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CHARACTERISTICS AND GENESIS OF TWO ANDOSOLS IN CENTRAL ITALY

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SUMMARY

Two types of andosols were observed near Lake Vico (Latium), on an extinct volcano. Both derived from ashes and lapilli of the Late-Pleistocene, but the climatic conditions were different.

The first one is located on Mt. Fogliano (940 m o.s.l.), under the coldest and wettest climate of this region and under a beech-forest. It is a weakly differentiated andosol, of a humic and melanic type (Melanalland). This soil contains aluminium-rich amorphous organo-mineral products, which have a high ratio of variable charges (~ 80 %). The pH is ~ 5-6, in spite of a base-saturation ratio ~ 20 %. This andosol shows a high content in chelated-Al in the top-soil, followed by the formation of proto-imogolite in the middle of the profile and the sudden appearance of halloysite at its bottom, in coarser lapilli.

The second soil is located on the South-slope of Mt. Venere (700 m o.s.l.), under a sunnier climate and an oak-forest. It is a well differentiated andosol, of a moderately unsaturated and chromic type (Hapludand). This soil does not show chelated-Al; its pH is higher and the rate of variable charges is less (~ 55 %) than in the former. Some allophane is forming in the top of the profile, while halloysite appears at its bottom, in scoriaceous lapilli.

Some hypothesis are suggested on the genesis of both types of andosols, in a mediterranean country, according to the peculiarities of their climate conditions and of their organic constituents.

RESUME

Deux types d'andosols ont été observés près du Lac Vico (Latium), sur un volcan éteint. Les deux dérivent de cendres et lapilli du Pléistocène supérieur. Mais les conditions climatiques diffèrent.

Le premier est situé sur le Mt. Fogliano (alt. 940 m), sous le climat le plus froid et humide de la région et sous une forêt de hêtres. C'est un andosol faiblement différencié, de type humique et mélanique. Il est riche en produits organo-minéraux amorphes et très alumineux, à fort taux de charges variables (~ 80 %). Le pH est ~ 5-6 magré un taux de saturation en bases de ~ 20 %. Ce sol présente une forte teneur en Al-chélaté en haut du profil, la formation de proto-imogolite dans sa partie médiane et l'apparition brusque d'halloysite à sa base, dans des lapilli plus grossiers.

Le deuxième est situé sur le versant Sud du Mt. Venere (alt. 700 m), sous un climat plus ensoleillé et une forêt de chênes. C'est un andosol bien différencié, de type modérément désaturé et chromique. Il ne présente plus d'Al-chélaté; le pH est moins acide et le taux de charges variables diminue (~ 55 %). Il se forme de l'allophane dans le haut du profil et de l'halloysite à sa base, dans des lapilli scoriacés.

Des hypothèses sont proposées sur la genèse de ces deux types d'andosol, en région méditerranéenne, en relation avec les particularités de leurs conditions climatiques et de leurs constituants organiques.

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RESUMEN

Dos tipos de andosol han sido observados cerca de Lago Vico (Latium), sobre un volcán apagado. Ambos derivan de cenizas y escorias del Pleistocéno superior, pero bajo dos condiciones climáticas differentes.

El primero se encuentra sobre el Mte Fogliano (940 m s.n.m.), con el clima más frio y humedo de la región y bajo un hayal. Este suelo es ríco en productos organo-minerales amorfos y muy aluminosos, con una fuerte proporción de cargas variables (~ 80 %). El pH es ~ 5-6, mientras el porcentaje de saturación en bases cambiales alcanza ~ 20 %. Este suelo muestra un fuerte contenido de Al-chelatado en la parte superior, mientras la proto-imogolita se forma en el medio del perfil y la haloisita aparece subitamente abajo, en las escorias más gruesas.

El secundo suelo está ubicado sobre el vertiente sur del Mte. Venere (700 m s.n.m.), con un clima más asoleado y bajo un encinar Se trata de un andosol bien diferenciado, de tipo moderadamente desaturado y cromico. No tiene más Al-chelatado y la proporción de cargas variables decrece (~ 55 %). Alofana está formandose en la parte superior del perfil y haloisita abajo, en los lapilli escoriáceos.

Unas hipótesis son propuestas sobre la génesis de ambos tipos de andosol, en una región mediterránea, en conexion con las particularidades climaticas y los constituyentes organicos de ellos.

