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A climo and litho soil-sequence on the Vico volcano (Italy)

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ABSTRACT

The studied area is the volcanic complex of Vico, which is connected to the Roman-Campanian potassic alkaline province. After a pedological survey, a sequence of five soil profiles at different elevations was selected.

The soil sequence is correlated with significative changes in the principal climatic parameters ; therefore it is possible to emphasize the climatic effect on the development of soils.

From 965 m at the top of Mt. Fogliano to about 600 m, in a udic and mesic pedoclimate, the soils are always andic, but with spodic characteristics when they are located on sites with a colder perudic regime. From 600 m to about 300 m, in an udic regime, with a dry season and a transitional mesic to thermic regime, the soils show a genesis of crystallized clay in almost all profiles. Finally, below 300 m, in a xeric and thermic pedoclimate the soils always show a clay translocation.

However the climatic effects have been reinforced by two lithological factors. At the upper part of the sequence, very porous, loose and more recent pyroclastic materials favoured the formation of Andisols. Whereas at the lower part, cemented, indurated and older pyroclastic materials favoured the formation of clays and then their lateral translocation.

KEY WORDS : Italy — Vico's volcano — Volcanic soils — Mediterranean climo-sequence : Andisols, Brown soils, Fersiallitic soils.

RÉSUMÉ

CLIMO ET LITHO-SÉQUENCE DES SOLS DU VOLCAN DE VICO (ITALIE)

La région étudiée, au nord de Rome, concerne l'appareil volcanique de Vico, du Quaternaire supérieur ; les dernières éruptions datent de moins de 100 000 ans. Ce volcan appartient à la province magmatique « alcaline-potassique » de la région Rome-Campanie. A la suite d'une cartographie pédologique détaillée de la majeure partie de l'appareil volcanique, une séquence topoclimatique de sols a été définie. Cinq, parmi les nombreux profils observés, ont été choisis à des altitudes représentatives des principales zones climatiques.

Les changements observés dans les sols, correspondent bien aux effets de variations significatives des paramètres climatiques. Il s'agit donc d'une climoséquence, qui se manifeste dans les sols, du haut vers le bas du versant, par les principales propriétés suivantes :

— De 965 m, à la cime du Mt. Fogliano, jusqu'à une altitude d'environ 600 m, en régime pédo-climatique mésique-udique (tempéré-humide), les sols ont des caractères andiques bien marqués ; ce sont des Andisols. Cependant sur le sommet, en climat plus froid et plus humide, les sols acquièrent des caractères podzoliques discrets, dus à la prédominance des chélates d'aluminium sur l'allophane : ce sont des Allic-Andisols.

— Entre 600 et 300 m d'altitude, en régime climatique de transition (tempéré sub-humide), il y a genèse de minéraux argileux dans les sols ; mais il y persiste quelques propriétés andiques près de la surface. Ce sont des sols Bruns-andiques (Andic Dystrochrepts) et des sols Bruns-mésotrophes.

— En-dessous de 300 m d'altitude, en régime thermique-xérique (méditerranéen), tous les sols sont très argileux et ils présentent des translocations d'argile dans le profil. Les moins développés d'entre eux, sont des sols Bruns faiblement lessivés (Dystric Xerochrepts) ; les plus profonds, rubéfiés, sont des sols Fersiallitiques lessivés (Ultic Palexeralfs).

Cependant les effets évidents de cette variation climatique, sur la genèse et la distribution des sols de Vico, sont renforcés par deux causes stationnelles (objet d'une étude en cours) : 1° — Dans la zone supérieure, des matériaux pyroclastiques très poreux et plus récents favorisent la genèse des Andisols ; 2° — Dans les zones médianes et surtout inférieures, les matériaux pyroclastiques sont cimentés et indurés, moins poreux et plus anciens ; ce qui favorise la genèse d'argiles, puis leur translocation latérale dans le profil.

MOTS-CLÉS : Italie — Volcan de Vico — Sols volcaniques — Climoséquence méditerranéenne : Andisols, Sols Bruns, Sols Fersiallitiques.

RIASSUNTO

CLIMO A LITO SEQUENZA DEI SUOLI DEL VOLCANO DI VICO (ITALIA)

Dopo uno studio pedologico esteso a buona parte del complesso vulcanico di Vico, che appartiene alla regione Romano-campana alcali calcica, sono stati selezionati cinque profili dislocati a differenti altitudini di una toposecuenza.

La successione dei suoli coincide con variazioni significative dei parametri principali del clima, per cui si puo definire una variazione dell'effetto del fattore clima sulle tendenze evolutive dei suoli.

Da 965 m della cima del Mt. Fogliano fina ai 600 metri, con un pedoclima udico e mesico, i suoli sono sempre andici ma con discrete caratteristiche spodiche nelle parti più elevate che sono più fredde e costantemente umide. Dai 600 ai 300 metri circa, dove vi è un pedoclima udico con stagione secca e mesico al limite del thermico, i suoli presentano genesi di argilla cristallizzata in buona parte del profilo. Infine al di sotto di 300 metri circa, con un pedoclima xerico e termico, i suoli manifestano sempre migrazione di argilla.

Tuttavia gli diversi effeti climatici hanno stati rinforzati per due fattori litologici. Nella parte superiore della sequenza, i materiali piroclastici, che sono molto porosi, senza coesione, e piu recenti, hanno favorito la formazione degli andisuoli. Mentre nella parte inferiore, i materiali piroclastici, che sono cementati, induriti e piu vecchi, hanno favorito la formazione delle argille e la loro migrazione laterale.

PAROLE CHIAVE : Italia — Vulcano di Vico — Suoli vulcanici — Climosequenza mediterranea : Andisuoli, Suoli Bruni, Suoli Bruni lisciviati.

