

## Properties and genesis of Andisols (1) *Propriétés et formation des Andisols*

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The last proposals of ICOMAND (2) (1983) in order to define Andisols seem too restrictive. That is the reason why it is interesting to recall some of the fundamental properties of Andisols, according to their genesis.

### PROPERTIES

I. **Their parent material** is mainly pyroclastic and of volcanic origin. It is composed of very fine particles, not only of glass, but also of microlites in a proportion varying with their more or less siliceous composition. This material is very porous and presents very large surfaces to weathering.

II. **The weathering products** of Andisols are very active and specific due to their nature and their properties.

#### 1. THE MAIN CONSTITUENTS ARE :

- gels of aluminium, iron and silicon hydroxides or oxo-hydroxides,
- « short-range order » minerals, like allophane, imogolite, hisingerite, ferrihydrite, opal,
- organo-mineral complexes.

2. THE SPECIFIC PROPERTIES derive from the large specific area of these products and their high chemical reactivity. Moreover, these properties decrease from the natural wet state to the air-dried state, and this change is more or less irreversible.

a - Three properties are general and could be the most important :

- A high water retention capacity, which decreases irreversibly through drying,

— A high, but pH dependent, Cation Exchange Capacity,

— A low bulk density and a high micro-porosity.

b - Three other properties are very frequent, but not general :

— A noteworthy and pH-dependent Anion Exchange Capacity,

— A high Phosphorous retention Capacity.

— A considerable fraction of Aluminium (> 1 %) which is easily soluble by Oxalate (pH = 3, in the dark) or KOH (1N, at room T).

c - However, it is very important to determine also some other specific properties such as :

— the amount of amorphous and paracrystalline products, by a differential chemical dissolution method and the SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> molar ratio of these products,

— The D pH (pH H<sub>2</sub>O — pH KCl),

— The pH in NaF (1 M) solution,

— The Z P C.

Among these properties, the most practicable and useful are : the bulk-density, the pH in NaF, the water retention capacity (at 1/3 and 15 bars) on natural wet soils samples and the rate of irreversibility of this property after air-drying (rate of dehydration irreversibility), the oxalate extractable Aluminium and the Phosphorus retention capacity. But we also have to pay attention to : the Cation Exchange Capacity and the rate of D CEC value, the base saturation ratio, the amount and the chemical composition of the amorphous and paracrystalline components, the mineralogical

(1) Note for the final discussion. 6th International soil classification workshop in Chile and Ecuador (8-20 January 1984).

(2) ICOMAND : International COMmittee for the classification of ANDisols.

determinations by diverse methods and some microscopical studies (through optical microscopy and Scanning Electron Microscopy).

## GENESIS

### I. Main factors of evolution

The nature of the amorphous and paracrystalline constituents of Andisols changes, according to the *time* and the *ambient conditions* of weathering (over and in the soil). The two main factors of pedogenesis are the *age* of the volcanic materials and the *climate* or the pedo-climate.

A third factor, not so well known, is the chemical composition, more or less siliceous, or aluminous, or ferriferous, or Ca, Mg, Na or K-rich, of the volcanic parent material.

The composition of the weathering products and consequently their properties reflect the conditions of their formation in Andisols. This composition and the properties change gradually with time, until, another non-andic soil appears, more or less rapidly.

### II. Main families of weathering products

Although the aluminous-allophanes are very frequent in Andisols, they are neither always present nor generally predominant. But there are other mineral products in an amorphous, or paracrystalline (of short range order) and even crystalline state. According to the genetic factors of the Andisols formation, six families of the mineral products due to weathering could be taken into account. At once some suggestions could be made tentatively for the correlation with the proposals made by ICOMAND about the Andisol classification.

1ST FAMILY : amorphous products, very *rich in silica*,  $\pm$  allophane ; poor in  $Al_O$  (1)  $< 1\%$ , with a low P-retention (2)  $< 60\%$ .

(corresponding to the very young « vitric » Andisols).

