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PODZOLISATION IN THE EXTREME NORTH WESTERN REGION OF FRENCH GUYANA

A curious and very strong process of impoverishment of the soils

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INTRODUCTION

In the extreme north-western region of French Guyana, some distinct passages from white to reddish-yellow sandy-clay formations have been observed over a very short distance (about one meter). We underline that in the others Guyanas (Surinam and Guyana), for an identical material, the same process exists, on a larger scale. Several hypothesis have been made (overthrust, successive sedimentation, lixiviation.)

Several sequences of soils have been studied in different pedological areas. Results registered in the laboratory and the field confirm our hypothesis: Podzolic differenciation and lixiviation of the elements.

This paper will summarize the consequences of this discrepancy from the point of view physico-chemical impoverishment of these soils, and their issue to a true mineral residual skeleton, inappropriate to any culture.

SITUATION AND GEOGRAPHIC LIMITS

We have worked on two sequences of soils situated on the St. JEAN N-E map of the National Geographic Institute (IGN 1/50.000). At ALBINA (Surinam), in geomorphologically identical conditions the same process have been observed and studied.

CLIMATOLOGY

Humid Equatorial climate marked by two strongly pronounced, contrasted dry seasons.

Pluviometry: Station: Saint-Laurent
Average 1956 - 1965. mm.

Station	J	F	M	A	M	J	J	A	S	O	N	D	Year
St. Laurent	216	184	174	218	322	327	233	164	76	79	162	219	2.374

The particular character of the studied area is not as subject to regular ventilation as the coastal plain, evaporation is relatively less important and the water potential is ameliorated.

Temperature: Yearly average: 26°4.C.
Humidity: True annual average humidity: 86%
Wind: 27 m./s. (annual average: St. Lanrent 1951-1965)

VEGETATION AND BIOLOGICAL ACTIVITY

Two very different species of forests apparently in relation with the sandy-detritical formations white and reddish-yellow have been distinguished. On the reddish-yellow sand, we have a floristic variant of the classical Amazon forest on granite. On the bleached sand, this forest is perceptibly different and evokes a different ecology. Abundance of epiphytes which make it look like a tropical mountain forest suggests an hygrometry that is always considerably related to a stronger lighting of the underwood.

Some termitarium erected on more than one meter in reddish-yellow sandy-clay formation and realizing a true ploughing of the superior part of the soils have been observed. These organisms are responsible for the homogeneity of the horizons permitting the departure of the pedogenetical process.

MORPHOLOGY AND HYDROGRAPHIC SYSTEM

Table-land is strongly notched by headwater erosion of percolating waters running freely in these coarse sands. These waters collect on the border of these table-lands generating creeks, with water, a reddish-brown colour well known in the Guyanas and more generally in all podzolized tropical regions.

GEOLOGY AND SEDIMENTOLOGY

The material has been identified (Qt), that is to say the Old terraces by the geologist. The "série détritiqua de base" (white sand serie of Guyana and Zanderij series of Surinam) is largely represented. For some sedimentologists, these table-lands are sand-water-downs (arenaceous rocks in situ). The morphoscopic examination and cumulated curves of these sandy formations tend to confirm the idea of torrential drift. The association of heavy minerals (zircon - staurolite - disthene..) always found in the detritic sandy formations reddish-yellow and white, give evidence of this origin; these minerals are always present in the meridional precambrian schist.

In any case, no granulometric difference between the reddish-yellow and the white formation has been observed. These sands are curiously associated in the land morphology. Pedogenesis seems to be the only one factor for the disparity.

SEQUENCES STUDIES. PHYSICO-CHEMICAL CHARACTERISTICS

GRANULOMETRY

From the periphery to the center of the table-land, we observe in the sequence progress a progressive impoverishment of the colloidal fraction; correlatively there is an enrichment of the fine and coarse sands. In some profiles presence of an accumulation horizon of clay shows a vertical lixiviation of this fraction. Table I are given the analytics results of two profiles situated at the sequence extremities:

PERMEABILITY

The permeability has been measured in the field with the MUNTZ apparatus (modified by J.L. THIALS) and in the laboratory (K DARCY on repaired samples). In any case we observe a clear decrease of the permeability from a relatively low depth at the periphery of the table-lands (50 cm.). These profiles show an extreme permeability (K > 140 cm./h.) in the upper horizons, quickly stopped in the lower parts when the coarse elements are slowed down by the fine sands. Indeed, the clay content cannot in many cases elucidate this decrease. On the other hand, a correlation seems to exist between the content of fine sands (50 μ - 0.1 mm.) and the permeability; this last decreases when the content of fine sands grow.

