QUANTITATIVE CLAY MINERALOGICAL ANALYSIS OF HIGHLY WEATHERED NATAL SOILS

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Abstract

The clay fraction of a Balmoral, Griffin and Clovelly soil was studied by selective dissolution analysis, cation exchange measurements, and thermogravimetric analysis. Amorphous material varying from 20% to 40% were present in all three soils. In general, the chlorite content varied between 20% and 35% while the kaolin content varied between 40% (Balmoral) and 15% (Clovelly). 10% to 20% mica was found in the Clovelly and Griffin soils, probably present as small isolated residual cores.

Introduction

In the Highlands and Midland Mistbelt of Natal the combined effects of a humid climate and long exposure to weathering are evident in the acid, highly leached and highly weathered upland soils of this zone. It is known that the colloidal fraction of these soils is largely responsible for their characteristic properties, e.g. high phosphate sorption, presence of exchangeable Al in toxic amounts, considerable pH dependent negative charge and relatively high positive charge (5, 6, 7). These properties have invited investigation into the nature of the crystalline and amorphous clay-size components with major emphasis on the latter more active forms. In this paper exchange properties and clay mineral data for three important highly weathered soils of Natal will be presented.

Materials and Methods

The A and B horizons of soil profiles representative of the Balmoral series (derived from dolerite) and the Griffin and Clovelly series (derived from shale) were used in this investigation. The Griffin series is intermediate in texture between the Cleveland and Farmhill series, while the Clovelly series is intermediate between the Oatsdale and Balgowan series. The soils studied occur widely in the Highlands and Midland Mistbelt areas of Natal and individuals of the three are to be found closely associated in the landscape.

Some important properties of the soil studied are presented in Tables 1 and 2. Mechanical analysis was conducted by hydrometer method after dispersion with NaOH; organic carbon by wet oxidation; free iron oxides by sodium dithionite-citrate extraction. Positive and negative charges and exchangeable metal cations were determined by NH_4Cl extraction at the field pH value of the soil (6). The field pH value is taken as that measured in a 1:2.5 : : soil : 0.01 M $CaCl_2$ suspension. Exchangeable Al was determined according to the method of Skeen & Sumner (8).

The clay size fraction was isolated for X-ray diffraction and quantitative analysis, as follows: After removal of organic matter by peroxide treatment the colloids were deflocculated with NaOH (to pH 8.0) and centrifuged at 750rpm for 4.5 minutes. The clay was then siphoned off to a depth of 10cm. When the bulk of the clay had been removed by repeating this procedure, flocculation with NaCl and deferration with sodium dithionite in the presence of sodium citrate followed. The bleached clay was then dewatered by centrifugation, washed with 80% ethanol until salt-free, dried and very gently ground.

Quantitative clay analysis was carried out by the technique proposed by Alexiades & Jackson (1). Using this technique the following determinations were made:

(i) mica by $HF\text{-}HClO_4$ dissolution;
(ii) vermiculite on the basis of the part of the CEC measured by Ca replaced by Mg, which is blocked by K-fixation on oven-drying at 110°C and subsequently not exchanged by NH_4;
(iii) montmorillonite on the basis of the CEC not blocked by K and NH_4 sequence for vermiculite;
(iv) chlorite by thermal gravimetric analysis;
(v) amorphous material and
(vi) kaolin by NaOH-thermal selective dissolution; and
(vii) quartz by pyrosulphate fusion.

Results and Discussion

Table 1 shows that these soils have a high free iron oxide content, especially the red Balmoral. Despite the high clay content (generally > 50%) CEC is low with Al often the dominant cation in Balmoral and Griffin sub-soils. Considerable positive charge is present giving a low effective nett negative charge (Table 2). Despite the low negative charge measured at field pH, a large pH dependent charge is present (6).

X-ray diffraction patterns for clay from the various horizons of the Balmoral, Griffin, and Clovelly soils show kaolin as the dominant mineral with moderate amounts of gibbsite present. Furthermore, a moderate to strong asymmetrical peak in the vicinity of 14A indicates the presence of chlorite.

Quantitative data for deferrated clays are given in table 3. The kaolin + amorphous component is dominant in all horizons of the Balmoral soil with 24-27% chlorite present. Less than 5% of 2:1 clays is present in the B horizon.

Data for the Griffin and Clovelly soils generally show less kaolin, a slightly lower amorphous component, but a higher chlorite content compared with the Balmoral. However, considerable mica is present especially in the Clovelly solum, although X-ray data did not indicate its presence. The shale parent material of these two soils is high in mica and the mica content of the Clovelly solum indicates that it is the less weathered soil.

