decreasing from 0.28 and 0.27 to 0.21 with expansion, and from 0.22 and 0.21 to 0.17 in case of the agricultural area only.

The average land area and income of a small farm family are approximately 1.5 hectares and 1,335 pesos/month, respectively. The Department of Agriculture in the Philippines plans to increase the farm family income to at least 2,000 pesos/month.

Of the four crops, rice, corn, coconut and sugarcane, rice generally exhibited an upward trend in terms of area harvested, yield and total production except for the calendar year 1983 when both irrigated and rainfed rice crops experienced a decline of about 10 percent due to insufficient rainfall (Fig. 1 and 2). During that year the first semester crop was more adversely affected.

Corn showed the same trend as rice but experienced more frequent decreases in the area harvested and yield. For coconut the same trend was observed where yield and production declined in 1982 and 1983. Significantly, coconut which is a permanent crop, appears to have a slow recovery period and by 1986 it had recovered only 22 percent of the decrease experienced in 1983.

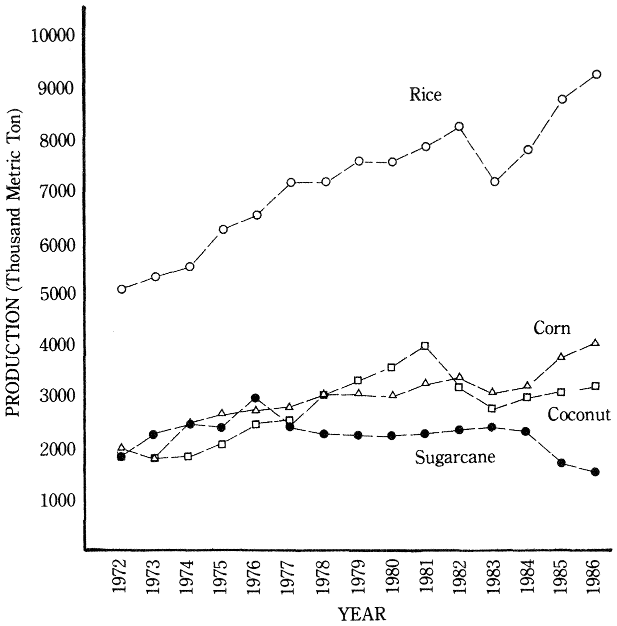

Fig. 1. Production of Rice, Corn, Coconut (Copra) and Sugarcane (Centrifugal) for Calender year 1972-1986

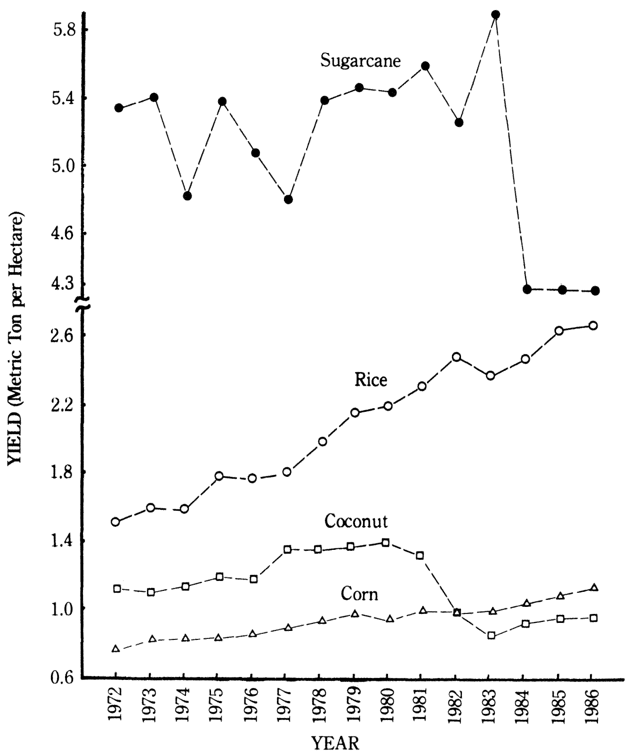

Fig. 2. Yield of Rice, Corn, Coconut (Copra) and Sugarcane (Centrifugal) for Crop years 1972-1986

I. 2. Climate

The Philippines has an annual mean temperature of 27°C, maximum monthly temperature of 29°C during April to June and minimum of 20°C during the period December to January. The difference of the monthly mean temperature is narrow with fluctuations of at most 5°C.

Agroclimatic map of the Philippines was prepared by the International Rice Research Institute using data from the Philippine Atmospheric, Geophysical, and Astronomical Services Administration. According to this map, the Climate of the Philippines is classified into 13 areas with periods of dry months and wet months (Fig. 3). A dry month and a wet month correspond to a rainfall amount of less than 100 mm per month and more than 200 mm per month, respectively. There are also peak rainfall areas with one or more months with a precipitation of more than 500 mm per month. Generally speaking, the wet zone is distributed along the Philippine sea and the dry zone is found in the area along the Luzon sea, Zamboanga and General Santos in Mindanao island. The Dry zone of Luzon island has a peak rainfall of one or two months with more than 500 mm per month. The climate of the Philippines is affected by a large number of typhoons, 32% reaching central

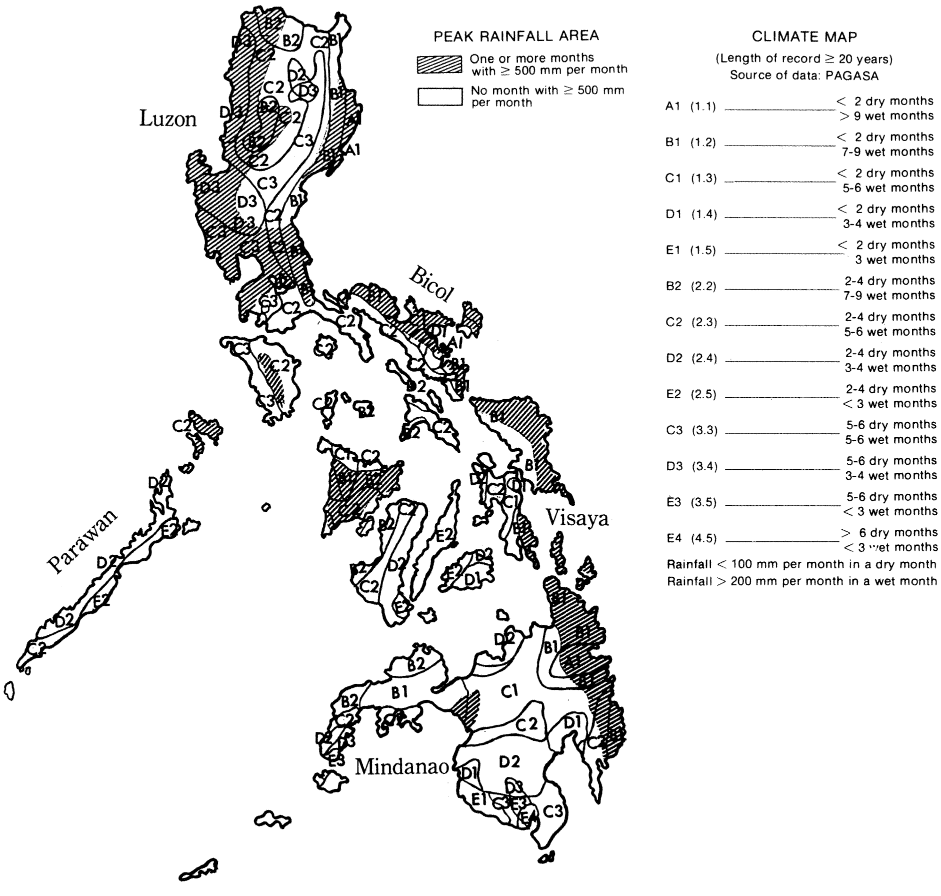

Fig. 3. Agroclimatic map of the Philippines

and northern Luzon, but few (7%) reaching southern Visaya. They occur unfrequently in (1%) Mindanao.

I. 3. Status of Soil Surveys, Classification and Problem Soils

As observed by Raymundo (1977), and Alcasid and Santos (1978), only reconnaissance soil surveys have been conducted with mapping of 1 to 250,000 by the Bureau of Soils.

Mariano and Valmidiano (1972) presented what can be considered as the first approximation of soils of the Philippines using the Great Soil Group category with an attempt to follow the Soil Taxonomy (1975). The use of such surveys and classification of Philippine soils is limited, and it is necessary to refine the series concept adopted. The methodology adapted was modified in order to meet the requirements of the agricultural development program and the needs to individual farmers.

Briones (1982a) summarized the general limitations and constraints of some of the major Great Group of Soils of the Philippines as shown in Table 2. Additionally, Briones estimated problem soils for rice based on the studies of Ponnamperuma and associates as follows:

Saline soils	400,000 (ha)
Acid sulfate soils	20,000
Peat soils	15,000
Alkali soils	5,000

Table 2. General limitations and constraints of some major Great Soil Groups of the Philippines

Great Soil Group	Inferred Constraints
Tropudults	Low mineral contents, aluminum and manganese toxicities probable, P fixation possible.
Paleudults	High aluminum, low mineral contents, N deficiency and low CEC, moderate P fixation.
Tropaquepts	Higher redox, aeration problems.
Dystradepts	High P fixation, low N release, nutrient imbalances, and water stress.
Tropudalfs	Slow water movement, erosive at high rainfall intensities, some tiallage problems moisture stress for drier counterparts.
Pellusterts	Narrow tillage range, moisture stress, very slow water movement.
Chromusterts	Same as Pellusterts but may have high contents of carbonates, P availability lower.
Tropaquents	Higher redox, drainage problem.
Fluvaquents	High redox, drainage problem, iron toxicity possible.

I. 4. Objectives

As the Philippine islands are part of a ring of fire surrounding the Pacific Ocean, a large number of volcanic ash soils are widely distributed. Mariano (1964) reported that Andepts are present around Mount Banahaw and the Taal volcano in Southern Luzon, Mount

Isarog and Mount Mayon in Bicol, in some parts of Negros island and in the Cotobato plain in Mindanao island when certain criteria of the Soil Taxonomy (1970) are used.

Briones (1982a) indicated that the Inceptisols occupy about 3,945,580 hectares accounting for 14% of the total area and 20% of the cultivated area of the country.

The authors' estimation of Mariano and Valmidiano's soil map (1973) shows that Andepts may occupy an area of about 935,879 hectares of which 24% consists of inceptisols accounting for 3% of the total area and 5% of the cultivated area, as shown in Table 3. The extent of Inceptisols is approximately equal to that of Vertisols. Ash-derived Tropepts, Aquepts and other soils, in addition to Andepts, may still increase the area of volcanic ash soils in the Philippines.

Presently, only few studies on the physico-chemical properties (Umali; 1982), mineral composition (Galvez; 1957a and 1957b, Briones; 1964, Montecillo and White; 1979), and soil genesis, survey and classification (Mariano; 1964, Valmidiano, Arnold and Derting; 1977, Fernandez and de Jesus; 1980) of volcanic ash soils in the Philippines have been conducted. Therefore, the principal objective of this study is to provide further analysis on the nature as well as the distribution of the volcanic ash soils in the Philippines and then to compare them with some volcanic ash soils of the temperate zone, such as Japan.

Table 3. Areas and ratios of various soil orders including Andepts in the philippines.

Soil Order	Area (hectares)	Ratio for total area (%)	Ratio for cultivated area (%)
Utisol	11,311,230	40	57
Inceptisol	3,945,580	14	20
Andept	935,879	3	5
Others	3,009,901	11	15
Alfisol	2,765,487	10	14
Vertisol	1,015,724	4	5
Entisol	658,536	2	3
Mountain area	8,289,008	30	—
Cultivated area	19,696,557	70	100
Total area	27,985,565	100	—

II. DISTRIBUTION AND MORPHOLOGICAL CHARACTERISTICS

In this chapter, the morphological characteristics are presented and described for volcanic ash soil profiles.

II. 1. Location of Soil Profiles

The locations of the soil profiles are shown in Figure 4.

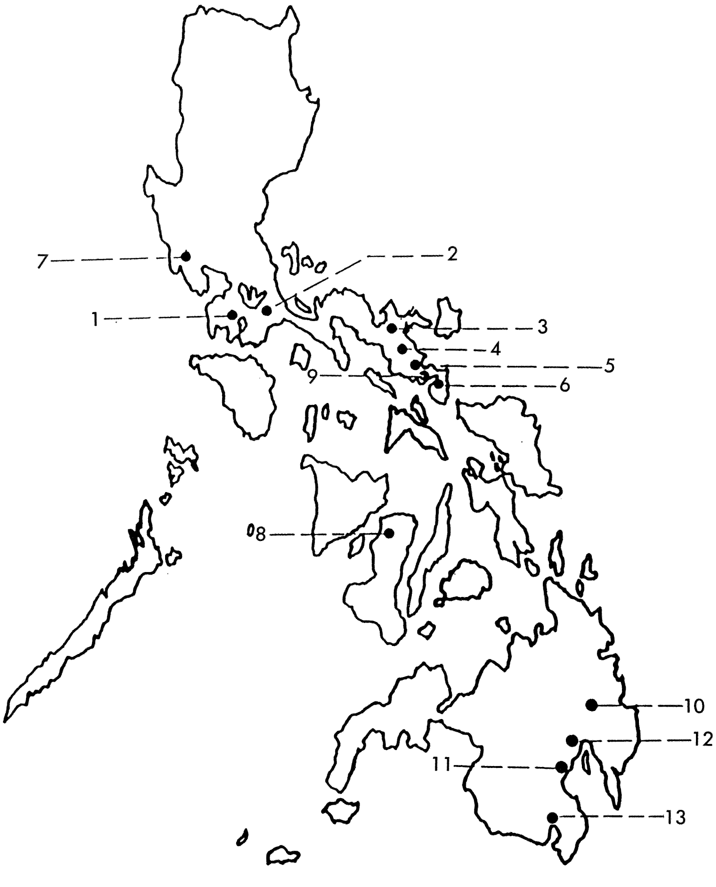

Fig. 4. Location of soil profiles in the Philippines.

1. Northwestern part of Taal volcano.
2. Northeastern part of foot of Banahaw volcano.
3. Northwestern part of foot of Isarog volcano.
4. Northeastern part of foot of Iriga volcano.
5. Northwestern part of foot of Mayon volcano.
6. Northwestern slope edge of Bulusan volcano.
7. Southwestern foot slope of Pinutubo mountain volcano in Zambales Province.
8. Northwestern part of Canlaon volcano in Negros Occidental.
9. Sorsogon red yellow soil (non-volcanic ash soil).
10. Monkayo red yellow soil (non-volcanic ash soil).
11. Bago Oshiro soil (non-volcanic ash soil).
12. Catarunan soil (rendina, non-volcanic ash soil).
13. General Santos soil (volcanic soils from Matutum Volcano)

II. 2. Description of Profiles

II. 2. 1. Northwestern slope of Mount Taal

Taal volcano is located at 640 m above sea level and 55 km south of Manila. A small crater can still be seen at the Taal lake. From Manila to Tagaytay, a gradual slope is observed (Fig. 5). These gently sloping areas are planted to papaya, mango, abaca, coffee, banana, pineapple and coconut in addition to grassland, vegetables and other upland crops. Intercropping as well as multiple cropping is practiced in this area. Alicante et al (1935) reported that the materials on the slope could be adobe, tuff and volcanic ash. Such materials may readily be observed from exposed layers. For instance, a 10-m deep road-cut near the Susanna Heights interchange of the south super highway (Fig. 6) shows that the lowest layer of this profile is a very compact illuvial layer consisting of a mixture of gravel and sand. The entire illuvial layer has a dark brown loam texture with tiger mottles. These features indicate that the layers may have been under submerged conditions in the geological past. There are two kinds of adobe on these loamy layers. One is

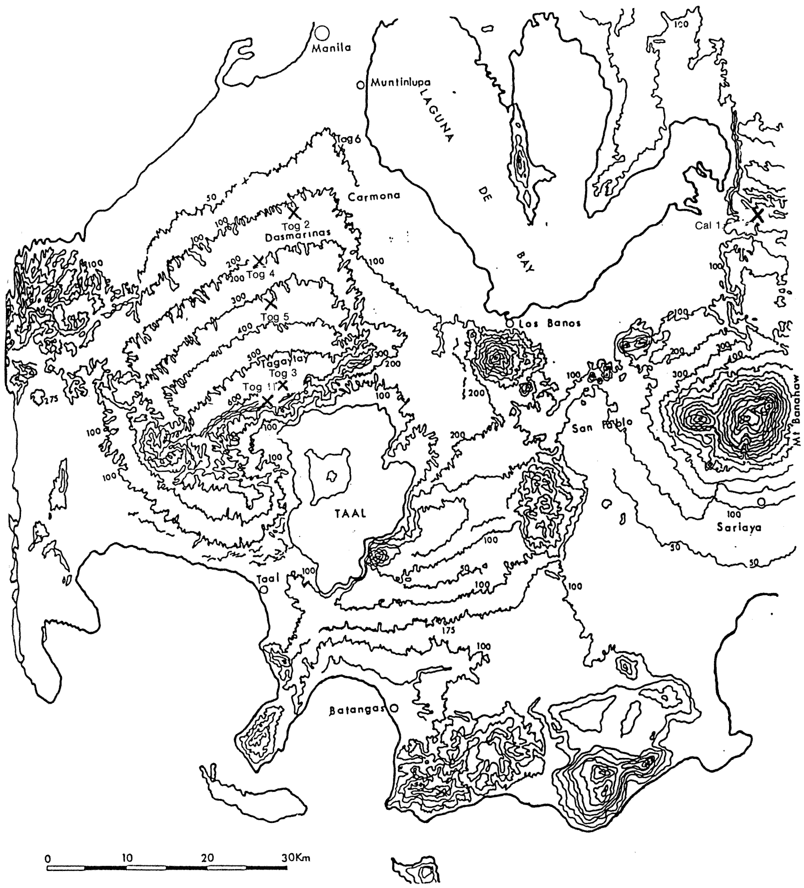

Fig. 5. Topography map around Taal and Banahaw volcanoes in southern Luzon.
X: Location of soil profile

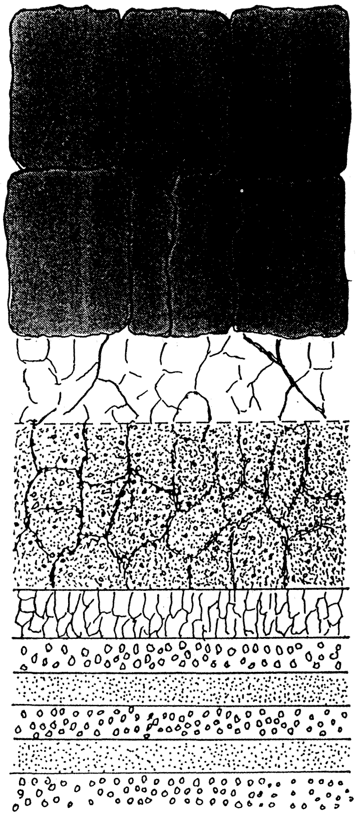

Fig. 6. Observation of "Adobe" in Tag-6.

gray brown and compact that crumbles when small pressures are exerted, whereas the other is very hard and apparently cemented. The latter overlies the former. According to Kuno's classification (Wentworth and Williams; 1932) of such rock formation, the lower adobe layer may be identified as lapili tuff while the upper is just plain tuff.

In relatively less eroded surfaces, these adobes show a yellowish brown layer with fine gravels. One of these profiles (Tag. 6 in Fig. 5) is near the 50 m contour line rather far from direct influence of volcanic deposition and therefore, it becomes reasonable to speculate that these materials may have accumulated from higher elevations, hence the layer may only be secondary in origin.

In Dasmarinas (Tag. 2: annual rainfall, 2026 mm and mean temperature, 27°C) a pale yellow layer with a platy to angular blocky structure can be seen over the adobe layer. According to Kuno's classification (1932), this layer may be considered to be a pumice tuff (Description 1).

Above this layer (75–105 cm), weathered materials of pumice tuff mixed with parts of B2 horizon form the B3 horizon.

The dark brown B2 horizon contains red scoria (2 to 3 mm in diameter) and gray scoria particles (about 1 mm in diameter).

The surface layer has many cracks and a subangular blocky structure 2 to 3 cm in diameter. As described, this profile shows the stratigraphy of volcanic ash/weathered pumice tuff/pumice tuff/adobe (tuff).

Description 1

Profile No. Tagaytay-2 (Tag-2)

Date of examination: November 17, 1982
Examined by: H. Otsuka and T. Adachi*
Location: Palapala, Dasmarinas, Cavite
Land form: Pyroclastic flow land, undulating volcanic foot slope, 180 m above sea level
Land use: Uncultivated, wild grass
Parent material: Volcanic ash

Horizon	Depth		Description
Ap	0—25	cm	Brownish black (10YR 3/2 moist) to brown (7.5YR 4/3 dry), moist, light clay, strong, coarse (20—30 mm) subangular blocky, sticky and very plastic, firm moist, common interstitial pores, few scoria (2—3 mm), common humus, abrupt, wavy boundary.
B2	25—45	cm	Dark brown (10YR 3/3 moist) to brownish black (7.5YR 3/2 dry), heavy clay, moist, strong coarse angular blocky, sticky and very plastic, firm moist, common red and gravy scoria, common humus, gradual, smooth boundary.
B3(IIC1)	45—75	cm	Brown (7.5YR 4/3 moist) to bright yellowish brown (7.5YR 3/4 dry), light clay, strong coarse angular blocky, sticky and very plastic, firm moist, gradual, smooth boundary.
IIC2	75—105	cm	Brown (10YR 4/4 moist) to light yellow (2.5YR 7/4 dry), light clay, strong coarse (50—100 mm) angular blocky, sticky and very plastic, broken thick manganese cutan, clear, smooth boundary.
IVR	105—	cm	Pyroclastic flow, "Adobe".

*Kyushu National Agricultural Experiment Station, Ministry of Agriculture, Forestry and Fisheries, Japan.

There are two kinds of soil profiles near the top of the mountain (Tag. 1 and 3: annual rainfall, 2321 mm and mean temperature, 22.7°C). One of these (Description 2) shows the presence of adobe (tuff), pumice tuff, B2 horizons which contain 2 to 3 mm red scoria, 1 mm gray scoria particles and a humic volcanic ash layer (VA1) with scoria particles also. The other profile (Description 3) has a young pumice layer between the surface humic layer and buried humic layer. The young pumice layer with a yellow color may be derived from materials accumulated during the eruption of 1966.

The basic soil profile of the northwestern slope of Mount Taal may reflect the properties of layers forming the characteristic stratigraphy consisting of young humic volcanic ash including young pumice/comparatively old humic volcanic ash/weathered pumice tuff/pumice tuff/tuff. The relationship between the model soil profiles, elevation and distance from the crater is shown in Figure 7. It was generally observed that the tuff and the adobe tended to be shallow, and the humic layer to be thinner with decreasing elevation and increasing distance from the crater. However, the presence of young volcanic ash on slopes located at less than 400 m above sea level, was not apparent (Description 4).

It may then be considered that the present surface layers of the area at lower elevations correspond to the buried layers of areas at high elevations.

Description 2

Profile No. Tagaytay-1 (Tag-1)

Date of examination: November 17, 1982
Examined by: H. Otsuka and T. Adachi
Location: Near Vista Lodge, Tagaytay City
Land form: Pyroclastic flow land, undulating, top of
Taal volcano foot slope, 640 m above sea level
Land use: Uncultivated, wild grass
Parent material: Volcanic ash

Horizon	Depth	Description
A	0—12 cm	Brownish black (5YR 2/1), moist, clay loam, fine granular blocky, sticky and plastic, very friable moist, very abundant humus, clean, smooth boundary.
IIA	12—27 cm	Black (5YR 1.7/1), moist, clay loam, fine granular blocky, sticky and plastic, very friable moist, abundant humus, clear, smooth boundary.
IIIA11	27—35 cm	Black (5YR 1.7/1), moist, light clay, sticky and plastic, friable moist, very abundant humus, gradual, smooth boundary.
IIIA12	35—44 cm	Very similar to horizon above except for abundant humus, clear, smooth boundary.
IVA1	44—51 cm	Brownish black (5YR 2/1), moist, light clay, angular blocky, sticky and plastic, slightly firm moist, few scoria, abundant humus, gradual smooth boundary.
IVB2	51—136 cm	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.
VC1	136—166 cm	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.
VIC2	166—230 cm	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.
VIC3	230—270 cm	Yellowish brown (10YR 5/6), light clay, moist, very firm moist, abundant gravels (2—3 mm), sticky and plastic, clear, smooth boundary.
VIIR	270— cm	"Adobe" mud flow bed.

Description 3

Profile No. Tagaytay-3 (Tag-3)

Date of examination: May 20, 1983
Examined by: H. Otsuka
Location: Kaybagal, Tagaytay
Land form: Pyroclastic flow land, undulating volcanic foot,
610 m above sea level
Parent mateial: Volcanic ash

Horizon	Depth	Description
A	0—15 cm	Brownish black (10YR 2/2) moist dull yellowish brown (10YR 4/3), moist, sandy loam, fine granular, sticky and plastic, very friable moist, abundant humus, clear, smooth boundary.

Description 3 (continued)

Horizon	Depth	Description
B	15—35 cm	Black (10YR 2/1 moist) to grayish brown (10YR 4/2 dry), moist, sandy loam, fine granular, common gravel (20—30 mm), sticky and slightly plastic, very friable moist, common humus, clear, smooth boundary.
IIC	35—43 cm	Brownish black (10YR 3/2 moist) to dull yellow orange (10YR 6/3 dry), moist, gravel (young pumice 20-30 mm), massive, nonsticky and nonplastic, extremely firm moist, black (10YR 1.7/2 moist) inside pumice, abrupt, smooth boundary.
IIIA	43—60 cm	Black (10YR 2/1 moist) to grayish yellow brown (10YR 4/2 dry), light clay, friable moist, few scoria (2—3 mm), gravels (1—2 mm, light yellow orange (7.5YR 8/3 dry), very abundant humus, clear, smooth boundary.
IVB1	60—75 cm	Very dark brown (7.5YR 2/3 moist) to brown (7.5YR 4/3 dry), moist, light clay, slightly firm moist, sticky and very plastic, common gravel, common scoria (2—3 mm), common humus, gradual, smooth boundary.
IVB2	75—125 cm	Very dark brown (7.5YR 2/3, moist) to dark brown (7.5YR 3/3 dry), moist, light clay, sticky and plastic to very plastic, few scoria (5YR 3/6 moist, 5YR 4/8 dry), common gravel (1—2 mm, light yellow orange 7.5YR 8/6 moist, 7.5YR 8/3 dry), few pumice materials, common humus, gradual, smooth boundary.
VC1	125—150 cm	Very dark reddish brown (5YR 2/3 moist) to dark brown (7.5YR 4/6 moist) to dark brown (7.5YR 4/6 moist) to bright yellowish brown (10YR 6/6 dry), moist light clay, sticky and plastic, few pisolite, few pumice materials, gradual, smooth boundary.
VC2	150—195 cm	Very dark brown (7.5YR 2/3 moist) to brown (7.5YR 4/6), moist, clay loam, sticky and plastic, common pumice (10YR 7/6 moist), common scoria (7.5YR 5/2 moist), few manganese concretions, gradual, smooth boundary.
VC3	195— cm	Dull yellowish brown (10YR 5/4 moist) to dark brown (7.5YR 3/4 dry), moist, clay loam, common pumice (bright yellowish brown 7.5YR 6/6), gravel (yellowish gray 2.5YR 6/1).

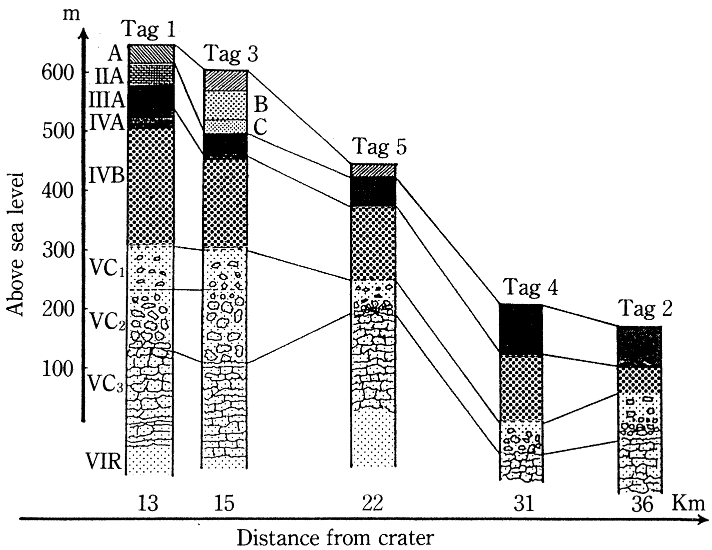

Fig. 7. Chronosequence of profile with increasing altitude and distance from crater.

Description 4

Profile No. Tagaytay-4 (Tag-4)

Date of examination: May 20, 1983
Examined by: H. Otsuka
Location: Punongbayan, General Trias, Cavite
Land form: Pyroclastic flow land, undulating volcanic foot slope, 230 m above sea level
Land use: Cultivated
Parent material: Volcanic ash

Horizon	Depth		Description
Ap	0—10	cm	Dark brown (7.5YR 3/3 moist) to brown (7.5YR 4/4 dry), moist, clay loam, sticky and plastic, many roots, common humus, medium granular, gradual, smooth boundary.
A3	10—20	cm	Very dark brown (7.5YR 2/3 moist) to brown (7.5YR 4/4 dry), moist, clay loam, sticky and plastic, common humus, gradual, smooth boundary.
IIA	20—35	cm	Dark reddish brown (5YR 3/4 moist) to dull reddish brown (5YR 4/4 dry), and few dull reddish brown (5YR 7/4 dry), clay loam to light clay, sticky and plastic, few gravels (1—2 mm light yellow orange 7.5YR 8/3 dry), common humus, gradual, smooth boundary.
IIIA	35—50	cm	Dark reddish brown (5YR 3/4 moist) to dull reddish brown (5YR 4/4 dry) and common dull reddish brown (5YR 5/4 moist) to dull yellow orange (10YR 7/4 dry), moist, clay loam to light clay, sticky and plastic, few gravels (1—2 mm light yellow orange), common humus, gradual, smooth boundary.
IVA	50—65	cm	Dark reddish brown (5YR 3/4 moist) to reddish brown (5YR 4/4 dry) and dull reddish brown (5YR 5/4 moist) to dull yellow orange, moist, light clay, sticky and plastic, few gravels (light yellow orange), common humus, gradual, smooth boundary.
IVB11	65—80	cm	Bright yellow brown (10YR 6/6 moist) to dull yellow orange (10YR 7/4 dry) and very dark reddish brown (5YR 2/3 moist) to dark reddish brown (5YR 3/3 dry), light clay, sticky and plastic, few gravels (similar to above horizon), gradual, smooth boundary.
IVB12	80—100	cm	Brownish black (5YR 2/3 moist) to dark reddish brown (5YR 3/3 dry) and bright yellowish brown (10YR 6/6 moist) to dull yellow orange (10YR 7/4 dry), clay loam, sticky and plastic, few gravels (similar to above horizon), gradual, smooth boundary.
IVC	100—	cm	Brown (10YR 4/6 moist) to bright yellowish brown (10YR 7/6 dry), clay loam, sticky and plastic, coarse angular blocky, weathered tuff.

Description 5

Profile No. Caliraya-1 (Cal-1)

Date of examination: November 16, 1982
Examined by: H. Otsuka and T. Adachi
Location: Around Caliraya Lake, Cavinti, Laguna
Land form: High terrace of basalt
Land use: Uncultivated, tall grass
Slope: Undulating
Parent material: Volcanic ash/basalt

Horizon	Depth		Description
A1	0—10	cm	Dark brown (7.5YR 3/3), moist, subangular blocky and granular (3 mm), heavy clay, sticky and very plastic, abundant humus, clear, smooth boundary.
A3	10—24	cm	Brown (7.5YR 4/3), moist, subangular blocky and moderate coarse (20—30 mm) angular blocky, sticky and very plastic, heavy clay, abundant humus, clear, smooth boundary.
B1	24—40	cm	Brown (7.5YR 4/4), moist, fine angular blocky, heavy clay, sticky and very plastic, common humus, clear, smooth boundary.
B21	40—70	cm	Brown (7.5YR 6/6), moist, fine (5—10 mm), angular blocky, sticky and very plastic, heavy clay, gradual, smooth boundary.
B22	70—85	cm	Reddish brown (5YR 4/6), moist, fine angular blocky, sticky and very plastic, heavy clay, gradual, smooth boundary.
IIB3	85—120	cm	Reddish brown (5YR 4/6), moist, fine angular blocky, sticky and very plastic, heavy clay, abundant gravels, abrupt, smooth boundary.
IIIC	120—	cm	Reddish brown (2.5YR 4/6) and dull yellow orange (10YR 6/4), moist, fine angular blocky, sticky and very plastic, heavy clay, "Tiger" mottle.

II. 2. 2. Northeastern part of Mount Banahaw (Caliraya district)

Mount Banahaw (2165 m) rises southeast of Laguna lake. The terraces of the slopes toward Laguna lake at about 200 to 300 m elevation (Cal-1 in Fig. 4) indicate the effects of water creating such landform. The area has an annual rainfall of 2864 mm and a mean temperature of 25.2°C.

Alicante et al (1948) examined some soil profiles of the area where the dominant series was the Luisiana series which supports the growth of coconut, buripalm, pandanus, sugarcane, upland rice, corn, banana, sweet potato, pineapple and lanzones. A panoramic view of the dominant vegetation which consists of coconuts can be seen from the vantage point of the Japanese Garden located on the embankment of Caliraya lake.

At least three kinds of soil profiles can be observed on the road-cuts along the road from Pagsanjan to Caliraya. One of these contains a surface layer dark brown in color, rich in humus and granular in structure. The B horizon derived from volcanic ash and a non-volcanic ash IIB horizon with many gravels of reddish brown color are shown in Description 5. The layer with tiger mottles is below the reddish brown layer. As suggested earlier, this layer could have been influenced by water long time ago.

Another soil does not have the reddish brown layer. Instead the layer with tiger mottles dominates and continues until IIB horizon.

The third kind of soil profiles does not show the IIB horizon, but exhibits a weathered pumice tuff under the B horizon of volcanic ash over laying the dark brown buried A horizon (perhaps an A horizon with reddish brown color) which extends down to the tiger mottled layer.

These three kinds of profiles are distributed in the area, and it is considered that the basic stratigraphy of the Caliraya area is that of volcanic ash/gravel layer/dark brown layer/reddish brown layer/tiger mottle layer. A more detailed soil survey should reveal the interrelationship between the profiles and even the origin of volcanic tuff.

The presence of a well-developed soil structure which may indicate higher degrees of weathering is one of the prominent morphological characteristics of volcanic ash layers. But the kind of volcanic ash which differs from that observed in Japan and other places does not provide a definite evidence for the presence of allophane. Furthermore, particles of pisolite 2 to 3 cm in diameter are observed in the weathered pumice tuff. It is interesting to note that these pisolite particles are similar to the materials present in soil profiles in Chikugo, Kyushu, Japan (Otsuka; 1980).

The weathered pumice tuff of Taal volcano also contains pisolite particles. The morphological characteristics of the tuff of Mount Banahaw also appears to be similar to that of Taal volcano.

II. 2. 3. Bicol district

Bicol district is located in the southeastern part of Luzon island, more like an extension of a belt. There are volcanoes along this belt, namely: Mt. Isarog, Mt. Iriga, Mt. Mayon and Mt. Bulusan.

(1) *Northwestern mountain slope of Isarog volcano* (Isarog Soil)

On the slopes of Mount Isarog, experiments were carried out by the Benchmark Soils Project of the University of Hawaii in collaboration with the Philippine Union College (PUC) and Philippine Council for Agriculture Resources Research and Development (PCARRD). Naga city can be seen in a westerly direction from this site (Fig. 8).

A soil profile from an uncultivated area is listed in Description 6. The A horizon is granular in structure, rich in humus and the B horizon has a well developed subangular to angular soil structure similar to the shallow Kuroboku (Andosol) in Japan. All the layers of this profile showed positive indications of the presence of allophane as reported by Amano (1981) when the same materials were examined.

(2) *Northeastern mountain slopes of Iriga volcano* (Iriga Soil)

Iriga volcano which is located 30 km southeast of Isarog volcano is identified as a strato volcano like Mt. Fuji in Japan (Fig. 8). The soil profile (Description 7) was examined at the road-cut of Santiago, Iriga City. This profile has a humus layer more than 50 cm deep and black brown in color. It has a fine texture (light clay), fairly developed soil structure but gave negative results in the allophane test.

(3) *Northwestern part of Mayon volcano* (Mayon Soil)

Mayon volcano which is 2421 m high, is a conical strato volcano located in the northwestern part of Legaspi City. The surface layers formed along the slopes are often eroded even at 200 m above sea level due to the presence of very steep slopes. The volcanic ash derived from Mayon volcano however, can be observed on terraces near foot slopes.

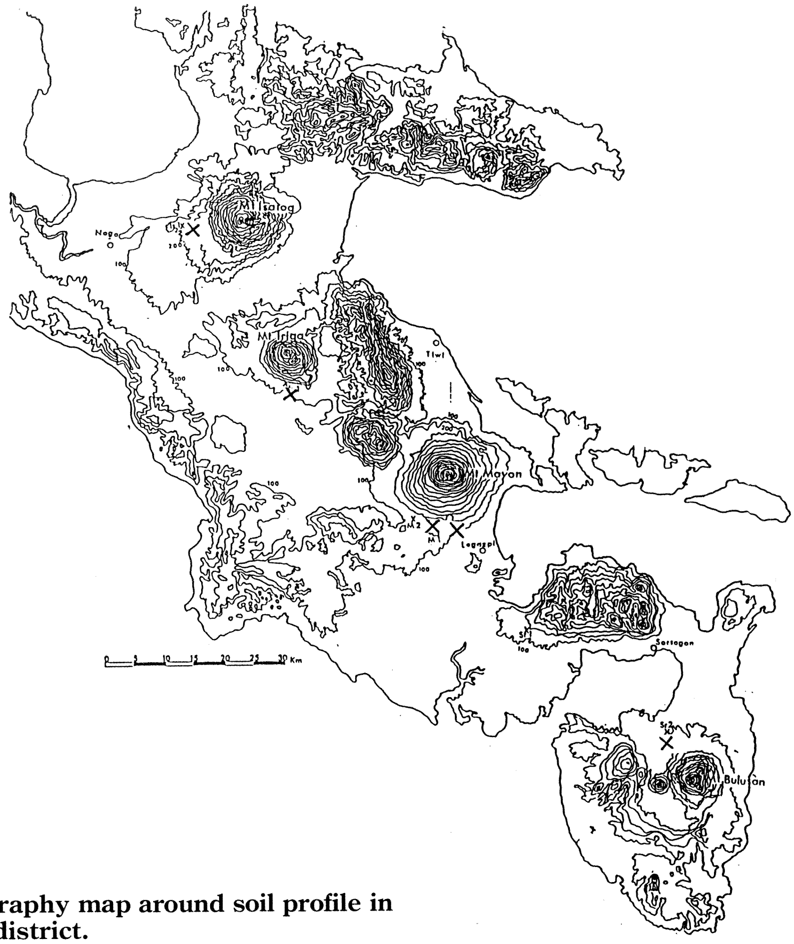

Fig. 8. Topography map around soil profile in Bicol district.

Is 1: Isarog-1, Ir 1: Iriga-1, M 1: Mayon-1,
M 2: Mayon-2, Sr2: Sorsogon-2.

The profile of Mayon 2 (Description 8) was examined at the edge of the Mount Mayon slope where a deposited humic layer is found under thick young volcanic ash. The profile of Mayon 1 (Description 9) was examined at a road-cut of the northern terrace of Mayon volcano along highway route 1. The morphology of M-1 shows a fine-grained texture which may indicate the presence of old volcanic ash while M-2 is coarse-grained and contains relatively young volcanic ash. M-1 did not show a positive reaction to the allophane test, while M-2 reacted positively.

(4) *Northwestern slope of Bulusan volcano* (Sorsogon 2)

Bulusan volcano is located 70 km southeast of the Mayon volcano. The description is obtained from a profile (Description 10) on the edge of the slope of Bulusan volcano (Fig. 8). The surface layer (A horizon) is thin and has a very low humus content. The profile has a fine-grained and well-weathered volcanic ash layer similar to that of the dark brown forest soils of Japan and other places.

Description 6

Profile No. Isarog-1 (IS-1)

Date of examination: November 25, 1982
Examined by: T. Adachi and H. Otsuka
Location: Philippine Union College, Carolina, Camarines Sur
Land form: Volcanic foot slope, undulating, pyroclastic flow land, 200 m, a.s.l.
Land use: Uncultivated, wild grass
Parent material: Volcanic ash

Horizon	Depth		Description
A11	0—6	cm	Back (7.5YR 2/1), moist, clay loam, fine granular, very friable moist, slightly sticky and slightly plastic, very abundant humus, clear, smooth boundary, C 15.
A12	6—15	cm	Black (7.5YR 1.7/1), moist, clay loam, fine granular, very friable moist, slightly sticky and plastic, very abundant humus, clear, smooth boundary, C 20.
A13	15—25	cm	Black (7.5YR 1.7/1), moist, clay loam, fine granular, very friable moist, slightly sticky and plastic, very abundant humus, clear, smooth boundary, C 18.
IIA	25—32	cm	Brownish black (7.5YR 2/2), moist, clay loam, fine granular, very friable moist, slightly sticky and slightly plastic, abundant humus, clear, smooth boundary, C 23.
IIIB11	32—46	cm	Dark brown (10YR 3/4), moist, clay loam, fine subangular blocky, friable moist, slightly sticky and plastic, gradual, smooth boundary, C 26.
IIIB12	46 — 57	cm	Brown (10YR 4/4), moist, clay loam, fine subangular blocky, friable moist, slightly sticky and plastic, gradual, smooth boundary, C 26.
IIIB21	57—77	cm	Brown (10YR 4/6), moist, clay loam to light clay, fine angular blocky, friable moist, slightly sticky and plastic, gradual, smooth boundary, C 22.
IVB22	77—107	cm	Brown (7.5YR 4/6), moist, clay loam to light clay, fine angular blocky, friable moist, slightly sticky and slightly plastic, abrupt, smooth boundary, C 22.
VA	107—	cm	Dark brown (7.5YR 3/4), moist clay loam to light clay, fine angular blocky, friable moist, slightly sticky and slightly plastic, common humus, C 22.

C: Compactness index

Description 7

Profile No. Iriga-1 (Ir-1)

Date of examination: December 3, 1983
Examined by: H. Otsuka
Location: Santiago, Iriga
Land form: Undulating foot slope
Land use: Coconut
Parent material: Volcanic ash

Horizon	Depth		Description
A11	0—15	cm	Black (5YR 1.7/1 moist) to brownish black (10YR 3/2 dry), clay loam, fine granular structure, sticky and plastic, many roots, very abundant humus, clear, smooth boundary, C 10.

Description 7 (continued)

Horizon	Depth		Description
A12	15—30	cm	Brownish black (5YR 2/1 moist) to dark brown (10YR 3/3 dry), light clay, medium subangular blocky structure, sticky and plastic, many roots, very abundant humus, clear, smooth boundary, C 13.
A13	30—50	cm	Brownish black (5YR 2/1 moist) to dull yellowish brown (10YR 4/3 dry), light clay, medium angular blocky structure, sticky and plastic, many roots, abundant humus, clear, smooth boundary, C 18.
IIB11	50—70	cm	Brownish black (5YR 2/2 moist) to dull yellowish brown (10YR 5/3 dry), clay loam to light clay, medium angular blocky structure, sticky and plastic, many roots, common humus, gradual, smooth boundary.
IIB12	70—85	cm	Dark reddish brown (5YR 3/2 moist) to grayish yellow brown (10YR 5/2 dry), clay loam to light clay, common humus, abrupt, smooth boundary, C 20.
IIIC	85—90	cm	Volcanic gravel layer
IVB	90—	cm	Dark reddish brown (5YR 3/3 moist) to grayish yellow brown (10YR 6/2 dry), sandy loam, sticky and nonplastic, C 19.

Description 8

Profile No. Mayon-2 (M-2)

Date of examination: December 3, 1983
Examined by: H. Otsuka
Location: San Rafael, Guinobatan, Albay
Land form: Pyroclastic flow, foot slope of mountain
Laud use: Coconut
Parent material: Volcanic ash

Horizon	Depth		Description
A1	0—15	cm	Brownish black (7.5YR 2/2 moist) to dull yellowish brown (10Y/R 4/3 dry), loam, few fine granular, common roots, abundant humus, clear, smooth boundary.
IIAC	15—30	cm	Very dark brown (7.5YR 2/3 moist) to grayish yellow brown (10YR 5/2 dry) sandy loam, fine granular, abundant medium gravels, common roots, abundant humus, clear, smooth boundary.
IIIA3	30—45	cm	Dark brown (7.5YR 3/3 moist) to dull yellowish brown (10YR 5/2 dry) loam to clay loam, fine granular, common roots, abundant humus, clear, smooth boundary.
IIIC	45—53	cm	Brownish black (7.5YR 3/3 moist) to dull yellowish brown (10YR 5/4 dry), loamy sand, scoria 1 to 3 mm, common roots, clear, smooth boundary.
IVA3	53—65	cm	Black (7.5YR 2/1 moist) to dull yellowish brown (10YR 4/3), sandy loam, crumble, common humus, clear, smooth boundary.
VA11	65—80	cm	Black (7.5YR 2/1 moist) to brownish black (10YR 3/2 dry), light clay, medium subangular blocky, few roots, very abundant humus, gradual, smooth boundary.
VA12	80—95	cm	Black (1.7/1 moist) to brownish black (10YR 2/3 dry), light clay, fine to medium subangular blocky, very abundant humus, few roots.
VIA3	95—109	cm	Brownish black (7.5YR 2/2 moist) to dull yellowish brown (10YR 4/3 dry), silty clay loam, very weak subangular blocky to massive common to abundant humus.