1. INTRODUCTION

Some andosols have been observed at the top of the Vico volcano, in Central Italy. They are lying on the most recent pyroclastic products and under the most temperate and wet climate of this region: either outside the caldera at its rim, on Mte Fogliano, or inside on the summit of Mte Venere cone. Two types of andosols are distinguished. One, on Mte Fogliano, has a very deep humic horizon, without B horizon; other, on Mte Venere, has a well differentiated B horizon. We will show the main characteristics of the both soils, and then deduce their meaning about the genesis and the classification.

2. LOCATION, ENVIRONMENT

Vico is located in the North of Roma, at 42°20'N and 12°10' O. The volcano forms a wide cone. But it is depressed by a central caldera, in the bottom of which (atl. 510 m) lies the Vico lake and in the middle rises the pyroclastic cone of Mte Venere (alt. 838 m). Mte Fogliano is the highest point (alt. 965 m) on the western flank of the caldera. The first andosol (profile 12) has been observed near the top of Mte Fogliano (alt. 940 m), the second (profile 13) on the southern slope of Mte Venere (alt. 700 m). On the Mte Fogliano, the climate is colder and cloudy, of "perhumid" type, and the vegetation is a beech-forest; on the western slope of Mte Venere, the climate is sunnier and the vegetation is an oak-forest. In the both situations the parent material originates from the last eruptions of Mte Venere, the age of which is recent (< 90.000 ans). There are alkaline-trachytic ashes in the upper part of soil and phonolitic-tephritic cinders at their bottom. These products are vitreous and very porous, rich in microlites and phenocrystals of K-feldspars, and then in aluminium and potassium but poor in calcium, iron and magnesium. In addition the drainage of the rain is very high in the soil.

3. MORPHOLOGY

3.1. MTE FOGLIANO SOIL (Profile 12)

The profile shows successively the following horizons: A_0 (0-5 cm), organic leaf-litter – A_1 (5-42 cm), black and very humiferous – A_{13} (42-83 cm), slightly more brownish and less humiferous – C_1 (83-100 cm), brownified ash – C_2 (100 to > 120 cm), weathered cinder. Then this soil is little differentiated, black and very humiferous. The loamy texture of humic horizons, the very fine and friable structure, the low bulk-density (0.8-0.9) and a very high reaction to NaF test, characterize an andosol.

3.2. MTE VENERE SOIL (Profile 13)

The main horizons are successively: A_1 (0-48 cm), very dark brown and very humiferous – A_3 (48-68 cm), yellowish-brown, gradual transition – B_1 (68-96 cm), more reddish – B_2 (96-120 cm), more brownish, slightly/sticky and plastic, containing more cinders – B_3 (120 to > 140 cm), brownish and weathered cinders. This soil is well differentiated. For the most part (0-98 cm), it has typical characteristics of andosol: a fine texture, a very friable structure, a low bulk density (0.9) and a high reaction to the NaF test. In the depth, the soil becomes slightly clayey and plastic, and it reacts more slowly to the NaF test. This shows a difference in the nature of the weathering products according to a change of the parent material.

4. MINERALOGY, GEOCHEMISTRY

4.1. MTE FOGLIANO SOIL

The mineral part of soil is constituted at least by 75 % of unweathered glass and of primary minerals (residue determined after acid dissolution). The latter comprise near 90 % of feldspars, ⅔ of which are made of sanidine and ⅓ of plagioclases (albite-oligoclase), and only 10 % of ferro-magnesian minerals, mainly aegyrinic-augite, plus a few biotite and basaltic hornblend, and traces of ilmenite (determined by X Ray diffraction and optical microscopy). The whole composition of these minerals is similar of an alkaline trachyte.