INTRODUCTION

On the volcanic complex of Vico, an extinct volcano ranging from an elevation of 965 m down to 45 m at the Tiber river on the north of Rome (fig.1), we have observed a vertical zonation of the soils. Vico is a complex volcano, with a central caldera. The last superficial products, after the caldera formation, are mainly pyroclastic (cinder, ignimbrite, tuff) and recent (late Pleistocene). Fig.2 et 3.

Although an effect of the parent material on soil development was demonstrated earlier (LORENZONI *et al.*, 1985), it is also possible to show the effects of elevation and climate changes on the soil genesis.

Five profiles were selected, described and sampled. Samples were then analyzed, following the requirements of the ICOMAND Andisols proposals (1986). Some of field and laboratory data obtained in this investigation are presented in this paper.

1. EARLIER INVESTIGATIONS

Previous studies have been made on several climosequences of volcanic soils in Italy. LULLI (1971) observed that on Mt. Amiata, an extinct volcano in Central Italy, the Inceptisols have acquired some spodic characteristics above the elevation of 1400 m.

A similar climosequence was found on Mt. Vulture (LULLI and BIDINI, 1980), an extinct recent volcano in southern Italy, where the soils become more andic with the elevation and acquire weak spodic characteristics above 1300 m.

The different types of soils of the volcanic complex of Vico have been described in other studies. After an introductory paper (LORENZONI *et al.*, 1984) and an investigation on phosphate retention by the soils (BIDINI and DE CAROLIS, 1984), an initial work indicated that the soils on pyroclastic flows were affected in their genesis by their parent material and showed a process

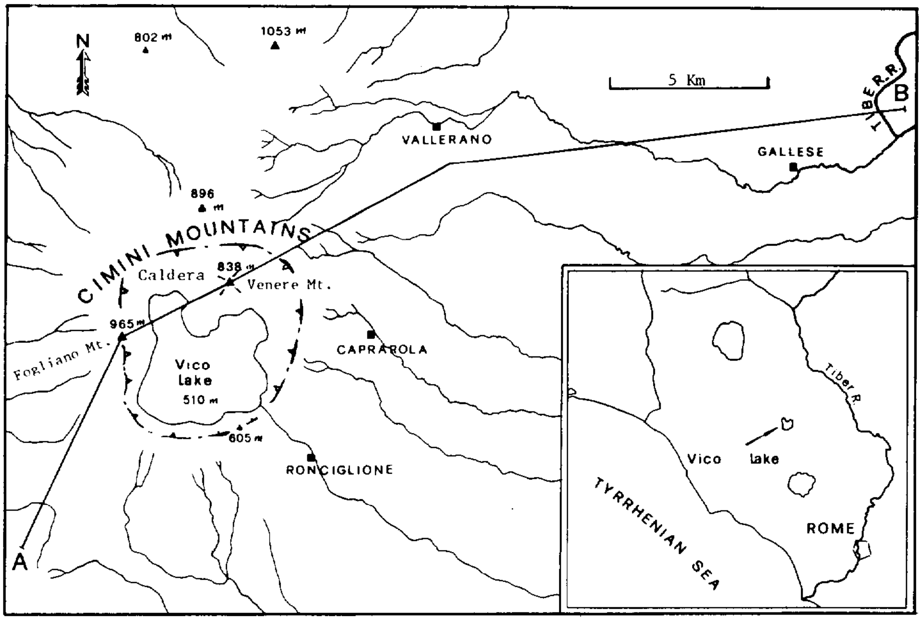

FIG. 1. — Location of the soil sequence of Vico

of crystallized clay formation. A second study showed that the transition from andic to brown pedogenesis is due to a decrease of the vitreous components in soils (LULLI *et al.*, 1985). A third paper described the pedological units found within the caldera (BIDINI *et al.*, 1985) and the nature of soils in relation with their topographic position.

Another paper defined precisely the most andic forms found on Vico (QUANTIN *et al.*, 1985). Some typical soils of this volcanic complex were studied from a mineralogical (LORENZONI *et al.*, 1986) as well as a geochemical point of view (BIDINI *et al.*, 1986).

2. SETTING, MATERIALS AND METHODS

2.1. Climate

The climatic differences between the upper part of the volcano, caldera included, and the lower part are important. Thornthwaite's Moisture Index varies appreciably with elevation. Climate, perhumid A at 965 m, becomes suhhumid C2 at 45 m ; Evapotranspiration Potential (ETP) changes so much that the climate evolves from mesothermic first (B1') at the top of Mt. Fogliano to mesothermic second (B2') at the Tiber river level. Fig.4.

The climate from 45 m (O.S.L.) to an elevation of 560 m is, according to Köppen, subtropical temperate with a dry season (Cs) better known as Mediterranean, and above 560 m to 965 m, temperate without dry season (Cf).

2.2. Soils and soil parent-material

SOILS

A general Soil Survey on the complex volcano of Vico showed that soil differences are related mainly to the parent materials, the relief and the climate.

Five soil profiles were selected along a soil topoclimosequence. Fig.5. The standards for the designation of horizons are from the Soil Taxonomy (1975) and from ICOMAND (1986) ; the description of sites and modalities horizons are from FAO (1975). The location, the elevation, the dominant plant species, and the characteristics of climate, of the five profiles are given in table I.

The numeration of the five soil profiles follows the soil toposequence from top to down. But the reference soil profiles numbers are respectively 12, 111, 51, 19 and 30.

PARENT-MATERIAL (Fig. 2, 3)

After SOLLEVANTI (1983) the complex volcano of Vico is a part of the Roman-Campanian potassic alkaline province. It is formed over a basement of clays and sands of Mio-Pliocenic sediments (Fig.2).

