III/- (4)

# / Soils of the South Ecuadorian Andes /

Fourth International Soil Classification Workshop
RWANDA (1981)

GONZALEZ A.

COLMET DAAGE F.

Publication ORSTOM-Antilles n°P109-4

Diffused by F. COLMET DAAGE at the :

FOURTH INTERNATIONAL SOIL CLASSIFICATION WORKSHOP - RWANDA - 1981

# DEEP SOILS FROM THE ANDES ALTITUDES WITH 14 Å OR INTERSTRATIFIED CLAY MINERALS AND EXTRACTABLE ALUMINIUM

## SOILS OF THE SOUTH ECUADORIAN ANDES

A. Gonzalez - F. Colmet Daage

Red clayey soils 2-3 meters thick, or more, exist in numerous places in the Andes south of the equator. These soils were mapped by PRONAREG, with the technical assistance of ORSTOM, on se scale of 1/50 000e.

The direction of the wind is constant throughout the year : from the west (the Pacific) from the east (Amazonia). This leads to considerable variation in the amount of rainfall over very little distance.

The slopes exposed to the wind from the coast or from Amazonia are moist, while the leeward slopes and the north-south valleys are very dry.

Within a very small distance, one can go from deep, acid red soils with gibbsite to more or less thin soils with calcium carbonate accumulation and a predominance of montmorillonite.

The soil maps clearly illustrate the variations in rainfall, cloud cover, etc...

Probably in the past, the overall climate in these mountainous regions was wetter, but the differences from one area to the next that exist today must have existed then, too.

Red clayey soils are found especially in regions with high rainfall; generally, on the upper parts of the slopes facing the east or west winds.

As the east-west valleys, channel the clouds and then force them to rise, the slopes located at the end of these valleys are the wettest.

In the regions of altitude, the red soils often have umbric horizons, of varying thickness. There may have been a mixture with very very fine ash.

### Red Soils with an umbric horizon

In the top 20 cm, the soil is dark brown (10 YR 2/1 wet), silty and very friable with a low apparent density of 0.57.

Then from 1 meter to at least 1.5 meter, the soil is clayey red (10 R 5,8).

Chunks easily crumble into pseudo-sand exactly like an oxic horizon.

Deeper down is the weathered horizon of differing colors.

All the primary minerals are totally weathered over several meters depth. The parent material is dacitic volcanic flow.

All the horizons react to the Fieldes test. Base saturation is very low (0.5 me%) and the pH in the KCl is less than 4.

Potassium chloride extracts 8 me% of aluminium at the surface and 15 me % in the depths.

The umbric horizon, probably rejeuvenated by the very fine volcanic ash (this is very far from the volcanoes), contains metahalloysite as well as small quantities of vermiculite chlorite like interstratified clay minerals.

In the red horizons of the depths, there is metahalloysite or fire clay likely with 14 A° minerals, but which are difficult to bring out.

There is also gibbsite, goethite, and hematite.

The particularly low saturation of the soil explains the high percentages of extractable aluminium.

| Depth in cm | Sum of the bases | C.E.C. | S/T | pH KCl | pH Water | mé % $Al^{+++}$ |
|---|---|---|---|---|---|---|
| 0 - 15 | 0,5 | 47 | 1 | 3,8 | 4,5 | 8 |
| 50 | 0,4 | 29 | 2 | 3,8 | 4,6 | 15 |

-Sum of bases and C.E.C by Ammonium Acetate: mé.p 100 of soil.
-Al by normal KCl

### Red Montmorillonitic soils

The soil is brownish-red over 10 cm, well-structured, friable; then it turns red (10 YR 4/6 wet), clay, but which crumbles rather well. This is not an oxic horizon.

At about 1 meter in depth, fragments from the clayey parent material appear. Some of it is still a little hard.

The surface horizon has 14 me% of exchangeable bases but the soil is desaturated in the depths (1.5 me%.) The total cation exchange capacity is high. The pH in the KCl is less than 4.

Potassium chloride extracts 3 me% of aluminium at the surface: 14 me% at 50 cm; and 32 me% at about 1 meter in depth.

Fire clay or metahalloysite is accompanied by badly crystallized montmorillonite with a little hematite and goethite.

When unstable montmorillonite is present, especially in the depth, there are very high amounts of extractable aluminium.

| Depth in cm | Sum of the bases | C.E.C. | $Al^{+++}$ | pH KCl | pH Water |
|---|---|---|---|---|---|
| 0 - 20 | 13.7 | 29 | 3.4 | 4.1 | 5.1 |
| 40 - 60 | 1.6 | 31 | 13.4 | 3.9 | 4.7 |
| 120 | 1.5 | 43 | 32.4 | 3.7 | 4.5 |

-Sum of bases and C.E.C. by ammonium acetate : mé p.100 of soil.
-Al by normal KCl: mé p.100

Red Soil with Vermiculite like clay mineral

The soil is dark brown over 10 cm, rather compact. Then it turns to bright red (2.5 YR 5/8) over more than one meter. It is clayey, compact, and crumbles badly.

