A STUDY OF PLANT SPECIES AND SOILS IN DIFFERENT VEGETATION ZONES IN AN INDONESIAN MOIST FOREST

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ABSTRACT

The vegetation and soils of selected vegetation zones in peninsular Ujung Kulon, a tropical lowland moist forest in Indonesia, were investigated. Eight 25 x 50 m sites exhibiting distinctive forest associations and/or soils were chosen for study.

Vegetation sites were sampled for tree height, diameter at breast height (dbh), tree and sapling count and basal area. Species identification of trees on the sites was made.

Soil morphological properties were described. Samples from each site were analyzed chemically for cation exchange capacity (CEC), pH, exchangeable cations (Na, Ca, M_g, K and Mn), P, Si, N, organic C and carbonates. Physical properties investigated included bulk and particle density, particle size distribution and volumetric water content on an oven-dry basis.

Primary and clay minerals were identified from X-ray diffraction traces and total oxides analysis.

Vegetation results depict a heterogeneous forest of wide species diversity, suggesting many unique associations which form a large mosaic. Some associations appear to be perpetuated as a result of edaphic factors.

It is thought that excessive drainage on site 1, on level ground along the south coast, combined with a porous, shallow soil leads to droughtiness which, in turn, results in open forest in which few tree stems are present.

Site 2, along a minor drainage in central Ujung Kulon, is low in volume of stems and in species diversity, partially as a result of repeated stream erosion which favors the establishment of the pioneer

bamboo Schizostachyum blumei over other forest species.

Sites 3 and 5 are examples of lowland, moderately sloping, well drained, fully stocked forest stands that do not show evidence of either excessive droughtiness of soils or of waterlogging. The sites are somewhat comparable in regard to frequency of trees and saplings, and average dbh; but differ in basal area and average height. Site 3 trees have, on the average, $7m^2/ha$ greater total basal area and 6 m greater height than site 5 trees. These sites are floristically different except for the common occurrence of Arenga obtisifolia, the most common tree found in lowland niches not affected by brackish water. Arenga is absent above approximately 50 m elevation.

Sites 4 and 8 are influenced by a seasonal water table which restricts species composition to plants able to withstand prolonged waterlogging. The species differences between these sites may also be affected by soil pH. Site 8 is typical of the Corypha utan - Ardisia humilis association which is the largest in Ujung Kulon.

Sites 6 and 7 are found in steep, mountainous terrain. They exhibit the greatest frequency of stems and total basal area.

Establishment and eventual perpetuation of Arenga dominance may have been faciliated by the partial destruction of the overstory by tidal wave action following the eruptions of the volcano Krakatau in 1883.

Soil chemical and physical properties of the 1883 tuff attest to a nutrient-poor material with low ion exchange capacity and soil structure properties that probably impeded normal water infiltration and root proliferation for some decades following deposition.

Numerous chemical nutrient determinations of the soils,

supplemented by leaf tissue analysis, failed to establish definite relationships between nutrient status and apparent site productivity.

Newly mineralized soil horizons overlying the tuff show evidence of a rapid rate of soil development. The overlying horizons closely resemble the residual subsoils in most chemical and physical properties; conversely, they only weakly resemble the tuff layer.

Primary minerals are dominated by quartz in most cases; cristobalite, calcite, pyrophosphate, feldspars and silicates are also found. Clay minerals are smectite and kaolins.

A reconsideration of the theoretical range of the Krakatau ejecta is explained in an appendix.

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INTRODUCTION

Ujung Kulon Nature Reserve at the extreme western tip of Java was chosen as the site of this study as an example of one of the few remaining and relatively undisturbed tropical lowland forests on populous Java. The name Ujung Kulon means "West Point" or "Western Tip" in the Indonesian language, but the entire nature reserve of the same name encompasses some 41,120 hectares of land including several islands (see Figure 1). For the purpose of this study the name Ujung Kulon refers only to the peninsular part of Java between 6^{o} 38' and 6^{o} 52' South Latitude and 105^{o} 12' and 105^{o} 30' East Longitude. Pulau Peucang, a small island 0.5 km north of Ujung Kulon served as the field headquarters.

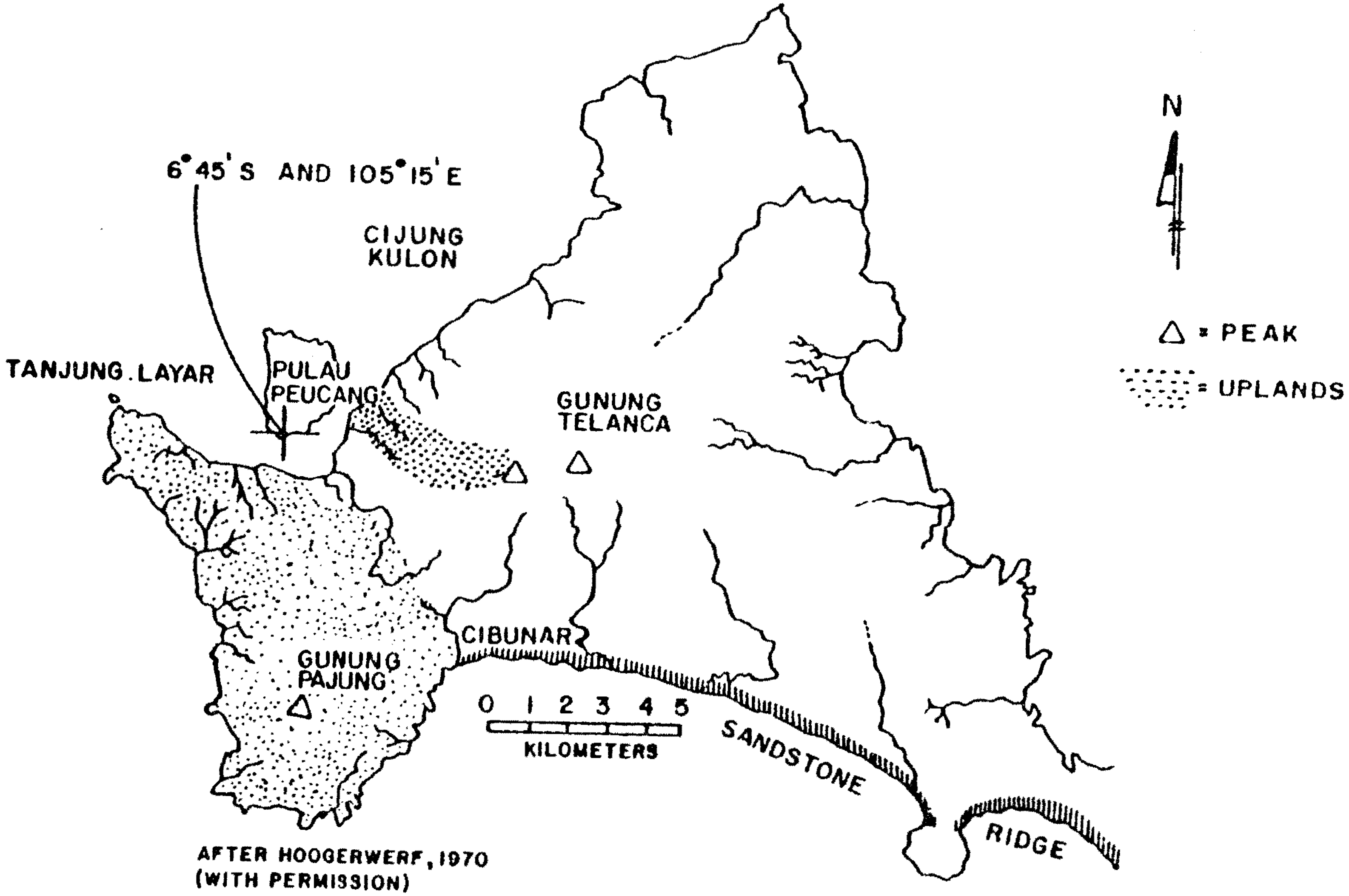
Names and spellings of locations show considerable variation between archaic and modern Dutch and Indonesian languages. As late as 1973, Bahasa Indonesia, the national language of Indonesia, was undergoing major spelling changes. Hence, most of the literature references are at variance with the current usage found herein.

As the first basic research venture of its kind in Ujung Kulon, an essentially virgin forest, the study was broad in scope but rather narrow in interpretation. A few working objectives, however, preceded the commencement of the investigations. The objectives were:

1. To describe the vegetation in selected plots which represent different vegetation zones in Ujung Kulon.
2. To characterize the soils in the selected plots.
3. To investigate the inter-relationships which may exist between the vegetation and soil parameters within the study areas.

FIGURE 1

PENINSULAR PORTION OF UJUNG KULON



AFTER HOOGERWERF, 1970
(WITH PERMISSION)

Perhaps Hilgard (1912) stated the overall objectives of the basic research approach best when he wrote, "Since the native vegetation normally represents the result of secular or even millenial adaptation of plants to climatic and soil-conditions, this use of the native flora seems eminently rational. Moreover, it is obvious that if we were able to interpret correctly the meaning of such vegetation with respect not only to cultural conditions and crops, but also as regards the exact physical and chemical nature of the soil, so as to recognize the causes of the observed vegetative preferences; we should be enabled to project that recognition into those cases where native vegetation is not present to serve as a guide; and we might thus render the physical and chemical examination of soils as useful practically, everywhere, as is, locally, the observation of the native growths."

LITERATURE REVIEW

The entire western tip of Java, except for a brief period of Japanese occupation during World War II, has remained in a wild state since 1883.

At that time the eruption of the volcano Gunung Krakatau and two subsequently generated tidal waves destroyed several small villages along the coast of Ujung Kulon in West Java (Hoogerwerf, 1970). In 1923 the area was set aside as a nature reserve (Satmoko, 1961). Today Ujung Kulon is best known as a last stronghold of the one-horned Javan rhinoceros, *Rhinoceros sondaicus sondaicus*.

Physiography

Pennisular Ujung Kulon covers approximately 26,600 hectares (ha) which can be divided into three broad physiographic regions: The steep uplands of the western third of the peninsula located west of the streams Cibunar and Cijung Kulon; a lower, dissected marl plateau in the middle of the Reserve; and a vast lowland in the northern and eastern sectors (Figure 1).

The western uplands are formed by an obtuse conical trachyte dome (Indonesian Forest Service, 1957) with ridges which finger out along from the summit of the Gunung Pajung (Gunung, meaning "mountain", is abbreviated as G.) range. It is commonly thought that the 480 m summit of G. Pajung is the highest peak in Ujung Kulon (Hoogerwerf, 1970), however, the summit of G. Guhabendang, at 500 m is the highest point in the Reserve. Nevertheless, G. Pajung is a well-known landmark inasmuch as the massif carries its name, because of the existence of a triangulation point marker on its summit, and because of a narrow but permanent trail connecting the summit with Tanjung Sangjangsirah on the west and Cibunar on the east.

Terrain of the G. Pajung massif is characterized by many short but steep ridges formed from mixed volcanic and sedimentary rocks. Intermountain valleys are numerous but have rather shallow and infrequent streambeds owing to rapid infiltration of rain water into highly permeable soil. Major streams are few in the G. Pajung area, numbering 10-12. None are very wide or deep, even as they empty into the sea after following a dendritic course.

A roughly plateau-like region in the middle of the Reserve is generally known as the G. Telanca area, which has a less abrupt topography. It consists of low escarpments of 80-100 m elevation, with a maximum elevation of 140 m. The escarpments slope outward in all directions to form broad fans. Rapid decomposition of the erodable marl parent material, the backbone of the Telanca formation, is chiefly responsible for the development of narrow and deep stream beds between escarpments. Vesicular marl outcroppings are common in the Telanca area. Rock outcroppings are otherwise uncommon throughout Ujung Kulon except along ridge lines.

Streambeds may be dry throughout the rainy season as a result of excessive internal drainage, except during and after torrents. One permanent and deep stream near the northern periphery of the Telanca area has a visible length of only 400 m, although the watershed feeding it is comparatively extensive. As reported by Schenkel and Schenkel-Hulliger (1969) streams which originate in the G. Telanca area deposit lime sinter in their streambeds while still in their upper reaches, however, the streams of the G. Pajung massif do not deposit lime. On the other hand, they reported that fossilized wood can be found in the streambeds west of Cibunar and Cijungkulon, whereas fossilized wood had not been reported in eastern rivers of Ujung Kulon. The present author found many pieces of fossilized wood in the Cidaun streambed, midway between the Telanca and G. Pajung formations.

About half of Ujung Kulon is low-lying land rising to less than 50 m in elevation and is located north and east of G. Telanca. Here, slow moving rivers are broad and moderately deep. Some are navigable by small boat for several kilometers inland. During the rainy season the ground is often inundated with brackish or tidal swamp water of a meter or more in depth.

Marine sands, shells and coral are the chief geologic parent materials in the northeast, but there are also extensive pockets of coarse pumice which has a pronounced effect on soil morphology. Large rounded pumice remnants are common even on the south coast of the isthmus which connects Ujung Kulon with West Java. These pumice stones were apparently deposited in 1883 and after as tidal waves washed over the isthmian lowland.

Along the south coast, a prominent sandstone ridge arises where the G. Pajung eastern drainage and the G. Telanca western drainage spill into the Indian Ocean at Cibunar. The ridge follows the coast south-easterly for several kilometers, however, the width of the mostly level ridge never exceeds one-half km, and the ridge is usually not recognized as a major physiographic feature. Schenkel and Schenkel-Hulliger (1969) did, however, recognize the formation and its characteristic vegetation.

Climate

Ujung Kulon has a seasonal perhumid climate with a humidity index of over 100, and a mean annual temperature of 26^{o} C, according to work by Schmidt and Ferguson (Soerianegara, 1972). Rainfall information varies somewhat according to source (Table 1). As early as 1876 meteorological records were kept for Tanjung Layar. It is assumed that all rainfall data come from Tanjung Layar records, there being no other meteorological stations in the vicinity. No data for the area, however, have been published since 1944. Hoogerwerf (1970) gave monthly rainfall averages covering a period of some 40 years. He reported a yearly average of 3249 mm. Soerianegara (1972) gave a 3137 mm yearly average. Boerema (1925) published rainfall maps of the Ujung Kulon peninsula using rainfall ranges of certain months to show the transition of rainfall from west to east as a result of monsoonal effects. Yearly range of 2600-3550 mm west of G. Pajung and 2800-3800 mm east of G. Pajung in Boerema's publication was based on the period 1879-1922.

Hoogerwerf's (1970) averages of rainfall and Boerema's (1925) ranges were in agreement in all months except April, May and September -- the months singled out by Boerema for illustration. In those months, Boerema's maps showed 50-100 mm greater rainfall east of G. Pajung than west of the mountain, leading to a higher total yearly rainfall range east of G. Pajung. On the other hand, Hoogerwerf claimed just the opposite, "...the author's (Hoogerwerf's) long experience indicates that in the mountain range in question considerably more rain falls than in the more eastern parts of the

Table 1. Monthly average rainfall or rainfall range data for Ujung Kulon, from various sources.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Source
Rain (mm)	450	342	301	257	163	214	150	184	122	206	330	446	3185	a
	443	377	325	258	171	178	130	138	141	263	351	474	3249	b
	444	376	344	250	170	161	116	114	110	232	358	462	3137	c
West of G. Pajung	330-400	300-400	300-400	200-300	150-200	150-200	100-150	100-150	100-150	200-300	300-400	400-500	2600-3550	d
East of G. Pajung	300-400	300-400	300-400	300-400	200-300	150-200	100-150	100-150	150-200	200-300	300-400	400-500	2800-3800	d
No. of days with rain	20	18	17	14	10	9	10	7	8	11	15	21	160	a

Source: a - Batavia magnetisch en meteorologisch observatorium (annual reports) 1896-1909 (based on 14 years).

b - Hoogerwerf, A., 1970 (based on about 40 years).

c - Soerianegara, I., 1972. (after Berlage, 1949 and Schmidt and Ferguson, 1951, basis unknown).

d - Boerema, J., 1925 (based on 44 years).

peninsula." Differences, however, are not large enough to be significant from an overall climatic viewpoint.

Hodder (1968) used the Lauer classification system of humid tropical climates which was based on an earlier index of aridity by DeMartonne. According to the DeMartonne index,

$$20 \rightleftarrows \frac{12p}{t + 10} \qquad (1)$$

where p = average montly precipitation in mm

t = average monthly temperature in °C

All of Ujung Kulon would be classified as humid equatorial using the rainfall data from various sources and the approximate monthly temperature of 26° C. Walter, _et al_. (1975) designated the western tip of Java as an example of an equatorial climate (type I) with monthly rainfall exceeding 100 mm. An indication of seasonal variation in monthly rainfall based on the number of days with rain and monthly rainfall is shown in Table 1, computed from annual meteorological records of a 14-year period (Batavia Magnetisch en Meteorologisch Observatorium 1896-1909). A further temperature refinement may be calculated for various places in Ujung Kulon using the formula of Braak, cited by Hong and Schuylenborgh (1959) for estimating temperature when elevation is known. The formula:

$$t = 26.3 - h(0.6\ ^{\circ}\mathrm{C}) \qquad (2)$$

where, t = temperature, °C

h = elevation in hectometers (100 m)

would reflect temperatures of about 23.5 °C for G. Pajung compared to 26.1 °C in the sealevel areas.

Vegetation Disturbance History

The earliest recorded intrusions by man into Ujung Kulon were made in 1807. Attempts were made to establish a naval port opposite Pulau Peucang (abbreviated to P. Peucang) to take advantage of its strategic location (Hoogerwerf, 1970) at the tip of Java. Fortifications were built there but because many workmen succumbed to "noxious vapours" from the newly worked ground they fled in large numbers. Nothing came of the port construction.

In 1853, another expedition initiated by the Organization for Scientific Research in the Netherlands Indies landed off the village of Djungkulan (sic), at the time 'the only inhabited place in Java's western corner', according to Veth as cited by Hoogerwerf (1970). The purpose of the expedition was to investigate the possibility of developing the coal seams found there. In the expedition's report of 1854, it was also noted that 'palms and Indiarubber (sic) trees thrive in their thousands....there is a wealth of timber for ships and shore....' Although the coal seams were never exploited, large quantities of Indiarubber taken from _Ficus_ _elastica_ and other trees were exported from Djungkulan.

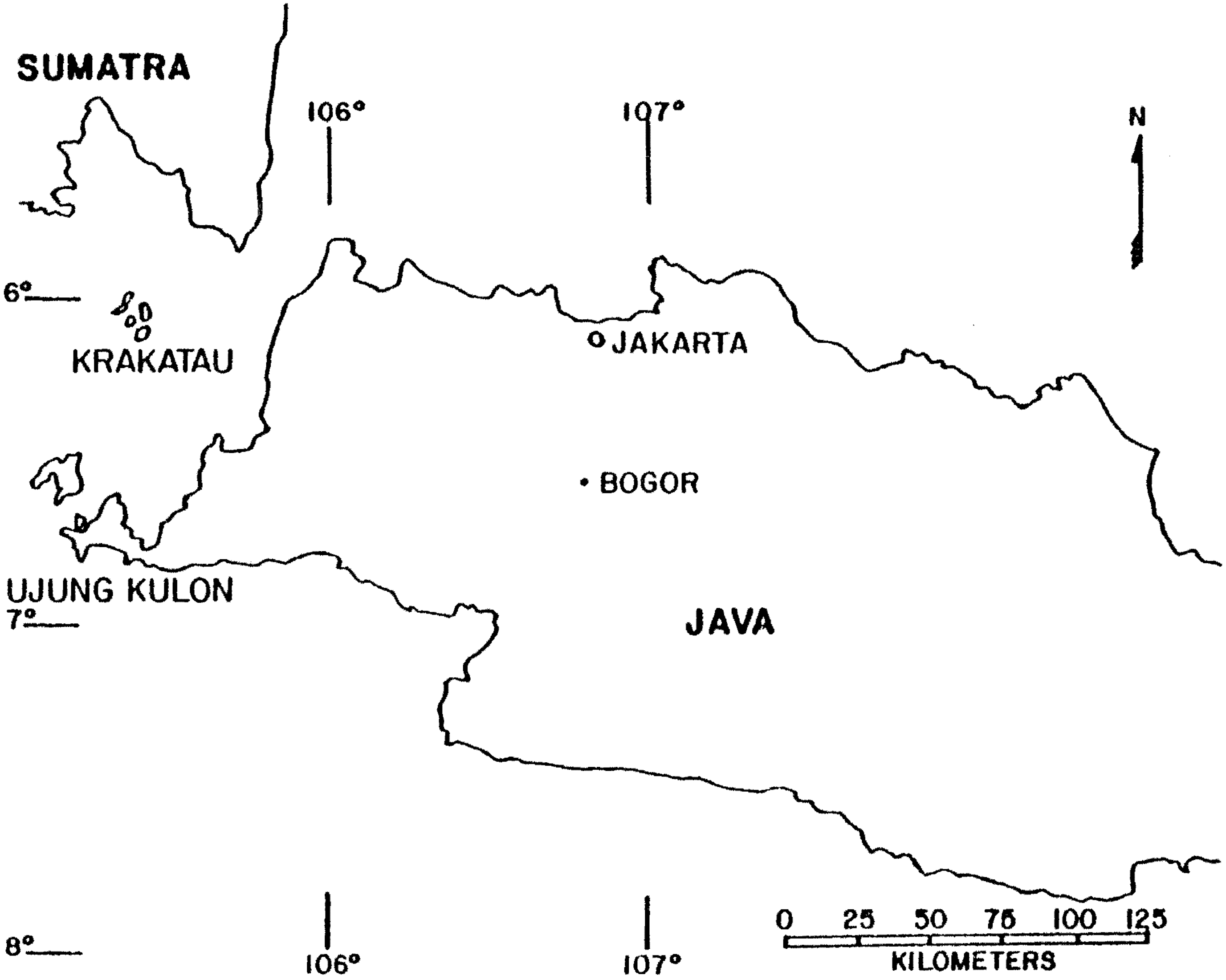
According to Hoogerwerf (1970) the extended village of Djungkulan apparently comprised no more than 40 huts and its inhabitants were probably dependent upon both fishing and subsistance agriculture. It may be presumed that foraging in the forest for fruit, nuts, berries and pot herbs was also practiced. Two smaller villages named Cikuya and Rumah Tiga sprang up later on P. Peucang, but were destroyed along with Djungkulan in the tidal waves following the eruption of G. Krakatau in 1883. Survivors escaped by fleeing to the high ground at Tandjung Layar (Hoogerwerf, 1970) where a lighthouse was maintained at Java's First Point. Man's activities, then, have had some influence on species distribution, particularly in the more accessible areas.

Although the Krakatau eruption and related occurrences have had the most profound consequences in regard to vegetational disturbances in Ujung Kulon and elsewhere, most discussions on the matter are largely speculative. Accordingly, the issue of post-Krakatau changes is left for the DISCUSSION section of this study. It would be helpful at this stage to describe the Krakatau phenomena in an isolated context, as a means by which one may better assess the results and observations which were outgrowths of this study.

Krakatau and its Aftermath

The several small islands which comprise the Krakatau Group are located in the Sunda Strait midway between South Sumatra and West Java, and NNE of Ujung Kulon at a distance of 56-84 km (Figure 2). The cataclysmic events by which Krakatau attained world prominence, and which are important considerations in this study, date from August 26-28, 1883. At that time, heightened volcanic activity on the island of Krakatau which had commenced earlier that year climaxed in a series of severe eruptions, including submarine eruptions. They produced the loudest sound ever heard by human ears (Furlong and Furlong, 1974), spewed forth an estimated 13 cubic miles (54 cu. km) of material (Wexler, 1951) and killed about 36,000 people (Furneaux, 1964) shortly thereafter as a result of two tidal waves which

FIGURE 2
KRAKATAU AND ENVIRONS



were generated.

Volcanic activity in the Krakatau Group was known prior to and after the 1883 paroxysm. Stehn (1929) outlined four phases of activity beginning with a coalescence of two andesitic volcanos, Danan and Perboewatan, with the basaltic cone of Rakata to form the island of Krakatau during Pleistocene time.

Note: A considerable portion of West Java is covered by dacitic tuff expelled by the now disappeared Danau volcano of Pleistocene age (Schuylenborgh, 1956). The original location of the Danau was probably in Bantam Province, West Java near the present-day city of Pandeglang. It was alluded to by Mohr (1930) who discussed a lake named Danau di Bawah as being formed from a sunken crater. The Danau, source of the Bantam tuffs, should not be confused with the Danan volcano, one of three active craters which disappeared in August 1883.

Andesitic flows, via a fissure, also penetrated Rakata. In May 1680, ending 203 years of quietude, fresh andesite flowed from Krakatau (Krüger, 1971). It was the only other known eruption in historic times (Stehn, 1929). A more recent period of volcanism began early in 1928 with the emergence of Anak Krakatau (the child of Krakatau) from a seamount astride Rakata. Though both Danan and Perboewatan disappeared in their entirety in 1883, half of Rakata remained. The island is, therefore, sometimes referred to as Rakata rather than Krakatau.

Steam, gases and ash which are currently being emitted from Anak Krakatau are localized within the vicinity of the crater, in the same manner by which Stehn (1929) wrote of the products of the period May to August 1883 remaining localized. Only the August 26-28 ejecta, then, is considered as a source of soil parent material as will be discussed in this study. To what extent the Krakatau phenomena affected the vegetation of Ujung Kulon, and the ejected material served as a source of soil parent material is a key issue.

The products of the Krakatau eruptions consisted of a broad range of materials. Near the eruption point obsidian and dark glassy rock formed the principal components, according to Stehn (1929). Other strata showed a slow change from rough bombs to fine ashes. Most investigators agree that sorting of materials by weight took place in the air. Lighter colored materials which were also of lower density, were usually found in upper strata. However, deposits of pumice and ash of 100 m thickness were found in the vicinity of the eruption point. One sample of ash described by Mohr (1944) showed the following fractions:

Pumice	69.8%
Heavy glass particles	21.1
Feldspars	6.0
Magnetite	0.9
Pyroxene	2.2
	100.0%

Other samples showed different ratios of minerals. Verbeek (1885) who published a massive monograph on the Krakatau phenomena, cautioned that place of sample collection and time in the eruption sequence (beginning, middle, end, etc.) were important considerations affecting mineral ratio.

The terminology of volcanic material deserves some attention. Material, by grain size, representing more than 50% of the total volume normally determines the classification (Wedepohl, 1969). Composition of the parent lava of the ejecta is included as an adjective in the combined name. Tuffs, which are compacted ash deposits (Macdonald, 1972) or other pyroclastic material of small grain size (Wedepohl, 1969) are the indurated equivalents of volcanic ash and dust deposits. A grain size classification by Wentworth and Williams (1932), however, described as fine ash and dust all pyroclastics <0.25 mm; coarse ash >0.25 mm to <4 mm; and lapilli anything >4 mm and up to 260 mm. The term "pumice" apparently is not favored among contemporary geochemists, since no mention of pumice can be found in a number of texts on the general subject of pyroclastics. Earlier literature, however, makes frequent reference to the term "pumice" to mean stone-sized volcanic glass of light weight and color which contains numerous cavities resulting from expulsion of water vapor at high temperature during eruption.

All Krakatau ejecta, irrespective of size, covered an area of 827,000 sq. km (Stehn, 1929). Little information is available on distribution range according to particle size or weight. Furneaux (1964) summarized some of Verbeek's (1885) observations in a popular account of the Krakatau story. He reported that according to Verbeek, some 4.3 cu. miles (17.91 cu. km) of material had been ejected. Wexler (1951) and others thought it was a gross underestimate. Of Verbeek's estimate, he assigned: 2.86 cu. miles (11.91 cu. km) of material falling within a radius of 9.3 miles (15 km), partly on the islands of the Krakatau Group where pumice lay in banks 100 ft (30.5 m) thick; pumice layers of 3-5 ft. (.9-1.5 m) thickness at 12 miles (19.2 km) distance; 1 foot (.30 m) at 13-24 miles (21-39 km); and 2-8 inches (5.1 - 20.3 cm) at 31 miles (50 km). Unfortunately, the word "pumice" was the only one used to describe the ejecta in the Furneaux account. The map (Figure 3) of the Krakatau ejecta included all particulate matter, irrespective of size or weight, as transcribed by Furneaux.

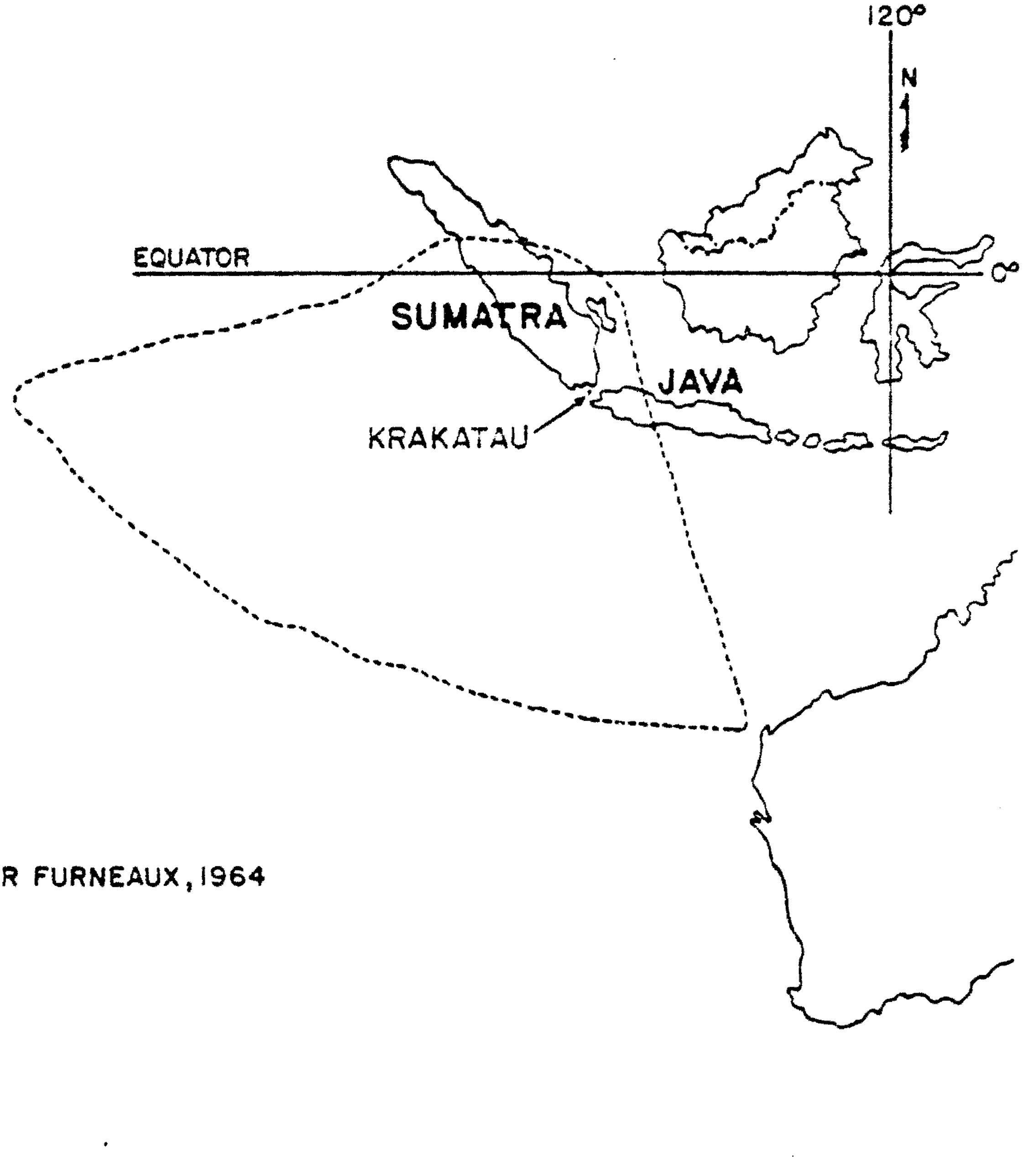
The effects of prevailing winds caused the ejecta downfall pattern to be elliptical rather than circular. If most heavy particles were returned to earth near the craters, could one expect to find any material other than ash or dust in Ujung Kulon - at least 56 km away? If so, how much? And most importantly, to what extent did it affect the existing vegetation or alter the soil environment, causing concurrent and/or future manifestations? Several documented accounts about Krakatau debris suggest that the composition of ejecta reaching Ujung Kulon was not solely limited to wind borne ash and dust.

The violently explosive Vulcanian or Pelean-type eruption of Krakatau (Thornbury, 1954) may have showered bombs, lapilli and pumice stones in all directions. Except for that deposited on the islands of the Krakatau Group, most disappeared into the sea, so that an eruptive pattern could not be reconstructed with accuracy. Only 5% of the ejected material has been accounted for in the enlargement and reshaping of Verlaten and Lang islands (Figure 4).

Several reports placed ejecta at great distances. A brief account by Verbeek (1884) told of pumice and ashes of up to 0.3 m thickness at a radius of 22.5 - 40 km; 0.2 m thickness at 40 - 50 km; and down to 2, 1, and half a centimeter at still greater distances.