Vico is a central volcano, mainly composed of lava at its bottom, and with a composite pyroclastic summit caldera (Fig.3). It is located along a NE-SW

TABLEAU I
Location and characteristics of environment of the five profiles

N°	Soil type	Location	Principal vegetation	Parent material	Elevation (m)	Air Temp. (°C)	Annual precip.
1	Allic Fulvi-udand(12)	Monte Fogliano	Fagus silvatica	lava + cinders	960	10.4	1956
2	Typic Melan-udand(111)	Croce S.Matteo	Quercus cerris	lava + cinders	722	11.8	1643
3	Andic Dystr-ochrept(51)	San Martino	Castanea sativa	magmaphre-atic tuffs	626	12.4	1560
4	Dystric Xer-ochrept(19)	Madonna del Barco	Quercus pubescens	pyrocla-stic flow	300	14.4	1180
5	Ultic Pale-xeralf(30)	Nepi	Quercus pubescens	pyrocla-stic flow	225	15.0	1090

fracture system. The lavas are of various composition, including phonolitic-tephrites, tephritic-phonolites and slightly under-saturated trachytes. During the caldera formation, the volcano produced four main pyroclastic flows. Finally a post caldera activity is characterized by the emission of tephritic-phonolitic and tephritic products (lava and cinder cone of Mt. Venere, < 90.000 years old). The soils derive mainly of the last pyroclastic and trachytic products. A rejuvenation, more or less important, by the last tephritic cinders of Mt. Venere occurs near the rim of the caldera wall.

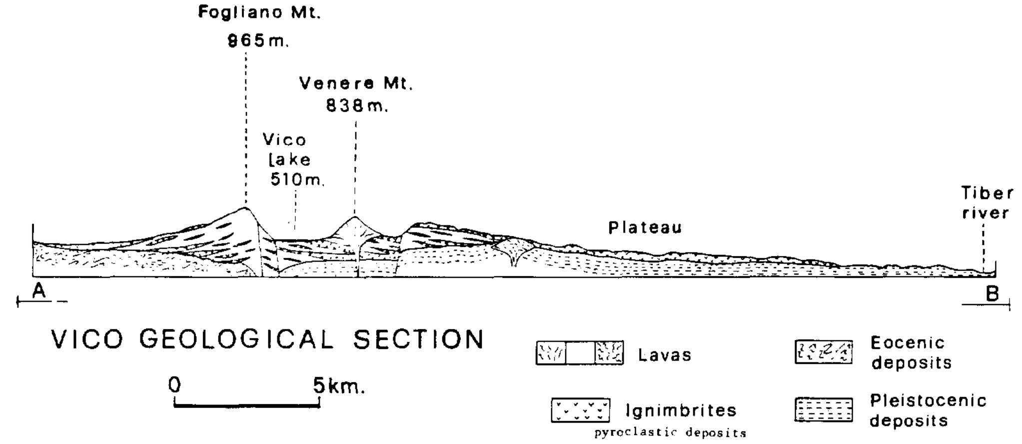

FIG. 2. — Transect of the bed-rock of Vico

2.3. **Soils climatic regimes** (fig.4)

The values reported in table I indicate appreciable differences in the climatic parameters of the five selected profiles. Mean annual air temperatures range from 10.4°C for profile 1 at 960 m a.s.l. on Mt. Fogliano to 15.0°C for profile 5 at 225 m. a.s.l. near Nepi. From these data we estimated that temperature gradient was about 0.6°C per 100 m.

Mean annual rainfall of the five profile sites, given in Table I, ranges from 1956 mm at 960 m.a.s.l. to 1090 mm at 225 m a.s.l.

Referred to classes in Soil Taxonomy, soil tempera-

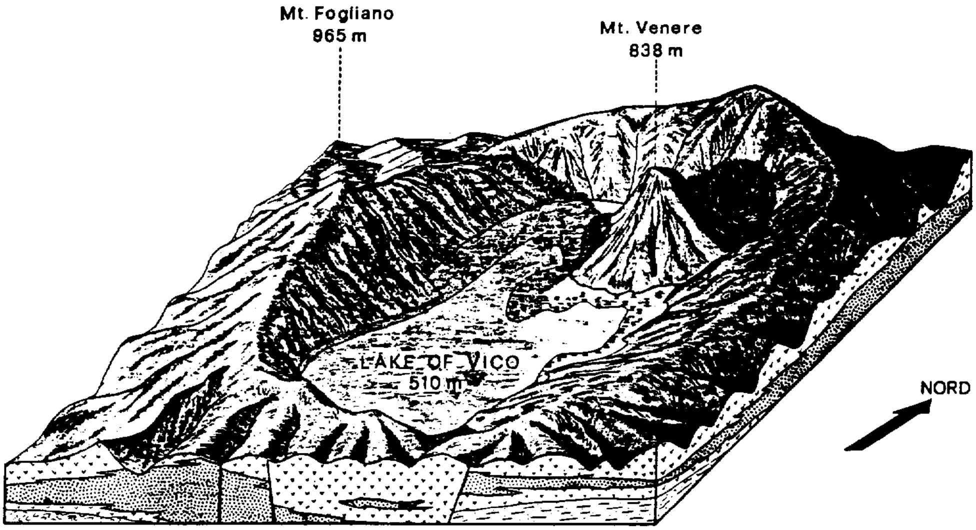

FIG. 3. — Landscape of the Vico volcano and block diagram of bed-rock

tures are *thermic* up to 350 meters above sea level and those at highest elevations are *mesic* (fig.4) ; the moisture regime is *xeric* up to 500 meters above sea level and then *udic* up to the top of Mt. Fogliano (fig.5), and it is even near *perudic* at its summit.