We note the very strong variations between the results registered in the field and these obtained in the laboratory. These differences show how much we have to refrain from deducing physico-chemical properties of these soils by laboratory results.

Sample	DEPTH cm.	K cm./h. Laboratory		"I situ"
			fine sand %	
BM 21	1 - 10	148	12.5	183 (30 - 40 cm.)
22	30 - 50	58	14.	9.3 (80 - 90 cm.)
23	62 - 74	5.6	18.5	
24	115 - 130	3.3	22.	
25	150 - 170	7.6	21.	

The depth of the impermeability level decreases from the center to the periphery of these table-lands.

The result is a temporary underground sheet of water which will be responsible of accelerating the podzolisation and impoverishment process.

STRUCTURAL INSTABILITY. (Is of HENIN)

The structural instability Is, is always lower than I. It seems that the richness in organic matter of these soils, migration being easy in the sandy horizons, leads to stabilize them structurally.

pH - EXCHANGEABLE BASES

These soils are extremely acid. $4.6 < pH < 5.2$. This pH places the iron in its state of ion Fe^{2+}, easily mobile. A direct relation between organic matter and pH has been observed. pH decreases when organic matter grows.

Exchangeable bases are non-existent: the total of bases is lower than 0.50 me/100 g.

ORGANIC MATTER

The further we go from the ferrallitic soils to the podzolic soils, the more the rate in humic matter poorly evolved, poorly polymerized, more susceptible of migration increases (simplified electrophoresis). This fact seems to be tied to the progressive impoverishment in iron from the ferrallitic to the podzolic soils.

	Podzolic Soils			Ferrallitics Soils				
Profile	BMA 21	22	23	BMA 31	32	33	BMA 41	42
Organic Matter %	5.9	0.1	2.2	1.5	1.6	0.8	1.2	1.3
C o/oo	34.3	0.6	12.9	8.8	8.8	4.4	1.8	7.4
N o/oo	1.78	0.28	0.63	0.77	0.73	0.45	0.63	0.56
C/N	19	2.	20.5	11.4	12.1	9.7	10.8	13.2
Humification Rate	6.1		58.1	27.2			29.4	
Gray Humic acid %	24.		48.2	40.7			34.8	
Intermediair Humic acid %	8.		13.3	14.8			17.4	
Brown humic acid %	68.		38.5	44.5			47.8	

The rates of organic matter remaining strong in the podzolics soils comparatively to the ferrallitics soils, the products of decomposition and the substances issued forth in the presents conditions of podzolisation remain poorly evolved, particularly movable, and more susceptible to move in the profile (clay--iron - silica - aluminum - oxyde).

IRON

We note an absolute accumulation of iron sesquioxydes at the level where spots and reddish-yellow stretches are found in the profile. These oxides seem to have been transported to their accumulation point from a homogeneous parental material; if it was an alteration position, we would not observe a variation in the profile. Now, in all studied sequences this variation has been effectively observed. In succession of this podzolic differenciation there is a relative concentration of iron sesquioxydes in major horizons. We notice moreover a decrease of the sesquioxides rate in succession of the material impoverishment of the fine colloidal fraction.

We can deduce from this that from one homogeneous parental material where the iron has been already strongly taken off during its transportation, exportation of iron sesquioxides, principally under the influence of organic acids and water can occur.

The ferric-oxides formation by spontaneous oxidation in the superior horizons naturally more draining may take place during the dry season (BLOOMFIELD) and induce the ulterior fixing of ferrous complexes (SEGALEN 1964). So, according to the changing of seasons oxidation of ferrous complexes may take place (dry season). This layer relatively unstable of ferric-oxides formed, would serve as catalyser to the stabilization of new complexes and organic chelates ferrous - organic, moving vertically in the profile.

The consequence in the profile is a lixiviation of the A_2 horizon which goes on increasing as long as the conditions of reduction (induced by the underground water, organic-matter and microorganisms) will continue, even temporarily. The clay mobility associated with the drainage conditions temporarily unfavourable at the level of impermeability is tied without doudt to the destruction of the clay-iron oxides agregates, when this last is mobilized in its reduced form, which permits to the clay to migrate easier (F. de CONINCK - A. HERBILLON).

Consequence of this iron exportation under its ferrous-complexe form is a progressive increase by relative accumulation of the quartzous elements, which, by the loss of iron lose their crystallo-chemical stability and tend to divide up with increased specific surface. Because of this, these sands can not be used in hydroponic culture. The perpetual splitting up of these quartz grains leads to a warping of the coarse elements at a low depth which fact again contributes to increase impermeability in the profile and provokes root asphyxiation.

