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Characterization of a Buried Latosol from Northern Puerto Rico

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INTRODUCTION

It is an accepted fact in pedology that soils with fully developed profiles existed long before today's soil mantle was formed. Most of these ancient soils have disappeared through the process of erosion; however, in certain places the soils were buried by rock materials and their profiles remain intact. These buried profiles may well serve as a key to the study of the role that past interactions among climatic and geologic processes played in soil formation.

Buried soils have, since long, been a subject of investigation by soil scientists (*3*, *4*).[2] Recently Kaye (*1*) observed the occurrence of buried profiles along the northern coast of Puerto Rico.

Kaye observed that "West of Arecibo, in a series of interesting road cuts and excavations, ... [porous sandstones of aeolian origin] can be seen deposited against the eroded slopes cut into the marine sands and limestones. Between the two types [of rocks, sandstone, and limestone] is a well-developed soil zone consisting of a red sandy loam" (*1*). He further observed a similar buried soil, some 1 to 4 feet in depth, interbedded between two sandstones in a hill west of the mouth of the Manatí river and that other exposures of the same type occurred as far east as Carolina. According to Kaye, in some places the Islote (*5*) soils could be traced as mere outcrops of these buried soils. He claimed that the Islote soils, whether buried or in outcrops, could be traced to a period of low sea level during one of the Pleistocene glacial stages and that probably the origin of the soils dated from a pre-Wisconsin glacial stage. Based on his geologic observations Kaye presented an

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[2] Italic numbers in parentheses refer to Literature Cited, p. 126.

interesting hypothesis propounding that laterization processes acted with more effectiveness in the past than they do at the present.

OBJECTIVE

There is a need of more detailed studies of buried profiles; these may provide information on the significance of past time as a factor in soil formation. Although it may help toward a better understanding of the paleopedology of Puerto Rico, this paper is merely a first approach to the subject. Herein are reported some morphological, physical, and chemical data on a buried soil profile exposed in a road cut in northern Puerto Rico; comparisons are made between the properties of the buried profile and those of its purported outcrops, an Islote soil nearby.

MATERIALS AND METHODS

Morphological studies were conducted on road-cut exposures in State Road No. 2, west of the city of Arecibo, in the northern coast of the Island. Information was secured as to number of horizons, thickness, color (based on moist field conditions and using the Munsell color-chart standards), and apparent texture and structure. Samples were taken from each horizon for analyses in the laboratory. (See Fig. 1.)

Undisturbed soil cores (3″ x 3″) were taken from each horizon by using an Uhland sampler. Hydraulic-conductivity measurements were made by recording the rate at which water moved through a column of saturated soil at a known head. Quick drainage was determined by placing the saturated soil core on a Büchner funnel at a 60-cm. tension and measuring the water drained out in 15 minutes. Water removed and retained at pF 1.78 was measured by bringing the soil to equilibrium in a 60-cm. tension table, and determining the variation in weight of the core. Water remaining at pF 2.7 and at pF 4.2 was determined by submitting saturated soil samples to pressures of ½ and 15 atmospheres, respectively, in special chambers and plates. The maximum saturation was calculated using the data obtained from the above-described moisture determinations.

The soil cores were dried at 110° C. and the bulk density of each sample was computed by dividing the net dry weight of each soil core by its original volume. The pore space was determined by assuming that the soil specific gravity was 2.65.

Mechanical analysis was done by the pipette method, using centrifugation instead of filtration through a Chamberlain filter. The pH was determined electrometrically by means of a Macbeth pH-meter. Total nitrogen was determined by the standard Kjeldahl method and the organic matter by chromic acid titration. The cation-exchange capacity was determined by the ammonium acetate method.

EXPERIMENTAL RESULTS

SOIL MORPHOLOGY

Profiles of a buried soil were examined in a road cut near Km. 78 H. 9, Road No. 2. The slope of this buried soil was estimated to be approximately 30 or 35 percent. Over the top layer of soil there is a mass of porous calcareous sandstone, deposited in a cross-bedded fashion, and some 18 to 25 feet in height. One of the most striking features of this buried soil

FIG. 1.—View of the buried latosol in a roadcut at the outskirts of Arecibo.

profile is the red color of the solum that grades into the shattered yellower sandstone. Numerous iron concretions throughout the solum are also a rather prominent feature of this profile. Thickness of the A and B horizons is variable, ranging from 1 to 4 feet. Medium to coarse structure predominates in the A horizon, the aggregates being rather small. The B horizon tends to be more firm and tight. The C horizon consists of a nonaggregated shattered sandstone rock material.