Description 9

Profile No. Mayon-1 (M-1)

Date of examination: December 3, 1983
Examined by: H. Otsuka
Location: Makabog, Daraga, Albay
Land form: Pyroclastic flow, undulating foot slope
Land use: Uncultivated
Parent material: Volcanic ash

Horizon	Depth		Description
A1	0—15	cm	Brown (7.5YR 4/3 moist) to dull brown (7.5YR 5/3 dry), light clay, medium subangular blocky, sticky and plastic, many big roots, abundant humus, gradual, smooth boundary, C 10.
A3	15—25	cm	Dark brown (7.5YR 3/4 moist) to dull brown (7.5YR 5/3 dry), light clay, medium subangular blocky, sticky and plastic, many roots, abundant humus, common round medium gravel, gradual, smooth boundary, C 16.
B	25—50	cm	Dark brown (7.5YR 3/3 moist) to brown (7.5YR 4/4 dry), light clay, medium angular blocky, sticky and plastic, common fine roots, common humus, common gravel, clear, smooth boundary, C 15.
IIB	50—80	cm	Dark brown (7.5YR 3/3 moist) to dull brown (7.5YR 5/3 dry), light clay, medium angular blocky, sticky and plastic common humus, common gravel, clear, smooth boundary, C 18.
IIIA1	80—105	cm	Brownish black (7.5YR 3/2 moist) to dull brown (7.5YR 5/4 dry), light clay, medium angular blocky, sticky and plastic, common humus, gradual, smooth boundary.
IVA3	105—	cm	Brownish black (7.5YR 3/2 moist) to bright brown (7.5YR 5/6 dry), light clay, common humus, medium angular blocky, C 25.

Description 10

Profile No. Sorsogon-2 (Sr-2)

Date of examination: December 3, 1983
Examined by: H. Otsuka
Location: Casiguran, Sorsogon
Land form: Undulating, edge of Mt. Bulusan foot slope
Land use: Coconut uncultivated

Horizon	Depth		Description
A1	0—10	cm	Brownish black (5YR 2/3 moist) to dull brown (7.5YR 5/8 dry), light clay, fine to medium granular, sticky and plastic, many roots, abundant humus, clear, smooth boundary, C* 9.
A3	10—20	cm	Dark reddish brown (5YR 3/3 moist) to brown (7.5YR 4/4 dry), light clay, fine granular to subangular blocky, sticky and plastic, many roots, common humus, clear, smooth boundary, C 11.
B1	20—30	cm	Dark reddish brown (5YR 3/3 moist) to bright brown (7.5YR 5/6 dry), heavy clay, medium subangular blocky, sticky and plastic, common few humus, gradual, smooth boundary, C 17.

Description 10 (continued)

Horizon	Depth	Description
B21	30—45 cm	Dull reddish brown (5YR 4/4 moist) to orange (7.5YR 6/6 dry), heavy clay, medium subangular blocky, sticky and plastic, common roots, gradual, smooth boundary, C 18.
B22	45—75 cm	Dark reddish brown (5YR 3/4 moist) to bright reddish brown (5YR 5/6 dry), heavy clay, sticky and plastic, sub to angular blocky, gradual, smooth boundary, C 19.
B3	75—95 cm	Dark reddish brown (5YR 3/6 moist) to dull reddish brown (5YR 5/4 dry), light to heavy clay, sticky and plastic, common roots, gravel, saprolite, gradual, smooth boundary, C 19.
C	95—125 cm	Reddish brown (5YR 4/6 moist) to bright reddish brown (5YR 5/8 dry), light clay to heavy clay, medium subangular blocky, common gravel saprolite, sticky and plastic, clear, smooth boundary, C 19.
IIB	125 cm	Bright reddish brown (5YR 5/6 moist) to dull orange (5YR 6/4 dry), heavy clay, subangular to angular blocky, common Mn mottles, C 16.

C: Compactness index

II. 2. 4. Southwestern foot slope of Pinutubo volcano

Santo Tomas river is flowing along the road which runs from San Marcelino town. Marella river, a tributary of Santo Tomas river originates from Mount Pinutubo flowing around Mount Bagano (320 m). Some parts of the area are on the foothills of the Pinutubo volcano and others are river terraces formed by the Marella river (Fig. 9).

Citrus trees are planted in some parts of the area with indigenous vegetation growing in the remaining part.

The profile of Z-1 (Description 11) corresponds to the foothills where citrus trees are planted after sugarcane. The profile contains a black brown, thick (more than 45 cm) humic layer and then a C horizon which changes to a white color after drying as Shirasu, a pyroclastic flow material in Southern Kyushu, Japan. The C horizon also contains many pumice particles. All the layers of this profile showed a positive reaction to the allophane test.

The profile of Z-2 (Description 12) is located on the terrace of the Marella river. The layers of this profile may be secondary deposits influenced by water. The surface layer is thin and poor in humus. Many rounded sandstones are observed under the humic layers which may indicate the action of water on this material.

The Z-3 profile (Description 13) was observed on a terrace opposite to Z-2. This profile showed a similar morphology to that of Z-2 which also contained many rounded stones in the subsoil. Both profiles Z-2 and Z-3 showed a positive reaction to the allophane test.

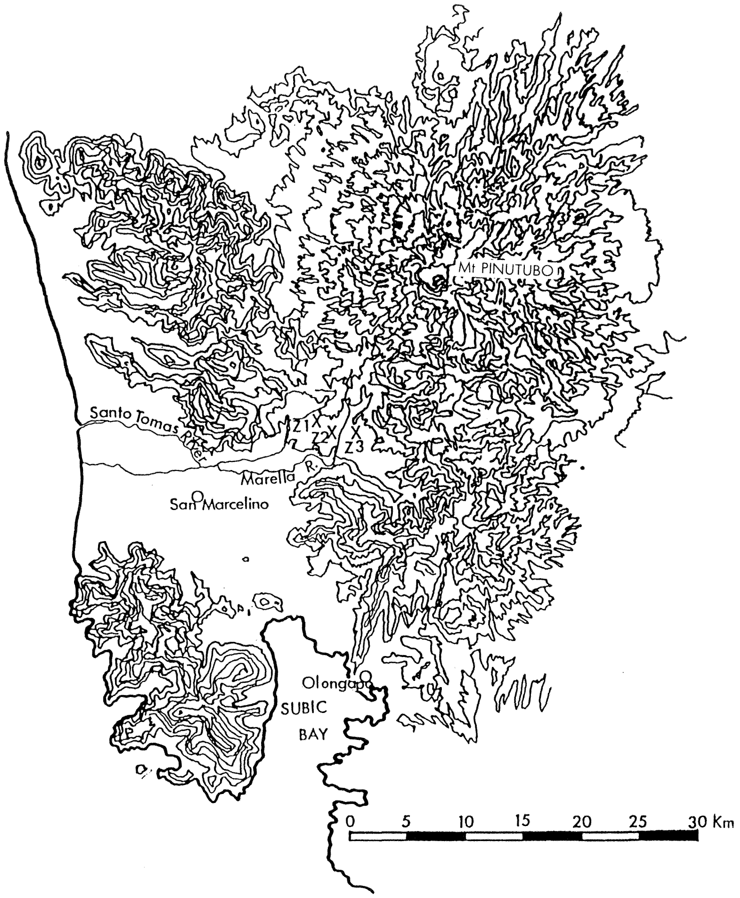

Fig. 9. Topography map around Pinutubo volcano.

Z 1: Zambales-1
Z 2: Zambales-2
Z 3: Zambales-3

Description 11

Profile No. Zambales-1 (Z-1)

Date of examination: January 27, 1984
Examined by: H. Otsuka, A. M. Briones and Ed. Paningbatan
Location: Santa Fe, San Marcelino, Zambales
Land form: Pyroclastic flow, undulating foot slope,
160 above sea level
Land use: Citrus orchard after sugarcane
Parent material: Volcanic ash

Horizon	Depth		Description
Ap	0—18	cm	Black (7.5YR 1.7/1 moist) to very dark brown (7.5YR 2/3 dry), loam, crumble to fine granular structure, friable sticky and plastic, many roots, very abundant humus, clear, smooth boundary.

Description 11 (continued)

Horizon	Depth		Description
IIA1	18—35	cm	Black (5YR 1.7/1 moist) to brownish black (7.5YR 2/2 dry dry), moist, loam, common pumice, (5 mm in diameter), fine weak subangular, friable, sticky and plastic, many roots, abundant humus, clear, smooth boundary.
IIA3	35—45	cm	Black (10YR 1.7/1 moist) to brownish black (10YR 2/2 dry), moist, loam, common pumice (5 mm in diameter), fine weak subangular structure, sticky and plastic, few roots, abundant humus, abrupt, smooth boundary.
IIB	45—55	cm	Black (10YR 2/1 moist) to dark brown (10YR 3/3 dry), moist, loam, common pumice, few roots, common humus, clear, smooth boundary.
IIC1	55—68	cm	Brownish black (10YR 3/2 moist) to brown (7.5YR 4/3 dry), moist, loam, abundant pumice materials, fine subangular structure, clear, smooth boundary.
IIC2 (or IIIC2)	68—98	cm	Dull yellowish brown (10YR 5/4 moist) to dull yellow orange (10YR 7/3 dry), moist, sandy loam, very abundant pumice material and gravels, gradually, smooth boundary.
IIC3 (or IV2)	98—	cm	Dull yellowish brown (10YR 6/6 dry), moist, sandy loam, very abundant pumice materials.

Description 12

Profile No. Zambales-2 (Z-2)

Date of examination: January 22, 1984
Examined by: H. Otsuka, A. M. Briones and Ed Paningbatan
Location: San Isidro, Castellejos, Zambales
Land use: Uncultivated, wild weeds
Topography: River terrace (alluvial fan)
Parent material: Volcanic ash

Horizon	Depth		Description
A11	0—11	cm	Brownish black (7.5YR 3/1 moist) grayish brown (7.5YR 4/2 dry), moist, clay loam, granular structure, few gravel, abundant humus, gradually, smooth boundary.
A12	11—12	cm	Black (10YR 7.1/1 moist) to brownish black (10YR 3/2 dry), loam, granular structure, common gravel, abundant humus, gradually, smooth boundary.
IIA (or A13)	23—36	cm	Black (5YR 7.1/1 moist) to brownish black (7.5YR 4/1 dry), moist, sandy loam, granular structure, abundant gravel (2—3 cm in diameter), abundant humus, clear, smooth boundary.
IIIAC	36—60	cm	Black (10YR 2/2 moist) to brownish black (10YR 3/2 dry), moist, loamy sand, very abundant gravels (2 to 20 cm in diameter), abrupt, smooth boundary.
IVC1	60—75	cm	Grayish yellow brown (10YR 5/2 moist) to grayish yellow brown (10YR 6/2 dry), moist, loamy sand, very abundant gravels, gradually, smoth boundary.
IVC2	75—85	cm	Dull yellow orange (10YR 7/3 moist) to (10YR 6/3 moist), moist, loamy sand, abundant gravels.

Description 13

Profile No. Zambales-3 (Z-3)

Date of examination: January 28, 1984
Examined by: H. Otsuka, A. M. Briones and Ed. Paningbatan
Location: San Isidro, Castellejos, Zambales
Land form: Alluvial fan (river terrace)
Land use: Uncultivated since one year, wild grass after sugarcane cropped for five years
Parent material: Volcanic ash

Horizon	Depth	Description
A11	0—10 cm	Black (7.5YR 1.7/1 moist) to brownish black (10YR 3/2 dry), clay loam, fine granular structure, many roots, slightly sticky and slightly plastic, abundant humus, gradually, smooth boundary.
A12	10—34 cm	Black (10YR 1.7/1 moist) to brownish black (10YR 3/2 dry), loam to sandy loam, fine granular structure, many roots, slightly sticky and slightly plastic, abundant humus, clear, smooth boundary.
IIA	34—47 cm	Black (7.5YR 2/1 moist) to brownish black (7.5YR 2/1 dry), sandy loam, slightly sticky and nonplastic, abundant humus, clear, smooth boundary.
IIIAC	47—73 cm	Similar to IVAC of Z-2.
IVC1	73-80 cm	Similar to IVC1 of Z-2.
IVC2	80—90 cm	Similar to IVC2 of Z-2.

II. 2. 5. Negros soils

Ashes erupted from Canlaon volcano are known to distribute around Bacolod City (annual rainfall, 2350 mm, and mean temperature, 26.9°C) in Negros island.

In this survey, five profiles were examined. These profiles are located at increasing elevation at N-4 (50 m), N-5 (100 m), N-1 and N-3 (150 m) and N-6 (370 m) (Fig. 10).

N-4 is located in the coastal plain and iron mottles are easily observed in this profile. The presence of the mottles indicates the influence of reduction associated with a certain degree of submergence. N-5 is on a rolling hill with a surface layer that contains small amounts of volcanic ash. However, the parent materials were found to be igneous in nature according to Alicante et al. (1951).

Except for the N-5 profile, the other profiles showed a positive reaction to the allophane test. The materials also contained relatively high amounts of available phosphorus based on a field tests.

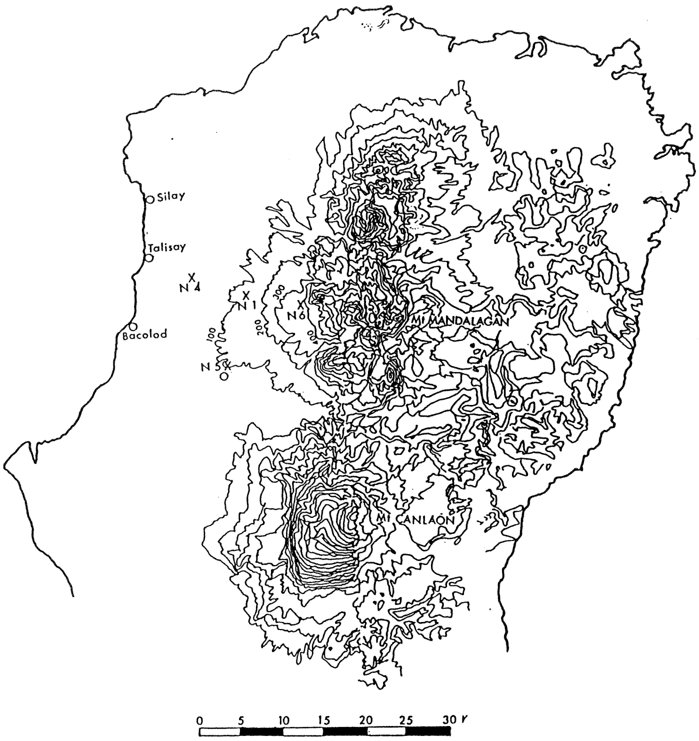

Fig. 10. Topography map around Mount Canlaon and Mount Mandalagan in northern Negros Occidental.

N 1: Negros-1, N 4: Negros-4, N 5: Negros-5,
and N 6: Negros-6.

Description 14

Profile No. Negros-1 (N-1)

Date of examination: May 18, 1984
Examined by: H. Otsuka and Ed. Paningbatan
Location: Hda. Ana Moria, Talisay, Negros Occidental
Land form: Pyroclastic fall and flow land, foot of Mt. Canlaon, the surface layer was gradually eroded
Land use: Sugarcane
Parent material: Volcanic ash
Land owner: Lito Coscuella

Horizon	Depth		Description
Ap1	0—19	cm	Brownish black (10YR 2/2 moist) to dull yellowish brown (10YR 5/3 dry), moist, loam, nonsticky and non-plastic, many roots, rich humus, granular, clear, smooth boundary, available phosphate content high, allophane test strong, C 13.
Ap2 (or A13)	19—32 to 42	cm	Brownish black (10YR 2/2 moist) to grayish yellow brown (10YR 4/2 dry), moist, loam, nonsticky and nonplastic, very rich humus, granular, clear, wavy boundary, available phosphate content high, allophane test strong, C 26.

Description 14 (continued)

Horizon	Depth		Description
B1	32 to 42—59	cm	Brownish black (10YR 2/3 moist) dark brown (10YR 3/4 dry), moist, clay loam, sticky and plastic, subangular blocky, common humus, available phosphate content high, allophane test strong, C 22.
B2	50—75	cm	Dark brown (10YR 3/4 moist) to brown (10YR 4/4 dry), moist, clay loam, sticky and plastic, angular blocky, common weathered pumice (0.5—5 mm), available phosphate content high, allophane test strong, C 23.

N-2 belongs to same field. As it is located near the top of the foot slope, the surface layer is eroded slightly strong. N-3 is adjacent to N-1.

Description 15

Profile No. Negros-4 (N-4)

Date of examination: May 18, 1984
Examined by: H. Otsuka and E. Paningbatan
Location: Hda. Santa Teresita, Talisay, Negros Occidental
Land form: Coastal alluvium
Land use: Sugarcane
Parent material: Volcanic ash

Horizon	Depth		Description
Ap1	0—20	cm	Brownish black (10YR 2/2 moist) to dark brown (10YR 3/3 dry), moist, loam, nonsticky and nonplastic, many roots, rich humus, crumble, common iron mottles, gradual, smooth boundary, available phosphate content high, allophane test weak, C 23.
Ap2	20—28	cm	Brownish black (10YR 2/2 moist) to dull yellowish brown (10YR 4/2 dry), moist, clay loam, slightly sticky, and slightly plastic, rich humus, many mottles, clear, smooth boundary, available phosphate content high, allophane test weak, C 23.
B11	28—48	cm	Dark brown (7.5YR 3/4 moist) to brown (7.5YR 4/6 dry), moist, light clay, sticky and plastic, common humus, subangular blocky, many Fe mottles, gradual, smooth boundary.
B12	48—78	cm	Dark brown (7.5YR 3/4 moist) to brown (10YR 4/4 dry), moist, light clay, very sticky and very plastic, many gray scoria sand, angular blocky, common humus, common Fe mottles, C 23.

Description 16

Profile No. Negros-5 (N-5)

Date of examination: May 19, 1984
Examined by: H. Otsuka and Ed. Paningbatan
Location: Hda. Bituin, Murcia, Negros Occidental
Land form: Rolling slope
Land use: Sugarcane
Parent material: Volcanic ash

Description 16 (continued)

Horizon	Depth		Description
Ap11	0—10	cm	Brownish black (5YR 2/2 moist) to dull reddish brown (5YR 4/3 dry), moist, heavy clay, very sticky and plastic, granular, very weak allophane test, clear, smooth boundary.
Ap12	10—23	cm	Brownish black (5YR 2/2 moist) to grayish brown (5YR 4/2 dry), moist, heavy clay, very sticky and very plastic, subangular blocky, common iron mottles (reddish brown (5YR 4/8), gradual, smooth, C 17.
Ap2	23—33	cm	Brownish black (5YR 1/3 moist) to grayish brown (5YR 4/2 dry), very sticky and plastic, subangular blocky, including stem of sugarcane, common iron mottles, abrupt, smooth, C 12.
B1	33—70	cm	Dark brown (7.5YR 3/4 moist) to dull brown (7.5YR 5/4 dry), moist, heavy clay, very sticky and very plastic, subangular blocky, few manganese mottles, many white sand particles (feldspar), gradual, smooth, C 21.
B2	70—83	cm	Dark brown (7.5YR 3/3 moist) to brown (7.5YR 4/4 dry), moist, heavy clay, common iron and manganese mottles, very sticky and very plastic, C 23.

Description 17

Profile No. Negros-6 (N-6)

Date of examination: May 19, 1984
Examined by: H. Otsuka and Ed. Paningbatan
Location: Hda. Perpetua, Cabatangan, Talisay, Negros Occidental
Land form: Pyroclastic fall, foot slope of Mt. Mandalgan
Land use: Road cut, uncultivated
Land owner: Yron Lacson
Parent material: Volcanic ash

Horizon	Depth		Description
A1	0—15	cm	Brownish black (10YR 3/2 moist) to grayish yellow brown (10YR 6/2 dry), sandy loam, nonsticky and plastic, many roots, rich humus, granular, clear, smooth boundary.
IIA	15—20	cm	Brownish black (10YR 2/2 moist) to grayish yellow brown (10YR 6/2 dry), sandy loam, nonsticky and nonplastic, rich humus, granular, clear, smooth boundary.
IIB	20—50	cm	Dull yellowish brown (10YR 4/3 moist) to dull yellow orange (10YR 7/3 dry), moist, sandy loam, nonsticky and nonplastic, clear, smooth boundary.
IIIC	35	cm	Dull yellowish brown (10YR 4/3 moist) to dull yellow orange (10YR 7/2 dry), moist, nonsticky and nonplastic, sandy loam to clay loam, volcanic sand, abrupt, irregular.
IVC	50—60	cm	Dull yellowish brown (2.5YR 4/3 moist) to light yellow orange (10YR 8/3 dry), moist, loam, slightly sticky and slightly plastic, common scoria (of 2—0.2 mm in diameter), (5Y 3/1 moist 5Y 5/1 dry), clear, smooth boundary)

Description 17 (continued)

Horizon	Depth	Description
VC1	60—100 cm	Bright yellowish brown (2.5Y 6/6 moist) to pale yellow (2.5Y 8/4 dry), clay loam, sticky and plastic, common scoria (5Y 3/2 moist 5Y 6/2 dry), common gravel, gradual, smooth boundary.
VC2	100— cm	Bright yellowish brown (2.5Y 6/6 moist) to pale yellow (2.5Y 8/3 dry), clay loam, sticky and plastic, common scoria (2.5Y 3/2 moist, 5Y 6/1 dry).

II. 3. Summary

Detailed morphological characterization of some pedons derived from volcanic ash materials of the Philippines was the first step of studies on the pedology of the Philippine soils. Profiles examined on the northwestern section of the Taal volcano indicated clear influences of eruption of the volcano and interruption with a sequence of the layers from the surface in the following order: volcanic ash/humic substances/weathered pumice tuff/pumice tuff/tuff. The last two layers (pumice tuff and adobe tuff) tended to thin out as the distance from the crater increased. The absence of top layers in the profile farther from the crater may indicate either the effect of erosional processes or that the erupted materials did not reach the existing surface at the time of the eruption.

The sequence of layering on the Caliraya terraces appeared to be that of volcanic ash/pumice tuff/dark brown layer/reddish brown layer/tiger mottle layer. Materials below the volcanic ash and tuff were derived from either basalt or andesite rock. It was also noted that pisolites were present in the pumice layer.

The characteristics reavealed in the soil profile along the footslopes of Isarog volcano were similar to those of Kuroboku (Andosol) in Japan at least in the presence of a brownish black surface, rich in humus, and granular structure. In general, the profiles of volcanic ash soils in the Philippines have a well developed structure. Those obtained from Mt. Isarog, Pinutubo, Canlaon and young volcanic ash of Mt. Mayon showed the presence of allophane based on a field tests for this clay material. No indication of allophane was observed for the other soils although they may contain relatively large amounts of humic substances.

III. SOME PHYSICAL AND CHEMICAL PROPERTIES

The surface of a landscape is sometimes covered with new deposits of pyroclastic and fragmented materials after the eruption of the volcano. Depending on the age (Otsuka; 1978, Yoshida and Kumada; 1979) of the deposits and the environmental conditions (Adachi; 1973, Kobo and Ohba; 1973) after the eruption, the development of the soils formed from these deposits ranges from immature Entisols to soils in advanced state of maturity such as Ultisols.

The physical and chemical properties of the soils derived from volcanic ash are strongly influenced by the degree of weathering of the pyroclastic materials. Therefore, the degree of weathering influences the productivity of volcanic ash soils as affected by the physics and chemistry of these systems.

It is important to examine certain physical and chemical properties of volcanic ash soils in the Philippines due to the dearth of studies regarding these soils for the purpose of soil resources inventory.

The objective of this study is to investigate some common physical and chemical properties of the soils for comparing their characteristics with those found in Japan.

III. 1. Materials and Methods

III. 1. 1. Soil Samples

Soil samples taken from each horizon of the profiles described in Chapter II were air-dried and passed through a 2-mm sieve.

III. 1. 2. Methods

(1) *pH*

Soil reaction was determined electrometrically using a pH meter. The pH in water and in 1 N KCl was determined on a 1:2.5 suspension, that is, to 10 g soil samples, 25 ml of distilled water or 1 N KCl was added (Mori and Shimada; 1970). The suspension was thoroughly stirred, allowed to stand for one hour and then the pH was determined. ΔpH means the difference between pH (H_2O) and pH (KCl).

The pH in NaF (Blackmore; 1978) was determined on a 1:50 suspension, that is, to 1 g soil sample, 50 ml of 1 N NaF was added. The suspension was thoroughly mixed and the pH was determined after 2 minutes.

(2) *Exchangeable Aluminum*

Twenty gram of soil sample was placed in 100 ml plastic bottles with a cover and 50 ml of 1 N KCl was added. The suspension was shaken vigorously for two minutes, allowed to stand for 30 minutes and filtered through a Whatman filter paper no. 2. Residues were washed with 50 ml of 1 N KCl three times. Using phenolphthalein as indicator, the filtrates were titrated with standardized 0.1 N NaOH to obtain a very light pink color. Then, one drop of standardized 0.1 N HCl and 10 ml of 1 N NaF were added and finally, the filtrates were titrated with standardized 0.1 N HCl until they became colorless. Exchangeable aluminum content was calculated according to the following formula:

Exchangeable Al (me/100 g) $= a \times 0.1 \times 50/20$ where a is the volume (ml) of the standardized 0.1 N HCl used (Takahashi; 1970).

(3) *Total carbon*

Sulfuric acid-dilution method (Walkley; 1947, Tatsukawa; 1966) was used for total carbon determination. To the soil sample (100 mg) placed in a 500 ml Erlenmeyer flask 10 ml of 1 N $K_2Cr_2O_7$ and 20 ml of concentrated sulfuric acid were added. The reaction was allowed to proceed for 30 minutes. Then, 150 ml of distilled water, 10 ml of 85% phosphoric acid, 200 mg of NaF and 10 drops of ortho-phenanthroline indicator were added. The mixture was titrated with 0.5 N ferrous sulfate solution to reach a purple color. Organic carbon content was calculated using the formula indicated below and the organic matter contents of the samples were obtained by multiplying the carbon content by 1.72. Carbon (%) $= (1 - T/S) \times 3.89/w$ where T is the volume (ml) of the ferrous sulfate used in the sample, S is the volume of the ferrous sulfate used in blank and W is the dry weight of the sample.

(4) *Total nitrogen*

Kjeldahl method was used for total nitrogen determination.

(5) *Phosphate absorption coefficient*

To a fifty gram soil sample 100 ml of 2.5% di-ammonium monophosphate $(NH_4)_2HPO_4$ (Sekiya; 1970) was added. The suspension was sometimes shaken and allowed to stand overnight. Then, the suspension was filtered through a filter paper. Phosphorus content of the filtrate was determined using the vanado-molybdate method.

The amount of Absorbed phosphorus (mg P_2O_5/100 g) was calculated as the difference between the phosphorus content of the extractant and that of the filtrate.

(6) *Cation exchange capacity (CEC) and exchangeable bases*

The CEC of the samples was determined using the Schollenberger method, that is saturating and continuous leaching of an 8 g soil with 100 ml of neutral NH_4 OAc. The adsorbed NH_4^+ ions were exchanged with K^+ ions by leaching the soil with a 100 ml of 10% KCl solution. Then, the NH_4^+ in the leachate was determined by simple distillation. Exchangeable bases replaced by NH_4^+ ions were also determined from the NH_4 OAc extract using a Shimazu atomic absorption/flame emission spectrophotometer (Kuramoto, Kosuge and Takahashi; 1970).

(7) *Particle size*

Ten gram sample was treated with 6% hydrogen peroxide (H_2O_2) for soil organic matter removal.

The coarse sand fraction was separated by allowing the suspension to pass through a 0.2 mm sieve.

To enhance the process of dispersion, suspensions of soils with a high content in allophane as Isarog (IS), Negros 6 (N-6) and Zambales 1 (Z-1) were adjusted to pH 4.0 with 0.1 N HCl while those of the other samples were adjusted to pH 10.0 with 0.1 N NaOH. These suspensions were stirred in a motor mixer for 5 minutes and shaken for two hours.

Clay and silt fractions were determined using the pipette method, that is, collecting aliquots at designated time intervals.

The fine sand fraction was determined by removing the silt and clay particles from the suspension by the use of a siphon.

(8) *Bulk density*

Bulk density was determined using the core method by the following formula: Bulk density weight of oven dry soil core (g)/volume of the samples (cm^3)

(9) *Water contents and water retention capacity*

The air dry moisture content of the samples was determined gravimetrically, that is, 10 g soil sample was placed in a tared beaker in an oven for at least 24 hours based on the formula: moisture (%) = 10g–wt.(g) of oven dried soil/wt.(g) of oven dried soil $\times$ 100

The energy-moisture content relationship of the soils for 1/3 and 15 bars was assessed by saturating the soil with distilled water, equilibrating for at least sixteen hours and then subjecting the samples to positive air pressures inside a pressure membrane or pressure plate extractor (Richards; 1941). When the equilibrium was reached, which was indicated by a no-flow condition, the moisture content of the samples was determined gravimetrically.

III. 2. Results

III. 2. 1. Tagaytay soils

Some physico-chemical properties of the soils are shown in Tables, 4, 5, 6, 7 and 8.

The values of the pH (H_2O) which ranged from 5.4 to 6.5 generally were slightly higher at lower depths, while the pH (KCl) ranged from 5.1 to 5.2 for young volcanic ash (upper layers) and 3.7 to 5.0 for the other layers, with smaller values for the lower layers. These values were corraborated by the exchangeable aluminum contents which were higher in the lower layers.

Tag-1 and Tag-3 located at higher altitude showed pH (H_2O) values ranging from 5.9 to 6.4 and pH (KCl) values of 3.7 to 4.7, while the other samples showed pH (H_2O) values ranging from 5.4 to 6.1 and pH (KCl) values ranging from 3.7 to 4.7, indicating that the latter samples had been leached and were more weathered than the former.

The values of pH (NaF) ranged from 9.2 to 9.8 which fall within one of the criteria for classifying soils under the suborder Andepts although bulk densities and moisture content at 1/3 bar are at best marginal for such taxonomic classification. The ΔpH values ranged from 1.0 to 2.3. These values were higher than those of the typical volcanic ash soils in Japan.

Soil organic matter contents varied from one layer to the next and from site to site. The largest accumulation of soil organic matter was observed in the IIIA11 (buried A horizon) of Tag-1 (8.1% soil organic matter content). Comparison of the soil organic matter contents of all the surface layers showed that Tag-3 which is relatively young had the highest organic matter content (4.6%). Irregular distribution of soil organic matter is an indication of surface disturbance such as deposition of new ash, hence the burying of the existing layers. It was further observed that the soil organic matter contents of the surface layers decreased with elevation.

The C/N ratio of the surface layers (A horizon) and humic buried layers of Tag-1 and Tag-3 which are located or a high elevation ranged from 10 to 28 while those of the A horizons and humic buried layers of areas at a low elevation ranged from 7 to 12. Other B horizons and buried B and C horizons of soils at a high elevation and those at a low elevation had C/N ratios of 9 to 16, respectively.

High organic matter contents of the samples from a high elevation may be due to the lower temperature (mean temperature: 22°C) and wet environmental conditions (annual rainfall: 2300 mm) (Philippine Atmospheric, Geophysical and Astronomical Services Administration; 1976) that favor the accumulation of residues and reduced decomposition. At a low elevation, relatively dry environmental conditions could be dominant due to the high temperatures (annual mean temperature: 27°C) and lower rainfall (annual rainfall: 2026 mm). Increase rate of soil organic matter decomposition could decrease the accumulation of organic matter at lower elevations.

Phosphate absorption coefficients ranged from 770 to 964 for young volcanic ash layers and 794 to 840 for Adobe (lapili tuff). In the other layers the coefficients ranged from 1230 to 1764. The weathered tuff samples showed a high phosphate absorption coefficient

Table 4. Physico-chemical properties.

Pedon: Dasmarines, Cavite (Tag-2)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Tag-2-1	A	6.2	4.7	1.5	9.5	0.03	3.3	1.9	0.18	11	1340	34.6	16.88	7.40	2.92	0.37	97.7
2	B2	6.0	4.2	1.8	9.6	0.13	1.7	0.9	0.08	11	1406	36.9	12.50	7.50	4.13	0.37	66.4
3	IIC1	6.1	4.0	2.1	9.7	0.13	1.0	0.6	0.04	16	1600	39.7	14.38	8.91	1.76	0.92	65.4
4	IIIC2	6.5	4.3	2.2	9.6	0.29	0.2	0.13	0.01	12	1372	35.2	13.75	6.93	3.73	0.35	70.3
5	IVC2	6.3	4.0	2.3	9.6	0.34	0.1	0.07	0.01	8	840	32.0	11.88	5.33	4.01	0.38	47.5

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Tag-2-1	A	2.8	26.4	36.3	34.5	Lic	1.13	7.8	32.6	23.6
2	B2	1.9	26.2	23.7	48.3	HC	1.06	10.5	40.7	30.5
3	IIC1	18.1	45.5	29.5	6.8	SL	0.82	13.3	48.0	37.3
4	IIIC1	6.4	50.3	22.8	20.3	CL	0.93	10.9	42.3	29.6
5	IVC2	2.3	55.5	30.4	11.8	L		8.7	35.8	21.9

Table 5. Physico-chemical properties.

Pedon: Tagaytay (Tag-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Tag-1-1	A	6.1	4.6	1.5	9.5	0.08	4.4	2.6	0.15	18	1372	34.6	16.25	6.67	1.48	0.77	71.4
2	IIA	6.3	4.7	1.6	9.4	0.05	6.7	3.9	0.17	24	1306	39.0	11.25	6.85	1.12	0.36	50.2
3	IIA11	6.2	4.9	1.3	9.4	0.03	8.1	4.8	0.19	26	1500	46.3	17.50	10.0	1.72	0.47	64.1
4	IIIA12	6.3	4.9	1.4	9.7	0.03	6.3	3.7	0.16	24	1380	42.7	19.38	9.06	1.78	0.49	71.9
5	IVA1	6.3	4.8	1.5	9.5	0.04	4.8	2.8	0.10	28	1506	39.2	15.62	7.81	1.80	0.51	65.7
6	IVB2	6.3	4.6	1.7	9.6	0.04	2.2	1.3	0.09	15	1530	39.6	12.50	9.64	2.08	0.55	62.6
7	VC1	6.4	4.4	2.0	9.6	0.08	0.9	0.6	0.05	12	1630	41.5	14.38	9.64	2.66	0.77	66.1
8	VC2	6.4	4.3	2.1	9.8	0.10	0.9	0.5	0.04	12	1620	40.2	13.75	8.50	2.56	0.80	63.7

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Tag-1-1	A	10.8	59.6	13.2	16.4	SCL	1.10	8.7	41.3	23.1
2	IIA	8.4	34.5	24.6	32.5	LiC	1.07	8.6	41.8	22.8
3	IIA11	5.9	21.9	29.2	43.0	LiC	1.01	10.9	48.8	31.2
4	IIA12	5.3	24.9	21.7	48.1	HC	0.95	11.6	49.9	32.3
5	IVA1	6.0	30.8	30.8	32.4	LiC	1.01	11.3	49.8	31.3
6	IVB2	6.9	18.1	25.7	49.3	HC	1.02	14.2	50.2	37.5
7	VC1	5.1	47.2	23.0	24.7	SLC	1.01	16.6	58.6	41.2
8	VC2	5.4	57.0	21.6	16.0	SCL	0.92	15.8	59.6	40.9

Table 6. Physico-chemical properties.

Pedon: Kaybagal, Tagaytay (Tag-3)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	△pH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Tag-3-1	A	6.3	5.2	1.1	9.3	tr	4.6	2.7	0.22	12	964	28.5	13.13	5.52	1.38	0.40	71.7
2	B	6.2	5.1	1.1	9.3	tr	2.8	1.6	0.12	14	860	20.8	9.38	5.16	1.28	0.38	77.9
3	IIC		5.1		9.2	tr	2.1	1.2	0.09	12	770	16.8	8.13	4.84	1.36	0.38	87.5
4	IIIA	6.2	5.0	1.2	9.2	tr	4.1	2.4	0.15	16	1370	37.1	14.38	7.29	2.5	0.50	66.5
5	IVB1	6.4	4.6	1.8	9.3	tr	1.7	1.0	0.10	10	1510	36.6	16.88	9.32	3.69	0.25	83.2
6	IVB2	6.2	4.6	1.4	9.3	tr	1.2	0.7	0.08	9	1510	39.1	10.63	8.70	4.01	0.59	61.2
7	VC1	6.1	4.4	1.7	9.4	0.05	0.9	0.5	0.06	9	1670	40.9	11.88	7.76	4.37	0.47	59.8
8	VC2	5.9	4.8	1.6	9.4	0.10	0.7	0.4	0.04	9	1230	38.9	10.63	8.65	4.01	0.67	61.6
9	VC3	6.0	4.3	1.7	9.3	0.05	0.7	0.4	0.05	9	1340	40.7	11.25	8.13	3.97	0.67	59.0

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Tag-3-1	A	18.1	40.0	20.0	21.9	SCL	1.11	5.1	31.0	19.0
2	B	23.1	44.7	18.3	14.3	SL	1.17	2.9	30.4	15.6
3	IIC	52.6	26.1	13.7	7.7	SL		3.0		
4	IIA	8.7	28.1	30.8	33.1	LiC	1.19	5.1	40.5	27.2
5	IVB1	3.9	34.6	28.9	32.7	LiC	1.11	11.4	46.0	35.4
6	IVB2	3.3	48.2	24.1	24.4	CL	1.16	12.7	49.6	38.7
7	VC1	3.9	39.8	28.2	28.1	LiC	1.12	13.1	50.4	39.5
8	VC2	8.5	55.1	20.2	16.2	CL	1.00	11.7	51.4	38.0
9	VC3	9.2	62.2	21.1	7.5	SL	0.86	9.4	51.2	36.9

Table 7. Physico-chemical properties.

Pedon: Bagongbayan, General Trias, Cavite (Tag-5)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	△pH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Tag-5-1	Ap	5.6	4.3	1.3	9.3	0.08	2.1	1.2	0.12	10	1335	33.1	10.63	7.55	2.36	0.36	65.0
2	A3	5.8	4.5	1.0	9.2	0.03	1.9	1.1	0.11	10	1250	31.3	14.38	8.75	1.0	0.40	78.4
3	IIA	5.7	4.2	1.5	9.3	0.08	1.4	0.8	0.09	9	1630	36.1	10.63	9.53	0.56	0.61	59.1
4	IIIA	5.9			9.3	0.23	1.2	0.7	0.08	9	1560	39.2	17.50	10.42	0.48	0.65	74.1
5	IVA	5.9			9.3	0.18	1.1	0.6	0.08	7	1640	40.2	13.13	10.0	0.48	0.64	60.3
6	IVB11	5.8			9.4	0.35	0.8	0.5	0.05	10	1640	39.7	16.88	9.64	0.50	0.59	69.5
7	IVB12	5.8			9.4	0.55	0.9	0.5	0.06	9	1670	39.9	12.5	10.05	0.42	0.68	59.3
8	IVC	5.6			9.4	1.00	0.3	0.2	0.03	6	1764	37.6	15.63	6.75	0.34	0.94	62.9

Table 7. Physico-chemical properties. (continued)

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Tag-5-1	Ap	7.4	35.4	28.9	28.3	LiC		6.8	37.4	24.1
2	A3	10.4	35.7	33.8	20.1	CL		7.2	37.0	23.5
3	IIA	1.6	24.4	29.6	44.4	LiC		9.4	48.4	31.7
4	IIA	3.4	26.0	29.0	41.6	LiC		10.4	51.6	35.7
5	IVA	4.4	37.2	36.6	21.8	CL		11.2	51.6	36.3
6	IVB11	11.1	24.1	31.8	33.0	LiC		11.9	54.2	37.3
7	IVB12	12.8	30.5	32.5	24.2	CL		11.0	59.9	38.0
8	IVC	34.4	37.6	20.8	7.2	SL		10.6	57.5	35.9

Table 8. Physico-chemical properties.

Pedon: Paliparan, Carmona (Tag-4)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	(KCl)	ΔpH	(NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Tag-4-1	A	5.4	4.4	1.0	9.3	tr	3.8	2.2	0.18	12	1240	33.1	14.38	9.10	1.54	0.50	77.1
2	B1	5.5	4.0	1.5	9.4	0.17	1.7	1.0	0.10	10	1240	33.1	16.88	7.14	0.58	0.58	76.1
3	B2	5.5	4.0	1.5	9.4	tr	1.5	0.6	0.12	8	1406	36.6	16.25	9.95	0.58	0.67	75.0
4	IIC1		4.0		9.5	tr	1.0	0.1	0.07	9	1470	42.0	17.50	9.31	0.48	0.80	66.9
5	IIC2	5.6	3.7	1.9	9.4	tr	0.2	0.3	0.02	6	1370	38.1	16.25	8.07	0.56	0.84	67.5
6	IIIC1	5.7	4.3	1.4	9.4	0.05	0.5	0.3	0.04	7	1310	39.2	15.0	9.0	2.64	1.02	70.6
7	IVC2	5.7				tr	0.5	0.3	0.07	5	794						

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Tag-4-1	A	6.7	30.2	32.6	30.5	LiC		16.8	32.3	23.3
2	B1	3.9	28.3	39.5	28.3	LiC		7.5	36.5	26.3
3	B2	2.7	23.8	30.8	42.7	LiC		10.3	40.9	30.2
4	IIC1	13.2	28.9	31.2	26.7	LiC		9.1	46.1	30.6
5	IIC2	34.5	35.9	23.7	5.9	SL		8.0	38.7	22.2
6	IIIC2	70.6	18.8	8.8	1.8	LS		7.1	33.8	25.4
7	IVC2							3.0	35.0	

Table 9. Physico-chemical properties.

Pedon: Caliraya (Cal-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	△pH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Cal-1	A	5.60	4.6	1.0	10.0	0.03	6.6	3.8	0.25	15	750	20.8	4.98	4.21	0.28	0.28	47.3
2	A3	4.90	3.9	1.0	10.9	2.80	3.4	2.0	0.16	12	750	15.0	1.45	1.75	0.14	0.28	24.2
3	B1	4.80	3.8	1.0	10.3	4.48	1.8	1.1	0.10	11	980	13.0	0.84	1.04	0.06	0.33	17.5
4	B21	4.90	3.8	1.1	10.3	3.25	0.9	0.5	0.06	8	880	12.2	1.72	0.75	0.06	0.45	24.4
5	B22	5.10	3.8	1.3	10.3	3.48	0.7	0.39	0.06	7	840	11.2	0.80	0.87	0.08	0.37	19.0
6	IIB3	5.0	3.8	1.2	10.4	3.30	0.5	0.30	0.04	7	650	10.7	0.94	0.92	0.06	0.36	21.3
7	IIIC	5.70	3.8	1.2	10.5	4.78	0.5	0.30	0.03	9	840	11.7	1.39	1.33	0.10	0.38	27.3

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Cal-1	A	4.9	13.7	21.8	59.6	HC	0.92	5.10	43.1	19.4
2	A3	3.3	13.2	21.9	61.6	HC	1.07	4.90	41.9	28.6
3	B1	0.50	6.7	16.3	76.5	HC	1.05	5.60	48.3	32.1
4	B21	2.4	6.1	12.2	79.3	HC	1.05	5.60	49.4	34.4
5	B22	7.0	8.2	15.4	69.4	HC	1.07	5.60	49.5	33.7
6	IIB3	6.3	10.6	19.3	63.7	HC	1.05	5.0	51.1	34.2
7	IIIC	10.0	10.8	20.7	58.5	HC	0.99	5.70	52.4	36.6

ranging from 1620 to 1764. It was observed that the phosphate absorption coefficient increased with the depth of the profile which appeared unrelated to the clay contents. If this trend is correct, when phosphate is applied, such absorption should be considered in order to maintain a certain level of P availability.

The young volcanic ash had cation exchange capacity (CEC) values ranging from 16.8 to 28.5 me/100 g while in the other layers the values ranged from 32.0 to 46.3 me/100 g. It was also observed that the CEC values increased with the depth of the profile.

The samples contained high amounts of exchangeable cations. The values ranged from 10.6 to 19.4 me/100 g, 4.8 to 16.7 me/100 g, 0.3 to 1.0 me/100 g and 0.3 to 1.0 me/100 g for exchangeable Ca, exchangeable Mg, exchangeable K and exchangeable Na, respectively. These values were higher than those recently determined in volcanic ash soils in Japan (Kurobokudo cooperative research group; 1984) which ranged from 0.03 to 10.04 me/100 g for Ca, from 0.02 to 3.4 me/100 g for Mg, from 0.05 to 1.9 me/100 g for K and from 0.00 to 2.21 me/100 g for Na.