FIGURE 3

. AREA BLANKETED BY ASH AND OTHER EJECTA

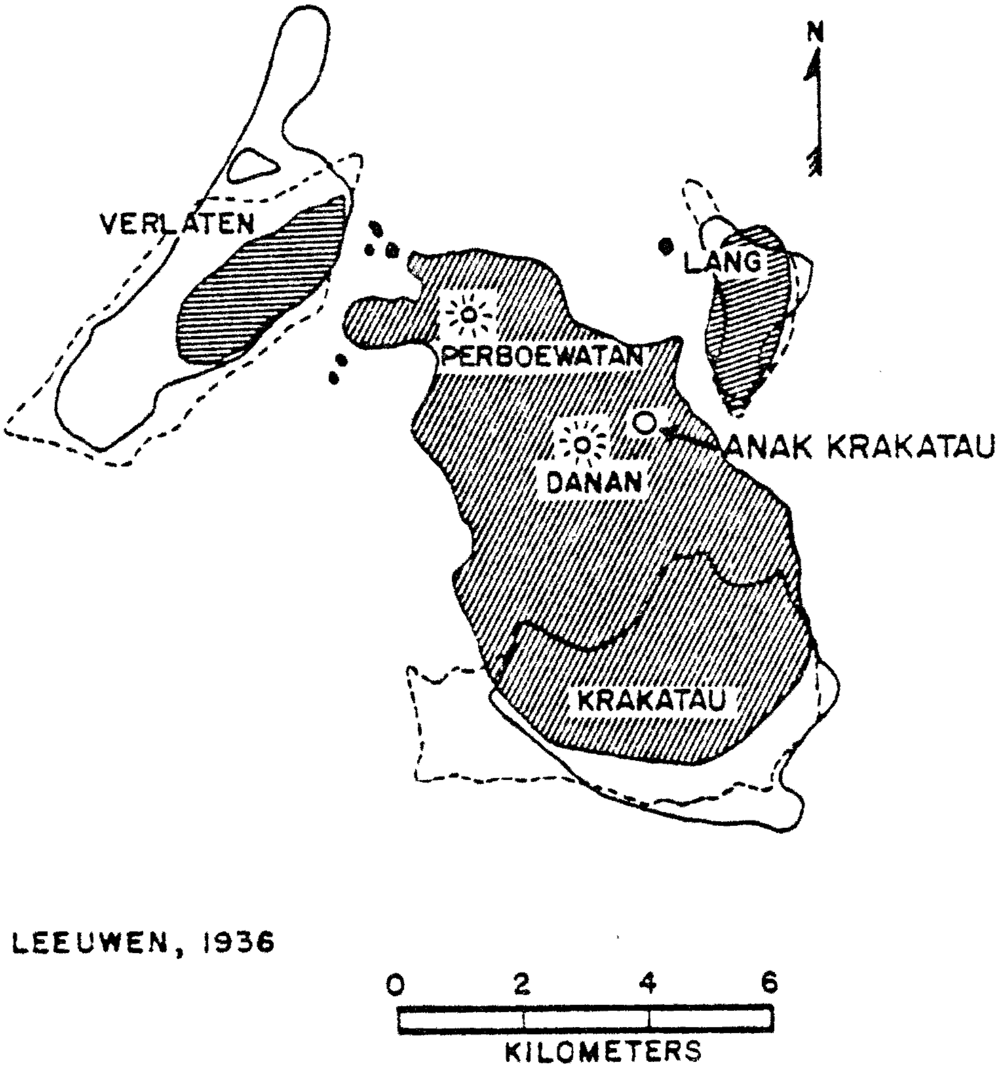


AFTER FURNEAUX, 1964

FIGURE 4

COASTLINE CONFIGURATION OF THE KRAKATAU GROUP

HATCHED AREA - PRIOR TO 1883
DASHED LINE - SHORTLY AFTER 1883 ERUPTIONS
SOLID LINE - PRESENT DAY



AFTER LEEUWEN, 1936

He noted, however, that pumice stones the size of a fist were thrown at a distance of 40 km. Several ships in the Sunda Strait also logged reports of falling ash and hot pumice; among them the *Bay of Naples*, 100 miles (161 km) to the west of Krakatau. Leeuwen (1936) reported that large blocks of pumice burned holes in clothes and sails on the ship *Berbice* at a distance of 70 - 80 km from Krakatau. Those ships' logs showed moderate to strong winds from SSW to WSW, although Verbeek (1885) noted that prevailing winds in the area were SE and NE during that time of year.

Pumice stones also fell in other directions. A telegram from Batavia (Jakarta) told of stones which fell in Serang (Anon., 1883), a town 78 km E of Krakatau. Verbeek (1885) wrote of blocks the size of a human head which apparently fell in Ujung Kulon. As for tuff and ash, Verbeek also tabulated data for several locations in West Java and South Sumatra, with corresponding thickness of occurrence. He himself measured a thickness of 10 mm at Java's First Point in Ujung Kulon.

Scientific Research in Ujung Kulon

Due to its remoteness from the populated areas of Java, few people have had occasion to traverse the peninsula. Bantam Province in general has a low population density compared to the rest of Java. With rough terrain and seasonal flooding in the lowlands, Ujung Kulon had little to offer except its strategic location and its plethora of wildlife.

Besides the one-horned Javan rhinoceros, *Rhinoceros sondaicus sondaicus* as the chief attraction, Ujung Kulon has numerous other animal species. Some of the more interesting include the banteng, *Bos javanicus javanicus*; leopard, *Panthera pardus melas*; crocodile, *Crocodylus porosus*; reticulated python, *Python reticulatus* and three species of deer: the Javan deer, *Rusa timorensis russa*; the barking deer, *Muntiacus muntjak muntjak*; and the mouse deer, *Tragulus javanicus javanicus*. In former times the Javan tiger, *Panthera tigris sondaica* was found extensively throughout Ujung Kulon, but its presence there now is in dispute. Grazing animals, therefore, have an influence on some sections of Ujung Kulon.

Entry into the area has been restricted since 1921 when a 300 sq. km nature reserve was promulgated (Satmoko, 1961). Consequently, most scientific interest has been on the part of zoologists, ornithologists and others interested in the wildlife. Some, notably Hoogerwerf (1970), Schenkel and Schenkel-Hulliger (1969) and Satmoko (1961) have also described some aspects of vegetation and physiography. Wirawan (unpublished) and Dransfield (unpublished) have also conducted botanical expeditions in Ujung Kulon; but "An inventory of the plant species and communities of Ujung Kulon does not yet exist, nor has a study of its plant ecology been made so far", according to Schenkel and Schenkel-Hulliger (1969). No published quantitative studies of the vegetation of the peninsula have ever been made.

Some quantitative and considerable descriptive information on the vegetation of nearby P. Peucang by Hoek and Kostermans (1950), Kartawinata (1965) and SEAMEO: BIOTROP (1972) is available. Due, however, to the destruction of vast forest areas on P. Peucang during the tidal waves of 1883, the forest associations of P. Peucang and Ujung Kulon are not comparable.

No known soil studies have been undertaken in Ujung Kulon. A general soils map of the peninsula has been published, but without accompanying data, by the Soils Research Institute of Indonesia (Lembaga Penelitian Tanah, 1966). Soerianegara (1972) undertook a study of four soil profiles on nearby P. Peucang. He also studied soils (1970) of the Mount Honje Forest Reserve, 10-20 km to the east of and adjacent to Ujung Kulon. Schuylenborgh (1957) investigated soil genesis processes in several locations in West Java and South Sumatra over a period of years, but none very close to Ujung Kulon.

The Issue of Vegetation Classification

Based on temperature, rainfall and overall physiognomy Ujung Kulon would likely be classified as tropical rain forest by most naturalists. The SEAMEO: BIOTROP study (1972) did just that in regard to the forest on P. Peucang. Beard (1942, 1949) and Wadsworth and Bonnet (1951) described forests in Puerto Rico having only 2030-3203 mm yearly rainfall as montane rain forest. Cain *et al*. (1956) and, in part, the classical text *The Tropical Rain Forest* by Richards (1952) dealt with Brazilian forest, much of which was about 2500 mm annual rainfall. Even the monsoonal forests of Thailand were discussed by Kira (1969) as tropical rain forest. Perhaps the assessment of the nature of rain forest which was most uncritical was given by McPherson and Johnston, writing in Southworth and Johnston (1967). They implied that rain forest could exist in areas with as little as 75 inches (1905 mm) annual rainfall so long as the evergreen nature of the forest prevailed.

In the Life Zone System of Holdridge (1967), Ujung Kulon would properly be called a Tropical Lowland Moist Forest. The Holdridge system makes use of temperature, rainfall and potential evapotranspiration as major parameters for classification of vegetation within latitudinal regions and altitudinal belts, which also modify the classification nomenclautre. To be called a tropical (lowland) rain forest, an area in a tropical latitude and in a basal altitudinal belt (below 500 m) must have at least 8000 mm of annual rainfall, according to the Holdridge system.

The acceptance of the Holdridge classification is justified in this study primarily because West Java has areas of much higher rainfall than does Ujung Kulon and consequently, much greater species complexity that is inherent in the system. Holdridge (1967) found that species complexity varied proportionally with the rainfall within the tropical zone of the Americas. Soil conditions, however, also affect species diversity and height growth. Tschirley *et al*. (1970) noted that an increase in soil moisture retention beyond the point of adequate aeration decreased species diversity. A"physiological drought" in Talparo clay caused by premature swelling shut of surface soils during early monsoon rains in Trinidad (Chenery and Hardy, 1945) was confirmed by Pellek (1971) who measured highly significant differences in tree height of similar aged *Tectona grandis* on Talparo clay and adjacent soils with more moisture. Beard (1942, 1949) and Wadsworth and Bonnet (1951) also found physiological drought under wet conditions at high elevations due to impeded drainage. Excessive aeration also leads to droughty soils; examples of low moisture retention in sandy soils are commonplace.

MATERIALS AND METHODS

This study was divided into two main phases:

I. Field Observations and Data Collection

A ground reconnaisance of salient vegetation associations and soil groups was made to complement or replace preselected sites from a map transect. The work included vegetation data collection, soil profile descriptions, and soil and plant material collection.

II. Laboratory Determinations

Chemical, physical and mineralogical properties of the soil from each horizon were determined. Replication of all determinations was carried through for several samples which were chosen at random. Chemical analysis of plant material was performed on leaves of the most common species found in the study sites.

PHASE I. Field Observations and Data Collection

1. Determination of Sampling Sites

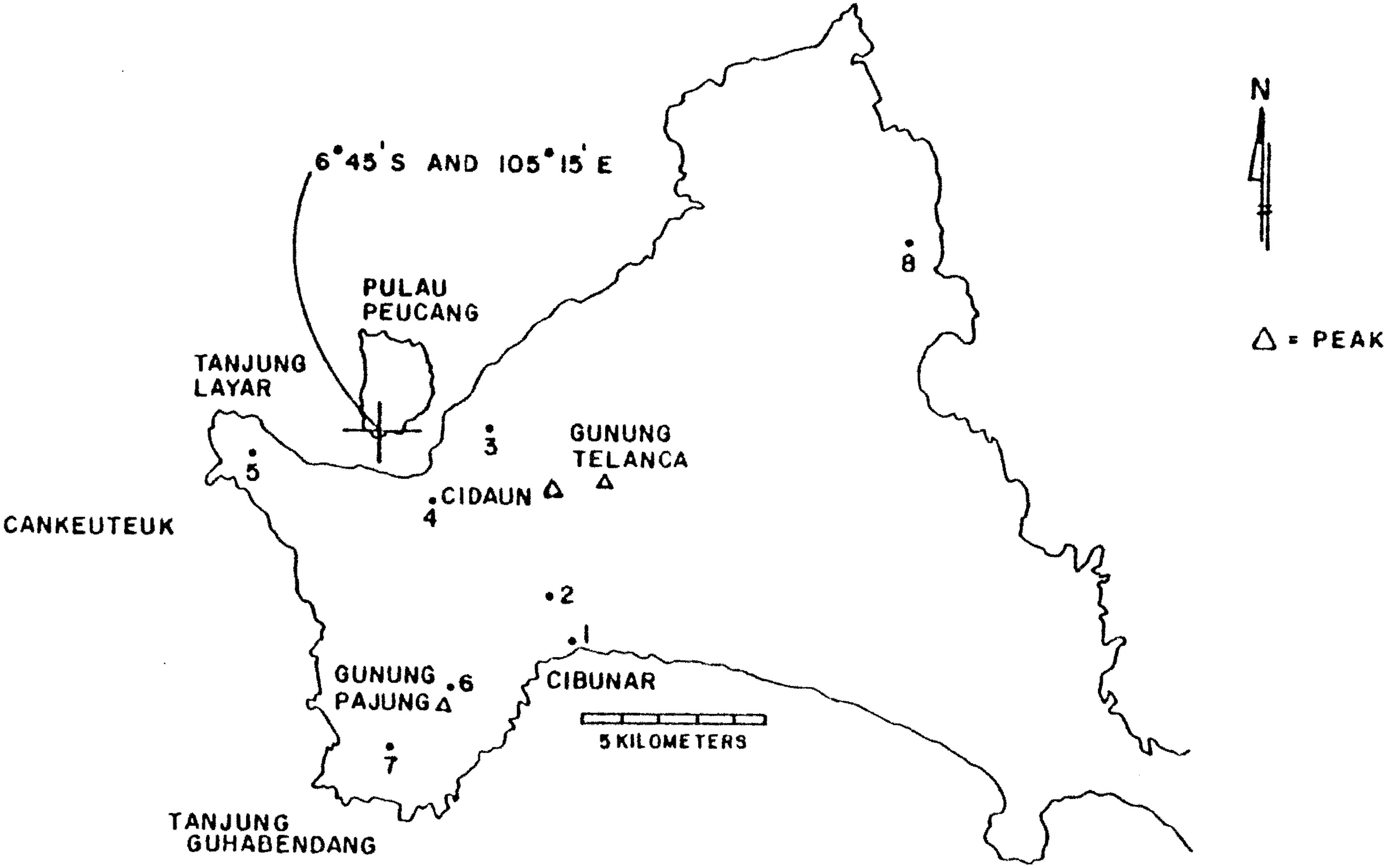
Four sampling points were pre-selected from a map transect line (Figure 5) running N 45° E from Tanjung Guhabendang on the SW to its termination just south of the mouth of Cikarang on the NE coast of Ujung Kulon. Transect alignment was chosen on the basis of best representation of altitudinal zones and terrain features in conjunction with prevailing wind information given by Satmoko (1961) and rainfall data from Soerianegara (1972). These pre-selected sites, designated sites 7, 6, 2 and 8 respectively, were 2, 4, 8 and 17 km, respectively, from the initial point at Tanjung Guhabendang. Other sites initially chosen along the transect were eliminated due to excessive time needed to cut access trails and make other preparatory arrangements. Instead, additional sampling sites designated 1, 3, 4 and 5 were chosen near Cibunar, G. Telanca, Cidaun and Cankeuteuk, respectively.

2. Size and Configuration of Sampling Sites

All sampling sites were 25 x 50 m rectangular plots. They were somewhat larger than the most efficient size of 10 x 20 m to estimate the density of major species (Lang *et al*., 1971) but nonetheless efficient when species are aggregated (Cain and Castro, 1959; Grieg-Smith, 1965). The major axis was parallel with the slope, or if on level ground, the major axis was oriented E-W. Approximate elevation of the plots was taken from a topographic map with 25 m contour intervals while slope within plots was determined by the use of an altimeter.

FIGURE 5

VEGETATION AND SOIL SAMPLING SITES IN UJUNG KULON



3. Vegetation Data Sites

Within each site data were collected on trees and saplings only. Trees were defined as single-stemmed perennial plants measuring greater than 25 cm in diameter at breast height (dbh), 1.37 m above the ground at mid-slope. Saplings were defined as single-stemmed perennial plants having tree-like form, but 10-25 cm dbh. Total counts of trees and saplings in each site were made. Trees were measured in cm at dbh using a steel diameter tape. Total top heights of trees were determined to the nearest meter with a Blume-Leiss altimeter fitted with a range finder device. Species identification was made on site, or by verification of specimens with herbarium sheets and staff personnel at Herbarium Bogoriense in Bogor.

Leaf samples of the major species within each site, whether shrubs, saplings or trees, were collected for subsequent chemical analysis. Leaf material from a maximum of four species in each site was taken, and analyzed using emmission spectrography (Appendix A).

Bearing and distance between sites were determined by hand-held compass and pacing, respectively. Within-plot lateral distances were regulated with a cloth meter tape.

Basal area, the cross-sectional stem area at dbh, was subsequently calculated as m^2/ha for trees; and as basal area range of trees and saplings - at low range and upper range.

4. Field Soil Data Sites

A pit was dug to a depth of 1.5 m in the approximate center of each 25 x 50 m site. If less than 1.5 m, the depth was either to the water table or to the bedrock. The number and depth of soil horizons were recorded. Coding of horizons adopted was similar to that of Parsons and Herriman (1975). Soil color of moist soil was determined by means of Munsell Soil Color Charts, while soil texture (apparent soil texture) and structure were recorded according to the procedure prescribed in the U.S.D.A. Soil Survey Manual (Soil Survey Staff, 1951). An adequate sample from each horizon of the central pit and from an alternate pit was collected and stored in triple-thickness plastic bags for subsequent chemical, physical and mineralogical analyses. The soil samples were identified by labeling them according to their relationship to others in the same profile and the spatial location of profiles in each site. Samples were labeled consecutively clockwise with respect to the transect bearing, starting with the central pit. Thus, the sample marked 6-1A11 designated the A11 horizon of the central pit in site No. 6; 6-2A11 was a corresponding horizon found at the NE plot periphery; 6-3A11 from the SE; 6-4A11 from the SW; and 6-5A11 from the NW.

Although most analyses were conducted on samples taken from the central pit, some were limited to samples collected from the peripheral pits. Bulk density, ρ_B, and soil moisture tension were obtained from mean values of five bulk density rings per plot, one from the central pit and the others from peripheral pits. Due to the thinness of some horizons and the existence of rocks and roots ρ_B and soil moisture tension determinations were limited to only three depths: 0-15 cm, 15-30 cm, and 30-45 cm. The number of horizons and horizon depth were also recorded for the shallower peripheral pits. No attempt was made to determine the lower limit of the deepest horizons encountered because the subsoils appeared to be very thick in most cases. Small samples from each horizon of the central pits were taken for pH and field moisture content determinations. Bulk density by core ring method; pH in water and KCl by glass electrode using water:soil ratio of 5:1; moisture content by constant weighing in a Brabander dry stove; and soil moisture tension at 10 cm, 100 cm, 1/3 bar and 15 bar suction were all determined at the Soils Research Institute in Bogor.

PHASE II. Laboratory Determinations

1. Plant Tissue Samples

Leaf samples collected in each site were oven dried and ball milled in preparation for chemical analysis. Only three plant species represented sites 1 and 4, all other sites had leaf material from 4 species. Due to lack of sampling control, the number of plant species represented and most importantly -- the lack of duplication of most species among all the sites -- the usefulness of the samples in overall interpretations were precluded. Results of the analyses are found in Appendix A.

2. Soil Preparation and Handling

Upon arrival in Honolulu, the bagged soil samples were ventilated then fumigated with methyl bromide to destroy any pathogens present. After repacking, the samples were divided into lots of approximately equal weight. One lot was repacked in triple-thickness plastic bags for storage. The other lot was passed through a 20-mesh sieve in a wet condition before repacking in plastic bags. Fresh samples, as needed, were taken from the sealed bags. For most chemical and mechanical analyses fresh sub-samples of air-dried soil were used. Three 2.0 gram samples of sieved, air-dried soil were oven-dried at 105^{o} C for 24 hours to determine the moisture factor of air-dried samples. A mean calculated moisture factor was henceforth used to express analytical results on an oven-dry basis.

3. Soil Physical Properties

In addition to the ρ_B, and soil moisture tension data determined at the Soil Research Institute in Bogor, particle density, ρ_p and particle size distribution were also completed to permit verification of apparent texture.

a. Particle density

Particle density ρ_p was determined by the pycnometer method on three replicates which had passed a 20-mesh sieve. Subsamples of approximately 10 g were used and weighed to the nearest mg. The dimensions, mass and density of pumice fragments which were larger than soil-sized separates were also recorded.

b. Particle size distribution

Approximately 25 g of sieved soil were dispersed with 50 ml of 10% sodium hexametaphosphate (Calgon) solution and 100 ml of water in plastic breakers, a modification of the method described by Kilmer and Alexander (1949). The mixture was sonicated at factor 60 - HiSpeed for 10 minutes using a BIOSONIK IV unit. Silt and clay were separated by washing into liter cylinders by wet sieving through a 325-mesh sieve. The sand fractions remaining on the sieve were subsequently dried and separated into fractions of: very coarse sand (VCS); coarse (CS); medium (MS); fine (FS); and very fine sand (VFS) by passing through nested sieves of mesh numbers 18, 35, 60 and 150, respectively. The fraction passing the 150-mesh sieves was collected on absorbant paper. All sand fractions were then determined gravimetrically.

Aliquots of 25 ml of the silt + clay suspension were taken by the pipette method from the liter cylinders made up to 1000 ml volume. Aliquots were taken at various times, corresponding to sedimentation times of particles of 20, 10, 5 and 2 μ in diameter. A Calgon blank was taken with each series of soils tested. Textural class names were designated according to the U.S.D.A. textural triangle (Figure 7). In some cases the determination was repeated to achieve a clearcut textural designation. When two different textures were determined, both textural designations were given.

c. Supplemental color coding by size fraction

In the process of separating the whole soil into sand, silt and clay fractions for mineralogical analysis, it was observed that samples of soil from disparate profiles often appeared similar in color when grouped into similar particle size classes. Munsell color code comparisons were, therefore, made of samples after they had been grouped into size separates. Comparisons among silt and clay separates were made on wet paste which had been collected in 50 ml centrifuge tubes. Sands were powdered with mortar and pestle, passed through a 200-mesh sieve, then wetted before the color comparisons were made.

4. Soil Chemical Analyses

The lack of data on Ujung Kulon soils dictated that several fundamental determinations of nutrient status be conducted. Modifications, as seemed warranted, were made to increase the precision in the physical conduct of the determinations or to enhance the applicability of the results. This latter point was especially true in regard to the determination of cation exchange capacity, CEC.

By universal standards, the pH of the extracting solution in the N NH_4OAc method (Chapman, 1965) is adjusted with either ammonium hydroxide, NH_4OH or acetic acid to a pH of 7.0. The CEC is then determined by titration of excess NH_3^+ ions which are displaced from the exchange complex by designated replacement ions. Other basic ions including calcium, (Ca^{++}); magnesium, (Mg^{++}); potassium, (K^+) and sodium, (Na^+) were concurrently leached from the exchange sites and determined separately as milliequivalents per 100 g of soil (meq/100 g). The sum of the Ca^{++}, Mg^{++}, K^+ and Na^+ in meg/100 g divided by the CEC, also expressed in meq/100 g is commonly known as percentage base saturation, % B.S. More fully the expression is:

$$\% \text{ B.S.} = \frac{Ca^{++} + Mg^{++} + K^+ + Na^+}{CEC} \times 100 \qquad (3)$$

Current classification of soils depends, in part, on both CEC and % B.S. derived by N NH_4OAc extraction at pH 7, in most cases. Yet Tamimi et al. (1972) and Uchida (1973) have found that CEC changes if the NH_4OAc is not at pH 7. If the pH of the soil surrounding plant roots is other than pH 7, they reasoned, then the CEC would, likewise, differ accordingly. Solubility and uptake of nutrients in the soil are affected by the soil pH; accordingly, the exchangeable cations and CEC should be determined at the soil pH and not at pH 7. Uchida, (1973) determined that exchangeable bases did not differ significantly between extraction at pH 7 or at soil pH for soils with pH - dependent charge. Soils with pH - dependent charges can be recognized by either increase or decrease (Δ pH) in pH that occurs between measurement of the hydrogen ion activity in water vs. its activity in N unbuffered KCl. Keng and Uehara (1973) illustrated that a soil material possesses a net negative charge when the pH in N KCl is more acid than the pH in water. In this study, CEC was determined with N NH_4OAc at pH 7, and with NH_4OAc adjusted to the pH of the soil. The % B.S., however, was determined only on those samples whose cations were also extracted at soil pH -- the latter technique.

a. Cation exchange capacity

1. N NH_4OAc adjusted to soil pH

Freshly air-dried 10.00 g (oven-dried basis) soil samples passing a 20-mesh sieve were shaken intermittantly with 200 ml of N NH_4OAc which had been adjusted to the soil pH (± 0.01 pH unit). After 24 hours the solution was filtered through #6 filter paper in a 70 mm Buchner funnel with suction into a 500 ml Erlenmeyer flask. Four successive leachings with the above N NH_4OAc in 50 ml aliquots were collected in labeled flasks whose contents were later analyzed for exchangeable bases.

A clean suction flask was attached, and 15-20 ml of the NH_4OAc were added to the leached soil. The presence of Ca in the leachate was checked by adding a few drops of 1 N NH_4Cl, 10% ammonium oxalate and dilute NH_4OH to ca. 10 ml of the leachate in a Pyrex test tube, as described by Chapman (1965). Upon heating to near the boiling point, the presence of Ca was indicated by turbidity or by a white precipitate. All soils from sites 3 and 8 showed positive Ca tests, but additional leaching with NH_4OAc failed to result in calcium depletion from the soil. All samples from other sites showed negative Ca tests.

Three further leachings with 50 ml aliquots of $\underline{N}$ NH_4Cl and once with 0.25 $\underline{N}$ NH_4Cl were followed by 200 ml of 99% isopropyl alcohol in successive 50 ml aliquots. A test for chloride was made by adding a few drops of 0.10 $\underline{N}$ silver nitrate ($AgNO_3$) in a test tube containing ca. 10 ml of the leachate. The presence of chloride was indicated by a white precipitate. None was detected.

The washed soil was transferred to another flask and shaken for 30 minutes with 200 ml of 4% KCl and filtered. An additional 200 ml KCl was added in 50 ml aliquots, then the leachate was made up to 500 ml volume with KCl. A 100 ml aliquot was transferred to a Kjeldahl flask to which was added 25 ml of 50% NaOH and a few pieces of zinc. A reagent blank was also prepared for distillation on the Kjeldahl apparatus. About 60 ml of distillate was collected in 100 ml of 3% boric acid and 10 drops of bromocresol green-methyl red mixed indicator. The distillate containing NH_4^+ ions was then titrated with 0.038 $\underline{N}$ H_2SO_4. CEC of the soil was determined by the formula:

$$\text{CEC}_{(\text{meq}/100\text{ g})} = \text{ml of } H_2SO_4 \times \underline{N} \text{ of } H_2SO_4 \times 10 \times 5 \qquad (4)$$

2. CEC with N NH_4OAc at pH 7

The procedure used was similar to the one above, however, no test for Ca or Cl was made. The procedure was carried out primarily to establish a CEC based on saturating the soil with N NH_4OAc at pH 7 -- the standard method used in soil classification work. There were wide discrepancies between the results using the two procedures. Since no cations were determined in the leachate of the pH 7 extractant, calculation of the % B.S. and pertinant discussions were precluded, and such information was limited to NH_4OAc extraction at soil pH.

b. Exchangeable bases

The filtered NH_4OAc extract that was made up to a volume of 500 ml with NH_4OAc adjusted to soil pH was used for Ca, Mg, K and Na determinations. Ca, Mg, and K were analyzed, along with appropriate standard solutions and reagent blanks, using a Perkin-Elmer Model 303 atomic absorption spectrophotometer. Sodium was determined with a Beckman DU flame spectrophotometer.

c. Organic carbon

The Walkley-Black method (Walkley and Black, 1934) was used but further modified in this study when it was observed that the prescribed volumes of potassium dichromate, $K_2Cr_2O_7$ were consumed before a titration end point was reached. Accordingly, 20 ml of N $K_2Cr_2O_7$ was used instead of 10 ml, as prescribed. Ten ml of 85% phosphoric acid were also used.

Due to their proximity to sea water and salt spray when in situ, the surface soils of sites 1, 4 and 8 were tested with $AgNO_3$ for the presence of chloride ion before beginning the experiment. All tests for chloride were negative. A 1.000 g sample of soil passing a 100-mesh sieve was used in the determination. Organic matter content was also estimated by using % O.M. = % O.C. X 1.724 as discussed by Jackson (1958).

d. Carbonate

A semi-quantitative determination of the presence of carbonates in the soil was made by saturating small amounts of soil with 4 N HCl. Carbonates, when found in significant amounts are mainly associated with calcium in marl, limestone or coral deposits with all forms being chemically the same -- calcium carbonate, $CaCO_3$.

Only the soils of sites 3 and 8 showed consistantly moderate to strong effervesence and were, threfore, the only samples chosen for quantitative CO_3-C determination. Weak effervesence of samples 1-1C and 2-1B22t was noted, but this was attributed to lack of precision in the method since the other horizons represented in those sites showed negative tests.

The method described by the U.S. Soil Salinity Laboratory (Allison and Moodie, 1965) for determining CO_3-C was attempted. In that method 0.5 N HCl was titrated against 0.25 N NaOH with 1% phenolphthalein in 60% ethanol as an indicator. Due to probable precipitation of iron as the pH changed, all samples became turbid. Also, the end point could not be detected with phenolphthalein as an indicator. Better results were obtained with the Piper (1942) rapid titration technique which called for 1 M HCl and 1 M NaOH and bromthymol blue as an indicator. Despite a caution in the method that water soluble carbonates must be accounted for in interpreting the experimental results, no water soluble carbonates could be detected in selected samples. Repeated titrations with blanks of standardized reagents demonstrated, however, that the test was very sensitive -- sharp equivalence points being repeatedly attained within ± 0.05 ml of titer.

e. Total nitrogen

Two grams of freshly air-dried soil passing through a 100-mesh sieve were analyzed for total nitrogen content by the Kjeldahl method. The collected distillate was titrated with 0.038 N H_2SO_4 and the content of nitrogen was expressed in percent by the formula

$$\% \text{ N} = \frac{\text{ml titer x } \underline{\text{N}} \text{ of acid x } 0.014}{\text{g of O.D. soil}} \times 100 \tag{5}$$

Reagent blanks were also prepared and titrated. Carbon-nitrogen ratios were computed using the results of determinations of % O.C. and % total N.

f. Extractable phosphorus

Two grams of 20-mesh soil were extracted with 200 ml of 0.02 N H_2SO_4 which had 0.3% ammonium sulfate, $(NH_4)_2SO_4$ in a modified Truog (Ayers and Hagihara, 1952) method. Aliquots of 25 ml of the centrifuged extract were made up to 50 ml volume by adding 2 ml of freshly prepared sulfomolybdate, extracting solution and a few drops of stannous chloride ($SnCl_2$) in a sequence which included the addition of ca. 5 ml of water after each reagent.

The samples were analyzed colorimetrically using a Coleman Jr. colorimeter at wavelength of 600 mμ. In some cases 10 ml aliquots were used in lieu of 25 ml aliquots if absorbance was beyond the range of the standards used.

g. Water-soluble silicon

Although silicon is not an essential element for plant nutrition, the high content of SiO_2 in the ash and tuff of the Krakatau eruption may have altered the SiO_2 content of the soil in important ways. Significant differences in the amount of water-soluble silicon, particularly in the tuff layer among sites, might be taken as one index of physico-chemical change resulting from differences in relief, rainfall, or biotic factors.

Three grams of <20-mesh soil were shaken continuously for 4 hours in a stoppered flask with 30 ml of H_2O, according to the method of Fox, *et al*. (1967). After centrifuging at high speed, 10 ml aliquots were made up to 50 ml volume with 1 ml of disodium sulfite, Na_2SO_3, sodium bisulfate + H_2SO_4 reducing solution and water. Silicon content was analyzed colorimetrically at 600 mμ with a Coleman Jr. colorimeter. Results were expressed as ppm in solution.

h. Other chemical analyses

Exchangeable manganese, Mn was determined with the atomic absorption spectrophotometer from the *N* NH_4OAc extract used for determining Ca, K, Mg and Na.

The results were taken from a standard curve of values charted on log-log graph paper.

The effects of fumigation, partial drying or prolonged storage of samples on soil pH were checked by comparison of pH readings with those obtained in Indonesia. No major changes were noted.

5. Mineralogical Analyses

a. The soils were separated into sand, silt and clay fractions. Sands were collected on a 325-mesh sieve. Clay was separated from silt after washing through the sieve, either by pipetting the suspended clay from a glass cylinder after overnight sedimentation, or by decanting off after being centrifuged at 750 rpm for more than 3 minutes. Attempts were made to minimize the clay contamination of the silt fraction by stirring and centrifuging silt samples and decanting off the clay. Due to insufficient clay content in the soils of sites 4 and 8, no attempt was made to separate silt from the clay in those samples. Also, due to insufficient soil, no silt + clay separation of sample 8-1C11 was conducted.

b. A few grams of unseparated silt + clay for total elemental analysis were collected from the cylinders. The samples were centrifuged at high speed then dried at 70^{o} C before other total analysis preparations were made, as described below. Whole soil samples of 1-1C, 3-4C, 5-1C and 6-1C were also prepared for total analysis by crushing air-dried samples with mortar and pestle, and passing the samples through a 200-mesh sieve.

In preparation for X-ray diffraction (XRD) studies, the silt and clay fractions were divided into two lots, one was saturated with N KCl and the other with N $MgCl_2$. After three centrifuge runs with the saturating salts, followed by three more runs with water, the supernatant was checked for chloride ion with N $AgNO_3$. Further washing was conducted as needed. Air-dried sand samples were powdered with mortar and pestle and passed through a 200-mesh sieve.

