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Red Acid Montmorillonitic Soils with Extractable Aluminium

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RED ACID MONTMORILLONITIC SOILS WITH EXTRACTABLE ALUMINIUM

I - SOILS WITH HIGH EXCHANGEABLE CATION CONTENT (Ca - Mg) by Yao Kouamé.

O.R.S.T.O.M. - MARTINIQUE

These are reddish brown or strongest red (10 R) soils in Martinique which are essentially composed of montmorillonitic clay mineral.

These soils are among the reddest in the West Indies.

The clay mineral content is high, normally more than 50% , and sometimes between 70 and 80 %

The percentage of exchangeable bases is high: 25 to 60 mé per cent of soil, and sometimes higher, with a very large proportion of magnesium.

The total exchange capacity determined by ammonium acetate can reach 100 mé per cent Magnesium content of 10 mé % definitely indicates montmorillonite, so that X-ray diffraction is unnecessary.

These soils were formed from volcanic sediment in the sea

Either the deposits came from marine eruptions, or they were projected from volcanoes directly into the sea, or they were carried there by rivers, clay beds alternating with volcanic deposit.

Thus, products from the weathering of primary volcanic minerals may coexist with inherited sedimentary clay materials.

The B horizon varies in depth -sometimes less than one meter,sometimes more :2 or 3 meters

The transition from the clayey B horizon to the more or less weathered, but undisturbed, sedimentary material is very clear. Subsequent landslides on the slope can, however, cause errors in interpretation

In all these profiles, even when the B horizon is less than I meter thick, exchangeable magnesium and the total exchange capacity decrease markedly from the depths to the surface.

For soils of moderate thickness, the X-ray diagrams of clay minerals change conspicuously in quality from the depth to the surface.

There is very nice montmorillonite at the base of the profile, just above the sedimentary material.Closer to the surface, swelling with glycerol is still unmistakeable, but the diagram as a whole is a little less clear.

In the deeper soils, 2 - 2.5 m in depth, the decrease in the amount of exchangeable magnesium and the total cation exchange capacity is much greater. The amount of magnesium can drop from 40-50 me % at 2 meters deep to 10-12 me % at the surface; the exchange capacity from 60-70 me to 25 me/100 at the surface.

The appearance of 7Å clay minerals mixed with montmorillonite at the surface can, thus, be easily observ--ed.

ALUMINIUM

Many of these soils have a high extractable aluminium content, extracted by the normal KCl solution. We noticed a direct relationship between the pH KCl and the presence of aluminium, over about 1000 samples.

When the pH KCl is over 4, it is very unusual to find extractable aluminium. When the pH is below 4, there is almost always aluminium. When it is 3,5 or 3,4 there are normally several mé. It is possible to find 30 me % of aluminium with 40 me Ca+Mg % exchangeable cations.

Extractable aluminium is higher in the depths. Montmorillonite is most unstable at the base of the profile and therefore liberates the most aluminium. The percentage of exchangeable bases is also higher in the depths.

Amounts of 15 to 20 me % of extractable aluminium are frequent p. 100 of soil.

The aluminium content is often negligible on the surface, ploughed horizon which has 4 to 6 % organic material. It is, however, higher in the depths. In some profiles, however, 2-4 me % of aluminium are found at the surface, rising to 10-15 me % at I m depth.

It should be noted that if these soils are treated with acids, the total exchange capacity increases considerably, sometimes 30 %.

HYPOTHESIS ABOUT THE FORMATION.

The sedimentary material-marine volcanic tuff is finely porous.

In the dry areas of Martinique (1000 to 1500 mm annually) weathering of this material produces vertisols The transition from hardly weathered material to clayey soil is very abrupt. There is very pure montmorillonitic clay mineral in the few centimeters where the two come in contact.

These red montmorillonitic soils receive 2 to 2.5 m of rainfall per year. Water infiltrates to the depths, moistening the material over a large thickness. There is little leaching and montmorillonite forms

The transition from the weathered parent material to the clayey soil, subject to cracking during the dry season, provokes a pellicular flow at the base of the profile, often accompanied by landslides. Montmorillonite weathers. This is especially noticeable at the base of the profile where montmorillonite is the most cristallized with the liberation of aluminium.

