THE CONSTITUENT MINERALS OF SOME SOILS OF PUERTO RICO

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INTRODUCTION

The constituent minerals of soils are the mineral groups which make up the bulk of the inorganic portion. These inorganic materials make up approximately 95 percent of soils in general and contribute materially to their properties. The importance of these minerals has been emphasized (9)[2] for some time in a general way, but data on most soils, and particularly, on tropical soils are lacking.

The constituent minerals in soils are feldspar, quartz, mica, and clay-mineral groups. The properties of these minerals vary considerably within a group or series. In studying the minerals of soils, it is of importance to determine the type of mineral of the particular group or series being investigated, that is to say, what kind of feldspar, clay mineral, etc., occurs in any particular soil.

The variability of the soils of Puerto Rico has been discussed by Bonnet (4), Roberts (13), Thorp (14), and others, but a complete mineral study for only one soil, Catalina clay, has been reported by Bonnet (3).

COLLECTION OF SOIL AND ROCK SAMPLES

Studies on the mineral characteristics and mode of formation of tropical soils were initiated, in February 1943, at the former Institute of Tropical Agriculture at Mayaguez, P. R., by Bonnet, the first junior author, then Assistant Director and Chief Soils Technologist, of the Institute. In September 1944, the studies were continued by Bonnet in the Soils Department of the Agricultural Experiment Station of the University of Puerto Rico at Río Piedras, under a cooperative agreement with the Institute. Dr. Jeffries visited the Institute for a 2-month period in 1943 and helped in the collection of the soil and rock samples throughout the Island of Puerto Rico and in the organization of the laboratory work carried later at the Experiment Station. The soils[3] were prepared for analysis at Río Piedras, and the sand, silt, and clay fractions together with the

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[2] Numbers in parentheses refer to Literature Cited, p. 139.

[3] Thanks are expressed to A. García-Porrata, Miss Socorro M. Gaztambide, Assistant Chemist, Institute of Tropical Agriculture, and F. Penne, Jr., assigned to do the laboratory work.

thin sections of the rocks, prepared by G. S. Rév of New York, were sent to Dr. Jeffries at Pennsylvania State College, for mineral identification. Dr. Jeffries was appointed Visiting Soil Scientist of the University of Puerto Rico for the 3-month period between February 8 and May 4, 1950 and while at the Experiment Station studied the final data and reorganized it for publication.

SOILS STUDIED

With the idea of increasing knowledge of the mineral character of the tropical soils of Puerto Rico, profile samples were secured in 1943 of the principal soil series of Puerto Rico. Special care was exercised to select typical profiles and the Soil Survey of Puerto Rico (13) was used at all times in deciding the areas from which samples were obtained. Where possible samples of rock formations associated with the soils were obtained to be studied also if it appeared desirable. In all, 42 soil profiles were sampled which included 118 soil samples and 76 rock samples.

The soils considered in this report are described by Roberts (13) as deep upland soils (including some medium-deep soils here), shallow upland soils, inner plains soils, medium friable terraces and alluvial fans, compact soils of terraces and alluvial fans, compact coastal plains, friable coastal plains and very friable coastal plains, well-drained river flood plains and poorly drained river flood plains. These soils belong to the zonal, intrazonal and azonal orders.

Table 1 shows the soil series, the physiographic areas where they occur, and the locations at which the samples were secured; it includes 41 soil types of the 42 soil profiles sampled. In table 2 the soil types are classified as soil series according to soil groups (13).

METHODS OF ANALYSIS

The methods of analysis used in this study were petrographic and X-ray procedures especially adapted for soils (10, 12).

All samples were air-dried, screened to pass a 20-mesh screen using as little grinding as possible. Free iron oxides were removed using the nascent-hydrogen methods of Jeffries (6, 7). After the removal of the free iron oxides the samples were dispersed and separated in their sand, silt and clay fractions. The very fine sand fraction 0.10–0.05 mm., was examined petrographically using the methods discussed by Marshall and Jeffries (12). No heavy mineral separations were carried out, as this study was confined to the constituent mineral groups referred to previously. The very fine sand, silt, and clay fractions were studied by X-ray methods using the Geiger Counter X-ray spectrometer as described by Jeffries (8). The patterns obtained were compared with those of minerals of known

TABLE 1.—*Soil series studied, physiographic areas where they occur, and location of samples*

Soil types	Physiographic area	Location	Longitude W.	Latitude N.
Aguilita clay	Upland shallow	4.7 Km. S. Boquerón Road	67°9.5′	17°58′
Aguirre clay	Flood and coastal plains, poorly drained	Colonia Fraternidad, Santa Rita, Ensenada	66°54.5′	18°1′
Alonso clay	Upland deep	Km. 34.7 Road 16, Yauco-Lares	66°51′	18°11.7′
Bayamón sandy clay	Coastal plains, friable	Side road to Hatillo, 0.7 Km. S.W. Arecibo-Lares Road	66°46′	18°26.6′
Cabo Rojo clay	Inner plains	Km. 2.4 Cabo Rojo, Puerto Real Road	67°10.5′	18°4.8′
Catalina stony clay	Upland deep	Km. 4.5 Mameyes-Yunque Road	65°46′	18°20.5′
Catalina clay	do.	Km. 9.6 Road 14, Consumo-Maricao	66°59′	18°11.5′
Cialitos clay, steep phase	do.	Km. 27.7 Road 14, Maricao-Indiera	66°54′	18°9′
Ciales clay loam	do.	Km. 41.6 Road 6, Adjuntas-Utuado	66°43′	18°13′
Coloso silty clay	Flood plains, poorly drained	1 Km. N.E. Central Eureka	67°7′	18°7.5′
Corozo fine sand	Coastal plains	Km. 75.0, Road 2 E. Arecibo	66°37.5′	18°27.5′
Coto clay, heavy phase	Coastal plains, friable	Km. 138.8, Road 2, Aguadilla-Isabela	67°7.5′	18°26.5′
Descalabrado silty clay	Upland shallow	Km. 217.5, Road 2, Sabana Grande-Yauco	66°57′	18°4′
Fraternidad clay	Terraces and alluvial fans	Colonia Marie Antonia, Santa Rita, Ensenada	66°54′	17°58′
Guánica clay	Flood plains, poorly drained	Balzac Faría farm, Colonia Limón, Guánica	66°56′	18°2′
Guayabo fine sand, shallow phase	Coastal plains	0.8 Km. S. Boquerón Road	67°9′	18°1.5′