Deeper than one meter, some different-colored spots appear.
These are caused by the minerals which are in the process of weathering
The weathered horizons are several meters thick. Some parts are still a little hard.
Echangeable cations are 13 me% at the surface and only 6 me% deeper down.
Extractable aluminium is negligible at the surface; 6 me% at 60 cm depth; and 9 me% at 1 m.
A fire-clay is found with the vermiculite and a little illite with gibbsite, hematite, and goethite.

| Depth in cm | Sum of the bases | C.E.C. | $Al^{+++}$ | pH KCl | pH Water |
|---|---|---|---|---|---|
| 0 - 20 | 13 | 25 | 0.09 | 4.6 | 5.6 |
| 30 - 80 | 3.3 | 21 | 5.7 | 3.9 | 4.9 |
| - | 6.7 | 22 | 8.8 | 3.8 | 4.8 |

-Sum of bases and C.E.C. by ammonium acetate : mé p.100 of soil.
-Al by normal KCl. mé p.100 soil

Soils with interstratified clay and more or less easy to identify 14 Å clay minerals
Tropudult - Dystropept

Most of the red clay soils in these regions contain, in the clay fraction, interstratified clay with 14Å minerals.

These clay minerals appear clearly in some cases, while in others, they are more difficult to bring out.

There is also illite on the soils formed from the metamorphic or non-volcanic sedimentary clay material.

Gibbsite is a very good sign of the wettest microclimates. It appears and disappears over a number of kilometers as one goes from a wet region to a drier one.

Almost all the soils with low base saturation have noticeable or considerable amounts of extractable aluminium.

The clearer the 14 Å interstratified clay mineral, the greater the percentage of extractable aluminium. The highest quantities of aluminium are in the depths where the weathering and transformation of the clay minerals are at a maximum.

When the pH in the KCl is less than 4, there is always extractable aluminium but aluminium may already exist in considerable quantity in these soils when the pH KCl is slightly higher than 4.

For these soils, the difference between the pH water and the pH KCl is around one unity, thus greater than the difference between pH water and pH KCl for kaolinitic soil. The following table gives various results.

RED SOILS WITH 14 Å INTERSTRATIFIED IN THE SOUTH ANDES OF ECUADOR

| Depth cm | Sum of bases mé % | C.E.C. mé % | Base satur. % | $Al^{+++}$ mé % | pH KCl | pH Water | Clay minerals |
|---|---|---|---|---|---|---|---|
| 0-20 | 6.3 | 23 | 27 | 4 | 4.1 | 5.2 | Fire clay or metahalloysite |
| 40-60 | 0.7 | 23 | 3 | 12 | 4.1 | 5.2 | Interstratified 14Å - gibbsite-goethite |
| 0-30 | 1.1 | 35 | 3 | 6.6 | 3.7 | 4.3 | Montmorillonite - kaolinite |
| 50-80 | 0.3 | 17 | 2 | 5.3 | 4.0 | 4.5 | Interstratified - gibbsite important |
| 0-20 | 6.6 | 21 | 31 | 1.3 | 4.1 | 4.9 | Chlorite - Fire clay gibbsite goethite |
| 50-70 | 3 | 17 | 18 | 4.1 | 3.9 | 4.8 | |
| 300 | 1.5 | 15 | 10 | 8.6 | 3.8 | 4.5 | |
| 0-20 | 1.1 | 22 | 5 | 3.6 | 4.1 | 4.6 | Vermiculite - Fire clay - gibbsite |
| 40-60 | 0.6 | 14 | 4 | 3.2 | 4.1 | 4.7 | |
| 0-20 | 16 | 30 | 53 | 0 | 4.5 | 5.1 | Interstratified vermiculite illite Kaolinite vermiculite goethite gibbsite hematite |
| 40-60 | 3 | 20 | 15 | 2.7 | 3.8 | 4.6 | |
| 80-120 | 1 | 19 | 8 | 3.8 | 3.8 | 4.4 | |
| 300 | 0.3 | 18 | 2 | 3.7 | 3.7 | 4.3 | |
| 0-20 | 12 | 25 | 48 | 0.1 | 4.6 | 5.2 | Fire clay vermiculite gibbsite goethite |
| 30-50 | 4 | 18 | 22 | 3 | 4.0 | 4.6 | |
| 70-100 | 1.4 | 18 | 9 | 4.5 | 3.9 | 4.4 | |

-Sum of bases and C.E.C by ammonium acetate.
-Al by normal KCl

CONCLUSION

14 Å minerals are often present in the form of interstratified clay minerals which are not always easy to bring out and can thus go unnoticed.