TOTAL ANALYSIS BY TRIACIDES ATTACKS

Investigating the total quantities, we notice in all cases an antagonistic evolution between iron-oxides and silica. But mobilization of the silica has also been observed in the concentration horizons of iron-sesquioxides. The silica seems to follow the iron in its migration in the form of iron-silicic or organo-silicic complexes.

Aluminium oxides follows the iron movement very well, showing a maximum in the horizons of concentration in iron-sesquioxides where the iron maximum and the silica minimum are.

Aluminium oxide accumulation is found specifically in the humoferruginous (B_2h - Fe) horizons which leads as to image the presence of chelates or organic complexes.

In the present conditions of podzolisation, aluminium is above all mobilized by surface-waters very rich in organic molecules, acids, which percolates easily and freely through a far too permeable material in the upper horizons, and which provokes its accumulation at the relatively less permeable level in the spodic horizon. Only Podzolization is able to make it move in the upper parts and its entrainment to the spodic horizons.

CONCLUSION

The podzolic differenciation we have observed here is astonishingly connected with the ferrallitization process. <u>This differenciation during the impoverishment of the ferrallitics soils seems to be complementary to the ferrallitization process</u>. There is not any break in the sequence of evolution. Podzolisation beginning only because of the direct action of ferrallitization (lixiviation stricto-sensu of clayey-colloidal fraction and formation of an impermeable level at a medium depth), had determined in the beginning the conditions of evolution of these soils. Formation of one horizon of accumulation modified strongly and more and more during its formation the hydric regimen of the soil.

The alternance of the dry and wet seasons, contrasted, accelerates the processus of evolution, because the material will react to this brutal variation (physico-chemical conditions of the material amplifies the micro-climatic contrast in the soil).

The more the process is engaged, the more its speed of evolution will grow. It will <u>catalyse itself</u>. The A_2 horizon, lixiviated, bleached, will increase as much as the alternance of oxidation and reduction conditions will permit the entertainment process (organic-matter, clay, iron, aluminium, silica...).

But exaggerated by the new characteristics of the profile and by the differenciation of new horizons, the pedo-climate of the soil will change. The contrasts between the new individualized levels will be exasperated: the A_2 horizon, lixiviated, bleached, takes exaggerated proportion. The formation of an humo-ferruginous alios (dark-brown) may be produced. The profile is characterized by the horizons: A_{00} - A_1 - A_2 - B_2h - B_2Fe - Gr - BC or C. (Podzol humo-ferruginous). At the extremity of this podzolic evolution, the exaggeration in the development of this A_2 horizon bleached, leads to a residual mineral quartzous skeleton, where the differenciated horizons are sometimes not observed on the first five meters. (Giant Podzol).

Experimental plantinga of PINUS (<u>Pinus caribea</u>) plantations in Surinam on such soils give very bad results.

TABLE 1.- Analytical Results of Two Profiles

Sol Ferrallitique Lessivé modal (Periphery of the table-land)

Horizon	Granulometry % 0-2 µ	2-50µ	50µ-2mm	>2mm	pH H_2O 1/2.5	Organic matter total %	C ‰	N ‰	S me	T me	S/T	Fe_2O_3 total %	Fe_2O_3 free %	Fe_2O_3 total / Fe_2O_3 free
A_1	13.	7.	78.	2.4	4.8	1.9	10.9	.84	.63	5.7	11.1	1.8	1.6	88.
A_2	20.	5.5	72.5	1.4	5.1	.5	2.9	.42	.26	3.9	6.7	2.4	2.	83
AB	24.5	4.5	69.	0.9	5.	.3	1.7	.35	.34	2.3	14.8	2.9	2.4	82
B	25.	5.	68.5	1.	5.	.2	1.2	.31	.27	2.6	10.	2.8	2.4	85
BP	15.5	5.5	79.	22.8	5.2				.13	.5	26.	2.4	2.3	95
BC	17.	10.	78.	27.5	5.2				.43	3.4	12.6	2.	1.9	95.