The weathered part of soil (extracted by ORSTOM Triacid-method) is very impoverished in silica and relatively enriched in aluminium and iron. The amorphous and paracrystalline (selectively dissolved by 2N HCl, or oxalate) fraction, constitutes only 6 to 11 % of soil, 3 to 5 % of which are allophane (imogolite-formula), and 3 to 6 % are chelated or para-crystalline Al and Fe hydroxides. The molar SiO_2/Al_2O_3 ratio near 0.5 shows these products are very aluminous. The $< 2\ \mu$ fraction is constituted mainly of gels of fibrous allophane (observed by TEM), that looks like the proto-imogolite (FARMER et al. 1978, VIOLANTE & TAIT 1979), as also of organo-mineral complexes. For the most part of soil, there are only traces of clay minerals: (10 Å) halloysite and (10-14 M) altered mica. However at the bottom of soil profile, in the brownish cinders, sphaeroidal (10 Å) halloysite appears suddenly in a great quantity (> 10 %), while allophane decreases strongly (to 2 %). The quantity of allophane increases first until the bottom of humic horizons and after it decreases in the mineral horizon to the benefit of halloysite.

4.2. MTE VENERE SOIL

The mineral composition is similar to that of Mte Fogliano soil. However, there are some significant differences. The part of unaltered glasses and phenocrystals is restricted to 65-60 % in the A and B_1 horizons, even 55 % in the weathered cinders, at the soil bottom. The weathering seems more advanced than in the Mte Fogliano soil. In addition, the proportion of plagioclase is higher (~ 50 % of feldspars). The volcanic parent material is a little richer in iron, calcium and magnesium, and then more basic.

The amorphous and para-crystalline fraction is a little more abundant than in the former soil: ~ 12 % in the A_1 horizon, 9 % in the A_3, 7 % in the B_1. Nevertheless it decreases suddenly in the B_2 and B_3 horizons, at the bottom of the soil. The molar SiO_2/Al_2O_3 ratio of the products is near 1. That shows again an aluminous allophane; although the part of allophane is greater (9 % in A_1, 6 % in B_1) and that of complexed or crypto-crystalline Al and Fe hydroxides is lesser (~ 1-2 %). In the upper part of soil (A and B_1), the $< 2\,\mu$ fraction shows mainly a fluffy gel, classic for granular allophane. There are only traces of clay minerals: (10-14 Å) altered mica, smectite and (10 Å) halloysite. But at the bottom, in the brownified cinders, some sphaeroidal and tubular (10 Å) halloysite appears suddenly in a great quantity (10-20 %), while the allophane decreases (to 2-1 %).

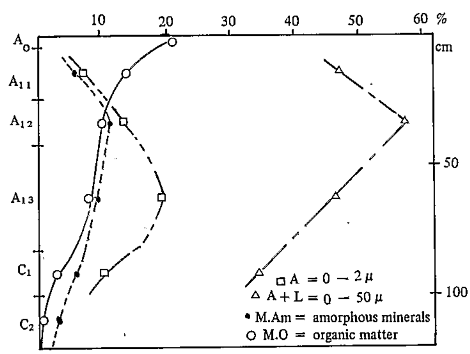

Fig. 1: Distribution of organic matter, amorphous minerals and $< 50\,\mu$, $< 2\,\mu$ fractions, in profile 12.

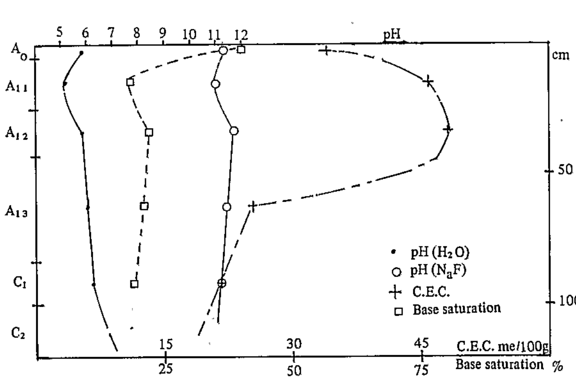

Fig. 2: Variation of pH, CEC and base saturation in profile 12.

5. PHYSICAL AND CHEMICAL PROPERTIES

5.1. MTE FOGLIANO (Fig. 1 and 2)

5.1.1. Physical properties

The soil is loamy (46-56 % of $< 50\ \mu m$) and very humiferous until a depth of 80 cm. The organic matter content decreases gradually, from 14 % in A_{11}, to 7 % in A_{13}, while the clay ($< 2\ \mu m$) increases from 10 to 20 %. The amorphous mineral fraction increases first from 6 to 11 %, and after decreases in parallel with the organic fraction. The water retention capacity of air-dried soils is only $\sim$ 20 % at 15 bars and $\sim$ 30 % at ⅓ bar. These low values are probably due to the drying effect. The structural stability is strong (Henin's index Is < 1).