TABLE 1.—*Continued*

Soil types	Physiographic area	Location	Longitude W.	Latitude N.
Humacao clay loam	Terraces and alluvial fans, medium friable	Km. 85.0 Road 3, Humacao-Yabucoa	65°48.5′	18°8′
Islote loamy sand	Coastal plains	3 Km. W. Arecibo, Road 2	66°45.5′	18°28′
Jácana clay	Upland shallow	Km. 11.3 Road 18, Cabo Rojo, Boquerón	67°8.5′	18°3.5′
Juncos clay	Upland deep	Km. 7.9 Road 5, Caguas-Gurabo	65°58′	18°15.5′
Lares clay	Terraces, medium friable	Km. 5.8 Road 8, Moca-San Sebastián	67°6.5′	18°23′
Las Piedras clay loam	Inner plain	Km. 23.7 Road 5, Las Piedras-Humacao	65°52′	18°11′
Los Guineos clay	Upland, deep	Km. 13.6 Mameyes-Yunque Road	65°47′	18°18.5′
Mabí clay	Inner plain	4 Km. E. Cabo Rojo, Road 29, Cabo Rojo-San Germán	67°6′	18°5.5′
Maleza loamy sand	Coastal plains, very friable	4 Km. N. Cabo Rojo, Lighthouse	67°12′	17°57′
Matanzas clay	do.	Entrance Camp Borinquen, 0.3 Km. from Road 2	67°8.5′	18°27′
Moca clay	Inner plain	Km. 151.1 Road 2, E. Aguada	67°11′	18°23.5′
Múcara silty clay loam	Upland, deep	Barrio Llanos Tuna, 1 Km. E. of Km. 11.3 Road 18, Cabo Rojo-Boquerón	67°8′	18°3′
Nipe clay	Upland, deep	Km. 10, Mayaguez-Joyuda Road	67°11′	18°9′
Pandura sandy clay loam	do.	Km. 16 Road 5, Juncos-Las Piedras	66°54′	18°12.5′
Paso Seco silty clay	Terraces and alluvial fans	Hacienda Verdaguer of Central Aguirre, Guayama	66°7′	17°57′

TABLE 1.—*Concluded*

Soil types	Physiographic area	Location	Longitude W.	Latitude N.
Río Piedras clay....	Upland, deep	Exp. Station, Río Piedras, La Ceiba field	66°3.5′	18°23.3′
Sabana Seca sandy clay loam.........	Coastal plains, compact	Km. 2.7 Road 46, Río Piedras-Sanatorio	66°4′	18°23.5′
St. Lucie fine sand..	do.	0.3 Km. W. Km. 3.3 Arecibo-Lares Road	66°45.5′	18°27.4′
San Antón loam....	Flood plains, well drained	Hacienda Esperanza of Central Aguirre, Salinas	66°16′	17°57.5′
Santa Isabel clay...	Terraces and alluvial fans, compact	Hacienda Teresa of Central Aguirre, Salinas	66°16.5′	17°58′
Soller clay loam, shallow phase.....	Upland, deep	Km. 25.9 Road 34, San Sebastián-Guajataca	66°59′	18°21′
Tanamá stony clay.............	Upland, shallow	Km. 149.1 Road 2, E. Aguada	67°10′	18°23.5′
Teja loam..........	Upland, deep	Km. 92.3 Road 3, Humacao-Yabucoa	65°50.7′	18°5.7′
Toa silty clay loam.	Flood plains, well drained	Finca Javieri, Central Eureka, 1.9 Km. S. Hormigueros	67°8′	18°7′
Utuado loam.......	Upland, deep	Demonstration farm, Utuado	66°42′	18°16′
Viví sandy loam....	Flood plains, well drained	Km. 97.6 Road 3, Humacao-Yabucoa	65°52.5′	18°4′

composition and the presence and abundance of the various mineral groups estimated.

THE MINERALS OF THE ROCKS

The rock samples secured along with the soils consisted of andesites, quartz diorites, basalts, serpentines, limestones, sandstones, and shales. The minerals identified in these rocks in standard thin sections are given in table 3.

The important minerals from the standpoint of soil formation are

TABLE 2.—*Classification of soil series studied in arid and humid areas, according to soil groups (13)*

Zonal				
Gray-Brown	Red and yellow podzolic	Reddish-brown lateritic	Yellowish brown lateritic	Laterite
Humid Area				
Ciales	Cabo Rojo	Alonso	Coto	Nipe
Humacao	Lares	Bayamón	—	—
Juncos	Los Guineos	Catalina	—	—
Las Piedras	Moca	Cialitos	—	—
Teja	—	Islote	—	—
Utuado	—	Maleza	—	—
		Matanzas	—	—
		Río Piedras	—	—

Zonal			Intrazonal				Azonal soils		
Reddish prairie	Reddish chestnut	Reddish brown	Rendzina	Planosol	Ground water podzol	Wiesenboden	Alluvial	Lithosols and shallow soils	Sands
Arid Area									
—	Fraternidad	Jácana	—	—	—	—	—	—	—
Paso Seco	—	—	Aguilita	Santa Isabel	—	Guánica	Aguirre San Antón	Descalabrado	—
Humid Area									
—	—	—	—	—	—	—	—	—	—
Mabí	—	—	Soller	Guayabo	—	—	—	Múcara	—
—	—	—	—	Sabana Seca	Corozo	—	Coloso	Pandura	St. Lucie
—	—	—	—	—	—	—	Toa	Tanamá	—
—	—	—	—	—	—	—	Viví	—	—
—	—	—	—	—	—	—	—	—	—

quartz, the feldspars, hornblende, and biotite. It is of interest to note the lack of microcline, orthoclase, muscovite, and certain common accessories notably, tourmaline. The only mineral noted that contains appreciable potassium is biotite.

MECHANICAL ANALYSIS OF THE SOILS

Before mechanical analysis the free iron oxides were removed using the nascent hydrogen methods described by Jeffries (6, 7). Then the iron-free soils were dispersed and separated into their sand, silt, and clay fractions. The very fine sand fraction was separated from the total sands by methods described by Marshall and Jeffries (12).

Table 4 shows the soil series, arranged in physiographic areas, depth of sampling, the content of the various size separates, and the loss on removal of the free iron oxides.