A typical profile of this buried latosol can be described as follows:

A. 0–21″ Red (2.5 *YR* 4/8) loamy sand with a moderately well-developed structure and cleavage planes in all directions. The aggregates are rather small, almost rounded, $\frac{H}{V} = 1$, with medium to coarse internal porosity. Numerous iron concretions are present.

B. 21–42″ Red (2.5 *YR* 4/6) sandy clay; probably the tightest layer in the profile. Weakly developed structure, almost massive with predominantly horizontal cleavage. The aggregates are medium in size, rounded to subangular, $\frac{H}{V} > 1$, with medium to coarse internal porosity. Many large iron concretions are present together with many water-worn pebbles.

C. 42–80″ Brownish-yellow (10 *YR* 6/6) unaggregated sandstone of marine origin with black streaks throughout.

MECHANICAL COMPOSITION

This soil is a loamy sand; there is, however, some clay accumulation particularly in the C horizon as compared to the A and B as shown in table 1.

PHYSICAL PROPERTIES

Table 2 gives the results of hydraulic-conductivity measurements and other soil-moisture studies conducted on a number of undisturbed soil cores collected at the buried-profile site. Hydraulic conductivity was moderately slow in the A horizon, slow in the following horizon, and moderately slow through the desintegrated parental sandstone. Quick-drainage values (water drained at 15-minutes under a 60-cm. tension) followed the same pattern as the hydraulic conductivities. Maximum saturation decreased from nearly 40 percent at the upper 21 inches to 34 in the next layer, but increased to 42.5 in the sandstone.

Table 3 presents data on bulk density and total porosity. Bulk-density values were all high, approaching 1.90 gm./cc. in the 21 to 42″ layer, the tightest of the profile. Total-porosity values were larger where bulk-density values were smaller. They ranged from approximately 30 percent in the tight subsoil to over 40 percent in the parent material.

CHEMICAL PROPERTIES

The results of the chemical analyses of the various horizons of this buried soil are shown in table 4. The pH values indicate alkalinity, which decreased slightly with depth. This soil was exceedingly low in organic matter throughout the profile. Nitrogen levels were very low, too. The cation-exchange capacity of the topsoil can be ranked as low, but there were moderate increases when penetrating through the subsoil to the weathered sandstone.

TABLE 1.—*Mechanical analysis of a buried latosol derived from sandstone in northern Puerto Rico*

Horizon	Depth	Sand (>0.02 mm.)	Silt (0.02–0.002 mm.)	Clay (<0.002 mm.)
	Inches	*Percent*	*Percent*	*Percent*
A	0–21	80.0	14.6	5.4
B	21–42	75.4	18.5	6.1
C	42+	76.0	14.0	10.0

TABLE 2.—*Hydraulic-conductivity and other soil-moisture data obtained from a buried latosol in northern Puerto Rico*

Horizon	Depth	Hydraulic conductivity	Water drained at 60 cm. in 15 minutes	Maximum saturation	Water removed at pF 1.78	Water remaining at—		
						pF 1.78	pF 2.7	pF 4.2
	Inches	*In./hr.*	*Percent*	*Percent water*	*Percent*	*Percent*	*Percent*	*Percent*
A	0–21	0.97	6.51	39.80	5.79	31.81	4.25	2.42
B	21–42	.14	3.18	34.00	2.24	31.25	6.74	4.41
C	42+	.30	5.51	42.50	3.33	38.39	8.16	4.13

TABLE 3.—*Bulk density and porosity for each horizon of a buried latosol in northern Puerto Rico*

Horizon	Depth	Bulk density	Porosity
	Inches	*Gm./cc.*	*Percent*
A	0–21	1.74	34.56
B	21–42	1.88	29.65
C	42+	1.44	40.51

TABLE 4.—*Mean pH, organic matter, nitrogen, and cation-exchange capacity for each horizon of a buried latosol in northern Puerto Rico*

Horizon	Depth	pH	Organic matter	Nitrogen	Cation exchange capacity per 100 gm. of dry soil
	Inches		*Percent*	*Percent*	*M.e.*
A	0–21	8.2	0.057	0.010	3.8
B	21–42	7.6	.092	.010	7.2
C	42+	7.2	.092	.004	8.4

DISCUSSION

The morphological studies pointed to the striking, well-defined red coloring, dominating the soil above the brownish-yellow unconsolidated parental sandstone. This coloring is indicative of good oxidation and concentration of iron, which indicates that laterization must have been a very active process at the time this soil was developed.