5.1.2. Chemical properties

The (H_2O)pH is very acid, $\sim$ 5, in the topsoil; afterward it rises gradually to 7, at the bottom (C_2). The (NaF) pH is always > 11. The (pH 8) CEC value is high, near 45 me/100 g in the A_{11} - A_{12} horizons, and decreases to 25 me/100 g in A_{13} and C_1. But the $\triangle$CEC value is very high, near 25 me/100 g in A_{13}, where the rate of $\triangle$ CEC is $\sim$ 80 %. This value and the ZPC $\sim$ 5 (in A_{13} soil without organic matter) characterize some aluminium rich allophanic products. The base-saturation is near 20 % in the whole profile. The available phosphorus is less than 10 % of total phosphorus (P-retention capacity = 95 %). The exchangeable Al^{3+} is $\sim$ 1.6 - 1.7 me/100 g in the $A_{12} - A_{13}$ horizons.

5.2. MTE VENERE SOIL (Fig. 3 and 4)

5.2.1. Physical properties

The soil is loamy (44 - 54 % of $< 50\ \mu m$) and very humiferous (9 - 6 % of Org. Mat.) until a depth of 50 cm. Afterward, it becomes apparently more sandy (70 % of $> 50\ \mu m$) and less humiferous (2 - 1 % of Org. Mat.). However the $< 2\ \mu m$ fraction remains near 10 - 12 % for the main part of soil, except the B_3 horizon at the bottom where the clay increases to 26 %. The amorphous mineral fraction is near 12 % and maximum in the humic horizons; afterward it decreases gradually to 3 % in parallel with the fall in humus content, in the $B_2 - B_3$ horizons, where some clay minerals (halloysite) are formed in abundance. The water-retention capacity of air-dried soil is near 20 % at 15 bars and $\sim$ 30 - 25 % at ⅓ bars. The structural stability is very good (Is < 0.5).

5.2.2. Chemical properties

The (H_2O) pH is slightly acid: $\sim$ 6.3 - 6.4 in the humic horizons, rising gradually to 7 in $B_2 - B_3$. The (NaF) pH is $\sim$ 12-11 in the A and B_1 horizons, afterward it decreases to $\sim$ 10 in $B_2 - B_3$. The (pH 8) CEC value is high: $\sim$ 45 - 35 me/100 g in the humic horizons and $\sim$ 20 me/100 g in the mineral horizons. The $\triangle$ CEC value is only 10 me/100 g in the B_1 horizon, in spite of its allophane content. However the rate of $\triangle$ CEC $\sim$ 55 % and the ZPC $\sim$ 4.4

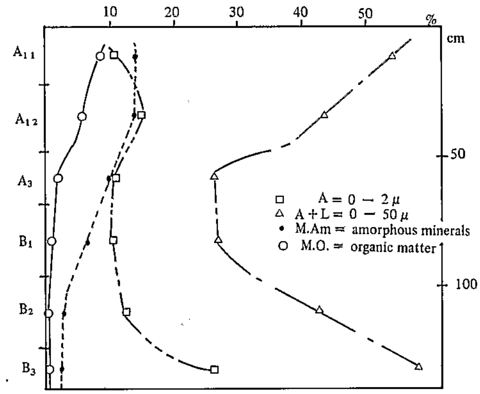

Fig. 3: Distribution of organic matter, amorphous minerals and < 50 μ, < 2 μ fractions in profile 13.

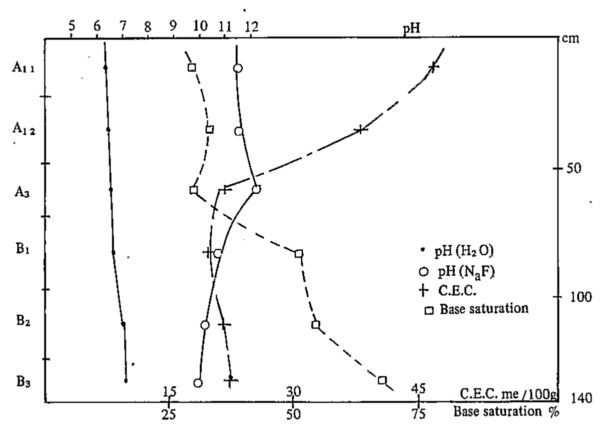

Fig. 4: Variation of pH, CEC and base saturation in profile 13.

characterize well a moderately aluminous allophanic product. The base saturation is near 30 % in the humic horizons, and afterward rises progressively to 50 and 65 % in the B_2 and B_3 horizons. The exchangeable Al^{3+} is very low. The rate of available phosphorus is less than 15 % of the total phosphorus (P-retention capacity = 95 - 88 %).