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EXPERIMENTATION

Agronomic experiments were done on a soil with the following chemical characteristics :

mé p. 100 g sol

Depth in cm.	Al	Ca	Mg	C.E.C.	pH KCl
0 - 20	5	13	12	39	3.7
40 - 50	9	19	28	62	3.7
100	15	18	38	70	3.6

-Ca,Mg,C.E.C. by ammonium acetate pH 7
-Al by normal KCl

Okra, cabbage, peanuts, corn, and lettuce were tested.
The tests were done, either with potassium nitrate alone, or with lime and phosphate.

In all cases, adding lime and phosphate cause the extractable aluminium to disappear in the ploughed horizon. The percentage drops from 5 me to 0.2 me %. However at a depth of 40-50 cm, the amount of aluminium remains the same, around 5-8 me %, and the plant roots can absorb aluminium.

Adding lime and phosphates is necessary for good growth or correct fructification (the case of corn). Growth is much better with lime and phosphorus, but the leaves and roots can have also high amounts of aluminium.

Adding phosphorus and lime only affects the surface horizon. This permits the plant to get off to a good start, but very quickly the roots sink into the lower horizons, very rich in aluminium.

Cabbage grows very badly without phosphate or lime. The aluminium content in the leaves rises from 300 ppm in healthy plants, to 4000-5000 in sick plants, with the amount of phosphorus dropping by half.
Similar differences between healthy and puny plants have been observed for okra and peanuts. Lettuce did not withstand the acidity from the beginning.
But there is often relativly good yield with high aluminium content.
The large quantities of exchangeable cations, calcium, magnesium, and also alumina phosphate, which are present seem to more or less cancel out the excess of aluminium and the toxic effect it has on certain plants, like sweet potato, even though the plant absorbs large amounts of it.

Bananas and lemons seem to withstand the high aluminium content of these soils.

II - SOILS WITH VERY LOW EXCHANGEABLE CATION CONTENT (F.Colmet-Daage)

In the West Indies, the soils are rich in extractable aluminium, but also have high percentages of exchangeable cation, calcium, and magnesium.
In Ecuadorian Amazonia, parent material is marine montmorillonitic clay minerals which are exposed to a hot climate with 4 m of rainfall annually.
The topography is that of small hills next to very steep slopes of uniform altitude.

The soils are reddish, clayey, and very deep. The B horizons may be several meters thick.

The montmorillonite is well weathered in the top layers of the profile and the proportion of clay mineral at A^? is much higher at the surface than in depth, but glycerol swelling is still very clear.

What differentiates these soils from the ones previously studied is the total desaturation of the profile; less than 1 me of bases to about 3 m depth; then the percentage rapidly increases as one goes deeper.
The amount of extractable aluminium is already high at the surface (11 me %) and increases with depth, to 1.5 m, the horizon where the weathering of montmorillonite is the most active (37 me %).

Abstract of analytical data

Depth in cm.	clay %	Exchangeable cations Ca	Mg	C.E.C	base satur %	Al mé p.100	H mé p.100	P.Al mg%	pH water	pH KCl
RED MONTMORILLONITIC SOIL WITH HIGH EXCHANGEABLE CATIONS Ca+Mg										
0-5	63	6.1	6.1	25	56	2.7	0.1	18	4.6	3.8
10-15	62	5.0	5.0	24	47	6.5	0.4	7	4.5	3.6
40-50	51	7.8	11.4	29	69	4.0	0.2	2	4.7	3.7
75-80	48	7.8	13.8	36	63	6.7	0.3	1	4.7	3.6
105	50	8.4	20.0	46	65	10.1	0.4	1	4.7	3.5
0-5	58	16	16.9	57	63	15.2	1.1	31	4.6	3.5
8-15	52	13	16	67	47	23	2.0	21	4.5	3.4
25-28	47	13.7	20.5	79	45	32	1.4	4	4.6	3.4
45-55	35	9.4	24	82	41	35.5	2.2	3	4.6	3.5
110	35	6.0	37	84	52	36.4	1.9	1	4.6	3.4
RED MONTMORILLONITIC SOIL WITH VERY LOW EXCHANGEABLE CATIONS CONTENT										
0-15	-	0.8	0.4	26	6	12	0.5		3,9	3.6
30-50	52	0.3	0.2	25	3	12	0.8		4,2	3.9
100	52	0.04	0.06	32	1	20	1.3	-	4,6	3.9
150	16	0.2	1.2	59	3	37	1.3		4,9	3.8
500	-	17	8.8	47	36	11	0.2		5,3	3.7