A Phillips X-ray diffractometer using copper K-α radiation with wavelength $\lambda = 1.5418$ A was used. Mg-saturated wet paste samples of both silt and clay on glass slides were prepared and analyzed from 2°, 2θ to 64°, 2θ goniometer reading. Mg-saturated, ethylene glycol solvated samples were traced from 2°, 2θ to 16°, 2θ. K-saturated silt and clay samples were analyzed from 2°, 2θ to 16°, 2θ after heating for over two hours at temperatures of 110° C, 300° C and 525° C.

Untreated powder samples (sand) were prepared in slotted aluminum slides and traced from 16°, 2θ to 64°, 2θ.

Total Oxide Analyses

Sufficient sample (about 5 g) of silt + clay was oven-dried to 110° C. Exactly 0.500 g of the O.D. soil was blended with 1.500 g of lithium tetraborate ($Li_2B_4O_7$) and fused in a furnace at 1000° C for about one hour. The fused pellets were then ground and pressed into wafers for total oxides analyses by an Applied Research Laboratories Model 72000 X-ray quantometer.

Due to the large discrepancies in loss of weight on ignition, (LOI) determination among some samples, the quantometer results were recalculated on an ignited basis. No Na_2O readings were obtained because the tube with Na wavelength was not in operation. Also, all results totaled more than 100% due to positive deviation from the regression equations used in calibration of quantometer standard samples.

In addition to the regular samples, whole soil samples from 1-1C, 3-4C, 5-1C and 6-1C were also analyzed by the quantometer.

RESULTS

Vegetation

The data in Table 2 summarize the counts of trees and saplings; the mean diameter at breast height (dbh) of trees; basal area (ba) of trees; ba range of saplings (from a minimum of 10 cm dbh to a maximum of 25 cm dbh); and total ba range of both trees and saplings. Because precise dbh of saplings was not measured, both lower and upper ba range is given. Table 2 is arranged in order of ascending ba upper range. Comparisons of tree ba between sites and range of total ba of trees and saplings are shown in Figure 6.

The great range in ba among forested sites, reaching a maximum of 45.2 m^2/ha in site 7 indicates a very heterogeneous forest in Ujung Kulon. Inasmuch as basal area utilizes stem diameter at 1.37 m above the ground, those sites which were composed of primarily grassy or herbaceous vegetation (sites 4 and 1, respectively) yielded little information. It was necessary, therefore, to supplement the within-site data with descriptions of the understory species and their features; also, to include some general descriptions of physiognomic features outside the sites. Accordingly, a more complete listing of vegetation found on and around the sites is given in Table 3. To facilitate identification, their synonyms are also given.

Description of Vegetation Sites

One criterion for selection of sites 1, 3, 4 and 5, which were not on the N 45° E transect, was the apparent internal homogeneity of vegetation exhibited therein. Gerard (1965) noted that such homogeneous entities are often dissected from their surroundings and may be

Table 2. Tree and sapling data of 25 x 50 m Ujung Kulon vegetation plots.

Site	Mean dbh cm	Mean hgt m	# Trees	Tree ba m^2/ha	# Saplings	Sapling ba range m^2/ha	Total # stems >10 cm dbh	Total ba range m^2/ha
4	a*	a	0	a	0	a	0	a
1	67.0	10	1	2.82	1	0.06 - 0.39	2	2.88 - 3.21
	Trees represented:	*Corypha utan* (1)						
2	60.2	19	4	10.66	17	1.07 - 6.68	21	11.73 - 17.34
	Trees represented:	*Arenga obtusifolia* (1), *Artocarpus elastica* (2), *Dillenia excelsa* (1)						
5	40.6	22	9	10.36	32	2.01 - 12.58	41	12.37 - 22.94
	Trees represented:	*Diospyros macrophylla* (1), *Drypetes macrophylla* (5), *Mangifera indica* (1), *Memecylon edule* (1), *Pterospernum diversifolium* (1)						
8	53.8	18	11	21.30	19	1.20 - 7.47	30	22.50 - 28.77
	Trees represented:	*Corypha utan* (8), *Neonauclea calcinia* (2), *Vitex quinata* (1)						
3	40.9	28	14	17.74	29	1.82 - 11.40	43	19.56 - 29.14
	Trees represented:	*Aglaia argentia* (2), *Aglaia elliptica* (1), *Cryptocarya* sp. (2), *Cryptocarya ferrea* (1), *Dillenia* sp. (1), *Lophopetalum javanicum* (1), *Polyalthea longipes* (1), *Strombosia javanica* (1), *Syzygium lineatum* (1), *Wetria macrophylla* (3)						

a* - no trees or saplings.

Table 2. Tree and sapling data of 25 x 50 m Ujung Kulon vegetation plots (Cont'd.).

Site	Mean dbh cm	Mean hgt m	# Trees	Tree ba m^2/ha	# Saplings	Sapling ba range m^2/ha	Total # stems >10 cm dbh	Total ba range m^2/ha
6	44.9	24	17	25.84	38	2.39 - 14.93	55	28.23 - 40.77
	Trees represented:		*Astronia* sp. (1), *Fagraea auriculata* (1), *Ficus pisocarpa* (1), *Neesia altissima* (1), *Sandoricum koetjape* (1) *Syzygium syzygoides* (2), Unknown (10)					
7	47.3	24	18	29.07	41	2.58 - 16.11	59	31.65 - 45.18
	Trees represented:		*Ficus vasculosa* (2), *Meliosma nitida* (1), *Neesia altissima* (3), *Neonauclea pallida* (1), *Ryparosa javanica* (1), *Syzgium syzygoides* (1), Unknown (9)					

FIGURE 6

TREE BASAL AREA, BASAL AREA RANGE OF TREES AND SAPLINGS, AND TREE AND SAPLING COUNT IN EACH SITE

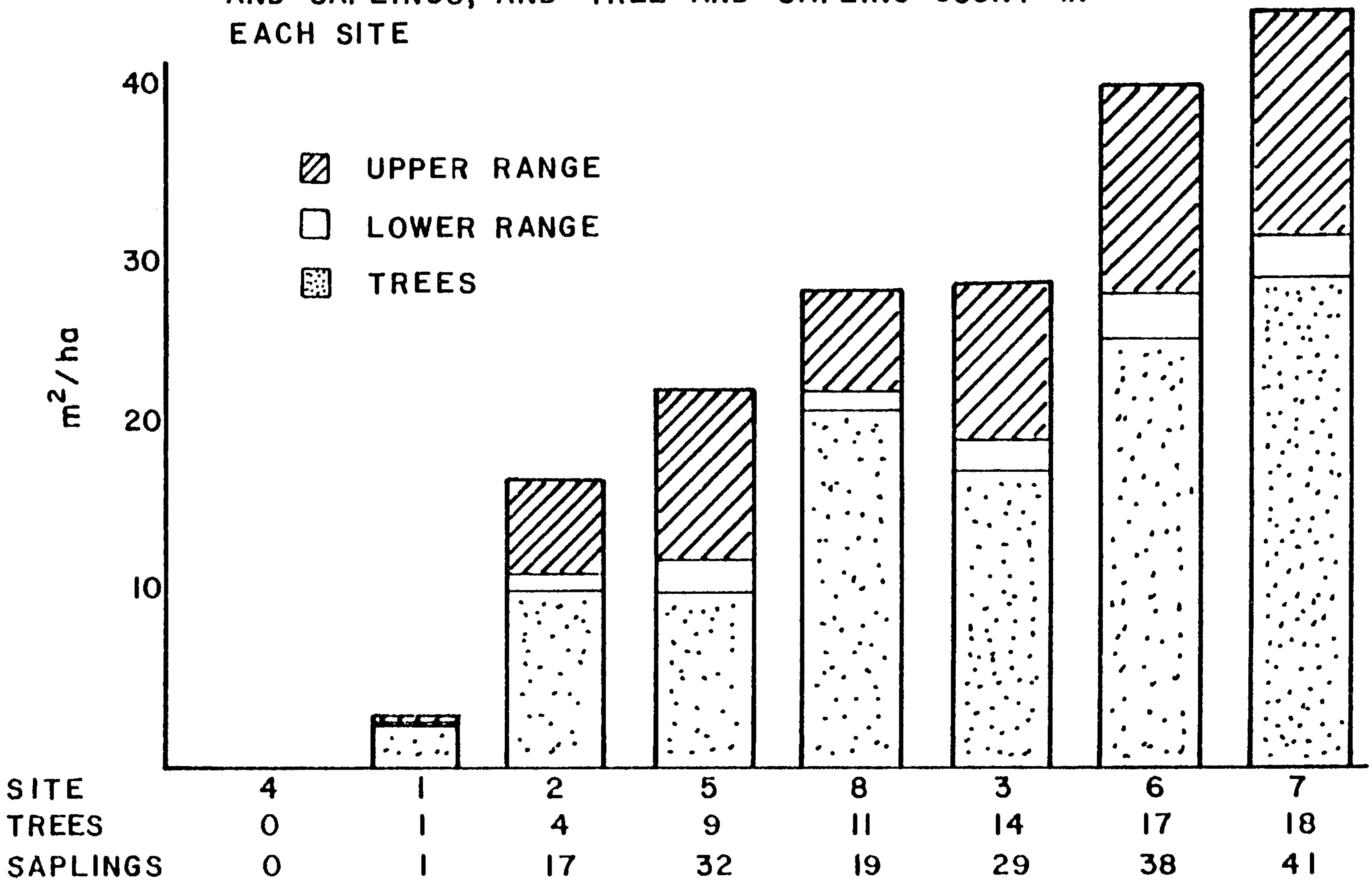


Table 3. Botanical names and synonyms of important species found on and around Ujung Kulon vegetation sampling sites.[1]

Botanical name	Synonym	Family
Aglaia argentea Bl.	-	Meliaceae
Alglaia elliptica Bl.	-	Meliaceae
Ardisia humilis Vahl	-	Myrsinaceae
Arenga obtusifolia Bl.	*A. westerhoutii* Griff.	Arecaceae
Artocarpus elastica Reinw. ex Bl.	-	Moraceae
Astronia sp.	-	Melastomataceae
Chrysopogon aciculatus (Retz.) Trin.	*Andropogon aciculatus* Retz.	Poaceae
Corypha utan Lamk.	*C. elata* Roxb., *C. gebanga*, Bl. Sphalm., *C. gebanga* Bl.) Bl., *C. sylvestris* (Bl.) Bl nom. illeg.	Arecaceae
Cryptocarya ferrea Bl.	*C. tomentosa* Bl.	Lauraceae
Cryptocarya sp.	-	Lauraceae
Dillenia excelsa (Jack) Gilg.	*D. pauciflora* (Zoll. & Mor.) Gilg., *Wormia excelsa* Jack	Dilleniaceae
Dillenia obovata (Bl.) Hoogl.	*D. aurea* Auct. non J. E. Smith	Dilleniaceae
Dillenia sp.	-	Dilleniaceae
Diospyros macrophylla Bl.	-	Ebenaceae
Drypetes macrophylla (Bl.) Pax & K. Hoffm.	*Cyclostemon macrophyllus* Bl.	Euphorbiaceae
Fagraea auriculata Jack	-	Loganiaceae
Ficus microcarpa L.f.	*F. retusa* Auct. non L.	Moraceae

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[1] Source: Backer, C. A. and Bakhuizen Van Den Brink, R.C., 1963-68. *Flora of Java*, Vol. I-III.

Table 3. Botanical names and synonyms of important species found on and around Ujung Kulon vegetation sampling sites (Cont'd.).

Botanical name	Synonym	Family
Ficus pisocarpa Bl.	F. microstoma Wall ex King	Moraceae
Ficus vasculosa Wall ex Miq.	-	Moraceae
Hyptis rhomboidea Mart. & Gall	H. capitata Auct. non Jacq.	Lamiaceae
Lagerstroemia flos-reginae, Retz.	L. speciosa Auct. (L.) Pers.	Lythraceae
Lantana camara L.	L. aculeata L.	Verbenaceae
Lophopetalum javanicum (Zoll.) Trucz	Solenospermum javanicum Zoll.	Celastraceae
Mangifera indica L.	M. laurina Bl.	Anacardiaceae
Meliosma nitida Bl.	M. sumatrana (Jack) Walp.	Sabiaceae
Memecylon edule Roxb.	-	Melastromataceae
Neesia altissima (Bl.) Bl.	-	Bombacaceae
Neonauclea calycina (Bartl. ex D.C.) Merr.	Nauclea purpurascens Korth	Rubiaceae
Neonauclea pallida (Reinw ex Havil.) Bakh. f.	Nauclea pallida Reinw. ex. Havil.	Rubiaceae
Polyalthia longipes (Miq.) K. & V.	-	Annonaceae
Pterospermum diversifolium Bl.	-	Sterculiaceae
Ryparosa javanica (Bl.) Kurz. ex K. & V.	-	Flacourtiaceae
Sandoricum koetjape (Burm. f.) Merr.	S. indicum Cav., S. nervosum Bl.	Meliaceae
Schizostachyum blumei Nees	S. longispeculatum (Kurz) Kurz	Poaceae

Table 3. Botanical names and synonyms of important species found on and around Ujung Kulon vegetation sampling sites (Cont'd.).

Botanical name	Synonym	Family
Streblus spinosus (Bl.) Corner	*Taxotrophis javanica* (Bl.) Bl., *T. spinosa* (Bl.) Steen. ex Back	Moraceae
Strombosia javanica Bl.	-	Olacaceae
Syzygium lineatum (DC.) Merr. & Perry	*Eugenia lineata* (DC.) Duthie, *E. teysmanni* (Miq.) K. & V.	Myrtaceae
Syzygium syzygoides (Miq.) Amsh.	*Eugenia cymosa* (Auct. non Lamk.)	Myrtaceae
Vitex quinata (Lour.) F.N. Will	*V. heterophylla* Roxb., *V. sumatrana* Miq. *V. velutina* K. & V.	Verbenaceae
Wetria macrophylla (Bl.) J.J.S.	-	Euphorbiaceae

variously described as stands, samples, communities or associations. Sites 1, 3, 4 and 5, then, were selected as examples of salient associations within the forest. Sites 2, 6, 7 and 8 represent preselected sites without regard to the vegetation association they may have represented.

Site 4, Cidaun

On the low end of the tree biomass scale, site 4 was chosen as representative of a grazing ground of the banteng, *Bos javanicus javanicus*. Since the site center was chosen at random it was only coincidental that the site contained no trees or saplings. Scattered trees do exist, those of *Dillenia obovata* being favored in management practices because the soft fruits are eaten by the animals. Heavy grazing by the banteng and other animals restricts the growth of vegetation to mostly grasses, *Chrysopogon aciculatus* being the chief one. Also found are seasonal aquatic plants like *Hyptis rhomboidea* which grows in shallow depressions with a high water table during the rainy season. The basal area of an alternate but typical grazing ground site (not described) was 0.68 m^2/ha, and restricted to only trees and saplings able to withstand the grazing pressure.

Site 1, Cibunar

The area along the coast east of Cibunar is also an abandoned banteng grazing ground, but it is not maintained in the same manner as the grazing ground at Cidaun. Consequently, a primary successional growth of chest-high *Lantana camara* virtually dominates the area, with only an occasional *Corypha* or *Arenga* palm emerging through the under-growth. The *Lantana* effectively inhibits the establishment of shade intolerant species. Occasional grassy patches are connected by narrow game trails. Toward the inland periphery of the narrow sandstone plateau on which site 1 is located, the *Lantana* gives way to nearly pure stands of *Arenga obtusifolia*, the most common palm found in lowland Ujung Kulon (Dransfield, unpublished). The *Arenga* are associated with deeper soils where they occur just north of the site.

Site 2, Cikendeng

Located astride two minor drainages, site 2 is unique among the sites studied as the only one containing a bamboo stand. Nearly the entire understory is dominated by the bamboo *Schizostachyum blumei* which grows horizontally in some places, excluding light and all other forms of vegetation. Although bamboo thickets are found elsewhere in Ujung Kulon, they are not commonplace, and may be seen along ridges as well as along stream beds.

The low basal area in site 2 is the result of a bamboo stand in contact with another forest association in which *Artocarpus elastica* and *Arenga obtusifolia* are well represented. Although *Artocarpus* is quite common in the lowland flats of Ujung Kulon, the only two representatives recorded were found on site 2, belying its actual frequency of occurrence. Another tree typical of the flats is *Lagerstroemia flos-reginae*, but it was not found on any of the sample sites.

Site 5, Cankeuteuk

The basal area range of site 5 is rather broad. A fuller lower canopy of saplings in site 5 makes a difference in stocking of this site. If upper ba range of saplings were added to the measured ba of trees in site 5 and lower ba range of saplings in site 8 were compared, the total ba would be about the same -- 22.9 m^2/ha in site 5 and 22.5 m^2/ha in site 8. The high frequency of the small diameter Ardisia humilis in site 8 tends to skew the mean ba toward the lower end of the range there. The common Arenga palm in site 5 tends to skew the range toward the higher end of the scale. Of 32 saplings counted in site 5, 10 were Arenga. Because the monocotyledonous palms have considerable diameter when they achieve sufficient height to be counted, at dbh, they measure closer to 25 cm dbh than to 10 cm dbh.

The high frequency of Arenga in the lowlands of Ujung Kulon has an effect which is not evident in the limited vegetation site data in this study. As Schenkel and Schenkel-Hulliger (1967) put it, "These palms are responsible for such poor light conditions in the lower stratum that no saplings can grow apart from young Arenga...." Accordingly, the inter-species relationships are a necessary part of the site descriptions. Tree and/or sapling number and size alone cannot adequately describe the overall physiognomy of the forest.

Except for the Arenga palm, no tree species found in site 5 was also found in other sites. The several Drypetes macrophylla contributed the greatest to ba, with 5 of the 9 trees representing 60% of the ba of all the trees. Drypetes was also well represented in the sapling and pre-sapling categories, although the short, stout and barbed Streblus spinosus is so dense in places that passage through the lowest canopy required cutting a tunnel.

A single representative of Diospyros macrophylla was recorded, yet this species is found extensively in uplands and in lowlands that are not subjected to flooding.

Site 8, Cikarang

The canopy of the seasonal swamps in the northeastern section of Ujung Kulon is singularly dominated by the palmate fronds of the Corypha utan. Few species are found here that grow tall enough to even be considered as co-dominants of Corypha. The tallest of the competitors in the sample site, Neonauclea calycina and Vitex quinata approach the shortest Corypha in height, but are spatially separated so that the Corypha have no restrictive influence over their growth. Corypha trees along constitute 74-95% of the ba, and number 8 of the 11 trees in the site.

The vast majority of the middle canopy is composed of Ardisia humilis trees and saplings. Because Ardisia is so widespread in the vast seasonal swamplands of the Northeast but does not often achieve large diameter, more saplings than trees were counted. The ba distribution, consequently, is likely to be skewed toward the lower end of the range.

It is probable that the Corypha-Ardisia association is one of the largest in Ujung Kulon, although most of the evidence results from empirical observations, rather than sample plot data. Inasmuch as the northeast side was subjected to direct inundation by the 1883 tidal waves (Hoogerwerf, 1970), it is presumed that the entire association is largely post-successional dating from that time. High soil pH (about 8.1) and thick tuffaceous layers in the area also contribute to the formation of the essentially edaphic mosaic with few species present.

Site 3, G. Telanca

The species complexity of trees in site 3 is more evident than for any other site by virtue of the more complete identification of its tree representatives. Ten taxa were identified by genus and/or species, and numerous unidentified saplings add to the complexity index[1/] of the site. Basal area of site 3 is nearly double that of site 2, although both are inland forest sites only a few kilometers apart and relatively undisturbed by animal grazing. Heights of the tallest trees *Syzygium lineatum*, *Lophopetalum javanicum* and *Cryptocarya sp.*, at 39, 37 and 32 m, respectively, are comparabe to the 38-40 m heights and 20-30 m average overstory heights of the trees studied on nearby P. Peucang (SEAMEO: BIOTROP, 1972).

Site 6, G. Pajung

Located in one of the remotest sections of Ujung Kulon, the G. Pajung massif has been little influenced by man, and not at all by tidal waves. The elevation of site 6 contributes to the increased

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[1/] Complexity index, C.I. = 10^{-3} (hbds), after Holdridge (1967).
h = hgt. of 3 tallest trees in m. for 1/10 ha plot.
b = ba in sq. m. for trees over 10 cm dbh, for 1/10 ha plot.
d = number of tree stems over 10 cm dbh, for 1/10 ha plot.
s = number of species of trees over 10 cm dbh, for 1/10 ha plot.

rainfall there, which is presumed to be the highest in Ujung Kulon. The apparent disagreement between Boerema (1925) and Hoogerwerf (1970) in regard to the amount of rainfall east and west of the summit notwithstanding, this author agrees with the latter that more rainfall occurs on the western side. Orographic uplift on the windward side, at least during the rainy season, seems to result in greater rainfall on the western slopes.

In site 6 the vegetation is considered as primary and an example of the favorable composition noted by Hoogerwerf (1970) in the Pajung Range. Only two trees exceeded 80 cm in dbh, however. The mean height of trees was only 24.2 m, with the tallest dominants of 41, 39 and 38 m, comparable with the heights of trees on low-lying P. Peucang.

The ba range of saplings is thought to be normally distributed here, since no Arenga palms were encountered. Dransfield (unpublished) noted that Arenga is not found at elevations over 150 m. On the basis of normal distribution of saplings, the mean ba of site 6 would be 7.31 m^2/ha for saplings, combined with measured tree ba, giving a mean total of 33.15 m^2/ha. This is about the 145 sq. ft./A (33.29 m^2/ha) of ba attained by a primary tropical high forest under favorable conditions as cited by Dawkins (1959).

Site 7, Guhamasigit

On the western slope of the G. Pajung massif, the Guhamasigit site has rainfall which approaches that found on top of G. Pajung. From the ba data and the number of trees found in the site it appears that the complexity of the site exceeds all others investigated.

Nevertheless, mean height and dbh did not vary appreciably from the values found in site 6.

Only one tree is outstandingly large, an unknown with a dbh of 102 cm and a height of 30 m. The penultimate diameter is only 70 cm dbh. Mean tree height in site 7 is only slightly less than that found in site 6. Both sites are completely within a large upland high forest community, and both would probably be mapped as identical units on any large scale vegetation map.

Sites 6 and 7 resemble each other in volume of stems, length of boles and the type of understory vegetation, which is lacking in *Arenga* palm. Some of the tree and sapling species which occur in site 6 also occur in site 7, including *Neesia altissima* and *Syzygium syzygoides*. The data are too scanty to make close comparisons, but it is safe to say that whereas all the other sites investigated are notable for the heterogeneity among them, sites 6 and 7 exhibit several homogeneous physiognomic features.

Soils

Data on soil profiles of Ujung Kulon soils are presented in Tables 4-11. Verification of textural designation by particle size distribution is given in Table 12.

Depth of solum varied from a minimum of 72 cm in 1-1 to well over the maximum depth limit adopted for convenience of 150 cm, in 2-1, 5-1, 6-1 and 6-2. In sites 4 and 8 the sampling depth was limited by the water table. Bedrock R in site 1 appeared to be sandstone; in site 3, a marl; in site 5 an unconsolidated conglomerate containing dissimilar rocks; and in site 7 a soft pink-gray saprolitic siltstone.

Table 4. Ujung Kulon Field soil description, Site 1.

Location: Cibunar
Relief : Simple
PARENT MATERIAL: Sandstone, Volcanic Tuff
PHYSIOGRAPHY: Level coastal terrace
DRAINAGE: Excessive
ELEVATION: 25 m
SLOPE: 0-2%
EROSION: Moderate

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
1-1	A	0-7	Dark brown, 7.5YR 4/4	Loamy sand	Medium crumb, strong	Non sticky, non plastic	Very abrupt, irregular and discontinuous
	C	7-15	Olive grey, 5Y 5/2	Sand	Fine granular, moderate	Non sticky, non plastic	Very abrupt, irregular discontinuous
	IIC	15-72	Dark yellowish brown, 10YR 3/4	Loamy sand	Very fine granular, weak	Non sticky, non plastic	Very abrupt
	R	72+					
1-3	A	0-10	Dark yellowish brown, 10YR 4/4	Loamy sand	Medium crumb, strong	Non sticky, non plastic	Very abrupt, irregular, discontinuous
	C	10-15	Pale olive, 5Y 6/3	Sand	Fine granular, moderate	Non sticky, non plastic	Very abrupt, irregular, discontinuous
	11C	15-62	Dark yellowish brown, 10YR 3/4	Loamy sand	Very fine granular weak	Non sticky, non plastic	Very abrupt
	R	62+					

Table 5. Ujung Kulon field soil description, Site 2.

Location: Cikendeng
Relief: Complex

PARENT MATERIAL: Sedimentary rock
PHYSIOGRAPHY: Hilly lowland
DRAINAGE: Imperfect
SLOPE: 15%
ELEVATION: 25 m
EROSION: V. severe

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
	A	0-13	Gray, 2.5YR 5/0	Silt loam	Medium crumb, moderate	Slightly sticky, slightly plastic	Gradual, irregular
2-1	B22	13-71	Brown, 10YR 5/3	Silty clay	Very fine sub angular blocky, moderate	Slightly sticky, plastic	Clear
	B22t	71-150+	Pale brown, 10YR 6/3 with 15% yellowish red, 5YR 5/8 mottles	Clay	Medium platy	Slightly sticky, slightly plastic	--
	A11	0-3	Very dark gray, 5YR 3/1	Silt loam	Medium crumb, moderate	Non sticky, non plastic	Abrupt
	A12	3-9	Dark brown to brown, 10YR 4/3	Silt loam	Medium crumb, moderate	Non sticky, non plastic	Clear, irregular
2-4	C	9-12	Brown, 10YR 5/3	Loamy sand	Medium granular, weak	Non sticky, non plastic	Clear, irregular
	IIC	12+	Yellowish brown, 10YR 5/8	Silt	Fine, sub angular, blocky	Slightly sticky, slightly plastic	--

Table 6. Ujung Kulon field soil description, Site 3.

Location: Telanca
Relief: Complex

PARENT MATERIAL: Marl, volcanic tuff
PHYSIOGRAPHY: Mountainous upland
DRAINAGE: Excessive
SLOPE: 25%

ELEVATION: 25-30 m
EROSION: Slight

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
3-1	A11	0-4	Very dark brown 10YR 2/2	Silty loam	Coarse crumb, moderate	Slightly sticky, slightly plastic	Clear, irregular
	A12	4-10	Dark brown, 10YR 3/3	Silty loam	Coarse crumb, moderate	Slightly sticky, slightly plastic	Abrupt, irregular, discontinuous
	C	10-13	Olive, 5Y 5/3	Loamy sand	Medium granular, weak	Non sticky, non plastic	Abrupt, irregular, discontinuous
	IIC	13-95	Dark brown to brown, 10YR 4/3	Clay loam	Medium crumb, moderate	Sticky, plastic	--
	R	95+	--	--	--	--	--
3-4	A11	0-5	Black, 10YR 2/1	Silty loam	Coarse crumb, moderate	Slightly sticky, non plastic	Abrupt
	A12	5-15	Dark yellowish brown, 10YR 4/4	Silty loam	Medium crumb, moderate	Slightly sticky, slightly plastic	Clear, irregular, discontinuous
	C	15-20	Light olive gray, 5Y 6/2	Fine sand	Fine granular, weak	Non sticky, non plastic	Abrupt, irregular, discontinuous
	IIC	20-80	Dark brown, 10YR 3/3	Clay loam	Medium granular, moderate	Slightly sticky, slightly plastic	--
	R	80+	--	--	--	--	--

Table 7. Ujung Kulon field soil description, Site 4.

Location: Cidaun
Relief: Simple

PARENT MATERIAL: Alluvial sand, volcanic tuff
PHYSIOGRAPHY: Lowland alluvial fan
DRAINAGE: Poorly drained
SLOPE: 0-2%
ELEVATION: <25 m
EROSION: None

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
4-1	A11	0-2	Dusky red, 2.5YR 3/2	Loamy sand	Fine granular, weak	Non sticky non plastic	Abrupt
	A12	2-6	Very dark gray, 2.5YR 3/0	Loamy sand	Fine granular, weak	Non sticky, non plastic	Abrupt, irregular discontinuous
	C	6-10	Reddish brown, 2.5YR 4/4	Coarse sand	Coarse granular, single grain	Non sticky, non sticky	Abrupt, irregular discontinuous
	IIC1	10-55	Reddish brown, 5YR 4/3	Fine sand	Fine granular, single grain	Non sticky, non plastic	Gradual
	IIC2	55-82+	Yellowish brown, 10YR 5/8	Very fine sand	Very fine granular, single grain	Non sticky, non plastic	--
4-3	A11	0-2	Dusky red, 2.5YR 3/2	Loamy sand	Fine granular, weak	Non sticky, non plastic	Abrupt
	A12	2-10	Dark brown, 7.5 YR 3/0	Loamy sand	Fine granular, weak	Non sticky, non plastic	Abrupt
	IIC1	10-70	Brown, 7.5YR 4/4	Fine sand	Fine granular, single grain	Non sticky, non plastic	Gradual
	IIC2	70-110+	Yellowish red, 7.5YR 5/6	Very fine sand	Very fine granular, single grain	Non sticky, non plastic	--

Table 8. Ujung Kulon field soil description, Site 5.

Location: Cankeuteuk
Relief: Complex, hilly
PARENT MATERIAL: Mixed sedimentary and volcanic rocks
PHYSIOGRAPHY: Low mountain slope
DRAINAGE: Moderate-well
ELEVATION: 25-50 m
SLOPE: 27%
EROSION: Uneroded to slight

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
5-1	A11	0-4	Black, 10YR 2/1	Silty loam to sandy clay loam	Coarse crumb, moderate	Slightly sticky, non plastic	Abrupt
	A12	4-10	Very dark gray, 10YR 3/1	Silty loam	Coarse crumb, moderate	Slightly sticky, slightly plastic	Abrupt, irregular discontinuous
	C	10-14	Olive, 5Y 5/3	Loamy sand	Medium granular, weak	Non sticky, non plastic	Abrupt, irregular discontinuous
	IIC	14-150+	Dark gray, 10YR 4/1	Sandy clay to clay	Fine sub angular, blocky, firm	Slightly sticky, plastic	--
5-3	A11	0-3	Very dark brown, 10YR 2/2	Loam	Coarse crumb, moderate	Slightly sticky, non plastic	Abrupt
	A12	3-7	Very dark gray brown, 10YR 3/2	Loam	Medium crumb, weak	Slightly sticky, non plastic	Abrupt, irregular discontinuous
	C	7-13	Gray brown, 2.5Y 5/2	Sand	Medium granular, weak	Non sticky non plastic	Abrupt, irregular discontinuous
	IIC	13-130	Dark gray brown, 10YR 4/2	Sandy clay	Fine sub angular, blocky, firm	Slightly sticky, plastic	--
	R	130+					

Table 9. Ujung Kulon field soil description, Site 6.

Location: Gunung Pajung
Relief: Complex, steep
PARENT MATERIAL: Sedimentary rock, tuff
PHYSIOGRAPHY: Mountainous slope
DRAINAGE: Mod. well
SLOPE: 32%
ELEVATION: 460 m
EROSION: Moderate

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
6-1	A11	0-2	Dark brown to brown, 7.5YR 4/2	Sandy loam	Medium crumb, weak	Non sticky, non plastic	Abrupt
	A12	2-11	Dark yellowish brown, 10YR 4/4	Loamy sand	Fine crumb, weak	Non sticky, non plastic	Clear, wavy
	C	11-20	Gray to light gray, 5Y 6/1	Sand	Fine crumb, weak	Non sticky, non plastic	Clear, discontinous
	IIC	20-150+	Brownish yellow, 10YR 6/8	Clay loam	Coarse subangular, blocky moderate	Non sticky, slightly plastic	-
6-2	A11/A12	0-5	Dark brown, 10YR 3/3	Silt	Medium crumb, weak	Slightly sticky, non plastic	Abrupt, discontinuous
	C	5-9	Olive, 5YR 5/4	Silty sand	Fine granular, weak	Non sticky, non plastic	Abrupt, discontinuous
	IIC	9-150+	Brownish yellow, 10YR 6/8	Clay	Medium subangular, blocky, moderate	Slightly sticky, plastic	-

Table 10. Ujung Kulon field soil description, Site 7.

Location: Guhamasigit
Relief: Complex, v. steep

PARENT MATERIAL: Sedimentary rock
PHYSIOGRAPHY: Mountainous slope
DRAINAGE: Excessive
SLOPE: 52%

ELEVATION: 300 m
EROSION: Moderate

Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
A11/A12	0-11	Dark brown, 10YR 3/3	Silt loam	Medium crumb, moderate	Slightly sticky, slightly plastic	Gradual
11C	11-120	Yellowish brown, 10YR 5/8	Silt	Medium sub-angular, blocky, moderate	Slightly sticky, slightly plastic	Gradual
R	120+	-	-	-	-	-

7-1

Table 11. Ujung Kulon field soil description, Site 8.