The presence of 14 Å minerals causes extractable aluminium to appear in much higher quantities than in the kaolinite soils.

It is difficult to determine the percentage of these 14 Å minerals which are usually interstratified clay minerals.

These red soils receive the most rainfall of all the soils in the southern mountains most of which suffer from drought.

The land is often gently rolling, quite exceptional for these regions and altogether favorable; yet, these red soils are cultivated very little or not at all because of their infertility.

Crops could be grown if fertilizer and especially phosphate were added.

The policy of the government is to actively reforest by making contracts with the land owners.
Radiata pin and eucalyptus globulus show definite signs of growth trouble.
Yet, in the deep, fertile, volcanic ash soils of the center and north of the Ecuadorian Andes, these species are prosperous and give excellent results at the same altitude.
Trees grow very well near the inhabited areas where there is domestic fertilizing debris. It can thus be supposed that the problem comes from poor nutrition due to the presence of aluminium. Tests now being done will give the answer.

On the other hand, the pin patula and eucalyptus saligna, both which were introduced recently, seem well adapted to these soils. Those in charge of reforestation are beginning to plant them.

Coffee is grown in the other zones, between 1000 and 1800 meters, generally on the wettest sides of the slopes. No fertilizer is used, and the yield is mediocre.

## DESATURATED UMBRIC MONTMORILLONITIC SOIL OF ALTITUDE OF PERU F.Colmet-Daage

These soils were found at about 3 500 m altitude in the altiplano of Peru.
They have an umbric horizon 30-40 cm thick; are silty, react to the Fieldes test, and look like an allophane soil.
Deeper, there is a faded light yellowish-beige horizon. Deeper still, a thick, clay or silty-clay yellow soil (apparent density 0.8 to 1.3).

The clay is composed mainly of montmorillonite.
It is well-crystallized in the depths, but less so at the surface. It is mixed with a little 7 A° clay which often contains gibbsite.

The pH KCl is close to or less than 4 for all the profiles.

Extractable aluminium, already high in the umbric horizon (8-10 me%) rises to 15-19 me% in the yellow horizon where the weathering and transformation of the montmorillonite is the most intense.

The umbric horizon is totally desaturated in all the profiles.
However, the yellow horizon, which is deeper, may either be desaturated (0.8 me %), or high in exchangeable bases (37 me %), which does not cause much variation in the amount of extractable aluminium in the horizon where the transformation of clay minerals seems to be the greatest.

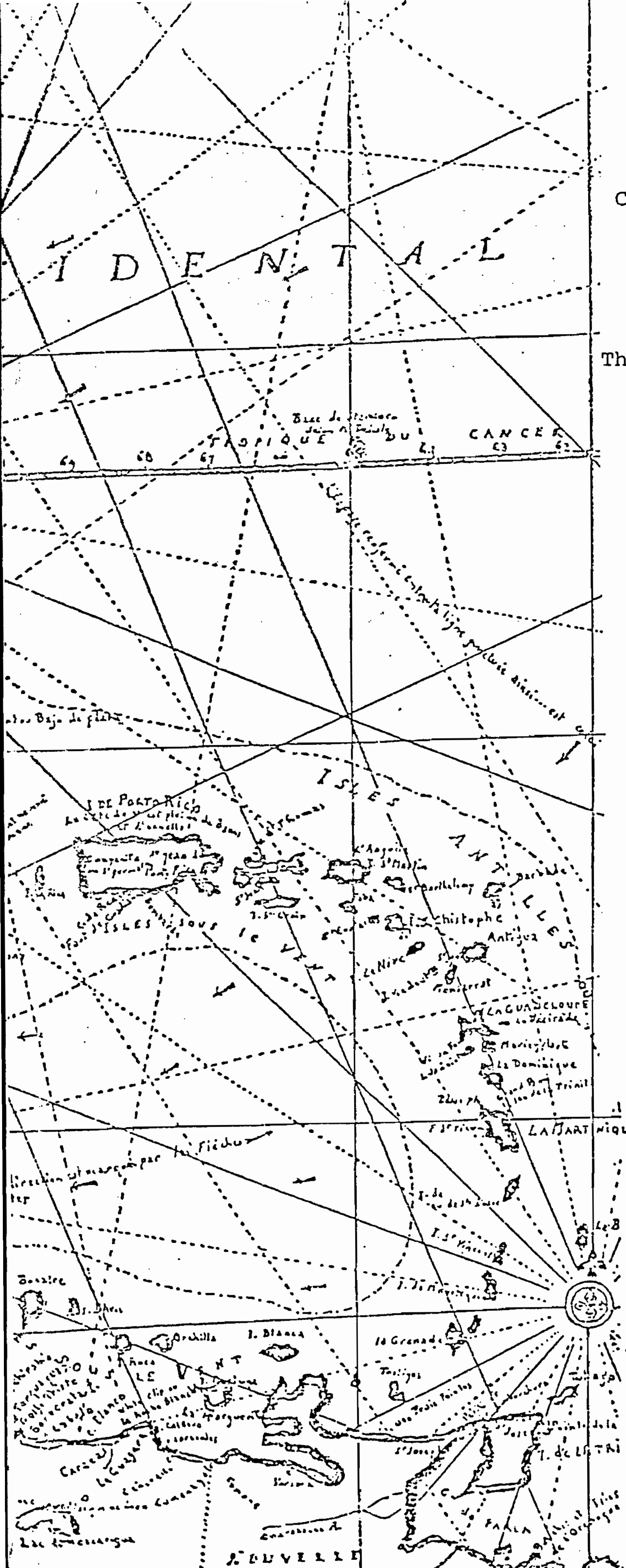
MONTMORILLONITIC SOILS WITH EXTRACTIBLE ALUMINIUM - ALTIPLANO (PEROU)