2D FAMILY : amorphous and paracrystalline products containing a *silica-rich* and  $\pm$  ferriferous allophane ( $SiO_2/Al_2O_3$  molar ratio  $< 2.5$ ), a few opal and fine amorphous silica, a few amorphous Fe-oxy-hydroxides and traces or not of smectites and halloysite ; poor in  $Al_O$ , with a low P-retention.

(corresponding to the Ustands, some « mollic » or « eutric » subgroups of the Udands, and probably the Torrands and the Xerands).

(1)  $Al_O$  = Acid-Oxalate extractable Aluminium.

(2) P-retention = Phosphate retention capacity.

(3) rate of dehydration irreversibility = percentage of the difference in water retention capacity on natural wet and air dried soil samples.

(4) rate of  $\Delta$  CEC = percentage of the  $\Delta$  CEC value (between pH 9 and 4) on the pH 9 CEC value.

3D FAMILY : amorphous and paracrystalline products very rich in aluminous-allophane of « halloysitic » type ( $SiO_2/Al_2O_3$  molar ratio  $\sim 1.5 - 2.5$ ), rich in Fe - oxyhydroxides gels and traces or not of halloysite and goethite ; rich in  $Al_O > 1\%$  with a high P-retention  $> 80\%$ , high rate of dehydration irreversibility (3)  $> 50\%$  and high rate of  $\Delta$  CEC value (4)  $> 55\%$ . (corresponding mainly to the Udands and perhaps to some of the Borands).

4TH FAMILY : amorphous and paracrystalline products very rich in alumina, containing mainly imogolite and  $\pm$  aluminous allophane ( $SiO_2/Al_2O_3$  molar ratio  $< 1.5$ , generally  $\sim 1.0$  or less),  $\pm$  rich in Al and Fe - hydroxides or oxy-hydroxides gels, a few gibbsite and ferrihydrite, traces or not of halloysite and goethite ; very rich in  $Al_O$ , with a very high P-retention  $> 90\%$ , very high rate of dehydration irreversibility  $> 75\%$ , and very high rate of  $\Delta$  CEC  $> 65\%$ . (corresponding mainly to the Hydrudands).

5TH FAMILY : amorphous, paracrystalline and crystalline products extremely rich in alumina and iron oxyhydroxides, very poor in silica, containing mainly gibbsite and gels of paracrystalline (fibrous) Fe oxyhydroxides (probably largely substituted by Al), few allophane or imogolite, very few disordered kaolinite or halloysite ; rich in  $Al_O$  and  $Fe_O$ , with a very high P-retention, very high rate of dehydration irreversibility and rate of  $\Delta$  CEC. (corresponding to a « gibbsitic » (or oxidic) subgroup of the Hydrudands, of which they are probably the oldest stage of weathering).

6TH FAMILY : amorphous products poor (or very poor) in allophane and imogolite, but very rich in Al - organo - mineral complexes, with aluminous 2 : 1 clay minerals and some gels of Fe oxyhydroxides ; rich in  $Al_O$  and exchangeable  $Al^3+$  ; very high P-retention. (corresponding to the Allands).

## CONCLUSION

We could distinguish two main groups of Andisols :

- 1. The first two families contain a silica-rich allophane, have low values of  $Al_O$  and P-retention and present generally lower rates of dehydration irreversibility and of  $\Delta$  CEC. They correspond to young soils or soils developing under a drier climate or on the most basic rocks (Mg-rich).
- 2. The other four families are more or less-rich in alumina. They have high values of  $Al_O$  and P-retention

and present generally high rates of dehydration irreversibility and of  $\Delta$  CEC. They correspond to older soils, mainly developing under a wet climate. The wetter is the climate, the higher are the four main properties ( $Al_0$ , P-retention, the rates of dehydration irreversibility and of  $\Delta$  CEC value). The progression of these properties is connected with a higher desilicification of the

weathering products, an increase in organo-mineral complexes and a decrease in the base saturation of the Cation Exchange Capacity.

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