6. ORGANIC FRACTIONS AND ORGANO–MINERAL COMPLEXES

6.1. MTE FOGLIANO SOIL (Fig. 5 and 6)

N.B. To interpret the organic fractions, see the diagram in LULLI et al., 1983, p. 46.

a) The decrease in organic matter content is fairly slow through the whole profile. Nevertheless the humification is very high (AH + AF ~ 75 - 80 % of total C). Since the A_{11} horizon, the plant residues (ML) are very few. Three organic fractions are predominating:

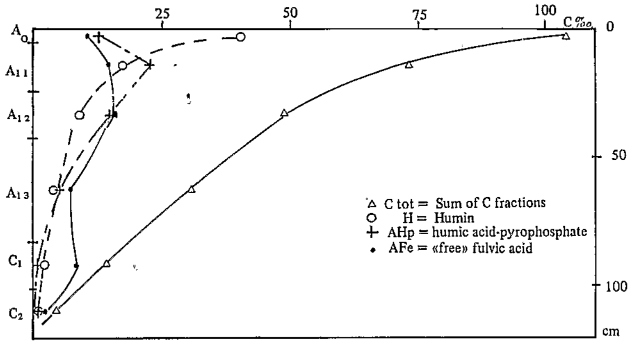

Fig. 5: Distribution of organic fractions as C % of < 2 mm soil, in profile 12.

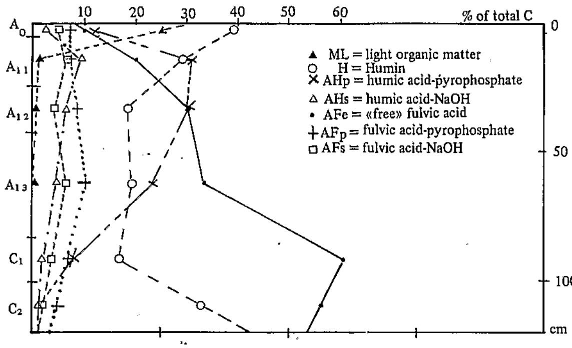

Fig. 6: Relative evolution of organic fractions as % of total Carbon, in profile 12.

humin, "free" fulvic-acid (PO_4H_3 extract) and "pyrophosphate extractable"-humic-acid. The humin seems essentially an inherited fraction, since it decreases regulary through the profile, until it becomes stable in the C horizons, where humin is enriched by a form of "condensation". The pyrophosphate-humic acids are polycondensed humic products, that are stabilized by complexation with Al and Fe. These products increase with depth in the upper part of humic soil, where they are forming in abundance and predominating; afterward they decrease progressively. The free-fulvic acids are little condensed and unstable forms of humus, that give chelates with Al. They increase with depth till the bottom of A_{12} horizon, and afterward decrease slowly. Nevertheless in relative value, their proportion is still increasing, so that the free-fulvic acids become predominating in A_{13} and C_1 horizons, until in C_2, where they begin to be changed likely in humin by condensation.

b) The analysis of Al and Fe extracted by four specific reagents (dithionite, oxalate, pyrophosphate, tetraborate, after JEANROY 1983) shows the following data. The free (non-allophanic) aluminium (pyrophosphate-extractable) is abundant. It decreases slowly from 1.2 to 0.9 %, through the $A_1 - A_{12}$ horizons, and falls suddenly to 0.4 % in C_1. The whole free Al is complexed and almost 100 % chelated (in the tetraborate extract) in the whole soil profile. The free Fe is less, decreasing progressively from 0.8 to 0.4. Moreover the complexed part of iron is restricted: ~ 64 % in A_{12}, 26 % in C_1. It is not truly chelated since it is not in the tetraborate extract, but it is rather as pseudo-complexed oxyhydroxides in the pyrophosphate extractable-humic acid forms.