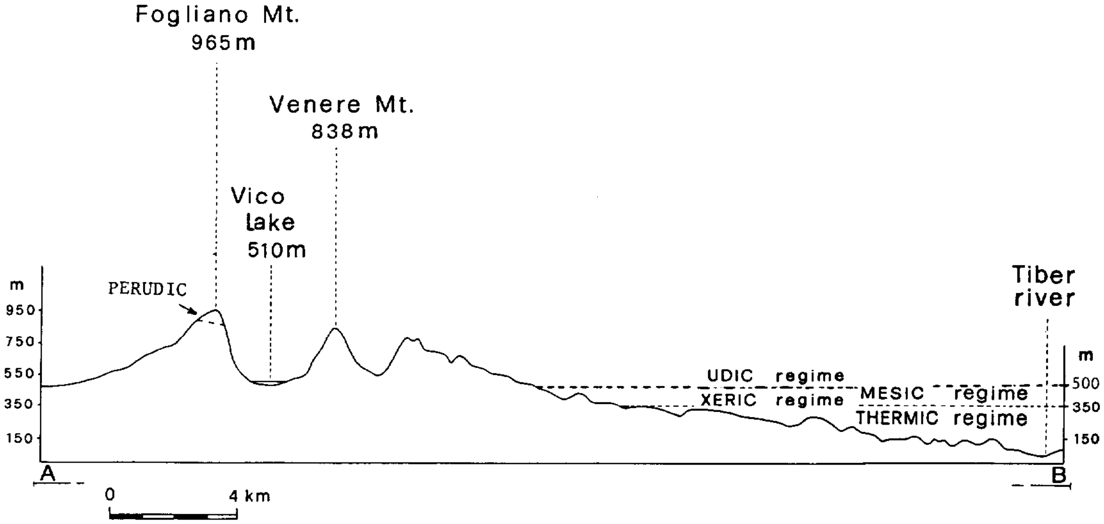

FIG. 4. — Distribution of soil climatic regimes of Vico

2.4. Land use

The land use changes according to the climate. The hazel-nut cultivation is wide spread, from 300 m to about 700 m. In this zone, chestnut is also used as well as coppice, and another crops. Above 700 m, the forestry, predominanty of Turkey oak and of beech, is the principal land use.

Maize, wheat, olives and vines are cultivated on the low land, below 300 m of elevation. Cattle breeding also occure here.

2.5. **Analytical methods**

Soil samples for these analyses were first crushed in order to pass through 2 mm screen. For particle-size distribution, organic matter was first destroyed with H_2O_2 ; samples were dispersed mechanically, and the clay fraction estimated by the Counter method. Organic matter content was determined by the Walkley-Black and total Nitrogen by the Kjeldahl methods. The exchangeable cations were determined by atomic absorption in extracts obtained by leaching samples with NH_4 Acetate at pH7. Titrable acidity was determined according to PEECH *et al.* (1962) by KCl at pH 8.2. Subsamples were ground to pass through an 80-mesh screen for extraction with dithionite-citrate-bicarbonate (MEHRA and JACKSON 1960), with Na-pyrophosphate and with NH_4-oxalate at pH3 (SCHWERTMANN 1964). Amounts of Fe, Si and Al in the extracts were determined by atomic absorption. Phosphorus retention was determined by the BLACKEMORE method (1978).

The allophane content was calculated as following :
— In the case of andisols (profiles n° 1, 2) or andic soils (n° 3) with an alumina-rich allophane (Si/Al mol. < 0.5), we calculated its content from the oxalate extracted silica, after the imogolite formula (SiO_2 Al_2O_3, $2.5H_2O$).
— In the case of other soils (profiles n° 4, 5, the A horizons of profile 4 excepted), with a silica-rich allophane (Si/Al mol > 1) we used the oxalate extracted alumina as basis, after an allophane-halloysite formula ($2\ SiO_2$-Al_2O_3-$2.5\ H_2O$).
— In the rare intermediate cases we used an intermediate approximation.

3. CHARACTERISTICS, CLASSIFICATION AND DISTRIBUTION OF SOILS

3.1. **Characteristics**

The descriptions and analytical data of five profiles are summarized in the following four tables.

In table II the main morphological characteristics of selected soil profiles are summarized, while in tables III, IV and V all analytical data are reported. The data in these last three tables provide the major basis for the classification of the five soils and concerning their genesis.

MORPHOLOGICAL FEATURES

The structure of the A horizons, is ranging from granular and fluffy in the Andisols to crumb in the clayey soils. In the B horizons, the structure is fairly continuous, although microporous, and very friable in the Andisols (Udands ; profiles 1, 2) whereas it becomes more angular, blocky and firm in the Brown Soils (Ochrepts, profiles 3, 4), and finally prismatic in the clayey Fersiallitic Soils (Xeralfs : profile 5), at the bottom of the soil sequence.

PHYSICAL PROPERTIES

The bulk density is generally < 0.9 in the Andisols or in soils with some andic properties (profiles 1, 2 and 3) of the two wettest zones : whereas it is always $>$ 1 in the more clayey soils (profiles 4 and 5) of the lowest and driest zones. The mesured clay content is increasing from profile 1, located at 960 m, to profile 5, located at 225 m. The granulometric composition is loam in profile 1 and silty clay loam in profile 5, the clay content in the B horizons ranging from 10 % to 42 %.

CHEMICAL PROPERTIES

The average organic matter content of the A horizons decreases from 15 % in profile 1 at 960 m to 3 % in profile 4 at 300 m of elevation, although all soils were under a continous forest cover.

The measured CEC (1) is always high. But this value is peculiarly high with regard to the clay content in the Andisols or andic soils (profiles 1, 2 and 3). The effective CEC (2) in soil with variable charge is much lower. Indeed, the titrable acidity (measured at pH 8.2) rise to 30-60 mé/100 g in the A horizons, whereas the pH is ranging from 5.5 to 6.3.

The pH in NaF measured is higher than 11 in Andisols and decreases in all the other soils, reaching 7.9 in the A horizon of the fersiallitic soil. The phosphate retention ranges from 96 % in the andisols to 61 % in the surface horizons of the fersialitic soil.