Location: Cikarang
Relief: Nearly level

PARENT MATERIAL: Marine sediments, tuff
PHYSIOGRAPHY: Lowland swamp
DRAINAGE: Poor
SLOPE: 2%

ELEVATION: <25 m
EROSION: Slight

	Horizon	Depth (cm)	Color (moist)	Texture (apparent)	Structure	Stickiness, plasticity	Boundary
8-1	A	0-13	Black, 5YR 2/1	Loamy sand	Medium crumb, weak	Non sticky, non plastic	Clear
	C11	13-23	Very dark grey brown, 10YR 3/2	Fine gravel	Medium granular, weak	Non sticky, non plastic	Abrupt, irregular discontinuous
	C12	23-34	Pale brown, 10YR 6/3	Medium sand	Medium granular, weak	Non sticky, non plastic	Gradual
	IIC1	34-47	Olive brown, 2.5Y 4/4	Fine sand	Very fine platy, weak	Non sticky, non plastic	Gradual
	IIC2	47-57+	Pale yellow, 5Y 7/4	Coarse sand	Very fine platy, weak	Non sticky, non plastic	--
8-3	A	0-13	Black, 2.5Y 2/0	Gravel to very coarse sand	Medium granular, weak	Non sticky, non plastic	Clear
	IIC1	13-24	Very dark grey brown, 10YR 3/2	Gravel to very coarse sand	Medium granular, weak	Non sticky, non plastic	Abrupt, irregular discontinuous
	IIC2	24-56+	Dark brown, 10YR 3/3	Medium sand	Very fine platy, weak	Non sticky, non plastic	--

Few soil horizons were observed. Those sites where slope permits continuous removal of both excess rain water and surface soil (sites 1, 2, 3, 5, 6 and 7) had only 3 or 4 horizons and a relatively uniform, deep subsoil. Differentiation of subsoil horizonation in sites 4 and 8 may reflect past changes in sedimentation deposition patterns.

The precisely dated age of the C horizon (1883) obviates the rapid rate of soil development above it. Also, the usually abrupt boundary between the surface soil horizon(s) points to rapid alteration. The A11 surface horizon, when distinguished, averaged 3.1 cm in thickness (Tables 4-11). An A12, when visible as a separate entity, averaged 6.6 cm in thickness (also refer to Appendix B). The absence of the A11, A12 sequence in site 2 is thought to be due to erosion. In sites 6 and 7 the A11/A12 horizon indicates that normal A11, A12 horizonation is distinguishable but, due to slope effects, there is considerable soil mixing. Morphological properties of the various horizons highlight the dissimilarities of the tuffaceous C horizon, in particular.

Table 12 shows that most profiles are rather loamy or sandy. Clay texture, for the most part, is found only in the subsoil. In site 2 the whole profile is more clayey due, perhaps, to repeated erosion of the surface layers, resulting in a truncated soil. The C horizons are more finely textured than the field soil descriptions in Tables 4-11 would indicate.

Bulk density and soil moisture information are given in Table 13. With soil pores completely filled (at 0 cm suction), site 3 has slightly greater percentage water volume than site 7, which has the next highest water percentage. The site 3 profile, however, has the

Table 12. Mean particle density, ρ_p; particle size distribution and textural class designation.

Site/ horizon	ρ_p	%VCS[a]	%CS[b]	%MS[c]	%FS[d]	%VFS[e]	% Silt	%Clay	Textural designation
1-1A	2.67	1.42	10.85	18.14	21.34	7.76	29.65	10.84	Sandy loam
1-1C	2.44	3.99	8.50	9.86	12.22	14.20	45.23	6.01	Fine sandy loam
1-1IIC	2.78	1.72	13.93	19.69	18.78	6.46	20.75	18.67	Sandy loam
2-1A	2.50	3.46	4.61	3.07	4.25	8.04	46.72	29.86	Clay loam
2-1B22	2.62	1.65	5.60	3.51	3.04	3.76	31.10	51.34	Clay
2-1B22t	2.72	0.05	0.11	0.15	0.52	2.18	31.42	65.57	Clay
3-1A11	2.49	1.90	2.22	2.59	4.63	8.14	44.77	34.04	Clay loam
3-1A12	2.60	1.93	4.26	2.48	4.43	4.88	34.48	47.55	Clay
3-1C	2.44	10.67	4.90	2.79	5.90	12.10	47.45	16.19	Loam
3-1IIC	2.66	4.06	3.64	2.28	3.53	4.38	30.53	48.92	Clay
4-1A11	2.43	10.36	27.45	24.91	25.41	9.44	2.43	0.0	Coarse sand
4-1A12	2.55	2.03	12.14	19.02	26.77	16.44	17.22	5.88	Loamy sand
4-1C	2.63	4.58	13.97	17.74	24.99	15.51	13.70	9.51	Sandy loam
4-1IIC1	2.68	2.88	13.25	18.54	29.14	13.60	12.40	10.18	Sandy loam
4-1IIC2	2.68	2.44	13.93	20.87	28.09	13.70	11.70	9.26	Loamy sand
5-1A11	2.43	3.11	12.33	10.80	16.83	10.05	31.31	15.57	Fine sandy loam
5-1A11(repeat)	2.43	-------------		55.73	-------------		22.20	22.07	Sandy clay loam
5-1A12	2.51	3.90	12.51	11.19	15.03	8.52	32.18	16.66	Loam
5-1C f	2.52	4.81	7.96	7.52	14.39	13.15	39.35	12.82	Loam
5-IIC	2.63	2.66	7.06	7.08	10.99	9.30	30.81	32.10	Clay loam
5-1IIC(repeat)	2.63	-------------		35.52	-------------		21.29	43.20	Clay

a - VCS = very coarse sand
b - CS = coarse sand
c - MS = medium sand
d - FS = fine sand
e - VFS = very fine sand
f - = 3 determinations

Table 12. Mean particle density, ρ_p; particle size distribution and textural class designation (Cont'd.)

Site/ horizon	ρ_p	%VCS[a]	%CS[b]	%MS[c]	%FS[d]	%VFS[e]	% Silt	% Clay	Textural designation
6-1A11	2.35	2.05	7.53	5.01	8.70	11.05	46.81	18.85	Loam
6-1A12	2.37	3.04	7.19	6.03	9.50	12.63	42.13	19.47	Loam
6-1C	2.44	4.41	7.35	6.34	11.10	17.57	46.98	6.24	Fine sandy loam
6-1IIC	2.67	2.50	3.97	3.08	5.23	6.21	39.71	39.30	Clay loam
6-1IIC(repeat)	2.70	2.58	3.17	2.52	4.83	6.16	40.32	40.43	Silty clay
6-1IIC(repeat)	2.87	--------------		21.19	---------------		32.04	46.77	Clay
7-1A11/A12	2.53	6.75	7.31	7.02	13.60	8.44	30.50	26.37	Loam
7-1IIC	2.68	5.17	5.79	5.55	10.68	7.17	33.44	32.30	Clay loam
8-1A	2.39	11.33	7.21	7.39	15.67	24.34	25.50	8.57	Fine sandy loam
8-1C11	2.41	10.10	4.58	4.28	22.25	33.97	20.72	4.10	Loamy fine sand
8-1C12	2.60	3.15	4.97	8.90	26.87	25.38	23.22	7.51	Sandy loam
8-1IIC1	2.63	3.36	5.11	5.88	27.11	31.00	21.32	6.22	Very fine sandy loam
8-1IIC2	2.70	5.56	15.64	21.71	30.65	12.41	9.58	4.46	Loamy sand

Table 13. Mean bulk density and mean percent water by volume (O.D.) and percent available water of Ujung Kulon soil profiles.

			Suction[a]					
	Depth (cm)	Mean B.D.[a] g/cm^3 (O.D.)	0cm	10 cm	100 cm	1/3 bar	15 bar	Percent available 1/3 - 15 bar
			Percent					
Site #1	0-15 cm	1.03	61.27	49.47	36.22	30.61	14.72	15.89
	15-30 cm	1.07	61.47	48.48	36.25	30.66	16.43	14.23
	30-45 cm	1.06	62.01	50.28	31.38	27.79	18.92	8.87
Site #2	0-15 cm	0.90	64.08	62.51	53.75	47.80	35.06	12.74
	15-30 cm	0.86	67.02	62.30	54.42	49.33	37.57	11.76
	30-45 cm	0.86	67.18	61.25	56.29	52.15	42.99	9.16
Site #3	0-15 cm	0.71	72.37	40.68	36.08	32.66	24.50	8.16
	15-30 cm	0.73	72.56	40.91	36.76	33.99	27.93	6.06
	30-45 cm	0.84	68.42	50.60	44.36	41.22	32.26	8.96
Site #4	0-15 cm	1.20	51.81	41.28	33.19	27.62	17.46	10.16
	15-30 cm	1.39	48.13	43.38	33.03	25.01	17.28	7.73
	--- b	----	-----	-----	-----	-----	-----	-----
Site #5	0-15 cm	0.96	61.75	53.25	44.02	36.81	24.37	11.44
	15-30 cm	0.97	63.12	54.73	46.93	40.25	28.64	11.61
	30-45 cm	0.93	64.64	53.22	45.16	39.15	28.21	10.94
Site #6	0-15 cm	0.75	68.22	57.95	43.26	28.79	20.24	8.55
	15-30 cm	0.97	63.87	60.44	54.79	45.23	33.92	11.31
	30-45 cm	1.03	61.64	59.82	54.78	46.12	32.89	13.23

a - Mean of 5 rings

b - No 30-45 cm samples due to high water table

Table 13. Mean bulk density and mean percent water by volume (O.D.) and percent available water of Ujung Kulon soil profiles (Cont'd.).

	Depth (cm)	Mean B.D. g/cm^3(O.D.)	Suction 0cm	 10 cm	 100 cm	 1/3 bar	 15 bar	Percent available 1/3 - 15 bar
			Percent					
Site #7	0-15 cm	0.71	71.94	56.61	49.25	38.03	26.44	11.59
	15-30 cm	0.78	70.89	59.29	51.65	40.33	29.41	10.92
	30-45 cm	0.77	71.27	60.06	53.12	40.87	31.23	9.64
Site #8	0-15 cm	0.62	74.14	51.14	41.21	28.67	11.08	17.59
	15-30 cm	0.91	65.79	55.33	47.21	25.56	11.28	14.28
	30-45 cm	1.15	56.85	50.97	45.98	24.74	12.75	11.99

least propensity to retain water despite having considerably more clay in the profile.

Results of chemical analyses are given in Tables 14-17. Soil pH is moderately acid (in the pH 5.0-6.0 range) in most cases, with a minimum of 5.06 in 6-1IIC. The entire profile of site 8 is above pH 7.0 due to decomposing shells, while only horizon IIC in site 3 is above pH 7.0 due to the presence of marl.

The CEC determined at soil pH is greatest in the surface soil 3-1A11, which also has appreciable clay (Table 12) and organic material, as evidenced by a high organic C content (Table 16). Conversely, the lowest CEC is found in the loamy sand of 8-1IIC2 which has a comparatively low content of both clay and % O.C.

Calcium dominates among the exchangeable bases (Table 15) in most cases, particularly in sites 3 and 8 where water-soluble Ca precluded a calculation of percent base saturation (% B.S.). In sites 6 and 7 Mg exceeded Ca in the surface soil; deeper in these profiles potassium and sodium also exceeded the Ca levels in most instances.

The % O.C. declined sharply with depth (Table 16) but CO_3-C, where it occurred, was many times higher in the subsoil with depth, thus contributing to a trend toward uniformity in C/N ratios, except in sites 1, 4 and 5.

Extractable P levels were variable between surface soils and subsoils in different profiles (Table 17). Site 8 had the highest amount of P in the surface (275 ppm) but relatively less in the two tuff layers below (92 and 60 ppm, respectively). Horizons in site 3 had the penultimate amount of P in any single profile, but there was considerably

Table 14. Soil pH and cation exchange capacity of soil profiles of Ujung Kulon, determined by two methods.

Site/horizon	Soil pH	CEC me/100g Soil At soil pH	 At pH 7
1-1A	5.78	17.86	15.01
1-1C	5.98	11.35	9.59
1-1IIC	6.33	19.90	14.92
2-1A	5.12	34.10	28.22
2-1B22	5.17	38.86	43.72
2-1B22t	5.26	46.36	46.75
3-1A11	6.49	54.06	48.12
3-1A12	6.84	40.66	41.82
3-1C	6.82	15.30	11.00
3-1IIC	7.73	33.49	32.77
4-1A11	5.41	16.58	18.00
4-1A12	5.32	13.54	14.33
4-1C	5.28	13.11	11.15
4-1IIC1	5.33	12.40	8.17
4-1IIC2	5.52	12.92	8.95
5-1A11	5.73	31.16	29.64
5-1A12	5.28	29.59	20.49
5-1C	5.24	14.54	12.08
5-1IIC	5.64	36.24	31.01
6-1A11	5.63	26.17	18.24
6-1A12	5.56	20.71	15.45
6-1C	5.39	12.30	6.16
6-1IIC	5.06	20.80	15.28
7-1A11/A12	5.72	26.12	22.40
7-1IIC	5.19	24.22	20.74
8-1A	7.13	40.56	44.41
8-1C11	7.99	11.59	12.32
8-1C12	7.93	13.58	12.62
8-1IIC1	7.94	14.39	11.39
8-1IIC2	7.99	9.88	7.97

Table 15. Exchangeable bases and percent base saturation in Ujung Kulon soil profiles.

	meq/100g						
Site/horizon	Ca	Mg	K	Na	ΣBases	CEC at soil pH	% B.S.
1-1A	4.54	2.50	0.41	0.71	8.16	17.86	45.69
1-1C	2.76	0.91	0.56	0.96	5.19	11.35	45.73
1-1IIC	11.15	1.93	0.91	0.48	14.47	19.90	76.56
2-1A	6.48	6.74	2.00	0.65	15.87	34.10	46.54
2-1B22	11.94	7.87	2.34	0.41	22.56	38.86	58.05
2-1B22t	21.20	8.11	1.08	0.29	30.86	46.36	66.18
3-1A11	46.38	3.54	2.19	0.54	52.65	54.06	97.39
3-1A12	33.06	3.19	0.94	0.59	37.78	40.66	92.92
3-1C	13.19	0.97	0.45	0.50	15.11	15.30	98.76
3-1IIC	68.40	0.51	1.15	0.46	70.52	33.49	>100 a
4-1A11	3.31	1.18	0.40	0.68	5.57	16.58	33.59
4-1A12	3.44	0.98	0.19	0.63	5.29	13.54	38.70
4-1C	3.52	1.16	0.14	0.60	5.42	13.11	41.34
4-1IIC1	6.22	2.42	0.12	0.77	9.53	12.40	76.85
4-1IIC2	6.84	2.06	0.23	0.52	9.65	12.92	74.69
5-1A11	22.46	6.76	2.47	0.61	32.30	31.16	103.66
5-1A12	14.92	4.86	2.21	0.70	22.69	29.59	76.68
5-1C	6.90	3.01	1.23	0.54	11.68	14.54	80.33
5-1IIC	15.70	9.57	1.78	1.30	28.35	36.24	78.23
6-1A11	1.35	1.66	1.33	0.65	4.99	26.17	19.07
6-1A12	0.34	0.55	0.91	0.52	2.32	20.71	11.20
6-1C	0.28	0.18	0.66	0.67	1.79	12.30	14.55
6-1IIC	0.04	0.85	0.16	0.47	1.52	20.80	7.31
7-1A11/A12	3.96	4.32	0.58	0.52	9.38	26.12	35.91
7-1IIC	0.56	1.86	0.32	0.67	3.41	24.22	14.08
8-1A	107.00	2.78	0.52	0.47	110.77	40.56	>100 a
8-1C11	45.68	1.28	0.40	0.30	47.66	11.59	>100 a
8-1C12	53.62	2.93	0.32	0.50	57.37	13.58	>100 a
8-1IIC1	43.59	2.47	0.15	0.46	46.67	14.39	>100 a
8-1IIC2	50.62	3.54	0.18	0.40	54.74	9.88	>100 a

a - Due to water soluble Ca

Table 16. Percent organic carbon, carbonate-carbon and total nitrogen; and carbon-nitrogen ratios in Ujung Kulon soil profiles.

Site/horizon	% O.C.	% CO_3 - C[a]	% N	C/N ratio
1-1A	1.24	-	0.16	7.8
1-1C	0.91	-	0.12	7.6
1-1IIC	1.02	-	0.68	1.5
2-1A	1.89	-	0.27	7.0
2-1B22	1.20	-	0.16	7.5
2-1B22t	0.47	-	0.07	6.7
3-1A11	5.61	3.88	0.52	11.0
3-1A12	2.70	2.69	0.30	9.0
3-1C	0.96	2.75	0.09	10.7
3-1IIC	1.88	27.5	0.23	8.2
4-1A11	5.81	-	0.50	11.6
4-1A12	3.29	-	0.33	10.0
4-1C	1.46	-	0.18	8.1
4-1IIC1	0.91	-	0.14	6.5
4-1IIC2	0.51	-	0.07	7.3
5-1A11	5.73	-	0.44	13.0
5-1A12	3.30	-	0.37	8.9
5-1C	0.94	-	0.11	8.5
5-1IIC	0.72	-	0.07	10.3
6-1A11	4.81	-	0.36	13.4
6-1A12	3.41	-	0.29	11.8
6-1C	1.20	-	0.09	13.3
6-1IIC	0.94	-	0.08	11.8
7-1A11/A12	4.14	-	0.39	10.8
7-1IIC	1.11	-	0.12	9.2
8-1A	5.28	9.75	0.52	10.2
8-1C11	1.31	23.5	0.12	10.9
8-1C12	1.39	26.25	0.12	11.6
8-1IIC1	0.88	34.5	0.09	9.8
8-1IIC2	0.80	48.0	0.08	10.0

a - Mean of replicate determinations

Table 17. Phosphorous, silicon and manganese levels of Ujung Kulon soils.

Site/horizon	ppm		
	P	Si	Mn
1-1A	85	28.1	0.29
1-1C	160	38.1	0 [a]
1-1IIC	26	26.1	0 [a]
2-1A	34	37.3	1.75
2-1B22	8	41.4	0.75
2-1B22t	3	42.1	tr [b]
3-1A11	122	103.4	tr [b]
3-1A12	122	73.1	tr [b]
3-1C	170	75.6	0 [a]
3-1IIC	34	65.5	0 [a]
4-1A11	10	18.1	0.36
4-1A12	6	16.6	0.30
4-1C	4	19.0	0.31
4-1IIC1	4	23.6	0.07
4-1IIC2	4	29.1	tr [b]
5-1A11	50	36.2	0.61
5-1A12	42	28.1	0.49
5-1C	68	34.6	0.46
5-1IIC	4	65.5	0.28
6-1A11	16	24.1	2.24
6-1A12	8	34.2	0.44
6-1C	23	33.1	tr [b]
6-1IIC	19	25.1	0.78
7-1A11/A12	8	22.1	0.33
7-1IIC	4	19.6	1.62
8-1A	275	66.6	0.07
8-1C11	92	64.0	0.21
8-1C12	60	57.6	0.66
8-1IIC1	26	65.1	0.28
8-1IIC2	26	41.6	0.48

[a] - Non detectable in 8 readout counts

[b] - tr = trace, detectable but below 0.05 ppm mean

high P in the C horizon (170 ppm). Sites 1, 5 and 6 had the greatest amount of P in the C horizon.

Water-soluble Si was extremely high in 3-1A11 and substantially higher in the entire profile than in other sites except the site 8 profile and in 5-1IIC. By contrast, Mn levels were low. In many cases Mn was not detectable, or detectable at a mean level of less than 0.05 ppm. Only 3 horizons showed Mn in excess of 1.0 ppm.

Mineralogical information is given in Tables 18 and 19. Quartz predominates in the sand and silt fractions of most horizons of each profile (Table 18) and in most profiles. In site 5 plagioclase replaces quartz in the sand fraction of all horizons except in 5-1IIC, where plagioclase has not been identified; in the silt and clay fractions cristobalite and smectite predominate. The subsoil sand and silt of 3-4IIC contain calcite. At the deepest levels of site 8, the presence of calcium phosphate is indicated. Moderate amounts of smectite, halloysite and kaolin occur commonly in the silt and clay fractions of most profiles.

Total oxides are given in Table 19. Reported percentage totals are several percent high due to positive deviation from regression equations used in internal standards employed in calibration of the X-ray quantometer. Also, some error exists due to the absence of Na_2O values.

Table 18. Primary and secondard minerals identified from X-ray diffraction patterns, and unidentified peaks in soils of Ujung Kulon.

Site/horizon	Mineral	Unidentified peaks (Mg-saturated paste only) d-spacing (Angstroms)
1-1A		
Sand	Quartz	3.19
Silt	Quartz	4.13,2.43,3.21,3.77
Clay	Quartz	4.15
1-1C		
Sand	Quartz	4.04,3.22,2.91
Silt	Quartz, halloysite[a]	3.21
Clay	b	
1-1IIC		
Sand	Quartz	3.14,3.21,2.55,3.23, 3.80
Silt	Quartz, halloysite	----
Clay	Quartz, halloysite	4.17,3.19,2.69,7.14
2-1A		
Sand	Quartz	4.29,3.23,1.98
Silt	Quartz	3.19,4.46,4.04
Clay	Smectite, kaolin	----
2-1B22		
Sand	Quartz	4.29,4.50
Silt	Quartz	3.19,4.46,20.0,3.52
Clay	Smectite, kaolin, halloysite	----
2-1B22t		
Sand	Quartz	4.48,31.8
Silt	Quartz, halloysite	3.19,4.46,3.77,3.00
Clay	Smectite, kaolin, halloysite	----
3-4A11		
Sand	Quartz	3.20,4.06,1.72
Silt	Quartz	----
Clay	Kaolin, halloysite	----
3-4A12		
Sand	Quartz	2.96,3.21,4.06,1.51, 1.50,1.78
Silt	Quartz, halloysite	----
Clay	Kaolin, smectite, halloysite	10.04

a - Silt + clay
b - No sample

Table 18. Primary and secondary minerals identified from X-ray diffraction patterns, and unidentified peaks in soils of Ujung Kulon (Cont'd.)

Site/horizon	Mineral	Unidentified peaks (Mg-saturated paste only) d-spacing (Angstroms)
3-4C		
Sand	Quartz	3.24,3.77,3.36,1.82
Silt	Quartz, halloysite	1.82
Clay	Kaolin, halloysite	7.14,4.72,3.35,2.87, 3.24
3-4IIC		
Sand	Calcite	3.35
Silt		3.20,3.34,2.43,2.40
Clay	Smectite, kaolin, halloysite	7.24,4.82
4-1A11		
Sand	Quartz	3.20,3.22,4.08,3.78, 3.66,3.49
Silt	Quartz	3.19,3.77
Clay	c	----
4-1A12		
Sand	Quartz	3.19,3.65,3.77,4.06, 1.98
Silt	Quartz, smectite,[a]	3.21,3.43,4.04
Clay	b	----
4-1C		
Sand	Quartz	3.19,3.23,4.08,3.74, 3.66,1.98
Silt	Quartz, smectite,[a]	3.19,3.23,3.77,4.05, 4.48,3.49
Clay	b	
4-1IIC1		
Sand	Quartz	4.06,3.22,2.53,1.98
Silt	Quartz, smectite,[a]	3.22,10.00
4-1IICa		
Sand	Quartz	3.20,3.21,3.77,4.06, 3.90,3.66,2.29,1.98
Silt	Quartz, smectite,[a]	3.22,3.19,4.08,3.77, 4.44,10.0
Clay	b	----

a - Silt + clay
b - No sample
c - No clay in horizon

Table 18. Primary and secondary minerals identified from X-ray diffraction patterns, and unidentified peaks in soils of Ujung Kulon (Cont'd.).

Site/horizon	Mineral	Unidentified peaks (Mg-saturated paste only) d-spacing (Angstroms)
5-1A11		
Sand	Feldspar	
Silt	α Cristobalite, smectite	3.21,4.46,3.78
Clay	Smectite	----
5-1A12		
Sand	Plagioclase	2.14,1.92,2.84,1.61
Silt	α Cristobalite, smectite	----
Clay	α Cristobalite, smectite	----
5-1C		
Sand	Plagioclase	2.30,1.80,1.78
Silt	α Cristobalite	3.35,3.21,4.40
Clay	Smectite	----
5-1IIC		
Sand	α Cristobalite	3.22,3.65,3.77,1.70, 3.02,2.94,2.16
Silt	α Cristobalite, smectite	3.21,3.83,4.40,3.31, 2.98,2.56
Clay	Smectite	----
6-1A11		
Sand	Quartz	4.06,3.77,1.85
Silt	Quartz	2.81,4.46
Clay	Kaolin, halloysite	4.15,4.42,7.19
6-1A12		
Sand	Quartz; calcium - aluminum silicate[d]	3.48
Silt	Quartz	2.13
Clay	Kaolin, halloysite	4.15,3.86,4.44,7.25
6-1C		
Sand	Quartz	3.22,3.65,4.06,4.25, 3.77,2.52
Silt	Quartz	4.44,3.19
Clay	Kaolin, halloysite	4.39,7.14,14.25
6-1IIC		
Sand	Quartz	3.23,3.80,2.17
Silt	Quartz	3.52,3.24,3.77,2.16
Clay	Kaolin, halloysite	4.17,7.25

d - $CaAl_2Si_2O_8$

Table 18. Primary and secondary minerals identified from X-ray diffraction patterns, and unidentified peaks in soils of Ujung Kulon (Con'd.).

Site/horizon	Mineral	Unidentified peaks (Mg-saturated paste only) d-spacing (Angstroms)
7-1A11/A12		
Sand	Quartz	3.80,3.25,3.00
Silt	Quartz	3.53,3.24
Clay	Kaolin, halloysite	7.19,5.98
7-1IIC		
Sand	Quartz	3.24,3.80,3.03
Silt	Quartz	3.52,3.23,3.77,2.16, 2.12
Clay	Kaolin, halloysite	7.31,4.17
8-1A		
Sand	Quartz	3.49,3.22,3.05
Silt	Quartz, kaolin,[a]	10.04
Clay	b	----
8-1C12		
Sand	Quartz	3.00,3.04,1.88,2.49, 2.70,2.10
Silt	Quartz, kaolin, halloysite[a]	
Clay	b	
8-1IIC1		
Sand	Quartz	3.00,3.04,3.40,2.71, 1.88,2.49
Silt	Quartz, calcium phosphate[e], kaolin,[a]	3.03,10.04
Clay	b	----
8-1IIC2		
Sand	Quartz	3.00,3.41,1.89,2.71, 3.29,2.26,1.86, 3.77,2.38
Silt	Quartz, calcium phosphate[e], halloysite[a]	8.42,10.04
Clay	b	

a - Silt + clay
b - No sample
e - $Ca_2P_2O_7$

Table 19. Percent total oxides in Ujung Kulon soils (on ignited basis).

Site/horizon	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	CaO	P_2O_5	Others-a,b	Total
1-1A	56.35	21.72	16.96	1.75	2.13	0.94	1.43	3.33	104.61
1-1C	65.97	20.69	7.98	1.80	2.54	1.83	0.84	2.34	103.99
1-1IIC	49.13	23.02	23.08	1.54	2.02	0.66	1.43	3.96	104.84
1-1C (whole soil)	66.73	19.72	8.30	1.89	2.35	2.41	0.68	2.43	104.51
2-1A	69.86	22.01	7.22	2.00	1.84	0.60	0.41	2.29	106.23
2-1B22	64.58	26.22	8.79	2.19	1.82	0.39	0.31	2.35	106.65
2-1B22t	62.28	27.67	8.96	2.66	2.01	0.61	0.25	2.24	106.68
3-4A11	55.03	27.16	10.61	1.80	1.57	4.59	1.27	2.69	104.72
3-4A12	55.18	29.02	11.46	1.73	1.54	2.67	1.20	2.70	105.50
3-4C	68.98	20.66	5.81	1.60	2.78	2.13	0.45	2.18	104.59
3-4IIC	48.05	31.04	12.82	1.86	0.98	7.74	1.40	2.71	106.60
3-4C (whole soil)	68.67	20.02	5.69	1.44	2.67	2.42	0.43	2.14	103.48
4-1A11	72.45	19.45	7.28	1.81	2.16	0.89	0.42	2.16	106.62
4-1A12	68.64	22.66	7.67	1.82	1.98	0.68	0.35	2.20	106.00
4-1C	64.61	23.44	9.78	2.09	2.12	0.70	0.35	2.30	105.39
4-1IIC1	62.59	24.57	10.77	2.17	2.08	0.85	0.36	2.39	105.78
4-1IIC2	60.56	25.69	11.74	2.73	2.07	0.98	0.35	2.33	106.45

a - TiO_2, MnO; b - no Na_2O calculated.

Table 19. Percent total oxides in Ujung Kulon soils (on ignited basis) (Cont'd.).

Site/horizon	SiO_2	Al_2O_3	Fe_2O_3	MgO	K_2O	CaO	P_2O_5	Others-a,b	Total
5-1A11	69.94	22.54	5.92	1.91	2.73	1.67	0.39	2.00	107.10
5-1A12	69.09	23.72	6.28	1.97	2.66	1.41	0.40	2.07	107.60
5-1C	69.92	21.56	5.68	1.69	2.78	1.70	0.32	2.08	105.73
5-1IIC	67.26	26.64	6.30	2.18	2.03	0.69	0.20	1.89	107.19
5-1C (whole soil)	66.14	22.47	5.84	1.70	2.14	3.48	0.32	2.23	104.32
6-1A11	66.17	24.37	7.95	1.39	2.00	0.75	0.37	2.35	105.35
6-1A12	63.93	26.27	8.27	1.36	2.00	0.74	0.39	2.35	105.31
6-1C	66.96	22.43	6.58	1.70	2.44	1.55	0.33	2.24	104.23
6-1IIC	57.87	31.60	10.77	1.22	2.14	0.00	0.28	2.39	106.27
6-1C (whole soil)	67.95	20.80	6.10	1.65	2.55	2.10	0.33	2.23	103.71
7-1A11/A12	59.95	30.12	9.20	1.52	2.87	0.14	0.37	2.47	106.64
7-1IIC	58.18	30.87	10.07	1.65	3.03	0.00	0.30	2.47	106.57
8-1A	62.65	20.24	8.02	2.37	1.64	7.98	1.01	2.31	106.22
8-1C12	57.88	19.97	8.09	2.38	1.60	12.04	0.57	2.23	104.76
8-1IIC1	58.85	21.39	8.32	2.66	1.55	10.90	0.47	2.18	106.32
8-1IIC2	60.28	23.07	8.69	2.56	1.61	7.45	0.43	2.19	106.28

DISCUSSION

Density, Stocking and Site Utilization

Numerical abundance and spatial distribution of species must be taken into account before an understanding of plant community organization can be obtained, in the viewpoint of Hairston (1958). In the opinion of Gause (1936) the most important structural feature of a community is a definite quantitative relationship between abundant and rare species. The plant community can best be described as a spatial and temporal organization of organisms (Dansereau, 1963) with differing degrees of integration. Despite close interrelationships, the ultimate unit of vegetation is not the plant community but the individual plant type whose representatives show similar ecological behavior (Mueller-Dombois and Ellenberg, 1974). Abundancy contributes to homogeneity, whereas rarity is a sign of heterogeneity within a particular community. Spatial homogeneity, however, requires that a species be distributed equally in all parts of an area; i.e., the probability of encountering the species in all parts is the same. Tests of homogeneity in a statistical sense are rarely applied in multi-species communities (McIntosh, 1967), and usually homogeneity is determined subjectively.

The paucity of information within each site and the inadequate number of sample sites in this study compound the problem of drawing meaningful inferences from the Ujung Kulon vegetation data. Attempts to delimit the various community boundaries by investigating only selected associations was done at the sacrifice of randomness. Comparisons of site utilization among associations was not possible because no true replication of conditions existed.

Density of trees and saplings, i.e., the number of stems per unit area is generally greater in the well drained uplands than in lower elevation sites (see Figure 6) having less relief. Sites 6 and 7, as typical of the upland situation exhibit good drainage. They contain 43 and 41 stems, respectively. Site 8, on poorly drained, flat ground contains 30 stems. Sites 1 and 2 have low stem counts.

There is apparently greater site utilization in the uplands on the basis of stocking, as well. Stocking is a relative, rather than an absolute measure of site utilization; and often employs the determination of dbh and ba. The use of dbh alone has serious drawbacks because mean dbh depends upon the number of trees in each site, as well as tree size. Exceptionally large or small trees tend to greatly affect mean dbh since sample size is small. Site 5 with 9 trees and mean dbh of 40.6 cm appears to be comparable to Site 7 with 18 trees and 47.3 cm mean dbh, a dbh change of 16.5% between the two sites. Median dbh in Sites 5 and 7 were 35 cm and 39 cm, respectively. From the standpoint of total ba per site, however, from 12.37 - 22.94 m^2/ha in site 5 to 31.65 - 45.18 m^2/ha in Site 7, the percent change of the ba range is 85.4 - 42.7.

This grouping of total ba by sites also suggests greater site utilization in the uplands. Basal area alone does not constitute an index of site productivity. Productivity is measured against some age standards, but lacking true growth rings in most species, actual age of trees in undisturbed forests of the tropics is mostly a matter of conjecture. In mixed forest of multi-aged species there is, as yet, no precedent for the concept of site index. The use of basal area assumes some maximum tree crown capacity as a function of stem diameter. Penetration of light is thus limited and some equilibrium between canopy trees and understory species comes about, perhaps one reason why Dawkins (1959) assigned a maximum value for primary tropical high forest of about 33.27 m^2/ha. Even higher ba in sites 6 and 7 may be due to more compact crowns of species found there. At any rate, the differences in elevation alone would suggest the possibility that lower basal areas in the lowlands may be due, in part, to the destruction of part of the overstory by the tidal waves of 1883.