TABLE 3.—*Minerals present in rocks of Puerto Rico collected*

Quartz	Hornblende	Apatite	Magnetite
Albite	Augite	Hypersthene	Chromite
Oligoclase	Biotite	Olivine	Calcite
Andesine	Chlorite	Zircon	Cordierite
Labradorite	Serpentine	Rutile	Sericite
—	Titanite	—	Epidote

THE CONSTITUENT MINERALS OF THE SOILS

The constituent minerals as determined in this study consisted of the quartz, feldspar, and clay-mineral groups. As was previously stated another group of minerals is of great importance in soils in general—the muscovite mica group, but no muscovite mica was identified in any of the soils studied. This is of interest and will be discussed later. Therefore, three constituent mineral groups will be considered. In general, quartz was identified in all the very fine sand and silt fractions and in some clay fractions. Feldspar occurred in varying quantities in 21 of the profiles studied and was entirely absent, or was present in minute traces only, in the other profiles. The chief feldspars identified were oligoclase, albite, and andesine, with varying small amounts of labradorite and, in a very few cases, extremely small quantities of orthoclase. In most cases the feldspar fraction was a mixture of these feldspars. As a rule, however, one feldspar was the most abundant and it was generally, albite or oligoclase.

The distribution of feldspar in the soil profiles was of decided interest. In some cases the quantities of feldspar decreased with depth, and quartz increased; in other cases the reverse was true. Some of the inferences from this finding will be discussed later.

TABLE 4.—*Mechanical analyses of soil samples by physiographic regions*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
Upland deep							
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Alonso	91	8–18	5.75	5.93	34.67	23.50	30.15
	90	18–32	7.29	6.76	26.75	22.00	37.20
Catalina	172	[2]	2.65	8.80	19.23	26.27	43.05
	81	[3]	.93	4.37	22.82	43.95	27.93
Cialitos	84	33–20	.37	2.68	28.35	45.00	23.60
	83	33–45	1.30	5.65	15.20	48.30	29.55
Ciales	93	[2]	16.48	25.95	41.62	9.15	6.80
	92	[3]	52.04	20.87	9.89	9.25	7.95
Juncos	58	0–8	6.06	15.92	23.72	33.05	21.25
	57	8–15	13.46	13.40	32.29	26.35	14.50
Los Guineos	186	0–24	77.60	5.70	2.25	3.70	10.75
	185	24–43	55.90	6.15	10.27	23.15	4.53
	184	32–48	37.35	8.45	15.65	17.36	21.19
	183	48+	38.75	10.05	16.65	17.20	17.35
Múcara	9	0–10	22.79	13.40	9.90	24.55	29.36
	8	10–18	38.90	17.10	7.50	13.26	23.24
	7	18–30	54.85	10.95	3.70	10.05	20.45
	6	30+	39.55	14.00	3.55	13.35	29.55
Nipe	16	0–16	36.00	10.54	3.10	23.30	27.06
	17	16–36	6.59	.87	.95	28.65	62.94
	18	36–120	14.35	.58	.80	20.12	64.15
	19	120–240	.81	.20	.33	18.42	80.24
	156	[4]	12.25	4.92	2.68	25.97	54.18
	157	[4]	5.78	3.05	3.40	44.37	43.40
Pandura	62	0–12	65.69	16.91	4.40	6.45	6.55
	61	12–24	73.45	5.20	3.90	8.35	9.10
	60	24+	47.35	7.10	7.60	28.55	9.40
Soller	117	[2]	.75	2.25	5.80	53.80	37.40
Teja	71	0–12	43.72	25.92	11.41	12.35	6.60
	70	12+	64.25	5.50	7.70	10.40	12.15

TABLE 4.—*Continued*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
Upland deep (continued)							
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Utuado	98	0–24	59.30	11.75	8.85	11.35	8.75
	97	24–56	14.00	30.80	22.10	19.40	13.70
	96	56–64	26.65	26.25	19.45	13.85	13.80
	95	72–64	71.40	10.55	5.10	6.45	6.50
Río Piedras	190	[2]	4.10	3.68	12.70	62.17	17.35
Upland shallow							
Aguilita	103	0–12	4.14	3.96	27.71	29.66	34.53
Tanamá	109	[2]	12.90	10.35	22.15	36.70	17.90
Descalabrado	23	0–10	28.90	17.80	15.20	20.05	18.05
	24	10–24	17.77	20.90	20.45	26.55	14.33
	25	24+	29.10	20.04	16.95	21.75	12.16
Jácana	4	0–7	14.50	13.05	18.85	23.46	30.14
	3	7–12	20.10	10.55	13.89	23.80	31.66
Inner plains							
Cabo Rojo	135	0–24	21.07	13.25	25.50	26.35	13.83
	134	24–36	12.30	13.58	29.32	34.25	10.55
	132	36+	10.12	14.16	22.12	32.80	20.80
Las Piedras	66	0–20	59.30	11.27	7.03	15.50	6.90
	65	20–44	61.80	9.35	4.10	14.85	9.90
	64	44–48	47.35	7.10	7.60	28.55	9.40
	63	48+	73.45	5.20	3.90	8.35	9.10
Mabí	15	0–10	13.05	21.95	14.80	24.25	25.95
	14	10–30	12.05	19.69	13.20	31.45	23.61
	13	30+	17.75	14.25	11.10	27.30	29.60
Moca	106	[2]	3.60	12.60	7.20	46.60	30.00
Terraces and alluvial fans—medium friable							
Humacao	68	0–20	37.62	26.26	12.12	14.70	9.30
	67	20–44	23.30	20.05	16.80	28.90	10.95
Lares	114	0–60	11.48	7.75	12.92	35.25	32.60
	113	60+	11.00	5.80	13.95	44.95	24.30