The amounts of aluminium, iron and silicium which are extractable by oxalate, dithionite and pyrophosphate reagents, and the amount of allophane are gathered in the table V. Among them, the data of aluminium are of particular interest, because these values are useful as diagnostic criteria for the classification of Andisols.

The amount of allophane is remarkably decreasing from the top to the lower part of the soil toposequence : but, a very important change occurs in the Andisols near the summit under a beech forest (profile 1, at 960 m). The Al-pyrophosphate extract equals the Al-oxalate one, and there is few Si-oxalate. In this case, the Al extract becomes mainly from Al-complexed forms ; but there are few allophane and there is some exchangeable-Al (1.6-1.7 mé/100 g). In addition the ratio of pyrophosphate extractable Al + Fe/dithionite-citrate extractable Al + Fe is largely greater than 1. This fact suggests an acido-complexolytic process, like in the case of Spodosols, as we demonstrated previously (QUANTIN *et al.* 1985). On the contrary, in the Andisol located at the lower elevation under an oak-forest (profile 2, at 722 m), there are very few

TABLEAU II

Main morphological properties of the five profiles

Horizon	Depth (cm)	Color moist	Texture	Structure	Consistence	Cutans	Boundary
Allic Fulviudand, profile 1 at 960 m							
A1	0-19	10YR2/1.5	L	fine med. crumb	v.friable	-	clear wavy
A2	19-37	10YR3/2	Stl	fine granular	v. friable	-	gradual wavy
A3	37-78	10YR3/3	L	med. s.blocky	v. friable	-	gradual wavy
Bw	78-95	10YR5/4	Sl	loose	friable	ferrans	gradual wavy
C	95-108	-	-	loose	friable	-	abrupt linear
Typic Melanudand, profile 2 at 722 m							
A1	0-6	10YR2/2	L	fine granular	v. friable	-	clear smooth
A2	6-41	10YR2/2	L	fine med. granular	v. friable	-	gradual wavy
2A3	41-57	10YR3/3	Ls	fine med. granular	v. friable	-	gradual wavy
2Bw	57-86	10YR4/6	Sl	fine s.blocky	friable	-	gradual irr.
2C	86-118+	10YR4/4	Ls	fine granular	friable	-	-
Andic Dystrochrept, profile 3 at 626 m							
A1	0-3	5YR3/2	Cl	fine crumb	v. friable	-	clear wavy
BA	3-40	7.5YR4/3	L	fine a.s.blocky	friable	-	clear wavy
Bw1	40-65	7.5YR4/6	L	med. a.s.blocky	firm	patchy argillans	gradual smooth
Bw2	65-90	7.5YR5/6	Sl	med. a.s.blocky	firm	patchy argillans	gradual irr.
BC	90-160	10YR6/6	Sl	massive	friable	-	gradual irr.
C	160-200+	10YR6/6	Sl	massive	friable	-	-
DystricXerochrept , profile 4 at 300 m							
A1	0-8	10YR3/2	L	fine crumb	v. friable	-	clear wavy
A2	8-20	10YR3.5/2	L	med. s.blocky	v. friable	-	gradual wavy
Bw	20-45	10YR3/3	Cl	med. a.s.blocky	friable	-	abrupt smooth
C	45-65		Sl	massive	firm	few argillorgans	diffuse
Ultic Palexeralf, profile 5 at 225 m							
A	0-3	10YR4/4	Cl	v.fine crumb	friable	-	abrupt wavy
E	3-15	10YR4/6	Cl	fine a.blocky	friable	-	clear wavy
BE	15-30	7.5YR4/4	Stc	fine a.blocky	firm	patchy argillans	abrupt smooth
Bt1	30-50	7.5YR4/4	Stc	med. prismatic	v. firm	cont. argillans	clear wavy
Bt2	50-90	7.5YR4/4	Stc	med. prismatic	v. firm	cont. argillans	gradual wavy
Bt3	90-130	7.5YR4/4	Stc	med. prismatic	v. firm	cont. argillans	gradual wavy
BC	130-180	5YR4/4	Stcl	coar. a.blocky	firm	broken argillans	abrupt broken
C	180-220+	7.5YR4/6	Stc	massive	friable	-	diffuse

Cl:clay loam; L:loamy; Ls:loamy sand; Sl:sandy loam; Stc:Silty clay; Stcl:Silty clay loam; Stl:silty loam.

Al-pyrophosphate extracts and only traces of exchangeable-Al. Indeed the Si-oxalate amount is related with the Al-oxalate to form allophane, of imogolite formula (Al/Si = 2) ; the amount of which could be around 14-17 % of the soil in the major part of this profile.

The other three soils yield only few Al and Si-oxalate extracts, a large part of which being also extractable by pyrophosphate. Then, they contain very few allophane, < 1 % of whole soil, even in the case of the andic Brown soil (profile 3, Andic Dystrochrept). Indeed, these soils are mainly made of clay and iron-oxide minerals. Only the andic Brown Soil presents a little allophane (1-2 %) in the top-soil.

3.2. Classification

An attempt is made to classify the soils, according to : 1) the ICOMAND proposal (circular letter n° 8,