Percentage base saturation of the samples was high. The values obtained ranged from 50.2 to 87.5%.

Exchangeable cation contents and base saturation were independent of sites, layers and elevation. The high base contents of the samples may be attributed to the parent materials. Thus, it is important to identify the mineralogical composition of the parent materials.

As described in Chapter II, when the IIIA or IVA horizon of Tag-1 and Tag-3 was compared to the A horizon of the profile from a low elevation, it appeared that the speed of weathering of the latter horizon may be faster than that of the former because the clay minerals of soils at higher elevations with a high phosphate absorption coefficient and CEC can be linked to the presence of more amorphous materials while the clay minerals of soils at low elevations with low phosphate absorption coefficients and CEC had been altered to crystalline clay minerals. Clay mineralogy will also be discussed in the further report.

The young volcanic ash of Tag-3 had clay contents ranging from 7.7% to 21.9% which were lower than those of the other buried layers. The young volcanic ash and IIC horizon of Tag-3 which are composed of pumice gravels are considered to be materials derived from the 1966 eruption of the Taal volcano. On the other hand, the clay contents of the young volcanic ash in Tagaytay were higher than those of the young volcanic ash which was deposited after the 1775 eruption of Sakurajima volcano in Kagoshima, Japan (Otsuka and Kumada; 1978). It was observed also that the surface of the pumices has been softened and transformed into some types of clay. Therefore, it is considered that the rate of weathering of volcanic ash is faster in Tagaytay than in Kagoshima, Japan.

Bulk density ranged from 0.82 to 1.19 g/cm^3. The bulk density of the pumice layer which ranged from 0.82 to 1.12 g/cm^3 and was lower than that of the other layers with values ranging from 0.95 to 1.19 g/cm^3. Except for IIC of Tag-3, these values are outside the range of the values of bulk density for soils that can be classified as Andepts according to the Soil Taxonomy (1975).

Water retention at 1/3 bar and 15 bar ranged from 32.3% to 59.9% and 19.0% to 41.2%, respectively. The amount of water retained increased with the depth of the profile except for the Adobe layer. Water contents at both suctions appeared to be much lower than those of the soils identified as Andepts.

The physico-chemical characteristics of the Tagaytay soils on the foot slopes of Taal volcano can be summarized as follows:

1. At high elevations, larger amounts of organic matter accumulated with high C/N ratios compared with the corresponding values at lower elevations.
2. Generally, the content of exchangeable cations and base saturation were high.
3. Water retention capacity of the Tagaytay soil increased with the depth of the profile and the maximum retention capacity was exhibited by the pumice tuff layer.

III. 2. 2. Caliraya soil

Table 9 shows the physico-chemical properties of the Caliraya soil with a tiger-mottle layer below the gravel layer.

The pH (H_2O) and pH (KCl) values ranged from 4.8 to 5.7 and from 3.8 to 4.6, respectively. These values were lower than those of the Tagaytay soils. The pH (NaF) values ranged from 10.0 to 10.9 which were higher than those of the Tagaytay soils.

Exchangeable aluminum contents were very high (2.80 to 4.78 me/100 g) except for the A horizon (0.03 me/100 g) unlike those recorded from the layers of volcanic ash soils from Tagaytay.

Soil organic matter content of the A horizon was relatively high (6.6%) and decreased with the depth of the profile. Likewise, the C/N ratios of the samples decreased with the depth of the profile (15 to 7).

Phosphate absorption coefficients were unexpectedly low (750 to 850) considering the soils' well-known phosphorus fixation capacity. Off hand, the low phosphate absorption coefficient and high pH (NaF) values may indicate that the reaction of F^- ion with -OH groups of amorphous aluminum and iron, allophane and halloysite may be stronger than that of PO_4^{-3} ion. However, further studies are required to verify this assumption.

Cation exchange capacity (CEC) of the samples was relatively low (10.7 to 20.8 me/100 g). The high clay contents but low CEC values would indicate the dominance of kaolinitic clay minerals.

Exchangeable cation contents ranged from 0.80 to 4.98 me/100 g for Ca, from 0.75 to 4.21 me/100 g for Mg, from 0.06 to 0.28 me/100 g for K and from 0.33 to 0.45 me/100 g for Na. Generally, the amounts of exchangeable cations were larger in the A horizon than in the lower layers. The base saturation ranged from 17.5 to 47.4% which was very much lower than that of the Tagaytay soils. This lower base saturation may be due to prolonged leaching under a high precipitation of 2864 mm/annum.

The bulk density values ranged from 0.92 to 1.07 g/cm^3 with the A horizon showing the lowest values.

Water contents ranged from 4.9 to 5.7%. The water retention capacities at 1/3 bar and 15 bar ranged from 41.9 to 52.4% and from 19.4 to 36.6%, respectively. These values were lower than those of the Tagaytay soils.

The physico-chemical properties of the Caliraya soil can be summarized as follows:

1. The very low pHs are associated with high exchangeable aluminum contents.
2. Soil organic matter content of the A layer is high, while that of the other layers is low.
3. Phosphate absorption coefficients and CEC are relatively low.
4. Bulk densities are relatively high but water retention capacities are low. The data obtained indicated the dominance of kaolinite clay minerals.

III. 2. 3. Isarog soil

As described in Chapter II, the morphology of the Isarog soil profile was very similar to that of the Kuroboku (Andosol) which accumulates large amounts of humus. The physico-chemical properties of the Isarog soil are presented in Table 10.

The pH (H_2O) values ranged from 5.4 to 5.9 and pH (KCl) values from 4.5 to 5.5. The values tended to increase with the depth of the profile. The values of ΔpH which ranged from 0.4 to 1.1 were lower than those of the other soils. The pH (NaF) values were high (10.7 to 11.5) suggesting that the amorphous content of the samples is high, especially the allophane content. It was also observed that the pH (NaF) decreased with the depth of the profile.

Exchangeable aluminum contents ranging from 0.05 to 0.75 me/100 g were very low.

Accumulation of soil organic matter in the A horizon was very high (14.7 to 19.1%) compared to the other soils. C/N rations were high, ranging from 12 to 21.

Phosphate absorption coefficients ranging from 1240 to 2186 were very high. These data indicate that the samples have a high allophane content, as shown also by the pH (NaF) values.

CEC values of the A horizon were very high (40.7 me/100 g) whereas those of other horizons ranged from 20.5 to 34.8 me/100 g. High CEC of the A horizon was attributed to the high organic matter content.

Exchangeable cations contents were low compared to other soils. The samples contained 1.1 to 3.6 me Ca/100 g soil, 0.1 to 1.8 me Mg/100 g, 0.24 to 1.0 me K/100 g and 0.20 to 0.25 me Na/100 g. Base saturation ranging from 5.4% to 22.7% was also very low.

The very low clay contents (16.7% to 24.0%) and bulk density values suggested that the

Table 10. Physico-chemical properties.

Pedon: Isarog, Naga (IS-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H₂O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
IS-1-1	A11	5.4	4.5	0.9	11.5	0.38	19.1	11.1	0.54	21	2186	40.7	1.47	1.25	0.24	0.25	7.9
2	A12	5.4	4.5	0.9	11.3	0.75	14.2	8.3	0.60	14	1940	40.7	1.06	0.81	0.12	0.21	5.4
3	A13	5.6	4.5	1.1	11.2	0.43	14.7	8.6	0.50	17	1630	40.7	1.23	1.25	0.12	0.20	6.9
4	IIA	5.7	4.9	0.8	11.2	0.13	9.5	5.5	0.30	19	1750	34.8	1.52	0.48	0.12	0.21	6.7
5	IIIB11	5.8	5.4	0.4	11.3	0.05	4.8	2.8	0.19	15	1600	24.4	1.53	0.10	0.12	0.23	8.1
6	IIIB12	5.9	5.5	0.4	11.1	0.03	2.9	1.7	0.15	12	1960	20.5	1.66	1.23	0.10	0.24	15.7
7	IVB21	5.9	5.3	0.6	11.1	0.05	4.1	2.4	0.14	17	1240	22.6	1.75	1.77	0.14	0.24	17.2
8	IVB22	5.8	5.2	0.6	11.0	0.10	2.9	1.7	0.13	14	1308	23.6	3.53	1.44	0.10	0.24	22.7
9	VA	5.8	5.2	0.6	10.7	0.05	2.6	1.5	0.11	14	1308	28.2	2.50	1.25	0.08	0.22	14.4

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
IS-1-1	A11	5.6	42.9	27.5	24.0	CL	0.69	14.1	63.8	36.5
2	A12	3.8	42.2	36.1	19.5	CL	0.67	14.8	65.8	36.5
3	A13	3.9	42.7	29.1	24.2	CL	0.63	19.7	67.7	39.8
4	IIA	3.1	55.1	21.3	20.5	CL	0.72	19.1	58.2	
5	IIIB11	2.9	58.2	22.2	16.7	CL	0.73	19.7	60.8	40.2
6	IIIB12	4.0	50.5	28.5	17.0	CL	0.74	21.5	62.5	42.8
7	IVB21						0.83	15.8	56.6	35.4
8	IVB22						0.90	19.0	54.4	36.8
9	VA						0.74	23.4	61.0	43.6

samples could be classified in the suborder Andepts.

Water contents ranged from 14.1 to 23.4% in the air-dry state, from 54.4 to 67.7% at 1/3 bar and from 35.4 to 42.8% at 15 bar. These values indicated that the water retention capacity of the samples was high.

To summarize, the Isarog soil has a low ⊿pH, very high pH (NaF), low soil organic matter contents and phosphate absorption coefficients, high CEC, low exchangeable cation contents, low bulk density and high water retention capacity.

III. 2. 4. Iriga soil

In Table 11, the physico-chemical properties of the Iriga soil are presented.

The values of pH (H_2O) ranged from 6.4 to 6.7 and those of pH (KCl) from 5.2 to 5.9. The pH (NaF) values ranged from 10.3 to 10.4.

Phosphate absorption coefficients were relatively high (1070 to 1190), except for one sample which showed a phosphate absorption coefficient of 700. The pH values and

Table 11. Physico-chemical properties.

Pedon: Iriga (IR-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H$_2$O)	pH (KCl)	△pH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
IR-1-1	A11	6.4	5.5	0.9	10.4	t	7.3	4.2	0.26	16	1190	27.7	12.97	5.73	2.36	0.34	77.2
2	A12	6.4	5.3	1.1	10.3	t	4.7	2.7	0.15	18	1190	25.8	12.34	5.94	1.77	0.42	79.3
3	A13	6.4	5.7	0.7	10.4	t	3.1	1.8	0.12	15	1160	22.9	11.17	4.84	2.16	0.62	81.9
4	IIB11	6.6	5.2	1.4	10.3	t	2.3	1.3	0.10	13	1070	21.5	9.77	5.42	1.89	0.79	83.0
5	IIB12	6.7	5.9	0.8	10.3	t	0.7	0.4	0.04	10		12.0	5.66	1.75	0.95	0.42	73.5
6	IIIC	6.7	5.3	1.5	10.3	t	0.4	0.2	0.02	11	500	8.1	4.13	1.47	0.79	0.32	82.5

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
IR-1-1	A11	15.5	37.9	23.2	23.4	CL	1.12	6.5	35.1	
2	A12	9.9	33.9	28.9	27.3	LiC	1.12	7.9	33.6	
3	A13	13.3	31.5	28.1	27.1	LiC	1.16	7.9	34.3	
4	IIB11	12.4	35.7	25.4	26.5	LiC	1.18	8.1	35.1	
5	IIB12	37.3	40.9	11.9	9.9	SL		3.0	19.9	
6	IIIC	34.6	53.5	8.7	3.2	LS	1.61	3.1	19.6	

phosphate absorption coefficients indicated that the soil samples contain some amorphous materials.

Because of the high pH the soil samples contained only trace amounts of exchangeable aluminum. This may imply that since the materials are ash-derived, the aluminum may have already been used to form clay minerals either amorphous or crystalline so that allophane and/or 1:1 type clay minerals are expected to dominate the colloidal fraction.

The amount of soil organic matter in the A horizon was relatively high (7.3%). The C/N ratios of the A11, A12 and A13 horizons were relatively high (15 to 18) while those of the other layers were low (10 to 13).

Cation exchange capacities (CEC) ranged from 8.1 to 27.7 me/100 g. The values decreased with the depth of the profile. The data show that CEC is directly related to soil organic matter and texture. Exchangeable Ca content ranging from 4.1 to 13.0 me/100 g with the highest value observed in the A horizon decreased with the depth of the profile. In three horizons, A11, A12 and A13, the values of exchangeable Ca amounting to 11.2 to 13.0 me/100 g, are comparable to those of the Tagaytay soils.

Exchangeable Mg and K contents ranged from 1.47 to 5.93 me/100 g and 1.5 to 5.9 me/100 g, respectively. The exchangeable Na content on the other hand, was low (0.3 to 0.8 me/100 g). Among the soil samples used in this study, the Iriga soils exhibited the highest degree of base saturation (73 to 83).

Bulk densities were high (1.18 to 1.41 g/cm^3) the values increasing with the depth of the profile.

Water content in the air dry state and at 1/3 bar was relatively low; ranging from 3.0 to 8.1% and 19.6 to 35.1%, respectively.

As described above, the Iriga soil has a high pH, high exchangeable cation contents and base saturation. However, the low CEC and low water content indicate the influence of kaolin clay minerals, while the low pH and high phosphate absorption coefficient suggest the presence of amorphous materials such as allophane or aluminum hydrooxide/oxide.

III. 2. 5. Mayon soils

Two kinds of volcanic ash profiles from the Mayon volcano were described in Chapter II. One consisting of young ash (M-2) deposited on the edge of the mountain slope and the other (M-1) of relatively old ash on the terrace. The physico-chemical properties of the Mayon soils are shown in Tables 12 and 13.

The pH (H_2O) and pH (KCl) values of M-1 ranged from 6.0 to 6.5 and 4.6 to 5.1 while those of M-2 ranged from 6.3 to 6.7 and 5.1 to 5.4, respectively. It was observed that the pH of the young volcanic ash soils were higher than those of the old ash soils. The ΔpH of M-2 ranged from 0.95 to 1.52, while that of M-1 from 0.9 to 1.8. The pH (NaF) values of M-2 (10.9 to 11.4) were higher than those of M-1 (9.7 to 10.2). The high pH (NaF) values of M-2 and its positive reaction to the allophane test indicated that M-2 contains a large amount of allophane.

Soil organic matter contents of M-1 ranged from 0.4 to 3.8% the values decreasing with the depth of the profile. M-2 profile had a higher soil organic matter content (2.4 to 5.3%) and humic buried layers.

Both M-1 and M-2 had low exchangeable aluminum contents; M-1 (0.02 to 0.06 me/100 g) and M-2 (less than 0.02 me/100 g).

CEC of M-1 (17.4 to 19.8 me/100 g) were higher than those of M-2 (2.6 to 17.0 me/100 g). This may be attributed to the low clay content of M-2.

Exchangeable Ca content ranged from 5.3 to 6.7 me/100 g for M-1 and 1.3 to 7.1 me/100 g for M-2. Exchangeable Mg content of M-1 ranged from 1.9 to 2.8 me/100 g while that of M-2 ranged from 0.3 to 2.2 me/100 g. Exchangeable K content of M-1 ranged from 0.1 to 0.8 me/100 g with values decreasing with the depth of the profile while that of M-2 ranged from 0.2 to 0.5 me/100 g with values increasing with the increase of the soil organic matter contents. Exchangeable Na contents of M-1 ranged from 0.7 to 1.7 me/100 g while those of M-2 from 0.2 to 0.5 me/100 g. Exchangeable Na contents increased with the depth of the profile for both M-1 and M-2. Although the contents of exchangeable cations of M-1 were higher than those of M-2, the base saturation of M-1 (50 to 58.6) was lower than that of M-2 (52.6 to 72.4%) which is still immature in its weathering process.

Phosphate absorption coefficients of M-1 ranged from 1000 to 1320 while those of M-2 from 400 to 1000, the difference being attributed to the texture.

Clay contents of M-1 (44.9 to 64.8%) were higher than those of M-2 (1.6 to 19.1%) which consists of young coarse volcanic ash. Clay contents of M-1 increased with the depth of the profile.

Water contents of M-1 ranged from 5.2 to 13.8% and increased with the depth of the profile. The water contents of M-2 ranged from 3.0 to 12%. Humic buried layers showed a high water content while in the other layers the water content was very low. A similar behavior was observed for the water retention capacity (1/3 bar). The values of M-1 (26.3 to 49.6%) increased with the depth of the profile while those of M-2 (17.3 to 33.0%) were lower humic buried layers had higher capacities than the other layers.

As described above, there were two kinds of volcanic ash soils derived from Mount

Table 12. Physico-chemical properties.

Pedon: Mayon-1 (M-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/ 100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
M-1-1	A1	6.0	5.1	0.9	10.2	0.04	3.8	2.2	0.18	12	1160	18.5	6.02	2.06	0.78	0.71	51.7
2	A3	6.3	5.0	1.3	10.1	0.02	1.9	1.1	0.11	10	1000	18.0	6.72	1.88	0.40	1.20	56.7
3	B	6.4	4.9	1.5	9.9	0.02	1.1	0.6	0.07	9	1000	17.7	6.47	2.39	0.40	1.13	58.6
4	IIB	6.4	4.7	1.7	9.8	0.06	0.8	0.5	0.05	9	1000	17.4	6.30	2.25	0.42	1.18	58.2
5	IIIA1	6.4	4.6	1.8	9.8	0.05	0.5	0.3	0.04	8	1320	18.2	5.53	2.49	0.22	1.25	52.3
6	IIIA3	6.5	4.7	1.8	9.7	0.04	0.4	0.2	0.04	6	1000	19.8	5.27	2.83	0.13	1.69	50.0

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
M-1-1	A1	27.9	23.7	23.4	24.9	CL	1.12	5.2	26.3	
2	A3	17.7	23.9	20.8	37.7	Lic	1.11	8.3	33.4	
3	B	16.2	21.8	22.0	40.0	LiC	1.08	10.1	36.9	
4	IIB	10.7	19.9	20.3	49.1	HC	1.04	12.9	41.6	
5	IIIA1	8.1	16.4	22.3	53.2	HC	1.03	12.5	44.1	
6	IIIA3	4.6	11.3	19.3	64.8	HC	0.96	13.8	49.6	

Table 13. Physico-chemical properties.

Pedon: Mayon 2 (M-2)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/ 100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
M-2-1	A1	6.25	5.30	0.95	11.4	tr	3.9	2.3	0.25	9	680	6.45	2.42	0.67	0.44	0.16	57.2
2	IIAC	6.25	5.25	1.0	11.3	tr	3.1	1.8	0.19	9	670	5.50	2.31	0.43	0.40	0.17	60.3
3	IIIA3	6.50	5.40	1.10	11.2	tr	2.4	1.4	0.14	10	630	5.02	2.30	0.63	0.21	0.18	66.0
4	IVC	6.45	5.30	1.15	11.3	0.01	2.6	1.5	0.15	10	400	2.63	1.33	0.26	0.15	0.16	72.4
5	IVA3	6.45	5.20	1.25	10.9	tr	3.1	1.8	0.16	11	610	6.93	2.67	0.62	0.,51	0.24	58.2
6	VA11	6.45	5.25	1.20	10.85	0.02	5.0	2.9	0.28	10	1000	16.97	7.14	2.05	0.55	0.42	59.9
7	VA12	6.35	5.20	1.15	10.9	0.02	5.3	3.1	0.29	11	1030	16.01	6.83	2.21	0.22	0.53	61.1
8	VA13	6.65	5.125	1.525	11.0	0.02	1.6	0.9	0.19	5	764	7.89	2.61	0.89	0.20	0.45	52.6

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
M-2-1	A1	43.2	38.5	16.7	1.6	SL	1.29	3.4	19.7	
2	IIAC	50.0	31.4	17.1	1.5	SL	1.32	4.9	21.3	
3	IIIA3	49.6	33.0	15.1	2.3	SL	1.40	3.0	18.9	
4	IVC	82.3	12.1	3.0	2.5	LS				
5	IVA3	58.3	21.6	14.1	6.0	SL	1.37	3.1	17.3	
6	VA11	22.9	43.6	29.5	4.0	SL	0.93	9.2	33.0	
7	VA12	33.3	42.2	21.0	3.5	SL	0.93	12.0	29.3	
8	A3	17.2	38.5	25.2	19.1	CL	1.16	5.1	21.7	

Mayon: one consisting of relatively old volcanic ash showing a high phosphate absorption coefficient, higher water contents and a fine texture. The other soil was composed of young volcanic ash with a low clay content, low phosphate absorption coefficient and low water content. Both M-1 and M-2 had a high pH (H_2O), high exchangeable cation content and high base saturation.

III. 2. 6. Volcanic ash derived from Bulusan volcano (Sorsogon 2)

The physico-chemical properties of the volcanic ash soil deposited after the eruption of the Bulusan volcano (Sorsogon 2) are shown in Table 14.

The pH (H_2O) and pH (KCl) values ranged from 5.1 to 5.5 and 3.8 to 4.6, respectively. These values reflected the strong acidity of the samples. This was further supported by the values obtained for the exchangeable aluminum contents (0.1 to 0.3 me/100 g) which were higher than those of other volcanic ash soils. ΔpH values were high (0.9 to 1.35) and pH (NaF) ranged from 10.2 to 10.9.

Soil organic matter contents ranging from 0.4 to 4.04 decreased with depth. Accumulation of soil organic matter was low in this soil.

Phosphate absorption coefficients were relatively high (1120 to 1516). Cation exchange capacities were low (16.0 to 17.4 me/100 g). Exchangeable Ca contents ranged from 1.0 to 2.7 me/100 g, exchangeable Mg contents ranged from 1.7 to 2.3 me/100 g, exchangeable K

Table 14. Physico-chemical properties.

Pedon: Sorsogon (SR-2)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
SR-2-1	A1	5.5	4.6	0.9	10.2	0.12	4.0	2.4	0.16	15	1120	17.0	2.28	2.31	1.47	2.11	48.1
2	A3	5.3	4.2	1.1	10.6	0.41	2.3	1.3	0.11	12	1130	16.0	1.67	1.91	0.33	1.94	36.5
3	B1	5.3	4.1	1.2	10.8	0.78	1.2	0.7	0.08	8	1190	16.0	1.16	1.69	0.32	2.46	35.1
4	B21	5.3	4.1	1.3	10.9	1.03	1.1	0.6	0.08	8	1190	16.0	1.05	1.69	0.27	2.26	32.9
5	B22	5.2	3.9	1.4	10.9	2.29	0.8	0.5	0.06	8	1516	16.9	1.06	1.89	0.28	2.51	33.8
6	B3	5.1	3.9	1.3	10.9	2.82	0.5	0.3	0.02	16	1190	17.4	1.08	2.02	0.28	2.07	31.2
7	C		3.8		10.9	2.84	0.6	0.4	0.05	7	17.0	1.92	1.77	0.19	0.19	0.94	28.4
8	IIB	5.2	3.8	1.4	10.9	3.01	0.4	0.2	0.05	5	1130	16.5	2.66	2.16	0.21	0.76	35.1

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
SR-2-1	A1	14.2	40.8	33.2	11.8	L	1.05	8.0	36.4	
2	A3	5.8	11.7	20.9	61.6	HC	1.02	9.4	39.8	
3	B1	3.8	36.8	24.5	34.9	LiC	1.00	10.7	42.6	
4	B21	3.1	30.3	26.2	40.4	LiC	0.97	11.8	42.1	
5	B22	2.4	40.5	23.0	34.1	LiC	1.04	11.9	43.4	
6	B3	2.6	34.8	28.0	34.6	LiC	1.04	11.9	43.4	
7	C	2.4	48.2	20.7	28.7	Lic	0.98	13.1	45.3	
8	IIB	3.9	34.6	28.6	32.9	LiC	1.06	10.7	44.9	

contents ranged from 0.2 to 1.5 me/100 g and exchangeable Na contents from 0.85 to 2.5 me/100 g. The contents of exchangeable Ca, Mg and K were slightly lower but that of exchangeable Na was higher compared to the values recorded in the other soils.

Base saturation ranged from 28.4 to 48.1% and except for the A1 horizon with a low clay content, the percentage can be considered to be low.

Except for the A1 loamy layer, the texture of the other layers consisted of light clay and heavy clay.

Water contents were slightly high (8.0 to 13.1%) and water retention capacities at 1/3 bar ranged from 36.4 to 45.3%. These values increased with the depth of the profile.

It was observed that the volcanic ash soil derived from materials deposited after the eruption of the Bulusan volcano (Sorsogon 2) had a low pH, high exchangeable aluminum content, medium to low base saturation and high exchangeable Na content. Cation exchange capacity was low despite the relatively high clay content in the lower layers and lower bulk density values were conspicuous. In general, these characteristics suggest that the soils belong to Andepts.

III. 2. 7. Zambales soils

Zambales volcanic ash has been ejected from Mt. Pinutubo, as cited in Chapter II. Based on the morphological characteristics, Z-1 deposited on the terraces is considered to have not been affected by the river while Z-2 and Z-3 showed signs of riverine influence. Their physico-chemical properties are shown in Tables 15, 16 and 17.

The pH (H_2O) values of Z-1, Z-2 and Z-3 ranged from 5.6 to 6.4, 6.2 to 6.8 and 5.7 to 6.2, respectively. These values were higher compared to those of other volcanic ash soils.

pH (NaF) values were higher than 11.6 indicating the presence of large amounts of amorphous materials such as allophane.

Soil organic matter contents of Z-1 ranged from 9.9 to 10.9% while those of Z-2 and Z-3 from 3.7 to 6.3%. Higher accumulation of organic matter seems to be associated with the geographical conditions of deposition of volcanic ash. River affected deposits (secondary deposits) such as in Z-2 and Z-3 have lower organic matter contents than natural deposits (Z-1). The C/N ratios of the A horizon of Z-1 (18 to 19) were higher than those of Z-2 and Z-3 (14 to 16).

All the samples had low exchangeable aluminum contents (trace to 0.48 me/100 g).

Phosphate absorption coefficients of Z-1 were greater than 1200, except those of IIC2 and IIC3 horizons while those of Z-2 and Z-3 were low (500 to 932). This may be due to the much higher amorphous material contents of Z-1.

Cation exchange capacity of Z-1 ranged from 3.9 to 16.4 me/100 g, of Z-2 from 4.5 to 13.6 me/100 g and that of Z-3 from 3.1 to 7.0 me/100 g. These profiles which showed the lowest clay content (hence, low CECs) among the volcanic ash soils collected in this study may provide confirmatory evidence for the transformation of the ash materials to allophane if indeed allophane is established as a constituent of the clay fraction. Generally, the CEC values decreased with the depth of the profiles. Exchangeable Ca contents of Z-1 and Z-3 were lower (0.4 to 2.3 and 0.3 to 0.5 me/100 g) than those of Z-2 (0.3 to 5.9 me/100 g). The same trend was observed for the exchangeable Mg contents of the samples. Exchangeable K and Na contents of Z-1 however, were higher (0.2 to 0.4 me K/100 g and 0.19 to 0.25 me Na/100 g) than those of Z-2 (0.1 to 0.3 me K/100 g and 0.11 to 0.16 me Na/100 g) and Z-3 (0.05 to 0.1 me K/100 g and 0.14 to 0.20 me Na/100 g). Exchangeable Ca and Mg contents decreased with the depth of the profile while exchangeable K and Na contents increased with the depth of the profile as in the case of the Tagaytay soils. This observation indicated that K and Na were readily leached to the lower layers.

Table 15. Physico-chemical properties.

Pedon: Zambales (Z-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H₂O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/ 100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Z-1-1	Ap	6.4	5.3	1.1	11.8	0.04	10.9	6.3	0.35	18	1250	16.42	2.34	0.42	0.33	0.22	20.2
2	IIA1	6.0	4.56	1.44	11.93	0.48	10.2	5.9	0.31	19	1380	14.59	0.58	0.14	0.27	0.20	8.1
3	IIA3	5.9	4.65	1.25	11.93	0.33	9.8	5.7	0.30	19	1620	14.59	0.59	0.07	0.23	0.20	7.6
4	IIB1	6.10	5.06	1.04	11.95	0.06	4.8	2.8	0.17	16	1380	9.12	0.33	0.03	0.19	0.19	8.1
5	IIC1	6.20	5.25	0.85	11.9	0.04	3.6	2.1	0.13	16	1290	7.82	0.34	0.03	0.15	0.19	9.1
6	IIC2	5.6	4.55	1.05	11.85	0.38	1.2	0.7	0.05	14	900	4.17	0.39	0.03	0.15	0.25	19.6
7	IIC3	6.20	5.0	1.20	11.7	0.06	0.9	0.5	0.04	13	670	3.91	0.38	0.14	0.37	0.25	28.9

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Z-1-1	Ap	39.5	31.2	19.8	9.3	SL	0.86	3.9	37.2	
2	IIA	39.9	32.3	25.8	2.0	SL	0.96	5.8	31.6	
3	IIA3	37.1	38.1	22.8	2.0	SL	1.02	5.74	29.7	
4	IIB1	47.7	33.0	15.9	3.4	SL	1.08	5.40	22.8	
5	IIC1	52.5	27.1	13.8	6.6	SL	1.02	5.40	18.6	
6	IIC2	52.2	38.6	8.4	0.8	SL	1.05	4.80	18.1	
7	IIC3	52.5	31.7	14.8	1.0	SL	1.20	3.10	17.6	

Table 16. Physico-chemical properties.

Pedon: Zambales 2 (Z-2)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H₂O)	pH (KCl)	ΔpH	pH (NaF)	Exch. Al (me/ 100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Z-2-1	A11	6.23	5.08	1.15	11.55	tr	6.2	3.6	0.25	14	930	13.62	5.92	2.03	0.25	0.15	61.4
2	A12	6.65	5.48	1.17	11.8	0.01	4.5	2.6	0.19	14	856	6.99	2.56	0.60	0.13	0.13	49.4
3	IIA	6.55	5.63	0.92	11.85	0.01	3.7	2.1	0.13	16	780	5.97	1.63	0.53	0.10	0.16	40.3
4	IIIAC	6.65	5.65	1.0	11.85	0.01	3.1	1.8	0.12	15	740	4.54	1.22	0.34	0.09	0.11	38.7
5	IVC1	6.80	5.70	1.1	11.75	0.01	1.4	0.8	0.05	16	500	1.56	0.34	0.17	0.11	0.12	47.4
6	IVC2	6.75	5.70	1.05	11.70	0.01	0.9	0.5	0.03	16		1.04	0.33	0.12	0.10	0.12	64.4

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Z-2-1	A11	50.1	21.0	17.3	11.6	SL	1.04	3.1	26.6	
2	A12	66.0	25.7	7.0	1.3	LS	1.42	2.7	17.5	
3	IIA	71.1	18.3	9.9	0.7	LS	1.42	3.5	12.2	
4	IIIAC	76.1	17.7	4.5	1.7	LS	1.49	3.1	11.8	
5	IVC1	95.4	2.8	0.6	1.2	LS	1.51	1.1	6.8	
6	IVC2	96.1	1.6	0.2	2.1	LS		1.2	5.8	

Table 17. Physico-chemical properties.

Pedon: Zambales 3 (Z-3)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	pH ΔpH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
Z-3-1	A11	5.7	4.65	1.05	11.9	0.32	5.3	3.1	0.20	16	800	7.04	0.34	0.05	0.10	0.14	9.0
2	A12	5.98	4.9	1.08	11.9	0.10	4.3	2.5	0.16	16	932	4.95	0.20	0.04	0.09	0.14	9.7
3	IIA	6.15	5.28	0.88	11.85	0.04	2.8	1.6	0.11	15	864	3.13	0.45	0.06	0.05	0.20	24.5

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
Z-3-1	A11	46.8	41.4	7.7	4.1	LS	1.22	2.9	24.5	
2	A12	59.0	31.1	7.2	2.7	LS	1.44	3.7	16.0	
3	IIA	60.4	33.3	4.6	1.7	LS	1.36	3.9	14.0	

The degree of base saturation varied from 8.1 to 28.9% in the Z-1 soil samples, 40.3 to 61.3% in the Z-2 samples and 9.0 to 24.5% in the Z-3 soils. Z-2 had the highest degree of base saturation among these pedons.

The soils had coarse textures (sandy loam or loamy sand) and contained less than 10% clay. In Z-2, the proportion of coarse sands ranged from 50.1% to values as high as 96.0%.

Water contents ranged from 1.1 to 9.9% and 5.8 to 37.2% in the air dry state and at 1/3 bar, respectively. These low water retention capacities as in the case of the CEC can be attributed to the low clay contents.

As described above, the Zambales soils have a high pH (H_2O) and pH (NaF), a coarse texture, and low water contents. But despite the very low colloidal content natural deposits (Z-1) appear to show high phosphate absorption coefficients and a low base saturation. The absorption capacity of this soil to phosphate presents an interesting subject to pursue later.

III. 2. 8. Negros soils

The physico-chemical properties of the Negros soils are shown in Tables 18, 19, 20 and 21.

The pH (H_2O) values ranged from 4.1 to 5.4 for N-4, 4.8 to 5.6 for N-1 and 5.7 to 6.6 for N-6. It was observed that the samples at higher elevations showed a high pH. A similar trend was observed for the pH (KCl) values. The pH (NaF) values ranged from 9.7 to 10.0 for N-4, 11.4 to 11.6 for N-1 and 11.7 to 12.1 for N-6; the difference in the range of pH (NaF) between the profiles suggests elevation effects so that samples at higher elevations probably contain more amorphous materials. When the exchangeable aluminum contents were examined they ranged from 0.29 to 2.3 me/100 g for N-4, 0.02 to 0.72 me/100 g for N-1 and 0.02 to 0.41 me/100 g for N-6, a decreasing trend with increasing elevation that could very well be attributed to the formation of aluminum compounds.

Soil organic matter contents ranged from 0.5 to 1.9% for N-4 and N-5. N-1 and N-6 showed higher soil organic matter contents ranging from 2.1 to 6.6% and 2.6 to 5.5%, respectively.

Table 18. Physico-chemical properties.

Pedon: Negros 1 (N-1)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	△pH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
N-1-1	Ap1	5.60	4.9	0.7	11.4	0.02	6.6	3.8	0.28	14	1340	14.07	4.19	0.26	0.85	0.13	38.6
2	Ap2(A13)	5.30	4.5	0.8	11.5	0.50	6.6	3.8	0.29	13	1580	14.59	2.25	0.21	0.55	0.13	21.6
3	B1	4.80	4.4	0.4	11.6	0.72	3.3	1.9	0.19	10	1760	13.03	0.81	0.29	0.63	0.13	14.3
4	B2	4.90	4.6	0.3	11.5	0.369	2.1	1.2	0.14	9	1580	11.67	0.86	0.07	0.63	0.13	14.5

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
N-1-1	Ap1	23.8	46.4	27.7	2.1	SL	0.98	8.34	37.2	
2	Ap2(A13)	25.6	45.8	27.8	0.8	SL	0.98	9.58	39.6	
3	B1	26.6	64.9	7.8	0.7	LS	0.94	12.08	34.0	
4	B2	35.8	57.5	3.8	2.9	LS	0.94	10.26	31.7	

Table 19. Physico-chemical properties.

Pedon: Negros 4 (N-4)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H_2O)	pH (KCl)	△pH	pH (NaF)	Exch. Al (me/100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
N-4-1	Ap1	4.4	3.7	0.7	9.7	2.32	1.9	1.1	0.03	37	440	7.82	0.61	0.61	0.14	0.08	18.3
2	Ap2(A3)	4.1	3.8	0.3	9.9	2.01	1.9	1.1	0.10	11	520	6.78	0.81	0.25	0.64	0.11	26.7
3	B11	4.5	3.8	0.7	10.2	1.75	1.4	0.8	0.13	6	820	10.67	2.63	0.80	0.64	0.22	40.2
4	B12	5.4	4.10	1.3	10.0	0.29	1.2	0.7	0.02	35	660	8.86	3.72	0.96	0.16	0.43	59.5

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
N-4-1	Ap1	21.0	55.3	7.3	16.4	SCL	1.34	2.8	21.2	
2	Ap2(A3)	17.2	55.9	9.5	17.4	SCL	1.30	5.8	22.0	
3	B11	13.0	47.6	14.4	25.0	SCL	1.13	7.5	33.0	
4	B12						1.18	8.4	31.4	

Table 20. Physico-chemical properties.

Pedon: Negros 5 (N-5)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H₂O)	pH (KCl)	pH △pH	pH (NaF)	Exch. Al (me/ 100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
N-5-1	Ap11	6.15	5.3	0.85	10.05	0.02	1.4	0.8	0.10	8	700	7.6	4.31	0.45	0.27	0.12	68.2
2	Ap12	6.10	5.6	0.5	9.9	tr	1.9	1.1	0.10	11	720	7.8	5.81	0.43	0.28	0.15	85.3
3	Ap2	6.25	5.5	0.75	10.0	tr	1.4	0.8	0.09	9	800	7.8	5.28	0.44	0.20	0.21	79.4
4	B11	6.30	5.1	1.2	9.9	tr	0.5	0.3	0.07	4	720	8.6	3.73	0.42	0.13	0.30	53.3
5	B2	6.70	5.1	1.6	10.4	tr	0.5	0.3	0.02	15	860	9.4	4.03	0.77	0.12	0.32	55.9

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
N-5-1	Ap11					1.25	3.61	26.1		
2	Ap12					1.29	3.23	25.5		
3	Ap2					1.25	4.36	28.9		
4	B11					1.25	6.20	36.7		
5	B2					1.15		38.0		

Table 21. Physico-chemical properties.

Pedon: Negros 6 (N-6)

CHEMICAL PROPERTIES

Sample No.	Horizon	pH (H₂O)	pH (KCl)	pH △pH	pH (NaF)	Exch. Al (me/ 100 g)	O.M. (%)	T-C (%)	T-N (%)	C/N Ratio	P-Adsorp. Coeff.	CEC (me/ 100 g)	Exch. Cation (me/100 g) Ca	Mg	K	Na	Base Saturation (%)
N-6-1	A1	5.7	4.7	1.0	11.7	0.41	3.6	2.1	0.44	5	1060	9.9	0.53	0.05	0.13	0.17	8.9
2	IIA	5.6	4.65	1.95	12.1	0.41	5.5	3.2	0.33	10	1200	8.34	0.31	0.04	0.13	0.17	7.8
3	IIB	5.8	5.10	0.7	11.9	0.10	2.6	1.5	0.25	6	920	4.69	0.36	0.03	0.13	0.16	14.4
4	IIIC	5.9	4.8	1.1	11.9	0.12			0.21		900	4.17	0.28	0.03	0.09	0.15	13.3
5	IVC	6.3	5.2	1.1	11.9	0.05			0.23		1380	7.56	0.95	0.07	0.14	0.16	17.5
6	VC1	6.05	5.25	0.8	12.0	0.02			0.02		1580	8.86	1.14	0.14	0.17	0.17	18.3
7	VC2	5.95	5.3	0.65	11.9	0.02			0.11		1540	9.28	1.59	0.08	0.11	0.19	21.0

PHYSICAL PROPERTIES

Sample No.	Horizon	Particle Size Distribution Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture	Bulk Density (g/cc)	Moisture Content (%)	Water Retention 1/3 bar (%)	15 bar (%)
N-6-1	A1	33.0	41.5	18.1	7.3	SL	1.03	11.2	34.4	
2	IIA	31.6	44.6	15.7	8.1	SL	0.98	9.6	33.9	
3	IIB	47.5	37.9	10.8	3.8	LS	1.25	6.0	23.1	
4	IIIC	62.2	25.3	8.9	3.6	LS	1.43	3.4	18.1	
5	IVC	37.0	38.9	18.9	5.2	SL	0.99	12.3	30.8	
6	VC1	30.0	46.3	16.5	7.2	SL	0.70	25.1	47.9	
7	VC2	31.9	42.8	20.2	5.1	SL	0.80	19.1	48.6	

Phosphate absorption coefficients of N-4 and N-5 were low (440 to 860) while those of N-1 (1340 to 1760) and of N-6 (900 to 1580) were high. These ranges followed the trend of soil organic matter contents in these pedons.

Cation exchange capacities of N-1 (11.7 to 14.6 me/100 g) were relatively high compared to those of other areas (4.7 to 10.7 me/100 g).

Exchangeable Ca contents were high in N-5 (3.7 to 5.8 me/100 g) but low in N-6 (0.28 to 1.59 me/100 g). Exchangeable Mg contents were high in N-5 (0.42 to 0.77 me/100 g) and low in N-6 (0.07 to 0.29 me/100 g). Exchangeable K contents of N-1 (0.55 to 0.85 me/100 g) were higher than those of N-6 (0.09 to 0.17 me/100 g). Exchangeable Na contents ranged from 0.107 to 0.427 me/100 g and increased with the depth of the profile. Thus, leaching of Na is indicated by the data.

Degrees of base saturation of N-6, N-1, N-4 and N-5 ranged from 7.8 to 21.0%, 14.6 to 38.6%, 18.3 to 59.5% and 68.2 to 85.3%, respectively. As anticipated the areas at lower elevations have higher base saturations than those located at higher elevations. In the case of N-6, the degree of base saturation increased with the depth of the profile. Therefore it is reasonable to assume that the bases from the upper layers have leached or have moved downward and accumulated in the lower layers or that the lower layers might have weathered, hence releasing these bases.

It is recalled that N-1 and N-6 are located at higher elevations, have a coarse texture (loamy sand and sandy loam) with clay contents lower than 8.1% while N-4 and N-5 showed a fine texture (silty clay loam and heavy clay) with 16 to 48% clay contents. Increasing amounts of clay were observed in the lower layers. Assuming that pedon N-4 was influenced by river, then clay materials might have been deposited as a result.

Water contents of the air-dried samples and water retention at 1/3 bar of N-6 ranged from 3.4 to 25.1% and 18.1 to 48.6%, respectively. These values were higher compared to those of other soils in the area which contain 3.4 to 25.1% water in the air dry state with 21.1 to 38.6% of water retention capacity or 1/3 bar.

The analyses point to the probability that N-6 may contain higher amounts of amorphous material while the 1:1 clay minerals like kaolinite or metahalloysite may dominate the rest.

III. 3. Discussion

III. 3. 1. pH

Figure 11 is plotted to show the relationship between pH (H_2O), X, and pH (KCl), Y. A regression line was obtained and is expressed as,

$$Y = 0.828 \times 0.20 \ (r = 0.784)$$

Data points of the Isarog, Zambales, Negros, Iriga and Mayon-2 soils are concentrated on the upper part of the regression line while those of the Tagaytay, Mayon-1, Caliraya and Sorsogon-2 soils dot the lower portion of the line. The scatter of points for ΔpH and pH (KCl) does not show any apparent relation although the Tagaytay soils displayed the highest change while the Negros and Isarog soils the least indicating that the latter two pedons may contain greater quantities of amorphous material (Fig. 12).

Figure 13 shows the relationship between the pH (KCl) and exchangeable aluminum content. Generally, the exchangeable aluminum content decreased logarithmically with the pH (KCl). The pH (KCl) values of the Isarog, Negros, Zambales, Iriga and Mayon-1 soils were higher than those of the other samples. This may be ascribed to higher amounts of amorphous materials containing OH-groups and exchanging with Cl^- ion.

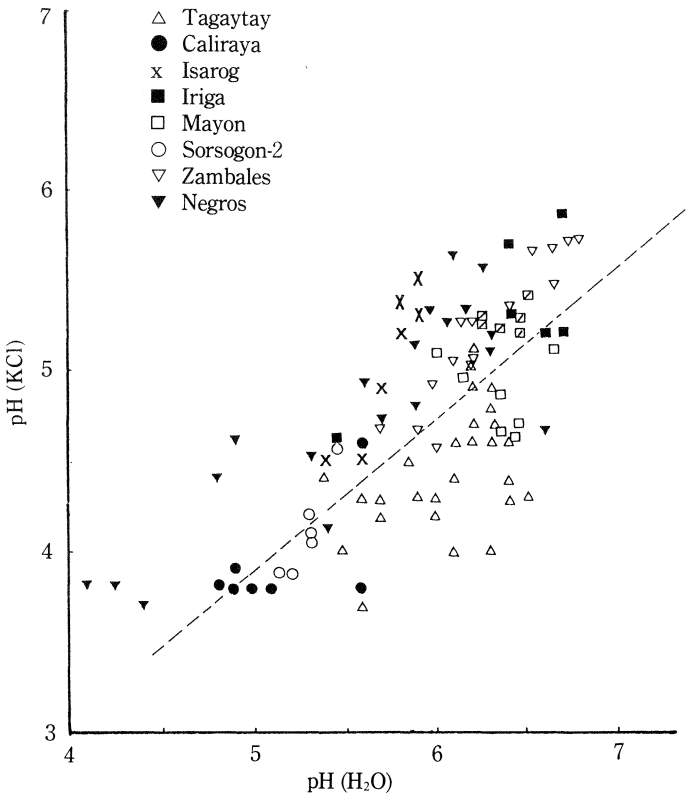

Fig. 11. Relationship between pH (KCl) and pH (H_2O).