TABLE 4.—*Continued*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
Terraces and alluvial fans—compact							
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Fraternidad	30	0–7	35.48	15.30	10.30	28.40	10.52
	39	7–18	30.75	9.95	13.40	44.25	1.65
	28	18–36	16.40	11.45	14.40	40.05	17.70
	28B	36+	18.65	12.10	11.10	41.01	17.14
Paso Seco	37	0–10	25.15	20.55	11.05	28.80	14.45
	36	10–18	35.10	18.00	11.35	12.90	22.65
	35	22–35	17.37	28.23	17.35	22.70	14.35
Santa Isabel	44	0–8	21.54	23.59	18.32	22.75	13.80
	43	8–16	46.10	10.37	8.17	23.41	11.95
	42	16–24	28.95	10.80	9.15	27.30	23.80
Coastal plains							
Sabana Seca	194	0–12	57.05	5.45	6.30	21.50	9.70
	193	12+	80.75	9.72	5.70	3.83	—
Coto	122	[2]	6.26	3.16	13.78	23.00	53.80
Bayamón	165	0–18	50.83	7.62	2.37	25.25	13.93
	164	18–24	14.90	2.10	1.20	59.70	22.10
Matanzas	119	[2]	1.75	2.25	5.80	53.80	37.40
Corozo	147	0–2	93.75	1.15	.20	3.05	1.85
	150	2–12	91.90	1.00	.20	3.30	3.60
Guayabo	105	12–36	71.02	12.93	5.22	5.65	5.18
	104	36+	52.30	2.05	1.50	28.80	15.35
Islote	141	0–40	89.00	1.90	1.75	1.30	6.05
Maleza	101	[2]	89.85	.95	.80	3.90	4.50
St. Lucie	169	[5]	65.85	2.05	4.05	23.50	4.55
Flood plains							
Viví	73	0–15	43.23	28.14	9.48	14.40	4.75
	72	15+	62.06	24.64	6.55	4.30	2.45

TABLE 4.—*Concluded*

Soil series	Sample No.	Depth	Coarse sand	Very fine sand	Silt	Clay	Lost on cleaning[1]
Flood plains (continued)							
		Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
San Antón	41	0–24	12.04	26.76	25.05	20.50	15.65
	40	24–29	22.84	27.61	18.25	16.80	14.50
	39	29–44	15.20	21.00	12.00	22.65	29.15
	38	44+	61.60	5.85	5.00	7.75	19.80
Toa	52	0–16	4.45	18.45	13.85	29.55	33.70
	51	16–34	.92	21.30	18.88	35.30	23.60
	50	34–46	3.95	11.65	15.00	39.00	30.40
Aguirre	31	0–10	27.20	7.90	8.40	30.26	26.24
	32	10+	12.59	17.77	17.26	31.83	20.25
Coloso	49	0–10	14.60	11.45	14.45	38.95	20.55
	48	10–34	5.93	8.95	19.92	45.15	20.05
	47	34–52	1.15	9.05	23.80	47.20	18.80
	46	52+	.98	8.32	24.17	47.68	18.85
Guánica	34	[2]	6.87	18.26	12.62	38.35	23.90
	33	[3]	12.20	8.77	11.28	41.80	25.95

[1] Includes free or hydrated oxides of iron, aluminum and titanium, free silica, carbonates, organic matter, and soluble cations and salts.

[2] Surface.

[3] Subsoil.

[4] Soil below concretions.

[5] Subsurface.

A few of the very fine sand and silt fractions which contained no feldspar were of interest in that they consisted almost wholly of some quartz and large plates of kaolin. This was particularly true in the Los Guineos soil but was also noted in several other highly weathered soil profiles.

The clay minerals identified were kaolin, illite, montmorillonite, and one identified tentatively as beidellite. The most abundant clay minerals were kaolin and the beidellitelike mineral, illite was next in abundance, followed by montmorillonite. In some cases the clay fractions were mixtures, but in many they were apparently very well-developed single clay minerals. Where illite or chlorite was identified in the upper horizons weathering reactions changed these minerals in the lower horizons to kaolin or beidellite.

The constituent minerals identified in the very fine sand, silt, and clay fractions of the soils indicated, and their relative abundance in the soil profile are shown in table 5. For convenience the soils have been arranged according to the physiographic areas in which they occur.

The method of determining the presence of the various mineral groups was by comparing typical X-ray patterns of the soil fractions with those of known minerals. In addition to X-ray patterns of the very fine sand fractions, petrographic examinations were carried out to determine the presence or absence of small quantities of feldspar which would not be apparent in the X-ray patterns.

DISCUSSION OF FINDINGS

This study was conducted on the very fine sand, silt, and clay fractions of the soils indicated from which the free iron oxides had been removed. The soils studied were of the zonal, intrazonal and azonal orders and were from 15 of the great soil groups, as shown in table 2. In most cases soil profiles were studied; in a few, however, where it was impossible to secure profile samples, surface soils alone were investigated.

The constituent minerals of soils which have been previously discussed are those of the quartz, feldspar, mica, and clay-mineral groups. Study of the X-ray patterns showed that the muscovite mica group was not present in the soils studied, consequently any comparisons made are based on the quartz, feldspar, and clay-mineral groups. The presence or absence of feldspar in the various soils studied (table 5) showed that in the upland soils, which included a group of 17 soil series, 8 contained feldspars in appreciable quantities, 1 in very small quantities and feldspars were completely absent or were present in only minute traces in the other 8. Feldspars were present in 2 of the soils of the inner plains, and absent in 2. The group of soils from the terraces and alluvial fans included 4 soils containing feldspars and one without. All the soils of the coastal plains were practically free of feldspars; the river flood plain soils, however, all contained appreciable quantities Table 6 gives the soil series with and without feldspars.

Further study of the soils which contained feldspars showed that the feldspar content of the various horizons decreased with depth in some soils; in others it increased in the sand and silt fractions as has been previously noted.

Twenty-one of the soil series studied contained feldspars. It was noted that in 9 of these series the feldspar content of the very fine sand and silt fractions decreased with depth in the profile, and in 12 of them the feldspars increased with depth.

The feldspars typical of all soils were of the plagioclase series. The plagioclase feldspar series consists of solid solution mixtures of the albite

TABLE 5.—*Soil series and distribution of feldspars and clay minerals in the physiographic arid and humid areas*

Soil series	Physiographic arid or humid areas	Layer or depth of profile	Feldspar				Clay minerals identified and variations in profile[1]
			Relative abundance	Varieties	Variation in profile[1]		
					Very fine sand	Silt	
		Inches					
Aguilita	Upland, shallow, arid	[2]	Absent	—			Beidellite
Alonso	Upland deep, humid	8–18	Medium	Oligoclase	↑	↑	Kaolin
		18–32	—	do.	│	│	Do.
Catalina	do.	[2]	Absent	—			Do.
Ciales	do.	[2]	Medium	Oligoclase, andesine,	│	│	Kaolin + illite
		[3]	—	traces of labradorite and albite	↓	↓	Do.
Cialitos	do.	20–33	Absent	—			Kaolin, traces of illite
		33–45	—	—			Do.
Juncos	do.	0–8	Very high	Albite, andesine, trace of orthoclase	│	↑	Montmorillonite; Kaolin
		8–15	—	—	│	│	Montmorillonite; Kaolin, illite
Los Guineos	do.	0–24	Absent	—			Kaolin
		24–32	—	—			Do.
		32–48	—	—			Do.
		48+	—	—			Do.
Múcara	do.	0–10	Very high	Andesine	│	│	Beidellite
		10–18	—	Andesine, labradorite	│	│	Do.
		18–30	—	do.	│	│	Do.
		30+	—	do.	↓	↓	Do.