Traditional parameters of dbh and tree height have limited usefulness as indices of site utilization. Although Hoogerwerf (1970) attested to the primary nature of the forest in the G. Pajung Range, he seemed skeptical that much primary forest existed elsewhere in Ujung Kulon because few trees of large diameter are encountered. Only two specimens in the 80-100 cm dbh range were measured in site 6 and one in site 7, both in the G. Pajung Range. In the lowlands, _Artocarpus_ _elastica_ of 83 and 86 cm dbh were recorded in site 2, and a 93 cm dbh _Syzygium_ _lineatum_ was measured in site 3. Other equally large trees were found near and around sites 2, 3 and 5, but with the same low frequency as those encountered within the sites. Cain _et_ _al_. (1956) also noted that although very large trees do occur in tropical rain forest, their studies in Brazil gave them the impression of a forest composed of moderate to small trunks with long unbranched boles and relatively small crowns. Holdridge (1970) also reported a maximum dbh of 95.7 cm and a penultimate dbh of 80.0 cm in a primary forest in Puerto Rico. The long boles and small crowns of trees in sites 6 and 7 contributed to the present author's inability to get leaf samples for identification.

Taxonomic differences among the sampling sites were striking, since few of the same tree species were found in other sites. Method of seed dispersal is suspected to be one of the important factors in species homogeneity within sites, and similarly a factor in causing heterogeneity between sites. Many primary tree species of the tropics have large seeds which restrict rapid, widespread establishment (Gomez-Pompa _et_ _al_., 1972). The _Neesia_ _altissima_ found only in sites 6 and 7, for example, is quite widespread in the G. Pajung Range and would presumably grow in the vicinity of sites 3 and 5. Its heavy seed pods, however, are cast quite close to the parent trees and it is probable that the spread of the species is restricted to slow expansion. On the other hand, floatable seeds, especially those of _Arenga obtusifolia_ may predominate in the drained soils of the lowlands in voids created there by the tidal wave destruction of 1883. Otherwise, _Arenga_ is limited to vegetative propagation of suckering of underground parts of parent trees. Although _Arenga_ may have been established by seed floatation, apparently the trees don't tolerate prolonged exposure to salt water. No _Arenga_ were found in site 8.

Other edaphic conditions are thought largely responsible for restriction of plant species to various associations. The droughtiness of the soil in site 1 is thought to be largely a feature of the underlying sandstone parent material. After 10 days of continuous rain during March 1973, there was no sign of puddling in site 1; and soil moisture content was only about 25%. Also, the apparent excessive drainage may be due to fissured rocks in the fairly shallow soil.

An analogous situation seems to exist in the northern periphery of the Telanca area; at least in the upper part of the solum. The rapid infilitration of rain water into the soil in much of the watershed results in movement of water in underground streams. Where a high water table exists near sea level the trees establish shallow root systems and are readily blown down by waterspouts and high winds which occur in the coastal areas. The secondary appearance of the forest in the northeastern sections of Ujung Kulon may be a consequence of both high water table and wind blowdown of species not adapted to a wet soil regime. Mangroves and other species found in the littoral zone are better able to withstand those influences because of their adaptation of mechanical support.

On the basis of ground reconnaissance, the northeastern lowlands seem to have more clear-cut vegetation mosaic patterning than other areas. The tidal waves in 1883 may have been most destructive there, thus altering species succession. However, the thick ash fall itself, in terrain above the high water line was also an important factor in post-Krakatau succession.

Preliminary Biomass Estimation

Total biomass production is a useful indicator in describing site utilization. A reasonable *post facto* approximation can be made by applying the concepts of other investigators. Ovington and Olson (1970) calculated regression equations of oven dry weight of various plant parts (roots, boles, stems and leaves) in standing trees by direct weighing of typical representatives when they were removed and weighed by sections. The regression equations they employed for major trees, which are also used here were:

g (O.D. wgt) leaf....... $\ln y_1 = a + b_1 x_1 + b_2 \ln x_2$ (6)

where $a = 2.9254$ $b_1 = 0.0012$ $b_2 = 1.3277$

and x_1 was hgt in m and x_2 was dbh in cm. Coefficients a, b_1 and b_2 were different for various parts, thus:

bole....... $\ln y_1 = 4.3821 + 0.001\ x_1 + 1.9379 \ln x_2$ (7)

branches....... $\ln y_1 = 2.7453 + 0.0004\ x_1 + 2.2401 \ln x_2$ (8)

roots < 0.5 cm.....$\ln y_1 = 1.3583 - 0.0003\ x_1 + 0.8582 \ln x_2$ (9)

and roots > 0.5 cm....... $\ln y_1 = 3.002 + 2.5538 \ln x_2$ (10)

Minor trees were best represented by regression of biomass on dbh alone, and put into their Group C. Ovington and Olson (1970 also developed regressions for minor trees as follows:

g (O.D. wgt) leaf....... $\ln y_1 = 4.0243 + 1.5726 \ln x_2$ (11)

bole.......$\ln y_1 = 5.3717 + 1.8010 \ln x_2$ (12)

branch....... $\ln y_1 = 4.11894 + 1.9357 \ln x_2$ (13)

roots < 0.5 cm..... $\ln y_1 = 1.5415 + 0.9779 \ln x_2$ (14)

and roots > 0.5 cm..... $\ln y_1 = 4.2850 + 1.9367 \ln x_2$ (15)

Since saplings in this study were counted, only the mean dbh of 17.5 cm was used in all cases and the results rounded to the nearest kg. A different plant geometry exists for palms, therefore, the regression equation of Bannister (1970) for Euterpe globosa Gaertn. was:

Total biomass (O.D. wgt)....... $\ln y_1 = 3.84629 + 2.912322 \ln x_2$ (16)

and is used to compute the biomass of Arenga obtusifolia. Both palms belong to the same sub-family Arecoideae and have quite similar morphological features.

The Corypha utan, on the other hand, belongs to the sub-family Coryphoideae, so the use of Bannister's (1970) regression may not be appropriate. Tomlinson and Soderholm (1975) measured a single Corypha elata Roxb. in Florida and gave several oven-dry weights of the plant parts. By using proportional weights of various parts, the total biomass of the smaller Corypha utan in Ujung Kulon was estimated. Biomass of boles, however, was computed by considering the bole as an untapered cylinder with an estimated specific gravity of 0.95 and a dry matter content of 25%. Oven dry weight may be computed by first determining the volume of a cylinder, $V = \pi r^2 h$ (17) and then substituting in the specific gravity of the wood, g_s; the weight of dry wood, w_d; and 1002.12 kg/m^3, the weight of a cubic meter of water. Oven dry weight in kg is thus,

$$W = \pi r^2 h g_s w_d \text{ X } 1002.12 \text{ kg/m}^3 \tag{18}$$

All biomass estimates for this study have been summarized in Table 20. Lacking any other estimate, and although completely contrived, the biomass estimates made for Ujung Kulon are probably not in serious error, except for site 4. In theory, the overall morphological characteristics of forest trees and shrubs found in the same life zones are similar, according to Holdridge (1967). Inasmuch as rainfall and elevation are key parameters in the Holdridge system, the El Verde, Puerto Rico sites of the Ovington and Olson (1970) and Bannister (1970) studies should be comparable. The El Verde sites are

Table 20. Estimates of tree and sapling biomass of vegetation sites in Ujung Kulon.

Site	#	Major trees	#	Saplings	#	Arenga	#	Corypha	kg/site[a]	kg/ha[a]
1	0 -	-	0 -	-	1 -	20	1 -	2,936	2,956	23,648
2	3 -	5414	2 -	153	15 -	1024	0 -	0	6,591	52,728
3	14 -	8415	21 -	1609	8 -	546	0 -	0	10,570	84,560
4	b -		b -		b -		b -		b	
5	9 -	4646	22 -	1686	10 -	683	0 -	0	7,015	56,120
6	17 -	12584	38 -	2912	0 -	0	0 -	0	15,496	123,968
7	18 -	14023	41 -	3142	0 -	0	0 -	0	17,165	137,320
8	3 -	818	19 -	1456	0 -	0	8 -	18,284	20,558	164,464

a - oven dry weight
b - no trees or saplings in Site 4.

at 424 m elevation with 3120-4650 mm annual rainfall (Odum, 1970). Although no true mean rainfall has been established, the lower value seems more likely, and is close to that of Ujung Kulon. The average biomass estimate (excluding site 4) of 91,830 kg/ha for Ujung Kulon is less than the average given by Ovington (1965) or Sanchez (1973) for tropical forests. However, it is above the minimum of 71,900 kg/ha of live vegetation biomass given by Ovington (1965), even without changing the regression coefficients or any of the other assumptions.

Some of the low biomass estimates may be attributed to the effects of the coarse tuff. Warnaars and Eaves (1972) presented experimental evidence that excessive aeration and erratic water stress in coarse aggregates led to restricted root growth of emerging seedlings. Taylor (1974) demonstrated that rate of seedling emergence, plant height and weight of aerial and subterranean vegetative components of maize and sorghum were generally correlated with soil aggregate size -- root development was significantly more pronounced in soils with finer aggregates.

Interruption in Plant Succession

Except where erosion bared the soil to a mineral surface, the tuff layer may have been responsible for a prolonged interruption in plant succession. The interruption lasted perhaps a decade or longer, until biocycled organic residue of sufficient depth and water-holding capacity resumed its full role as a medium of seed germination and development. Normal development in a downward direction had to take place through a nutrient-poor and structurally inhospitable tuff layer.

Seeds which were cast prior to tuff deposition may have experienced little difficulty in emerging upward through the tuff. In spite of Verbeek's (1885) sole measurement of 10 mm tuff thickness at Java's First Point, this study indicates a tuff layer that is, on the average, 66.7 mm in thickness for 24 observations (Table 21, also see Appendix B).

Differences in tuff thickness resulted, in some part, by re-distribution by wind, gravity and stream flow. Also, the greater tuff thickness may have resulted from directional eruption as discussed by Colmet-Daage and Gautheyrou (1974): or due to localized wind currents and/or eddy effects. The work of Schuylenborgh (1954) inexplicably made no mention of the Krakatau tuff in soils that are 61 - 139 km SE of Krakatau in Bantam Province. Curiously, he was studying classification and genesis of soils derived from tuff (the G. Danau tuff) -- which he did identify deep in the profiles.

Many seeds, particularly those dispersed by the wind or light seeds with limited carbohydrate reserves may have succumbed in greater numbers and were subject to greater establishment problems than seeds in soil with little or no tuff layer. Consequently, spatial patterns of some species may have been permanently altered, and successional changes may have resulted.

Existing trees and shrubs probably did not suffer species extinction as a result of a decade or more of unfavorable germination medium, but they probably declined in growth rate and overall vigor due to water stress. In places where the tuff layer was thick enough to prevent normal seed germination, it probably also caused seasonal water stress by simulation of a long "capillary fringe" on the surface of the soil.

Physical Effects of the Tuff Layer

The granular, sandy apparent texture of the tuff was one of many physical properties which affected plant succession. At the outset, it is felt, the "sandy" nature of the tuff layer was more permeable to water; but, like sands in general, had low water holding capacity. In periods of low rainfall it tended to dry out to a greater extent than the underlying litter layer and/or surface soil having more organic matter. In time, organic residues from the forest canopy gradually buried the tuff. The water balance problem then became one of inability of water to percolate to lower depths until the entire tuff layer was nearly saturated.

Unsaturated flow of water through soil under suction is limited by the size, number and arrangement of the pores. Large pores fill last and empty first. In site 3, horizon 3-1A12 with 47% clay would be expected to exert a greater pressure gradient than in 3-1A11 with 34% clay. The theoretically greater pressure potential in the subsoil 3-IIIC, with 49% clay, cannot be realized because there is a relatively low pressure potential under unsaturated flow conditions in the tuff above it, which has only 16% clay. From that standpoint, the data in Table 13 are misleading since they do not represent continuous column simulation. Unfortunately, the realization came <u>ex post facto</u>; no soil moisture tension data were collected for the C horizons alone.

The available water supply as presented in Table 13 is an oversimplification. Available water capacity (AWC) of Salter (1967) as given by Williams and Joseph (1970) takes into account the depth of soil (d) and its apparent specific gravity (ASG) -- also known as bulk density -- expressed as wgt/vol, in addition to the conventional upper limits (UL) for water availability at 1/3 bar tension, and the lower limits (LL) at 15 bar--the permanent wilting point. AWC is then calculated as

$$\text{AWC} = \frac{(\text{UL}-\text{LL}) \times d \times \text{ASG}}{100} \tag{19}$$

and expressed as either inches per foot or cm per m. Although available water percentage in Table 13 seems to vary little with depth, the AWC by equation 19 varies nearly 20-fold between surface soils and subsoils. Moreover, the field capacity in sandy soils is closer to 1/10 bar than to 1/3 bar (Williams and Joseph, 1970), hence the coarser textured tuff and overlying horizons are not accurately represented by substitution into UL of 1/3 bar tension data. Salter (1967) found that 1/10 bar tension for UL was also more accurate for soils with good infiltration characteristics.

By equation (19) for example, the AWC of 0-15 cm depth in 6-1 (from Table 13) would yield only 0.96 cm/m because d is 15 cm and ASG is 0.75. On the other hand, the AWC of 6-1IIC is at least 17.71 because the measured d is at least 130 cm (Table 9) and ASG of 1.03 points to a greater storage capacity. The tuff layer of 6-1, with mean ASG of between 0.505 for pumice and about 0.80 for finer separates, could be expected to hold very little water.

During the first decades after tuff deposition the combination of the long "capillary fringe" followed by a disjunction of pressure gradient in the tuff may have meant that little or no water percolated to the root zone during the driest months. Schenkel and Schenkel (1973) reported one instance in which almost no rain fell for more than a month in Ujung Kulon. Table 1 attests to a decidedly dry season in terms of the frequency of rainfall occurrence.

Another physical effect of the tuff layer is the poor structural stability it possesses as a medium for mechanical support of roots. The apparent sandiness of the tuff in the upland sites borders on a gravelly texture in the lowland swales. Colmet-Daage and Gautheyrou (1974) also remarked on the single grain deceptiveness of fresh volcanic ash in Martineque which, nevertheless, was texturally a clay by mechanical analysis.

The problems of root establishment and water percolation are probably no longer noticeable in Ujung Kulon because the soil horizons are now sufficiently thick to contain enough roots for adequate water uptake.

Chamical Properties of Soil

a. Effective CEC

Uchida (1973) had previously determined that there were no statistical differences in exchangeable bases when extracted at both soil pH and pH 7, but that CEC determination was much more dependent upon extractant pH. Gross differences in CEC by the two methods used in this study were too large to ignore. Consequently, percentage base saturation calculations were affected. The % B.S. exceeded 100% only in sample 5-1A11 when the NH_4OAc was adjusted to soil pH--except for the calcareous soils of sites 3 and 8, as noted at the bottom of Table 15. The % B.S. of 103.66 in 5-1A11 probably reflects experimental error due to the sizeable quantity of Ca present.

It could be due to error in CEC determination as well, but the CEC as determined with neutral NH_4OAc is even lower, and would result in a larger B.S. of 108.97%. Using neutral NH_4OAc, the percent B.S. exceeds unity in samples 4-1 IIC1, 4-1 IIC2, 5-1A11 and 5-1A12, if all other factors remain the same.

Effective CEC is reputed to increase with increase in pH in soils having a pH dependent charge (Tamimi *et al*., 1972; Keng and Uehara, 1973). Yet CEC decreased in all samples from sites 1, 5, 6 and 7 when it was determined with neutral *N* NH_4OAc. Lowering of the pH of the extractant for samples 3-1 IIC and all samples of site 8 had varied effects on CEC. It lowered the value of CEC of samples 3-1 IIC, but raised it for 8-1 A and 8-1 C11, whereas the rest of site 8 soils showed lower CEC values.

b. Organic carbon

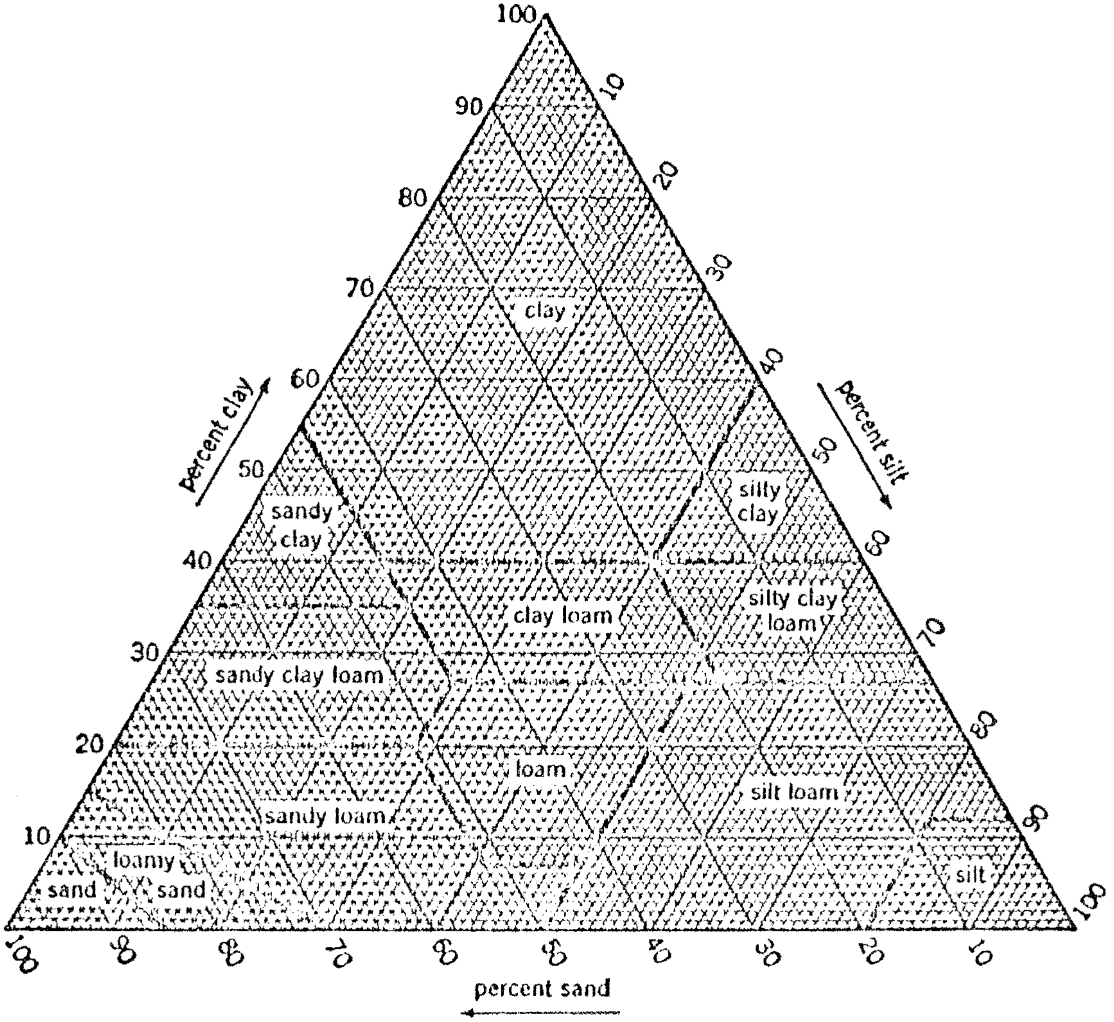
The levels of organic carbon, expressed as percent, decline rapidly from the surface soil to subsoil horizons (Table 16). A conventional conversion of % O.C. x 1.724 = % organic matter was used in this study. Soil organic matter contributes significantly to the CEC as evidenced from sample 4-1A11. This horizon has an exchange capacity of 16.58 meq/100 g despite having 2.43% silt and no clay at all. Most chemical activity takes place in the 20 μ or smaller size fraction, as suggested by Witt and Baver (1937). They indicated that 20 - 5 μ diameter silt had 1/10 the surface reactivity of coarse clay and less than 1/20 of the adsorptive capacity of colloidal clay (< 100 m μ diameter).

In the pipette method of mechanical analysis virtually all unexplained error goes into the silt fraction, and only a loss of sand in the various sieving and weighing operations could increase the value for silt. A part of the 2.43% silt presumably included some experimental error; also, some of the silt was of the relatively inactive size fraction above 20 μ . Therefore, the CEC in sample 4-1A11 may be predominantly attributed to its organic matter content.

Dead roots, leaves, branch material, animal wastes and all other sources of organic C which contribute to the high organic matter level of 4-1A11 may also contribute to the CEC. By Rode's (1962) estimate, the CEC of soil humus is 180-200 meq/100 g, and fresher organic residues show an exchange capacity of about 100 meq/100 g. With 10.02% O.M. in sample 4-1A11, it could have a CEC between 18.04 and 20.04 meq/100 g, which could be ascribed to O.M. matter alone. The determined CEC of 16.58 meq/100 g in a soil which is 97.57% sand shows that virtually all of the exchange capacity arises from the organic matter. In site 8 also, where most horizons have coarse textured soils, the organic matter plays an important role in the establishment and survival of vegetation. There, as elsewhere, organic matter contributes to water holding capacity and is a source of nutrients.

Most of the soils of Ujung Kulon are not very high in clay. Of 33 samples tested only 4 were clearly clay in texture and two other samples were borderline clays (see Figure 7). To account for the surprisingly high CEC of the coarse soils it seems evident that both % O.C. and clay content must be considered. Using data obtained in this study, a regression equation incorporating both % O.C. and % clay

FIGURE 7
SOIL TEXTURAL TRIANGLE



SOURCE: U.S.D.A. SOIL SURVEY MANUAL, 1951.

was worked out to predict CEC for the diverse soil conditions found within Ujung Kulon. The equation:

$$\hat{Y} = 0.582X + 10.542 \qquad (20)$$

where X = % O.C. + % clay

$\hat{Y}$ = predicted CEC in meq/100 g soil

and gave a better prediction of CEC than if either % O.C. or % clay alone were substituted for the X values. Regression coefficients of $r = 0.80$, 0.39 and 0.76 respectively, were obtained when X = % O.C. + % clay, X = % O.C. and X = % clay, respectively. Figure 8 shows a comparison of actual CEC values and the computed regression line for the relationship between CEC and % O.C. + % clay.

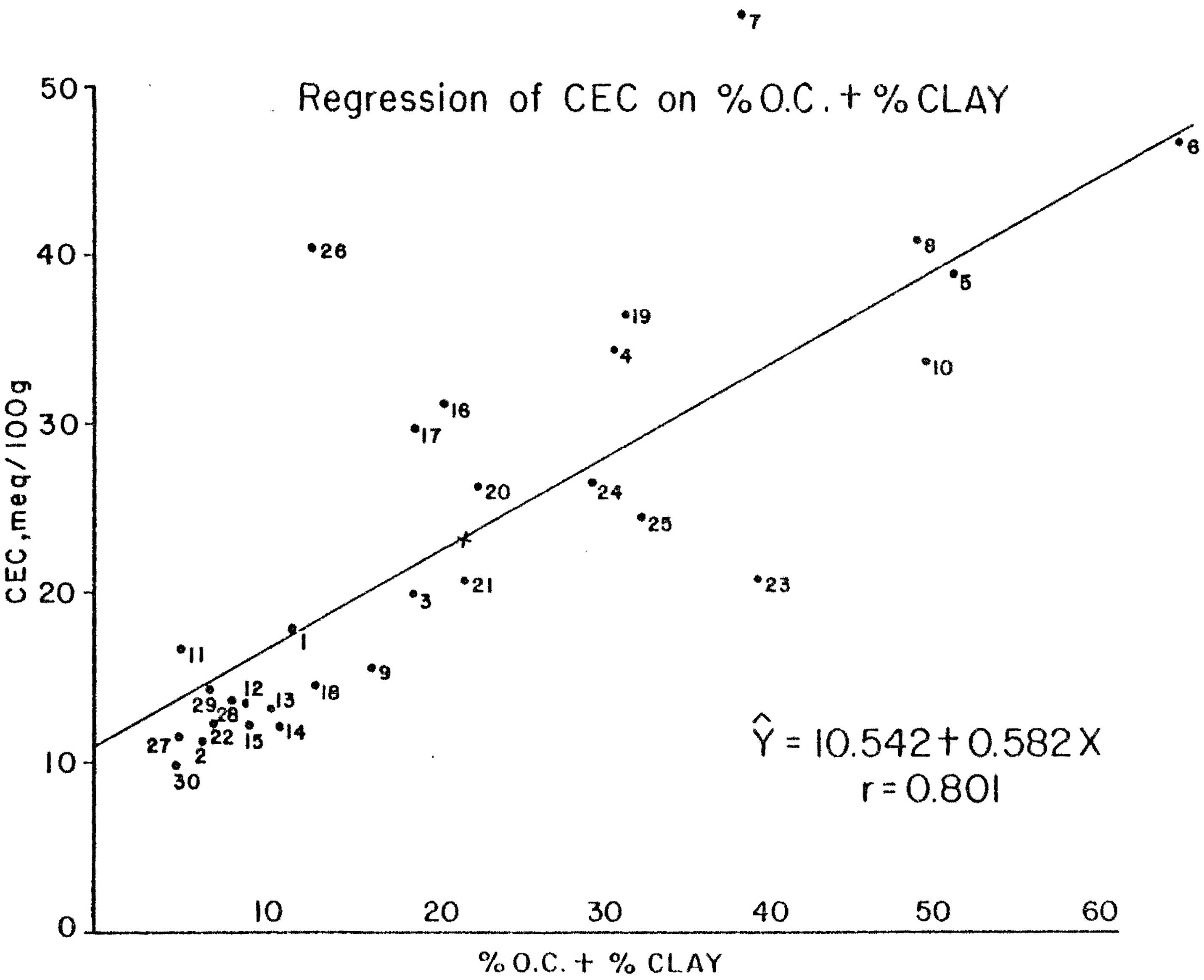
Mineralization and Soil Genesis Theories

A soil genesis theory (Tan and Schuylenborgh, 1961) developed largely by Schuylenborgh (Schuylenborgh and Rummelen, 1955; Schuylenborgh, 1957, 1958, 1959) which was propounded by Mohr (1922) and Joffe (1931, 1936) holds that:

Under suitable conditions of high base status, adequate air, water and temperature regimes, the organic matter decomposes completely so that the soil forming agent (which is the most important) is carbonic acid. Products of decomposition are CO_2 and water.

The differential rate of mineralization of soil organic matter was held to be of extreme importance for the process of soil formation (Hong and Schuylenborgh, 1959). A rapid mineralization of Ujung Kulon soils is supported by the findings of Schuylenborgh (1957) who reported litter layers of only one leaf thickness, and whole descriptions of profiles elsewhere generally lacked humus

Figure 8



Regression of CEC on %O.C. + %CLAY

layers. In Ujung Kulon the absence of a buried A horizon under the Krakatau tuff suggests that mineralization has gone to completion in all sites investigated.

Despite the lack of humus in surface soils of the lowland tropics, % O.C. is considerable. Jenny et al. (1949) found total nitrogen, organic matter and C/N ratios to be higher in Colombian forests than in similar well-drained upland soils of temperate areas. They estimated an average mineralization rate of 3% of the organic matter. They calculated that less than a decade was required to reach a near-equilibrium accumulation of forest litter in tropical forests, compared to 100-200 years under Ponderosa Pine in North America.

Elevation and temperature, however, play strong roles in litter accumulation within a narrow geographical region. Schuylenborgh (1958) showed that higher elevation soils have somewhat thicker humus layers and, consequently, higher O.M. values than lowland soils in Indonesia. He proposed 5 belts of soil development based somewhat on elevation:

1 - 1600m - 1300m elevation
2 - 1300m - 1000m
3 - 1000m - 600m
4 - 600m - 300m
5 - <300m

with considerations for pH, morphology, C/N ratios and R_2O_3/SiO_2 ratios. All of Ujung Kulon would be included in belts 4 and 5, and the soils therein he described as podzolized brown latosols and latosolic soils, respectively. In an earlier work, however, Schuylenborgh and Rummelen (1955) considered soils formed from andesitic tuff at an elevation of 1000-1500m as grey-brown podzolics, i.e. true Spodosols due to clay accumulation in the B horizon; while Tan and Schuylenborgh (1961) classified as brown podzolics the Sumatran soils found at 500-1100m, with red-yellow podzols at less than 500 m elevation.

The Schuylenborgh classification postulates were explained (Schuylenborgh, 1957) more fully for West Javan profiles derived from dacitic tuff of the Danau volcano which disappeared in the Pleistocene era. Four profiles at an elevation of ca. 70 m were examined by Schuylenborgh and classified into either:

(1) Podzolized Reddish-Brown Latosolic soil--on the basis of marked increase in clay content (indicating podzolization processes) and increase in SiO_2/R_2O_3 ratio with depth, or

(2) Red-Yellow Podzolic--increase in clay and a decrease in SiO_2/R_2O_3.

Schuylenborgh concluded (1957) that in the humid tropical region the C/N quotient of the podzolic soils is practically constant while the molar Al_2O_3/Fe_2O_3 ratio of the clay fraction increases with depth. In latosolic soils the C/N quotient and the Al_2O_3/Fe_2O_3 ratio in the clay decrease with depth.

The decreasing SiO_2/R_2O_3 ratios with depth and the increasing clay content (Table 21) in Ujung Kulon support the Schuylenborgh (1957) characterization of Red-Yellow Podzolic soils. The C horizon is seen as an anomoly. The C/N ratios in Ujung Kulon, however, do not seem to decrease with depth in all profiles -- one of the Schuylenborgh criteria for latosolic soils.

Soerianegara (1972) considered the buried clayey soils of marl origin of nearby P. Peucang as podzolized grumusol in accordance with earlier criteria of Dudal and Soepraptohardjo (1961) and Soepraptohardjo *et al*. (1966) for grumusols. He recognized that many of the properties did not agree because the uppermost horizons lack dark coloration of grumusols (Vertisols) and the Peucang soils did show eluvial and illuvial differentiation.

c. The C/N ratio

The near uniformity of C/N ratio found by Schuylenborgh and Rummelen (1955), Jenny *et al*. (1949) and in this study (see Table 16) indicate near equilibrium in soil development, as discussed by the various authors. In the Schuylenborgh and Rummelen study the uniformity of C/N ratio throughout the profile was true despite a 10-fold decrease in both % O.C. and % N with depth. The study by Jenny *et al*. (1949) suggests that uniform C/N ratios may be an indicator of virgin forest conditions. They found a C/N ratio of 9.6-11.0 in one virgin forest site in Costa Rica and 10.0-14.3 in another site. Results of the present study show a greater C/N range, but there was a trend towards uniformity.

The overall virgin forest status of Ujung Kulon has already been established, at least for the less accessible areas--sites 3, 5, 6 and 7. Alluvial accretions in sites 4 and 8 preclude them from consideration in the same manner; and due to probable extensive destruction of the vegetation in those sites in 1883, designation of virgin forest

Table 21. Percentage clay, SiO_2/R_2O_3 and Al_2O_3/Fe_2O_3 ratios of Ujung Kulon soils.

Site/horizon	% Clay	SiO_2/R_2O_3	Al_2O_3/Fe_2O_3
1-1A	10.84	1.46	1.28
1-1C	6.01	2.30	2.59
1-1IIC	18.67	1.07	1.00
2-1A	29.86	2.39	3.05
2-1B22	51.34	1.84	2.98
2-1B22t	65.57	1.70	3.09
3-4A11	34.04[a]	1.46	2.56
3-4A12	47.55[a]	1.36	2.53
3-4C	16.19[a]	2.61	3.56
3-4IIC	48.92[a]	1.10	2.42
4-1A11	0.0	2.71	2.67
4-1A12	5.88	2.26	2.95
4-1C	9.51	1.95	2.40
4-1IIC1	10.18	1.77	2.28
4-1IIC2	9.26	1.62	2.19
5-1A11	15.57	2.46	3.81
5-1A12	16.66	2.30	3.78
5-1C	12.82	2.57	3.80
5-1IIC	32.10	2.04	4.23
6-1A11	18.85	2.05	3.07
6-1A12	19.47	1.85	3.18
6-1C	6.24	2.31	3.41
6-1IIC	39.30	1.37	2.93
7-1A11/A12	26.37	1.52	3.27
7-1IIC	32.20	1.42	2.93
8-1A	8.57	2.22	2.52
8-1C11	4.10	----	----
8-1C12	7.51	2.06	2.47
8-1IIC1	6.22	1.98	2.57
8-1IIC2	4.46	1.90	2.65

a-Clay samples from 3-4 series.

in those sites is inappropriate. As discussed earlier, the mosaic of which sites 4 and 8 are representatives may be due, in part, to a residual pattern of succession first initiated by tidal wave action and/or piecemeal destruction of overstory vegetation by water spouts. Richards (1952) thought that tropical savannas, of which site 4 might be considered an example, are due to edaphic factors or are stages in a hydrosere. It seems that the latter reason is more valid in the case of site 4, inasmuch as a high water table exists for much of the year.