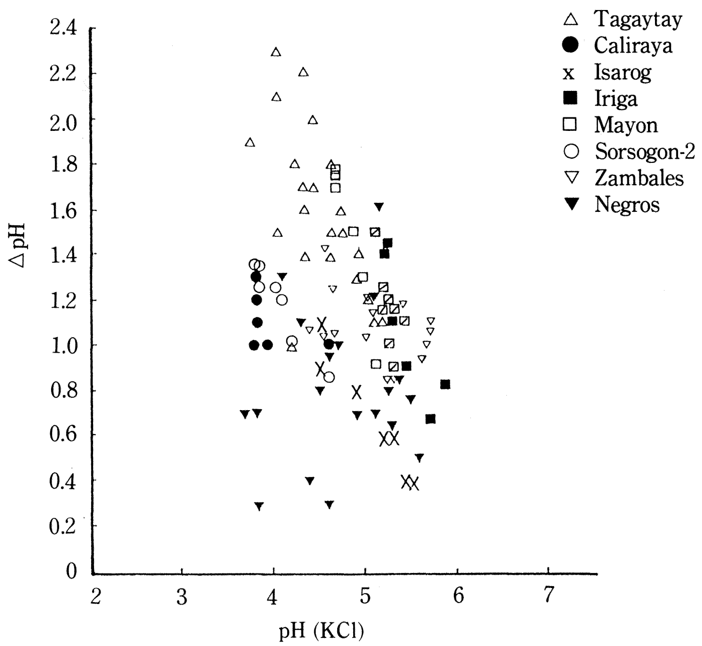

Fig. 12. Relationship between ΔpH and pH (KCl).

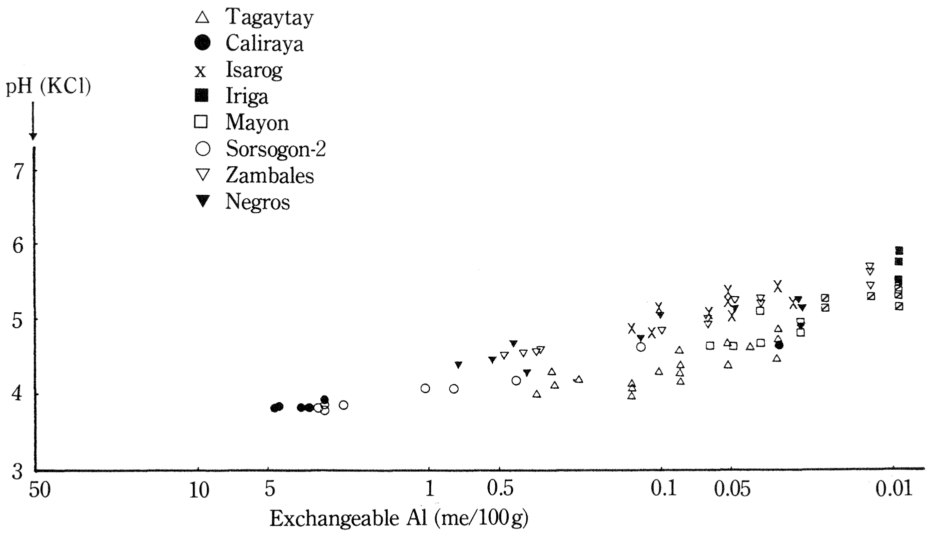

Fig. 13. Relationship between pH (KCl) and exchangeable aluminum content.

III. 3. 2. Cation exchange capacity (CEC) and exchangeable base contents

Figures 14, 15, 16 and 17 present the plots of the various bases against CEC. Exchangeable Ca^{++} contents of the samples were in the decreasing order of: Tagaytay > Iriga > Mayon > Zambales, Negros, Caliraya, Isarog, Sorsogon. Except for the Isarog samples, the apparent correlation between CEC and exchangeable Ca or Mg contents was rather clear (Fig. 14 and 15).

Tagaytay soils showed a wide range as well as the highest exchangeable K contents (0.5 to 4.2 me/100 g) but overall only a weak correlation was demonstrated between the contents of exchangeable K and CEC (Fig. 16). The same conclusion if not more so, is valid between the contents of exchangeable Na and CEC (Fig. 17). It should be added that the exchangeable Na contents of the Sorsogon 2, Mayon, Tagaytay and Iriga soils were low.

Figure 18 shows the spread of the base saturation values and the geographical location of the soil samples. It appears that the Iriga soil had exhibited the narrowest range but the highest percentage of base saturation, followed by the Tagaytay soils and the Mayon soils. The Zambales soils showed a wide range of base saturation (10 to 50%) whereas the Negros and Isarog soils showed consistently a low base saturation in a narrow range. Such a geographical distribution of base saturation is related to the locations and numbers of soils sampled and thus is subject to even drastic changes depending on the nature and age of the materials deposited as well as on the prevailing climate.

Except for the Isarog soil, Ca^{++} and Mg^{++} ratios per electric charge were stable, hence, it is considered that these two ions are resistant to the leaching process or may be replenished at a constant ratio as the materials weather.

Exchangeable Ca^{++} and Mg^{++} contents of the volcanic ash soils in Japan (Ministry of Agriculture and Forestry, Japanese Government; 1964, Kurobokudo Cooperative Research Group; 1984) were plotted against CEC (Figs. 19 and 20). As seen in Figure 14, there was a certain degree of similarity between the ash-derived soils of the Philippines and those from Japan with respect to the exchangeable Ca^{++} content, although the

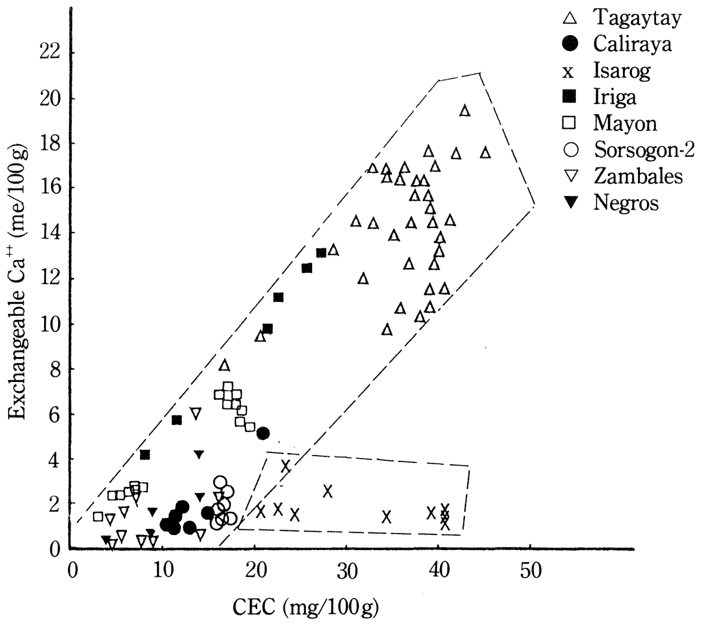

Fig. 14. Relationship between exchangeable calcium content and CEC.

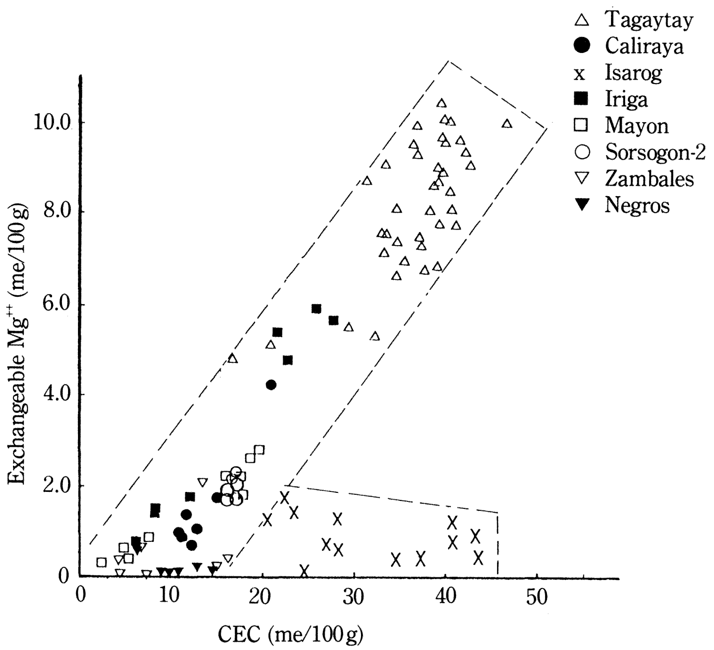

Fig. 15. Relationship between exchangeable magnesium content and CEC.

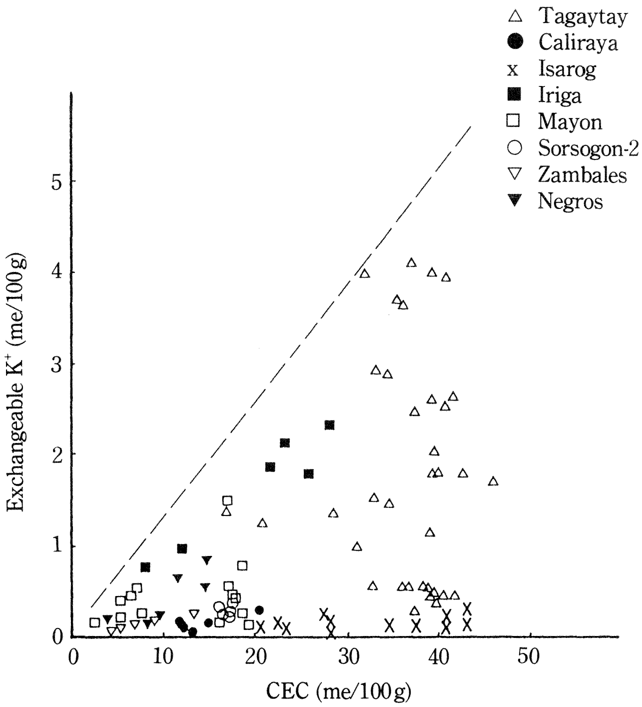

Fig. 16. Relationship between exchangeable potassium content and CEC.

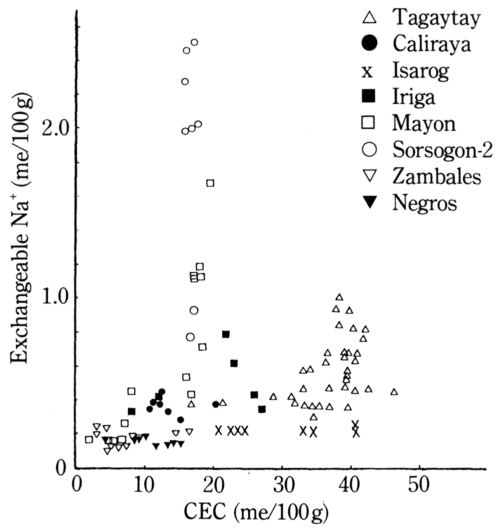

Fig. 17. Relationship between exchangeable sodium content and CEC.

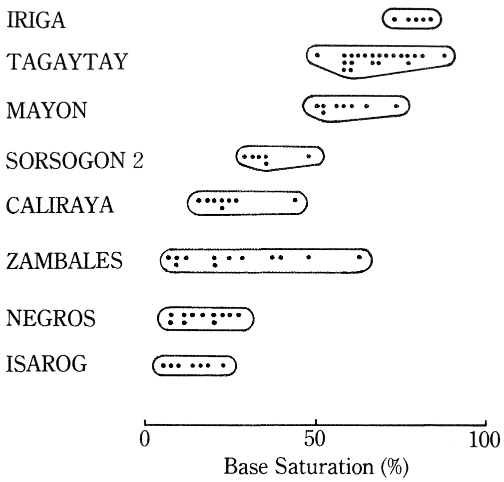

Fig. 18. Base saturation of the soils.

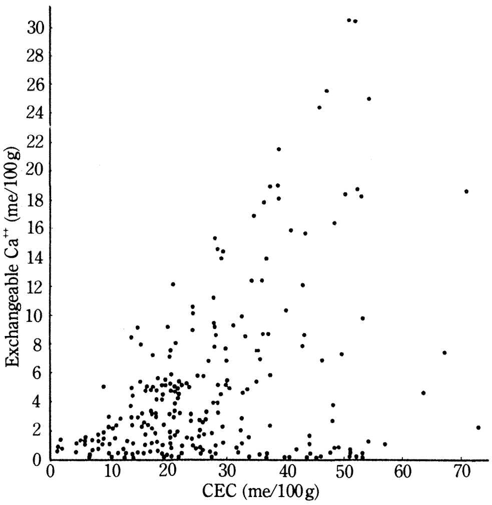

Fig. 19. Relationship between exchangeable calcium content and CEC of volcanic ash soils in Japan.

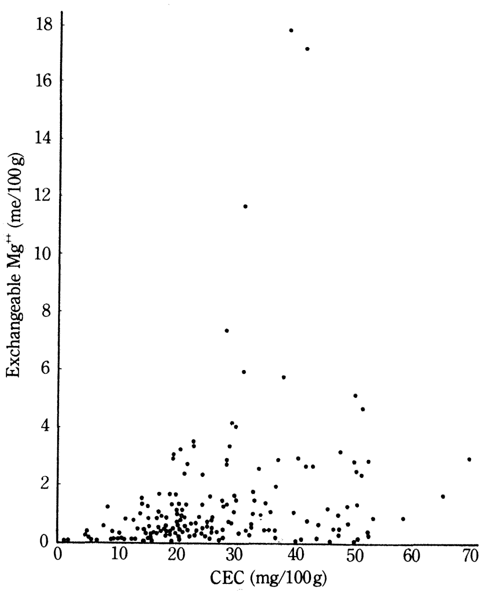

Fig. 20. Relationship between exchangeable magnesium content and CEC of volcanic ash soils in Japan.

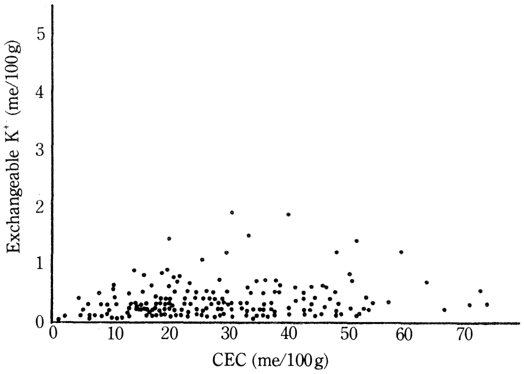

Fig. 21. Relationship between exchangeable potassium content and CEC of volcanic ash soils in Japan.

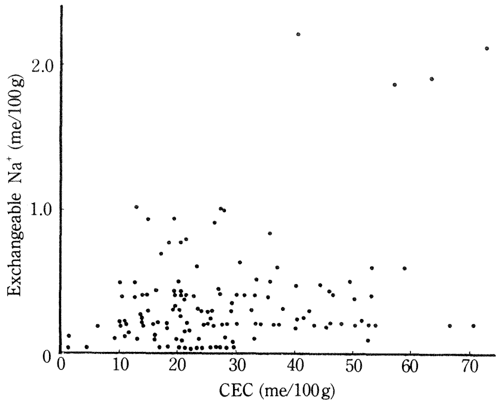

Fig. 22. Relationship between exchangeable sodium content and CEC of volcanic ash soils in Japan.

volcanic ash soils of Japan did not show a constancy in Ca^{++} content per charge. Exchangeable Mg contents of the volcanic ash soils in Japan were comparatively much lower than those of the Philippine soils and there of was no correlation between the CEC and exchangeable Mg^{++} content (Fig. 20). Mg^{++} ions of these soils may have been already lost through leaching and were not replenished during the weathering process of the parent materials. Furthermore, the contents of exchangeable K^+ and Na^+ of these soils (Figs. 21 and 22) were very low and were not correlated with the CEC values.

From these observations, it may be inferred that the exchangeable Ca^{++} and Mg^{++} of the volcanic ash soils in the Philippines are more resistant to leaching than those of the volcanic ash soils from Japan and that in general the Philippine soils contain larger amounts of exchangeable K^+ than the Japan soils.

III. 3. 3. Phosphate absorption coefficients

Volcanic ash soils in the Philippines showed a wide range of phosphate absorption coefficients (400 to 2186). The relationship between the phosphate absorption coefficient and base saturation is presented in Figure 23. Based on these two properties the soil samples may be classified into several groups. Group one consists of soils whose base saturation is less than 30% and phosphate absorption coefficient more than 1000. The Isarog, some of the Zambales and Negros soils belong to this group.

The second group (Group II), is composed of soils with less than 30% base saturation and phosphate absorption coefficient of less than 1000. The Caliraya, certain Zambales and Negros soils belong to this group.

Group III consists of soils having 30 to 50% base saturation with a phosphate absorption coefficient of more than 1000. Sorsogon-2 belongs to this group.

The fourth group is composed of soils with 30 to 50% base saturation and phosphate absorption coefficient of less than 1000. The soils belonging to this group include some of the Zambales and Caliraya soils.

The fifth group consists of soils whose values fall within the area of the triangle with a

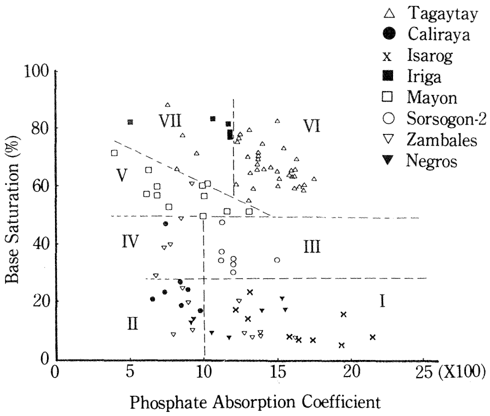

Fig. 23. Relationship between base saturation and phosphate absorption coefficient of volcanic ash soils in the Philippines.

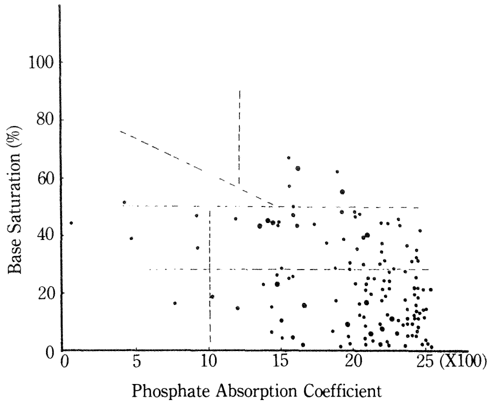

Fig. 24. Relationship between base saturation and phosphate absorption coefficient of volcanic ash soils in Japan.

base saturation ranging from 50 to 80% and phosphate absorption coefficient from 0 to 1500. Mayon soils and the rest of the Zambales soils belong to this group.

Group VI includes soils with more than 50% base saturation and more than 1200 phosphate absorption coefficient. The Tagaytay soils belong to this group.

The seventh group consists of soils with a base saturation greater than 55% and phosphate absorption coefficient less than 1200. The Iriga soil and young ash of Tagaytay belong to this group.

As shown in Figure 24, almost all the volcanic ash soils (Ministry of Agriculture and Forestry, Japanese Government; 1964, Kurobokudo Cooperative Research Group; 1984) in Japan fall within groups I and III.

To conclude, volcanic ash soils in the Philippines display a wide range of base saturation and phosphate absorption coefficients while those from Japan show a low base saturation and high phosphate absorption coefficients.

III. 3. 4. Soil organic matter (Humus)

Among the volcanic ash soils collected in the Philippines, the A horizon of the Isarog soil contained the largest amount of organic matter (19.1%). The A horizons of the other samples contained a lower amount of organic matter ranging from 2.1 to 10.8%. The relationship between soil organic matter contents of the A horizons including the A13 and A3 horizons, and annual rainfall is shown in Figure 25. It is seen that a larger soil organic matter accumulation occurs in areas with an annual rainfall in the range of 2300 to 2500 mm and that the accumulation decreases with increasing annual rainfall.

As shown in Tables 22 and 23, the adjacent or nearby weathe station indicates that the Isarog soil of Naga City has a mean temperature (Lucas, Mojica, Engle and Salazar: 1965) of 26,8°C; Zambales soils (PAGASA*; 1976) (Iba City) 27.3°C and Tag-1 (Tagaytay City)

PAGASA* : Philippine Atmospheric, Geophysical and Astronomical Services Administration

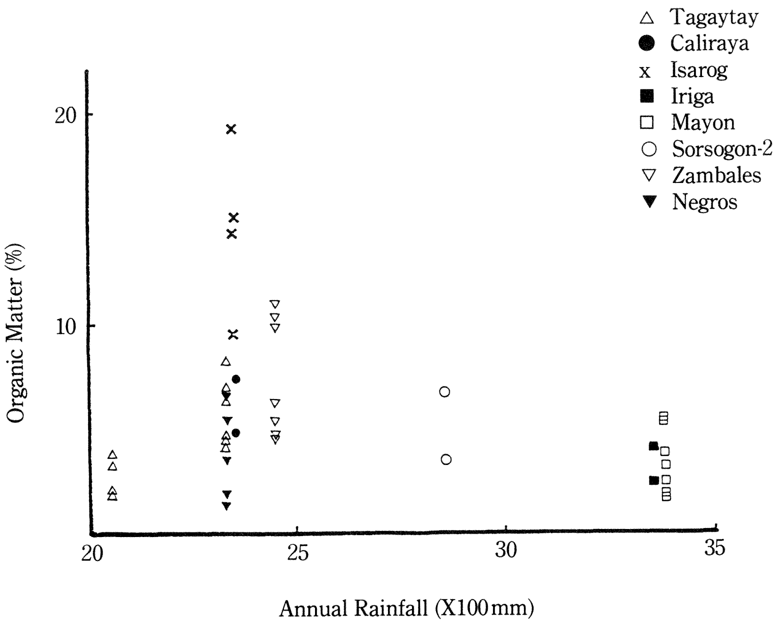

Fig. 25. Relationship between organic matter content and annual rainfall.

Table 22. Average monthly and annual rainfall (mm).

	Los Banos NAS (1983)	Iba, Zambales (1975)	Caliraya, Lumban Laguna (1951-1970)	General Trias Cavite (1920-1932)	Tagaytay City (1928-1932)	Naga City (1909-1956)	Legaspi City (1909-1956)	Negros Bacolod (1918-1951)
January	72.1	T	156.3	6.8	25.9	114.81	374.6	111.7
February	1.6	0.0	75.2	10.4	5.1	81.28	269.7	58.2
March	5.4	0.0	66.6	7.4	21.8	68.83	213.6	35.2
April	0.2	6.1	83.5	24.4	24.6	86.36	150.6	37.6
May	48.3	11.7	162.0	180.8	189.0	155.70	171.7	184.3
June	192.2	27.4	273.5	282.2	185.0	202.18	194.5	297.3
July	619.4	233.2	267.7	427.0	436.6	274.32	239.2	391.6
August	179.2	329.7	289.2	459.2	573.5	186.94	206.2	315.8
September	141.2	325.1	304.9	288.5	416.0	291.34	248.1	281.8
October	369.6	610.5	364.0	139.7	208.0	292.10	317.2	262.4
November	30.4	25.3	460.4	147.6	169.2	308.61	481.0	234.8
December	17.9	44.6	360.9	52.1	66.8	290.08	513.3	173.8
Annual:	1667.5	2457.9	2864.2	2026.1	2321.5	2352.55	3380.3	2324.5

Table 23. Average monthly and mean temperature (°C).

	Los Banos NAS (1983)	Iba, Zambales (1975)	Caliraya, Lumban Laguna (1951-1970)	General Trias Cavite (1920-1932)	Tagaytay City (1928-1932)	Naga City (1909-1956)	Legaspi City (1909-1956)	Negros Bacolod (1918-1951)
January	25.8	25.2	23.7	25.4	21.0	25.1	25.72	25.9
February	25.9	25.9	24.2	26.2	21.6	25.0	25.88	26.0
March	27.7	27.1	24.8	27.7	22.9	25.9	26.72	26.8
April	29.0	29.2	26.1	29.2	24.2	27.0	27.72	27.9
May	28.7	29.3	26.9	28.8	24.2	28.2	28.82	28.3
June	29.5	28.2	26.3	27.3	23.8	28.2	28.06	27.5
July	28.5	27.2	25.9	26.8	22.7	27.9	27.44	26.6
August	27.9	27.0	25.7	26.8	22.7	28.1	27.44	26.6
September	28.3	27.3	25.3	27.0	22.9	27.7	27.28	26.7
October	27.4	27.3	25.3	26.9	22.7	27.0	27.11	26.8
November	26.6	26.6	24.5	26.2	21.9	26.3	27.11	26.4
December	25.2	26.7	24.2	25.6	21.1	25.6	26.17	26.3
Mean:	27.5	27.3	25.2	27.0	22.7	26.8	27.06	26.8

have a mean temperature which is not too high, hence large organic matter accumulation in the Isarog soil. Thus, the organic matter content cannot be attributed to the effects of temperature alone and may be dependent if not more on the degree of weathering of the parent materials, kinds of plant residues as the source of organic matter and on the period of deposition of the ash. However, the differences in the accumulation of soil organic matter in the northwestern part of the Taal volcano could be attributed to differences in the mean temperature and annual rainfall (PAGASA; 1976). Large soil organic matter accumulation was observed in areas at lower elevations with a mean temperature of 27.0°C and an annual rainfall of 2026.1 mm. The C/N ratios in areas at low elevations were low while those in areas at high elevations were high so that the quality of soil organic matter may consequently be influenced by the temperature and rainfall. Further studies are needed to clarify the quality of soil organic matter in these soils.

III. 3. 5. Soil texture

The volcanic ash soils in the Philippines exhibited varying soil textures.

As shown in Figure 26, the Caliraya soil had the highest clay content (58.5 to 79.3%) followed by Mayon old volcanic ash soils (24.9 to 64.9%), Sorsogon-2 soil (11.8 to 61.6%), Tagaytay old volcanic ash soils (16.0 to 49.3%), Iriga soils (3.2 to 27.3%), Isarog soils (16.7 to 24.2%), Tagaytay young ash soils (7.7 to 21.9%), Zambales soils (0.7 to 11.6%), Negros soils (0.7 to 8.1%) and Mayon young ash soils (1.6 to 6.0%).

Assuming that the clay content is associated with the degree of weathering, it can be stated that the Caliraya soil was subjected to the strongest weathering, followed by Mayon old ash soil, Sorsogon-2 soil, Tagaytay old ash soil, Iriga, Tagaytay young ash soil, Zambales soils, Negros and Mayon young ash soils.

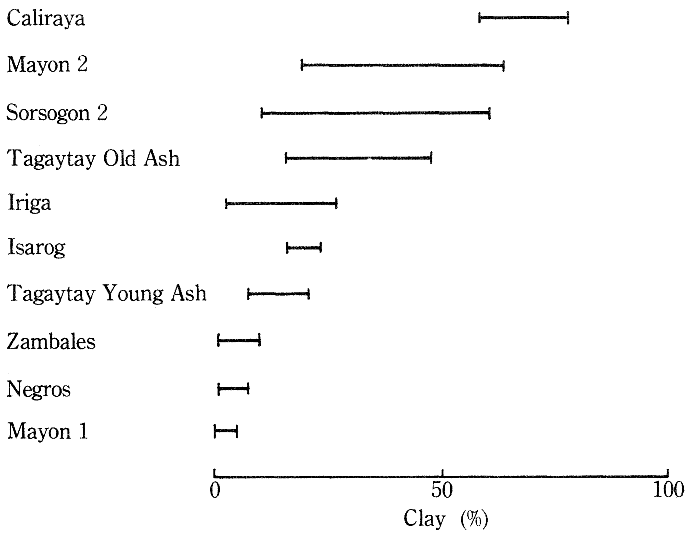

Fig. 26. Clay content of volcanic ash soils in the Philippines.

III. 3. 6. Bulk density and water content

The soils showed a wide range of bulk density values (0.63 to 1.29 g/cm^3) and water retention capacities (5.8 to 62.9% at 1/3 bar).

In Figure 27, on inverse relationship (r = −0.804) between bulk density and water content is observed. Isarog soil with low bulk density values showed a high water content while the Zambales and Mayon soils which have a coarse texture and the Negros (N-5) soils having a high bulk density showed low water contents. High water content and low bulk densities are characteristics of amorphous materials typified by the samples from Isarog.

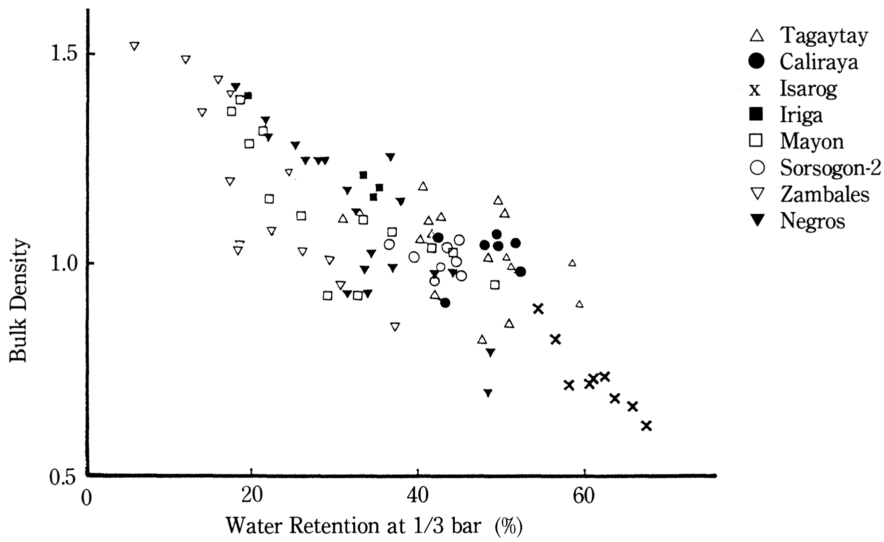

Fig. 27. Relationship between bulk density and water retention at 1/3 bar.

III. 4. Summary

For pedological as well as fertility purposes, the physico-chemical characteristics of the volcanic ash soils in the Philippines were clarified. The results indicated the following:

1. Tagaytay soils located on the northwestern slope of Taal volcano at high elevations showed a relatively high accumulation of soil organic matter and C/N ratio while those at low elevations exhibited a low soil organic matter accumulation and C/N ratios.
2. Caliraya soil had a very low pH and relatively high exchangeable aluminum content.
3. Isarog soil showed the highest soil organic matter contents at the surface, comparatively high pH(NaF), phosphate absorption coefficient and water contents but low exchangeable cation contents and bulk density. A similar behavior was observed for the Kuroboku soils in Japan.
4. Iriga soil had high pH, exchangeable cation contents and base saturation.
5. There were two types of soils from Mayon ash. One was a relatively old ash soil with a fine texture, high phosphate absorption coefficient and water content, while the other was coarse-textured, with a low phosphate absorption coefficient and young ash. Both exhibited high exchangeable cation contents.
6. Bulusan soil hand a low pH, high exchangeable aluminum content and low base saturation.
7. Zambales soils had a high pH, coarse texture, but low CEC and water content. The phosphate absorption coefficient was high under the natural, uncultivated conditions.
8. Negros soils displayed variations in the properties of volcanic ash soils. At high elevations the soils has high pH, organic matter content, phosphate absorption coefficient but low exchangeable cation contents while those deposited at low elevations had low pH, phosphate absorption coefficient and soil organic matter content.
9. Correlations were observed between pH (H_2O) and pH (KCl) of various samples suggesting that the Isarog, Zambales, Negros, Iriga and Mayon-2 soils may contain a greater amount of amorphous materials than the other soils included in this study.
10. Additionally, correlations were observed between the exchangeable Ca content and CEC and between the exchangeable Mg content and CEC but none between the exchangeable K content and CEC or between the exchangeable Na content and CEC.
11. The Iriga soil exhibited the highest degree of base saturation, followed by the Tagaytay soils, then Mayon, Sorsogon, Caliraya, Zambales, Negros soils while the lowest degree of base saturation was observed in the Isarog soil.
12. Based on the relationship between the phosphate absorption coefficients and base saturation of the samples, volcanic ash soils in the Philippines may be classified into several groups according to varying combinations of ranges in these two properties.
13. Maximum soil organic matter accumulation was observed in areas with an annual rainfall of 2300 to 2500 mm.
14. Detectable variations in the physico-chemical properties of Philippine volcanic ash soils stem from the differences in the nature of ejectas, position and time of deposition and rainfall characteristics.

IV. PHOSPHATE CONTENTS AND DISTRIBUTION IN PEDONS

Phosphate generally ranks second only to nitrogen as the most widely deficient macronutrient in the soils of the Philippines. These soils are acidic and contain large amounts of Fe/Al oxides and hydrous oxide which contribute to their high P-fixing capacity. The relatively young, acidic soils derived from volcanic ash such as the Andosols or Dystroandepts are also known to be deficient in phosphorus.

The pool of potentially available P or labile P is dependent upon the amounts of the various forms of phosphorus in the soil. Hence, it is important to clarify the status of the accumulation of phosphorus in soils.

Phosphate contents and distribution of volcanic ash soils in Japan have been extensively investigated by some scientists and researchers (Egawa and Sekiya; 1959, Onikura; 1963, Otsuka; 1978, Miyazawa; 1981, Amano; 1981). However, in the Philippines, there are only few reports (Singlachar; 1969 Dacayo; 1976, Briones; 1980) on phosphate in soils.

In this chapter, different forms of phosphorus were determined in order to gain information on the accumulation, the distribution and the transformation of phosphate in soils.

IV. 1. Materials and Methods

IV. 1. 1. Soil samples

The soil samples taken from each horizon of the profiles described in Chapter I were air-dried, pulverized and allowed to pass through a 0.25 mm sieve.

IV. 1. 2. Methods

(1) *Extraction and determination of Total P, Inorganic P and Organic P Extraction:*

The different forms of P were extracted and determined by the method of Metha et al. (1954) which is an alkaline extraction of P in NaOH after acid pretreatment and then P is determined colorimetrically. In the procedure, 1.0 g of soil was placed in a 100-ml centrifuge tube and 10 ml of HCl was added. The suspension was heated for 10 minutes (70°C), then removed and an additional 10 ml of HCl was added and mixed. This suspension was allowed to stand at room temperature for 1 hour and then 50 ml of water was added and mixed. The suspension was centrifuged and the clear supernatant liquid was poured into a 250 ml volumetric flask. Thirty ml of 0.5 N NaOH was added to the tube, the soil was stirred and the suspension was again allowed to stand at room temperature for 1 hour. The suspension was then centrifuged and the supernatant liquid was poured into the volumetric flask containing the acid extract. Then, 60 ml of 0.5 N NaOH was added to the tube, the soil was stirred and the tube was covered with an inverted beaker, followed by warming in an oven at 90°C for 16 hours. The tube was allowed to cool, the suspension was centrifuged and the supernatant liquid was poured into the flask containing the previous extracts. The residue was then washed with 0.5 N NaOH until the supernatant liquid was clear. The washings were combined with the extracts and then the combined extracts were diluted to the volume with water and mixed thoroughly.

Quantitative determination:

For total P determination, a 20 ml aliquot was pipetted from the combined extracts that had been shaken thoroughly. To the aliquot 1 ml of 72% $HClO_4$ was added, followed by evaporation to a residue of $HClO_4$ on the steam plate. The digestion was continued until the color of the residue no longer changed (no more dark particles). The digest was then cooled and transferred to a 100 ml volumetric flask and into it, 6 ml of 10% potassium ferrocyanide and 5 ml of 10% $MnSO_4$ were added. The pH of the solution was then adjusted to 7.0 by the addition of 1:1 NH_4OH drop by drop until the color of the solution became purple. Then, 3.5 ml of 2N H_2SO_4 was added, filled up to 50 ml with water and filtered. A 10 ml aliquot was taken from the filtrate, and 36 ml of water and 2 drops of p-nitrophenol were added. The pH was then adjusted to 7.0 by adding 1:1 NH_4OH until the solution became yellow and 2 ml of sulfomolybdic acid and 3 drops of freshly prepared $SnCl_2$ solution were added. The solution was filled up to 50 ml with water and its absorbance was read at 720nm after 5 minutes. The total P extracted was calculated as mg P_2O_5/100 g of the soil.

For inorganic P determination, a 20 ml aliquot was taken from the combined extracts and the same procedure was adapted as in the total P determination, except that no digestion was made.

The organic P content is expressed by the difference between the phosphorus content in the extract before and after the oxidation of the organic matter. It is therefore calculated as:

Organic P (mg P_2O_5/100 g) = Total P (mg P_2O_5/100 g) − Inorganic P (mg P_2O_5/100 g)

IV. 1. 3. Fractionation of phosphate

(1) *Ca-P extraction and determination*

To a 1.0 g soil sample in a 100 ml centrifuge tube, 100 ml of 2.5% HOAc was added. The suspension was shaken for two hours and then centrifuged. The soil was then washed with 50 ml of 1 *N* NH_4Cl twice and the washings were combined with the supernatant liquid in the 200 ml volumetric flask. The flask was filled up to 200 ml with water and then a 20 ml aliquot was taken and P was determined by method II (Chlorostannous-reduced molybdophosphoric blue color method in HCl system) (Black; 1965).

(2) *Al-P extraction and determination*

To the same soil used for the Ca-P determination, 100 ml of 1 N NH_4F was added and shaken for one hour. The sample was then centrifuged and Al-P was determined from the extract by Method II (Black; 1965).

(3) *Fe-P extraction and determination*

The remaining soil was washed with 50 ml of a saturated NaCl solution twice. Then 100 ml of 0.1 N NaOH was added into the soil and shaken for 2 hours and the suspension was allowed to stand for 24 hours. The suspension was the centrifuged and Fe-P was determined from the extract by method I (chlorostannous-reduced molybdophosphoric blue color method, in H_2SO_4 system) (Black; 1965)

(4) *Occluded-P*

The amount of occluded P was then calculated as the difference between the total inorganic P content determined from IV. 1. 2. (1) and the sum of Ca-P, Al-P and Fe-P.

IV. 2. Results

IV. 2. 1. Tagaytay soils

The phosphate contents of the Tagaytay soils are shown in Tables 24 and 25. The total

Table 24. P content of Tagaytay soil (Tag-1) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A	273.6	166.5 (61%)	107.1 (39%)	1.7 (2%)	13.8 (13%)	13.1 (12%)	78.5 (73%)
IIA	266.4	142.2 (53%)	124.2 (47%)	3.5 (3%)	17.4 (14%)	17.7 (14%)	85.6 (69%)
IIIA11	332.8	184.0 (55%)	148.8 (45%)	3.5 (2%)	13.8 (9%)	18.5 (12%)	113.0 (77%)
IIIA12	295.2	158.4 (54%)	136.8 (46%)	5.8 (4%)	11.5 (8%)	15.2 (11%)	104.3 (77%)
IVA	264.6	144.9 (55%)	119.7 (45%)	4.6 (4%)	10.4 (9%)	14.2 (12%)	90.5 (75%)
IVB	174.6	97.2 (56%)	77.4 (44%)	5.8 (8%)	7.5 (10%)	5.6 (7%)	58.5 (75%)
VC1	124.8	36.0 (29%)	88.4 (71%)	5.8 (7%)	9.3 (11%)	5.3 (6%)	68.0 (76%)
VC2	105.6	12.8 (12%)	92.8 (88%)	4.0 (4%)	9.2 (10%)	4.9 (5%)	74.7 (81%)

Table 25. P content of Tagaytay soil (Tag-3) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A	868.0	447.0 (51%)	421.0 (49%)	24.2 (6%)	163.9 (39%)	68.8 (16%)	164.1 (39%)
B	501.2	157.2 (31%)	344.0 (69%)	19.4 (6%)	123.0 (36%)	79.4 (23%)	122.2 (36%)
C	384.0	97.0 (25%)	287.0 (75%)				
IIA	423.6	181.6 (43%)	242.0 (57%)	10.9 (6%)	51.2 (21%)	54.1 (22%)	125.8 (52%)
IIIB1	254.0	95.6 (38%)	158.4 (62%)	5.8 (4%)	25.3 (16%)	12.2 (8%)	115.1 (72%)
IVB2	233.3	88.3 (38%)	145.0 (62%)	3.7 (3%)	23.0 (16%)	9.9 (7%)	108.4 (74%)
VC1	222.0	53.0 (24%)	169.0 (76%)	5.8 (3%)	27.6 (16%)	11.1 (7%)	124.5 (73%)
VC2	194.0	37.0 (19%)	157.0 (81%)	3.7 (2%)	20.7 (13%)	9.8 (6%)	122.8 (79%)
VC3	148.0	42.0 (28%)	106.0 (72%)	3.5 (3%)	20.5 (19%)	7.8 (7%)	74.2 (71%)

phosphate contents of the Tag-1 and Tag-3 soils ranged from 105.6 mg/100 g to 332.8 mg/100 g and from 148.0 mg/100 g to 868.0 mg/100 g, respectively. The total phosphate contents of young volcanic ash layers (A, B and C of Tag-3) were higher (384.0 mg/100 g to 868.0 mg/100 g) than those of the other layers. Furthermore, the total phosphate contents in both profiles of Tag-1 and Tag-3 tended to decrease with the depth of the profile.

The organic phosphate contents ranged from 107.1 mg/100 g to 447.0 mg/100 g for the A and buried A horizons and from 12.8 mg/100 g to 157.0 mg/100 g for the B and C horizons, including the buried B and C horizons. The young volcanic ash layer (C horizon) of Tag-3 contained 97.0 mg/100 g accounting for about 25% of the total phosphate contents after 12 years. The A and humic buried horizons contained greater amounts of organic phosphates and a higher percentage to total phosphate contents (43% to 61%) than the other layers (12% to 38%). The total inorganic phosphate contents of the Tag-1 soil ranged from 77.4 mg/100 g to 148.8 mg/100 g accounting for 12% to 61% of the total phosphate contents. These values tended to increase with the depth of the profile. Young ash layers of the Tag-3 soil contained 287.0 mg/100 g to 420 mg/100 g inorganic phosphate while the other layers 106.0 mg/100 g to 242.0 mg/100 g. The higher percentage of inorganic phosphate of the Tag-3 soil (49% to 81%) compared to that of Tag-1 may be attributed to the presence of young volcanic ash.

The amounts of calcium phosphate of the Tag-1 and Tag-3 soils ranged from 1.7 mg/100 g to 5.8 mg/100 g and 3.5 mg/100 g to 24.2 mg/100 g, respectively. The young ash layers had higher calcium phosphate contents (19.4 mg/100 g to 24.2 mg/100 g) than the other layers. The percentage of the calcium phosphate form to total inorganic phosphate ranged from 2% to 8%.

Aluminum phosphate contents ranged from 9.2 mg/100 g to 17.4 mg/100 g for Tag-1 and from 20.5 mg/100 g to 163.9 mg/100 g for Tag-3. These accounted for 8% to 14% and 13% to 39% of the total inorganic phosphate contents, respectively. The Tag-3 soil, especially the young ash layers showed higher aluminum phosphate contents and percentages than the Tag-1 soil.

The iron phosphate contents of the Tag-1 and Tag-3 soils ranged from 4.9 mg/100 g to 18.5 mg/100 g and 7.8 mg/100 g to 79.4 mg/100 g, respectively. The percentages of iron forms to total inorganic phosphates ranged from 5% to 14% for Tag-1 and 7% to 23% for Tag-3. Also, young ash layers showed higher iron phosphate contents and percentages. The IIA horizon of Tag-3 had a high iron phosphate content (54.1 mg/100 g) and high percentage (22%) which may be associated with the presence of young ash layers.

The occluded phosphate contents ranged from 58.5 mg/100 g to 113.0 mg/100 g for Tag-1 and from 74.2 mg/100 g to 164.1 mg/100 g for Tag-3. The percentages of occluded phosphate to total inorganic phosphate ranged from 69% to 81% for Tag-3 and 36% to 79% for Tag-1. Also, the young ash layers had higher occluded phosphate contents but a lower percentage of occluded phosphate (36% to 39%) to total inorganic phosphate.

As described above, Tag-3 soil, especially the young ash layers had high total phosphate contents and high inorganic phosphate contents, particularly the aluminum phosphate form.

IV. 2. 2. Caliraya soil

Total phosphate contents of the Caliraya soil (Table 26) ranged from 61.3 mg/100 g to

Table 26. P content of Caliraya soil (Cal-1) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A1	142.2	69.3 (49%)	72.9 (51%)	3.5 (5%)	10.9 (15%)	7.9 (11%)	50.6 (69%)
A3	138.0	76.0 (55%)	62.0 (45%)	5.5 (9%)	5.5 (9%)	4.5 (7%)	46.5 (75%)
B1	99.8	52.2 (52%)	47.6 (48%)	4.0 (8%)	8.1 (17%)	3.3 (7%)	32.2 (68%)
B21	77.0	24.5 (32%)	52.5 (68%)	2.8 (5%)	4.8 (9%)	2.0 (4%)	42.9 (82%)
B22	71.0	16.7 (23%)	54.7 (77%)	1.8 (3%)	5.6 (10%)	2.4 (4%)	44.9 (82%)
IIB3	63.0	21.0 (33%)	42.0 (67%)	2.8 (7%)	11.3 (27%)	2.2 (5%)	25.7 (61%)
IIIC	61.3	17.9 (29%)	43.4 (71%)	2.9 (7%)	5.5 (13%)	2.6 (6%)	32.4 (75%)

142.2 mg/100 g, the values decreasing with the depth of the profile. These values were lower than those of the Tagaytay soils.