TABLE 5.—*Continued*

Nipe	do.		Absent	—			Kaolin
Pandura	do.	0–12	High	Albite, trace of oligoclase and andesine	|	|	Kaolin, illite
		12–24	—	—	|	|	Do.
		24+	—	—	↓	|	Kaolin
Soller	do.	[2]	Absent	—			Do.
Tanamá	do.	[2]	do.	—			Do.
Teja	do.	0–12	Very high	Oligoclase, albite	|	|	Do.
		12+	—	—	↓	↓	Do.
Utuado	do.	0–24	Very low	Oligoclase and albite	↑		Do.
		24–56	—	—	|	absent	Do.
		56–64	—	—	|		Do.
		64–72	—	—	|		Do.
Río Piedras	do.	[2]	Absent	—			Do.
Descalabrado	Upland shallow, arid	0–10	Medium	Oligoclase, albite	↑	↑	Illite
		10–24	—	—	|	|	—
		24+	—	—	|	|	—
Jácana	do.	0–7	High	Oligoclase, albite	↓	↓	—
		7–12	—	—			—
Cabo Rojo	Inner plains, humid	0–24	Absent	—			Beidellite
		24–36	—	—			Do.
		36+	—	—			Kaolin, montmorillonite
Las Piedras	do.	0–20	Very high	Albite, andesine, traces of orthoclase	|	|	Kaolin ↑
		20–44	—	Andesine, albite	|	|	|
		44–48	—	Albite, oligoclase	|	|	|
		48+	—	Albite	↓	↓	Beidellite

TABLE 5.—*Continued*

Soil series	Physiographic arid or humid areas	Layer or depth of profile	Feldspars: Relative abundance	Feldspars: Varieties	Feldspars: Variation in profile[1]: Very fine sand	Feldspars: Variation in profile[1]: Silt	Clay minerals identified and variations in profile[1]
		Inches					
Mabí	Inner planes, humid	0–10	High	Oligoclase, albite	↑	↑	Kaolin, illite
		10–30	—	—	|	|	↑ ↑
		30+	—	—	|	|	Beidellite
Moca	do.	[2]	Absent	—			Kaolin, montmorillonite, illite
Lares	Terraces medium friable, humid	0–5	do.	—			Kaolin
		5+	—	—			Do.
Humacao	Terrace and alluvial fans, humid	0–20	High	Oligoclase, albite	|	|	Do.
		20–44	—	—	↓	↓	Do.
Fraternidad	Terraces and alluvial fans, arid	0–7	Very low	Albite, labradorite	↑	↑	Beidellite (carbonates)
		7–18	—	do.	|	|	—
		18–36	—	do.	|	|	—
		36+	—	do.	|	|	—
Paso Seco	do.	0–10	—	Albite	|	|	Kaolin, illite
		10–18	—	—	|	|	—
		22–35	—	—	↓	|	—
Santa Isabel	Terraces and alluvial fans, compact, arid	0–8	High	Oligoclase, albite, labradorite	↑	|	Kaolin, illite
		8–16	—	—	|	|	—
		16–24	—	—	|	|	—
Corozo	Coastal plains, humid	0–2	Absent	—			Kaolin
		2–12	do.	—			Do.
Islote	do.	0–40	—	—			Kaolin, illite
Sabana Grande	Coastal plains, compact, humid	0–12	Absent	—			Kaolin
		12+	—	—			Do.

TABLE 5.—*Concluded*

St. Lucie	do.	[2]	Absent	—			Do.
Coto	Coastal plains, friable, humid	[2]	Do.	—			Do.
Bayamón	do.	0–18	Absent	—			Do.
		18–24	—	—			Do.
Matanzas	do.	[2]	Absent	—			Do.
San Antón	Flood plains, well-drained, arid	0–24	High	Oligoclase, albite labradorite	↑	↓	Illite, kaolin, chlorite
		24–29	—	do.			↑ ↑ ↑
		29–44	—	do.			
		44+	—	—			Beidellite
Toa	Flood plains, well-drained, humid	0–16	High	Albite	↓	↓	Kaolin
		16–34	—	do.			↑
		34–46	—	do.			Beidellite
Viví	Flood plains, well-drained	0–15	Very high	Oligoclase, andesine, albite	↓	↑	Kaolin
		15+	—	—			—
Aguirre	Flood and coastal plains, poorly drained, arid	0–10	Medium	Albite	↓	↓	Beidellite
		10+	—	do.			Do.
Coloso	Flood plains, poorly drained, humid	0–10	Medium	Albite, oligoclase, orthoclase	|	↑	Kaolin
		10–34	—	—			Do.
		34–52	—	—			Do.
		52+	—	—			Do.
Guánica	Flood plains, poorly drained, arid	[2]	High	Albite, andesine	↓	↓	Beidellite
		[3]	—	—			Do.

[1] Arrow pointing up, down, and straight vertical line, indicate decrease, increase, and no change in feldspars, with depth, respectively.

[2] Surface. [3] Subsoil.

molecule Ab. ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$) and anorthite An. ($CaO \cdot Al_2O_3 \cdot 2SiO_2$). Albite and anorthite are designated as end members of the series and the intermediate compositions are generally expressed in the percentage distribution of the albite and anorthite molecules. Table 7 gives the plagioclase series, variety names, and limits of composition.