The low fertility level of this soil, as revealed by low cation-exchange capacity, and low organic-matter and nitrogen levels, further confirm the possibility that laterization was the process responsible for the genesis of this soil.

If the available water is regarded to be the difference between water remaining in the soil when tensions in the vicinity of pF 1.78 develop, and water remaining when permanent wilting occurs (pF 4.2), this soil could hold slightly above 10 acre-inches of water for crops in the upper 3 feet. Most of this water, however, would drain slowly under gravity, because practically all of it would be held at tensions below ½ atmosphere (pF 2.7).

The study of the physical properties of this soil is rather revealing. The fact that a very high percentage of the water held at pF 2.7 is unavailable, *i.e.*, held at tensions approaching pF 4.2, marks another similarity between this buried soil and other exposed latosols. Lugo-López (*2*) has shown that latosols approach the permanent wilting percentage, even when they contain relatively large amounts of water. This accounts for their relative droughtiness, usually observed under field conditions.

The moderate to slow water-conducting ability of this soil, in contrast to normal latosols of Puerto Rico, may be attributed to the compacting effect of the 18- to 20-foot layer of sandstone overlying the profile. The very high bulk-density values further indicate this compaction effect. Because of the sandy nature of the soil material many large pores remained unaffected as shown by the water retained and removed at pF 1.78. Most of these pores could be drained easily with further tensions up to pF 2.7.

Comparisons with data from Islote soils (fig. 2) outcropping about 3 km. west of the profile studied indicate similar cation-exchange capacity and about a tenfold increase in organic-matter and nitrogen levels in the outcropping soil. The pH of the buried soil is slightly higher than that of the outcropping soil. This increased alkalinity could be ascribed to the leaching of lime from the overlying highly calcareous sandstone.

Following the same comparison, but restricting it to the upper 21 inches of soil, the less dense soil was the outcropping one; it was more porous, but many more of its pores were coarse, draining easily and quickly, even at pF 1.78.

The subsoil of the outcropping Islote, however, was tight, dense, with but a small percentage of water being drained at low tensions. It was very similar to the buried profile subsoil in morphological, physical, and chemical properties, excepting perhaps the above-mentioned higher organic-matter and nitrogen levels.

From the foregoing observations this buried Islote soil profile could be classified as a latosol. So far, evidence has been provided herein indicative of the activity of laterization in past geologic periods. The interesting question raised by Kaye (*1*), as to whether this soil-forming process was more active in the past than at present remains yet to be answered.