The organic phosphate contents ranged from 17.9 mg/100 g to 76.0 mg/100 g accounting for 29% to 55% of the total phosphate contents. The A and B1 horizons contained higher amounts of organic phosphate and percentages than the lower layers.

The total inorganic phosphate contents ranged from 42.0 mg/100 g to 72.9 mg/100 g. The amounts of the calcium phosphate form ranged from 1.8 mg/100 g to 5.5 mg/100 g and the percentage to total inorganic phosphate ranged from 3% to 9% as in the case of the Tagatay soil. The iron phosphate contents ranged from 2.0 mg/100 g to 7.9 mg/100 g, accounting for 4% to 11% of the total inorganic phosphate contents. These values were lower than those of the Tagaytay soils. The occluded phosphate contents ranged from 25.7 mg/100 g to 50.6 mg/100 g and the percentages of occluded phosphate to the total inorganic phosphate ranged from 61% to 82% which were higher than those of the other soils.

IV. 2. 3. Isarog soil

Table 27 shows that the total phosphate contents of the Isarog soil ranged from 218.4 mg/100 g to 468.0 mg/100 g and decreased with the depth of the profile. These values were higher than those of Tag-1 and Caliraya but lower than those of Tag-3.

Isarog soil had higher organic phosphate contents (130.9 mg/100 g to 331.0 mg/100 g) which accounted for 53% to 72% of the total phosphate contents. The organic phosphate contents decreased with the depth of the profile, except for the A11 and IVB22 horizons. The A12 and A13 horizons may be humic horizons but this requires, a more detailed study.

The total inorganic phosphate contents ranged from 71.4 mg/100 g to 160.0 mg/100 g. The percentage of total inorganic phosphate to total phosphate ranged from 28% to 47%. These values were lower than those of the Tagaytay soils and Caliraya soil. The contents of the calcium phosphate form ranged from 4.3 mg/100 g to 11.5 mg/100 g, accounting for 3% to 11% of the total inorganic phosphate contents.

These values were similar to those of the Tagaytay and Caliraya soils. The aluminum

Table 27. P content of Isarog soil (IS-1) (mg P_2O_5/100 g.)

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A11	468.0	308.0 (66%)	160.0 (34%)	4.3 (3%)	116.2 (73%)	4.3 (3%)	35.2 (22%)
A12	458.0	331.0 (72%)	127.0 (28%)	4.3 (3%)	115.0 (91%)	5.2 (4%)	2.5 (2%)
A13	442.8	310.0 (70%)	132.8 (30%)	6.5 (5%)	94.3 (71%)	4.7 (4%)	27.3 (21%)
IIA	284.4	193.4 (68%)	91.0 (32%)	4.5 (5%)	63.8 (70%)	2.3 (3%)	20.4 (22%)
IIIB11	275.4	193.5 (70%)	81.9 (30%)	4.5 (6%)	49.5 (61%)	5.1 (6%)	22.8 (27%)
IIIB12	248.4	160.2 (64%)	88.2 (36%)	4.3 (5%)	54.6 (62%)	2.3 (3%)	27.0 (30%)
IIIB21	250.2	133.2 (53%)	117.0 (47%)	11.5 (10%)	38.0 (33%)	2.3 (2%)	65.2 (55%)
IVB22	240.8	169.4 (70%)	71.4 (30%)	4.6 (6%)	41.4 (58%)	0.3 (0%)	25.1 (36%)
VA	218.4	130.9 (60%)	87.5 (40%)	9.3 (11%)	46.0 (53%)	0.3 (0%)	31.9 (60%)

phosphate contents ranged from 38.0 mg/100 g to 116.2 mg/100 g and the percentages to total inorganic phosphate were high (53% to 91%), except that of the IIIB21 layer (33%). The iron phosphate contents ranged from 0.3 mg/100 g to 5.2 mg/100 g accounting for 0 to 6% of the total inorganic phosphate contents. Unlike the aluminum phosphate contents the iron phosphate contents and percentages of this soil were very low. The occluded phosphate contents and percentages to the total inorganic phosphate were as low as 2.5 mg/100 g to 35.2 mg/100 g except for the IIIB21 horizon (62.5 mg/100 g or 55%).

The Isarog soil had high organic phosphate contents and percentages, high aluminum phosphate contents and low occluded inorganic phosphate contents.

IV. 2. 4. Iriga soil

The total phosphate contents of the Iriga soil ranged from 276.7 mg/100 g to 505.6 mg/100 g which were higher than those of the other soils. The values decreased with the depth of the profile (Table 28).

Table 28. P content of Iriga soil (Ir-1) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A11	505.6	194.5 (38%)	311.1 (62%)	13.8 (4%)	64.4 (21%)	18.7 (6%)	214.2 (69%)
A12	435.6	162.6 (37%)	273.0 (63%)	10.8 (4%)	47.2 (17%)	24.7 (9%)	190.3 (70%)
A13	342.2	95.2 (28%)	247.0 (72%)	11.5 (22%)	53.5 (22%)	13.8 (6%)	168.2 (68%)
IIB1	322.8	105.0 (32%)	217.8 (68%)	10.8 (5%)	52.9 (24%)	23.0 (11%)	131.1 (60%)
IIIC	311.1	48.6 (16%)	262.5 (84%)	48.9 (19%)	58.7 (22%)	6.5 (3%)	148.4 (57%)
IVB	276.7	63.4 (23%)	213.3 (77%)	40.2 (19%)	55.2 (26%)	12.4 (6%)	105.5 (50%)

The organic phosphate contents ranged from 48.6 mg/100 g to 149.5 mg/100 g, accounting for 16% to 38% of the total phosphate contents. These percentages were relatively low compared to those of the other soils.

The inorganic phosphate contents ranged from 213.3 mg/100 g to 311.1 mg/100 g and the percentages of the total inorganic phosphate contents to the total phosphate contents were high (62% to 84%). The calcium phosphate contents ranged from 10.8 mg/100 g to 48.9 mg/100 g accounting for 4% to 19% of the total inorganic phosphate contents. The aluminum phosphate contents ranged from 17% to 26% of the total inorganic phosphate contents which were relatively higher than those of the Tag-1, Caliraya and Sorsogon-2 soils. The iron phosphate contents ranged from 6.5 mg/100 g to 24.7 mg/100 g, accounting for 3% to 11% of the total inorganic phosphate contents. The occluded phosphate contents ranged from 105.5 mg/100 g to 214.2 mg/100 g, accounting for 50% to 84% of the total inorganic phosphate contents. These contents were relatively high but the percentages were quite low.

IV. 2. 5. Mayon soils

As shown in Tables 29 and 30, the total phosphate contents of the Mayon 1 and Mayon 2 soils ranged from 79.5 mg/100 g and 316.7 mg/100 g and 240.0 mg/100 g to 377.8 mg/100 g, respectively.

The organic phosphate contents ranged from 27.1 mg/100 g to 214.6 mg/100 g for Mayon 1 and 92.9 mg/100 g to 161.1 mg/100 g for Mayon 2, accounting for 34% to 68% and 35% to 43% of the total phosphate contents, respectively.

The total inorganic phosphate contents of the Mayon 1 soil ranged from 50.0 mg/100 g to 102.1 mg/100 g, accounting for 32% to 66% of the total phosphate contents while those of the Mayon 2 soil ranged from 92.9 mg/100 g to 161.1 mg/100 g, accounting for 35% to 43% of the total phosphate contents. The high total phosphate contents of the Mayon 2 soil can be ascribed to its high inorganic phosphate contents. Calcium phosphate contents of the Mayon 1 soil ranged from 1.4 mg/100 g to 11.5 mg/100 g and the percentages from 1% to 22% while those of the Mayon 2 soil ranged from 10.8 mg/100 g to 35.9 mg/100 g, accounting for 6% to 18% of the total inorganic phosphate contents. The results showed that Mayon 2 had higher calcium phosphate contents and percentages than Mayon 1 and

Table 29. P content of Mayon 1 (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A1	316.7	214.6 (68%)	102.1 (32%)	1.4 (1%)	63.3 (62%)	7.2 (7%)	30.2 (30%)
AB	272.8	181.4 (66%)	91.4 (34%)	1.4 (2%)	7.5 (8%)	6.6 (7%)	75.9 (83%)
B	166.7	86.7 (52%)	80.0 (48%)	2.3 (3%)	4.8 (6%)	4.6 (6%)	68.3 (85%)
IIB	101.1	42.8 (42%)	58.3 (58%)	1.4 (2%)	4.8 (8%)	3.9 (7%)	48.2 (83%)
IIA1	79.5	27.1 (34%)	52.4 (66%)	11.5 (22%)	5.2 (10%)	3.3 (6%)	32.4 (62%)
IIIA3	100.0	50.0 (50%)	50.0 (50%)	2.9 (6%)	7.5 (15%)	1.1 (2%)	36.5 (77%)

Table 30. P content of Mayon 2 (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A1	355.6	151.2 (42%)	204.4 (58%)	14.4 (7%)	53.5 (26%)	6.5 (3%)	130.0 (64%)
IIAC	287.8	103.0 (36%)	184.8 (64%)	19.6 (11%)	27.6 (15%)	6.5 (3%)	131.1 (71%)
IIIA3	264.0	92.9 (35%)	171.1 (65%)	10.8 (6%)	34.5 (20%)	6.0 (4%)	119.8 (70%)
IVC			212.5	14.4 (7%)	10.9 (5%)	5.2 (2%)	182.0 (86%)
IVA3	280.0	100.0 (36%)	180.0 (64%)	22.3 (12%)	13.8 (8%)	5.2 (3%)	138.7 (77%)
VA11	320.0	115.0 (36%)	205 (64%)	13.8 (7%)	59.8 (29%)	6.6 (3%)	124.8 (61%)
VA12	377.8	161.1 (43%)	216.7 (57%)	35.9 (17%)	34.4 (16%)	7.2 (3%)	139.2 (64%)
VIA3	240.0	100.0 (42%)	140.0 (58%)	24.7 (18%)	26.5 (19%)	3.7 (3%)	85.1 (60%)

the other soils. The aluminum phosphate contents of Mayon 1 ranged from 4.8 mg/100 g to 7.5 mg/100 g accounting for 6% to 15% of the total inorganic phosphate contents except that of the A1 horizon which contained large amounts of phosphate (63.3 mg/100 g). Except for the IVC and IVA3 horizons, Mayon 2 had higher aluminum phosphate contents (27.6 mg/100 g to 53.5 mg/100 g) and percentages to total inorganic phosphate contents. The iron phosphate contents of Mayon 1 ranged from 1.1 mg/100 g to 7.2 mg/100 g, accounting for 2% to 7% of the total inorganic phosphate contents. The occluded phosphate contents of Mayon 1 soil were high (30.2 mg/100 g to 75.9 mg/100 g) accounting for 62% to 85% of the total inorganic phosphate contents, except that of the A1 horizon which contained only 30%. Mayon 2 soil also contained large amounts of occluded phosphates (60% to 86% of the total inorganic phosphate).

As described above, the Mayon 1 soil had high organic phosphate contents while the Mayon 2 soil had relatively high inorganic phosphate contents, particularly the aluminum phosphate form.

IV. 2. 6. Sorsogon 2 soil

The total phosphate contents of the Sorsogon 2 soil ranged from 58.0 mg/100 g to 134.0 mg/100 g which were relatively low (Table 31).

Table 31. P content of Sorsogon 2 (Sr-2) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A1	134.0	68.0 (51%)	66.0 (49%)	1.9 (3%)	4.9 (7%)	3.6 (6%)	55.6 (84%)
A3	110.0	25.0 (23%)	85.0 (77%)	3.2 (4%)	4.9 (6%)	4.6 (5%)	72.3 (85%)
B1	68.0	17.7 (26%)	50.3 (74%)	4.3 (9%)	2.3 (5%)	3.6 (7%)	40.1 (79%)
B21	90.0	38.5 (43%)	51.5 (57%)	2.5 (5%)	6.0 (12%)	4.9 (9%)	38.1 (74%)
B22	78.0	21.5 (28%)	56.5 (72%)	1.4 (2%)	2.3 (4%)	4.9 (9%)	47.9 (85%)
B3	59.0	15.0 (25%)	44.0 (75%)	3.2 (7%)	5.2 (12%)	4.3 (10%)	31.3 (71%)
C	92.0	25.5 (28%)	66.5 (72%)	1.4 (2%)	4.9 (7%)	3.0 (5%)	57.2 (86%)
IIB	58.0	26.5 (46%)	31.5 (54%)	2.2 (7%)	5.5 (18%)	1.4 (4%)	22.4 (71%)

The organic phosphate contents of this soil ranged from 15.0 mg/100 g to 68.0 mg/100 g, accounting for 23% to 51% of the total phosphate contents. Only the A1 horizon contained more than 50% organic phosphate.

The total inorganic phosphate contents ranged from 31.5 mg/100 g to 85.0 mg/100 g, accounting for 49% to 77% of the total phosphate contents. These percentages were relatively high except that of the A1 horizon. The occluded phosphate contents ranged from 22.4 mg/100 g to 72.3 mg/100 g, accounting for 71% to 86% of the total inorganic phosphate contents and these values were higher than those of the other soils. The amounts of calcium phosphate, aluminum phosphate and iron phosphates were similar to those of the other soils.

IV. 2. 7. Zambales soils

The total phosphate contents of the Zambales soils (Table 32) ranged from 211.1 mg/100 g to 680.0 mg/100 g. These values were relatively higher compared to those of the other soils.

Table 32. P content of Zambales 1 (Z-1) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A	575.0	295.0 (51%)	280.0 (49%)	5.3 (2%)	153.5 (55%)	4.6 (2%)	116.6 (42%)
IIA	675.6	400.0 (59%)	275.6 (41%)	3.5 (1%)	126.5 (46%)	4.4 (2%)	141.2 (51%)
IIA3	680.0	417.8 (61%)	262.2 (39%)	2.9 (1%)	115.0 (44%)	3.5 (1%)	140.8 (54%)
IIB1	528.9	357.8 (68%)	171.1 (32%)	5.8 (3%)	89.1 (52%)	2.6 (2%)	73.6 (43%)
IIC1	439.5	237.3 (54%)	202.2 (46%)	6.5 (3%)	69.0 (34%)	2.2 (1%)	124.5 (62%)
IIC2	327.8	111.1 (34%)	216.7 (66%)	5.8 (3%)	62.7 (29%)	2.6 (1%)	145.6 (67%)
IIC3	211.1	47.2 (22%)	163.9 (78%)	6.9 (4%)	74.2 (45%)	2.8 (2%)	80.0 (49%)

The organic phosphate contents of the A horizon was 295.0 mg/100 g while those of the buried humic layers and buried subsurface layers ranged from 400.0 mg/100 g to 417.0 mg/100 g and 47.2 mg/100 g to 357.8 mg/100 g, respectively. The percentages of organic phosphate to total phosphate contents were high in the buried humic layers (IIA, IIA3 and IIB horizons).

The total inorganic phosphate contents ranged from 171.1 mg/100 g to 280.0 mg/100 g, a low percentage to the total phosphate contents (32% to 49%), except that of the IIC2 and IIC3 horizons which contained 66% and 78%, respectively. The calcium phosphate contents ranged from 2.9 mg/100 g to 6.9 mg/100 g (1% to 4%) while the iron phosphate contents from 2.2 mg/100 g to 4.6 mg/100 g (1% to 2%). These values were similar to those of the other soils. The aluminum phosphate contents ranged from 62.7 mg/100 g, accounting for 29% to 555 of the total inorganic phosphate contents. These values were similar to those of the Isarog soil and relatively higher compared to those of the other soils. The occluded phosphate contents ranged from 73.6 mg/100 g to 145.6 mg/100 g accounting for 42% to 67% of the total inorganic phosphate contents. These values were as high as those of the Isarog soil.

Buried humic layers of the Zambales soils had high total phosphate contents, high organic phosphate contents, high inorganic phosphate contents, high aluminum phosphate contents and high amounts of occluded phosphates.

IV. 2. 8. Negros soils

The total phosphate contents of N-1 and N-6 were very high (416.7 mg/100 g to 696.7 mg/100 g) like those of the Zambales soils (Table 33 and 34).

The organic phosphate contents of N-6 ranged from 172.2 mg/100 g to 271.6 mg/100 g, accounting for 39% to 52% of the total phosphate contents. The IVC horizon contained

Table 33. P content of Negros 6 soil (N-6) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
A1	690.0	271.6 (39%)	418.4 (61%)	7.2 (2%)	175.4 (42%)	4.9 (1%)	230.9 (55%)
IIA	536.7	213.3 (40%)	323.4 (60%)	5.0 (2%)	162.4 (50%)	4.7 (2%)	151.3 (46%)
IIB	466.7	235.0 (50%)	231.7 (50%)	6.9 (3%)	102.1 (44%)	3.7 (2%)	119.0 (51%)
IIIC	416.7	188.4 (45%)	228.3 (55%)	6.9 (3%)	81.9 (36%)	3.2 (1%)	136.3 (60%)
IVC	603.3	316.6 (52%)	286.7 (48%)	12.1 (4%)	120.8 (42%)	4.0 (1%)	149.8 (53%)
VC1	536.7	206.7 (39%)	330.0 (61%)	16.7 (5%)	122.2 (37%)	4.0 (1%)	187.1 (57%)
VC2	436.1	172.2 (39%)	263.9 (61%)	9.2 (4%)	120.8 (46%)	4.6 (2%)	129.3 (48%)

Table 34. P content of Negros 1 soil (N-1) (mg P_2O_5/100 g).

Horizon	Total P	Organic P	Inorganic P				
			Total Inorganic P	Ca-P	Al-P	Fe-P	Occluded P
Ap	696.7	381.7 (55%)	315.0 (41%)	12.1 (4%)	165.3 (53%)	7.5 (2%)	130.1 (41%)
A13	563.3	296.6 (53%)	266.7 (47%)	8.1 (3%)	123.6 (46%)	6.8 (3%)	128.2 (48%)
B1	666.7	362.5 (54%)	304.2 (46%)	8.4 (3%)	120.8 (40%)	3.2 (1%)	171.8 (57%)
B2	650.0	298.6 (46%)	341.4 (54%)	11.6 (3%)	136.6 (39%)	5.8 (2%)	197.4 (56%)

very large amounts of organic phosphate in spite of its low organic matter content. This may be due to the large amount of organic phosphate present in its organic matter. N-1 soil contained higher organic phosphate contents (296.6 mg/100 g to 381.7 mg/100 g) than the N-6 soil. These accounted for 46% to 55% of the total phosphate contents.

The total inorganic phosphate contents ranged from 263.9 mg/100 g to 418.4 mg/100 g, accounting for 45% to 61% of the total phosphate contents. These values were also relatively high. The calcium phosphate and iron phosphate contents ranged from 5.0 mg/100 g to 16.7 mg/100 g and 3.2 mg/100 g to 7.5 mg/100 g, accounting for 2% to 4% and 1% to 3% of the total inorganic phosphate contents, respectively. The aluminum phosphate contents of these soils ranged from 81.9 mg/100 g to 175.4 mg/100 g making up 36% to 53% of the total inorganic phosphate contents. These values were as high as those of the Zambales soils. The occluded phosphate contents ranged from 128.2 mg/100 g to 187.1 mg/100 g, accounting for 41% to 60% of the total inorganic phosphate contents. These values were as low as those of the Zambales soil.

As described above, the Negros soils had high total phosphate contents, high aluminum phosphate contents and low occluded phosphate contents.

IV. 3. Discussion

IV. 3. 1. Total phosphate

The total phosphate contents ranged from 110 mg/100 g to 868.0 mg/100 g for the A horizons and buried A horizons and from 61.3 mg/100 g to 603.3 mg/100 g for the other layers. These values showed that the total phosphate contents varied from one layer to another. As shown in Figure 28, the Sorsogon-2 soil had the lowest total phosphate contents (58.0 mg/100 g to 134.0 mg/100 g). On the basis of the total phosphate contents the soils can be arranged in the increasing order of : Sorsogon-2 (58 mg/100 g to 134.0 mg/100 g), Caliraya soil (61.3 mg/100 g to 142.2 mg/100 g), Mayon 1 soil (79.5 mg/100 g to 316.7 mg/100 g), Tagaytay 1 soil (105.6 mg/100 g to 332.8 mg/100 g), Tagaytay 3 soil (148.0 mg/100 g to 868.0 mg/100 g), Isarog soil (218.4 mg/100 g to 468.0 mg/100 g), Mayon 2 soil (240.0 mg/100 g to 377.0 mg/100 g), Iriga soil (276.7 mg/100 g to 505.6 mg/100 g), Zambales soil (211 mg/100 g to 680 mg/100 g), Negros 1 soil and Negros 6 soil (416.7 mg/100 g to 696.7 mg/100 g).

The total phosphate contents tended to decrease with the depth of the profile, except those of the buried layers, young volcanic ash of Tagaytay soil (C horizon of Tag-3) and IVC horizon of Negros soils. These results showed that the total phosphate contents generally depended on the organic matter content and parent materisls. The young volcanic ash soils (A, B and C of Tag-3) Which had erupted from the Taal volcano in 1966 had the highest total phosphate contents.

Figure 29 depicts the relationship between the total phosphate contents and base saturation. The Tagaytay, Iriga, Sorsogon 2 and Caliraya soil samples showed a positive relationship between the total phosphate contents and base saturation while the Negros, Zambales and Isarog soil samples showed a negative relationship, except for the A horizon of Tagaytay 3 and Ap horizon of Negros (N-6).

The relationship between the total phosphate contents and total carbon contents is shown in Figure 30. In almost all the soil samples, the total phosphate contents increased with the amount of total carbon. However, the magnitude of increase varies from one soil

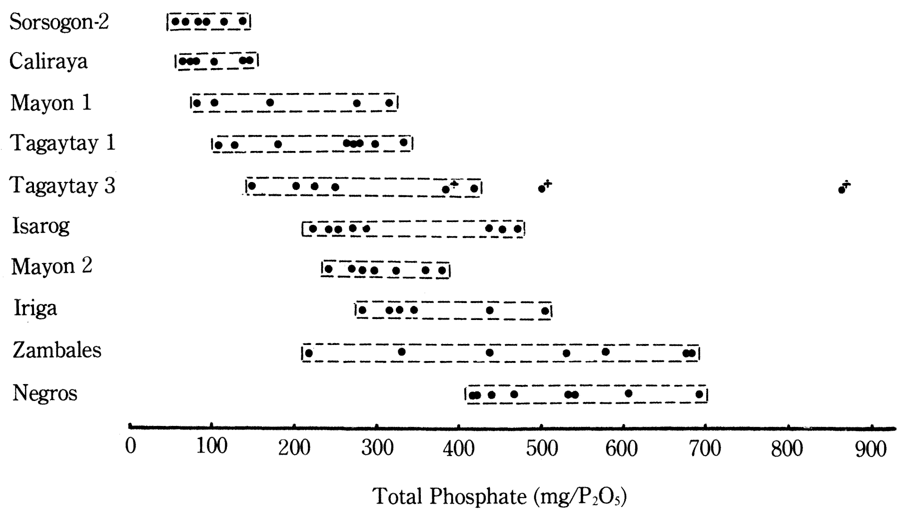

Fig. 28. Total phosphate contents of volcanic ash soils in the Philippines.
$\bullet^{+}$ Young volcanic ash.

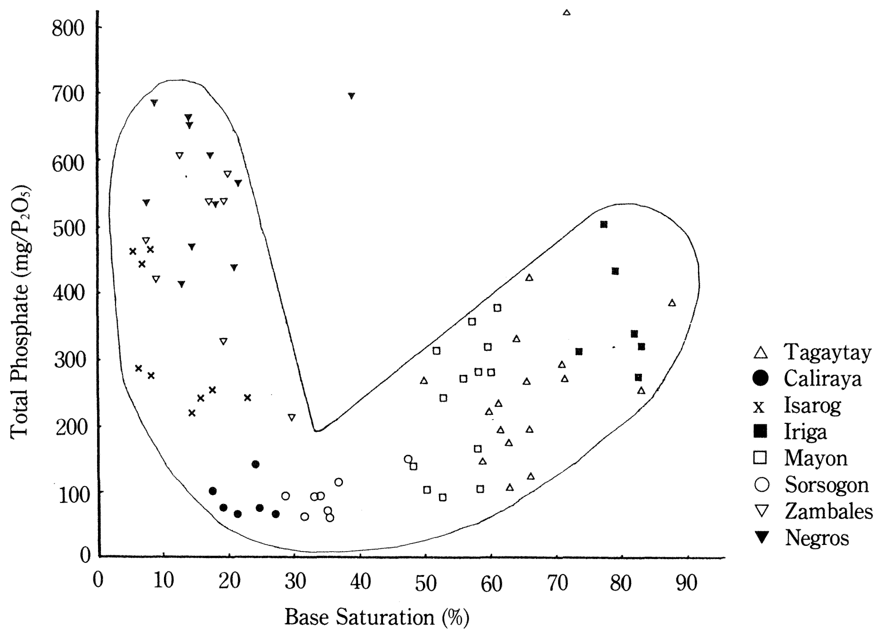

Fig. 29. Relationship between total phosphate contents and base saturation.

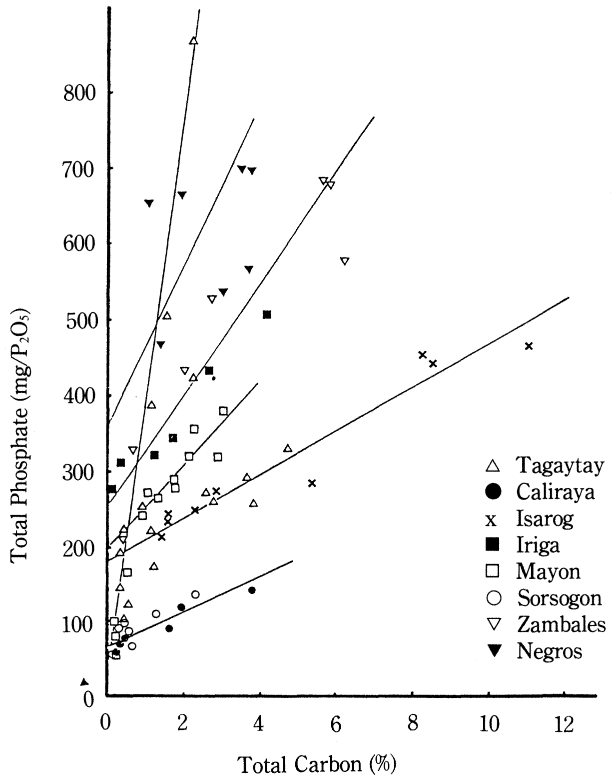

Fig. 30. Relationship between total phosphate contents and total carbon contents.

to another, as shown by the variation in the slope. The slope depends on the phosphate content of the organic matter present, total phosphate contents and/or on the parent materials present. The Tagaytay 3, Negros, Zambales and Iriga soils showed higher slopes compared to the other soils.

In Japan, the Second Laboratory of Soil Chemistry of the National Institute of Agriculture Sciences (Egawa and Sekiya; 1959) determined the total phosphate contents of volcanic ash soils. Their results showed that the total phosphate contents of the A horizon ranged from 160.0 mg/100 g to 505.0 mg/100 g Otsuka (1978) also found that the total phosphate contents of Andosols (Kurobokudo) in Kyushu, Japan ranged from 97 mg/100 g to 300 mg/100 g for the A horizons, from 105 mg/100 g to 621.9 mg/100 g for the humic buried layers and from 36.6 mg/100 g to 259.4 mg/100 g for the other layers. These values are relatively lower compared to those of the volcanic ash soils of the Philippines.

IV. 3. 2. Organic phosphate

The organic phosphate contents of volcanic ash soils in the Philippines ranged from 68.0 mg/100 g to 696.7 mg/100 g for the A horizon, from 92.9 mg/100 g to 417.8 mg/100 g for the humic buried layers and 12.8 mg/100 g for the other layers.

On the other hand, the organic phosphate contents of the volcanic ash soils in Japan (Otsuka; 1978) ranged from 28.1 mg/100 g to 209.3 mg/100 g for the A horizons, 65.0 mg/100 g to 353.1 mg/100 g for the humic buried layers and 24.0 mg/100 g to 174.8 mg/100 g for the other layers. Again, these values were lower than those of the volcanic ash soils in the Philippines.

Figure 31 shows the relationship between the organic phosphate contents and total carbon contents. Generally, the organic phosphate contents increased with the total

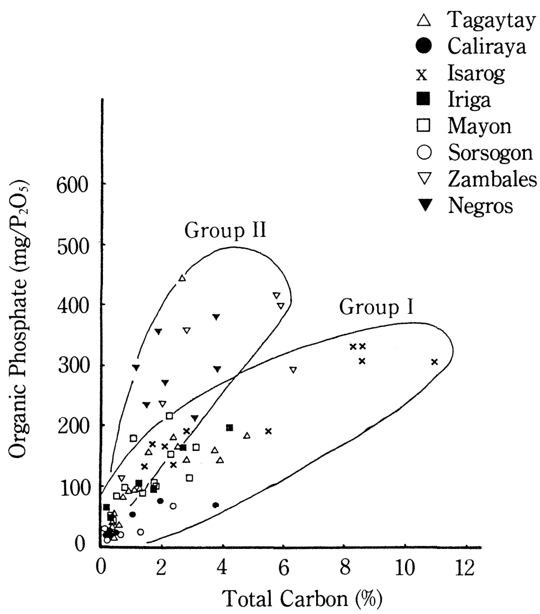

Fig. 31. Relationship between organic phosphate contents and total carbon contents.

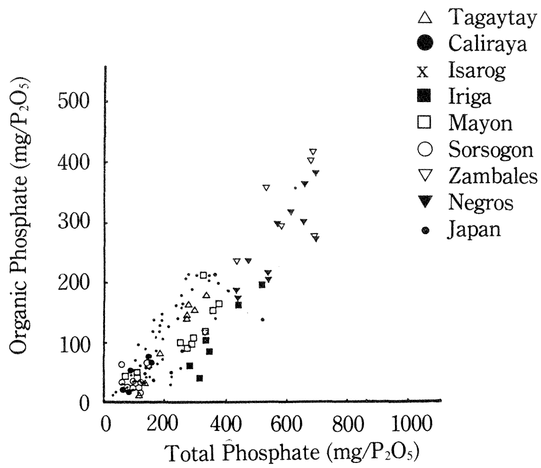

Fig. 32. Relationship between organic phosphate contents and total phosphate contents.

carbon contents. On the basis of the organic phosphate contents, two groups of soils were identified; Negros, Zambales, and A horizon of Tagaytay belonged to the second group (Group II), the high organic phosphate group and the other soils which had low organic phosphate contents belonged to the first group (Group I). In the Group II soils organic matter may contain large amounts of phosphorus.

The organic phosphate contents increased with the total phosphate contents (Figure 32).

Under uncultivated conditions, the balance between the total phosphate contents and organic phosphate contents of the volcanic ash soils both in the Philippines and in Japan, may be stable.

IV. 3. 3. Inorganic phosphate

The inorganic phosphate contents of the volcanic ash soils in the Philippines ranged from 31.5 mg/100 g to 421.0 mg/100 g, accounting for 28% to 88% of the total phosphate contents. The inorganic phosphate contents of the volcanic ash soils in Japan ranged from 28.0 mg/100 g to 268.8 mg/100 g, accounting for 10.7% to 87.3% of the total phosphate contents. These results showed that the inorganic contents of the volcanic ash soils in the Philippines were lower than those of the volcanic ash soils in Japan.

Calcium phosphate contents of the volcanic ash soils in the Philippines were 1.4 mg/100 g, accounting for 1% to 33% of the total inorganic phosphate contents. Calcium phosphate contents of volcanic ash soils in Japan ranged from 6.0 mg/100 g to 7.0 mg/100 g accounting for 2% to 8% of the total inorganic phosphate contents. The calcium phosphate contents of the volcanic ash soils in the Philippines varied widely while those in Japan were stable. The young ash layers of the Tagaytay 3, Mayon 2 and Iriga soils contained larger amounts of calcium phosphate. However, the average percentages of calcium phosphate to total inorganic phosphate of the layers ranged from 3% to 11%, as in the soils Japan.

Aluminum phosphate contents ranged from 2.3mg/100 g to 175.4 mg/100 g, accounting

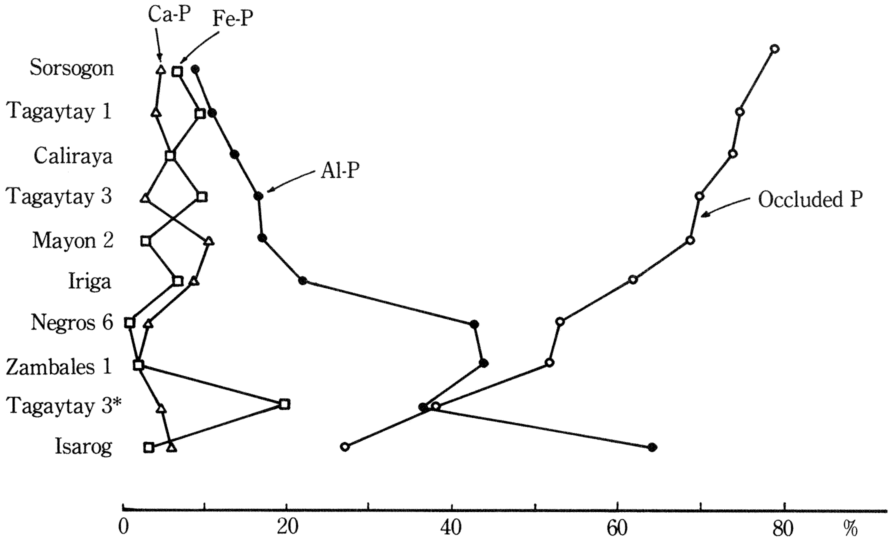

Fig. 33. Percentages of calcium (Ca-P), aluminum (Al-P), iron (Fe-P) and occluded form phosphate to total inorganic phosphate.

for 2% to 91% of the total inorganic phosphate contents. These values are very wide and vary from one soil to another. The average aluminum phosphate percentages to total inorganic phosphate of each soil ranged from 9% to 64% (Fig. 33). The aluminum phosphate contents of the volcanic ash soils in Japan ranged from 37 mg/100 g to 211 mg/100 g, accounting for 34% to 56% of the total inorganic phosphate contents. These values are similar to those of the Iriga, Negros, Zambales and Isarog soils in the Philippines.

The iron phosphate contents ranged from 0.3 mg/100 g to 79.4 mg/100 g, accounting for 0% to 23% of the total inorganic phosphate contents. The average iron phosphate percentages were low, ranging from 3% (Isarog) to 10% (Tagaytay), except for those of the young ash of Tagaytay 3 (20%). These values were lower than the percentages of aluminum phosphate contents to total inorganic phosphate contents. The iron phosphate contents (26 mg/100 g to 109 mg/100 g or 29% to 54% of the total inorganic phosphate contents) of the volcanic ash soils in Japan were higher than those of the Philippines.

The occluded phosphate contents ranged from 31.5 mg/100 g to 421.0 mg/100 g, accounting for 2% to 86% of the total inorganic phosphate contents.

On the basis of the percentages of occluded phosphate to total inorganic phosphate, the soils can be arranged in the decreasing order of: Sorsogon 2, Tagaytay 1, Caliraya, Tagaytay 3, Mayon 2, Iriga, Negros, Zambales, Tagaytay 3 (young ash layers), and Isarog.

As shown in Figure 33, as the aluminum phosphate percentages to total inorganic phosphate increased, the occluded phosphate percentages decreased.

Calcium and iron phosphate percentages to total inorganic phosphate were relatively stable.

IV. 4. Summary

The phosphate contents and distribution of volcanic ash soils in the Philippines were determined. The results indicated the following:

1. Tagaytay 3 soil, especially the young ash layers had higher total phosphate contents and higher inorganic phosphate contents, particularly the aluminum phosphate form than the Tagaytay 1 soil.
2. Caliraya soil showed very low total phosphate contents, organic phosphate contents and inorganic phosphate contents but very high percentages of occluded phosphate to total inorganic phosphate.
3. Isarog soil had high organic phosphate contents and percentage, high aluminum phosphate contents and low occluded phosphate contents.
4. Iriga soil had high total phosphate contents, very low organic phosphate contents and high inorganic phosphate contents and percentages, particularly the occluded phosphate form.
5. There were two kinds of volcanic ash profiles from the Mayon volcano. One consisting of a relatively old ash (M-1) had a low total phosphate content with high organic phosphate percentages but low inorganic phosphate percentage to total phosphate while the other one (M-2) which is a young ash, had high total phosphate contents, a low organic phosphate content and relatively high inorganic phosphate contents, especially the aluminum phosphate form.
6. Among the soils studied, Sorsogon soil had the lowest total phosphate contents. It had very low organic phosphate contents and percentages but high percentages of inorganic phosphates, particularly the occluded phosphate form.
7. The buried humic layers of the Zambales soils had high total phosphate contents, high organic phosphate contents and percentages, high aluminum phosphate contents and low amounts of occluded phosphate.
8. Negros soils had very high total phosphate contents, high aluminum phosphate contents and low occluded phosphate contents.
9. According to the increasing total phosphate content, the soils can be arranged in the following order: Sorsogon 2, Caliraya, Mayon 1, Tagaytay 1, Tagaytay 3, Isarog, mayon 2, Iriga, Zambales, Negros 1 and Negros 6.

V. ACCUMULATION AND PROPERTIES OF ORGANIC MATTER

Generally, the volcanic ash soils of Japan such as Kurobokudo, Andosols or Andepts are characterized by a high organic matter content, dark black brown color of layers whose ages range from recent to about 20,000 years B.P. including buried layers, with more humified humic substances (Kobo and Oba; 1974, Otsuka and Kumada; 1978, Kumada; 1981, Yamada; 1986), while there is no information on the status of soil organic matter in the corresponding soils from the Philippines.

The purpose of the study in this Chapter, is to obtain information on the properties of organic matter including the age of layers in the volcanic ash soils of the Philippines. These properties were compared with the properties of organic matter of volcanic ash soils in Japan.

V. 1. Materials and Methods

V. 1. 1. Soil samples used

The soil samples were described in Chapter II.

V. 1. 2. Methods

(1) *Humus composition analysis*

Humus composition analyses were carried out according to the method described by Kumada et al. (1967) as indicated below.

Extraction of humus: Air-dried samples (less than 2 mm) pulverized and passed through a 60 mesh sieve were used for the analysis. The extractable humus was obtained by placing weighed samples of soil containing less than 20 mg C (carbon) in a 50 ml conical flask with 30 ml of 0.1 *N* NaOH and heating at 100°C for 30 minutes in a boiling water bath with occasional shaking. After heating, 2 ml of saturated Na_2SO_4 solution as a coagulating agent was poured into the flask and the clear supernatant recovered by centrifugation. The soil residues were washed twice with 20 ml aliquots of 0.1 *N* NaOH containing 3% Na_2SO_4 and separated by centrifugation. The washed soil residues were put back in the flask with 30 ml of 0.1 *M* $Na_4P_2O_7$, shaken for 10 min. and heated at 100°C for 30 min. The $Na_4P_2O_7$ extract was separated by centrifugation, and the soil residue was washed twice with 20 ml aliquots of 0.1 *M* $Na_4P_2O_7$ containing 3% Na_2SO_4 and separated by centrifugation. The extracts and washings obtained by two extraction procedures were combined respectively, and filled up each two 100 ml with water.

Determination of humic acid and fulvic acid fraction: Separation of the two humic and fulvic acid fractions extracted was performed by adding 1 ml of conc. H_2SO_4 to 100 ml of the extracts. The acidified extract was transferred onto a funnel containing a dry paper filter. The precipitate, humic acid, was collected on the filter, and the filtrate, fulvic acid in a dry flask. When a large part of the fulvic acid was recovered, the flask was removed, and the humic acid gel on the filter was washed with dilute H_2SO_4 and water, respectively.

The humic acid was dissolved in 0.01 *N* NaOH and its absorption spectrum (220-700 nm) was analysed with a spectrophotometer within 2 hrs. after solution. The amounts of humic acid and fulvic acid in the fractions were determined by permangametry according to the method described by Simon (1938) and modified by Ohba (1964).

The volume in ml of 0.1 *N* $KMnO_4$ consumed by 1 g of the original soil sample was estimated by the same procedure as that used for the extracted humus fraction.

Age determination: 14C dating of the humic acids extracted with 0.1 *N* NaOH from buried humic acid layers was carried out by Prof. Dr. Kigoshi, Gakushuin University.

V. 2. Results

The results of 14C dating are presented in Table 35. In the Tagaytay samples (Tag-1), the ages of the humic layers were 1170 ± 70 yr. B.P. for IVA, 930 ± 70 yr. B.P. for IIA and 710 ±100 yr. B.P. for A, while in the Isarog Soil the age of A12 and IIA was similar. Tagaytay profile is slightly older than that of Isarog.

The results of humus composition analysis are shown in Tables 36 to 42.

Table 35. ^{14}C dating of humic acid

Soil Sample	Horizon	Depth	Code No.	Year
Tagaytay I	A	0–12 cm	GaK-12960	710 ± 100 yr. B.P. (1240 yr. AD)
	II A	12–27 cm	GaK-12961	950 ± 90 yr. B.P. (1000 yr. AD)
	III A11	27–35 cm	GaK-12963	930 ± 70 yr. B.P. (1020 yr. AD)
	IV A1	44–51 cm	GaK-12965	1170 ± 70 yr. B.P. (780 yr. AD)
Isarog	A13	15–25 cm	GaK-12960	610 ± 90 yr. B.P. (1340 yr. AD)
	II A	25–32 cm	GaK-12961	580 ± 90 yr. B.P. (1370 yr. AD)

B.P. : Age from 1950

V. 2. 1. Tagaytay 1

The humic extraction ratios (CE/CT) ranged from 66% to 82% in the A and buried A horizons and from 39% to 43% in the other horizons. These values revealed a higher humus extraction ratio in the A and buried A horizons while a lower humus extraction ratio in the buried B and C horizons. The ratios of free humic acid (fH) also showed high values (83%–88%) in the A and buried A, but low values (67%–74%) in the buried B and C horizons. This indicates that a large part of the extractable humus was obtained by 0.1 *N* NaOH extraction and the amount of humus obtained by 0.1 *M* $Na_4P_2O_7$ extraction was very small, especially in the A and buried A horizons. PQ values, the percentage of humic acid, were higher in the A and buried A horizons (72%–82% for PQ_1 and 70%–84% for PQ_2) than in the other layers (16%-30% for PQ_1 and 16%–44% for PQ_2).

The humic acids were classified on the basis of their absorption spectrum and Δlog K and RF values according to the method of Kumada et al. (Kumada, Sato, Ohsumi and Ohta,; 1967). The absorption spectra of humic acid of Tag-1 are shown in Figure 34. Table 35, shows that the NaOH—extracted humic acid was of the A type in the A and buried horizons but B type in the other horizons while the $Na_4P_2O_7$—extracted humic acid was of the A type and especially contained the Pg fraction (Otsuka and Kumada; 1978) (green humic acid) in the lower layers (Fig. 34). Green humic acid showed on absorption at 450 nm, 570 nm and 620 nm in the spectrum curve. The amount of green humic acid was graded 0, ±, +, ++ and +++ according to the height of the absorption peak. In this profile, the humic acid of IIIA11 (930 ± 70 yr. B.P.) underwent humification.

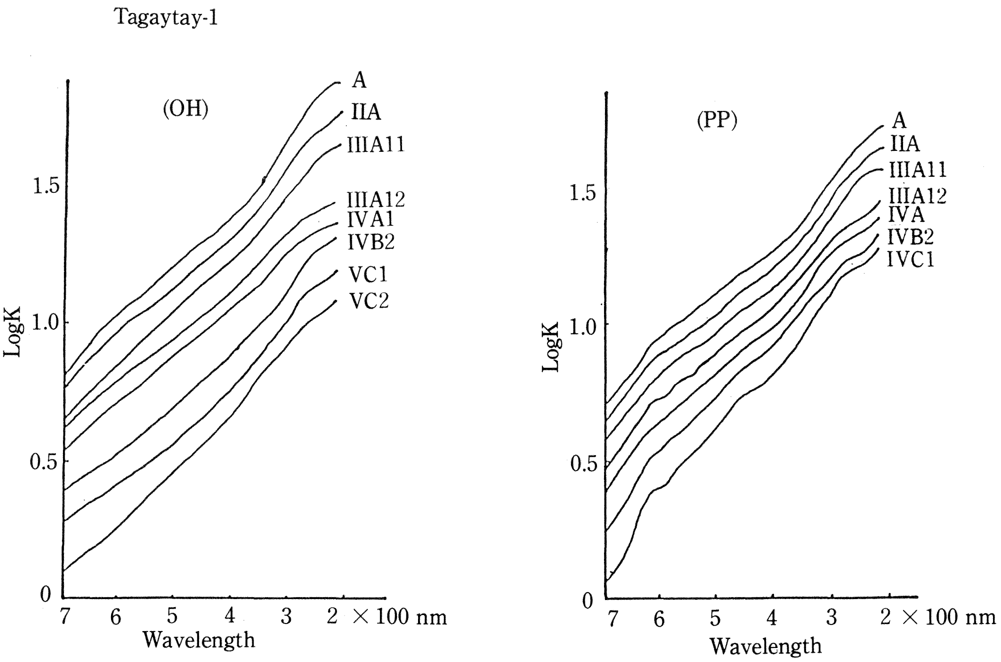

Fig. 34. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP).