TABLE 6.—*Soil series of Puerto Rico studied in which feldspars are present or absent*

Feldspars present	Feldspars present	Feldspars absent	Feldspars absent
Alonso	Mabí	Aguilita	Corozo
Ciales	Humacao	Catalina	Maleza
Juncos	Viví	Cialitos	Guayabo
Múcara	Fraternidad	Los Guineos	Islote
Pandura	Paso Seco	Soller	Sabana Seca
Teja	Santa Isabel	Tanamá	St. Lucie
Utuado	San Antón	Río Piedras	Coto
Descalabrado	Toa	Cabo Rojo	Bayamón
Jácana	Aguirre	Moca	Matanzas
Las Piedras	Coloso	Lares	Nipe
—	Guánica	—	—

TABLE 7.—*Variety names and composition limits of plagioclase feldspar series*

Variety name	Composition limits	Variety name	Composition limits
Albite	Ab_{10}-Ab_9An_1	Labradorite	Ab_5An_5-Ab_7An_3
Oligoclase	Ab_9An_1-Ab_7An_3	Bytownite	Ab_7An_3-Ab_1An_9
Andesine	Ab_7An_3-Ab_5An_5	Anorthite	An_{10}

TABLE 8.—*Comparison of the clay content of soils containing feldspars and those containing no feldspars in soils of the upland, inner plain, terraces, and alluvial fans*

Physiographic group	Clay content with feldspars present	Clay content with feldspars absent
	Percent	*Percent*
Upland soils	18.24	28.50
Inner plain soils	21.48	39.41
Terraces and alluvial fans	15.58	40.20

In the 21 soil series that contained appreciable quantities of feldspars the predominant feldspar was albite in 8 cases, oligoclase in 12, and andesine in 1. Minor quantities of andesine and labradorite were observed in many soils where the very fine sand and silt fractions were predominantly albite or oligoclase.

Study of the mechanical analyses in table 4 showed that, where comparisons could be made, the soils containing appreciable quantities of feldspar

TABLE 9.—*Clay content, cation-exchange capacity, and clay minerals present in the soils from Puerto Rico*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Reddish Brown	Jácana clay	3	12+[1]	23.80	26.11	Beidellite + kaolinite
		4	0-7[2]	23.46	22.63	Do.
Gray-brown podzolic or lithosol depending on depth and slope	Múcara silty clay loam	6	30+	13.35	36.71	Beidellite
		7	18–30	10.05	29.75	Do.
		8	10–18	13.26	31.04	Do.
		9	0–10	24.55	36.04	Do.
Reddish prairie	Mabí clay	13	30+	27.30	31.65	Beidellite
		14	10–30	31.45	34.02	—
		15	0–10	24.25	31.17	Kaolinite + illite
Lithosol associated with Prairie, Chernozem and Chestnut soils	Descalabrado silty clay	23	0–10	20.05	16.97	—
		24	10–18[1]	26.55	22.27	Illite
		25	24[3]	21.75	16.46	—
		26	[4]	29.70	19.78	—
Reddish chestnut	Fraternidad clay	28	18–36	40.05	15.19	—
		28B	36[5]	41.01	13.18	—
		29	7–18[6]	44.25	11.23	Beidellite
		30	0–7	28.40	21.03	Do.
Alluvial, poorly drained	Aguirre clay	31	0–10	30.26	42.06	Beidellite
		32	10+	31.83	26.20	Do.
Wiesenboden	Guánica clay	33	[7]	41.80	39.56	Beidellite
		34	[2]	38.35	43.20	Do.
Reddish prairie	Paso Seco silty clay	35	10–18	22.70	16.80	Kaolinite + illite
		36	0–10	12.90	20.10	—
		37	22–35	28.80	19.62	—
Alluvial, well-drained, semiarid and subhumid area	San Antón loam	38	44+	7.75	11.16	Beidellite
		39	29–44	22.65	22.63	—
		40	24–29	16.80	18.83	—
		41	0–24	20.50	23.74	Illite + kaolinite + chlorite

TABLE 9.—*Continued*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Reddish Chestnut, sometimes classified as a planosol	Santa Isabel clay	42	16–24	27.30	23.74	—
		43	8–16	23.41	23.08	—
		44	0–8	22.75	22.02	Kaolinite + illite
Alluvial, poorly drained, humid area	Coloso silty clay	46	52+	47.68	35.13	—
		47	34–52	47.20	35.51	—
		48	10–34	45.15	31.59	Kaolinite
		49	0–10	38.95	38.61	—
Alluvial, well-drained, humid area	Toa silty clay loam	50	34–46	39.00	37.20	Beidellite
		51	16–36	35.30	35.91	Kaolinite
		52	0–16	29.55	34.97	—
Gray-brown podzolic	Juncos clay	57	15–18	26.35	58.32	Montmorillonite + Illite and Kaolinite
		58	0–8	33.05	51.64	Montmorillonite and Kaolinite
Lithosol closely related to gray-brown podzolic	Pandura sandy clay loam	60	24+	7.20	7.61	Kaolinite
		61	12–24	5.00	6.93	Kaolinite + Illite
		62	0–12	6.45	8.16	Kaolinite + Illite
Gray-brown podzolic	Las Piedras clay loam	63	48+	8.35	12.18	—
		64	44–48	28.55	24.75	Beidellite
		65	20–44	14.85	9.04	—
		66	0–20	15.50	7.06	Kaolinite
Do.	Humacao loam	67	24+	28.90	14.56	Kaolinite
		68	0–24	14.70	11.39	Do.
Do.	Teja loam	70	12+	10.40	7.94	Kaolinite
		71	0–12	12.35	8.21	Do.
Alluvial, well-drained, subhumid area	Viví sandy loam	72	15+	4.30	4.85	Kaolinite
		73	0–15	14.40	7.70	Do.

TABLE 9.—*Continued*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Reddish-brown lateric	Catalina clay	81	[8]	43.95	10.77	Kaolinite
Reddish-brown lateric	Cialitos clay	83	33–45	48.30	17.83	Kaolinite
		83B	[9]	19.05	13.34	Do.
		84	20–33	45.00	14.24	Do.
		85	[10]	42.05	29.10	Do.
		87	[11]	3.90	5.84	Illite + Kaolinite
Reddish-brown lateritic	Alonso clay	90	32+	22.00	56.34	—
		91	8–18	23.50	43.04	—
Gray-brown podzolic	Ciales clay loam	92	[7]	9.25	11.80	—
		93	[12]	9.15	9.87	Kaolinite + Illite
Gray-brown podzolic or Lithosol, depending on depth and slope	Utuado loam	95	64–72	6.45	4.27	Kaolinite
		96	56–64	13.85	9.15	Do.
		97	24–56	19.40	10.77	Do.
		98	0–24	11.35	5.22	Do.
Planosol	Guayabo fine sand	104	36+	28.80	7.95	Kaolinite
		105	12–36	5.65	2.20	Do.
Red-and-yellow podzolic	Moca clay	106	[7]	46.60	34.11	Kaolinite, Montmorillonite, Illite
Lithosol related to the Reddish-brown lateritic	Tanamá stony clay	108	[2]	51.65	8.46	Kaolinite
		109	[13]	36.70	7.05	Do.
Red-and-yellow podzolic	Lares clay	113	60+	44.95	22.60	Kaolinite
		114	0–60[2]	35.25	16.54	Do.
Rendzina	Soller clay	117	0–18	53.80	63.53	Beidellite
Reddish-brown lateritic	Matanzas clay	119	[2]	60.50	7.12	Kaolinite
Yellowish-brown lateritic	Coto clay	122	[2]	23.00	7.70	Kaolinite