TABLEAU III
Granulometry and bulk density

Horizon	Coarse Sand % (2.0-0.2mm)	Fine Sand % (0.2-0.05mm)	Silt %	Clay % (<0.002mm)	Bulk density	% glass in sands
Allic Fulviudand, profile 1 at 960 m						
A1	33.1	12.2	39.3	15.4	0.8	
A2	22.6	13.4	56.2	7.8	n.d.	
A3	32.4	17.7	29.2	20.7	0.9	
Bw	45.5	19.0	24.8	10.7	n.d.	
Typic Melanudand, profile 2 at 722 m						
A1	27.9	17.6	33.3	23.0	0.8	
A2	28.6	20.2	42.4	8.7	n.d.	
2A3	43.4	20.1	23.7	12.8	n.d.	
2Bw	55.1	20.0	19.2	5.6	1.0	
2C	68.7	15.9	10.8	4.5	n.d.	
Andic Dystrochrept, profile 3 at 626 m						
A1	16.2	15.6	39.1	29.0	0.8	68
BA	18.4	20.4	36.4	24.8	0.7	n.d.
Bw1	17.3	25.1	41.1	20.1	0.9	79
Bw2	30.0	23.7	31.4	14.9	0.9	n.d.
BC	26.7	26.1	34.4	12.8	n.d.	84
C	28.1	35.3	26.8	9.8	n.d.	n.d.
Dystric Xerochrept , profile 4 at 300 m						
A1	30.5	18.6	31.7	19.2	1.3	73
A2	25.8	16.5	31.5	26.2	n.d.	78
Bw	22.4	14.4	23.1	40.1	1.2	82
C	38.7	21.4	26.3	13.6	n.d.	n.d.
Ultic Palexeralf, profile 5 at 225 m						
A	12.0	15.3	45.4	27.3	1.4	
E	10.6	13.8	41.0	34.6	n.d.	
BE	6.8	8.1	41.9	43.2	n.d.	
Bt1	6.2	5.8	46.4	41.6	1.5	
Bt2	5.9	5.7	46.0	42.4	n.d.	
Bt3	5.8	2.5	50.9	40.8	n.d.	
BC	4.6	2.5	54.4	38.5	n.d.	
C	3.5	2.7	47.9	45.9	0.9	

1986), 2) the US Soil Taxonomy (Keys to Soil Taxonomy, 1983) and 3) the proposal of some French Pedologists and following revisions about the Andosols (Groupe de Travail Andosols, 1972).

Soil Profile n° 1
1 — Allic Fulviudand, near Melanudand (ICOMAND)
2 — Typic, Dystrandept (S.T.)
3 — Andosol désaturé mélanique, intergrade cryptopodzolique (de climat tempéré perhumide et froid : Tm 10°C, Pm 1900 m) (G.T.A.)

Soil Profile n° 2
1 — Typic Melanudand (ICOMAND)
2 — Typic Dystrandept (S.T.)
3 — Andosol désaturé, non perhydraté, mélanique (de climat tempéré-humide Tm 12°C, Pm 1600 mm, déficit hydrique 3 mois) (G.T.A.).

Soil Profile n° 3
2 — Andic Dystrochrept (S.T.)
3 — Sol Brun andique, mésotrophe (de climat tempéré-humide : Tm 13°C, Pm 1400 mm, déficit hydrique 3 mois (G.T.A.)

Soil Profile n° 4
2 — Dystric Xerochrept (S.T.)
3 — Sol brun faiblement lessivé, mésotrophe (de climat méditerranéen) (C.P.C.S.)

Soil n° 5
2 — Ultric Palexeralf (S.T.)
3 — Sol fersiallitique désaturé, lessivé, hydromorphe en profondeur (de climat méditerranéen) (C.P.C.S.).

3.3. **Distribution along the climosequence** (fig.5)

We observed a fairly good soil climosequence, from the top to the lower part, outside of the Vico caldera :
— Andisols, above 600 m, within the humid temperate climatic belt (Tm 10-12°C, Pm 1900-1400 mm, light rainfall shortage < 3 months) ;