RED ACID SOIL WITH INSTABLE MONTMORILLONITIC CLAY MINERAL

- HIGH KCl EXTRACTIBLE ALUMINIUM
- HIGH EXCHANGEABLE CATIONS CONTENT

(MARTINIQUE)

PHYSICAL CHARACTERISTICS

PROFILE		Depth cm	pF 3	pF 4.2	humidity %	M.O. g.100	GRANULOMETRIE in g. p.100 gr of dried soil: Clay % < 2	silt fine 2-20	silt coarse 20-50	sand fine 50-200	sand coarse 200-2000	TOTAL %	pH of disper.	clay/silt	Fe_2O_3 DEB %
B837	A°	0 - 5 cm	43.0	37.7	7.21	3.34	63.43	16.83	4.08	2.94	1.13	98.96		3.03	10.
	A	10 - 15 cm	43.1	37.5	7.44	1.71	62.50	22.97	4.79	2.63	0.61	102.65		2.25	9.
	B	40 - 50 cm	43.5	37.5	8.02	0.59	51.10	21.78	7.54	4.36	0.55	93.94		1.74	8.
	C	75 - 80 cm	44.9	38.5	9.40	0.29	47.48	30.88	7.53	3.88	0.54	100.00		1.23	7.5
	D	102-105 cm	47.0	40.9	11.50	0.15	49.83	27.18	6.06	4.39	0.55	99.66		1.50	7.
B 838	A°	0 - 5 cm	49.3	44.6	12.16	4.14	57.68	16.88	2.94	2.72	1.44	97.96	pH 3.7	2.91	6.
	A	8 - 15 cm	48.4	44.0	13.14	2.43	51.80	27.15	1.58	2.63	1.58	100.31	pH 3.7	1.80	6.
	B	25 - 28 cm	48.8	44.7	14.43	0.83	47.40	23.25	4.32	8.25	1.56	100.04	pH 3.7	1.70	5.2
	C	45 - 55 cm	47.7	43.5	14.92	0.48	35.53	33.58	4.82	9.64	1.03	100.00	pH 3.9	0.92	5.1
	D	90-100 cm	45.9	41.6	14.75	0.14	34.40	31.38	5.32	12.07	0.81	98.87	pH 3.9	0.94	4.4

CHEMICAL CHARACTERISTICS

PROFILE		Depth in cm	pH soil/solut. =1/2.5 water	pH KCl	in milliequivalent gr per 100g air dried soil — Exchangeable cations (Am.Acetate): K	Na	Ca	Mg	S	T C.E.C.	Base saturat %	Al^{3+} KCl extract	H^+ KCl extract	Organic matter: C g‰	N mg‰	C/N	HUMIC ACIDS C o/oo	FULVIC ACIDS C o/oo
B 837	A°	0 - 5 cm	4.6	3.8	1.66	0.19	6.10	6.08	14.03	25.00	56.12	2.67	0.11	1.94	196.0	09.89	0.75	2.64
	A	10 - 15 cm	4.5	3.6	1.12	0.19	5.00	5.00	11.32	24.00	47.12	6.49	0.43	0.99	129.5	07.64	0.36	2.10
	B	40 - 50 cm	4.7	3.7	0.28	0.43	7.81	11.42	19.94	29.00	68.75	3.97	0.21	0.34	49.0	06.93	0.08	0.67
	C	75 - 80 cm	4.7	3.6	0.27	0.77	7.81	13.84	22.69	36.00	63.02	6.67	0.31	0.17	35.0	04.85	0.11	0.51
	D	102-105 cm	4.7	3.5	0.39	1.39	8.41	20.00	30.19	46.00	65.63	10.12	0.43	0.09	21.0	04.28	0.18	0.14
B 838	A	0 - 5 cm	4.6	3.5	3.26	0.34	15.94	16.84	36.38	57.50	63.26	15.22	1.11	2.40	262.5	09.14	0.59	3.12
	A	8 - 15 cm	4.5	3.4	2.66	0.29	12.76	16.00	31.71	67.00	47.32	22.97	1.98	1.41	182.5	07.74	0.85	2.87
	B	25 - 28 cm	4.6	3.4	.99	0.29	13.74	20.50	35.52	79.00	44.96	32.22	1.36	0.48	80.5	05.96	0.09	2.54
	C	45 - 55 cm	4.6	3.5	0.31	0.24	9.35	24.00	33.90	82.50	41.09	35.47	2.23	0.28	49.0	05.71	0.16	0.82
	D	90-100 cm	4.6	3.4	0.11	0.58	5.94	37.10	43.73	84.50	51.75	36.35	1.86	0.08	31.50	02.53	0.18	0.27