Although site 1 may be considered to be in near-equilibrium from a soil development standpoint, the predominance of herbaceous vegetation is not comparable to other sites studied. The site, however, is representative of the open shrub found along Ujung Kulon's south coast. In any case, additions of organic residue are not expected to be as great as in fully stocked forest sites. Site 2, which may be close to other forested sites in organic matter production may, however, be more representative of organic matter depletion rather than accretion, due to evidence of moderate to severe erosion.

Forms of Silicon in the Soil

Water soluble silicon levels in soil profiles varied appreciably between sites but showed only small increases with depth (Table 17). The C horizon showed a sharp increase in Si but the level normally decreased in the horizon below it. A typical laterization process whereby SiO_2 is leached downward leaving only sesquioxides at the surface cannot be discerned from the results obtained. Slightly higher content of Si in the C horizon may be due to a greater SiO_2 content of the tuff at the time of its deposition, as well as some desilication of the overlying horizons. Mohr (1944) reported about 66% SiO_2 in the Krakatau ash. The extremely high 103.4 ppm value for Si in 3-1A11 is beyond what can be found for soil Si in the literature (Dr. R. L. Fox, personal communication) but not beyond theoretical limits of Si solubility. Chan (1972) presented a graph of SiO_2 solubility at various pH levels; crystalline quartz at pH 2-4 was soluble to about 2 m mole/l, or about 56 ppm of Si in solution; at up to pH 8 the solubility increased to nearly 3 m mole/l, or 84 ppm of Si. Other forms of Si are even more soluble. Cristobalite, the least crystalline form of SiO_2 found in nature (Iler, 1955) also has the greatest solubility. Tridymite, a form of SiO_2 between quartz and cristobalite in solubility was known to be in the Krakatau ejecta (Stehn, 1929) but was not found in the X-ray diffraction patterns (XRD). Cristobalite, on the other hand, exists in site 5. Amorphous silica in the form of gel has a solubility of 0.01 - 0.015% (100-150 ppm) at ordinary temperatures, and the gel is thought to be abundant in organic matter. German researchers cited by Iler (1955) produced a solution of colloidal silica containing 200 mg of SiO_2 per liter (220 ppm) which later stabilized at about 165 ppm, comparing favorably with the findings of Iler (1955).

In all probability, the soil silicon in the sites is a combination of several forms found in nature. An accurate assessment is difficult because of the impurity of minerals found in nature when compared to the values of published "standard" end-members (Garrels and Christ, 1965). A compounding error may result from failure to recognize the silica that may result from cycling of decomposing plant parts.

Several tree species found in Ujung Kulon are known to contain amorphous silica. Sharma and Rao (1970) found silica in vessels, fibers, ray cells or vertical parenchyrma in about half of 134 species of Indian timbers. Many of the silica bearing genera included in their findings are also found in Ujung Kulon, among them: Vitex, Cryptocarya, Dillenia, Syzygium and Artocarpus. Range of silica content of these genera was 0.06 - 0.82% for Syzygium to Artocarpus, respectively. In the Philippines, the Forest Products Research Institute (1961) found 83 of 161 listed species contained silica inclusions. Streblus asper and Artocarpus elastica were highest among the 10 species found also in Ujung Kulon, with 4.82 and 3.96% silica, respectively. No attempt was made, however, to determine the silica content in Ujung Kulon vegetation. Nevertheless, it may be more than coincidence that the subsoil profiles of 5-1 where Streblus asper is found and 2-1 where Artocarpus elastica is growing have correspondingly high water-soluble silicon levels.

It would seem that the most important factor for the high Si content of sites 3 and 8 is the presence of carbonates in the soil. The work of Dienert and Wandenbulche reported by Iler (1955) demonstrated that alkaline salts accelerate the formation of soluble silica. Inasmuch as the solubility of silica rises sharply with a rise in pH (Iler, 1955), there is concurrent cause-effect condition within these sites. Although the pH of the soils in site 3 varied from 6.49 - 7.73, the pH of the marl rock itself was 8.1

Silica may be the chief cementing agent in the marl of site 3, and de-silication may lead to formation of the "lime sinter" as reported by Schenkel and Schenkel-Hulliger (1967) in streams of the Telanca area. The "sinter" is probably a combination of calcium carbonate and highly hydrated silica. Smooth surface crusts on rocks found in the downstream reaches of the Telanca watershed are probably a result of gradual evaporation of water rich in silica and calcium. Presumably, as long as the water head has sufficient pressure the silica and calcium are discharged into the sea. When rainfall diminishes, however, the width of streams decreases and the flow of water declines. Evaporation then takes place in isolated pools and along the peripheries of the water line. Once dehydration has taken place to a sufficient extent, the crust hardens and becomes relatively insoluble.

Although the carbonates responsible for catalysis of soluble silica are also found in site 8, and where high soil silica is evident, the lime sintering does not appear to take place. On the contrary, the seasonal flooding tends to cause broad lateral dispersion of the solutes. When drying occurs, the solutes are largely re-deposited in place, resulting in high values for Si in surface soils. The dissolved solutes within site 3 may, likewise, lead to high Si levels in the surface, but owing to deep internal drainage in the upper part of the Telanca escarpment, the crusting effect on rocks in the upper reaches of the streambeds is not evident.

Another feature shared by the soils in sites 3 and 8 is an apparent silicon-phosphate interaction. Limestone may be phosphatized (Clarke, 1924) and the highest levels of extractable P are found in the calcareous soils of sites 3 and 8. In site 8 the sharp reduction of P in the subsoil (Table 17) may be due to seasonal effects. Reduction of Fe^{+++} to Fe^{++} apparently releases mobile phosphate (Russell, 1950) which may be largely absorbed and stored in plant tissue, as discussed by Johnson (1976). When sampling is done in the dry season, the P levels might seem erroneously low. Leaf P was highest in sites 4, 1 and 8, respectively (see Appendix A). Although it is not known what species, if any, have normally high leaf P levels, the higher than average leaf P levels in site 4 may also be a result of seasonal reducing conditions in the soil.

Another apparent interrelationship exists between silicates, carbonates and phosphates. It is thought that the carbonate and/or bicarbonate ion is the cause of greater Si solubility and P solubility as well. In sites 3 and 8, high Si and P levels (Table 17) go hand in hand for the whole profile; however, Si decreases only gradaully between hozizons except for the C; and P decreases quite sharply in the subsoils. Since most plant roots go deeper than the shallow A11, A12, and C or corresponding overlying horizons, efficient plant extraction of P from subsoil is not unexpected. Normally high amounts of organically-bonded P is typical in surface residues, but may be significantly more so in these sites due to the presence of carbonate/bicarbonate ions. On the other hand, Si could reduce P uptake below its normal level. Schollenberger (1922) found an inverse relationship of P level and yield of wheat. He speculated that silicon as $CaSiO_3$ lime could have had a P uptake ameliorating effect when substituted for $CaCO_3$ which produced the lowest yields but had the highest P levels. More recent data do not support this idea (Dr. J. A. Silva, personal communication). Since both Si and P were high in the soils of sites 3 and 8, no definite conclusion can be reached about the nature of the relationship.

Soil Genesis in Ujung Kulon

The study of the processes of soil development in Ujung Kulon is facilitated by the presence of the precisely dated Krakatau tuff horizon in the soil. As a parent material, the tuff has been designated, where it was found, as the C horizon. Soil formation atop the C subsequent to tuff deposition must, therefore, represent either the weathering products and alteration of the C horizon; alluvial and/or colluvial accretions; soil genesis due to mineralization of organic matter; or accretions due to inverted or partially-inverted horizons resulting from upturned tree roots during wind blow-down. Lack of a C horizon would, on the other hand, indicate that erosion obliterated the tuff. Consequently, nothing could be said about the rate of soil formation in absolute terms. Approximations could be made, however, if the properties of the subsoils and other existing horizons were sufficiently identified by comparing them with adjacent pedons containing the C horizon.

Deep weathering is a well known feature of tropical soils. It stands to reason that if deep weathering were the rule, there must be a correspondingly high rate of new soil formation. In an attempt to determine the factors which affect that rate, Jenny (1941) focused on weathering rate of a variety of materials of known age, ranging from tombstones to natural soil profiles. The greatest weathering he recorded was to a depth of 80 mm over 568 years in natural soil, an average development rate of 0.141 mm per year. Tamm, as cited by Jenny (1941), estimated that a podzol with 4 inches (10.2 cm) of raw humus, 4 inches of A and 10-20 inches (25.4-50.8 cm) of B horizon requires 1000-5000 years to develop in Sweden, an average rate of 0.305-0.711 mm per year. Baren, as reported by Jenny (1941), measured 350 mm of new soil developed on Lang Island in the Krakatau Group only 45 years after the 1883 eruption, an astounding average of 7.78 mm per year.

Weathering of parent materials does not proceed uniformly over the years, however. It takes place slowly at first in coarse textured materials which have small surface area, proceeds more rapidly as surface area increases and again declines after most chemical dissolution has been completed. Temperature, rainfall, biota and the nature of the parent materials all play important roles in the rate, according to the celebrated integral soil development concept first expounded by Dokachiev. Since all factors operate along a continuum, each factor representing a differential component, true integration in the mathematical sense is not possible. It is more appropriate to say, therefore, that in this study, an average of about 98 mm of soil was formed in the interim 90 years since the Krakatau eruptions. Average thickness of combined A11 and A12 or corresponding horizons, when they occurred above an intact C horizon was 98 mm over 33 observations. Table 22 shows depth of overlying horizons and the relationship of depth to site.

The wide range in the thickness of horizons above the C horizon within each site are manifestations of microsite differences. Slope,

Table 22. Thickness and occurrence of horizons overlying Krakatau tuff (C horizon) in Ujung Kulon soils.

Site and pit		Depth of overlying horizons (cm)	C horizon thickness (cm)
1	1	8	4
	2	6	7
	3	5	6
	4	8	9
	5	18	7
2	1	-	absent
	2	-	absent
	3	-	absent
	4a	19	9
	4b	9	3
	5	-	absent
3	1a	10	3
	1b	12	uneven
	?	15	5
4	1	6	4
	3	10	absent
5	1a	9	absent
	1b	10	4
	2	10	absent
	3a	10	absent
	3b	7	6
	4	5	absent
	5	10	absent
6	1	11	9
	2	7	4
	3	12	6
	4	20	10
	5	2	3
7	1	10	15
	2	18	6
	3	8	10
	4	8	absent
	5	5	3
8	1	13	10
	1A	4	6
	2	5	absent
	3	13	11

perhaps, is the most important factor playing a role in horizon thickness in Ujung Kulon, inasmuch as slope influences or facilitates erosion. Localized difference in slope would be manifested in the horizons which overlie the C, as well as the C horizon itself. Colmet-Daage and Gautheyrou (1974) noted the effects of steep slope on differences in the thickness of ash deposits in Martinque and Guadeloupe. Absence of the C horizon in 4 of 6 borings in site 2 and in 5 of 7 borings in site 5 attest to conditions of localized erosion. Measurement of the thickness of overlying horizons, however, was done when both the overlying horizons and subsoils were identified. It is noted that in site 2 even the overlying horizons were eroded off, due perhaps to periodic minor flooding of this site which lies astride a small streambed.

Any attempt to estimate the rate of soil formation would best be made on flat rather than sloping ground. Only sites 1, 4 and 8 are sufficiently level to qualify, but it is thought that alluvial accretion predominates in site 4, while lateral transport of materials influences soil building in site 8 (where organic residues seem to concentrate in small hummocks). Only in site 1 does normal weathering with depth appear to be least influenced by outside conditions. Colluvial accretion effects can be seen, however, in pit 1-5 which is located near the base of a minor hump in an otherwise nearly level site.

The Tuff Layer

Identity of the Krakatau tuff layer is well established from the disparaties of chemical and physical properties it possesses in comparison with adjacent horizons. Some results must be viewed with reservations, however. In particular, many ionic species which are mobile in the soil may seem to cause abnormally high or low base status in the C horizon. Large differences may reflect ionic migration upward or downward in the solum at a given point in time, and be more related to capillary or gravitational forces at different seasons rather than relate to properties of the tuff itself. The CEC, it is felt, is a more nearly static and intrinsic chemical characteristic of the tuff than is the status of exchangeable bases or other important nutrients. The CEC of the C horizon has a standard deviation of only 1.67 meq/100g in the 6 sites where it was found and determined, compared to 11.48 meq/100g in the immediately adjacent overlying horizons and 9.89 meq/100g in horizons immediately below. Illustration of CEC differences by horizon is shown in Figure 9. Furthermore, differences in CEC are not significant among site profiles considered in their entirety but are significant at about a 2% level for various horizons within each site (Table 23).

By a Duncan multiple range test, (Duncan, 1955; Harter, 1960) a significant difference of intra-profile CEC occurs between the C horizon and the contact horizons, but not between the contact horizons. Due to absence of A12 horizons in sites 1 and 8, the immediate contact horizons in Table 23 have been designated as "upper" and "lower".

Differences in Munsell color values of the C horizon among the sites suggest that the original color of the tuff is being altered to more nearly that of the contact horizons. It is thought that color changes from dark to light reflect mostly organic matter and clay

Figure 9

CEC by Horizon of Selected Ujung Kulon Soil Profiles

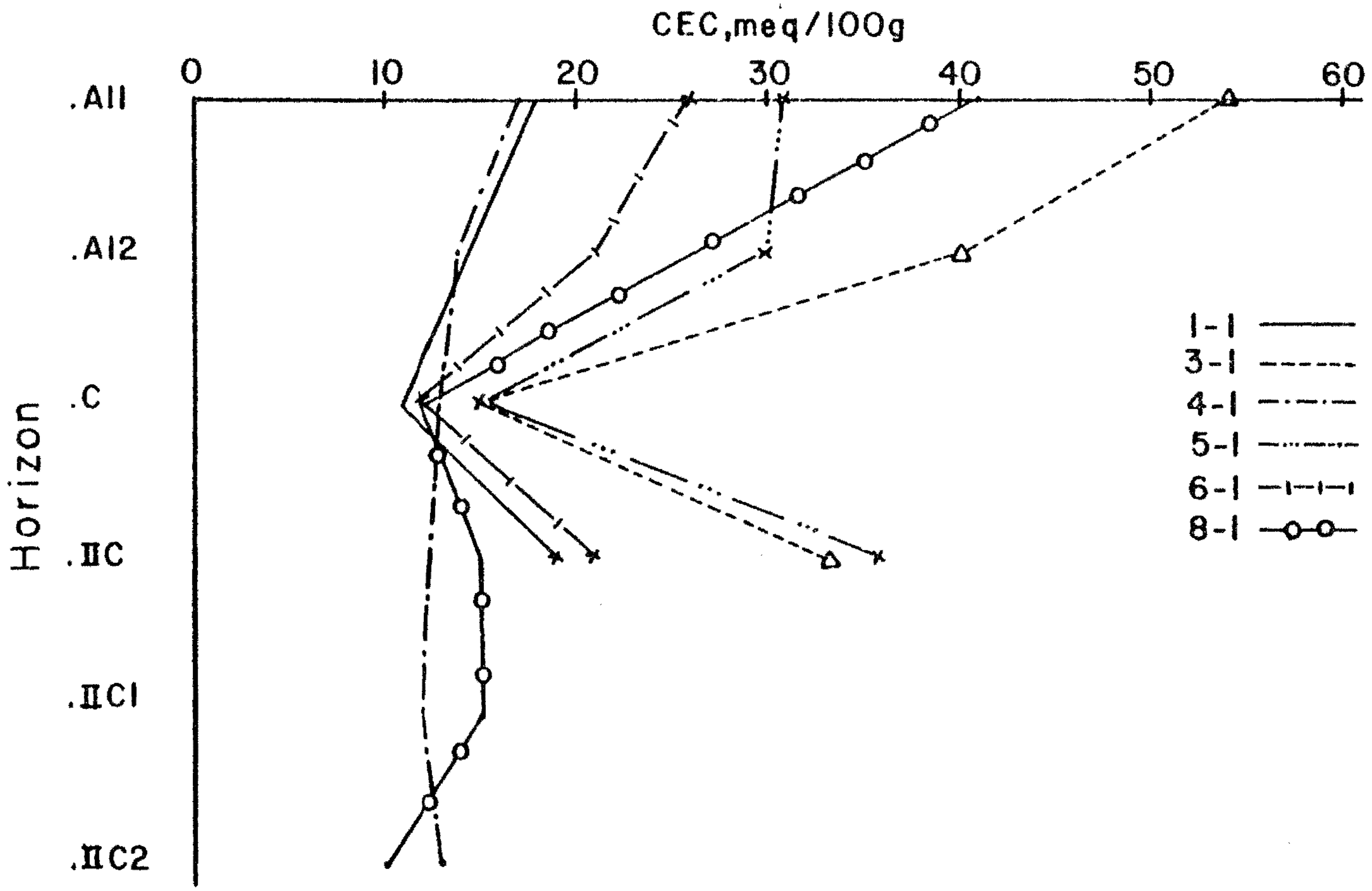


Table 23. Analysis of variance of intra-site and inter-site CEC of C horizons and contact horizons of selected profiles.

Horizon	Site 1	3	4	5	6	8	Total	$\bar{x}$ [1]
				CEC meq/100g				
Upper	18	40	14	30	21	41	164	27.3a
C	11	15	13	15	12	12	78	13.0b
Lower	19	33	12	36	21	14	135	22.5a
	48	88	39	81	54	67	377	

Source	df	MS
Sites	5	123.12
Horizons within site	2	319.06*
Error	10	54.72
Total	17	---

---

[1] Means designated with the same letter are not significantly different at $p < .05$.

eluviation. Indeed, most of the clay found in the C horizon appears to be coatings on the tuff particle surfaces.

If the organic matter and clay illuviates are mainly responsible for fluctuations in the CEC, then a closer approximation of the CEC of pure tuff could be determined by subtracting the relative proportions of % O.M. and % clay. Table 24 attempts to show this proposition. It was assumed, however, that for all samples 1.724 x % O.C. = % O.M.; all O.M. had 190 meq/100g of exchange capacity; and all clay had 25 meq/100g of exchange capacity. The higher values obtained for sites 3 and 5 would be further reduced if some proportion of the CEC were ascribed to smectite, which was found in both sites. Montmorillonite, according to Rode (1962) has a CEC of 60-100 meq/100g.

Some color changes are also attributed to indirect effects of the lower contact horizon. Most noticeable in this respect was in site 1, where ant and termite movement through the soil resulted in intermittant discoloration of the C horizon around well-travelled passageways. Both upper and lower contact horizons soil colors' could be seen in the vicinity of the passageways. Again, however, the color as well as the chemical properties are thought to be transported rather than <u>in situ</u> features. Nye (1961) suggested that considerable fertility may be ascribed to the activity of termites, inasmuch as increased crop yields have been reported in the vicinity of termite mounds.

Because the relatively fresh Krakatau tuff may be considered as point "zero" in soil genesis, any changes within a particular profile since deposition may be more manifested in the C horizon than elsewhere. Relative change among profiles might also be reflected in

Table 24. Net CEC of tuff, derived by subtraction of CEC components found in clay and organic matter.

Sample	Calculated CEC meq/100 g	Less clay content @ 25 meq/100 g		Less O.M. content @ 190 meq/100 g		Net CEC meq/100 g
		% clay	meq	% O.M.	meq	
1-1C	11.35	6.01	1.50	1.57	2.98	6.87
3-1C	15.30	16.19	4.05	1.67	3.17	8.08
4-1C	13.11	9.51	2.38	2.52	4.79	5.94
5-1C	14.54	12.82	3.20	1.62	3.08	8.26
6-1C	12.30	6.24	1.56	2.07	3.93	6.81
8-1C11	11.59	4.10	1.02	2.26	4.29	6.28
8-1C12	13.58	7.51	1.88	2.40	4.56	7.14

correspondingly greater change in the C horizon. Where erosion is severe, however, no comparisons are possible.

The light hues of the deep subsoils in sites 2, 5, 6 and 7 suggest that, as weathering progresses, soil color becomes increasingly lighter over much of Ujung Kulon. Decrease in particle size from sand to silt to clay fractions should be from darker to lighter hues if particle size reduction and lighter coloration proceed simultaneously. The data in Table 25 demonstrate a semi-quantitative technique for expressing the relationship of particle size separates and their corresponding color changes. In application, the surface soil is the reference color inasmuch as it has the darkest hue and lowest values and chroma. Departures of one unit in hue have arbitrarily been assigned a 3-count; departure in value of one unit a 2-count; and departure of one chroma unit a 1-count. Scoring is based on positional change rather than numerical unit change since chroma units assigned to different hues are currently inconsistent.

Intra-site and inter-site changes should reflect, to some degree, the extent and rate of weathering. Sharp color changes between soil horizons do occur, especially between the fresh C and the residual subsoils; but it is because the tuff layer is an anomalous intrusion that inter-site color changes may reflect soil neo-genesis processes most clearly.

It is recognized that a dark surface layer of organic residue is the norm. It is further recognized that not all soils would lend themselves to analysis in this manner. Spodosols, for instance, have abrupt color changes from light to dark between the elluviated A2 horizon and the diagnostic spodic horizon. The proposed technique herein used for Ujung Kulon soils must, therefore, be tested and refined to account for differences among other dissimilar soils.

Nevertheless, the arrangement of color chips in Munsell color coding is based on a logically progressive sequence which is supported by the consistance of within-profile changes as seen in Table 25. On the other hand, the reasons for inconsistancy of change between soil separates is not understood at this time. Any change at all demonstrates that soil color is not uniformly shared among sand, silt, and clay fractions. The change in color is indicative of a weathering process, albeit here expressed in a form which depends upon quantum change by discrete units rather than movement in a continuum. The very coarse sand fraction of 2-1B22t was found to contain only red mottles whereas cylinders of the clay suspensions of that horizon resembled 6-1IIC and 7-1IIC. For the most part, progressive lightening of intra-profile color change is clearly demonstrated in Table 25 because the bold contrasts of the mottle colors are not easily detected in the whole soil matrix; also the very coarse sand fraction of 2-1B22t represented less than 1% of the matrix. Neither do drastic color changes occur in the tuff horizon even though it is an anomoly, because of the migration of silt and clay through the profile.

The effects of slope and consequent erosion are, perhaps more important in obliterating regular horizonation than any other factors because of the speed with which the obliteration may be achieved. A notable example is the absence of A11 and A12 horizons in much of site 2, although supplementary horizon descriptions (2-3 and 2-4 in Appendix B) indicate they did exist. Steep slope in 7-1 obscured differentiation of the A11 from A12 in the main soil pit, but ample evidence of

Table 25. Units of change in Munsell color codes by horizons and between soil separates of Ujung Kulon soils.

Sample	Sand		Silt Color Code		Clay		Units change between separates	
		Units change		Units change		Units change	Sand to silt	Silt to clay
1-1A11	10YR 3/2	-	10YR 3/2	-	7.5YR 4/4	-	0	+ 1
1-1C	10YR 3/2	0	10YR 4/4	+4	a	-	+4	a
1-1IIC	10YR 3/2	0	7.5YR 3/2	-3	10YR 4/3	+2	-3	+ 6
2-1A	10YR 3/2	-	10YR 4/4	-	10YR 5/4	-	+4	+ 2
2-1B22	10YR 4/4	+4	10YR 5/4	+2	10YR 5/4	0	+2	0
2-1B22t	10YR 4/4	+4	10YR 5/4 b	+2	2.5Y 6/4	+8	+2	+ 5
3-4A11	10YR 2/2	-	10YR 2/2	-	10YR 4/4	-	0	+ 4
3-4A12	10YR 2/2	0	7.5YR 3/2 c	-1	10YR 4/4	0	-1	+ 7
3-4C	2.5YR 5/2	+9	10YR 4/4	+6	10YR 5/4	+2	-3	+ 2
3-4IIC	10YR 4/2	+4	10YR 4/4	+6	10YR 4/4	0	+2	0
4-1A11	10YR 2/2	-	10YR 2/2 d	-	-	-	0 e	
4-1A12	10YR 3/2	+2	10YR 2/2 d	0	-	-	-2 e	
4-1C	10YR 4/3	+6	10YR 3/2 d	+2	-	-	-4 e	
4-1IIC1	10YR 4/3	+5	10YR 3/2 d	+2	-	-	-3 e	
4-1IIC2	10YR 5/4	+8	10YR 4/4 d	+6	-	-	-2 e	

a - no sample
b - or 2.5Y 5/4
c - 3-4 A12 rep was 10YR 3/2
d - silt + clay
e - between sand and silt + clay

Table 25. Units of change in Munsell color codes by horizons and between soil separates of Ujung Kulon soils (Cont'd.).

Sample	Sand		Silt Color Code		Clay		Units change between separates	
		Units change		Units change		Units change	Sand to silt	Silt to clay
5-1A11	10YR 2/2	-	10YR 3/1	-	2.5Y 5/2	-	+1	+10
5-1A12	2.5YR 3/2	+5	10YR 3/2	+1	2.5Y 5/4	+2	-3	+ 9
5-1C	2.5Y 5/2	+9	10YR 4/2	+3	10YR 4/2	-5	-5	0
5-1IIC	5Y 5/3	+13	10YR 5/2	+5	10YR 5/2	-3	-7	0
6-1A11	10YR 3/2	-	10YR 4/4	-	10YR 5/4	-	+4	+ 2
6-1A12	10YR 4/2	+2	10YR 4/4	0	10YR 5/4	0	+2	+ 2
6-1C	2.5Y 4/2	+5	10YR 4/4	0	2.5Y 5/4	+3	-5	+ 5
6-1IIC	10YR 5/8	+8	10YR 5/8	+4	10YR 6/8	+4	0	+ 2
7-1A11/A12	10YR 3/2	-	10YR 4/4	-	10YR 5/4	-	+4	+ 2
7-1IIC	7.5YR 4/4	0	10YR 5/6	+3	10YR 5/6	+1	+6	0
8-1A11	10YR 2/2	-	10YR 2/1 d	-	-	-	-1	-
8-1C	10YR 4/2	+4	a	-	-	-	-	-
8-1IIC11	10YR 4/2	+4	2.5Y 3/2 d	+5	-	-	-1	-
8-1IIC12	10YR 5/2	+6	2.5Y 3/2 d	+5	-	-	-1	-
8-1IIC2	10YR 5/3	+7	10YR 4/2 d	+5	-	-	-3	-

the horizons was seen in other borings. Unfortunately, the overall steep slope within the sample plot precluded selection of a more representative main pit. On the other hand, truncation of the profile emphasizes the effects of slope. At the opposite extreme of slope, no A12 was distinguishable in 1-1 even though the ground was level. An irregular, discontinuous A12 was recorded, however, in alternate faces of 1-1 and was seen in other borings throughout Ujung Kulon. The amount of soil available for multipurpose sampling was insufficient, however, to maintain sampling integrity.

Absence of a C horizon in some areas of Ujung Kulon possibly may be attributed to removal of the tuff downfall by the action of the tidal waves which followed the eruptions of August 1883. Since the expulsion of the tuff from Krakatau preceded the last tidal wave, the washing action of the waves may have scoured the ground surface and re-arranged the tuff deposits in sites which were less than 20 m in elevation. Much water-borne tuff was also deposited in the lowlands below the tidal wave crests. Also, since much pumaceous material was expelled from beneath sea level, large floatable pumice stones were part of the cresting waters. Average density of 4 samples of pumice taken from the vicinity of Cidaun was 0.505 g/cm^3,ranging in weight from 5.52 g to 30.52 g.

Despite the fact that volcanic dust remained in the air currents for 2.5 years (Furneaux, 1964), local rain showers undoubtedly precipitated most of the ash in a short period of time, so that the ejecta, as a source of soil parent material, may be considered as laid down at one time.

Particles of tuff which were not water borne, ostensibly those heavier than air that descended in spots above the high water line, were composed of both wind blown fine and coarse materials. Assuming the 20 m was the actual high water mark, sites 2, 4 and 8 were definitely affected by wave action. Sites 1, 3 and 5 were borderline in elevation (refer to Tables 4, 6 and 8) and sites 6 and 7 were unaffected by the tidal waves. It is felt that site 1 was also unaffected by tidal waves inasmuch as it is on the south coast of Ujung Kulon and protected somewhat by G. Kendeng which rises to about 100 m elevation in a blocking position north of site 1.

Mineralogical Properties

Evaluation of the minerals present in Ujung Kulon soils is given in Table 18. In most cases, the primary mineral found is low-temperature quartz, αSiO_2, occurring in the sand and silt fractions (see X-ray powder diffraction file, Sets 1-5, catalogue No. 5-0490). A few exceptions do exist. The calcite parent material of the Telenca formation (site 3) is clearly evident in the sand fraction of 3-4IIC (see Appendix D) but, inexplicably, the major peak for calcite is missing in the silt fraction of 3-4IIC (Appendix E).

In site 5 the crystalline α quartz cannot be positively identified in any size fraction or in any horizon. Plagioclase appears to be present in the X-ray traces of sand and silt, and small amounts of tridymite or cristobalite in the silt and clay fractions (Appendix H). Since tridymite, cristobalite and α quartz are all species of SiO_2, identification in the traces is hampered, probably by mixture with primary plagioclase and with smectite which is also found in the clay fraction. As Garrels and Christ (1965) cautioned, "The most serious error likely to be made...is in forgetting how far minerals do deviate from pure end-member composition..."

In addition to α quartz in site 8, calcium phosphate was found in 8-1IIC1 and i-1IIC2 silt + clay. Perhaps the calcium phosphate did not appear in other X-ray traces owing to differences in oxidation states. The normally wet subsoils of site 8 also contain visably greater percentages of marine shell fragments in the soil fabric. In 8-1IIC2 shells composed about half of the whole soil. Phosphorus removed from skeletal structures of marine organisms may replace carbonates in calcareous sediments (Rankama and Sahama, 1950) but the transition is so rapid that, unlike the formation of calcite as in site 3 as discussed by Clarke (1924), no transition to aragonite is evident.

Various Ca, K and Na silicates in the soils of Ujung Kulon can be seen in some X-ray traces, but apparently they are so poorly crystalline that positive identification has not been established.

Secondary minerals which are found in the clay fraction -- and in the silt + clay where separation was not attempted -- seem to be limited to kaolin, smectite and halloysite for the most part. Selected examples of some primary and secondary minerals are given in Appendix C-J. Surface soils tend to have less secondary mineral content in the clay, although no attempt was made to quantify the amount in each horizon. A general lack of clay in the C horizon is an indication that no substantial amount of clay has been eluviated to the C horizon over the past 93 years. The X-ray diffraction pattern of the clay fraction of samples from 3-4C and 6-1C show traces of only kaolin, whereas 5-1C and 4-1C have smectite. If the soils of the Telanca area were grumusols (Vertisols) as mapped by the Indonesian Soils Research Institute (Lembaga Penelitian Tanah, 1966), then the smectite rather than kaolin should be found in 3-4C. Soerianegara (1972) perhaps recognized the anomaly and classified sandy soils over similar marl derived profiles on Pulau Peucang as latosolized tuffaceous regosols over podzolized grumusols. On the other hand, quartz and smectite are seen in 4-1C (Appendix F) and other horizons of site 4. Displacement of 2:1 clays from upper elevations in the terrain is the norm in soil transport; and rapid eluviation through the alluvial profile of site 4 apparently supercedes any genesis of kaolin clays.

Relative weathering by horizons can be deduced by the data given on Table 19. The total SiO_2 decreases with depth in all horizons except the C. In samples 1-1C, 3-4C, 5-1C and 6-1C the SiO_2 was higher than in the upper horizons; in sample 4-1C it was lower. Elevated SiO_2 levels in the tuff layer are attributed to the residual of the original tuff composition which Mohr (1944) reported averaged about 65% SiO_2. Where found in the Ujung Kulon sites, the tuff ranged from 64.06% - 69.62% in total SiO_2. Higher SiO_2 levels in the surface horizons are due, perhaps, primarily to biocycling of silica bodies in the litter. Nevertheless, plant roots in the lower horizons are thought to re-absorb soluble silica as it becomes available so that sequence de-silication, except in the anomalous C horizon is a true indication of soil genesis.

In site 8, however, there is no apparent de-silication with depth--in fact, the reverse appears to be the case. It can only be suspected that excess SiO_2 accumulates at lower depths in response to a normally high water table. Even though site 4 also has a high water table during the rainy season, increase in its level is due to downward percolation of water vertically through the profile. Increases in water-soluble Si tend to bear out that leaching is the mode of action. On the other hand, in site 8 the water table may actually rise predominantly by vertical upward movement of ground water rather than by direct filling by rain water, once widespread lateral movement of overflowed streams has infiltrated the lowest spots in the terrain. No trend can be seen in the data, however. Lateral transport presumably enriches the ground water and the fluctuating water table then becomes an important agent of transportation (Buol _et_ _al_., 1973) within the profile.

SUMMARY AND CONCLUSIONS

Vegetation

Ujung Kulon is an example of a tropical lowland moist forest. The evidence from eight sites investigated in this study points to wide range in species composition, tree frequency and basal area among sites. The heterogeneous forest thus described is composed of many distinct vegetation associations composing a large mosaic. Some associations appear to be perpetuated as a result of edaphic factors. It is thought that excessive drainage in site 1, on level ground along the south coast, combined with a porous, shallow soil leads to droughtiness which precludes the establishment of many species which are found elsewhere in Ujung Kulon. Also, the high density of *Lantana camara* found there inhibits shade intolerant species from becoming established.