Table 36. Humus composition of Tagaytay soil (Tag-1)

Hori-zon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	b_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
A	73	41.9	25.0	9.8	34.8	72	0.540	121	5.3	1.8	7.1	75	0.500	131	83	A	A
IIA	66	57.0	39.6	10.3	39.6	79	0.529	153	5.0	2.1	7.1	70	0.555	133	88	A	A
IIA11	82	84.1	58.9	13.0	71.9	82	0.524	163	10.2	2.0	12.2	84	0.474	166,	85	A	A
IIA12	76	62.4	42.5	11.0	53.5	79	0.530	160	7.2	1.7	8.9	81	0.490	153	86	A	A
IVA1	68	42.1	27.7	8.1	35.8	75	0.568	135	4.5	1.8	6.3	71	0.490	156	85	A	A_+
IVB2	42	12.1	2.7	6.2	8.9	30	0.620	80	1.4	1.8	3.2	44	0.586	100	74	B	A_+
VC1	43	5.7	0.8	3.0	3.8	21	0.679	68	0.3	1.6	1.9	16	0.605	148	67	B	A_+
VC2	39	4.3	0.5	2.6	3.1	16	0.699	63	0.2	1.6	1.2	17	0.575	112	72	B	A_+

Notes : CE/CT: [(HE$\times 5.4\times 10^{-4}$(g)/total carbon(%)]$\times$100(%), the ratio of extractable humus to total humus. HE: Extracted humus, the sum of 0.1N $KMnO_4$ml consumed by humic and fulvic acid fractions of the 2 extracts per 1g soil. a and b: The amount of humic acid and fulvic acid, respectively, calculated as ml of 0.1N $KMnO_4$ consumed by the fractions of each extract corresponding to 1g of soil sample. 1 and 2: The fraction extracted with 0.1N NaOH and 0.1M pyrophosphate, respectively. PQ: a/(a+b)$\times$100(%), percent of humic acid in extracted humus. Δlog K: $logK_{400}-logK_{600}$, where K is absorption coefficient at K_{400} or K_{600nm}. RF: $K_{600}\times 1000$/ml of 0.1N $KMno_4$ consumed by 30ml of the humic acid solution used for determining absorption spectra. fH: [(a_1+b_1)/HE]$\times$100(%), percent of free form humus in extracted humus. Type: The type of humic acid is determined according to KUMADA's classification.

V. 2. 2. Caliraya

The humic extraction ratios (CE/CT) ranged from 41% to 50%. These values were lower than those of the other soils (Table 37).

The percentage of free humic acid (fH) ranging from 87% to 93% was relatively high.

PQ values ranged 10 to 35% for PQ_1 and 27 to 54% for PQ_2. PQ_1 values of the A horizons were lower than those of the other horizons.

Table 37. Humus composition of Caliraya soil (Cal-1)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	b_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
A	50	42.4	13.0	23.7	36.7	35	0.699	51	3.1	2.6	5.7	54	0.633	62	87	B	B
A3	48	21.5	4.4	15.6	20.0	22	0.619	75	0.4	1.1	1.5	27	0.595	118	93	B_+	A_+
B1	47	9.9	0.9	8.3	9.2	10	0.638	78	0.2	0.7	0.7	20	0.539	77	93	B_+	B_{++}
B21			1.3	5.4	6.7	19	0.681	12								P_+	
B21																	

Notes : CE/CT: [(HE×5.4×10^{-4}(g)/total carbon(%)]×100(%), the ratio of extractable humus to total humus. HE: Extracted humus, the sum of 0.1N $KMnO_4$ml consumed by humic and fulvic acid fractions of the 2 extracts per 1g soil. a and b: The amount of humic acid and fulvic acid, respectively, calculated as ml of 0.1N $KMnO_4$ consumed by the fractions of each extract corresponding to 1g of soil sample. 1 and 2: The fraction extracted with 0.1N NaOH and 0.1M pyrophosphate, respectively. PQ: a/(a+b)×100(%), percent of humic acid in extracted humus. Δlog K: $logK_{400}-logK_{600}$, where K is absorption coefficient at K_{400} or K_{600nm}. RF: K_{600}×1000/ml of 0.1N $KMnO_4$ consumed by 30ml of the humic acid solution used for determining absorption spectra. fH: [(a_1+b_1)/HE]×100(%), percent of free form humus in extracted humus. Type: The type of humic acid is determined according to KUMADA's classification.

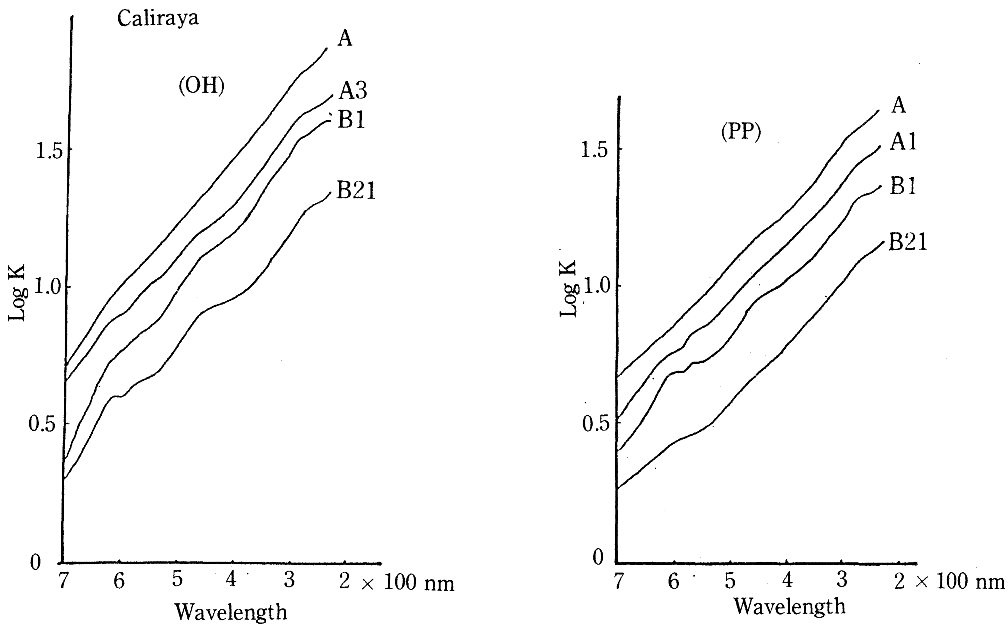

Fig. 35. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

Types of 0.1*N* NaOH-extracted humic acid were B, $B+P_{++}$ and of 0.1*M* $Na_4P_2O_7$-extracted humic acid B, B+, B_{++} and A (Fig 35). The amount of humification of these humic acids was relatively low.

V. 2. 3. Isarog

The age of the Isarog soil which is 610±90 yr.B.P. in A13 is similar to that of IIA (580±90 yr. B.P.).

Isarog profile with younger layers showed the highest organic matter content. The extraction ratios were 44–64% in the A and buried A horizons and 29–46% in the buried B horizons. These values were lower than the values of Tagaytay-1 (Table 38).

Table 38. Humus composition of Isarog soil (Is-1)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
A11	52	128.1	65.0	58.5	123.5	53	0.340	200	2.3	4.6	50	0.542	150	96	A	A
A12	64	118.3	59.2	51.0	110.2	54	0.550	144	3.5	8.1	45	0.509	127	93	A	A
A13	64	121.8	63.7	48.2	111.9	57	0.527	124	5.5	9.9	56	0.484	111	92	A	A_+
IIA	68	83.7	45.5	30.3	75.8	60	0.573	118	3.6	7.9	48	0.518	129	91	A	A_+
IIIB11	40	24.6	5.2	15.2	20.4	25	0.350	141	1.0	4.3	23	0.564	89	83	A_+	A_{++}
IIIB12	46	17.3	3.0	10.2	13.2	23	0.519	99	0.9	4.1	22	0.564	98	76	A_{++}	A_{++}
IIB21	29	15.6	3.3	9.9	13.2	25	0.526	170	0.3	2.4	12	0.490	158	85	A_+	A_{++}
IVB22			3.0	7.9	10.9	28	0.568	111	0.8							
VA	44	14.8	3.3	7.6	10.9	30	0.602	102	0.6	3.9	14	0.593	120	74	A_+	A_{++}

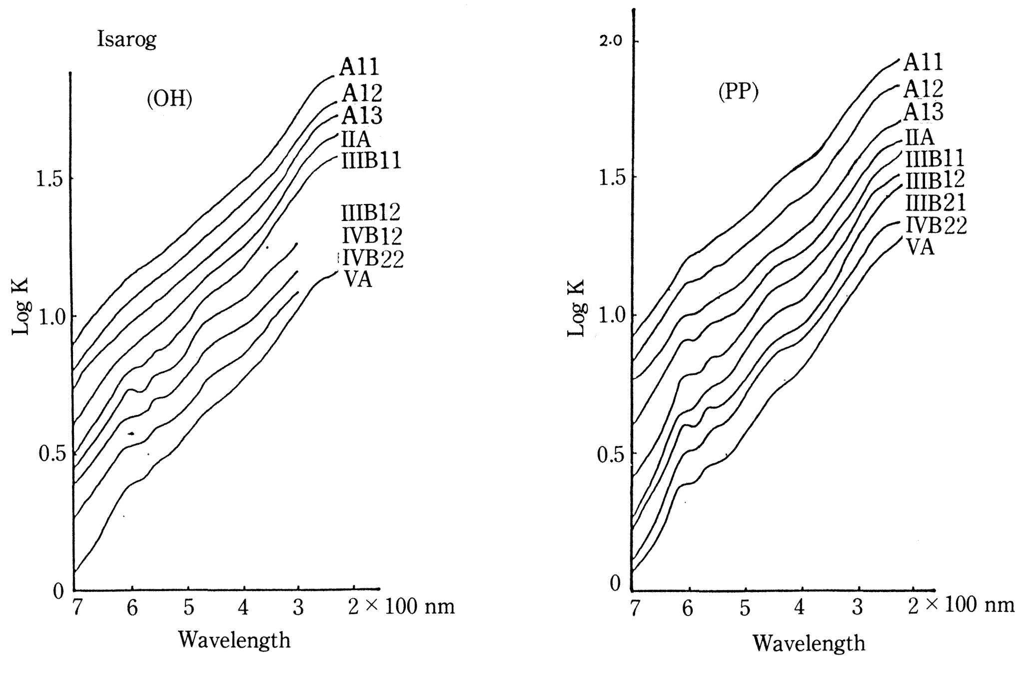

Fig. 36. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

The free humic acid ratios which were extracted with 0.1N NaOH were more than 91% in A and IIA and 74-85% in the other layers.

PQ_1 values were 53-60% until the IIA horizon, but in the lower layers lower values of 23-30% were recorded. PQ_2 was 45-50% in the A and IIA horizons and 12-23% in other buried horizons. PQ_1 may be higher than PQ_2. Humic acids which were of the A type in this profile contained the Pg fraction scored + and ++ in the lower layers (Fig. 28). The level of humification of humic acids of the A11 horizons was highest in this study.

V. 2. 4. Iriga

The extraction ratios of the samples of this ranged from 55% to 68%. These values are relatively high, especially in the buried B and C horizons (Table 39).

The percentage of humic acid (fH) which was extracted with0.1 N NaOH ranged from 30% to 77%. These values were lower than in the other profiles because the base saturation was higher.

Table 39. Humus composition of Iriga soil (Ir-1)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
A11	67	62.4	26.5	15.1	42.6	62	0.542	108	13.0	19.8	66	0.469	135	68	A	A
A12	60	36.1	18.5	9.2	27.7	67	0.534	116	5.0	8.4	60	0.475	242	77	A	A_+
A13	63	25.3	8.0	6.4	14.4	56	0.534	126	7.5	10.9	69	0.485	94	57	A	A_+
IIB11	55	16.0	4.1	5.5	9.6	43	0.565	97	3.0	6.4	47	0.501	138	60	A	A_+
IIB12	57	5.1	0.8	1.2	2.0	40	0.595	86	0.3	3.1	9	0.617	117	39	A	A_+
IIC	68	7.0	0.6	0.6	1.2	53	0.608	50	0.3	5.8	5	0.660	35	17	P	P_+

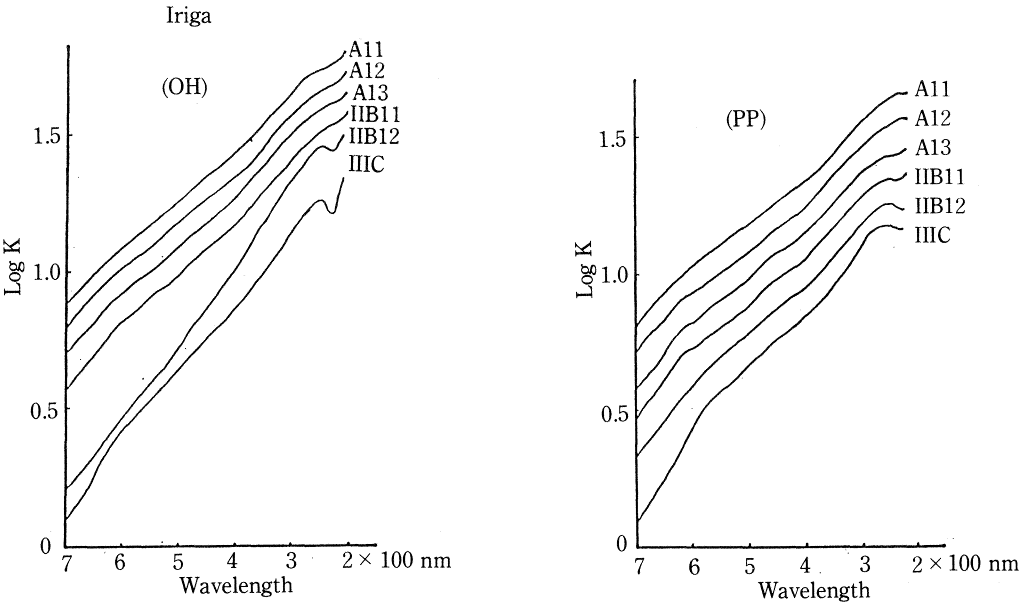

Fig. 37. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

PQ_1 values ranging from 40–53% in the buried B and C horizons were higher than those of the other profiles.

The types of humic acid were A, A_+, Po and P_+. Pg fractions were observed in the humic acid extracted with 0.1M pyrophosphate (Fig. 37).

V. 2. 5. Mayon

This profile is near Mayon volcano and has coarse-textured layers.

The extraction ratios ranged from 57% to 100%. These values were higher than those of the other profiles and tended to increase with depth (Table 40).

The percentage of free humic acid (fH) ranging from 80% to 91% was similar to that of Isarog.

PQ_1 values ranged for 45% to 48% from the A horizon to the IIIC horizon. These values were lower than the 50% values of IVA3 and 51% to 71% values of VA11 VA12 and VIA13. PQ_2 values also were higher in the A, IIAC, IIIA3 and IIIC horizons than in the IVA3 VA11,

Table 40. Humus composition of Mayon 2 soil (M-2)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	b_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
A1	57	28.9	12.7	13.7	26.4	48	0.590	70	1.4	1.1	2.5	56	0.504	124	91	B	A
IIAC	57	23.1	9.1	11.0	20.1	45	0.563	78	1.9	1.1	3.0	63	0.472	115	87	B	A
IIIA3	61	19.4	7.5	9.3	16.8	45	0.564	100	1.6	1.0	2.6	62	0.479	123	87	A_+	A
IIIC	52	17.3	7.2	7.7	14.9	48	0.555	105	1.3	1.6	2.4	54	0.480	130	86	A	A
IVA3	75	30.3	13.7	10.4	24.1	57	0.525	103	4.6	1.7	6.2	74	0.455	93	80	A	A
VA11	74	47.7	27.8	11.2	39.0	71	0.515	134	7.0	2.2	8.7	80	0.432	151	82	A	A
VA12	100	68.4	32.7	24.5	57.2	57	0.526	128	9.0	1.1	11.2	80	0.441	161	84	A	A_+
VIA3	91	32.7	14.9	14.5	29.4	51	0.527	120	2.2		3.3	67	0.438	135	90	A_+	A

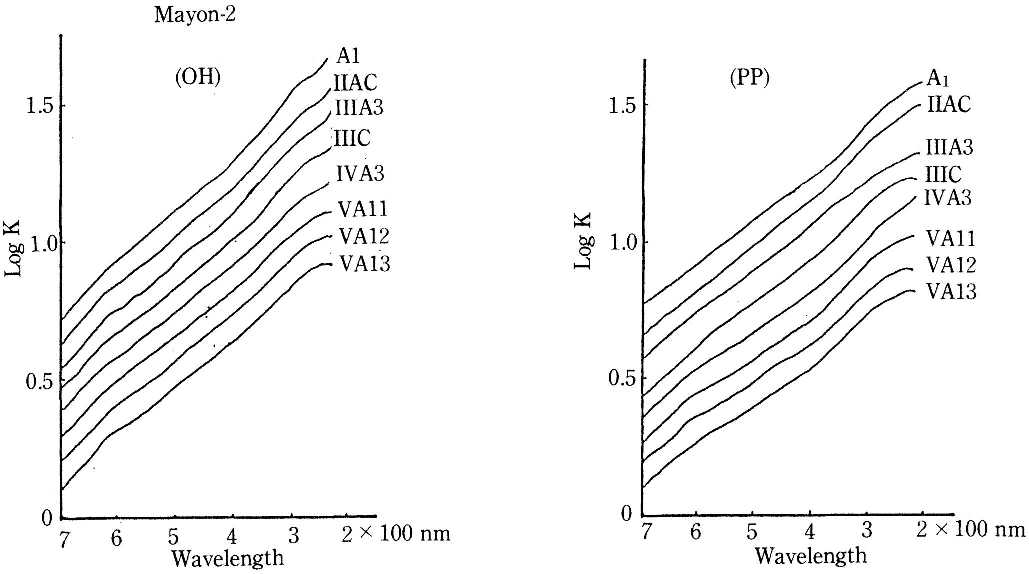

Fig. 38. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

VA12 and VIA3 horizons. $\Delta\log K_1$ values decreased with depth, while the RF_1 values increased with depth. The humic acid belonged to the A type (Fig. 38).

V. 2. 6. Zambales (Z-1)

Zambales samples had an extraction ratio ranging from 52% to 62%. These values were higher than the 50% values in the buried B and C horizons (Table 41).

PQ_1 values exceeded 50% (56–61%) in the A and buried A horizons, wile in the buried C horizons the values ranged from 23% to 33%.

The percentage of free humic acid (fH) ranged from 85% to 95%. These values were relatively high.

The types of humic acid were A, P_+ and $A_\pm$. The lower layers contained a small amount of Pg fraction (Fig. 39)

Table 41. Humus composition of Zambales soil (Z-1)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta\log K_1$	RF_1	a_2	b_2	a_2+b_2	PQ_2	$\Delta\log K_2$	RF_2	fH	Type	
A	62	87.2	48.8	31.8	80.6	61	0.499	117	2.2	4.3	6.6	33	0.462	100	92	A	A
IIA	59	77.3	42.2	30.7	72.9	58	0.481	144	1.0	3.4	4.4	23	0.422	100	94	A	A
IIA3	59	75.4	40.2	31.8	72.0	56	0.481	132	1.1	2.3	3.4	32	0.479	105	95	A	A
IIB	57	35.5	14.4	18.2	32.6	44	0.521	117	1.1	1.8	2.9	38	0.566	64	92	A	B
IIC2	52	8.1	1.8	5.1	6.9	26	0.524	73	0.3	0.9	1.2	25	0.597	45	85	$P_\pm$	$P_\pm$
IIC3	54	5.5	1.4	3.3	4.7	30	0.507	87	0.2	0.6	0.8	25	0.399	86	85	$A_\pm$	$A_\pm$

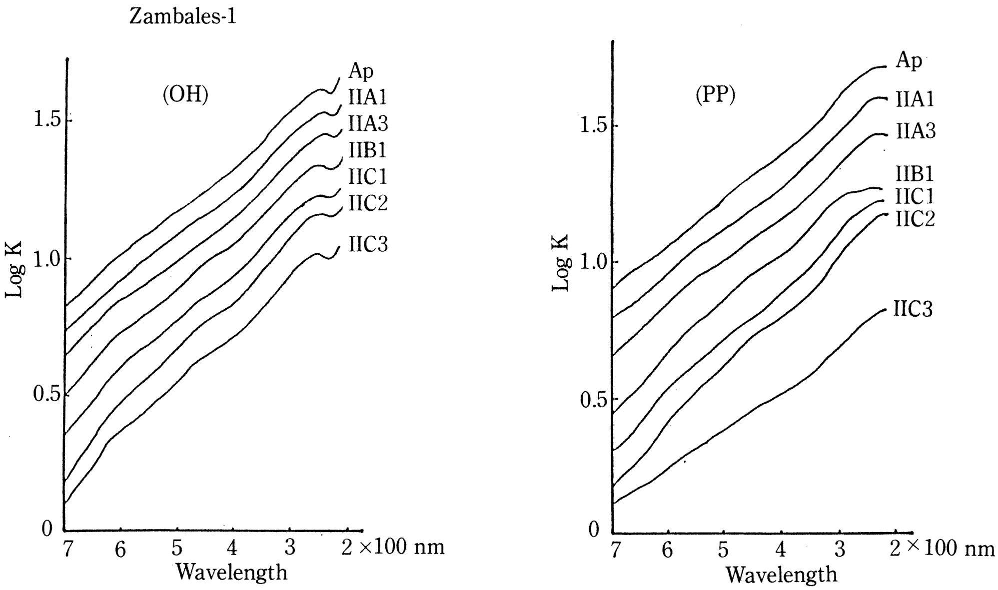

Fig. 39. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

V. 2. 7. Negros

Both Negros 1 and 6 soils showed a positive reaction to the allophane test. Negros 6 was located at a higher elevation than Negros 1.

The extraction ratios from Negros 1 were 51% and 57%, while the values of Negros 6 ranged from 57% to 81% (Table 42 and 43).

Table 42. Humus composition of Negros 1 soil (N-1)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	b_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
Ap	51	42.9	17.6	22.6	40.2	43	0.499	131	1.6	1.1	2.7	59	0.351	93	94	$A_{\pm}$	A
A13	57	48.2	25.5	19.8	45.3	57	0.488	124	0.9	2.0	2.9	31	0.546	114	94	$A_{\pm}$	A
B1			4.2	11.7	15.9	26	0.532	89	0.4				0.655	58		A_{+}	B_{++}
B2			0.9	6.4	7.3	12	0.593	102	0.7				0.772	55		$A_{\pm}$	$B_{\pm}$

Table 43. Humus composition of Negros 6 soil (N-6)

Horizon	CE/CT	HE	a_1	b_1	a_1+b_1	PQ_1	$\Delta logK_1$	RF_1	a_2	b_2	a_2+b_2	PQ_2	$\Delta logK_2$	RF_2	fH	Type	
A	81	37.2	13.0	23.1	36.1	36	0.561	53	0.4	0.7	1.1	36	0.804	22	97	P_{+}	R_p
IIA			10.6	23.4	34.0	31	0.569	73		0.3	2.0		0.699			$B_{\pm}$	
IIV	57	19.1	7.0	11.3	18.3	38	0.502	52	0.3	0.5	0.8	38	0.620	38	96	P_{+}	P_{++}
IIIC		21.0	4.4	16.3	20.7	21	0.516	90	0.1	0.2	0.3	33	0.660	33	99	A_{++}	B_{++}
IVC																	
VC1																	
VC2																	

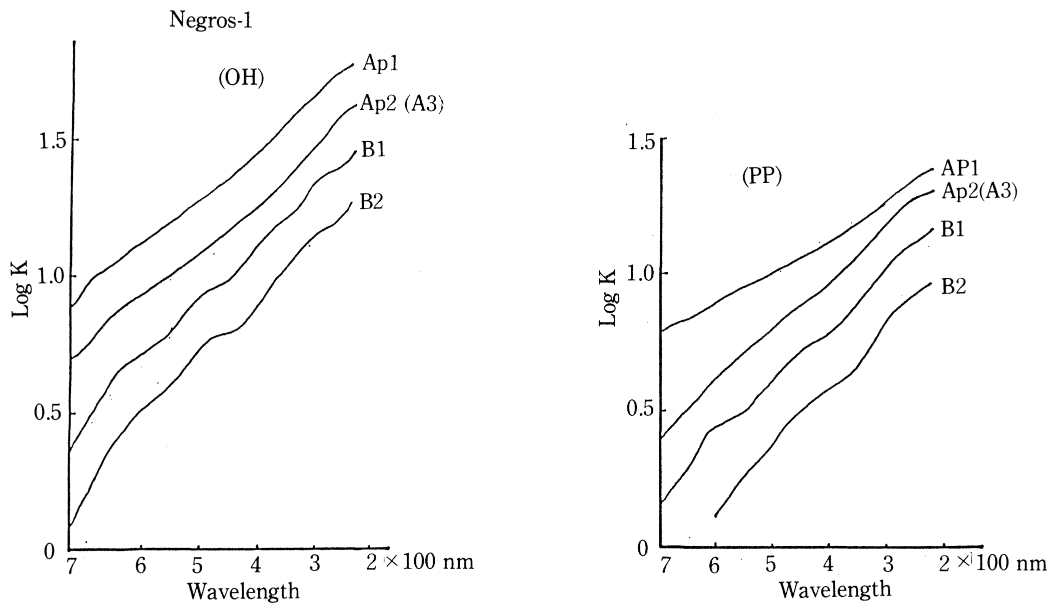

Fig. 40. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

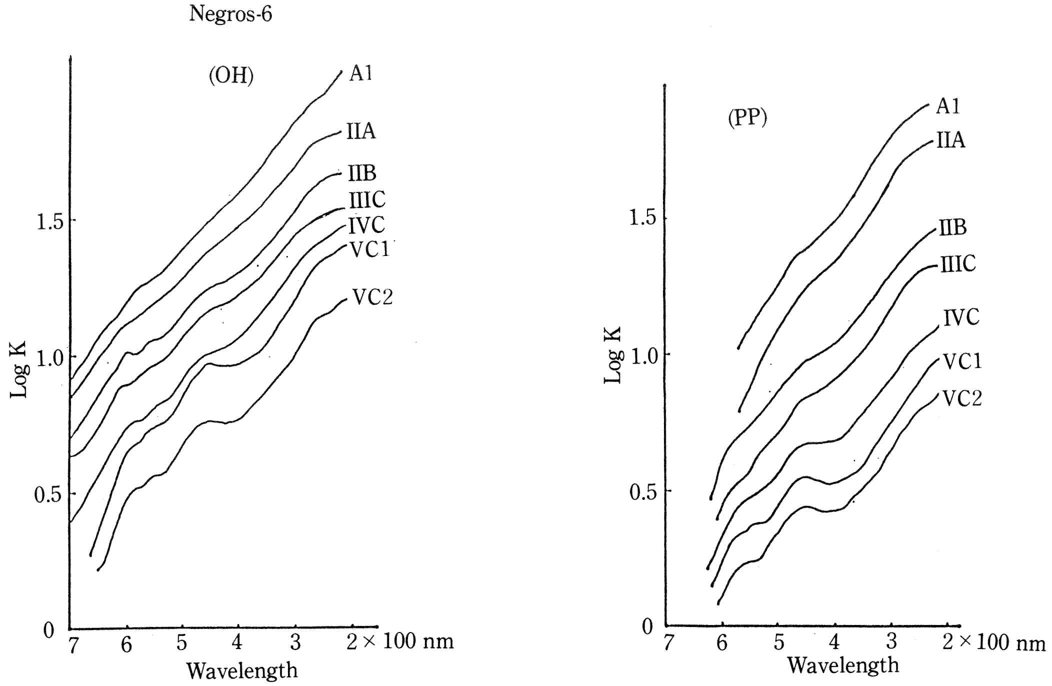

Fig. 41. Absorption spectra of humic acid extracted with NaOH (OH) and pyrophosphate (PP)

PQ_1 values of the Ap horizon were lower (43%) than those of the A_{13} horizon (56%) of Negros 1. PQ_1 values of Negros 6 ranged from 21% to 38% including the A horizon. These values were relatively very low. In the Negros 1 profile, $\Delta \log K_1$ of the Ap and A_{13} horizons was 0.499 and 0.488. These values were lower than those of the A and buried A horizons in Negros 6. RF_1 values of Negros 1 were 131 and 124. These values were higher than those (53 and 73) recorded in the A and buried A horizons in the Negros 6 profile. The degree of humification in Negros 1 may be higher than that in Negros 6.

Types of humic acid of Negros 1 wee A± A+, A, B ++ and B+. They contained a Pg fraction in the B1 horizon. On the other hand, in Negros 6 the type of humic acid were P+, B+, P±, A ++, Rp, P++ and B++. These samples contained a large amount of Pg fraction in the lower layers (Fig. 40 and 41).

V. 3. Discussion

V. 3. 1. Accumulation of organic matter

The amount of organic matter (humus) accumulated was 19.1% during 610 years in Isarog, while in Tagaytay 4.4% of organic matter accumulated during 710 years, 6.7% during 210 years, 8.1% during the same years and 4.8% during 550 years. The results showed that the larger accumulation of organic matter in the Isarog soil than in the Tagaytay soil may be due to differences in the climate, base saturation and mineralogical constituents that will be reported in the following chapter. It can be speculated that the

Isarog profile may contain much more aluminum that will combine with organic matter than the Tagaytay one.

V. 3. 2. Carbon content and C/N ratio

Organic matter contents of the A and buried A horizons of volcanic ash soils in the Philippines ranged from 0.79%(Negros 5 Ap) to 11.1%(Isarog A11) as carbon, while the C/N ratios ranged from 5 to 37%. These variations were very wide, because the accumulation of organic matter may be complicated and depend on the texture, composition of inorganic materials and age of soil layers, climate and topography at the sites. Figure 42 shows the relationship between the carbon content and C/N ratios of the volcanic ash soils in the Philippines. Tagaytay 1 soil showed an increase of the C/N ratio with the age of the layers. The buried soil layer (IVA) in Tagaytay 2 showed a C/N ratio of 28. In Japan also, Otsuka and Kumada (1978) and Yoshida and Kumada (1978) recognized that the C/N ratios of the buried layers tended to increase with the age of the layers (Fig. 43). The buried layers of Tagaytay 2 exhibited similar tendencies to those of the buried soil layers in Japan. The term "buried type" of C/N ratio increase can be proposed.

The relationship between the carbon contents and C/N ratios of upland cultivated volcanic ash soils (Kuroboku) in Kagoshima prefecture (Department of Soil Survey, Kagoshima Prefecture Experimental Station; 1959-1973) and in Miyazaki prefecture (Department of Soil Survey, Miyazaki Prefecture Experimental Station; 1960-1974) in Japan is shown in Fig. 44. The frequency distribution of the dots in Fig. 45, is very high in

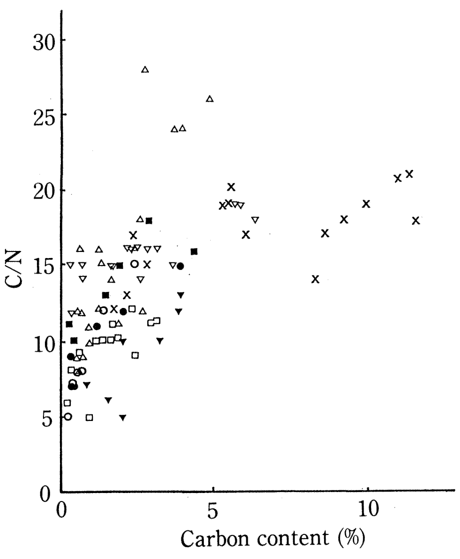

Fig. 42. Relationship between carbon content and C/N ratio of the volcanic ash soils in the Philippines

△ Tagaytay, ● Caliraya, × Isarog, ■ Iriga, □ Mayon-2, ▽ Zambales, ▼ Negros-1, ▼ Negros 6

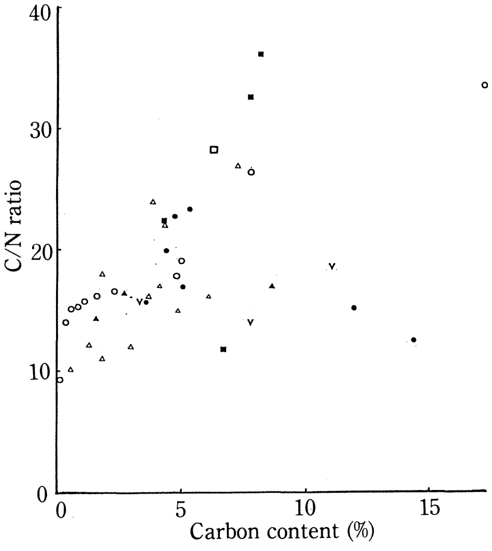

Fig. 43. Relationship between carbon content and C/N ratio of volcanic asho soil smaples in Japan

○ from A. SHINAGAWA
●V▲■△ from M. YOSHIDA

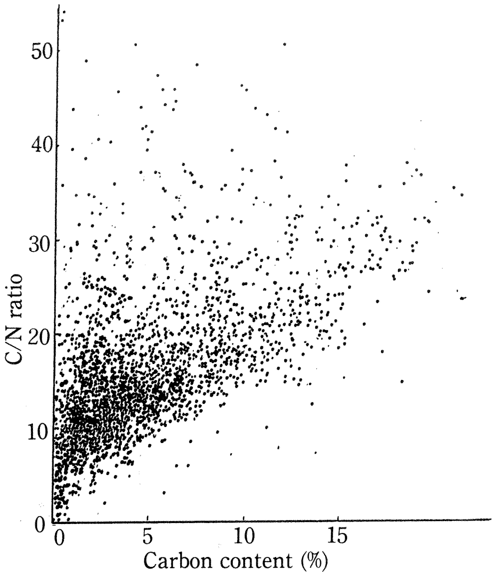

Fig. 44. Relationship between carbon contents and C/N ratios of upland cultivted volcanic ash soils in Kagoshima and Miyazaki prefectures in Japan

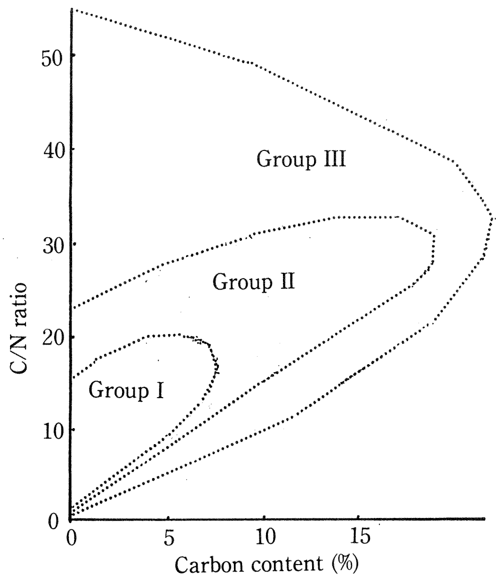

Fig. 45. Relationship between carbon content and C/N ratio

Group I, high in Group II and average in Group III.

Shinagawa (1962) observed that the C/N ratios of young volcanic ash surface soils derived from the Sakurajima volcano (1914 AD) increased with the carbon contents. The increase was not higher than in the case of buried soil layers.

Data on Ando soils in Japan edited by K. Wada (1986) which showed an increase of the C/N ratio with the carbon contents of the surface layers are similar to the data of the soil survey in Kagoshima and Miyazaki prefectures in Japan (Fig. 44). Isarog samples belonged to Group I in the Figure and the C/N ratios were low in the Tagaytay profile this Group I can be referred to as "surface type" of C/N ratio increase.

V. 3. 3. Characteristics of humus

The percentages of the extraction ratio of humus (CE/CT) to the carbon contents in the Ando soils in Japan (1986) are shown along with the carbon contents in Figure 46. Generally, the CE/CT values tended to increase with the carbon contents and the values exceeding 50% except for the 6 samples were stable. Two samples, Iwate 2 (O/A) and Iwate 4 (Ap) contains many plant residues and they exhibited low CE/CT values. The extraction ratios are likely to be low as suggested by Arai (1986). The other 4 samples showed high extraction ratios.

Figure 47 shows the relationship between the CE/CT and carbon content of the volcanic ash soils in the Philippines. CE/CT values tended to increase with the carbon content up to a value of 8%. However, the CE/CT values in the Philippines soils tended to be higher than in the Japan soil, even for a lower carbon content.

PQ_1 values in the Philippine soils (Fig. 48) increased with the C/N ratios as in the Japan

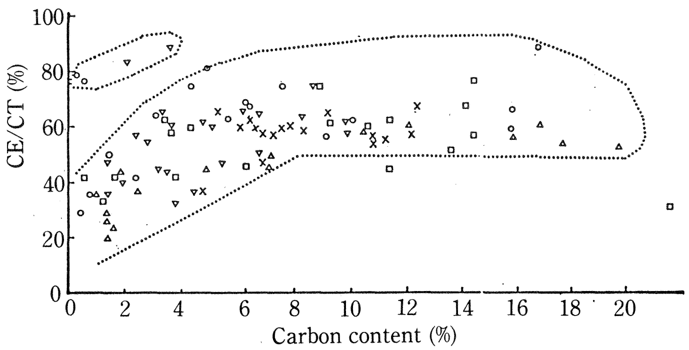

Fig. 46. Relationship between CE/CT and carbon content of the volcanic ash soils in Japan

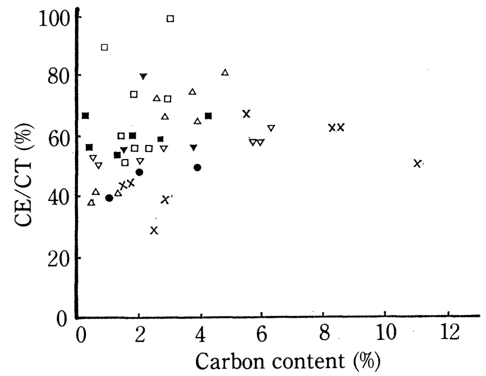

Fig. 47. Relationship between CE/CT and carbon content (%) of the volcanic ash soils in the Philippines

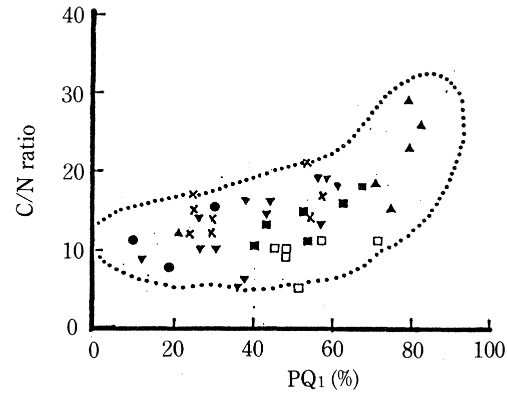

Fig. 48. Relationship between C/N ratio and PQ_1 in the Philippine soils

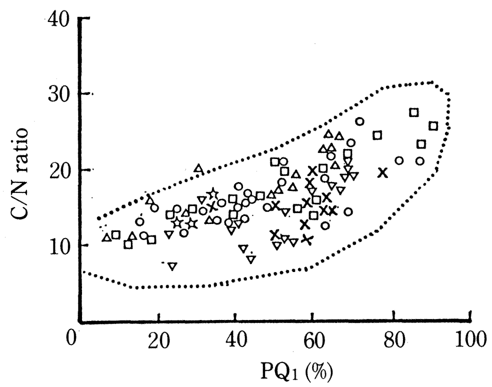

Fig. 49. Relationship between C/N ratio and PQ_1 in the Japan soils

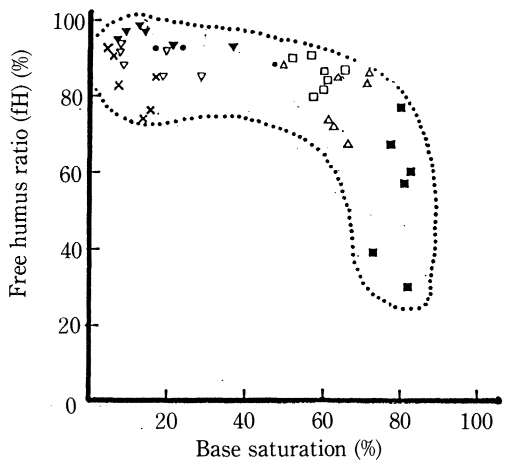

Fig. 50. Free humus ratio and base saturation (%) in the Philippine soils

soil (Fig. 49). Especially for a PQ of more than 50%, the C/N ratios increased abruptly.

Free humus ratios (fH) extracted with 0.1 *N* NaOH were plotted with the base saturation (%) in Figure 50. The fH values decreased with increasing base saturation in the Philippine soils. In the case of the Philippine, the fH values decreased after a base saturation value of more than 60%. Almost all the soil samples in Japan were similar to those in the Philippines except for samples which showed lower fH values (Fig. 50 and 51). Kumada (1967) classified the humic acids in to A, B, P, (Po) and Rp types according to the Δlog K and RF values (RF — Δlog K diagram) (Fig. 52 and 53). Free humic acid extracted with 0.1 *N* NaOH is shown in Figure 52 on the RF — Δlog K diagram. Thirty five of 49 samples belonged to the A type, 9 samples to the B type and 5 samples to the P type. Almost all the humic acids in the Philippines belonged to the A type. A and buried horizons contained humic acid of the A type except for the A1 and A3 horizon in Caliraya, A1 horizons in Mayon 2 and A1 and IIA horizons of Negros 6.

OTSUKA (1974a, 1974b,. 1979), OTSUKA and KUMADA (1974), and KUMADA (1981) suggested that the humic acids of volcanic ash soils in Japan evolved through the Rp-Po-B-A or of Rp-B-A series. Humic acids of the Tagaytay 1 and Caliraya soils belonged to the B and A types on the RF — Δlog K diagram, while the others belonged to the P, B and A types, respectively. These results suggest that the Tagaytay and Caliraya soils may have evolved through of Rp-B-A series and the other soils through the of Rp-Po-B-A series. Buried layers of Tagaytay 1 were young compared with the middle and lower layers of southern Kyushu, Japan (5540 yr. B.P. — 9000 yr. B.P.). In spite of the presence of young volcanic ash soil, the humic acids evolved through the Rp-B-A series or A-B-Rp degradation series. The humic acids of the Tagaytay 1 soil layers were similar to those of the "Kuroboku soil" around Chikugo, Japan which contains crystalline clay minerals.

Green humic acid fraction which showed on absorption at 620 nm, 570 nm and 450 nm

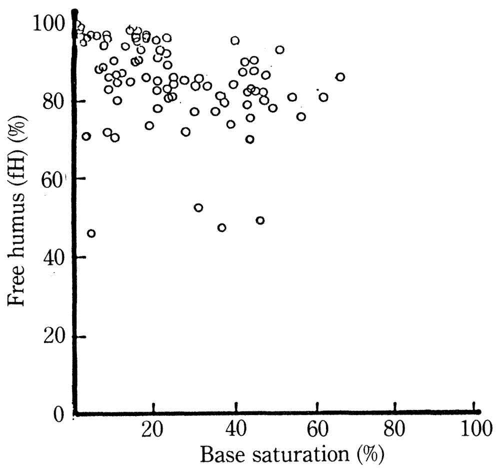

Fig. 51. Free humus ratio and base saturation (%) in the Japan soils.

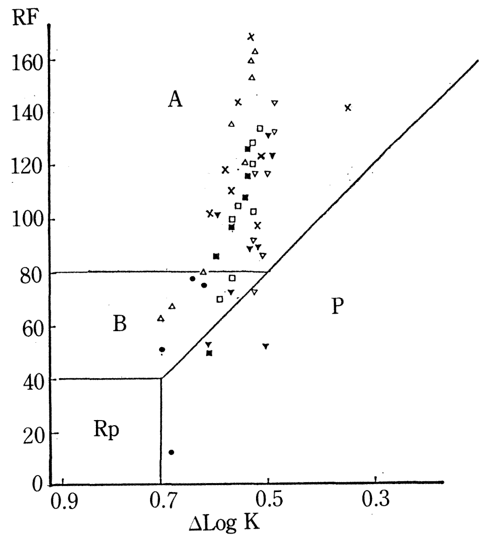

Fig. 52. RF and Δlog k diagram of humic acid extracted with NaOH for the soils of the Philippiones

was abundant in the sub-surface layers of the Isarog and Negros 6 soil profiles. Generally, humic acids extracted with 0.1 *M* $Na_4P_2O_7$ contained ranging amounts of the Pg fraction in the soil samples (Fig. 34–41).