TABLEAU IV
Chemical data

Horizon	Organic matter%	C%	N%	C/N	Ca	Mg	Na	K	Ac.	CEC.1	Base % satur.	Al(KCl) meq/100	ECEC.2 meq/100	pH H2O	pH KCl	pH NaF	P2O5 (ret%)
					(meq/100 g)												
Allic Fulviudand, profile 1				at 960 m													
A1	14.52	8.41	0.68	12	5.6	1.4	0.2	1.0	37.5	45.7	18.3	0.50	8.7	5.1	3.9	11.0	96.3
A2	15.90	9.30	0.60	16	7.3	2.2	0.9	0.5	37.5	48.4	22.6	1.60	12.5	5.8	4.5	11.7	96.5
A3	9.61	5.62	0.60	16	2.5	1.2	0.2	1.4	20.0	25.3	20.8	1.70	7.0	6.0	4.6	11.4	95.7
Bw	2.10	1.21	0.21	10	1.8	1.3	0.2	0.9	17.5	21.7	19.2	tr.	4.2	6.2	4.7	11.2	96.1
Typic Melanudand, profile 2				at 722 m													
A1	14.22	8.24	0.61	14	15.3	3.0	0.4	1.5	30.0	50.2	40.2	tr.	20.2	5.7	4.8	10.9	96.3
A2	13.24	7.67	0.42	19	6.7	0.9	0.2	0.7	60.0	68.5	12.4	tr.	8.5	5.5	4.4	11.7	95.8
2A3	5.80	3.36	0.20	15	5.8	0.8	0.9	0.9	37.5	45.5	17.6	tr.	8.0	6.1	4.9	11.5	90.6
2Bw	2.55	1.48	0.11	13	2.4	0.4	0.9	1.1	22.5	27.3	17.8	-	4.8	6.1	5.2	11.3	83.4
2C	1.41	0.82	-	-	2.2	0.3	2.2	1.9	17.5	24.1	27.4	-	6.6	6.3	5.1	11.0	81.3
Andic Dystrochrept, profile 3				at 626 m													
A1	9.50	5.50	0.36	15	12.4	11.2	1.4	1.9	22.5	49.4	54.1	-	26.9	6.8	5.6	9.1	77.7
BA	2.63	1.52	0.11	14	7.5	8.6	1.3	2.2	30.0	49.6	39.5	-	19.6	6.3	4.9	9.2	70.0
Bw1	1.20	0.70	-	-	8.2	8.5	2.3	3.3	17.5	39.8	56.0	-	22.3	6.3	4.7	9.3	75.2
Bw2	1.09	0.63	-	-	8.5	6.4	2.3	2.9	20.0	40.1	50.1	-	20.1	6.3	4.8	9.5	75.8
BC	0.40	0.23	-	-	9.4	4.0	2.4	0.6	17.5	33.9	48.8	-	16.4	6.5	4.5	8.9	76.5
C	-	-	-	-	7.3	1.4	2.7	0.5	15.0	26.9	44.2	-	11.9	6.6	4.7	8.5	n.d.
Dystric Xerochrept, profile 4				at 300 m													
A1	5.21	3.02	0.20	15	1.9	0.7	1.0	0.5	5.0	9.1	45.1	0.27	4.4	5.9	4.4	9.6	67.5
A2	1.94	1.12	0.08	14	1.9	1.1	1.0	0.6	10.0	14.7	31.3	0.75	5.5	5.6	4.0	8.9	68.1
Bw	1.18	0.68	0.06	11	1.7	1.3	1.0	1.0	10.0	15.0	33.3	0.63	5.6	5.7	4.0	9.8	70.1
C	0.23	0.14	-	-	1.4	0.7	1.6	0.5	5.0	9.2	45.6	0.25	4.5	6.4	4.2	9.1	48.0
Ultic Palexeralf, profile 5				at 225 m													
A	11.44	6.63	0.46	14	16.8	2.7	1.3	2.2	17.5	40.5	56.8	0.08	23.1	6.7	5.8	7.9	61.1
E	2.04	1.18	0.11	11	5.9	3.5	1.9	2.4	12.5	26.2	52.2	0.08	13.8	6.3	4.6	8.6	61.3
BE	1.47	0.85	0.10	8	5.9	3.8	1.5	1.6	15.0	27.8	46.1	0.10	12.9	6.1	4.6	8.7	68.8
Bt1	1.05	0.61	0.09	7	5.5	1.6	1.4	1.0	17.5	27.0	35.2	0.20	9.7	5.8	4.4	9.2	65.3
Bt2	1.10	0.63	0.08	8	5.4	1.5	1.8	1.0	12.5	22.2	43.8	0.13	9.8	5.9	4.5	8.8	68.3
Bt3	0.81	0.47	0.05	8	5.2	1.4	1.4	1.1	15.0	24.1	37.9	0.12	9.2	5.9	4.3	8.8	70.3
BC	0.64	0.36	-	-	4.9	1.5	1.7	1.3	22.5	31.9	29.5	0.57	10.0	5.6	4.1	8.6	74.7
C	1.14	0.66	-	-	0.5	1.5	1.3	1.0	15.0	19.3	22.6	1.54	5.8	5.5	3.9	8.7	74.7

CEC1= Sum of Ca,Mg,K,Na + Ac – Ac= H^+ pH 8.2 – ECEC2= Sum of Ca,Mg,K,Na + Al^{3+}

— Andic Brown Soils *(Andic Dystrochrepts)*, between 600 and 300 m, within the intermediate temperate climatic belt (Tm 134-14°C, Pm 1400-1200 mm, dry season of 3-4 months).

— Brown and Fersiallitic Soils *(Dystric Xerochrepts, Ultic Palexeralfs)*, below 300 m, under 300 m, under a Mediterranean climate.

However, near the top of the Caldera, under a colder (10°C) and almost perhumid micro-climate (in a beechforest), we observed « non allophanic » or « allic » Andisols. Whereas downward, under a slightly warmer and less humid climate (in an oak forest), there are typical (allophanic) Andisols. A similar, although more reddish, type of Andisol has been described at the same elevation, on the southern slope of Mt. Venere volcano (QUANTIN *et al.*, 1985).

We note also how the transitions between each main soil type, from each climatic belt to another, are very

TABLEAU V

Forms of Al, Fe and Si, and allophane content

Horizon	Al(o) %	Al(d) %	Al(p) %	Fe(o) %	Fe(d) %	Fe(p) %	Si(o) %	Si(d) %	Si(p) %	Alloph. %
Allic Fulviudand, profile 1 at 960 m										
A2	2.28	0.95	2.28	0.52	0.10	0.34	0.50	0.08	0.06	3.7 i
A3	1.98	0.70	1.98	0.34	0.13	0.17	0.64	0.05	0.01	4.7 i
Bw	1.70	0.43	1.70	0.25	0.07	0.06	0.67	0.05	tr.	4.9 i
Typic Melanudand, profile 2 at 722 m										
A1	2.34	0.85	0.18	0.83	0.40	0.62	1.19	0.12	0.05	8.8 i
A2	3.91	0.93	0.20	1.50	0.71	0.53	1.88	0.15	0.03	13.9 i
2A3	4.48	0.53	0.08	1.22	0.49	0.09	2.56	0.08	0.03	17.2 i
2Bw	3.88	0.52	0.03	0.99	0.20	0.02	1.99	0.09	0.01	14.7 i
2C	2.75	0.36	-	1.44	0.33	-	0.56	0.05	tr.	4.1 i
Andic Dystrochrept, profile 3 at 626 m										
A1	0.62	1.03	0.49	1.66	1.35	0.21	0.25	0.83	0.06	1.8 i
BA	0.56	0.85	0.36	1.62	1.40	0.31	0.12	0.56	0.05	0.9 i
Bw1	0.59	0.53	0.26	1.54	1.35	0.05	0.27	0.32	0.03	2.0 i
Bw2	n.d.	0.72	0.19	1.47	1.37	0.02	0.23	0.18	0.03	1.7 i
BC	n.d.	0.56	n.d.	0.84	0.82	-	0.26	0.11	0.02	1.9 i
C	n.d.	0.30	n.d.	0.42	0.34	-	0.19	0.07	0.02	1.4 i
Dystric Xerochrept, profile 4 at 300 m										
A1	0.31	n.d.	0.25	1.32	0.74	0.06	0.14	n.d.	0.03	1.0 i
A2	0.26	0.70	0.28	1.56	1.02	0.06	0.20	0.52	0.05	1.0 i
Bw	0.23	0.43	0.12	1.49	0.62	0.02	0.30	0.38	0.01	1.1 a
C	0.11	0.30	0.03	1.64	0.23	0.02	0.28	0.35	0.01	0.5 a
Ultic Palexeralf, profile 5 at 225 m										
A	0.25	n.d.	1.06	1.22	1.08	n.d.	0.27	n.d.	n.d.	1.2 a
E	0.29	1.32	n.d.	1.34	1.57	n.d.	0.26	0.62	0.03	1.2 a
BE	0.34	n.d.	n.d.	1.48	1.84	n.d.	0.32	n.d.	n.d.	1.5 a
Bt1	0.28	n.d.	0.06	1.84	1.97	n.d.	0.39	n.d.	n.d.	1.4 a
Bt2	0.27	1.58	-	1.71	2.46	n.d.	0.28	1.50	0.02	1.3 a
Bt3	0.29	n.d.	-	1.68	2.31	n.d.	0.39	n.d.	0.02	1.4 a
BC	0.32	2.12	-	1.70	3.08	n.d.	0.39	2.11	0.03	1.5 a
C	0.35	2.48	-	1.24	1.86	n.d.	0.54	n.d.	0.04	1.5 a