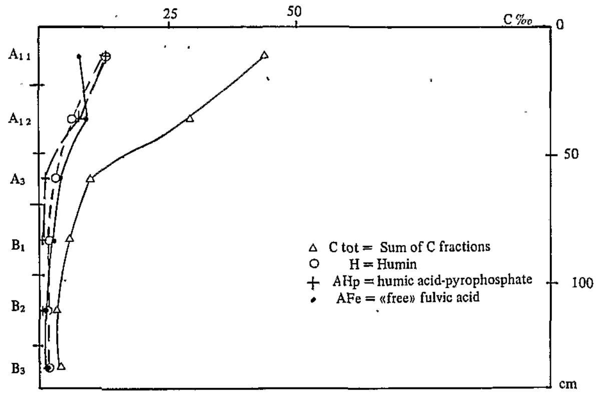

Fig. 7: Distribution of organic fractions as C % of < 2 mm soil, in profile 13.

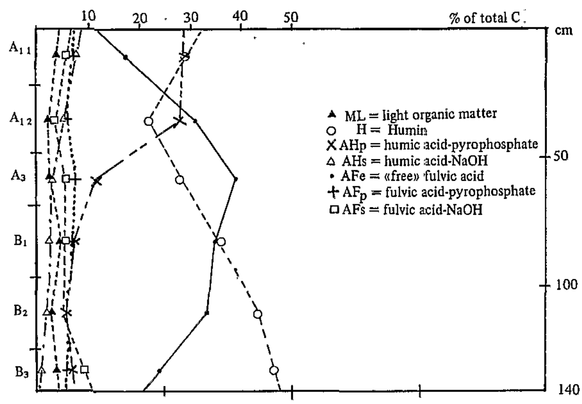

Fig. 8: Relative evolution of organic fractions as % of total Carbon, in profile 13.

6.2. MTE VENERE SOIL (Fig. 7 and 8)

a) The humification is very important (AF + AH ~ 70 - 75 % of total C). Few plant residues remain. The organic matter decreases gradually with depth in the $A_{11} - A_{12}$ horizons, then quickly in $A_3 - B_1$, and it is finally stabilized to 0.4 % of C in $B_2 - B_3$. The three main fractions are still humin, free-fulvic acids, pyrophosphate-humic acids. The humin decreases slowly. Nevertheless in relative proportion of total carbon, the humin increases since A_3 to B_2 and B_3 horizons, where it is predominating. As the humin decreases with depth, there is a corresponding increase in the pyrophosphate-humic acids, which derive of the humin. Indeed, these humic acids are growing and stabilized as Al-complexes in the A_{11} – A_{12} horizons, and afterward they change of form and decrease quickly. The free-fulvic acids increase clearly from A_{11} to A_{12}, and afterward decrease slowly. But, in proportion of total C, they increase even in A_3 and B_1, where they are predominating, and afterward decrease rapidly to turn in humin by condensation.

b) The diverse forms of extractable Al and Fe by 4 specific reagents are the followings. There is a little of free non-crystallized iron, ~ 0.5 - 0.4 % in the whole soil, but it is almost non-complexed and therefore at an oxy-hydroxide state. The oxalate extractable alumina is mainly engaged in the allophane structure. But there is a little of free alumina: ~ 0.5 % in A_{12}, 0.3 % in A_3 and 0.2 % in B_1. This non-allophanic alumina is half and half in chelated (tetraborate-extractable) and pseudo-complexed (pyrophosphate-extractable) forms. These data differ greatly with that of Mte Fogliano soil.

7. INTERPRETATION

7.1. ANDIC CHARACTERISTICS

Both soils have typical andic characteristics for the most part of their profile: a loamy and very humiferous texture, a low bulk density, the lack of evident clay minerals, mostly amorphous weathering products, a water retention capacity at 15 bars > 1/1 g of < 2 μ fraction, (NaF) pH > 10, CEC > 1 me/1 g of < 2 μ fraction, a rate of Δ CEC > 50 %, ZPC ~ 4.4-5, base saturation < 50 %, Phosphorus retention rate > 80 %, high content in Al-complexed humic and fulvic acids. These properties characterize the andosols which are formed under a regularly wet climate and are unsaturated in exchangeable bases. These soils remain still slightly weathered, according to the great quantity of residual primary minerals. But the colloidal fraction is largely dominated by aluminium-rich allophanic products and organo-mineral complexes. However, at the soil bottom, the disappearance of organo-mineral complexes coincides with the diminution of allophane to the benefit of halloysite formation.