V. 4. Summary

In this chapter, the properties of organic matter (humus composition) in the volcanic ash soils of the Philippines were determined by 14C dating of some humic acids. The results are summarized as follows:

1. ^{14}C dating of Tagaytay 1 revealed that the A horizon could be traced back to 710 yr. B.P. and the IVA_1 horizon to 1170 yr. B.P. Humic layers of the Isarog profile were formed around 580 yr. B.P. − 610 yr. B.P.
2. The accumulation of organic matter was highest in Isarog (19.1% as organic matter) and lowest in Tagaytay 1 (3.3% as organic matter), except for the Ap layes of Negros.
3. An amount of 19.1% organic matter had accumulated during 610 yr. in Isarog, while in Tagaytay-1, 4.4% organic matter has accumulated during 710 yr. in the A horizon, 6.7% during 210 yr. in the IIA horizon 4.8% during 550 yr. in the IVA horizon.
4. Generally, the C/N ratio increased with the carbon content in the volcanic ash soils of the Philippines and of Japan. There were two types of increase of C/N ratios: the "surface type" (surface layers or "Group I" for the C/N ratio-carbon content; the other the "buried type" (buried layers or "Group II or III" for the C/N ratio-carbon content.
5. The increase of the extraction ratio (CE/CT) with the carbon content until 8% and more was higher in the Philippine than in the Japan soils.
6. PQ values increased with the C/N ratio of volcanic ash soil in the Philippine and Japan soils.
7. The free humus extracted with 0.1 *N* NaOH decreased when the saturation exceeded 50%.
8. A and buried A horizons belonged to the A type humic acid except for 4 samples only.
9. Humic acids of the Tagaytay 1 and Caliraya soils belonged to the B and A types on the RF − Δlog K diagram, while the others belonged to the P, B and A types, respectively.
10. Sublayers of Isarog and Negros 6 contained higher amounts of green humic acid.

VI. CLAY MINERALOGY, DISSOLUTION ANALYSIS, ELEMENTARY COMPOSITION OF SAND FRACTION, AND SOIL CLASSIFICATION

There is a limited amount of information on the clay minerals contained in the volcanic ash soils in the Philippines. Galvez (1957a, 1957b) showed that montmorillonite is dominant with ferro-allophanes-like-materials in the soils from areas affected by volcanic ash deposition in the past. Briones (1964, 1982) demonstrated the dominance of montmorillonitic mineralogy in clay derived from volcanic paddy soils in Laguna and Quezon provinces. Ikawa (1979) observed that volcanic ash soils from Mt. Isarog contained a large amount of allophane clay minerals in experiments for the Benchmark Soils Pprojet of the University of Hawaii. Umali (1982) studied the classification of volcanic ash soils around Mt. Banahaw and recognized the presence of kaolinitic clay minerals.

In the earlier Chapters, soil profiles, physico-chemical properties, distribution and contents of phosphate, and properties of humus of the volcanic ash soils in the Philippines were analyzed. In this Chapter information on the clay mineralogy and elementary composition of the sand fraction of volcanic ash soils in the Philippines is presented. The volcanic ash soils were classified based on the Soil Taxonomy (1975), ICOMAND 9th circular letter (1987), and classification of cultivated soils in Japan (CCSJ) (1982).

VI. 1. Materials and Methods

Description of the soil profiles and physico-chemical properties of the soil samples were presented in Chapters II and III.

VI. 1. 1. Identification of clay minerals.

In accordance with usual methods (1966), the clay fraction was separated from the soil samples and treated with magnesium acetate and potassium acetate. Mg-clays and K-clays were analyzed by using on X-ray diffractometer, Rigaku Miniflex.

VI. 1. 2. Acid oxalate soluble manganese, iron, and aluminum, and dithionite-bicarbonate citrate soluble fractions in soil samples.

(a) Acid oxalate soluble fractions (Tamm's method) (1922)

One gram of air-dried soil samples was put into on Erlenmyer flask continuing the Tamm's reagent (0.1 M NH_4-oxalate, pH 3.30) and shaken for one hour. The suspensions were centrifuged and the supernatants were transferred into a 100 ml volumetric flask. The residues were washed with Tamm's reagent and 5% NaCl. The contents of Mn, Fe, and Al were determined using an atomic absorption spectrophotometer.

(b) Dithionite-bicarbonate-citrate soluble fraction (Mehra and Jackson's method) (1960)

Two grams of soil samples were put into 100 ml centrifuge tubes and treated with 40 ml Na-citrate and 1 g $Na_2S_2O_4$ at 80°C for 15 minutes. The suspensions were centrifuged and then the residues were washed with 5% NaCl solution. Supernatants were collected in to a 200 ml flask. The contents of Mn, Fe, and Al were determined using an atomic absorption spectrophotometer.

VI. 1. 3. Determination of weight loss after treatment with dithionite-bicarbonate-citrate solution and oxalate solution.

(a) Oxalate soluble fraction.

Five grams of soil samples were treated with 150 ml Tamm's reagent. The residues were washed with 80% ethanol until the supernatants were free from Cl^- after washing with 5% NaCl. Thereafter the residues were washed with acetone and dried. The residues were weighed after drying in the oven at 150°C for one night.

(b) Dithionite-bicarbonate-citrate soluble fractions

Five grams of soil samples were treated according to the same method that described in paragraph VI. 1.2. (b). The residues were washed with thanol after washing with a 5% NaCl solution. Thereafter the residues were washed with acetone as indicated in paragraph VI. 1.3. (a). The residues were dried in the oven and weighed.

VI. 1. 4. Elementary composition of sand fractions

Sand fractions of the soil samples (>2 mm) were collected and then ground to pass a less than 60 mesh sieve. Silica contents of the samples were determined by the weighing method after Na_2CO_3 fusion. Aluminum, iron and manganese contents were determined by atomic absorption spectrophotometery after $HF-H_2SO_4$ digestion.

VI. 2. Results and Discussion

VI. 2. 1. Clay mineral identification

X-ray diffractogram of the Tagaytay samples is shown in Fig. 53. Tagaytay-1 exhibited small peaks of 7.56 Å in the Mg- and K-clay samples of the A and IIA horizons (Fig. 53). Additionally, the K-clay samples showed a sharper peak after 250°C heating, but these peaks disappeared after 500°C heating. These peaks corresponded to metahalloysite or kaolinite. In the IIIA1, IIIA12,IVA,IVB and VC horizons, Mg- and K-clay samples showed predominant 10.1Å peak which shifted to 7.44Å. These samples were considered to contain halloysite. As the peaks were not high, it is considered that amorphous materials may be present.

The surface layer (A horizons) showed a small peak of 7.45Å in the Mg-clay and in the Mg-clay treated with glycerol in the Tagaytay-3 soil (Fig. 54). B and IIC horizons had no peak except for a small and broad peak near 7.45Å in the K-clay and K-clay heated 250°C. These horizons contained large amounts of amorphous materials with a small amount of metahalloysite. The results obtained with IIIA horizons were similar to those recorded in the A layer. Other horizons (IVB11, IVB12, VC1, VC2 and VC3) had small peaks of 10.1Å and 7.44Å in the Mg-clay and K-clay. These 10.1Å peaks shifted to 7.44Å after heating at 250°C. They corresponded to halloysite and metahalloysite or kaolinite. It is considered that large amounts of amorphous materials are present in these horizons. Clay samples of Tagaytay-2 had shoulder peaks of 7.45Å in the Mg- and K-clays. The peaks became higher after heating at 250°C. After heating treatment at 500°C, the 7.45Åpeaks disappeared. However the broad peak near 10.4Å (14.0–10.0Å) which appeared instead of 7.45Å was found to correspond to halloysite, metahalloysite or kaolinite. The broad peak near 10.4Å may corresponded to vermiculite-chlorite intergrade (Al-vermiculite). Generally the Tagaytay-2 profile contained halloysite, metahalloysite (or kaolinite) and Al-vermiculite. X-ray diffractogram of the Caliraya Soil is shown in Fig. 56. All of these clay samples

Tagaytay-1 (Tag-1)

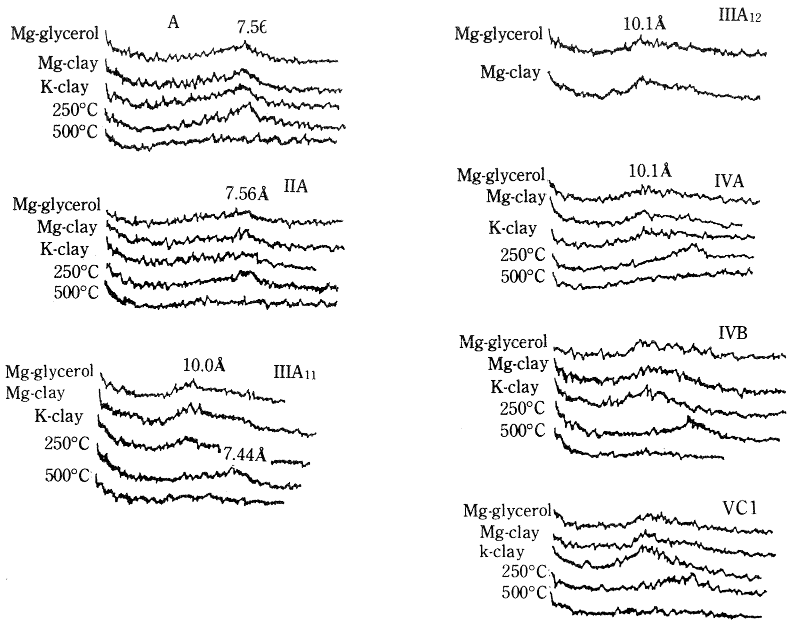

Fig. 53. X-ray diffractogram of Tagaytay-1 (Tag-1) clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

Tagaytay-3 (Tag-3)

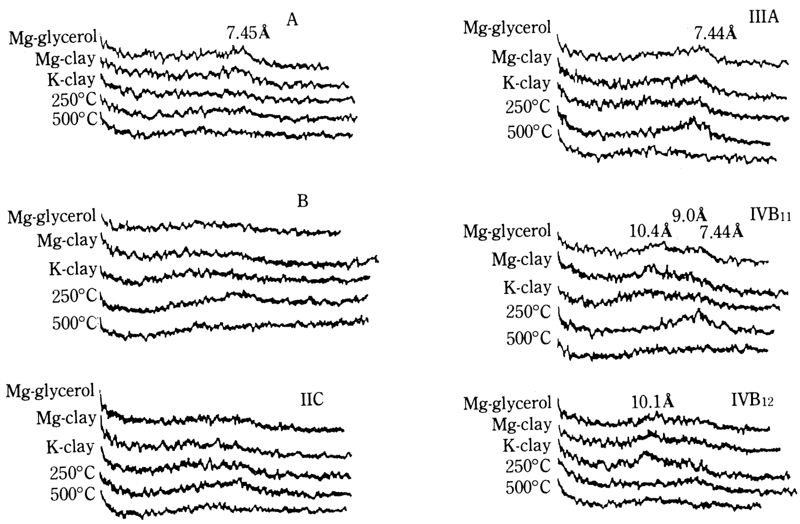

Fig. 54-1. X-ray diffractogram of Tagaytay-3 (Tag-3) clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

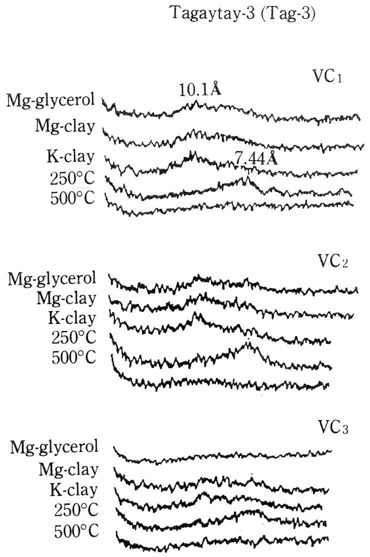

Fig. 54-2. X-ray diffractogram of Tagaytay-3 (Tag-3) clays treated with Mg++, K+, glyceroll and heating at 250°C and 500°C

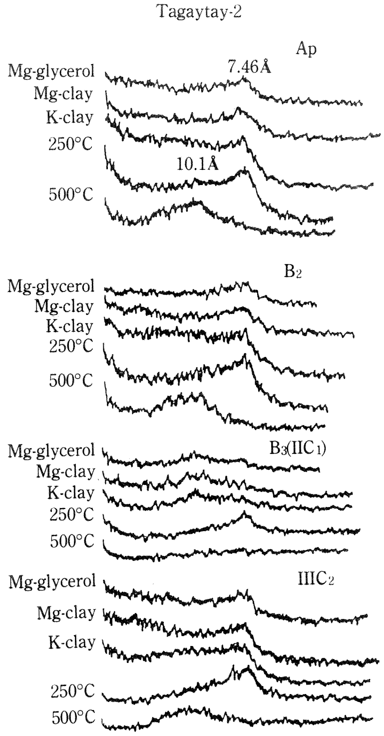

Fig. 55. X-ray diffractograom of Tagaytay-2 (Tag-2) clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

showed high and sharp peaks of 7.48Å and 3.71Å. These peaks were corresponded to metahalloysite or highly crystallized kaolinite. Additionally small peaks of 4.10Å also corresponded to geothite. All the layers showed similar results respectively.

A11 and A12 horizons of the Isarog profile showed no peak for all the treated clay samples (Fig. 57). These clay samples were found to consist of allophane. However, the IIA11, IIIB11, and IIIB12 horizons had broad peak like shoulders near 14Å and 7Å which disappeared after heating at 250°C and 500°C. These peaks corresponded to imogolite.

All the layers of the Iriga profile (Fig. 58) showed a 10.0Å peak in the Mg- and K-clays. These peaks shifted to 11.05Å by treatment with glycerol and to 7.45Å by heating at 250°C. The 7.45Å peaks disappeared after treatment at 500°C. Therefore these peaks were found to correspond to halloysite. As the 10.0Å peaks in the A_{11} horizon were not high and not sharp it is assumed that the A11 horizon may contain large amounts of amorphous materials.

Layers of the Mayon-1 profile had similar peaks to those of the Iriga profile. They showed sharp and high peaks of 10.0Å and 7.56Å in the Mg- and K-clays (Fig. 59). These peaks corresponded to halloysite and metahalloysite or kaolinite respectively.

Meanwhile the A1, and IIAC horizons of the Mayon-2 profile (Fig. 60) had no peak and the IIIA3, IIIC and IVA3 horizons showed small peaks of 10.0Å in the Mg- and K-clay.

These peaks which disappeared after heating at 250°C and 500°C corresponded to

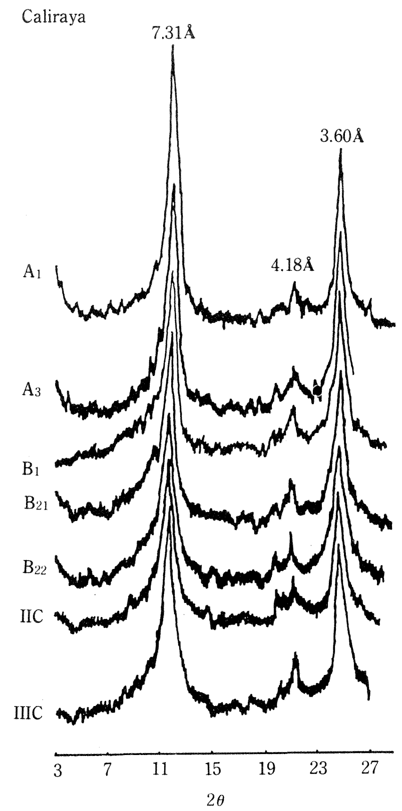

Fig. 56. X-ray diffractogram of Caliraya clays treated with K+

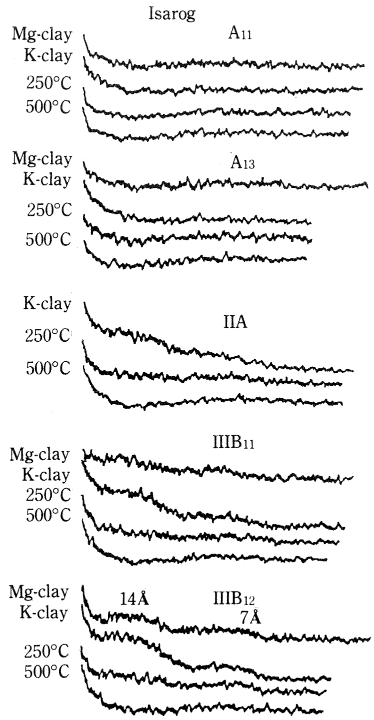

Fig. 57. X-ray diffractogram of Isarog clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

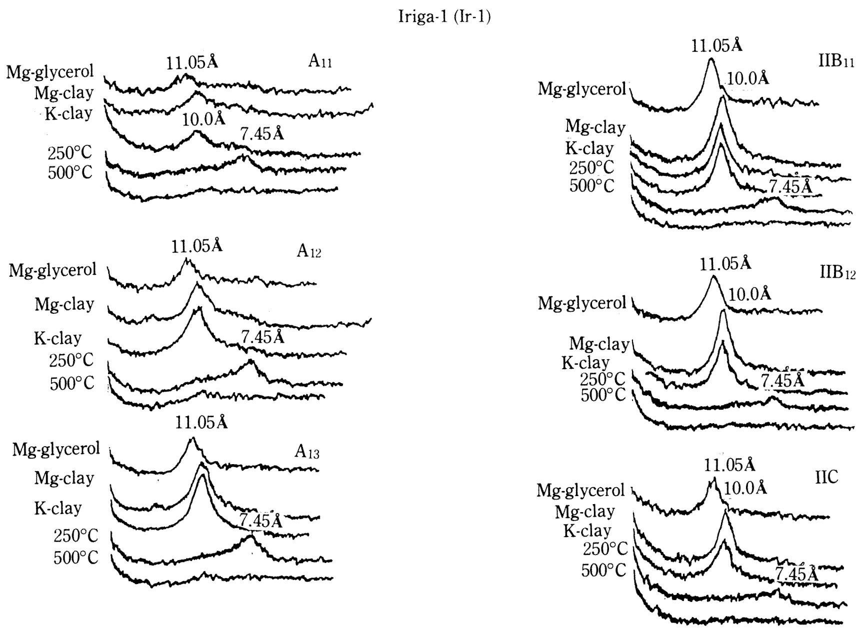

Fig. 58. X-ray diffractogram of Iriga clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

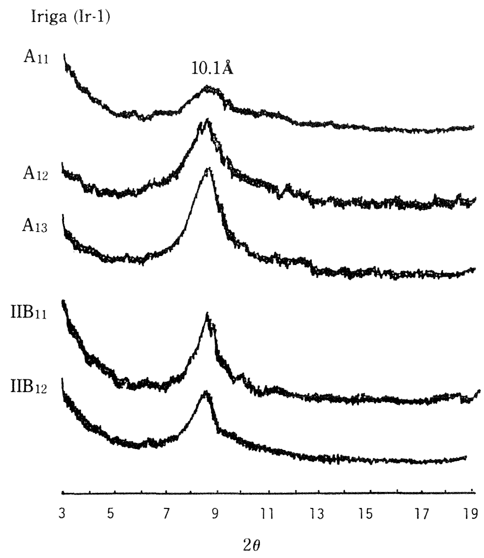

Fig. 58-1. X-ray diffractogram of Iriga clays treated with K+

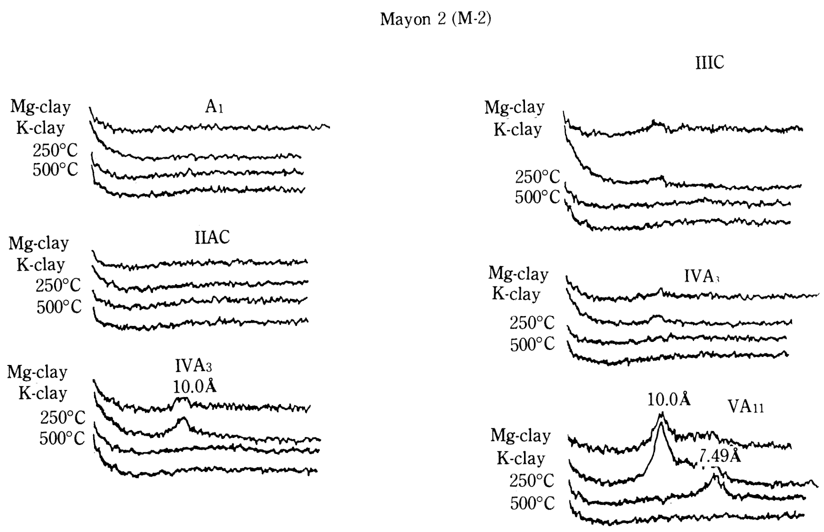

Fig. 59. X-ray diffractogram of Mayon-1 clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

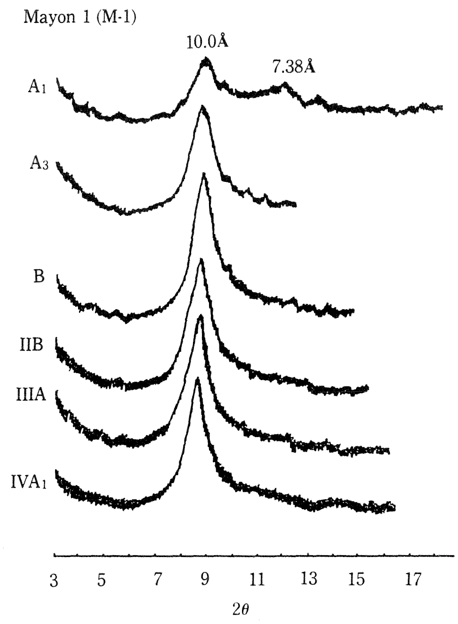

Fig. 59-1. X-ray diffractogram of Mayon-1 clays treated with K+

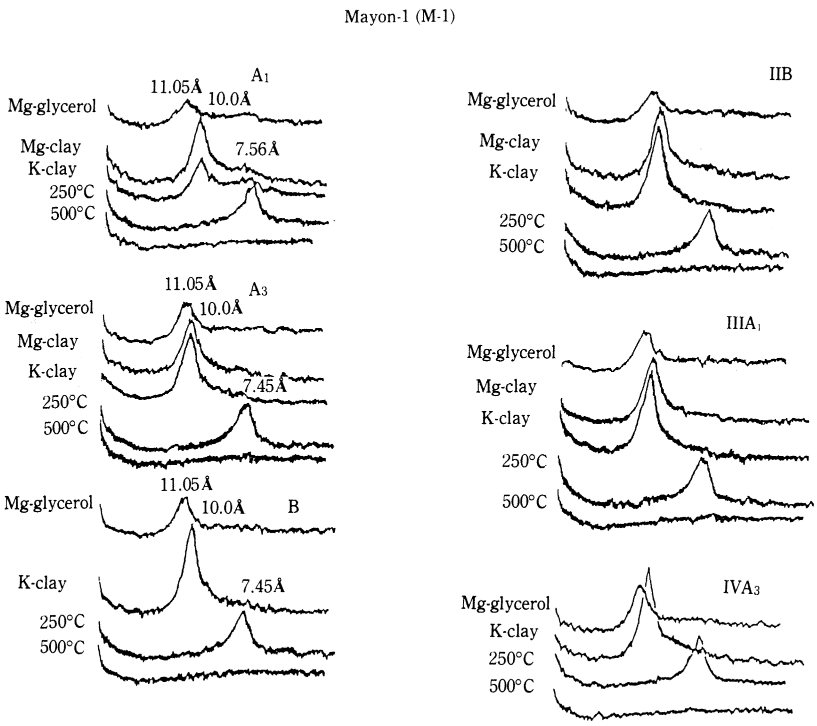

Fig. 60. X-ray diffractogram of Mayon-2 clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

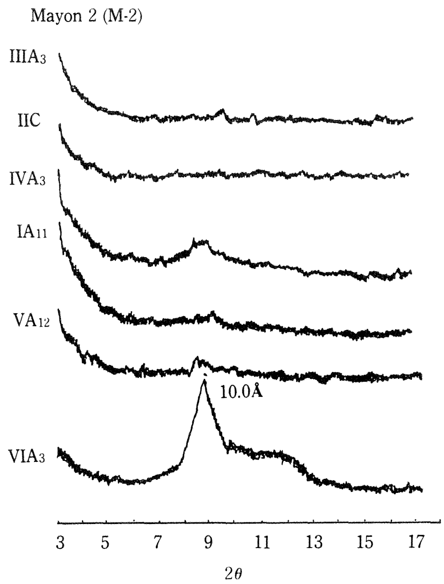

Fig. 60-1. X-ray diffractogram of Mayon-2 clays treated with K+

halloysite, which may not be well crystallized the lower horizon (VA11) of the profile showed a sharp peak of 10.0Å and a small peak of 7.49Å in the K-clay. The 10.0Å peak shifted to 7.49Å after heating at 250°C. This peak disappeared after 500°C heating. The VA11 layer contained highly crystallized halloysite.

In Sorsogon-2, all the horizons showed two peaks of 10.0Å and 7.56Å (Fig. 61). The 10.0Å peaks shifted to 11.0Å by treatment of Mg-clay with glycerol. The peaks of 10.0Å in the K-clay disappeared after heating at 250°C. Instead of 10.0Å, the peak of 7.56Å became higher and sharper. After heating at 500°C, these peaks disappeared. Therefore the Sorsogon-2 profile was considered to contained halloysite and metahalloysite or kaolinite.

Almost all the horizons of Zambales-1 had very small peaks near 14.4Å except for the IIC3 horizon which had a 10.0Å peak for the Mg-clay and k-clays (Fig. 62). These very small peaks disappeared after heating at 250°C and 500°C. It can be considered from these results that amorphous clay minerals were dominant and weakly crystallized clay minerals may be associated with allophane until the IIC2 horizon. The IIC3 horizon contained halloysite. Since the IIC3 horizon was similar to 'Shirasu' which contains pyroclastic materials derived from Aira caldera in Kagoshima, Japan this layer may be older and comparable to Shirasu and weathered by addition of silicate from the upper layers.

The X-ray diffractograms of Negros-6 are shown in Fig. 63. There were no high peaks in the samples except for low peaks near 20-12Å and 11-8Å for the Mg- and K-clays in the IVC and VC1 horizons. These broad peaks which disappeared after heating at 250°C and 500°C corresponded to imogolite. Allophane clay minerals were dominant in the A1, IIA, IIB, and IIIC horizons and imogolite clay minerals were present with allophane in the IVC, VC, and VC2 horizons.

The results of clay mineralogy in the volcanic ash soils from the Philippines enabled to classify the soils into 3 types as follows:

Ht type dominated by halloysite with metahalloysite or haolinite: Caliraya, Tagaytay-2, Mayon-1, Sorsogon-2, and Iriga Soils

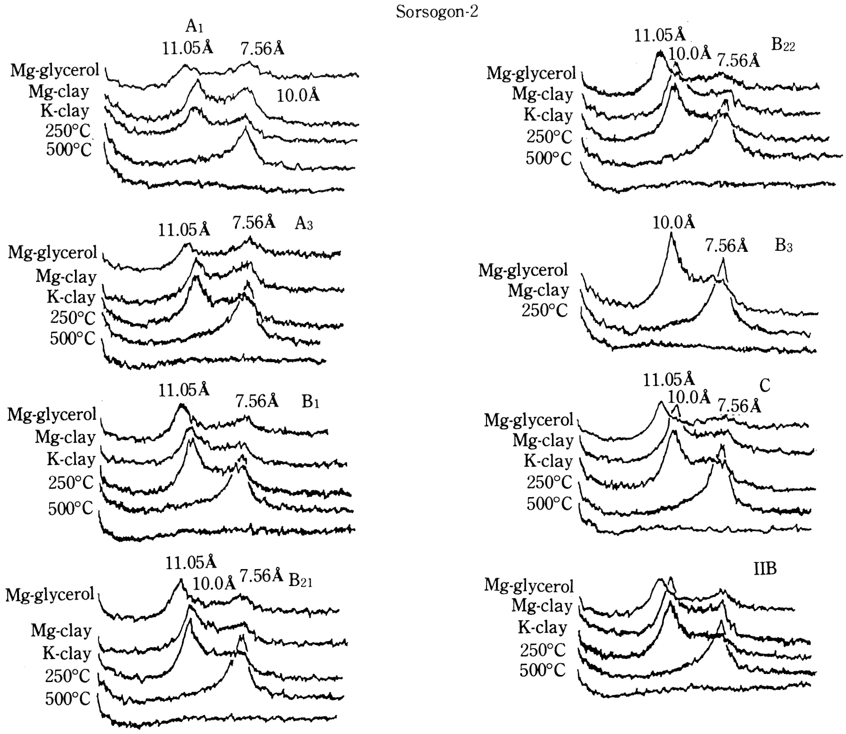

Fig. 61. X-ray diffractogram of Sorsogon-2 clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

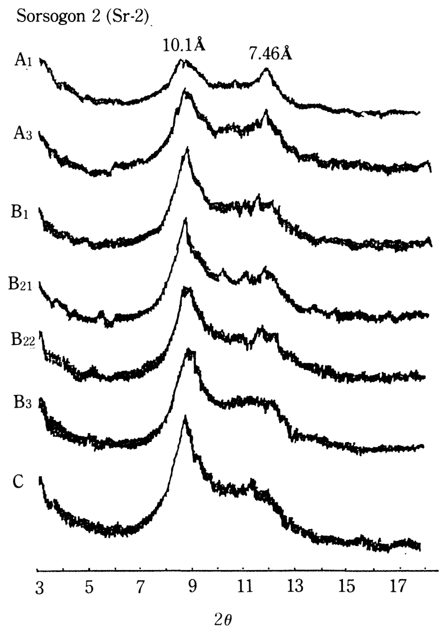

Fig. 61-1. X-ray diffractogram of Sorsogon-2 clyas treated with K+

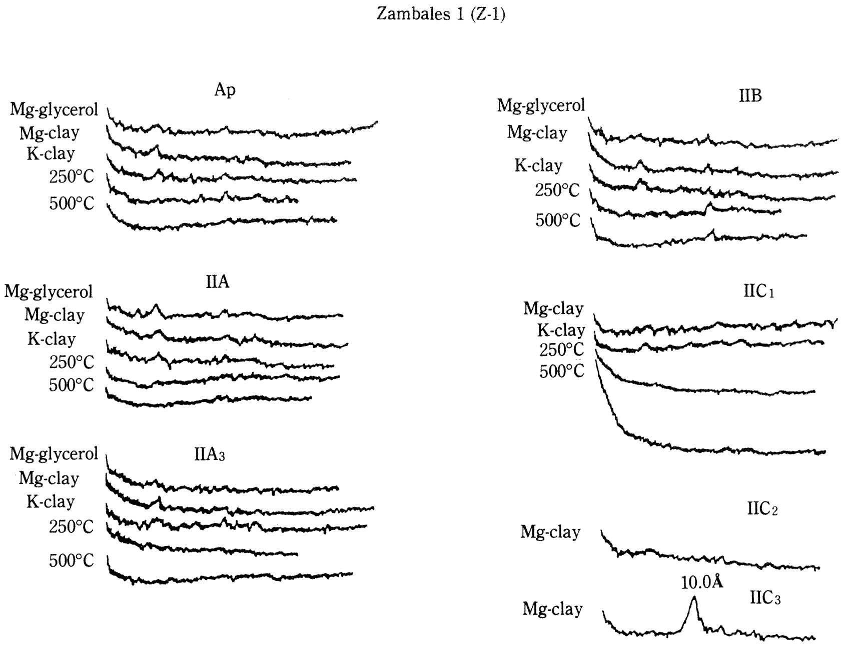

Fig. 62. X-ray diffractogram of Zambales-1 clays treated with Mg++, K+, glycerol and heating at 250°C and 500°C

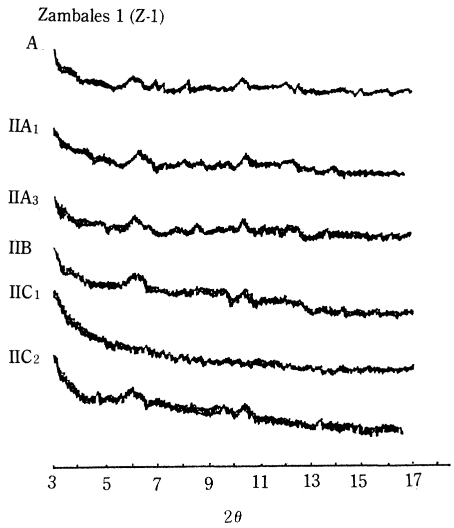

Fig. 62-1. X-ray diffractogram of Zambales-1 clays treated with K+

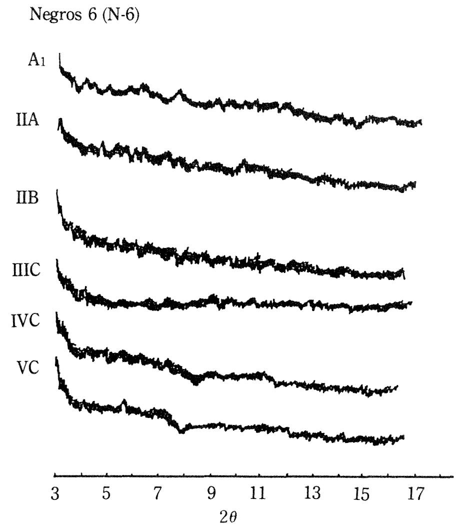

Fig. 63-1. X-ray diffractogram of Negros-6 clays treated with K^+

Allo type which is dominated by allophane and imogolite: Isarog, Negros-1 and -6, Zambales-1, and Mayon-2 soils.

Ht-Allo type which is intermediate between Ht type and Allo type: Tagaytay-1 and -3 soils.

VI. 2. 2. Dissolution analysis of soil samples

The results of the dissolution analysis are show in Table 44. Aluminum contents extracted with acid oxalate (Alo) ranged from 0.27% to 10.72% as Al_2O_3. Aluminum contents extracted with dithionite-bicarbonate-citrate (Ald) ranged from 0.25% to 3.43% as Al_2O_3. These contents showed wide range and were dependent on the soil profiles. Figure 64 shows the relationship between the Alo and Ald contents. The Alo contents of the Isarog, Zambales, Negros, and Mayon-2, Soils which belong to the Alloy type of clay mineralogy, increased with increasing Ald contents, where as in the Caliraya and Sorsogon Soils, which belong to the Ht type of clay mineralogy, they tended to decrease as the Ald contents increased. The Tagaytay and Iriga Soils showed low Alo and Ald contents, and were placed in the intermediate zone in Fig. 64.

Ald/Alo ratios of the Allo type samples (Isarog, Zambales, Negros, and Mayon-2) were below 0.2, while those of the Caliraya and Sorsogon samples Ht type were above 0.9. The values of the Tagaytay-1 and 03) ranged from 0.2 to 0.7.

Wada (1986) studies the dissolution analysis of Andepts and showed that acid oxalate dissolves all or some noncrystalline to low crystalline aluminosilicates and Fe oxidesin addition to Al- and Fe-humate complexes, while dithionite-bicarbonate-citrate diossolves noncrystalline and crystalline Fe-oxides and allophane-like constituents.

From the results described above, it appears that the Allo type samples contained a larger amount of noncrystalline and low crystalline aluminosilicates and Al-humates than the Ht type except for the Caliraya and Sorsogon soils which showed a lower pH(KC1), high exchangeable aluminum contents, and a high pH(NaF). Therefore the

Table 44-1. Analysis of dithionite-bicarbonate-citrate soluble and acid oxalate soluble fractions

Location	Horizon	Alo %	Feo %	Mno %	Alo+Feo %	Ald %	Fed %	Mnd %	Ald+Fed %
Tagaytay-1	A	1.50		0.12		0.40	1.71	0.12	2.11
	IIA	1.56		0.06	0.36	1.90	0.06	2.26	
	IIIA11	1.56		0.06		0.31	1.63	0.06	1.94
	IIIA12	1.66		0.18		0.36	2.21	0.18	2.57
	IVA1	0.80	1.14	0.15	1.94	0.33	1.67	0.15	2.00
	IVB2	0.89	0.71	0.13	1.60	0.27	1.36	0.13	1.53
	VC1	0.73	0.41	0.13	1.14	0.42	2.18	0.13	2.60
	VIC2	0.71	1.23	0.13	1.94	0.44	2.01	0.13	2.45
	VIC3	0.68	1.11	0.13	1.79	0.42	1.27	0.13	0.69
Tagaytay-2	A	0.38	1.39	0.16	1.77	0.27	1.68	0.16	1.95
	B2	0.53	1.33	0.12	1.86	0.31	0.68	0.12	1.99
	B3(IIC)	0.59	1.12	0.13	1.71	0.30	1.31	0.13	1.61
	IIIC	0.39	0.94	0.10	1.33	0.34	1.80	0.10	2.14
Tagaytay-3	A	0.79	2.13	0.08	2.92	0.54	2.25	0.15	2.79
	B	1.22	4.27	0.15	4.42	0.53	4.96	0.15	5.49
	IIC	1.38	5.20	0.15	6.58	0.63	4.99	0.15	5.62
	IIIA	1.12	5.01	0.15	6.13	0.74	5.21	0.16	5.95
	IVB1	1.12	4.98	0.15	6.10	0.53	5.14	0.16	5.67
	IVB2	1.12	3.10	0.15	4.22	0.55	4.00	0.15	4.55
	IC1	1.03	2.99	0.11	4.02	0.61	3.68	0.14	4.29
	VC2	1.08	2.83	0.10	3.91	0.55	3.61	0.14	4.16
	VC3	1.00							
Caliraya	A1	0.36	0.06	0.13	0.42	0.64	4.05	0.16	4.69
	A3	0.37	0.13	0.10	0.50	1.94	4.80	0.12	6.74
	B1	0.27	0.18	0.04	0.55	1.56	4.69	0.05	6.25
	B21	0.61	0.46	0.02	1.07	1.35	4.02	0.03	5.37
	B22	0.36	0.28	0.03	0.64	1.46	3.74	0.05	5.20
	IIB3	0.53	0.22	0.02	0.75	1.05	3.75	0.03	4.80
	IIIC	0.49	0.25	0.01	0.74	0.44	2.73	0.02	3.17
Isarog	A11	10.11	1.03	0.05	11.14	3.43	1.88	0.08	5.31
	A12	9.77	0.99	0.06	10.76	3.34	1.90	0.08	5.24
	A13	9.62	0.99	0.06	10.33	3.34	1.80	0.07	5.24
	IIA	10.72	1.12	0.07	11.84	2.63	2.17	0.06	4.80
	IIIB11	9.40	0.58	0.05	9.98	2.20	1.84	0.06	4.04
	IIIB12	9.07	0.42	0.05	9.49	1.49	1.69	0.06	3.18
	IIIB21	8.46	0.63	0.05	9.09	1.37	1.55	0.08	2.92
	IVB$_{22}$	7.52	0.29	0.03	7.81	1.48	2.34	0.06	3.82
	VA	7.08	0.29	0.04	7.37	1.47	2.36	0.07	3.83

Alo, Feo and Mno denote the amounts of Al_2O_3, Fe_2O_3, and MnO extracted by acid oxalate. Ald, Fed and Mnd are the amounts of Al_2O_3, Fe_2O_3 and MnO extracted by dithionite-bicorbonate-citrate.

Table 44-2. Analysis of dithionite-bicarbonate-citrate soluble and acid oxalate soluble fractions

Location	Horizon	Alo %	Feo %	Mno %	Alo+Feo %	Ald %	Fed %	Mnd %	Ald+Fed %
Iriga	A11	1.30	2.69	0.06	3.99	0.60	2.36	0.05	2.96
	A12	0.87	1.82	0.04	2.69	0.40	2.48	0.05	2.88
	A13	0.93	1.39	0.05	2.72	0.38	1.82	0.05	2.20
	IIV	0.88	1.71	0.05	2.59	0.49	2.82	0.06	3.31
	IIIC	0.58	0.70	0.03	1.28	0.34	0.49	0.03	1.23
	IVB	0.46	0.65	0.02	1.23	0.27	0.50	0.03	0.77
Mayon-1	A1	0.83	1.70	0.10	2.53	0.35	2.45	0.10	2.80
	A3	0.72	1.44	0.09	2.16	0.38	1.96	0.10	2.34
	B	0.64	1.21	0.10	1.85	0.33	1.81	0.12	2.14
	IIB	0.60	1.10	0.10	1.70	0.31	2.26	0.12	2.57
	IIIA1	0.45	0.91	0.13	1.36	0.27	2.49	0.14	2.76
	IVA3	0.40	0.80	0.12	1.20	0.25	1.65	0.12	1.90
Mayon-2	A1	1.63	0.78	0.02	2.41	0.66	0.71	0.02	1.37
	IIAC	1.64	0.75	0.02	2.39	0.44	0.83	0.02	1.27
	IIIA3	1.77	0.03	2.41	0.46	0.89	0.03	1.35	
	IIIC	1.64	0.72	0.04	2.36	0.48	1.13	0.04	1.61
	IVA3	1.0.90	0.05	2.54	0.55	1.04	0.03	1.75	
	VA11	2.03	1.01	0.03	3.47	0.49	1.01	0.03	1.75
	VA12	2.55	0.92	0.03	3.47	0.49	1.01	0.03	1.50
	VIA3	2.29	0.42	0.01	2.71	0.40	0.46	0.01	0.86
Sorsogon-2	A1	0.90	3.19	0.21	4.09	1.15	5.15	0.24	6.30
	A3	0.43	0.63	0.14	1.06	1.15	6.23	0.18	7.38
	B1	0.49	0.56	0.09	1.05	1.02	4.90	0.13	5.92
	B21	0.58	0.52	0.10	1.10	0.86	4.48	0.12	5.34
	B22	0.60	0.52	0.09	1.12	0.91	4.93	0.10	5.84
	B3	0.49	1.37	0.12	1.86	0.74	5.72	0.12	7.52
	C	0.91	1.62	0.11	2.53	0.95	6.57	0.12	7.52
	IIB	0.85	1.21	0.11	2.06	0.79	4.93	0.16	5.72
Zambales-1	A	4.65	0.43	0.03	5.08	1.28	0.43	0.02	1.71
	IIA1	5.58	0.56	0.03	6.14	1.50	0.45	0.03	1.95
	IIA3	5.37	0.56	0.03	5.93	1.23	0.47	0.03	1.70
	IIB	4.91	0.54	0.03	6.84	1.18	0.49	0.03	1.67
	IIC1	6.28	0.56	0.03	6.84	1.18	0.49	0.03	1.67
	IIC2	4.59	1.48	0.02	6.07	0.70	0.35	0.01	1.05
	IIC3	3.27	1.91	0.02	4.98	0.55	0.27	0.01	0.82
Negros-6	A1	3.70	0.40	0.02	4.10	1.18	0.42	0.03	1.60
	IIA	4.00	0.36	0.03	4.36	1.06	0.39	0.03	1.45
	IIB	2.60	0.29	0.02	2.89	0.78	0.32	0.02	1.10
	IIC	3.00	0.29	0.02	3.29	0.85	0.33	0.02	1.18
	IIIC	3.00	0.29	0.02	3.29	0.85	0.33	0.02	1.18
	IVC	4.90	0.42	0.02	5.32	1.09	0.50	0.03	1.59
	VC1	4.90	0.38	0.02	5.28	1.17	0.62	0.03	1.79
	VC2	3.70	0.33	0.02	4.03	0.88	0.56	0.03	1.44

Alo, Feo and Mno denote the amounts of Al_2O_3, Fe_2O_3, and MnO extracted by acid oxalate. Ald, Fed and Mnd are the amounts of Al_2O_3, Fe_2O_3 and MnO extracted by dithionite-bicorbonate-citrate.

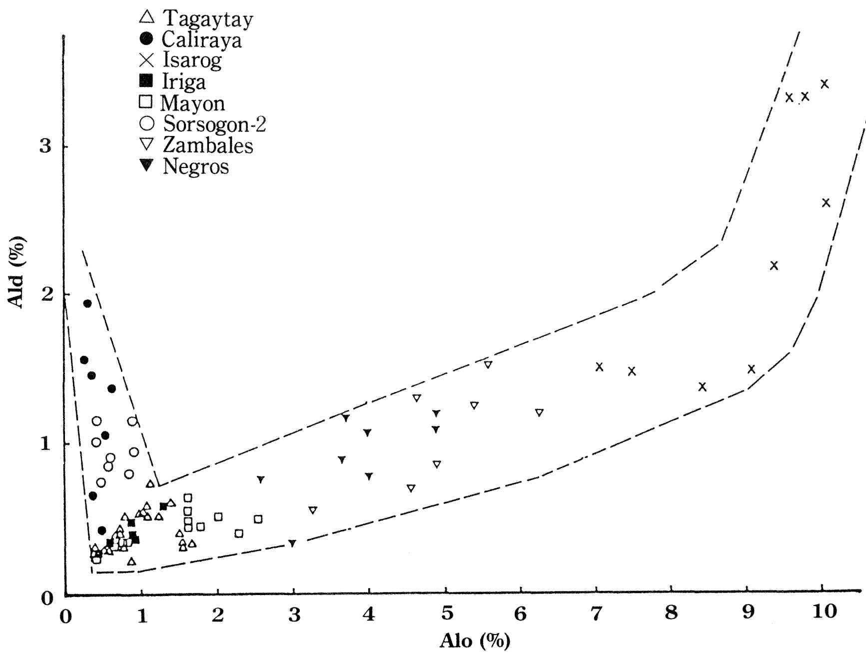

Fig. 64. Relationship between aluminum contents extracted with acid oxalate (Alo) and with dithionite-bicarbonate-citrate (Ald)

high Ald contents in the Caliraya and Sorsogon soils may be due to the high contents in exchangeable Al and/or allophane-like constituents which react with NaF.

Fed contents were relatively higher (2.13%–6.57%) in Caliraya, Srsogon, and Tagaytay-3 than in the other soils (Fig. 65). Feo contents of Tagaytay-3, Sorsogon, and Iriga A horizon were higher (2.65%–5.20%) than in the other soils (0.29%–1.82%).