PHOSPHORE AND MANGANESE

PROFILE	Depth in cm	Al^{3+} mé.g	Results in mg.p. 100 gr of air dried soil: MnO2 Exchangeable + water soluble	MnO2 easily reductible	P_2O_5 Total	P_2O_5 Truog	P2O5 Chang and Jakson method: P. soluble	P.Fe	P.Ca	P.Al
B 837	0-5 cm	2.67	8.60	5.00	75.00	14.00	0.65	37.50	4.00	17.75
	10-15 cm	6.49	7.20	3.50	38.00	05.00	0.50	24.75	3.00	06.75
	40-50 cm	3.97	1.80	2.70	13.60	00.45	0.50	04.75	1.25	01.75
	75-80 cm	6.67	1.80	2.70	07.60	00.35	0.50	02.75	1.00	01.25
	102-105cm	10.12	2.15	2.70	04.60	00.35	0.50	02.50	0.75	01.00
B 838	0-5 cm	15.22	23.00	3.50	115.00	37.00	1.00	60.50	9.00	30.75
	8-15cm	22.97	16.25	3.50	80.00	18.00	0.83	49.00	6.00	21.50
	25-28cm	32.22	3.15	3.50	17.00	01.50	0.65	05.75	2.25	04.00
	45-55cm	35.47	7.25	3.50	09.60	00.65	0.65	03.50	1.50	03.25
	90-100cm	36.35	5.00	3.50	08.60	00.65	0.65	02.75	1.25	01.50

METHODES

Al^+, H^- extract by Normal KCl

Exchangeable cations by Normal Ammonium Acetate at pH 7

TOTAL ELEMENTS g.p.100g of soil

N° sample		Deepth cm	H_2O^-	H_2O^+	MgO	CaO	Na_2O %	K_2O %	MnO %	P_2O_5 %	TiO_2 %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	Fe_2O_3 OEB %
B 837	A O	0 - 5 cm	2.69	15.56	1.01	<0.2	0.06	<0.1	0.07	0.10	1.17	40.20	24.60	13.10	10.
	A	10 - 15	2.83	14.01	1.04	<0.2	0.04	<0.1	0.07	0.05	1.12	40.70	25.75	13.45	9.
	B	40 - 50	3.39	11.94	1.36	0.16	0.05	0.21	<0.05	<0.1	0.80	44.10	25.20	11.70	8.
	C	75 - 80	4.05	10.90	1.57	<0.2	0.08	0.31	0.04	<0.1	0.77	45.10	23.95	11.80	7.5
	D	102 -105	5.22	9.72	2.24	0.32	0.12	0.62	0.1	<0.1	0.72	46.20	21.80	11.50	7.
B 838	A O	0 - 5 cm	6.55	14.79	2.32	0.71	0.10	0.45	0.12	0.19	1.20	43.25	17.40	11.75	6.
	A	8 - 15	7.25	12.86	2.47	0.63	0.07	0.36	0.09	0.10	1.23	44.80	18.	11.60	6.
	B	25 - 28	8.63	10.88	2.94	0.41	0.03	0.23	0.11	<0.1	1.17	45.70	17.	12.50	5.2
	C	45 - 55	8.97	10.41	3.06	0.32	0.03	0.23	0.06	<0.1	1.16	45.80	16.65	12.25	5.1
	D	90 -100	9.09	9.80	3.35	<0.2	0.04	0.16	0.04	<0.1	1.12	47.30	15.80	11.60	4.4