7.2. DIFFERENCES BETWEEN THE TWO ANDOSOLS

a) The Mte Fogliano soil shows an accumulation of raw organic matter on the surface and a deep penetration of humic and fulvic acids, without the formation of B horizon. The soil is acid, rich in Al and Fe organic complexes, the importance of which equals at least that of allophane. The aluminium is predominant in the weathering products, as well as chelates as proto-imogolite. That explains the Δ CEC rate ~ 80 % and the ZPC ~ 5. In addition, there is a relative enrichment in free fulvic acid to the bottom of humic horizons (where C/N ratio is 16-17). This soil presents in the same time some andic and podzolic features; but the latter are not conspicuous, due to the lack of iron migration, as it seems to be the same case in "cryptopodzoliques-humifères" soils (C.P.C.S. 1976). These transitional characteristics could be due to the peculiar conditions of soil formation: a temperate-perhumid climate with a cold winter, under a beech-forest, from trachytic ash (rich in silica and alumina). These peculiarities are near that of a similar andosol in the Mte Vulture (LULLI et al. 1983).

b) The Mte Venere soil shows a very clear B horizon, but no raw organic matter accumulation. The penetration of humic and fulvic acids is limited to the upper part of soil, although few free fulvic acids move till the top of B horizon. The soil is slightly acid and contains only few chelates, but rather pseudo-complexed forms of Al and Fe by humic acids. Moreover, the allophane is predominant among the weathering products, and its shape is rather globular than fibrous. The presence of Fe oxy-hydroxide, though at a crypto-crystalline state and in traces, becomes evident in the B horizons, while halloysite begins to form. The ratio of $\triangle$CEC $\sim$ 55% and ZPC $\sim$ 4.4 show that this soil contains less free alumina than the Mte Fogliano soil. Therefore the Mte Venere andosol is more typical. This fact could be explained by a sunnier climate, under an oak-forest, and a slightly more basic parent material.

7.3. CLASSIFICATION

The characteristics of both andosols lead to their following classification in the 1: French (1972), 2: American (1975) taxonomies and 3: after ICOMAND (1983) proposals.

	Mte Fogliano andosol	Mte Venere andosol
1:	Andosol peu différencié, humique, mélanique, intergrade crypto-podzolique	Andosol différencié, désaturé non perhydraté, chromique, modal
2:	Typic Dystrandept? or andic Haplumbrept?	Typic Dystrandept
3:	Typic Melanalland	Typic Hapludand

7.4. GENESIS OF ALLOPHANE AND HALLOYSITE

The distribution of allophane and halloysite through the profile of both andosols shows that their formation is controlled by the chelating reaction of free fulvic acid and the pseudo-complexing effect of humic acid.

In the Mte Fogliano humic andosol, while Al is largely chelated, the formation of allophane is delayed. This increases to the bottom of the humic horizons. The proto-imogolite, an Al-rich form of allophane, is predominant. This form is stabilized by adsorption of humic acids. Finally, in the C_2 horizon, the disappearance of complexing agents allows the formation of halloysite.

In the Mte Venere chromic andosol, Al is poorly chelated. Therefore the allophane is abundant from the top of soil. The globular shape, a less aluminous form of allophane, is predominant. It is stabilized by humic acid in the humic horizons, and afterward decreases progressively in the top of the B horizons, while halloysite begins to appear. At the soil bottom, in B_2 and B_3, the halloysite is forming in abundance, since the penetration of complexing agents is stopped. This formation could be developed from some silica in solution and from alumina which is released after the transformation of organic complexes.

8. CONCLUSION

Two types of andosol have been observed on the volcano of Vico. The "humic and melanic" one, in Mte Fogliano, is formed under the coldest and wettest climate. It is characterized by a deep penetration of complexing organic acid and moreover of Al-chelate, which retards the formation of allophane and favours the formation of proto-imogolite. This soil type is akin to the "cryptopodzoliques-humifères" soils and is classified as a Melanalland. The "chromic and unsaturated" type, in the Mte Venere, is located under a sunnier and less wet climate. The penetration of humic acid is limited. Moreover, the almost lack of Al-chelate allows the formation of allophane in abundance, afterward the differentiation of a rubefied B horizon, and finally, at the soil bottom, the abundant formation of halloysite. This typical unsaturated and chromic andosol is classified as a Hapludand.