Site 8, in the northeast lowlands, and to some extent, site 4, between two promontories, are influenced by a seasonal water table which restricts species composition to plants able to withstand prolonged waterlogging. Species composition differences between sites 4 and 8 may also be affected by soil pH. In site 4 management activities favor a cleared grazing area, and the grazing itself keeps the volume of vegetation at a low level.

Site 2, along a minor drainage in central Ujung Kulon, is low in volume of stems and in species diversity, probably as a result of repeated erosion of the surface soil. The presence of dense patches of bamboo in a broad-leaved species-bamboo association probably resulted from pioneer establishment of the bamboo *Schizostachyum* blumei in the eroded soil. Subsequent establishment of other species, except near the association peripheries was inhibited.

Sites 3, 5, 6 and 7 are examples of inland, sloping and well-drained forested areas that do not show evidence of either excessive droughtiness of soils or of waterlogging. The frequency of tree stems, the number of saplings present and the range of total basal area of trees plus saplings suggest that the absence of limiting soil physical factors results in markedly greater site utilization in those areas. Species heterogeneity among sites persists, however.

Greater homogeneity of intra-site speciation in sites 1 and 8 may be due to the effect of wind blowdown in addition to edaphic factors. Much of the northeast sector of Ujung Kulon, including the periphery of the Telanca area has a high water table where trees are typically shallow-rooted and subject to blowdown by wind and waterspouts.

Soils and Their Properties

Numerous chemical nutrient determinations of the soils, supplemented by leaf tissue analysis, failed to establish definite relationships between nutrient status and apparent site productivity. Due to high content of organic matter and the presence of smectite clay, the cation exchange capacity of most soil profiles is moderately high.

Calcium predominates among the exchangeable bases of surface soils, especially in sites 3 and 8 which have high soil pH readings and free $CaCO_3$. In subsoils of sites 6 and 7 the amount of exchangeable K and Na exceeds Ca. The volume of vegetation on the sites could not be correlated with the amounts of exchangeable bases or with the percentage base saturation. The greatest numbers and basal areas of trees and saplings occur in sites 6 and 7 which have among the lowest total of exchangeable bases and the lowest % B.S.

Organic carbon levels exceed 5% in about half of the surface soils investigated, but decrease sharply with depth. Those soils which have high organic C also have the greatest amount of total nitrogen, which is a maximum of about 0.5%. Lower percentages of organic C and N in other surface soils and in deeper horizons of all profiles except 1-1IIC generally correspond with one another so that the C/N ratio is relatively uniform.

Amounts of extractable soil phosphorous detected vary widely, from a low of 3 ppm to a high of 275 ppm. Although the highest P levels are found in surface soils in some profiles, high levels (up to 170 ppm) are also found in the C horizon.

The amount of water-soluble silicon detected is appreciable, thus reflecting the presence of α-quartz, an important primary mineral found in Ujung Kulon, and other forms of silicon, which include: silica bodies found in decomposing organic residues; cristobalite found in the silt and clay fractions; and residual SiO_2 in the Krakatau tuff. A probable P, Si and carbonate-bicarbonate ion interaction may explain the high values of those ions in the calcareous soils of sites 3 and 8.

In addition to α-quartz and cristobalite, the Ujung Kulon mineralogy also includes plagioclase, calcite and calcium phosphate among primary minerals; and smectite, and kaolin among secondary minerals.

This investigation showed evidence of a rapid rate of soil development in the area of study. Indications of clay increase with depth and a decrease of SiO_2/R_2O_3 ratios with depth point to a podzolization process of soil formation.

It is speculated that the anomalous C horizon may have been responsible for decreased tree growth and vigor for some time following deposition in 1883. Species distribution patterns of some plants may have also been affected. The low biomass estimates obtained may be partly due to the resultant stresses; to the edaphic considerations described; and to the natural limitations of productivity of a moist tropical forest.

Appendix A. Plant tissue analysis data of selected species of Ujung Kulon vegetation.

Site	Species	P %	K %	Ca %	Mg %	Na %	Cu ppm	Fe ppm	Zn ppm	B ppm	Mn ppm	Al ppm	Ba ppm
1	*Arenga obtusifolia*	0.13	0.63	0.53	0.29	0.01	8.3	80	7	27	63	50	0.3
	Corypha utan	0.17	1.19	0.59	0.24	0.04	7.2	66	11	23	181	50	0.0
	Lantana camara	0.47	2.27	1.83	1.01	0.13	25.8	168	62	84	174	150	9.4
2	*Arenga obtusifolia*	0.13	0.74	0.78	0.25	0.01	8.4	168	10	25	32	210	9.2
	Artocarpus elastica	0.14	0.86	1.25	0.13	0.04	7.2	204	10	33	54	300	44.1
	Dillenia excelsa	0.16	0.95	1.43	0.22	0.06	7.6	71	20	49	21	120	46.5
	Schizostachyum blumei	0.12	0.69	0.15	0.18	0.01	7.3	63	220	4	282	90	10.8
3	*Aglaia elliptica*	0.14	0.51	1.26	0.34	0.15	15.2	115	15	145	44	170	3.6
	Arenga obtusifolia	0.11	0.63	0.94	0.24	0.02	9.5	61	10	27	26	80	1.7
	Strombosia javanica	0.33	0.73	2.12	0.46	0.06	12.7	68	13	50	30	90	2.4
	Wetria macrophylla	0.17	0.66	2.36	0.26	0.02	8.5	84	13	61	49	100	3.9
4	*Chrysopogon aciculatus*	0.21	1.63	0.27	0.25	0.03	8.2	316	28	39	218	290	4.7
	Dillenia obovata	0.22	1.10	1.41	0.48	0.06	9.1	146	21	60	589	140	5.3
	Hyptis capitata	0.43	5.22	1.73	0.68	0.09	14.7	1183	97	108	664	950	34.1
5	*Arenga obtusifolia*	0.12	0.40	0.87	0.30	0.01	8.3	59	8	27	28	110	16.9
	Drypetes macrophylla	0.09	0.91	2.03	0.51	0.05	8.6	54	11	53	43	100	87.6
	Mangifera indica	0.10	0.45	2.38	0.40	0.02	12.6	63	10	26	239	110	105.3
	Memecylon edule	0.09	0.45	0.73	0.31	0.22	11.1	107	8	39	21	170	44.6
6	*Fagraea auriculata*	0.09	1.58	1.36	0.55	0.04	11.4	149	24	29	165	250	86.1
	Ficus pisocarpa	0.07	1.39	0.83	0.33	0.02	11.0	57	10	67	34	100	17.8
	Neesia altissima	0.12	0.98	1.03	0.42	0.06	9.1	116	15	56	474	230	29.8
	Syzygium syzygoides	0.09	0.90	1.54	0.41	0.06	10.8	85	21	70	593	160	29.0

Appendix A. Plant tissue analysis data of selected species of Ujung Kulon vegetation (Cont'd.).

Site	Species	P %	K %	Ca %	Mg %	Na %	Cu ppm	Fe ppm	Zn ppm	B ppm	Mn ppm	Al ppm	Ba ppm
7	*Ficus vasculosa*	0.15	0.15	0.80	1.23	0.38	9.4	442	16	149	432	810	80.0
	Meliosma nitida	0.14	2.02	0.54	0.60	0.05	12.8	224	10	91	202	470	19.3
	Neesia altissima	0.14	0.49	1.38	0.67	0.12	11.3	153	9	67	467	270	59.4
	Ryparosa javanica	0.31	1.38	0.73	0.85	0.06	12.3	82	14	67	140	150	37.3
8	*Ardisia humilis*	0.18	2.39	2.20	0.86	0.57	11.6	81	22	113	37	140	2.2
	Corypha utan	0.20	1.90	0.50	0.23	0.06	8.5	38	11	21	73	60	0.0
	Neonauclea calycina	0.15	1.06	1.52	0.29	0.09	11.4	46	16	155	30	80	3.1
	Vitex quinata	0.42	0.54	0.97	0.37	0.09	7.5	177	20	132	57	190	3.7

Appendix B. Depth in cm of horizons of main and supplementary profiles of Ujung Kulon soil sampling sites.

	Profile									
Site No.	1		2		3		4		5	
1	A11	0-2[a]	A11	0-1	A11	0-2	A11	0-1	A11	0-11
	A12	2-8[a]	A12	1-6	A12	2-5	A12	1-8	A12	11-18
	C	8-12[a]	C	6-13	C	5-11	C	8-17	C	18-23
	IIC	12-98[a]	IIC	13+	IIC	11+	IIC	17+	IIC	23+
	R	98+								
2	A	0-13	--	--	A11	0-3	A11	0-10	B1	0-10
	B22	13-71	--	--	A12	3-9	A12	10-19	B-IIC	10-43
	B22t	71-150	--	--	C	9-12	C	19-28	IIC	43+
					IIC	12+	IIC	28+		
3	A11	0-4	A11	0-4	--	--	--	--	A	0-5
	A12	4-10	A12	4-15	--	--	--	--	IIC	5+
	C	10-13	C	15-20	--	--	--	--		
	IIC	13-95	IIC	20-80	--	--	--	--		
4	A11	0-2	--	--	A11	0-2	--	--	--	--
	A12	2-6	--	--	A12	2-10	--	--	--	--
	C	6-10	--	--	IIC1	10-70	--	--	--	--
	IIC1	10-55	--	--	IIC2	70-110	--	--	--	--
	IIC2	55-82								

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[a] Alternate face of main pit

[b] Separate pit

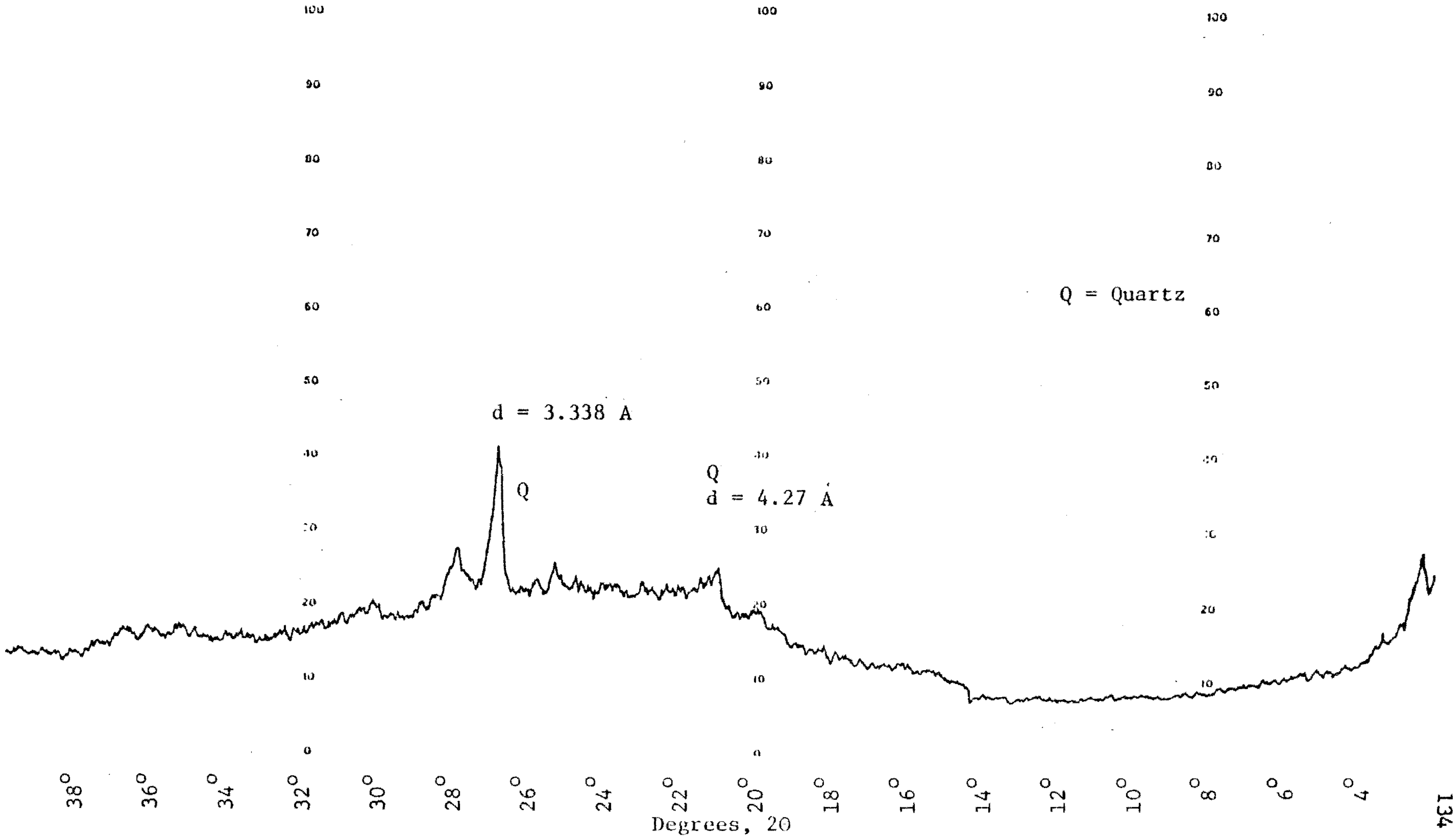
[c] No pit, underwater

[d] Alternate site

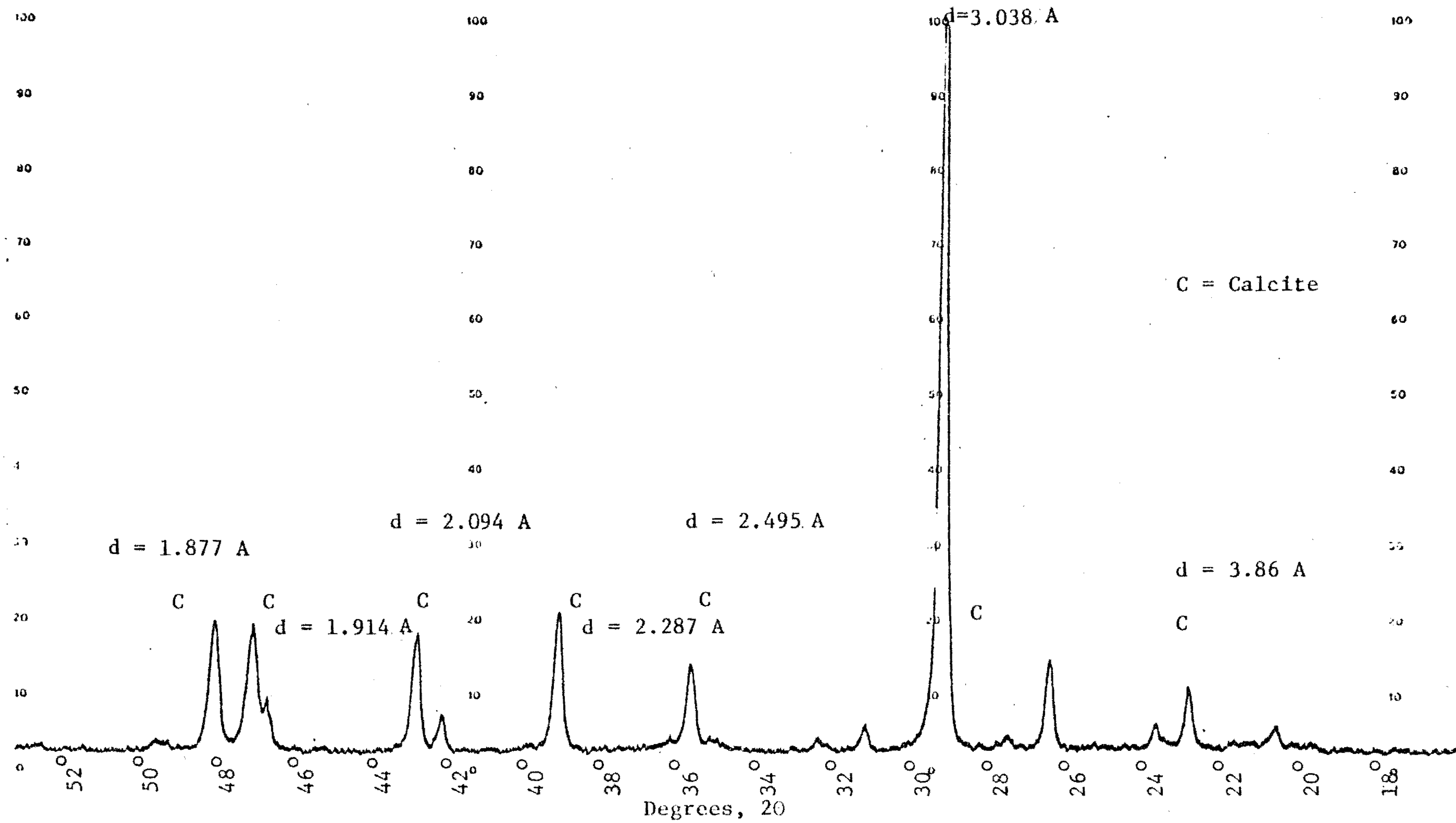
Appendix B. Depth in cm of horizons of main and supplementary profiles of Ujung Kulon soil sampling sites (Cont'd.).

	Profile									
Site No.	1		2		3		4		5	
5	A11	0-5[a]	A11	0-4	A11	0-2	A11	0-5	A11	0-3
	A12	5-9[a]	A12	4-10	A12	2-10	A12	5-70	A12	3-10
	IIC1	9-75[a]	IIC	10-75	C	10-30	B	70+	B	10+
	IIC2	75+ [a]			IIC	30+				
6	A11	0-2	A11	0-1	A11	0-4	A11/A12	0-20	A	0-2
	A12	2-11	A12	1-7	A12	4-12	C	20-30	C	2-5
	C	11-20	C	7-11	C	12-18	IIC	20-45	IIC	5+
	IIC	20-150	IIC	11+	IIC	18+	R	45+		
7	A11	0-2	A11	0-3	A11	0-2	A11	0-2	A11	0-3
	A12	2-10	A12	3-18	A12	2-8	A12	2-8	A12	3-5
	C	10-25	B	18-30	C	8-18	IIC	8+	C	5-8
	IIC	25+	C	30-36	IIC	18+			IIC	8+
			IIC	36+						
8	A	0-4[b]	A	0-5	A	0-13[c]	A	0-12	[c]	
	C	4-10[b]	C	5-36	C	13-24[d]	C11	12-90		
	IIC1	10-36[b]	IIC	36+	IIC	24+	C12	90-105		
	IIC2	36+					IIC	105+		

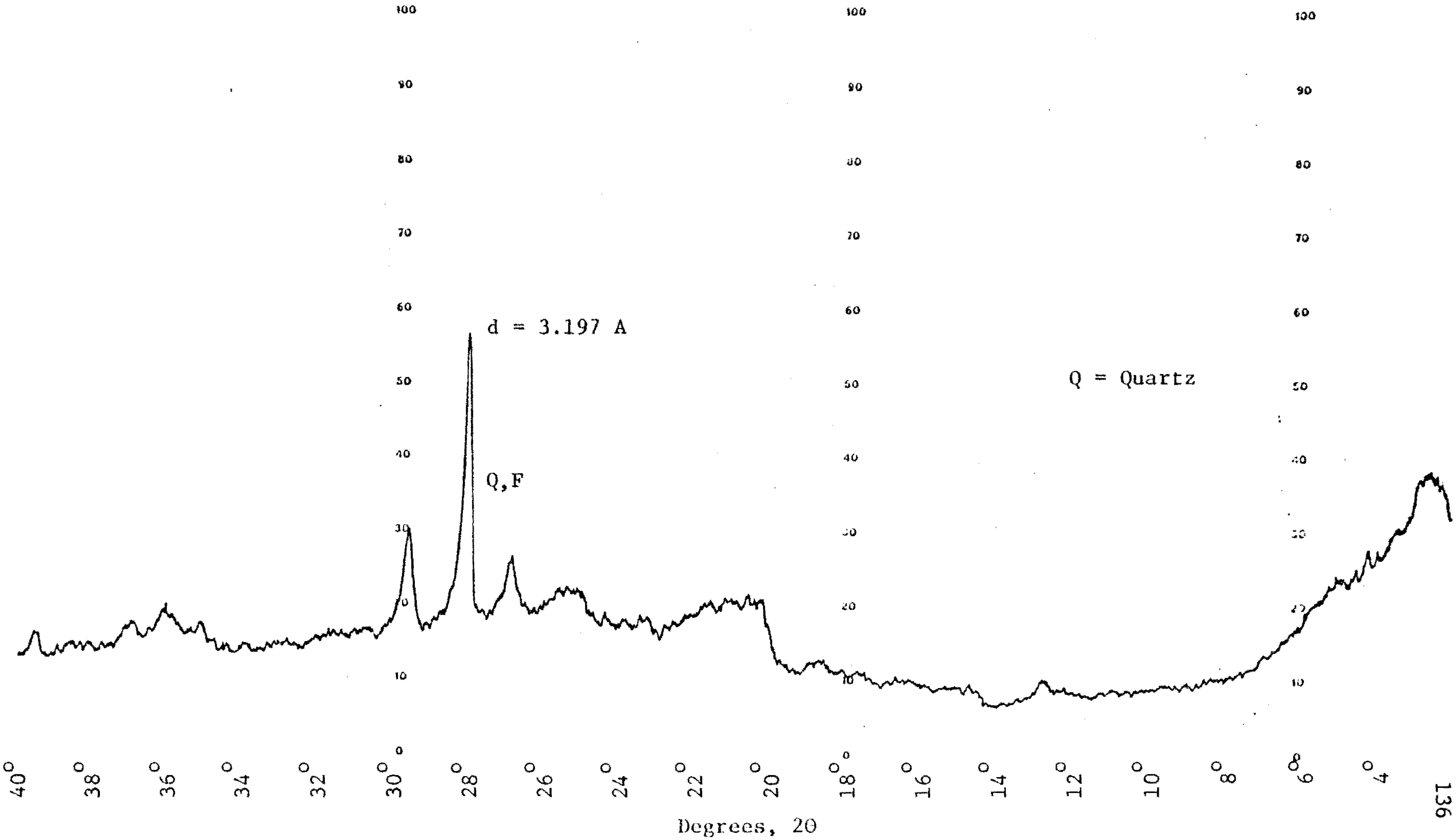
Appendix C. X-ray diffraction pattern of silt + clay fractions of 1C horizon in site 1 (Mg-saturated wet paste).



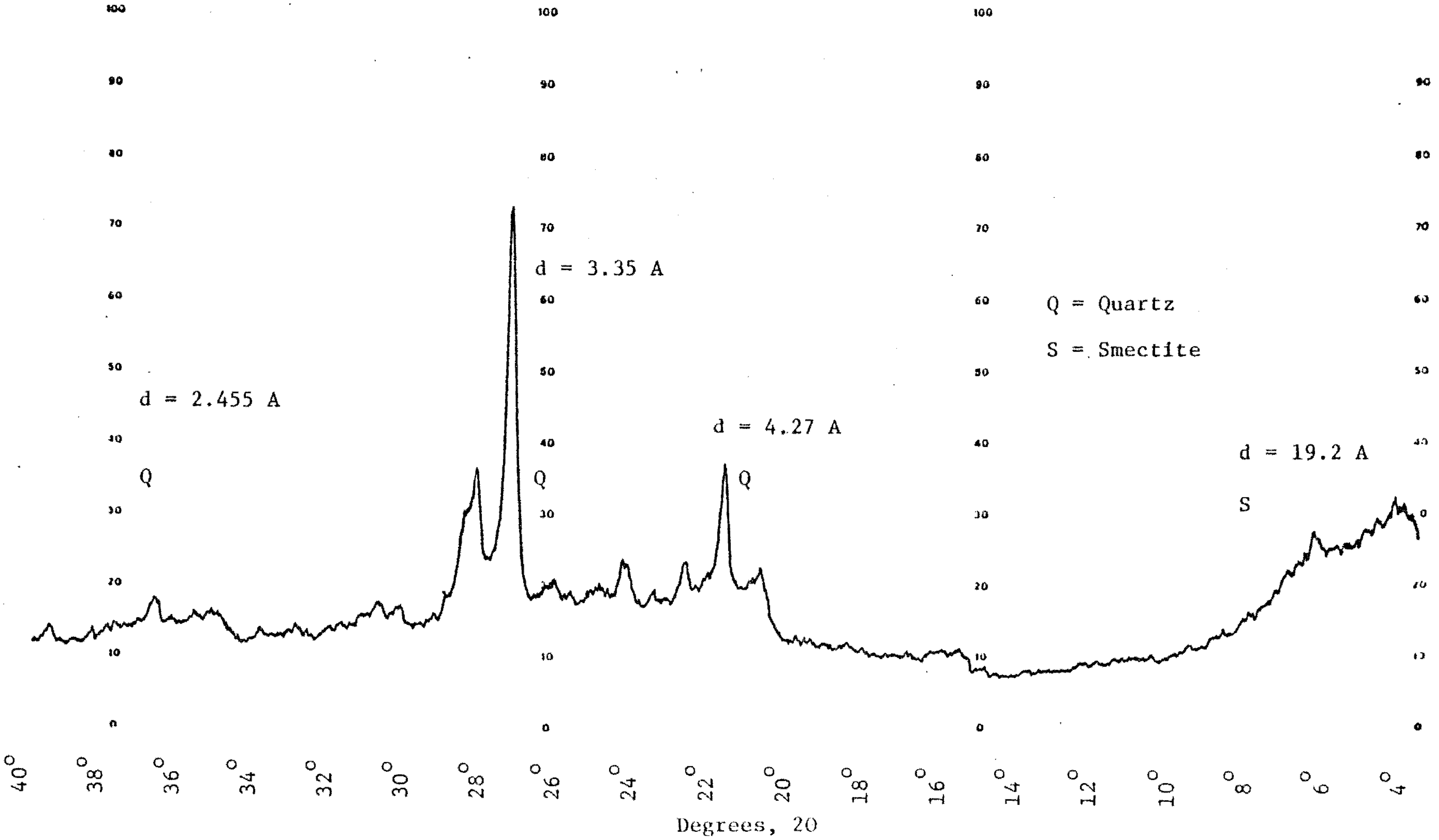
Appendix D. X-ray diffraction pattern of sand fraction of 4IIC horizon in site 3 (powder sample).



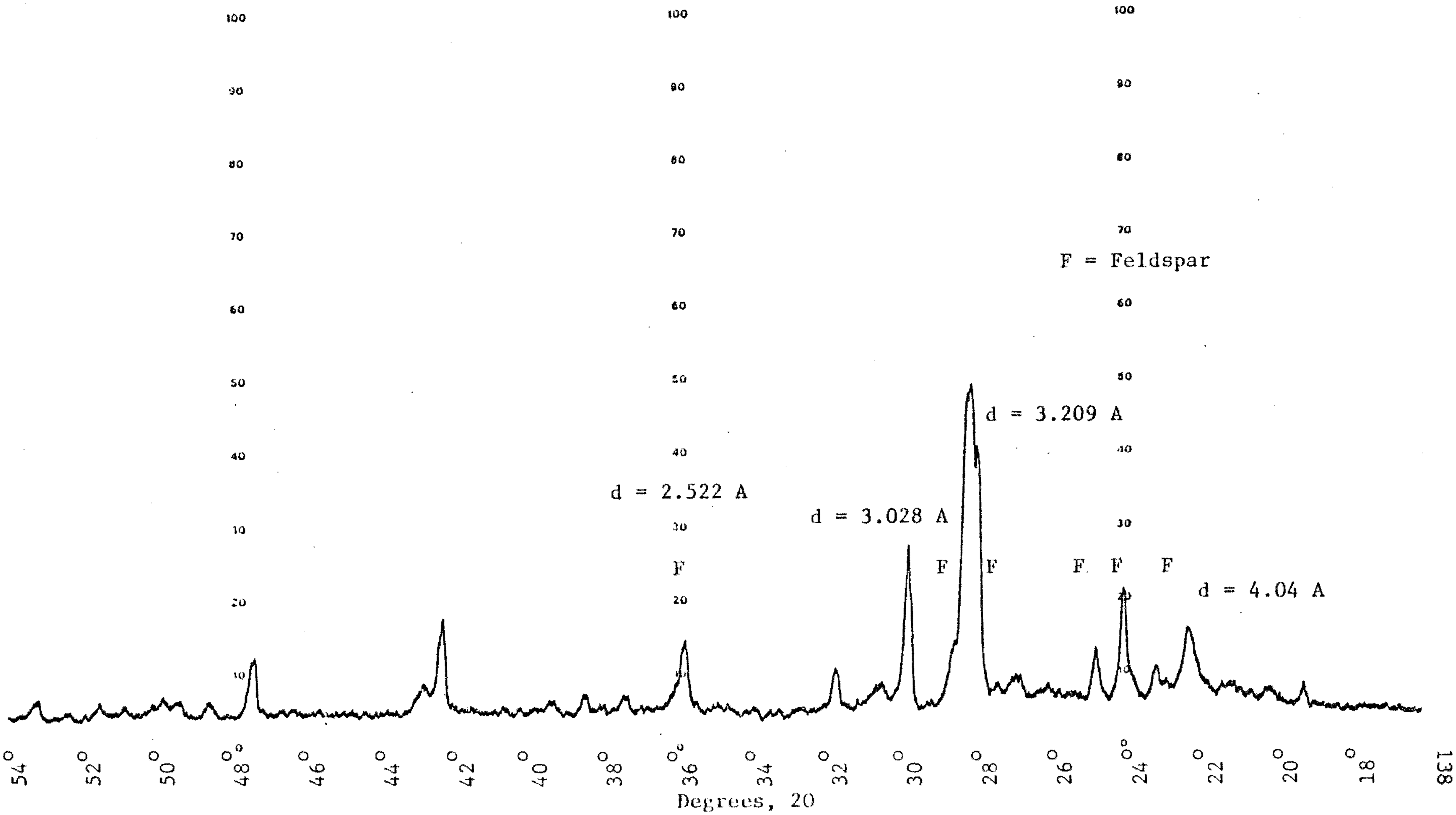
Appendix E. X-ray diffraction pattern of silt fraction of 4IIC horizon in site 3 (Mg-saturated wet paste).



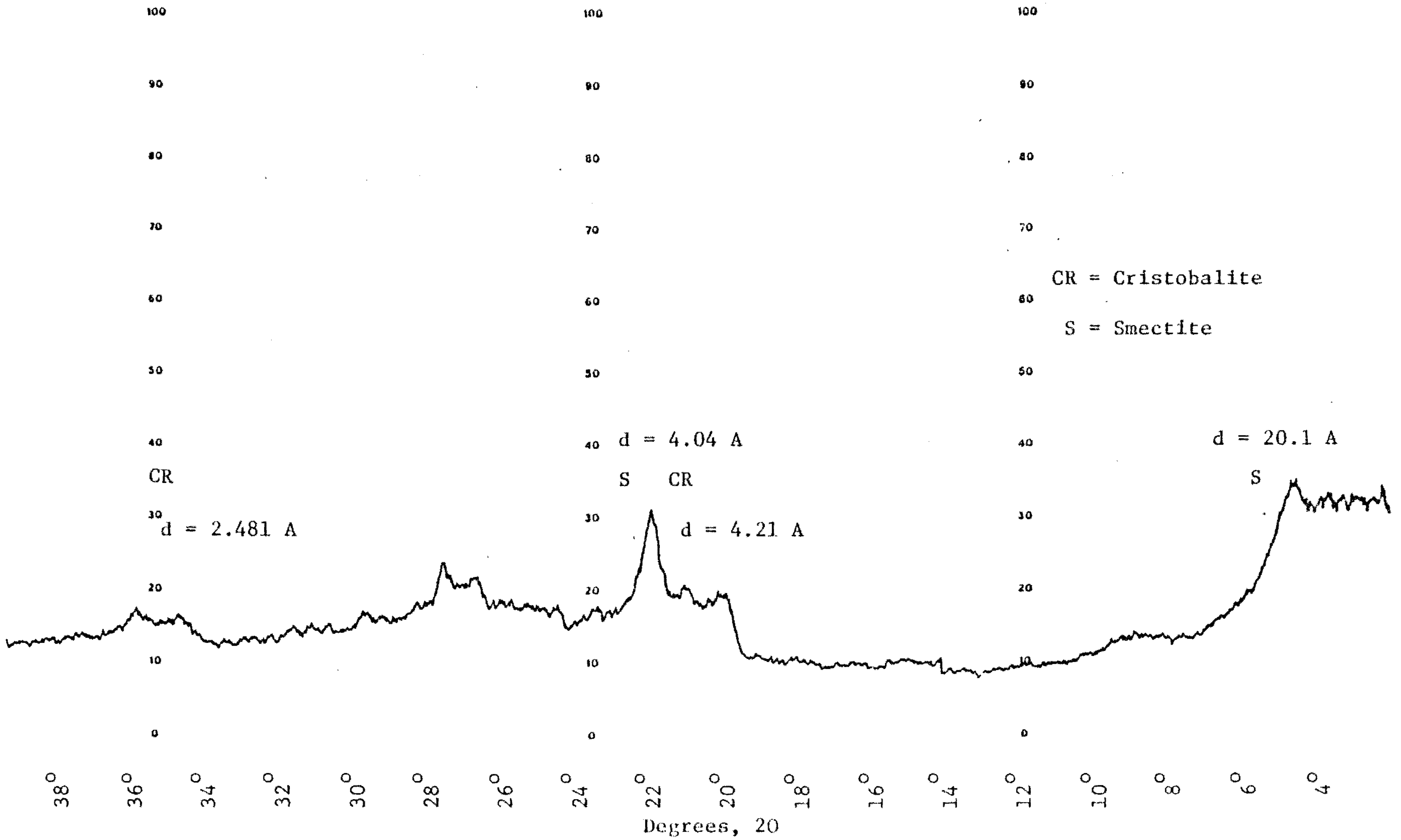
Appendix F. X-ray diffraction pattern of silt + clay fractions of 1C horizon in site 4 (Mg-saturated wet paste).