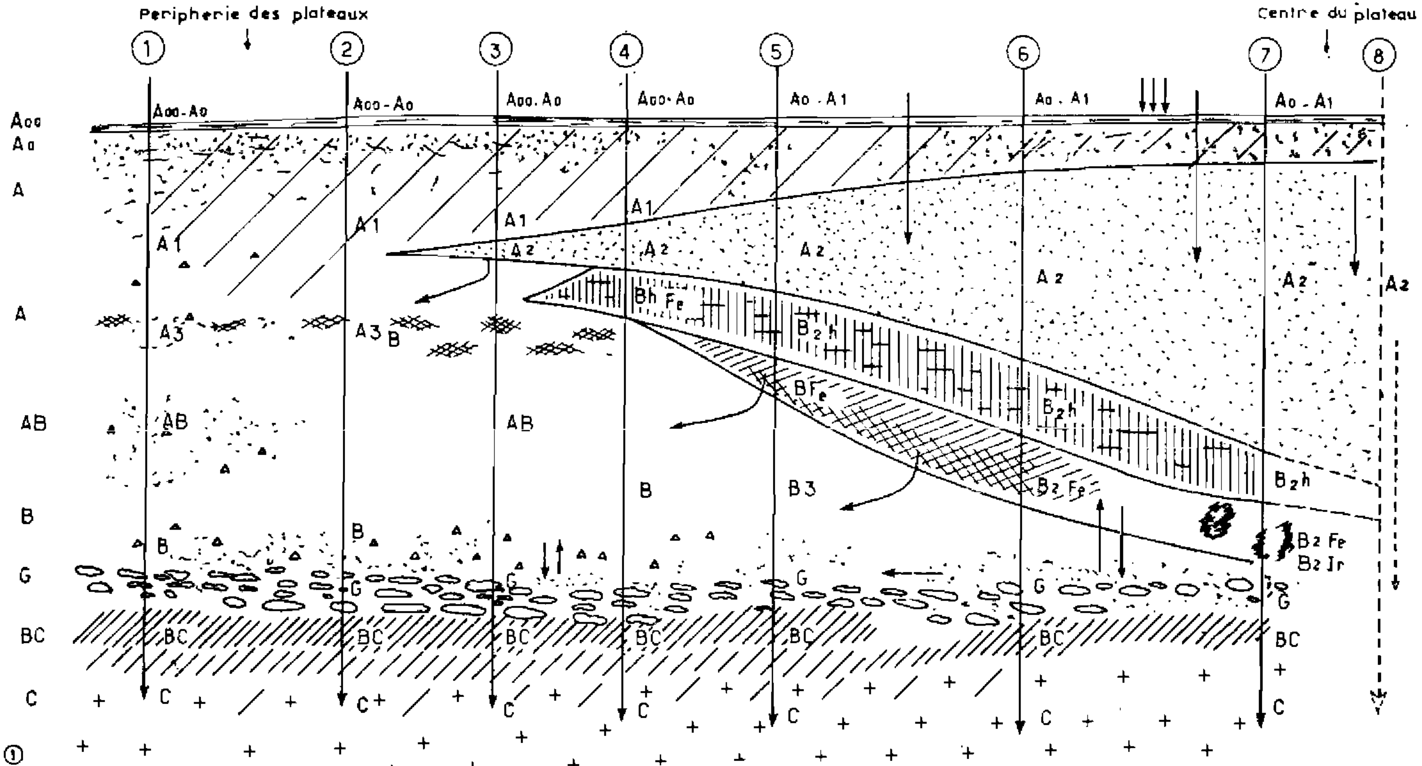
Podzol Geant (Giant Podzol) Center of the Table-land

Horizon	Granulometry %. 0-2 µ	2-50 µ	50µ-2mm	> 2 mm.	pH H_2O 1/2.5	Organic matter total %	C‰	N ‰	S me	S/T	Fe_2O_3 total %	Fe_2O_3 free %
A_{11}	1.	.6	97.	1.9	4.7	2.	11.4	.59	.60	18.8	.05	.05
A_{12}	.5	1.5	97.5	1.2	6.	.3	1.7	.21	.28	16.5	1.	.05
A_2	.5	2.5	97.	1.5	6.	.1	.7	.14	.29	72.5		.08
B_2h	1.	2.5	95.5	5.1	5.2	.2	1.2	.21	.37	74.		.3
B_2Ir	1.	3.5	94.5	7.8	5.3	.4	2.1	.21	.34	48.5		.8
BC	.5	3.	96.	12.7	5.6				.56	43.1		.2

The exagerated impoverishment leads to a mineral skeleton (Giant Podzol) where the fine and coarse sands (50 µ - 2 mm.) vary between 95 to 97 % ; in the entire profile, the clay fraction 0 - 2 µ) being insignificant (less than 1 %).

planche n°20

Differenciation Podzolique sur materiau parental homogène sablo argileux de la S.D.B



① Sol ferrallitique fortement désaturé en B. Appauvri modal.

② Sol ferrallitique fortement désaturé en B extrêmement appauvri modal.

③ Sol.ferral.ft. dés. en B. lessivé modal

④ Sol.ferral. ft.dés.en B. lessivé podzolisé

⑤ Sol podzolique hum.

⑥ Pseudopodzol humique

⑦ Podzol hum.

⑧ Podzol géant? Squelette minéral résiduel quartzeux.

Planche n° 4

EXTENSION DES FORMATIONS SABLO-ARGILEUSES.
DE LA S D B DANS L'EXTREMITE NO. DE LA
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