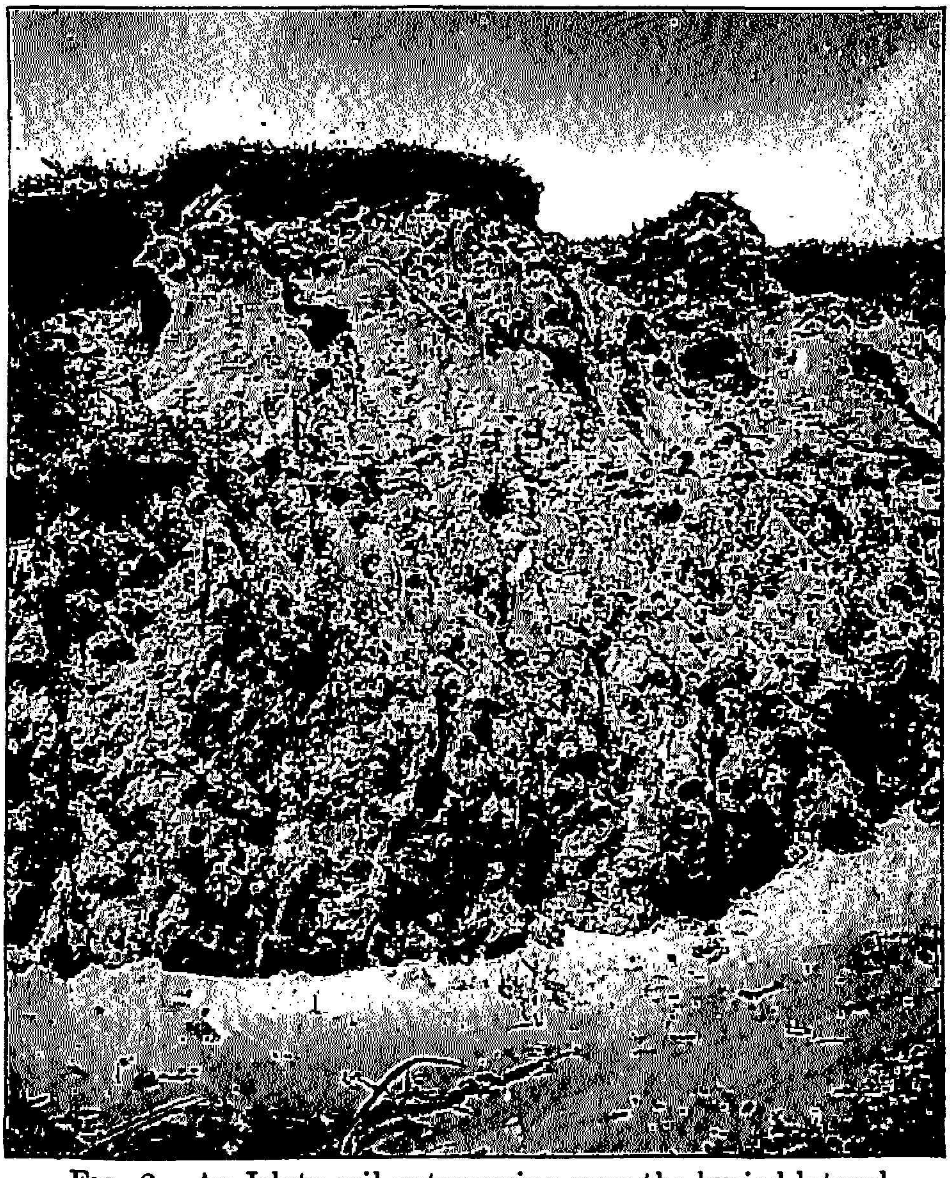

FIG. 2.—An Islote soil outcropping near the buried latasol.

SUMMARY

Data on the morphological, physical, and chemical properties of a buried soil profile in northern Puerto Rico are presented. The solum is of a distinct red color some 42 inches in depth, grading into a brownish-yellow unaggregated sandstone of marine origin and containing numerous iron concretions.

The soil is a loamy sand corresponding rather closely to the Islote soil, a somewhat extensive soil in northern Puerto Rico. The relatively high

water retention at pF 4.2 in comparison to that retained at pF 2.7 indicates the probable droughtiness of this soil, a feature of most latosols in Puerto Rico. The rather relatively low fertility status—low exchange capacity, organic matter, and nitrogen—is also characteristic of latosols. The alkalinity throughout the profile may partly be the result of lime leaching over a period of years from the overlying 18- to 25-foot layer of highly calcareous sandstone. The weight of this sandstone layer can also account for the compaction of the solum.

The over-all picture indicates that laterization was an active process in past geologic time, such as in the Pleistocene epoch when this soil was probably developed.

RESUMEN

Se presentan aquí datos sobre las propiedades morfológicas, físicas y químicas de un suelo sepultado en el norte de Puerto Rico. El suelo y subsuelo son rojos, con numerosas concreciones de hierro, con una profundidad media de unas 42 pulgadas, y descansan sobre material de piedra arenisca no consolidado, de origen marino y de color amarillo pardo.

El suelo es arenoso lómico y corresponde a los de la serie Islote que están extensamente distribuídos por la costa norte. La humedad retenida a tensiones en la vecindad del punto de marchitez permanente (pF 4.2) es bastante alta en relación a la retenida a pF 2.7, cosa característica de suelos lateríticos en Puerto Rico. Su fertilidad relativamente baja, indicada por una baja capacidad de intercambio y bajos niveles de materia orgánica y nitrógeno, es también característica de suelos lateríticos. La alcalinidad observada a través de todo el perfil puede deberse en parte a la lixiviación de compuestos de calcio de la capa de piedra arenisca carbonatada de 18 a 25 pies de grosor que sepulta este perfil. El peso de esta roca también ha causado gran compacción del suelo y subsuelo.

En general, se puede deducir que el proceso de laterización estuvo activo durante épocas geológicas pasadas, como en el Pleistoceno, cuando este suelo probablemente se formó.

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