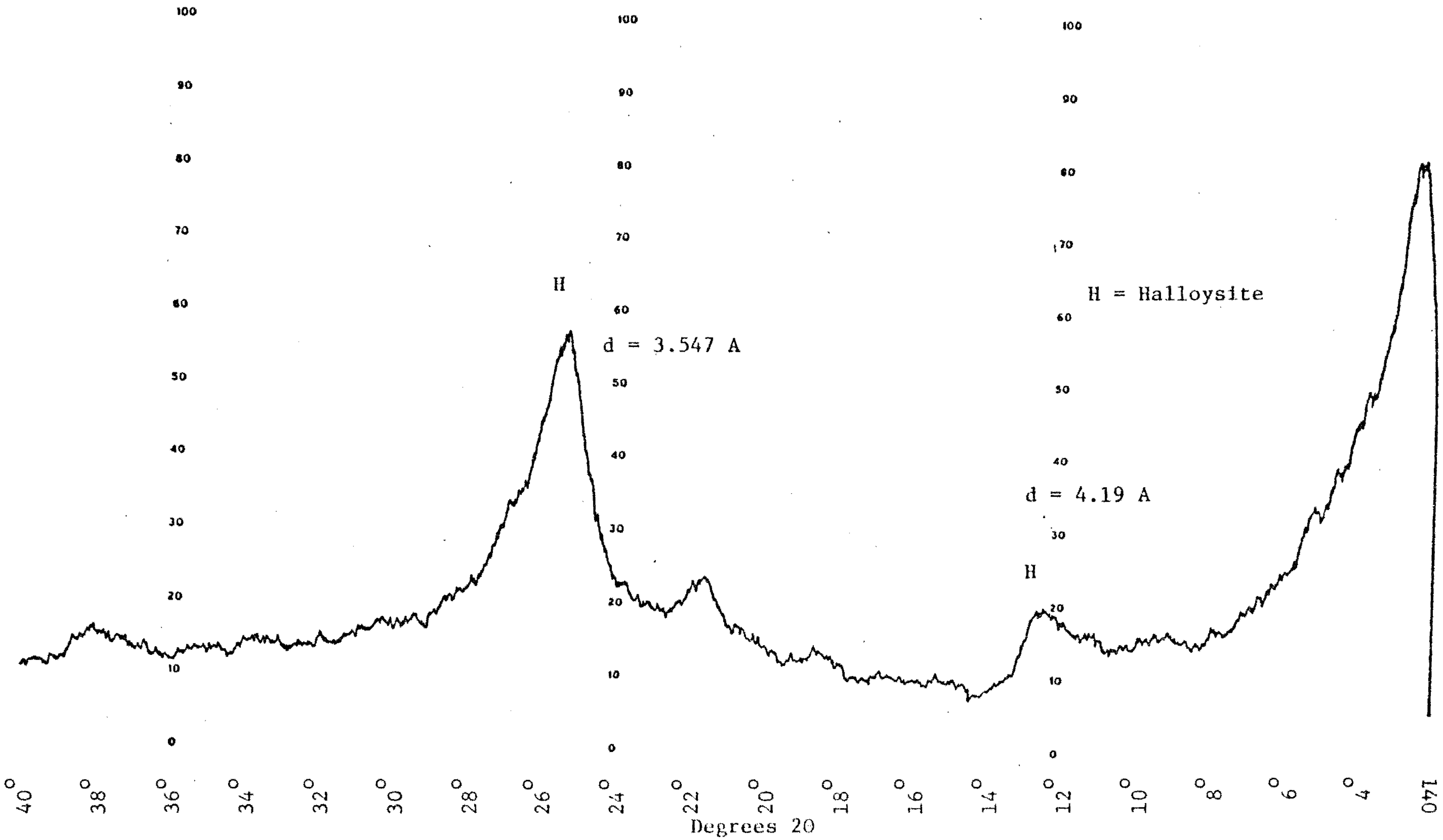
Appendix G. X-ray diffraction pattern of sand fraction of 1A12 horizon in site 5 (powder sample).



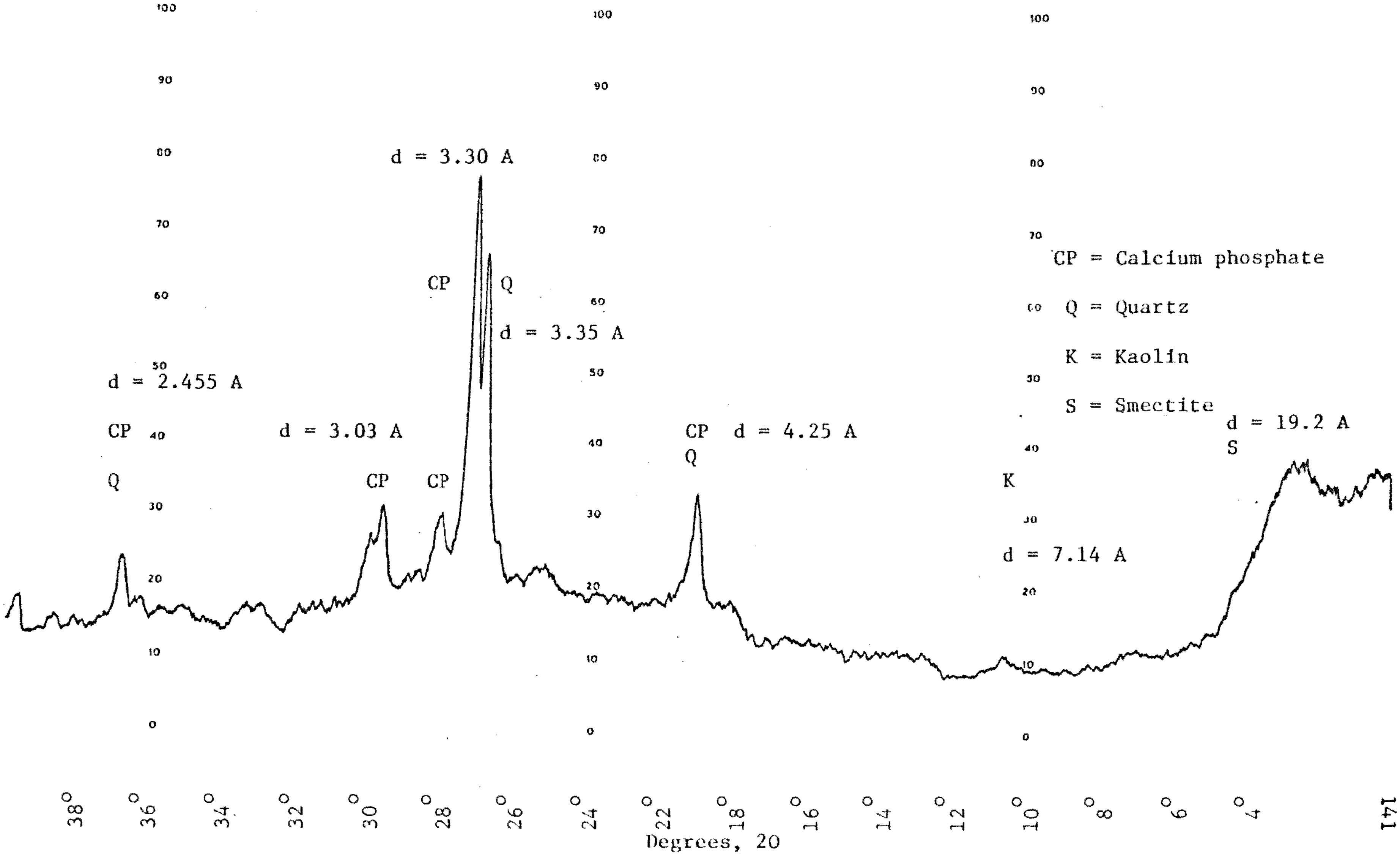
Appendix H. X-ray diffraction pattern of silt fraction of 1IIC horizon in site 5 (Mg-saturated wet paste).



Appendix I. X-ray diffraction pattern of clay fraction of 1IIC horizon in site 6 (Mg-saturated wet paste).



Appendix J. X-ray diffraction pattern of silt + clay fractions of IICl horizon in site 8 (Mg-saturated wet paste).



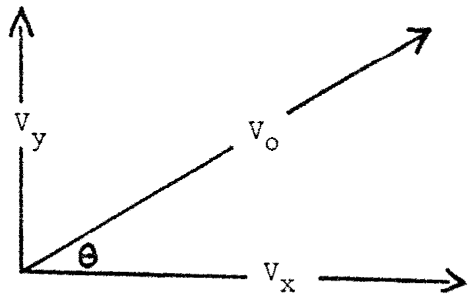
APPENDIX K

Range of Ejecta Dispersion

By theoretical considerations, some of which were given by Verbeek (1885), the ejecta of Krakatau--even free falling particles--could have reached all parts of Ujung Kulon. Assuming negligible air friction, as did Verbeek and also ignoring elevation since much of the ejecta was spewed forth from below the level of the sea, the maximum range of "free falling" bodies can be estimated by

$$R = V_o^2/g \tag{21}$$

at an angle of 45° which gives the greatest range. Knowing the initial velocity V_o is the problem, and must be determined indirectly from other information given by Verbeek. Treating vertical and horizontal components of ejecta trajectory as vectors, where V_x is the horizontal component and V_y is the vertical component, the resultant vector V_o -- or the initial velocity--is the hypotenuse of a right triangle with the angle $\Theta = 45^\circ$.



With angle Θ known,

$$\cos \Theta = V_x/V_o \tag{22}$$

and $$V_x = V_o \cos \Theta \qquad (23)$$

Likewise, $$V_y = V_o \sin \Theta \qquad (24)$$

Actual height y depends upon time of flight. The time to reach height y is designated as Ty, and height y at any time Ty is determined from the gravatation expression

$$y = VyTy - 1/2gt^2y \qquad (25)$$

where g is the force of gravity, 9.81 m/sec^2. Height y is a maximum at a point where the first derivative of (25) is equal to zero, so that with respect to time,

$$\frac{dy}{dt} = Vy - gTy \qquad (26)$$

at dy/dt = 0 equation (26) becomes

$$0 = Vy - gTy \qquad (27)$$

re-arranging to $$g\ Ty = Vy \qquad (28)$$

and $$Ty = \frac{Vy}{g} \qquad (29)$$

We can now solve for Vy by information given by Verbeek (1885) who assigned Ty as 1.5 minutes (90 sec.). Substituting in values in equation (28).

$$9.81\ m/sec^2 \times 90_{sec} = Vy$$

$$Vy = 882.9\ m/sec$$

It is also seen that V_x = 882.9 m/sec. Rewriting equation (24) to

$$V_o = \frac{V_y}{\sin \Theta} \qquad (30)$$

and substituting,

$$V_o = \frac{882.9\ m/sec}{0.707}$$

$$V_o = 1248.6\ m/sec$$

The total lateral distance V_x within the right triangle would, however, put ejected particles at the top of their trajectory. Total range R must be twice the time to rise, Ty. The formula then becomes

$$R = V_x 2Ty \qquad (31)$$

Substituting into (31)

$$R = 882.9 \text{ m/sec} \times 2 \times 90_{\text{sec}}$$

$$R = 158{,}922 \text{ m}$$

which rounds off to 159 km. Equation (21) gives the same result once the V_o has been established.

As was stated earlier, all of Ujung Kulon is between 56-84 km distance from Krakatau. Given sufficient force, many various sized particles could reach the remotest parts of Ujung Kulon. Actual trajectory is much less in air due to air resistance as well as gravity. Large, dense projectiles travel proportionally further in air than do smaller particles. Air resistance varies with form of projectiles, cross sectional area and the velocity of the projectile. An adaptation of the air resistance formula of Lissack (1907)

$$D = r \frac{g}{w} \qquad (32)$$

where D is drag or retardation, r is air resistance, g is force of gravity and w is weight of projectile in kilograms can be used to show that small particles of tuff had very limited range in air.

First, an approximation must be made of a particle of known size and sufficient weight to be relatively unaffected by wind. A fist-sized particle of pumice reported at Ketembang, some 40 km from Krakatau (Verbeek, 1885) would have a diameter of perhaps 10 cm.

Considered as a sphere, its volume

$$\text{Vol} = 4/3\ \pi\ r^3 \qquad (33)$$

is 523.6 cm^3. An average density of pumice, as previously computed was 0.505 g/cm^3. Weight of the pumice stone (technically its mass) is

$$\text{Mass} = \text{Density} \times \text{Volume}$$

$$= \frac{0.505\ g}{cm^3} \times 523.6\ cm^3$$

$$= 264.4\ g$$

Air resistance acting upon the pumice can now be compared with lighter and heavier particles. Ignoring the shape of projectile, air resistance varies with the square of projectile velocity at velocities over 1350 ft/sec (411 m/sec) and up to the 6th power of velocity at velocities under 900 ft/sec (274 m/sec), according to experimental evidence (Lissack, 1907). Using only v^2 as a substitute for r in equation (32) a new equation

$$D = \frac{V^2 g}{w} \qquad (34)$$

may be written. Using the initial velocity of eruption from equation (30) above, and ignoring units in the answer, the air resistance factor for the Ketembang pumice is then

$$D = \frac{1248.6\ (m/sec)^2\ .\ 9.81\ m/sec}{.2644\ kg}$$

$$= 5.8 \times 10^7$$

compared to 1.1×10^5 for a 300 pound (136.36 kg) artillery shell and 5.8×10^9 for a 2.64 g tuff particle. How then, according to Verbeek (1884) was pumice "... the size of a fist ... still thrown at a distance of 40 kilometers", and did pumice stones fall on Serang (Anon.

1883) some 78 km E of Krakatau as well as 70-80 km in the opposite direction (Leeuwen, 1936)? How did tuff particles of 0.146 g appear in the C layer of 6-1 in still another quadrant? According to equation (34) the retardation factor D of these small particles is about 1.0×10^{11}, but the distance at which they were found is about 78 km SSW of Krakatau.

The solution to the seeming paradox in which light vescicular tuff particles are carried to comparable distance as heavy particles may be related to movement of all particles in the ascending phase of flight. Perret, a volcanologist quoted by Holmes (1965) described a núee ardente (glowing cloud) as, 'an avalance of an exceedingly dense mass of hot, highly gas-charged and constantly gas-emitting fragmental lava, much of it finely divided, extra-ordinarily mobile, and practically frictionless, because each particle is separated from its neighbors by a cushion of compressed gas.' Although movement of true núees ardentes is primarily downward in response to gravity, the lack of friction and rapidly expanding gas characteristics could well apply to particles in the ascending phase.

If the ascent is also assisted by thermal currents and by virtue of the gas overcoming air resistance within the mass of ascending gases, the "free fall" of cinders and ash may not actually commence until the individual particles are beyond the effects of the gases in their particular trajectories. Holmes (1965) wrote of incadescent pumice of Krakatau which rose to 50 miles (80 km) in the air, but Wexler (1951) gave a 32 km maximum, which seems more accurate.

Thus it is that neither normal ballistics formulae nor trajectory <u>in vacuo</u> formulae adequately describe the kinetics of volcanic ejecta.

Heavy particles may behave more nearly like ordnance in flight because they are less affected by the gas propulsion, thus ballistics formulae for trajectory in air would seem more appropriate. Vescicular tuffs, however, of considerable cross-sectional area but low density would appear to conform more closely with the trajectory in vacuo concept. Accordingly, the trajectory estimations using both methods have been presented here. The difference in range between ballistics trajectory and in vacuo trajectory does not vary by more than a factor of 2.

Wind-assisted pumice would have a greater lateral range than in the examples used; contra-wind pumice would have lesser range. August jet-stream direction over the Sunda Strait is ENE; its velocity about 10 m/sec; its height about 12 km; and its vertical depth about 3000 m (Dr. C. S. Ramage, personal communication). Thus, falling pumice, cinders and ash of various sizes and descent angles would be displaced to the WSW on encountering the jet-stream.

Since most of the Krakatau ejecta was over water in the SW quadrant, the sole Verbeek (1885) measurement of 10 mm thickness in Ujung Kulon does not seem to be at all representative. The ENE jet-stream notwithstanding, cinders of 0.6 mm average diameter descended in Bogor, some 150 km ESE of Krakatau between 11 A.M. and 3 P.M. of August 27, reported by Verbeek (1885). Mohr (1944) seemed to confirm the role of wind dispersion near ground-level as well as within the jet-stream, however, his exact wording was somewhat confusing, "...toward Bantam the ash was blown back eastwards (sic.) by the high counter-trade winds, so that all the coarser ash had already fallen to the west before such material as reached greater heights began its journey eastwards." By convention, wind directional notations refer to point of origin, and not to path of destination as Mohr seemed to have implied.

LITERATURE CITED

Allison, L. E. and Moodie, C. D. 1965. Carbonate, pp. 1379-1396. In: Black et al. (Eds.) Methods of soil analysis: Part II. A.S.A. No. 9, Amer. Soc. Agron., Madison, Wisconsin.

American Society for Testing and Materials. 1967. X-ray powder data file, sets 1-5 (inorganic), Vol. PDIS. SIRB.

Anonymous. 1961. Occurrence of silica inclusions in Philippines woods. Forest Products Research Institute, Tech. Note No. 24. College, Laguna, Philippines. unpaged.

Anonymous. 1883. Notes. Nature 28:425.

Ayres, A. S. and Hagihara, H. H. 1952. Available phosphorous in Hawaiian soil profiles. Hawaiian Planters' Record 52(2):81-99.

Backer, C. A. and Bakhuizen van den Brink, R. C. 1963-68. Flora of Java, Vol. I-III. Walters-Noordhoff N. V., Groningen, Netherlands.

Bannister, B. A. 1970. Ecological life cycle of Euterpe globosa Gaertn., pp. B299-314. In: Odum, H. T. and Pigeon, R. F. (Eds.), A tropical rain forest. Div. of Tech. Info. U.S. Atomic Energy Comm.

Batavia Magnetisch en Meteorologisch Observatorium. 1896-1909. Regen waarne mingen in Nederlandsch-Indie.

Beard, J. S. 1949. The natural vegetation of the Windward and Leeward Islands. Oxford Forestry Memoirs, No. 21. Clarendon Press, Oxford.

__________. 1942. Montane vegetation in the Antilles. Carib. For. 3:61-74.

Black, C. A., Evans, D. D., White, J. L., Ensminger, L. E. and Clark, F. E. (Eds.). 1965. Methods of soil analysis: Part II. A.S.A. No. 9. Amer. Soc. Agron., Madison, Wisconsin.

Boerma, J. 1925. Regenval in Nederlandsch-Indie. Koninklijk Magnetisch en Meteorologisch Observatorium te Batavia. Landsdrukkerij-Weltevreden (Netherlands).

Buol, S. W., Hole, F. D., and McCracken, R. J. 1973. Soil genesis and classification. Iowa State Univ. Press, Ames, Iowa. 360 p.

Cain, S. A., Castro de Olivera, G. M., Pires, J. M. and da Silva, N. T. 1956. Application of some phytosociological techniques to Brazilian rain forest. Amer. Jour. Botany 43:911-941.

Chan, J. K. 1972. Chemical and morphological characterization of the noncrystalline fraction in the Hilo soil (Typic Hydrandepts). M.S. Thesis, Univ. of Hawaii, Honolulu, Hawaii.

Chapman, H. D. 1965. Cation-exchange capacity, pp. 891-901. *In*: Black et al. (Eds.) *Methods of soil analysis*: Part II. A.S.A. No. 9, Amer. Soc. Agron., Madison, Wisconsin.

Clarke, F. W. 1924. *The data of geochemistry*. U.S. Gov't. Print. Office, Washington, D.C. 841 p.

Chenery, E. M. and Hardy, F. 1945. The moisture profile of some Trinidad forest and cacao soils. Trop. Agric. 22:100-115.

Colmet-Daage, F. and Gautheyrou, J. 1974. Soil associations on volcanic material in tropical America with special reference to Martinique and Guadeloupe. Trop. Agric. 51:121-128.

Dansereau, P. 1963. The barefoot scientist. Colorado Quarterly 12:113.

Dawkins, H. C. 1959. The volume increment of natural tropical high forest and limitations on its improvement. Empire For. Review 38:175-180.

Decker, R. W. and Hadikusmo, D. 1961. Results of the 1960 expedition to Krakatau. J. Geophys. Research 66:3497-3511.

Dudal, R. and Soepraptohardjo, M. 1961. Soil classification and soil survey. Bogor Institute of Agricultural Sciences, Bogor, Indonesia. 94 p.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Fox, R. L., Silva, J. A., Younge, O. R., Plucknett, D. L. and Sherman, G. D. 1967. Soil and plant silicon and silicate response by sugar cane. Soil Sci. Soc. Amer. Proc. 31:775-779.

Furlong, W. and Furlong, J. 1974. Volcanoes: mavericks of the mountains. Holiday Magazine, April/May 1974, p. 29, 64, 66.

Furneaux, R. 1964. *Krakatoa*. Prentice-Hall, Englewood Cliffs, New Jersey.

Garrels, R. M. and Christ, C. L. 1965. *Solutions, minerals, and equilibria*. Harper and Row, New York. 450 p.

Gause, R. W. 1934. Principles of biocoenology. Quart. Rev. Biol. 11:320-336.

Gerard, R. W. 1965. Intelligence, information and education. Science 148:762-765.

Grieg-Smith, P. 1965. Notes on the quantitative description of humid tropical forest. In Symposium on Ecological Research in Humid Tropics Vegetation. Gov't. of Sarawak and UNESCO.

Hairston, N. G. 1959. Species abundance and community organization. Ecology 40:404-416.

Harter, H. L. 1960. Critical values for Duncan's new multiple range test. Biometrics 16:671-685.

Hilgard, E. 1912. Soils, their formation, properties, composition and relations to climate and plant growth in the humid and arid regions. MacMillian Co., New York. 563 p.

Hodder, B. W. 1968. Economic development in the tropics. Methuen and Co. Ltd., London. 246 p.

Hock, M. and Kostermans, A. 1950. Verslag over sen bozoek aan het Wildreservaat Udjung Kulon in juni 1950. Dienstrapport (report).

Holdridge, L. R. 1970. A system for representing structure in tropical forest associations, pp. B147-150. In: Odum, H. T. and Pigeon, R. F. (Eds.), A tropical rain forest. Div. of Tech. Info., U.S. Atomic Energy Comm.

__________. 1967. Life zone ecology. Tropical Science Center, San Jose, Costa Rica. 198 p.

Holmes, A. 1965. Principles of physical geology. Ronald Press, New York. 1250 p.

Hong, T. K. and v. Schuylenborgh, J. 1959. On the classification and genesis of soils, derived from andesitic volcanic material under a monsoon climate. Neth. Jour. Agric. Sci. 7:1-21.

Hoogerwerf, A. 1970. Ujung Kulon - the land of the last Javan rhinoceros. E. J. Brill, Leiden, Netherlands. 512 p.

Iler, R. K. 1955. The colloid chemistry of silica and silicates. Cornell Univ. Press, Ithaca, New York. 324 p.

Indonesian Forest Service. 1957. Nature park Ujung-Kulon. Bogor, Indonesia. unpaged.

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall, Englewood Cliffs, New Jersey. 498 p.

Jenny, H., Gessel, S. P. and Bingham, F. T. 1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. Soil Sci. 68:419-432.

Jenny, H. 1941. Factors of soil formation. McGraw-Hill, New York. 281 p.

Joffe, J. S. 1936. Pedology. Rutgers Univ. Press, New Brunswick, New Jersey. 545 p.

__________. 1931. Soil profile studies: III. The process of podolization. Soil Sci. 32:303-323.

Johnson, N. E. 1976. Biological opportunities and risks associated with fast-growing plantations in the tropics. J. For. 74:206-211.

Kartawinata, E. K. 1965. Notes on the vegetation of the Peutjang Island (SW Java). In: Symposium on Ecological Research in Humid Tropics Vegetation. Gov't. of Sarawak and UNESCO.

Keng, J. C. W. and Uehara, G. 1973. Chemistry, mineralogy and taxonomy of Oxisols and Ultisols. Soil and Crop Sci. Soc. of Florida Proc. 33:119-126.

Kilmer, V. J. and Alexander, L. T. 1949. Methods of making mechanical analyses of soils. Soil Sci. 68:15-24.

Kira, T. 1969. Primary productivity of tropical rain forest. Malayan Forester 32:375-384.

Krüger, C. (Ed.). 1971. Volcanoes. G. P. Putnam's Sons, New York. 163 p.

Lang, G. E., Knight, D. H. and Anderson, D. A. 1971. Sampling the density of tree species with quadrats in a species-rich tropical forest. Forest Sci. 17:395-400.

Lembaga Penelitian Tanah. 1966. Peta tanah tindjau Kabupaten Pendeglang. Bogor, Indonesia.

Lissack, O. M. 1907. Ordnance and gunnery. John Wiley & Sons, New York. 594 p.

Leeuwen, d.v., W. M. 1936. Krakatau. E. J. Brill, Leiden, Netherlands. 506 p.

Macdonald, G. A. 1972. Volcanoes. Prentiss-Hall, Englewood Cliffs, New Jersey. 510 p.

McIntosh, R. P. 1967. An index of diversity and the relation of certain concepts of diversity. Ecology 48:392-404.

McPherson, W. W. and Johnston, B. F. 1967. Distinctive features of agricultural development in the tropics, pp. 184-230. In Southworth, H. M. and Johnston, B. F. (Eds.), Agricultural development and economic growth. Cornell Univ. Pres, Ithaca, New York. 583 p.

Mohr, E. C. J. 1944. The soils of equatorial regions. Translated from Dutch by R. L. Pendleton. J. W. Edwards (Publ.), Washington, D.C. 694 p.

__________. 1930. De grond van Java en Sumatra. J. H. DeBussy, Amsterdam. 258 p.

__________. 1922. De bodem van Java en Sumatra.

Mueller-Dombois, D. and Ellenberg, H. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York. 547 p.

Nye, P. H. 1961. Organic matter and nutrient cycles under moist tropical forest. Plant and Soil 13:333-346.

Odum, H. T. 1970. The El Verde study area and the rain forest systems of Puerto Rico, pp. B3-32. In Odum, H. T. and Pigeon, R. F. (Eds.). A tropical rain forest. Div. of Tech. Info., U.S. Atomic Energy Comm.

Ovington, J. D. and Olson, J. S. 1970. Biomass and chemical content of El Verde lower montane rain forest plants, pp. H53-78. In Odum, H. T. and Pigeon, R. F. (Eds.). A tropical rain forest. Div. of Tech. Info., U.S. Atomic Energy Comm.

Parsons, R. B. and Herriman, R. C. 1975. A lithosequence in the mountains of Southwestern Oregon. Soil Sci. Soc. Amer. Proc. 39:943-948.

Pellek, R. 1971. A study of site factors associated with the growth and management of teak plantations in Trinidad. M. S. Thesis, Univ. of Florida, Gainesville, Fla.

Rankama, K. and Sahama, T. G. 1950. Geochemistry. Univ. of Chicago Press, Chicago. 912 p.

Richards, P. W. 1952. The tropical rain forest. Cambridge Univ. Press, Cambridge. 450 p.

Rode, A. A. 1962. Soil science. Translated from Russian. Nat'l. Science Foundation. 517 p.

Russell, E. J. 1912. Soil conditions and plant growth. 8th ed. (1950). Longmans, Green & Co., London. 606 p.

Salter, P. J. 1967. Methods of determining the moisture characteristics of soils. Expl. Agric. 33:163-173.

Sanchez, P. A. 1973. Review of soils research in tropical Latin America. N. C. Agric. Exp. Sta. Tech. Bul. 219.

Satmoko, K. P. 1961. Udjung Kulon Nature Park, Java. Nature Cons. in W. Malaysia 1-25.

Schenkel, R. and Schenkel, L. 1973. Protection and management of the Udjung Kulon National Park for the Javan rhinoceros and other species. World Wildlife Yearbook 1972-73, p. 128-132.

__________ and Schenkel-Hulliger, L. 1969. The Javan rhinoceros (Rh. sondaicus Desm.) in Udjung Kulon Nature Reserve. Its ecology and behavior. Acta Tropica 26:98-133.

Schollenberger, C. J. 1922. Silica and silicates in relation to plant growth and composition. Soil Sci. 14:347-362.

Schofield, R. K. 1949. Effect of pH on electric charges carried by clay particles. J. Soil Sci. 1:1-8.

Schuylenborgh, J. v. 1958. On the genesis and classification of soils derived from andesitic tuffs under humid tropical conditions. Neth. J. Agric. Sci. 6:99-111.

__________. 1957. Investigations on the classification and genesis of soils, derived from acid tuffs under humid tropical conditions. Neth. J. Agric. Sci. 5:195-206.

__________, and Rummelen, F. F. F. E. v. 1955. The genesis and classification of mountain soils developed on tuffs in Indonesia. Neth. J. Agric. Sci. 3:192-215.

SEAMEO: BIOTROP. 1972. Quantitative vegetational study of a tropical rain forest in the Peucang Island. S. W. Java. Tech. Report of Train. Course in For. Ecol., May 26 - July 6, 1972. Bogor, Indonesia. 32 p.

Sharma, M. and Rao, K. R. 1970. Investigations on the occurrence of silica in Indian timbers. Ind. For. 96:740-754.

Soerianegara, I. 1972. Soils of Peutjang Island, Southwest Java. SEAMEO: BIOTROP, Bogor, Indonesia. 15 p.

__________. 1970. Soil investigation in Mount Hondje Forest Reserve, West Java. Rimba Indonesia 25:1-16.

Soepraptohardjo, M., Soewardjo and Dudal, R. 1966. Exploratory soil map of Java and Madura, scale 1:250,000. Soil Research Institute, Bogor, Indonesia.

Stehn, C. E. 1929. Krakatau, Part I, the geology and volcanism of the Krakatau Group. Fourth Pacific Science Congress. 118 p.

Tamimi, Y. N., Matsuyama, D. T. and El-Swaify, S. A. 1972. Effect of $CaCO_3$, $CaSiO_3$ on P on pH-dependent charges and cation retention in an Hydric Dystrandept in Hawaii. Agron. Abst. 1972:89.

Tan, K. H. and Schuylenborgh, J. v. 1961. On the classification and genesis of soils developed over volcanic material under humid tropical conditions, II. Neth. J. Agric. Sci. 9:41-54.

Taylor, M. S. 1974. The effect of soil aggregate size on seedling emergence and early growth. East Afric. Agric. For. J. 40:204-213.

Thornbury, W. D. 1954. Principles of geomorphology. John Wiley & Sons, (New York). 576 p.

Tomlinson, P. B. and Soderholm, P. K. 1975. The flowering and fruiting of Corypha elata in South Florida. Principes. 19:83-99.

Tschirley, F. H., Dowler, C. C. and Duke, J. A. 1970. Species diversity in two plant communities of Puerto Rico. In Odum, H. T. and Pigeon, R. F. (Eds.). A tropical rain forest. Div. of Tech. Info., U.S. Atomic Energy Comm.

Uchida, R. S. 1973. The effect of calcium silicate on cation exchange cpacity and on exchangeable potassium, calcium and magnesium in a field trial on a Hydric Dystrandept. M.S. Thesis, Univ. of Hawaii, Honolulu, Hawaii.

U.S. Department of Agriculture. 1951. Soil survey manual. U.S. Gov't. Print. Office, Washington, D.C. 503 p.

Verbeek, R. D. M. 1885. Krakatau. Batavia.

__________. 1884. Notes. Nature 30:10-15.

Wadsworth, F. H. and Bonnet, J. A. 1951. Soil as a factor in the occurrence of two types of montane forest in Puerto Rico. Carib. For. 12:67-70.

Walker, A. 1947. A critical examination of a rapid method for determining organic carbon in soils - effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63:251-264.

Walker, H., Harnickell, E. and Mueller-Dombois, D. 1975. Climate-diagram maps of the individual continents and the ecological climatic regions of the earth. Translated from German. Springer-Verlag, Stuttgart. 36 p.

Warnaars, B. C. and Eavis, B. W. 1972. Soil physical conditions affecting seedling root growth, II. Mechanical impedence, aeration and moisture availability as influenced by grain-size distribution and moisture content in silica ponds. Plant and soil 36:623-634.

Wedepohl, K. H. (Ed.). 1969. Handbook of geochemistry. Springer-Verlag, (New York). 411 p.

Wentworth, C. K. and Williams, H. 1932. The classification and terminology of the pyroclastic rocks. Nat. Res. Council Bul. 89:19-53.

Wexler, H. 1951. Spread of the Krakatau volcanic dust cloud as related to the high-level circulation. Bul. Amer. Meteor. Soc. 32:48-51.

Whitt, P. M. and Baver, L. D. 1937. Particle size in relation to base exchange and hydration properties in Putnam clay. J. Amer. Soc. Agron. 29:905-916.

Williams, C. N. and Joseph, K. T. 1970. Climate, soil and crop production in the humid tropics. Oxford Univ. Press, Kuala Lumpur. 177 p.