| color horizon | Depth in cm | bulk density | Sum of bases mé % | C.E.C. mé % | Base Satur. % | $Al^{+++}$ (1) mé % | $Al^{+++}$ (2) mé % | pH KCl | pH Eau | C% | Clay minerals |
|---|---|---|---|---|---|---|---|---|---|---|---|
| black | 0 -20 | 0.96 | 2.8 | 40 | 7 | 8 | 9.3 | 3.9 | 4.6 | 5 | Montmorillonite-interstratified |
| - | 20 -40 | - | 1.8 | 40 | 5 | 11 | 11 | 3.9 | 4.6 | 3 | 7Å clay minerals and gibbsite |
| yellow | 70 | 1.1 | 0.8 | 35 | 2 | 17 | 17 | 4.0 | 4.7 | | Montmorillonite - little 7 A° clay |
| black | 0 -20 | 0.9 | 1 | 35 | 3 | - | - | 4.0 | 4.8 | | Montmorillonite, little 7 A° clay and gibbsite |
| - | 30 -50 | - | 0.6 | 38 | 1 | 9 | 10 | 4.0 | 4.8 | | |
| yellow | 80-100 | 0.8 | 37 | 85 | 4.3 | 18 | 19 | 3.9 | 5.2 | | Well cristallized montmorillonite and traces of kaolinite. |
| hlack | 0 -20 | 0.92 | 0.6 | 33 | 2 | - | - | 4.0 | 4.5 | 6 | Montmorillonite and kaolinite |
| - | 40 -70 | 0.9 | 0.3 | 39 | 1 | 10 | 10 | 4.0 | 4.7 | 4 | Montmorillonite very important and |
| yellow | 110-130 | 1.3 | 0.2 | 46 | 0.4 | 27 | 26 | 4.0 | 4.9 | 0.3 | well crystallized - gibbsite |
| black | 0 -40 | 0.8 | 1.3 | 46 | 3 | 6.5 | 6.2 | 3.9 | 4.6 | 9 | 7 A° clay and montmorillonite |
| yellow | 100 | 0.75 | 8 | 42 | 19 | 12.7 | 12.3 | 3.9 | 4.5 | 0.4 | Montmorillonite and traces of interstratified 7 A° clay mineral. |

(1) mesured (2) by titration NB Argile at 7 Å = fire clay or metahalloysite.

Sum of bases and C.E.C. by ammonium acetate . Al by normal KCl .

A.Gonzalez: Soil Scientist -Programa Nacional de Regionalizacion Agraria-Ministerio de Agricultura -QUITO-ECUADOR
F.Colmet-Daage- Adviser in charge of the Sierra Maps -ORSTOM-Martinique - Convenio Ministerio de Agricultura and Office de la Recherche Scientifique et Technique Outre-Mer. FRANCE.




F.COLMET DAAGE
Conférence Université Cornell (USA)

M.LEAMY, G.D.SMITH
F.COLMET DAAGE, M.OTAWA
The morphological characteristics
ANDISOLS

F.COLMET DAAGE
YAO KOUAME, J. ET M. GAUTHEYROU
A.GONZALEZ

Contributions au
"Fourth International Soil
Classification Workshop"
(RWANDA)

CENTRE DES ANTILLES

P 90-P 108-P 109