Caliraya and Sorsogon had high Fed/Feo ratios (4.1–67.5), while Tagaytay-3 showed lower Fed/Feo (1.0–1.3). Fed/Feo ratios in the other soils were low (0.14–4.0) except for the value of 5.3 in the Tagaytay-1 VC1 horizon. These results suggest that Caliraya and Sorsogon, which belong to the Ht type contained large amounts of and crystalline Fe oxides small amounts of Fe-humates, while the other samples contains large amounts of non- and/or low crystalline Fe oxides, and Fe-humates.

Manganese contents extracted with acid oxalate (Mno) tended to increase with increasing manganese contents extracted with dithionite bicarbonate citrate (Mnd)(Fig. 66). Mnd/Mno ratios ranged from 0.9 to 1.9 except for Zambales samples. The differences between these ratios were not wide, less than 1.0, though the Mnd/Mno ratios tended to increase with the decrease of Mno.

It can be considered from the results described above that the Ht type soils such as Caliraya and Sorsogon contain large amounts of noncrystalline and crystalline Fe oxides and allophane-like aluminosilicate, exchangeable aluminum, and small amounts of Al and Fe-humates, while the Allo type soils contain large amounts of non- and low crystalline aluminosilicates, and Al-humates. The Allo-Ht type soils and some Ht type soils except for Caliraya and Sorsogon may contain large amount of non-and low crystalline Fe-oxides, crystalline Fe oxides, and relatively large amounts of Fe-humates.

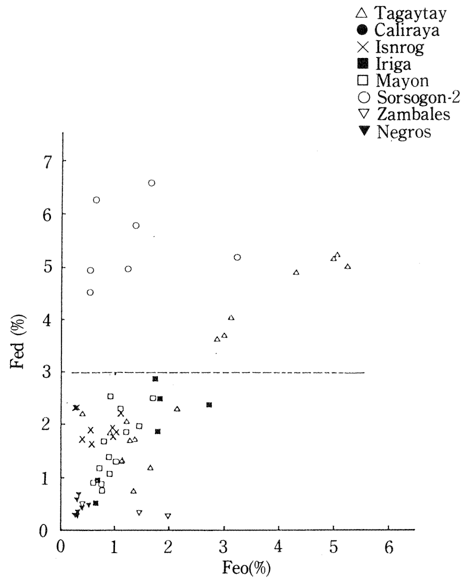

Fig. 65. Relationship between iron contents extracted with acid oxalate (Feo) and with dithionite-bicarbonate-citrate (Fed)

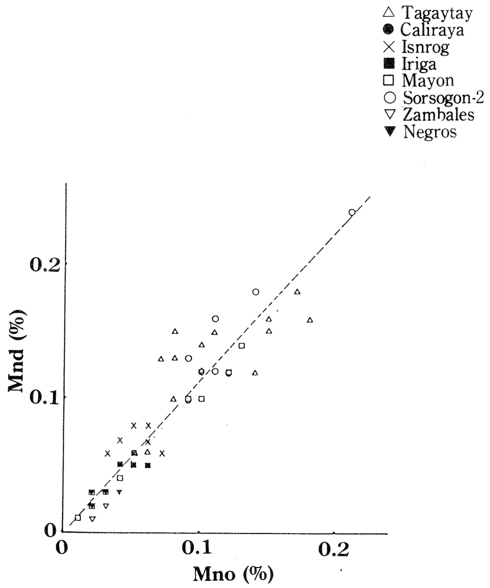

Fig. 66. Relationship between managnese contents extracted witha cid oxalate (Mno) and with dithionite-bicarbonate-citrate (Mnd)

Results of weight loss by treatment with acid oxalate (T) and dithionite bicarbonate citrate (M.J.) are shown in Table 45 together with those of ignition loss.

Ignition loss showed a positive correlation with the T* contents (%) and M.J.** contents (%) (Fig. 67 and 68).

T content (%) was higher than the M.J. content (%). Isarog, Negros, and Caliraya soils showed high T contents (%) exceeding 25%, while in the other soils the T content was less than 25%. M.J./T ratios tended to decrease with decreasing T contents (Fig. 69). Isarog, Negros, and Mayon-2, Zambales Soils had a low M.J./T ratio of less than 3, while the Iriga, Mayon-1, Sorsogon, and Tagaytay Soils had a M.J./T ratio of more than 3. As the T contents (%) tended to increase with the increase of Alo contents (Fig. 70), the low M.J./T ratio of the Isarog, Negros, and Zambales Soils may be attributed to high Alo contents, i.e. high Al-humate, high non- and low crystalline aluminosilicate contents.

M.J. contents were not correlated with the Fed contents, but tended to be correlated with the Fed plus Ald contents except for the Tagaytay-3 Soil (Fig. 71). The amounts of Ald plus Fed did not contribute to the M.J. contents in the Zambales, Tagaytay-1 and -2, and Mayon-2 Soils, which belong to the low Ald plus Fed groups. It may be considered that these samples contained large amounts of aluminosilicate with a high Si/Al ratio.

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* "T content" refers to the content of the residues extracted by the Tamm's reagent.

** "M.J. content" refers to the content of the residues extractes by the Mehra and Jackson's method.

Table 45. Weight loss by treatment with acid oxalate (T) or dithionite-bicarbonate-citrate (M.J.)

Sample	Horizon	I.L. %	T %	M.J. %	M.J. /T
Tagaytay-1	A	16.3	14.7	12.3	0.84
	IIA	17.1	19.4	14.1	0.73
	IIIA11	19.4	21.8	13.6	0.62
	IIIA12	17.6	23.5	15.2	0.65
	IVA	16.4	22.5	13.7	0.61
	IVB	15.0	19.0	9.6	0.51
	IVC1	15.4	21.0	9.4	0.45
	IVC2	14.1	20.7	7.2	0.35
	average	16.4	20.3	11.9	0.59
Tagaytay-2	A	15.0	11.7	5.7	0.49
	B2	13.5	13.7	7.6	0.55
	B3(IIC1)	12.7	13.7	6.6	0.48
	IIIIC2	15.3	11.5	6.2	0.54
	average	14.1	12.7	6.5	0.52
Tagaytay-3	A	12.2	22.1	10.9	0.49
	B	8.6	21.8	5.7	0.26
	IIC	8.1	13.9	8.5	0.61
	IIIA	14.0	18.4	5.9	0.32
	IVB1	13.0	15.3	2.8	0.18
	IVB2	13.4	15.8	7.3	0.46
	VC1	13.6	17.1	6.3	0.37
	VC2	12.7	16.7	7.3	0.44
	VC3	12.4	35.7	5.7	0.16
	average	12.0	19.6	6.7	0.37
Caliraya	A	20.7	31.5	8.8	0.28
	A3	17.5	31.2	16.1	0.52
	B1	15.7	30.4	8.8	0.29
	B21	15.4	15.1	14.2	0.94
	B22	15.5	17.3	11.0	0.64
	IIB3	14.9	23.6	12.3	0.52
	IIIC	15.2	22.9	8.3	0.36
	average	16.4	24.6	11.4	0.46
Isarog-1	A11	31.1	66.9	13.5	0.14
	A12	31.8	65.5	14.1	0.11
	A13	30.7	67.1	14.2	0.09
	IIA	24.7	54.8	7.6	0.13
	IIIB11	19.2	48.2	5.8	0.13
	IIIB12	16.9	47.1	6.1	0.13
	IVB21	16.7	45.9	4.6	0.14
	IVB22	16.7	42.6	12.8	0.15
	VA	16.6	43.5	11.5	0.15
	average	22.7	53.5	10.0	0.13
Iriga	A11	13.7	12.6	7.7	0.61
	A12	11.8	11.2	7.5	0.67
	A13	10.6	11.4	6.1	0.54
	IIB1	9.7	12.1	10.0	0.83
	IIIC	4.0	7.1	5.3	0.75
	IVB	3.2	7.3	1.7	0.23
	average	8.8	10.3	6.4	0.60
Mayon-1	A1	11.0	10.5	6.2	0.59
	AB	10.1	11.4	6.0	0.53
	B	16.1	11.7	10.4	0.89
	IIB	11.6	11.7	5.9	0.50
	IIIA1	12.0	12.8	7.1	0.55
	IVA3	13.5	12.7	11.7	0.92
	average	12.4	11.8	7.9	0.66
Mayon-2	A1	7.8	11.7	3.8	0.32
	IIAC	6.8	12.4	3.3	0.27
	IIIA3	6.0	12.9	3.3	0.26
	IIIC	6.1	20.1	4.5	0.22
	IVA3	8.0	12.9	6.0	0.47
	VA11	10.1	15.0	5.1	0.34
	VA12	10.1	14.3	7.3	0.51
	IVA3	5.1	11.1	5.5	0.50
	average	7.5	13.8	4.9	0.36
	#average	9.9	12.8	6.4	0.51
Sorsogon-2	A1	15.4	15.2	10.9	0.72
	A3	14.9	10.7	9.6	0.90
	B1	14.8	11.3	10.1	0.89
	B21	14.9	11.6	10.0	0.86
	B22	14.6	11.8	10.1	0.86
	B3	13.9	13.8	11.0	0.80
	C	18.1	14.6	10.6	0.73
	IIB	14.1	15.6	11.5	0.74
	average	15.1	13.1	10.5	0.81
Zambales-1	A_p	19.2	18.1	13.5	0.75
	IIA1	16.8	20.3	7.0	0.34
	IIA3	13.6	21.5	7.8	0.36
	IIB1	11.8	22.6	4.5	0.20
	IIC1	11.2	21.5	5.1	0.24
	IIC2	7.5	14.9	3.7	0.25
	IIC3	4.9	13.6	2.1	0.15
	average	12.1	18.9	6.2	0.33
Negros-6	A1	13.7	28.1	5.4	0.19
	IIA	12.5	23.8	4.0	0.17
	IIB	8.8	20.4	2.9	0.14
	IIIC	7.9	18.9	2.1	0.11
	IVC	10.9	30.1	2.6	0.09
	VC1	12.5	36.0	0.7	0.02
	VC2	10.9	30.0	8.5	0.28
	average	11.0	26.8	3.7	0.14

I.L.: Ignition loss.
T : Tamm's method.
M.J. : Mehra-Jackson's method.

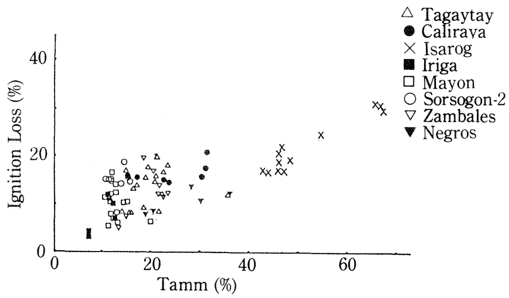

Fig. 67. Relationship between ignition loss (I.L.) and weight loss by treatment with acid oxalate (T)

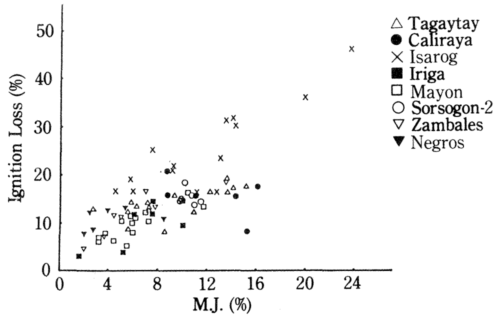

Fig. 68. Relationship between ignition loss (I.L.) and weight loss by treatment with dithionite-bicarbonate-citrate

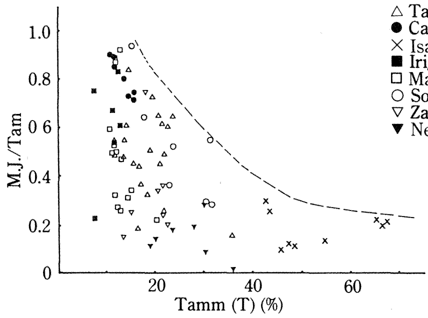

Fig. 69. Relationship between eight loss by treatment with dithionite-bicarbonate-citrate (M.J.) and weight loss by treatment with acid oxalate (T).

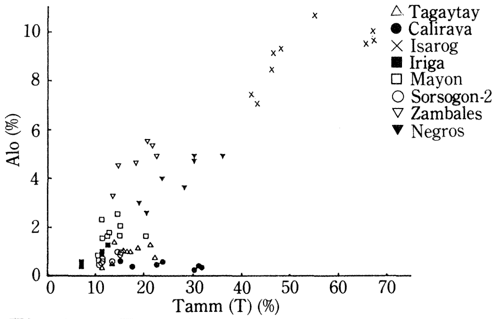

Fig. 70. Relationship between weight loss by treatment with acid oxalate (T) and aluminum contents extracted with acid oxalate (Alo)

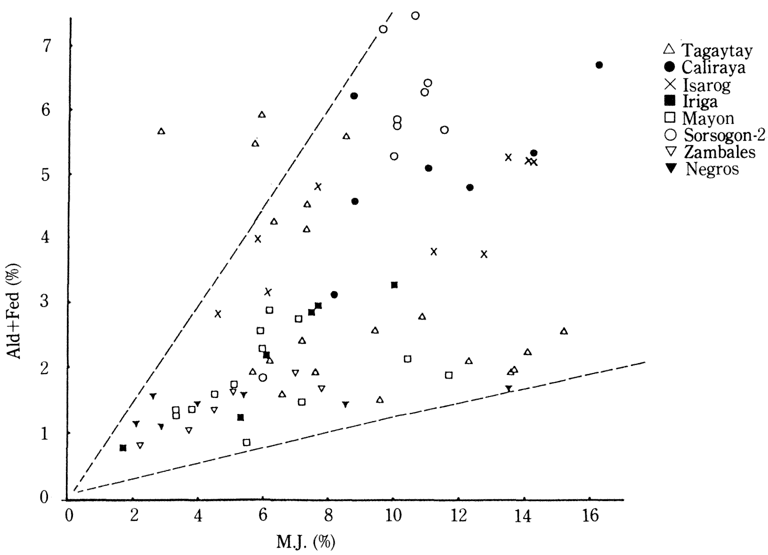

Fig. 71. Relationship between weight loss by treatment with dithionite-bicarbonate-citrate (M.J.) and aluminum and iron contents extracted with dithionite-bicarbonate-citrate (Ald+Fed).

VI. 2. 3. Chemical constituents of sand fractions

The analyses of the chemical constituents of the sand fractions was carried out to gain information on the parent materials and weathering conditions.

The element contents of the sand fractions are shown in table 46.

The average silica contents were highest in the Zambales soils (62.38%: 61.7-63.9%) and decreased in the order, Negros (56.91%: 54.31-59.4%), Mayon (54.25%: 50.04-56.56%), Tagaytay (48.99%: 40.50-56.95%), Sorsogon (42.26%: 40.66-44.34%) and Caliraya soils (31.01%: 38.19-32.33%), and Sorsogon 2 Soils (27.97%: 25.95-29.76%) than in the Tagaytay (24.43%: 19.51-29.23%), Mayon (24.01%: 21.05-26.37%), Negros (23,87%: 21.67-25.79%)

Table 46-1. Analysis of chemical constituents of sand frictions

Sample	Horizon	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	NnO %	CaO %	MgO %	K_2O %	*sum of base %	$H_2O(+)$ %	SiO_2 /Al_2O_3	SiO_2 /Fe_2O_3
Tagaytay-1	A	44.70	26.31	14.37	0.25	0.21	0.81	0.43	1.45	10.10	2.90	8.30
	IIA	51.13	25.33	11.36	0.18	1.09	2.69	0.51	4.29	5.80	2.40	12.00
	IIIA11	53.03	22.20	11.46	0.17	1.74	3.91	0.56	6.21	4.30	4.10	12.40
	IIIA12	51.88	20.99	11.79	0.16	1.77	4.07	0.50	6.34	4.00	4.20	6.60
	IVA	50.37	23.11	13.15	0.20	0.77	2.17	0.53	3.47	7.60	3.70	10.20
	IVB	53.68	21.63	11.77	0.21	0.62	2.00	0.73	3.35	5.80	4.20	12.20
	IVC1	52.44	21.64	13.17	0.20	0.22	1.51	0.49	2.22	7.60	4.10	10.60
	IVC2	42.52	25.11	15.66	0.21	0.04	0.60	0.30	0.94	13.20	2.90	7.20
	average	49.97	23.29	12.84	0.20	0.81	2.22	0.51	3.53	7.30	3.69	9.94
Tagaytay-3	A	56.72	19.51	10.11	0.16	1.71	2.42	0.69	4.82	3.00	4.90	15.00
	B	56.10	22.56	10.37	0.15	2.05	2.68	0.72	5.45	2.30	4.20	14.40
	IIC	56.95	21.56	11.17	0.18	1.23	2.21	0.77	4.21	4.40	4.50	13.60
	IIIA	53.28	22.84	9.37	0.21	0.61	1.40	1.03	3.04	7.80	4.00	15.20
	IVB1	43.03	27.80	13.37	0.24	0.14	0.75	0.51	1.40	10.20	2.60	8.60
	IVB2	44.18	28.83	13.57	0.22	0.07	0.50	0.47	1.04	12.00	2.60	8.70
	VC1	40.50	28.64	14.68	0.21	0.06	0.50	0.46	1.02	12.00	2.40	7.40
	VC2	40.50	29.07	14.83	0.20	0.04	0.36	0.42	0.82	12.60	2.40	7.30
	VC3	40.83	29.23	14.57	0.21	0.06	0.44	0.44	0.94	12.00	2.40	7.50
	average	48.01	25.56	12.45	0.20	0.66	1.25	0.61	2.53	8.48	3.33	10.86
Caliraya	A	30.02	26.89	24.33	0.19	0.07	0.38	0.24	0.69	13.10	1.90	3.30
	A3	31.82	28.38	23.50	0.19	0.01	0.31	0.15	0.47	12.20	1.90	3.60
	B1	32.33	30.20	20.78	0.12	0.03	0.16	0.11	0.30	12.80	1.80	4.20
	B21	32.13	26.95	26.65	0.11	0.04	0.20	0.15	0.39	12.30	2.00	3.20
	B22	28.19	29.52	25.10	0.13	0.01	0.24	0.29	0.54	13.30	1.60	3.00
	IIB3	30.72	31.05	23.18	0.09	0.01	0.08	0.10	0.19	13.40	1.70	3.50
	IIIC	31.88	29.26	23.84	0.08	0.01	0.14	0.13	0.28	13.10	1.90	2.90
	average	31.01	28.89	23.91	0.13	0.03	0.22	0.17	0.41	12.89	1.83	3.39
Isarog	A11	56.71	19.04	11.29	0.14	0.99	4.27	0.31	5.57	4.30	5.10	13.40
	A12	51.61	19.13	10.60	0.11	0.16	2.63	0.27	3.06	13.10	4.60	13.00
	A13	51.95	19.18	8.91	0.09	0.14	1.84	0.29	2.27	15.00	4.60	15.60
	IIA	59.47	19.85	10.85	0.13	0.59	3.56	0.30	4.45	4.70	5.10	15.00
	IIIB11	61.45	23.44	9.41	0.13	0.32	2.15	0.33	2.80	3.60	4.50	17.40
	IIIB12											
	IVB21	52.29	23.92	6.63	0.14	0.09	0.99	0.30	1.38	13.00	3.70	21.10
	IVB22	47.43	26.08	8.43	0.15	0.06	1.02	0.26	1.34	13.90	3.10	15.00
	VA	46.09	27.30	7.15	0.15	0.00	0.63	0.23	0.86	16.20	2.90	17.20
	average	53.38	22.24	9.13	0.13	0.29	2.14	0.29	2.72	10.48	4.20	15.96

* : The sum of CaO, MgO, and K_2O.

Table 46-2 Analysis of chemical constituents of sand fractions

Sample	Horizon	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	NnO %	CaO %	MgO %	K_2O %	*sum of base %	$H_2O(+)$ %	SiO_2 /Al_2O_3	SiO_2 /Fe_2O_3
Mayon-1	A1	53.67	21.05	9.77	0.16	3.47	5.16	0.38	9.01	1.40	4.30	14.70
	AB	53.89	22.49	11.52	0.17	2.50	4.11	0.33	6.94	3.30	4.10	12.50
	B	50.04	22.42	15.63	0.20	1.90	4.24	0.27	6.41	3.10	3.80	8.50
	average	52.53	21.99	12.31	0.18	2.62	4.50	0.33	7.45	2.60	4.07	11.90
Mayon-2	A1	55.26	26.06	7.57	0.13	3.47	3.67	0.63	7.77	1.00	3.60	19.50
	IIAC	56.56	25.69	7.17	0.13	3.11	3.27	0.65	7.03	1.10	3.70	21.10
	IIA3	56.08	26.37	6.78	0.13	3.48	3.06	0.65	7.19	1.00	3.60	22.10
	average	55.97	26.04	7.17	0.13	3.35	3.33	0.64	7.33	1.03	3.63	20.90
	#average	54.25	24.01									
Sorgogon-2	A1	42.38	27.69	11.62	0.33	0.04	0.57	0.30	0.91	15.30	2.60	9.70
	A3	41.57	25.95	20.82	0.35	0.08	1.64	0.28	3.00	7.20	2.70	5.30
	B1	43.05	28.85	11.42	0.18	0.02	0.44	0.21	0.67	13.30	2.50	10.10
	B21	40.66	29.76	14.00	0.18	0.01	0.48	0.20	0.69	13.10	2.30	7.80
	B22	41.55	29.24	13.23	0.16	0.02	0.41	0.18	0.61	13.00	2.40	8.40
	B3	44.34	26.35	12.88	0.17	0.02	0.43	0.20	0.54	12.70	2.80	9.20
	average	42.26	27.97	14.00	0.23	0.03	0.66	0.23	0.92	12.43	2.55	8.42
Zambales-1	A_p	62.37	23.33	5.04	0.11	1.70	2.98	0.53	5.21	2.70	4.50	33.00
	IIA1	61.71	22.53	5.58	0.11	1.90	3.74	0.48	6.12	1.80	4.70	29.50
	IIA3	63.90	21.95	5.20	0.13	2.30	3.65	0.42	6.37	2.20	4.90	32.80
	IIB1	62.37	21.68	5.75	0.15	2.42	4.13	0.40	6.95	2.60	4.90	29.00
	IIC1	61.57	22.32	7.53	0.15	2.03	3.40	0.41	5.84	1.50	4.70	21.80
	average	62.38	22.36	5.82	0.13	2.07	3.58	0.45	6.98	2.16	4.74	29.22
Negros-6	A1	58.53	22.58	5.63	0.14	2.52	3.32	0.69	6.53	3.80	4.40	27.80
	IIA	58.07	23.33	7.08	0.15	2.22	3.19	0.68	6.09	2.60	4.20	21.90
	IIB	59.54	24.29	5.34	0.13	2.42	2.96	0.71	6.09	2.60	4.20	29.80
	IIIC	54.31	21.67	13.65	0.19	2.59	4.03	0.61	7.23	1.00	4.30	10.60
	IVC	54.71	25.79	8.12	0.14	1.71	2.73	0.65	5.09	4.30	3.60	18.00
	IC1	56.31	25.57	5.20	0.13	1.72	2.59	0.68	4.99	5.30	3.70	20.90
	average	56.91	23.87	7.50	0.15	2.20	3.14	0.67	6.00	3.27	4.07	21.50

** : The sum of CaO, MgO, and K_2O. # : The average of Mayon-1 and Mayon-2.*

and Zambales soils (22.36%: 21.68–23.33%). The values of the SiO_2/Al_2O_3 ratio tended to increase with increasing silica contents (Fig. 72). The average values of the SiO_2/Al_2O_3 ratio were highest in the Zambales (4.7) and lowest in the Caliraya soils (1.8). The iron contents tended of to decrease with the decrease in the silica contents (Fig. 73). The Caliraya Soil had the highest iron contents (20.78–26.65%), while the Zambales soil showed the lowest iron contents (5.20–7.53%). Shoji (1975) suggested that pyroclastic materials could be classified the SiO_2 ba silica contents as follows;

Mafic (basaltic) materials: 45–53.3%
Intermediate (andesitic) materials: 53.5–62%
Felsic (dacitic and ryholitic) materials: 62–100%

According to Shoji's classification, the Zambales soil exhibited felsic characteristics (dacitic and ryholitic), while the Negros and Mayon soils exhibited andesitic characteristics and the Tagaytay and Isarog soils andesitic to basaltic characteristics. The Caliraya and Sorsogon soils had low silica contents (less than 45%), but high iron contents (11.42–26.65%), a low SiO_2/Fe_2O_3 ratio (2.9–10.1) and low average base contents (0.41, 0.92).

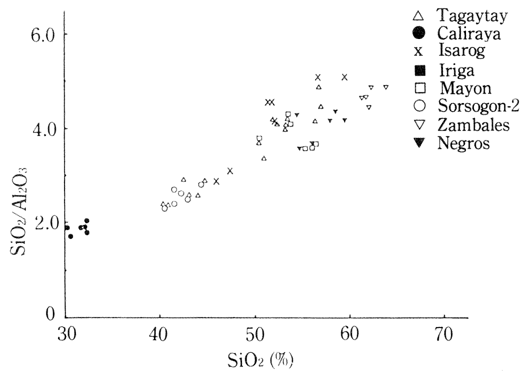

Fig. 72. Relationship between SiO_2/Al_2O_3 ratio and silica contents (SiO_2) of the sand fractions.

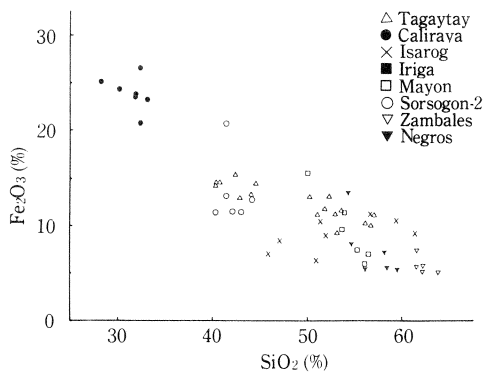

Fig. 73. Relationship between the iron (Fe_2O_3) and silica contents (SiO_2) of the sand fractions

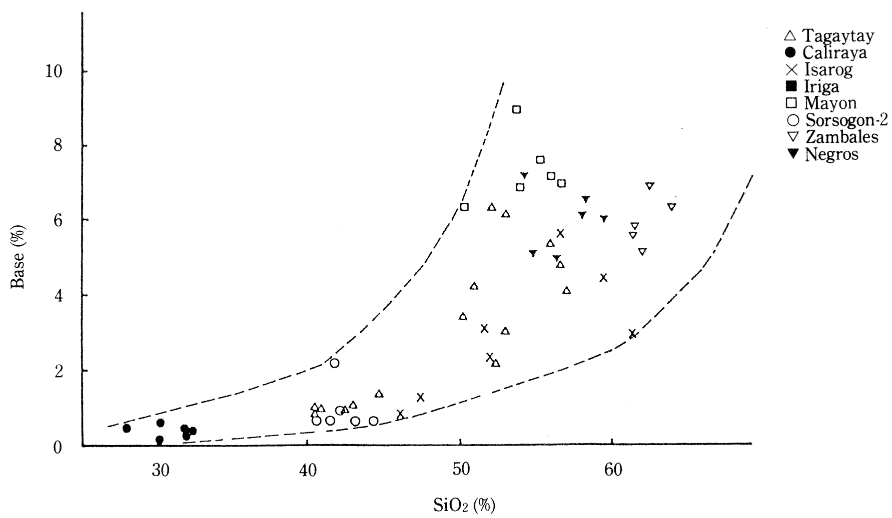

Fig. 74. Relationship between the sum of the contets of CaO, MgO, and K_2O and silica contents (SiO_2) of the sand fractions

Base contents tended to increase with the silica contents (Fig. 74) suggesting a loss of silica and base from the sand fraction by the weathering process. The sand fraction of the Caliraya soil appeared to be strongly weathered whereas the sand fractions of the other soils may also be more or less weathered in view of their high iron contents and low base contents compared with the rock constituents (1935).

In the previous Chapter, the ages of some layers of the Isarog and Tagaytay soils were determined by C^{14} dating. The IIA and IVA horizons in Tagaytay 1 were traced back to 930 yrs B.P.-1170 yrs. B.P. and the A13 and IIA horizons in Isarog to 580 yrs B.P.-610 yrs. B.P. The Tagaytay soils were slightly older than the Isarog ones, but it can be considered that the layers of the Tagaytay and Isarog soils had accumulated almost simultaneously based on the tephrochronology. As described above, the sand fractions of the Isarog and Tagaytay soils belonged to the basaltic andesitic group with similar parent materials and a similar degree of weathering.

VI. 2. 4. Weathering process of volcanic ash soils in the Philippines

The relationship between the phosphate absorption coefficient and base saturation was discussed in a previous chapter and the soil samples were classified into seven types (Fig. 23): type one (Type I) consist of soils with a base saturation less than 30% and phosphate absorption coefficient of more than 1,000, such as the Isarog and some of the Zambales and Negros soils. As they contain allophane and imogolite clay minerals they belong to the Allo-type as described above.

Second type (Type II), consists of soils with than 30% base saturation and a phosphate absorption coefficient of less than 1,000. The Caliraya, some Zambales and Negros soils belong to this type.

Tyep III consists of soils with 30 to 50% base saturation and a phosphate absorption coefficient of more than 1,000. The Sorsogon soils belong to this type.

The fourth type consists of soils with 30% to 50% base saturation and a phosphate absorption coefficient of less than 1,000. The soils belonging this type include some of the Zambales and the Caliraya Soils.

The fifth and seventh types consist of soils with a base saturation above 55% and a phosphate absorption coefficient of less than 1,200. The Iriga, young ash of Tagaytay, Mayon, and the rest of the Zambales soils belong to this type.

The sixth type soils showed a base saturation of more than 50% and a phosphorous absorption coefficient of more than 1,200. The Tagaytay soils belong to this type.

Type II to VI soils contained ranging amounts of halloysite and/or metahalloysite (kaolinite) clay minerals and their peaks tended to be sharper in the order of V < VI < IV, III < II. The degree of weathering may be determined based on this order which indicates that weathering may progress in the direction the arrowhead in Fig. 75.

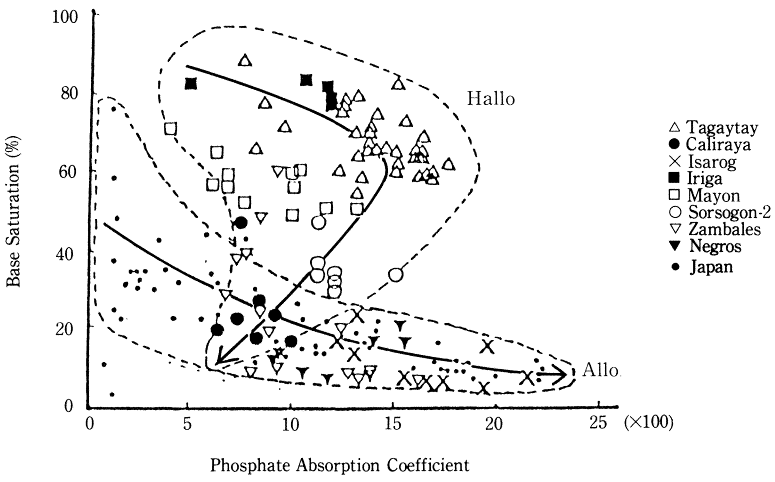

Fig. 75. Weathering direction of volcanic ash soils in the base saturation-phosphate absorption coefficient diagram

As shown in Figure 75, in the Takakuma volcanic ash soils from Mt. Sakurajima in Japan (1970, 1976) the phosphate absorption coefficient increased with the decrease of the base saturation. These soils have been deposited since 1779 years and contain allophane. Along with the progression of weathering, the phosphate absorption coefficient may increase while the base saturation decreases in the volcanic ash soils in Japan. Type I in the Philippines which overlapped with the Takakuma soil group in Japan, consisted of a halloysite type group and an allophane type group. It is assumed that the halloysite type group is influenced by tropical monsoon climate characterized by a rainy and dry season, whereas the allophane type group may be affected by the tropical rainforest climate where a dry season is lacking.

VI. 2. 5. Classification of Philippine volcanic ash soils

Any classification system that has been developed with the advance of the state of sciences involved is bound to contain certain defects or omissions. Soil Taxonomy (1975) is no exception and is continuously being modified as more of the soils of the world are known. Based on this view point, Guy D. Smith (1978) proposed a unprecedented modification of the Soil Taxonomy in 1987 by recognizing an 11th order named Andisols to which soils under the Andepts suborder would most likely belong.

Guy D. Smith recognized that the classification of Andepts presented in the Soil Taxonomy has a number of serious defects; that the soil reaction to NaF is inadequate to meet the requirement; that soil base saturation is used as a differential with a limit of 50%; that the use of thixotropic properties proves subjective in practice; that the soil moisture regime in Andepts has not been used as a differential as it has for all the other soils; that a fragmental particle size class is not provided for Andepts; and that little emphasis is placed on the unique moisture retention properties of such soil.

According to Hunter et al (1987), the central concept of this order as a soil that developed from volcanic tephra containing significant quantities of poorly-ordered complexes of Al, Si, Fe, or humus, or volcanic glass. By such recognition, it is the contention that this would allow greater recognition of the unique properties possessed by many soils that developed in volcanic tephra including low bulk density, low permanent charge, an exchange complex dominated by variable charge surfaces, high anion sorption, and high moisture retention.

To define this new order, the International Committee on the classification of Andisols (ICOMAND) was established which has issued throughout the 9 years of its existence 9 circulars. M.L. Leamy, the Chirman of ICOMAND, presented of the First International Soil Correlation Meeting (ISCOM) in 1986, the consensus about the Andisols, as follows:

> Andisols are mineral soils that have andic properties throughout all subhorizons, whether buried or not, which make up a continuous thickness of 35 cm or more or throughout a cumulative thickness of 40 cm within the top 60 cm. In both cases, the properties, commence at or within 25 cm of the mineral soil surface.

From ICOMAND Circular No. 9 (1987), the andic soil materials must meet one or more of the following four requirements:

1. a. Acid oxalate extractable aluminum plus 1/2 acid oxalate extractable iron is 2.0% or more, and
   b. Bulk density of the <2 mm fraction, measured at 1/3 bar water retention, is 0.90 g/cm3 or less, and

c. Phosphate retention is more than 85%; or
2. a. More than 60% by volume of the whole soil is volcaniclastic material coarser than 2 mm, and
   b. Acid oxalate extractable aluminum plus 1/2 acid oxalate extractable iron is 0.40% or more in the < 2 mm fraction; or
3. The 0.02-2.0 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 acid oxalate extractable aluminum plus 1/2 acid oxalate extractable iron of 0.40% or more, there is at least 30% volcanic lass in the 0.02-2.0 mm fraction, or
   b. If the <2 mm fraction has acid oxalate extractable aluminum plus 1/2 acid oxalate extractable iron of 2.0% or more, there is at least 5% volcanic glass in the 0.02-2.0 mm fraction, or
   c. If the <2 mm fraction has acid oxalate extractable aluminum plus 1/2 acid oxalate extractable iron of between 0.40% and 2.0%, there is enough volcanic glass in the 0.02-2.0 mm fraction that the percentage of glass, when plotted against the percentage of acid oxalate aluminum plus 1/2 acid oxalate iron, gives a point within the shaded area of Fig. 77.

Andisols will key out after Histosols in the Key to Soil Orders

A. Soils that .... Histosols

B. Other soil that

1. Do not have an albic horizon, or remnants of albic horizon, with an associated spodic horizon, unless it is a buried soil, and

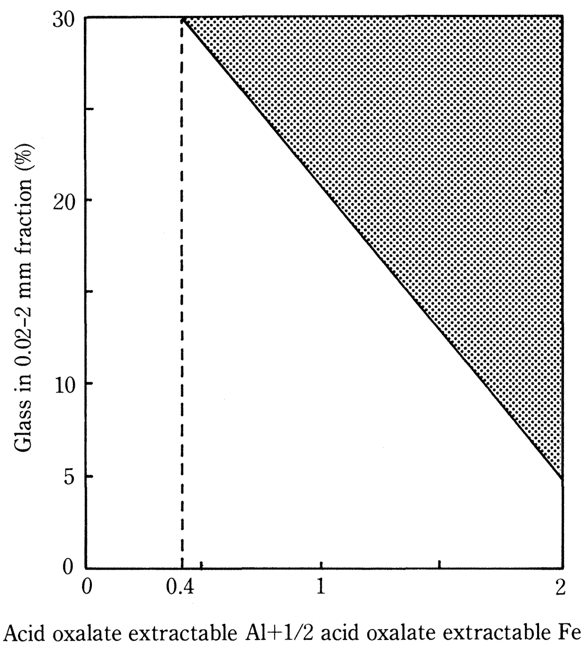

Fig. 77. Relationship between glass content (%) and acid oxalate extractable Al+1/2 acid oxalate extractable Fe (%)

2. Have andic soil properties
   a. Throughout all subhorizons, whether buried or not, which make up a thickness of 35cm or more within 60 cm of the mineral soil surface, or
   b. Throughout all subhorizons if a lithic or paralithic contact occurs within 35 cm of the mineral soil surface.

Using the criteria in the Soil Taxonomy for soils and the revisions proposed by ICOMAND, it is now possible to classify the soils of volcanic ash origin examined in the Philippine.

Tagaytay-1 fails in the bulk density criterion for Andepts as well as in the glass content requirement based on the amounts of sand. The soil however has a mollic epipedon and a cambic horizon with base saturations greater than 50% and, because the difference between mean summer and mean winter temperatures can be less than 5°C and a moisture regime likely to be udic due to a dry season of less than 3 months, the soil is considered to be a Udoll whose great group class is Hapludoll.

Glass contents in the 0.02–2.0 mm fraction and acid oxalate extractable iron contents were not determined for the upper layers of Tagaytay 1. However, if the glass contents are within the shaded area of Fig. 63, it is possible to classify this soil using the classification of ICOMAND circular letter No. 9 because acid oxalate extractable contents exceeded 0.4%. According to ICOMAND circular No. 9, Udand is keyed out because there is no aquic characteristics, no cryic, pergelic, aridic, xeric, ustic and perudic soil temperature and moisture regimes, and no horizons that have 15 bar water retention of less than 15% in air-dried samples. And then using the criteria of the great group and the subgroup Tagaytay 1 can be classified as Melanudand due to a high organic matter content of more than 6% and mollic epipedon.

Using the classification of cultivated soils in Japan (CCSJ) (1982), Tagaytay 1 pedon is classified as Humic Andosol.

Tagaytay-2 is too thin to be an Andept in addition to bulk densities greater than 1.0 g/cm^3 with low organic contents. The soil may however be placed under the suborder Ochrept and great group of Eutochrept because the base saturations exceeds 50%. As the acid oxalate extractable aluminum plus 1/2 acid oxalate extractable iron contents are less than 0.4%, this pedon can not be classified as Andisols using ICOMAND.

Using the classification of cultivated soils in Japan (CCSJ), the pedon of Tagaytay 2 may be classified as Light-colored Andosol.

If those glass fragments found by Briones (1964) in the sand fraction of soils derived from volcanic tuff hold as well for Tagaytay-3 soil, then this soil may be classified under the Andept suborder and Eutrandept great group. As acid oxalate extractable aluminum plus 1/2 acid oxalic extractable iron contents are 0.4–2.0%, if the glass contents in the 0.02–2.0 mm fraction are within the shaded area in Fig. 77, Tagaytay-3 may be placed as a Udand in the great group Hapludand and the subgroup Vitric Pachic Haplustand, because the B and IIC horizons may have vitric and pachic properties with abundant scoria and low 15 bar water content. Using Japan's classification (CCSJ), Tagaytay-3 was classified as Light-colored Andosol, Haraguchi series due to the presence of buried layers and scoria layers in the IIC horizon.

Tagaytay-4 and -5 can be disqualified Andepts due to the low organic carbon contents, inferred bulk densities that can be greater than 0.85 g/cm^3 and marginal phosphorus retention. These soils can be classified as Ochrept in the great group Eutrochrept. Using Japan's classification (CCSJ), the pedons may be classified as Light-colored Andosols.

The case of the Caliraya soil is a different matter because of the high clay content and apparent illuvial clay that morphologically exhibits argillic properties. Since the area receives more than 2250 mm of rainfall annually more or less distributed evenly (1982), the udic moisture regime may prevail. Based on othe properties, this soil is classified as a Udult in the great group Hapludult. Using CCSJ, Caliraya soil may be classified as Light-colored Andosol due to parent materials of volcanic ash derived from Mt. Banahaw.

Isarog soil has already been classified as a Hydric Dystrandept by the Benchmark Soils Project of The University of Hawaii when it conducted agrotechnology transfer studies on a network of tropical soil families. The properties presented in Table 47 merely serve to confirm this identification with the not that all the requirements of an Andept have been satisfied. Using the Andisol criteria the soil be classified in the suborder Udand in the great group Malanudand and the subgroup Hydric Melanudand. Using CCSJ, Isaog pedon can be classified as High-Humic Andosol.

The rest of the soils were subjected to the same scrutiny. The results of the entire exercise are shown in Table 47. Mayon-1 and Sorsogon as well as Tagaytay-2 and Caliraya can not be classified as Andisols because of the presence of less than 0.4% of acid oxalate extractable Al plus 1/2 iron contents.

Table 47. Classification of the 18 volcnic ash soils in the Philippines based on Soil Taxonomy, the proposed Andisols' criteria and classification of cultivated soils in Japan

Soil	Soil Taxonomy	ICOMAND	CCSJ
Tagaytay-1	Hapludoll	Pachic Hapludand	Humic Andosol
Tagaytay-2	Eutrochrept		Light Colored Andosol
Tagaytay-3	Eutrandept	Vitric or Pachic Hapludand	Light Colored Andosol
Tagaytay-4	Eutrochretp		Light Colored Andosol
Tagaytay-5	Hapludoll		Light Colored Andosol
Caliraya	Hapludult		Light Colored Andosol
Isarog	Dystrandept	Hydric Melanudand	High Humic Andosol
Iriga	Hapludoll	Pachic Hapludand	
Mayon-1	Dystrochrept	Vitric or Pachic Hapludand	Light Colored Andosol
Mayon-2	Vitrandept	Vitric or Pachic Hapludand	Light Colored Andosol
Sorgogon-2	Dystrochrept		
Zambales-1	Vitrandept	Vitric or Dystrict Haplustand	Humic Andosol
Zambales-2	Vitrandept	Vitric or Dystrict Haplustand	
Zambales-3	Vitrandept	Vitric or Dystrict Haplustand	
Negros-1	Vitrandept	Pachic Hapludand	Humic Andosol
Negros-4	Vitrandept	Typic Udivitrand	Light Colored Andosol
Negros-5	Eutrochrept		Light Colored Andosol
Negros-6	Vitrandept	Vitric or Akric Hapludand	Light Colored Andosol

It is noted that Andepts and Udoll can satisfy the new requirements to be classified as Andisols. Of the 18 profiles considered to be formed from volcanic ash, 11 of them are Andisols, the rest being either Inceptisol or Ultisol.

From the results of Fig. 76 and Table 46, it may be deduced that the volcanic ash soils in the Philippins have undergone a transition through two types as follows;

(1) Vitric Hapludand ➔ Pachic Hapludand ➔ Eutrochrept ➔ Dystrochrept ➔ Hapludult

(2) Udivitrand
Vitric Hapludand
(Vitric Haplustand)] ➔ Pachic Hapludand ➔ Hydric Melanudand

VI. 3. Summary

Clay mineralogy, the constituents of sand fractions of the volcanic ash soils in the Philippines were determined and these volcanic ash soils were classified using the Soil Taxonomy of USDA, ICOMAND 9th circular letter and the classification of cultivated soils in Japan. The weathering process of volcanic ash soils in the Philippines was also discussed.

The Caliraya, Tagaytay-2, Sorsogon and Iriga soils belong to the Ht type which is dominated by halloysite with metahalloysite or kaolinite. The Isarog, Negros-1 and -6, Zambales, and Mayon-2 soils belong to the Allo type which is dominated by allophane. The Tagaytay-1 and-3 soils belong to the Ht-Allo type which is intermediate between Ht type and Allo type.

Ht type soils such as Caliraya and Sorsogon contained a large amount of noncrystalline and crystalline Fe oxides and allophane-like aluminosilicates, exchangeable aluminum, and a small amount of Al- and Fe-humates, while the Allo type soils contained large amounts of non- and low crystalline aluminosilicates, and Al-humates. Allo type soils and some Ht type soils excluding Caliraya and Sorsogon may contain a large amount of non- and low crystalline Fe-oxides, crystalline Fe-oxides, and a relative amount of Fe-humates. It was considered that the Zambales, Tagaytay-1 and -2, and Mayon-2 soils contained large amounts of aluminosilicate with a high Si/Al ratio.

The weathering process of the volcanic ash soils in the Philippines could be analysed using the base saturation–phospahte absorption coefficient diagram with clay minerals.

Eighteen profiles were classified as Udoll (2 profiles) Ochrept (5 profiles), Andept (9 profiles) and Udult (one profile) using the Soil Taxonomy. Using ICOMAND, 10 of them were classified as Udand and Ustand. It was deduced that the volcanic as soils in the Philippines have undergone a transition through two types as follows: Vitric Hapludand ➔ Pachic Hapludand ➔ Eutrochrept ➔ Distrochrept ➔ Hapludult, and Udivitrand, Vitri Hapludand, or Vitric Haplustand ➔ Pachic Hapludand ➔ Hydric Melanudand.

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