N° sample		(Al_2O_3%+TiO_2%+Fe_2O_3%+P_2O_5%) (A)	(Al_2O_3%+Fe_2O_3%) = R_2O_3% (B)	(A)-(B)= (TiO_2+P_2O_5)	number of molécules				Characteristics molecular ratios		
					SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	SiO_2/Al_2O_3	SiO_2/R_2O_3	SiO_2/Fe_2O_3
B 837	A O	38.97	37.70	1.27	0.667	0.241	0.083	0.324	2.77	2.06	8.04
	A	40.37	39.20	1.17	0.676	0.252	0.084	0.336	2.70	2.01	8.05
	B	37.80	36.90	0.90	0.732	0.247	0.074	0.321	2.96	2.30	9.90
	C	36.62	35.75	0.87	0.749	0.234	0.074	0.308	3.20	2.43	10.12
	D	34.12	33.30	0.82	0.767	0.214	0.072	0.286	3.60	2.70	10.65
B 838	A O	30.54	29.15	1.39	0.720	0.171	0.074	0.245	4.21	2.94	9.73
	A	30.93	29.60	1.33	0.744	0.176	0.073	0.249	4.23	3.	10.20
	B	30.77	29.50	1.27	0.759	0.167	0.079	0.246	4.54	3.08	9.61
	C	30.16	28.90	1.26	0.760	0.163	0.077	0.240	4.66	3.17	9.90
	D	28.62	27.40	1.22	0.785	0.155	0.073	0.228	5.06	3.44	10.75

METHOD :

Fusion at 1200°C with strontium métaborate
Si,Al,Fe,Ti P by automatic colorimetry
Mg,Ca,Mn by absorption spectrometry
K,Na by emission spectroùetry

Results in gr of 100gr of soil

ACID MONTMORILLONITIC SOIL WITH VERY LOW EXCHANGEABLE CATIONS CONTENT AND HIGH KCl . EXTRACTIBLE ALUMINIUM

PAYS : EQUATEUR | REGION : FRANSCISCO DE ORELLANA ORIENTE | PROFIL : E 555 | Date : Nov. 74

Altitude : 300 m environ | Colmet Daage, Almeda, dystropept.

Roche mère : Formations sédimentaires,

Pluviométrie : environ 3 m bien répartis - Limon cocha : 253-222-240-337-331-286-284-200-219-273-275-187 = 3060 mm

Température air : moy. Mens. 24°6 - Max. Abs 33° - min.abs.18 °

Saison : Pluies fréquentes,

Végétation : Forêt à peine défrichée,

Modelé local : Forte pente 30 %,

Drainage externe : rapide,

Lieu : A 0,5 km environ au Sud du Rio Auca, sur la route qui va de Francisco de Orellana vers les puits de pétrole d'Auca Field - Au sud du Rio Napo

- <u>PROFIL</u> -

0 - 3 Feutrage de racines très dense, englobant de la matière organique décomposée brune 10 YR 3/4 -
Friable, mêlée aux racines,
Transition rapide.

3 - 20 Jaune clair un peu beige et décoloré, 7,5 YR 5/6 humide,
Argileux, plastique, se roulant bien entre les doigts, compact mais s'émiettant relativement bien dans la main en agrégats et blocs de 1/2 cm.
Encore quelques racines.

20 - 70 Orangé rougeâtre 2,5 YR 5/8 humide.
Très argileux, plastique, compact, dur à sortir de la sonde, modérément adhérent, le sol colle assez à la pelle. Structure d'ensemble continue - Très uniforme - Les deux faces de la structure sont légèrement brillantes quand le sol est bien humide - Quartz bien nus - Pores bien propres - Pas de revêtement - Pas de réaction au FNa - Peu de racines.

70 - 140 Plus rougeâtre 10 R 5/8 humide.
Argileux, plastique, uniforme, rares quartz - quelques fins minéraux brillants.