TABLE 9.—*Concluded*

Great soil group	Soil type	Sample No.	Depth	Clay content	Cation-exchange capacity	Clay minerals present X-Rays
			Inches	*Percent*	*M.e./100 gm. soil*	
Red-and-yellow podzolic	Cabo Rojo clay	132	36+	32.80	[14]	Kaolinite + Montmorillonite
		134	24–36	34.25	11.29	Beidellite
		135	0–24	26.35	14.08	Do.
		137	[15]	57.23	57.58	Do.
Laterite	Nipe clay	156	[16]	25.97	.78	Kaolinite
		157	[17]	44.37	.82	Do.
		159	[18]	9.38	19.94	Kaolinite + serpentine
		160	0–24[19]	.87	.82	—
Reddish-brown lateritic	Bayamón sandy clay	164	18–24	59.70	5.47	Kaolinite
		165	0–18[2]	25.25	5.22	Do.
		167	[20]	9.00	4.08	Do.
Ground-water podzolic	St. Lucie fine sand	169	[21]	23.50	3.48	Kaolinite
Reddish-brown lateritic	Catalina stony clay	172	[2]	26.27	11.16	Kaolinite
Red-and-yellow podzolic	Los Guineos clay	176	[22]	27.90	4.52	Kaolinite
		182	[23]	16.95	25.91	Beidellite
		183	48	17.20	7.44	Kaolinite
		184	32–48	17.36	7.57	Do.
		185	24–32	23.15	9.18	Do.
		186	0–24	3.70	8.70	Do.
Reddish-brown lateritic	Río Piedras clay	190	[2]	62.17	15.11	Kaolinite
Planosol or ground-water laterite	Sabana-Seca sandy clay	193	[24]	3.83	.47	Kaolinite
		194	0–12[2]	21.50	7.11	Do.

[1] B Horizon.
[2] Surface.
[3] C Horizon.
[4] Yellow decomposed rock.
[5] Below.
[6] Hard-layer pebbles.
[7] Subsoil.
[8] Soil directly from rock.
[9] Rock.
[10] Ashlike material.
[11] Weathered sandstone.
[12] Disintegrated rock.
[13] Soft limestone.
[14] Sample lost.
[15] Green clay.
[16] Below concretions.
[17] Above concretions.
[18] Residue.
[19] Soil.
[20] Sandy soil.
[21] Clay layer.
[22] Decomposed rock.
[23] Decomposed parent material.
[24] Organic-sandy layer.

had on the average a lower clay content than those containing none, or minute traces only. Table 8 shows these average figures for soils of the upland, inner plains, and terrace and alluvial fan groups.

The clay content, cation-exchange capacity, and clay minerals present in 38 soils series studied, comprising 99 samples at various depths, are reported in table 9. The clay minerals identified consisted of kaolinite, illite, montmorillonite, chlorite, and a mineral identified tentatively as beidellite. The soil samples wherein kaolinite was identified had the lowest mean clay content and cation-exchange capacity (table 10) and those in which montmorillonite was found had the highest. The mean cation-exchange capacity for soils containing beidellite and montmorillonite were approximately three and five times higher, respectively, than those containing kaolinite.

TABLE 10.—*Mean clay content, cation-exchange capacity, and clay-mineral content of soil samples studied*

Number of samples	Clay content	Cation exchange capacity	Mineral
	Percent	*M.e./100 gm. soil*	
42	26.57	10.07	Kaolinite
1	26.60	22.30	Illite
20	29.96	31.41	Beidellite
3	35.30	48.00	Montmorillonite

In the upland soils containing feldspar, kaolin was the predominating clay mineral with one exception (Descalabrado) where illite predominated. With the kaolin were varying quantities of montmorillonite, illite, and the beidellite mineral. Where no feldspar occurred kaolin was predominant with small quantities of illite.

The inner plains soils contained beidellite predominantly, apparently being formed from kaolin and, in addition, small quantities of illite and montmorillonite occurred.

In the terrace and alluvial fans kaolin was generally found with beidellite and illite.

In the coastal-plains soils where no feldspar was observed kaolin predominated, and in the river flood-plains soils, all of which contained feldspar, beidellite was the chief clay mineral with traces of illite and chlorite.

It was interesting to note that in many instances the beidellitelike mineral was formed in the lower horizons of soils in which the feldspar content of the very fine sand and silt fractions increased with depth. This can be seen in table 5 for Las Piedras, San Antón, and Toa. Where feldspar decreased with depth, kaolin appeared to predominate throughout the profile. Where illite and chlorite occurred in the upper horizons, weathering reactions appeared to change these clay minerals to beidellite. In the San Antón soil, illite, kaolin, and chlorite occur in the 0–24-inch horizon, chlorite does not occur in the 24–29-inch horizon, illite and kaolin persist to a depth of 44 inches, and beidellite occurs at 44 inches +. Apparently under the extreme weathering conditions in the Tropics, chlorite and illite are not very resistant.

In the course of this study some interesting observations were made which appear to lead to some valuable information. From the standpoint of the presence and absence of feldspars which has been noted previously herein, comparisons of the productivity ratings of these soils as reported in the Soil Survey Report (13) show that those containing feldspar have a productivity rating almost three times as high as those containing none, except where lack of rainfall and excessive erosion are factors.

Another comparison was based on the presence of available potassium. In a study using Hegari sorghum as a plant index (5) Capó determined the relative availability of nitrogen, phosphorus, and potassium in 56 soils of Puerto Rico. Included in that study were 25 of the soil series reported here. Fourteen of these soils contained feldspar in the very fine sand and silt fractions, and 11 did not. The average relative available potassium of these two groups showed that the soils containing feldspar also contained 2.2 times as much available potassium as those in which no feldspar occurred. Since the feldspars in these soils are plagioclase and should contain no potassium, and also since muscovite, another common potash mineral does not occur, the source of this available potash is of interest. As shown in table 8, the average clay content of the soils containing feldspar is lower than that of those which do not.