Clay-size micas, regarded as low stability minerals, may conceivably be present in amounts in excess of those consistent with the concept of highly weathered materials. This may be accounted for by partial chloritization of 2:1 intergrades which affords protection to residual mica cores. These cores may persist even under high-intensity weathering as suggested by the 12% and 22% mica determined in the B horizon of the Griffin and Clovelly soils respectively (Table 3).

The "amorphous" material as determined by selective dissolution analysis includes allophane, amorphous SiO_2 + R_2O_3, and gibbsite; although the latter is crystalline, it is relatively highly soluble in alkali (2). From the X-ray data it appears that a considerable portion of the "amorphous" component is gibbsite. De Villiers & Jackson (3) found up to 50% gibbsite in the clay fraction of a subsoil horizon of a highly weathered Natal soil.

Large amounts of chlorite are common components of these clays (Table 3). Recent investigations have shown that chloritized 2:1 layer silicates (14A) are present in relatively large amounts in certain highly weathered materials; 21 and 23% respectively was found in the B horizon clay from a Balmoral and Kranskop soil (4). In such cases, the stability of pedongenic aluminous chlorite against acid weathering seems to be greater than that of kaolin. In the highly aluminous environment of the weathering regime, alumination of interlayers of expansible clay minerals will reduce the CEC to low values, give rize to pH dependent charge characteristics, and stabilize the 2:1 layer clays.

Conclusions

Significant amounts of pedogenic aluminous chlorite were found in all three of the highly weathered Natal soils which were studied. The stability of this chlorite against acid weathering seems to be as great as that of kaolin.

Alkali extractable amorphous aluminosilicates are present in large amounts and constitute up to one third of the total clay fraction in some subsoil horizons. Evidence suggests that the major portion of this component is gibbsite.

Unexpectedly large amounts of mica are present in the shale derived soils, probably as small isolated residual cores protected by interlayer hydroxy-aluminium polymers.

The high amount of pedogenic aluminous chlorite together with the large amorphous component found in the clay fractions are largely responsible for the severe acidity, strong buffering capacity, aluminium toxicity, high phosphate fixing capacity, and large pH dependent CEC associated with these soils.

TABLE 1

Mechanical composition, carbon and free iron content of soils

Series	Depth cm.	Horizon	Clay %	Silt %	Sand %	Organic C %	Free Fe_2O_3 %
Balmoral	0—30	A	52.4	10.9	36.7	2.9	10.0
	30—100	B2	55.4	7.1	27.5	0.5	9.8
Griffin	0—30	A	48.9	12.4	38.7	3.4	5.8
	30—80	B1	51.4	13.8	34.8	1.5	6.8
	80—120	B2	59.6	8.3	32.1	0.8	7.0
Clovelly	0—30	A	51.3	12.5	36.2	1.9	5.1
	30—60	B2	53.2	14.5	32.3	0.9	5.3

TABLE 2

Exchange characteristics of soils

Series	Horizon	pH (0.01MCaCl$_2$)	Exchangeable Cations (me./100g) Ca	Mg	Na	K	Total	Al	Negative Charge (me./100g)	Positive charge (me./100g)	Nett charge (me./100g)
Balmoral	A	4.5	2.6	1.0	0.2	0.2	4.0	1.2	6.8	1.4	5.4
	B2	4.7	0.6	0.7	0.1	0.1	1.5	1.0	5.8	3.3	2.5
Griffin	A	4.0	2.5	1.0	0.2	0.2	3.9	2.3	8.6	1.6	7.0
	B1	4.2	1.2	0.5	0.1	0.1	1.9	1.8	6.5	2.3	4.2
	B2	4.5	1.5	0.5	0.1	0.1	2.2	1.5	6.8	2.0	4.8
Clovelly	A	4.1	2.8	0.4	0.1	0.3	3.6	2.0	7.5	0.6	6.9
	B2	4.6	2.2	0.6	0.1	0.3	3.2	0.9	6.4	0.9	5.5

TABLE 3

Mineral components (%) of clays

Series	Horizon	Mica	Vermiculite	Montmoril-lonite	Kaolin	Amorphous	Chlorite	Quartz	Total
Balmoral	A	3	2	3	24	41	24	2	99
	B2	1	1	2	32	38	27	2	103
Griffin	A	12	1	5	18	27	35	3	101
	B1	10	1	4	19	29	36	4	103
	B2	12	1	4	25	31	26	2	101
Clovelly	A	18	2	8	20	23	29	4	104
	B2	22	1	5	14	24	33	4	103

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