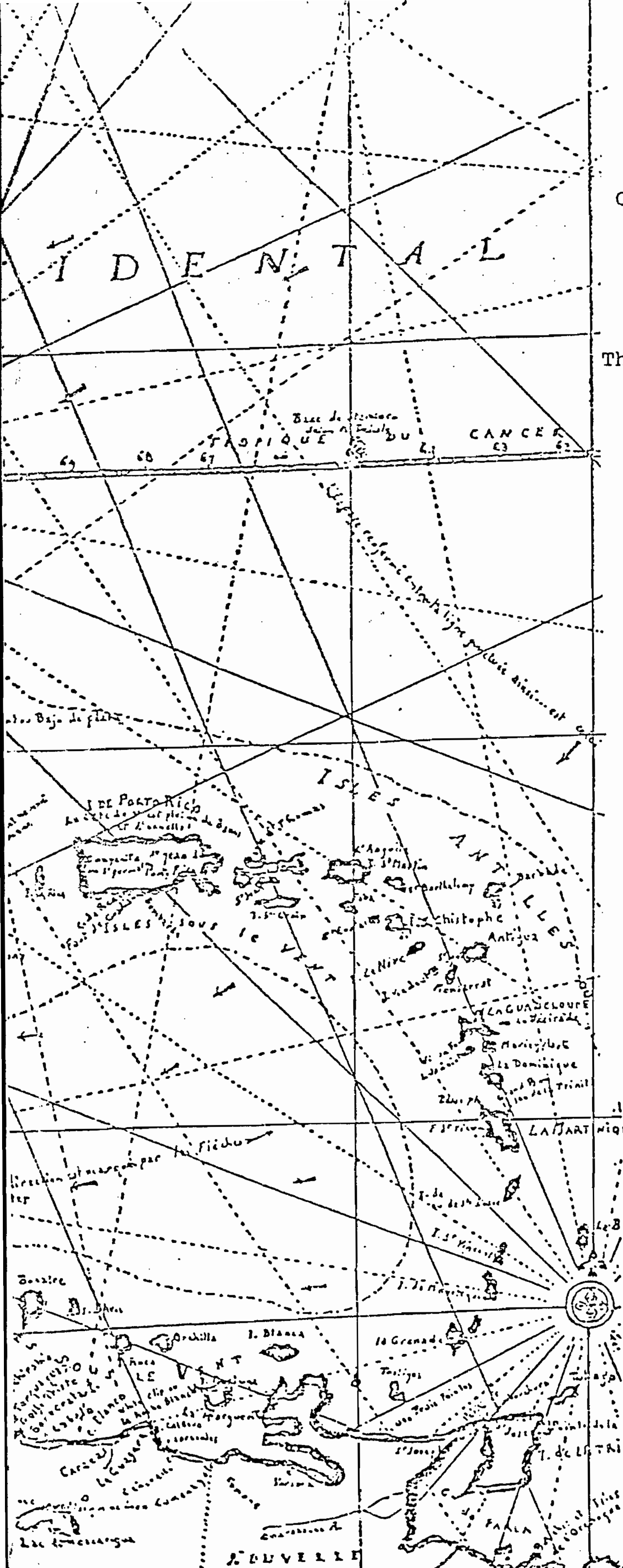
140 - 250 Quelques nodules d'argile originelle encore assez durs mais se coupant au couteau et qui deviennent de plus en plus fréquents. Beige et rougeâtre tacheté dans une matrice plus friable, argileuse, rougeâtre - Blocs durs de 2 à 3 cm ou moins d'argile originelle.
C'est assez irrégulier - Certains bancs horizontaux plus durs ont été mieux conservés que d'autres. L'argile rouge migre surtout dans les fissures entre les blocs.

50 - 400 Beige 5 Y 7/2 avec des faces rouge vif - Très minces pellicules 10 R 5/8 ou 7,5 R 5/8 -
Argile originelle dure - Beige clair 5 Y 7/2 - avec des faces bien angulaires rouge vif dans les fissures mais beige ailleurs. Ces faces rouges sont peu épaisses : 2 à 4 mm. L'argile dure consolidée s'émiette mal et est encore dure. On remarque très bien son littage horizontal - Elle se brise bien à la bêche car les blocs sont disjoints.

400 - 600 Argile très dure, encore peu réhydratée, très dure à briser à la bêche - Les blocs sont à peine disjoints - Il y a quelques fissures rougeâtres - L'argile est beige grisâtre, gris 5 Y 5/1 et verdâtre 5 G 6/1 avec quelques taches ocres.

E 555 a = 0 - 15 b = 30 - 50 c = 1 m d = 2,5 m
e = argile de profondeur.

Depth in cm	Clay %	M.O %	Base exchangeable me % Ca	Mg	Sum	CEC	Aluminium me% Dose	Titre	H	pH KCl	pH Water
0 - 15		6,4	0,8	0,4	1,2	26	11	12	0,5	3,6	3,9
30 - 50	52	3,4	0,3	0,2	0,7	25	11	12	0,8	3,9	4,2
100	52	2,0	0,04	0,06	0,4	32	20	20	1,3	3,9	4,6
150	16		0,2	1,2	1,9	59	33	37	1,3	3,8	4,9
500			17,5	8,8	26,8	47	10	11	0,2	3,7	5,3



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The morphological characteristics
ANDISOLS

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Contributions au
"Fourth International Soil
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(RWANDA)

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