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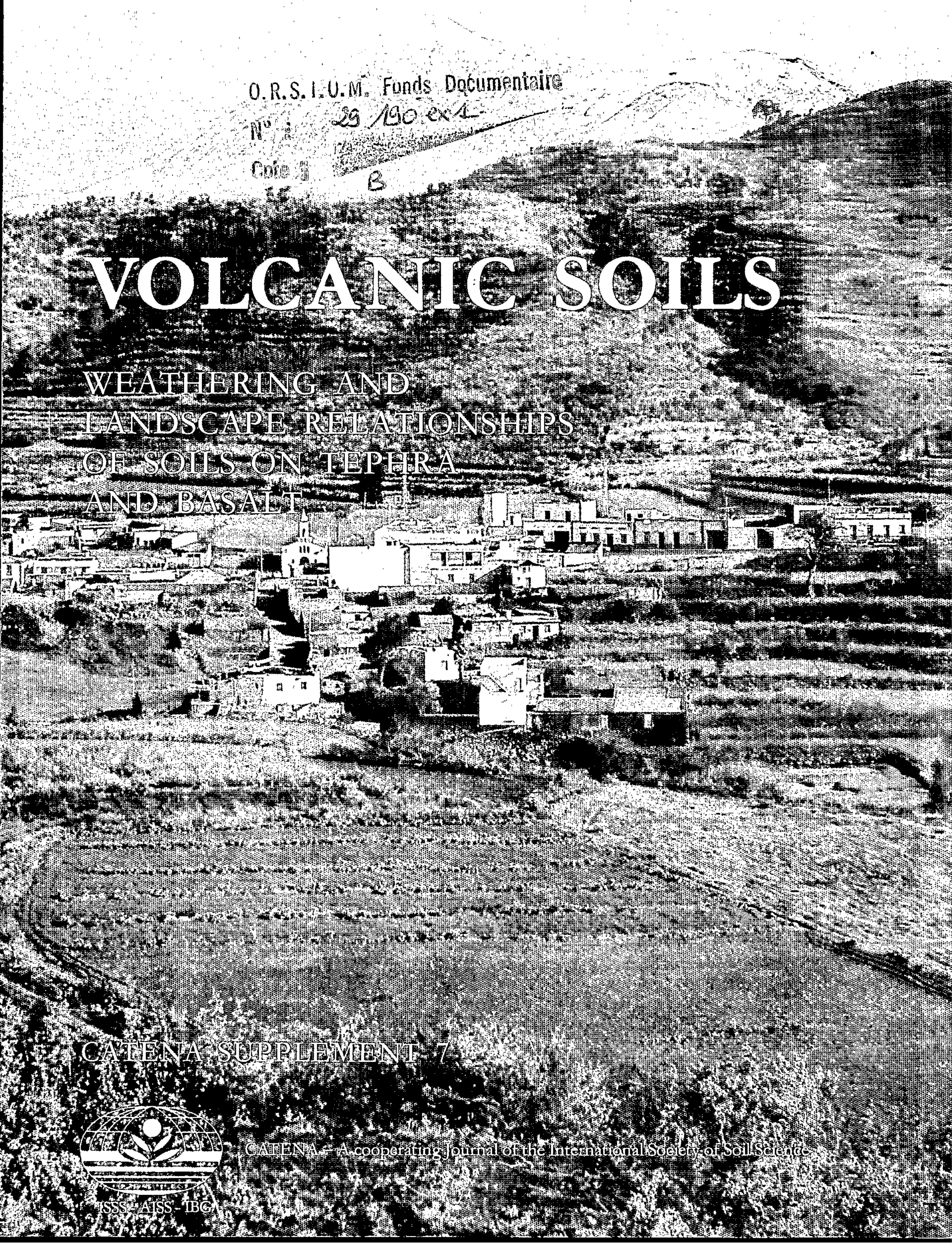
VOLCANIC SOILS

WEATHERING AND LANDSCAPE RELATIONSHIPS OF SOILS ON TEPHRA AND BASALT



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