The evidence suggests that the feldspar minerals might constitute a source of potash. Winchell (15) stated that, under certain conditions, the albite molecule forms three crystal phases with sanidine, adularia, and microcline, all of which are potash feldspars of the general formula $K_2O \cdot Al_2O_3 \cdot 6SiO_2$. In general, calling the potash feldspar orthoclase for comparative purposes, and using the abbreviations Or for orthoclase and Ab for albite, Winchell mentioned three possible series, vis, $Or_{50}Ab_{50}$ to about $Or_{10}Ab_{90}$, $Or_{80}Ab_{20}$ to about $Or_{40}Ab_{60}$ and $Or_{40}Ab_{60}$ to $Or_{10}Ab_{90}$.

SUMMARY

The constituent minerals in the very fine sand, silt, and clay fractions of some of the important soils of Puerto Rico were studied using petrographic and X-ray methods.

It was found that these soils could be divided into two general groups: Those that contained appreciable feldspar and those in which feldspars

were totally absent or occurred in minute traces. Study of the profile characteristics showed that the feldspar content of the profile allowed a further subdivision into: Those in which the feldspar decreased with depth; and those in which feldspar increased with depth. The feldspars identified consisted almost exclusively of plagioclase, albite, oligoclase, and andesine, these being the principal constituents, with traces of labradorite and very small traces of orthoclase.

The clay minerals identified in the soil studied consist of either kaolin, hydrous mica, or illite, one tentatively identified as beidellite, and montmorillonite, with mean cation-exchange capacities of 10.07, 22.30, 31.41, and 48.00 milliequivalents per 100 gm. of soil, respectively. Some soils contained a combination of two or three of these clay minerals. In the upland soils where feldspar occurred, kaolin was the predominating mineral with varying quantities of hydrous mica and montmorillonite. Where no feldspar occurred in the upland soils, the clay mineral was principally kaolin. The inner-plains soils chiefly contained beidellite, regardless of whether feldspar was present or not. Five soils of the terraces and alluvial fans contained feldspar and one did not, and kaolin was the principal clay mineral. The river flood-plain soils all contained feldspar and beidellite was the predominant clay mineral. The coastal-plain soils contained no feldspar and kaolin predominated.

The occurrence of the feldspar in a profile seems to have some bearing on the clay minerals formed by the weathering processes. Where feldspars increased with depth, beidellite seemed to be the ultimate clay mineral formed. Where feldspar decreased, the clay mineral formed was kaolin.

By comparing the presence or absence of feldspar with the productivity rating as determined by the Soil Survey of Puerto Rico, it was found that soils containing feldspar had a much higher productivity rating than those from which it was absent, or in which it occurred only in small traces—also that soils containing feldspar had a lower clay content than those which did not.

If the available potash content using Hegari sorghum was regarded as a plant index, comparisons showed that soils containing feldspar also contained about 2.2 times more available potash than those lacking feldspar.

In general, the results obtained indicate that the most productive soils studied were those that contained fairly large quantities of feldspar, had a low clay content, and the clay minerals of which were mixtures of kaolin, hydrous mica, and beidellite and, in some cases, montmorillonite.

RESUMEN

Los minerales constituyentes de todos los suelos son: el cuarzo, los feldespatos, las micas y los del grupo de la arcilla. Para identificar estos

minerales en los suelos de Puerto Rico que se estudiaron, se trataron las muestras, químicamente, con el objeto de eliminar la materia orgánica y los sesquióxidos de aluminio y de hierro. Los residuos limpios se separaron, mediante el análisis mecánico, en fracciones de arena muy fina, limo y arcilla. Se identificaron los minerales, constituyentes de cada una de estas fracciones, por medio de los métodos petrográficos y de los rayos X.

El cuarzo se encontró en las tres fracciones estudiadas, pero las micas y, especialmente, la mica muscovita que, generalmente, abunda en los suelos, no apareció.

Estos suelos estudiados pueden dividirse en dos grupos amplios; aquéllos que contienen suficiente cantidad de feldespatos y los que contienen indicios o ningún feldespato.

El estudio del perfil señaló también aquellos suelos en que los feldespatos disminuían, a medida que aumentaba su profundidad, y aquéllos donde los feldespatos aumentaban. Los feldespatos principales, identificados, consistían, principalmente, de los grupos plagioclasa, oligoclasa y andesina, con indicios de labradorita e indicios ínfimos de ortoclasa.

Los minerales identificados en el grupo de la arcilla, consistían de caolina, o de mica hidratada, ilita, o montmorillonita, con valores promedios, de intercambio de bases, de 10.07, 22.30, 31.41, y 48.00 miliequivalentes por 100 gramos de suelo, respectivamente.

También se identificó un grupo, tentativamente, como beidelita. Algunos suelos contenían una combinación de dos o tres minerales del grupo de la arcilla.

En los suelos de la altura de Puerto Rico que contenían feldespatos, el mineral predominante era la caolina, con cantidades variables de mica hidratada y montmorillonita. En aquéllos, donde no había feldespatos, el mineral predominante era la caolina, principalmente.

Los suelos del interior contenían beidelita, principalmente, con o sin feldespatos. Cinco suelos del grupo de las terrazas y abanicos de aluvión contenían feldespatos. Sin embargo, el otro suelo del grupo no lo tenía, pero en todos, el mineral predominante era la caolina.

Todos los suelos de las llanuras, sujetos a inundación, contenían feldespatos y beidelita.

Los suelos de las llanuras costaneras no contenían feldespatos, pero la caolina predominaba.

La presencia de los feldespatos en el perfil, señalaba una relación entre los minerales del grupo de la arcilla y el proceso de meteorización. Cuando los feldespatos aumentaban, según la profundidad, la beidelita predominaba, y cuando los primeros disminuían, la caolina predominaba.

En los suelos más fértiles, los feldespatos predominaban y el contenido de arcilla era menor que en los menos fértiles.

Tomando como base el contenido de potasa asimilable, determinado cuando se usó la planta sorgo Hegari, como índice, se encontró que los suelos que contenían feldespatos tenían alrededor de 2.2 veces más potasa asimilable que los que no los contenían.

Los resultados indican que los suelos más productivos fueron aquéllos con mayor cantidad de feldespatos y menor de arcilla. Los minerales de estos suelos más productivos, en el grupo de la arcilla, consistían de mezclas de caolina, mica hidratada, y en algunos casos de montmorillonita.

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