(i= of imogolite formula, a= of allophane-halloysite formula)

short. That shows how important the effect of climate changes are on soil properties.

The table VI summarizes the main data of this soil sequence.

TABLEAU VI

Principal variations in soil characteristics along the climosequence

	Andisols		Andic Brown Soils	Fersiallitic Soils
	Allic	Typic	Andic Dystrochrepts	Ultic Palexeralfs
Bulk Density	0.8-0.9	0.8-1.0	0.8-1.0	1.4-1.5
Organic Matter %	15-10	14-13	9-5	3-2
<2 µm fraction %	15-20	13-23	20-30	30-45
Al-oxalate %	2.3-1.7	2.3-4.5	0.6	0.3
Allophane %	2-5	8-17	1-2	0.5-1
Al-chelates %	2.3-1.7	0.2	0.4-0.2	<0.2
Al me/100g	0.5-1.7	tr	tr	tr
(NaF) pH	11.7-11.0	11.7-11.0	9.5-9.0	9.0-8.0
P retention %	96	96-85	77-70	70-60

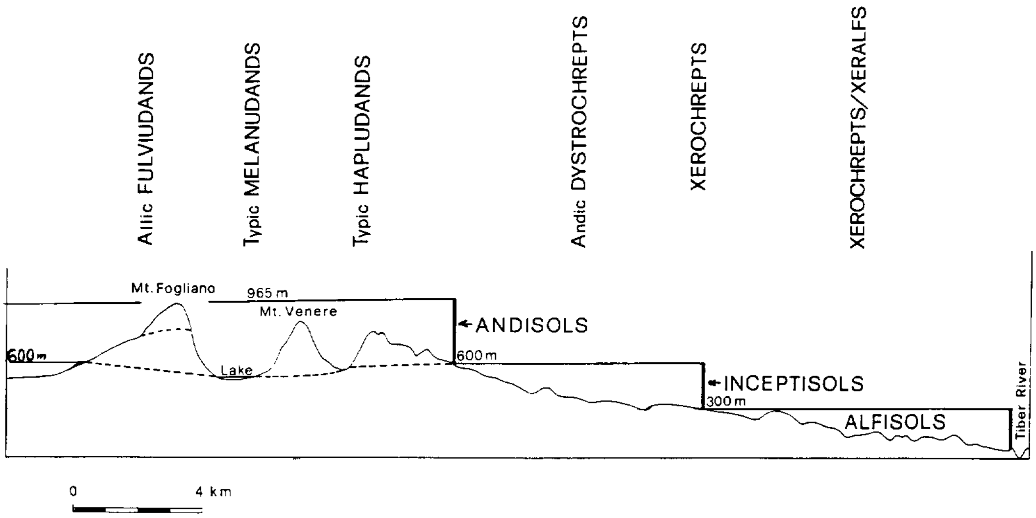

FIG. 5. — Soil climo-toposequence of Vico

We can emphasize the following transformations along the soil sequence, downward :
— from a deep humic-melanic soil, to a more differentiated brown or reddish clayey soil,
— from a « in micro-peds » very porous and loose structure to a hard and less porous blocky structure
— increase in bulk density from 0.8 to 1.5, whereas the organic matter content decreases from 15 % to 3 % in the A horizons.
— evolution from Al-rich organo-mineral complexes to clay formation and from Al-chelation, with few Al illuviation, to clay translocation and accumulation.

CONCLUSIONS

In conclusion, the soils of Vico manifest a very conspicuous topo-climosequence of weathering of pyroclastic materials, of the late Quaternary or of recent age.

This fact shows how in a Mediterranean country, a moderate relief like the Vico volcano, near 965 m o.s.l. high, can produce an important differentiation in the climate as well as in the soils properties, according to the altitude and to the slope orientation.

The studied sequence shows clearly great changes in the soils from the summit, downward, as following :
— from the Andisols very deep, dark, humiferous, porous and fluffy materials ;
— to Andic Brown Soils (Andic Dystrochrepts) marked by an intense clay formation (mainly halloysite) in free drainage conditions, but with only slight remaining andic properties and with very little clay translocations :
— to Brown Soils (Dystric Xerochrepts) with little evidences of andic characteristics in the top and little evidences of clay translocation in the lower part of the profile and then to Fersiallitic Soils (Ultic Xeralfs) very clavey, compact and bad draining, with argillans and ferri-argillans through the major part of the profile.

In addition, a very important process appears in some Andisols. Near the summit of the Caldera, the Al-chelatation process is predominating over the formation of allophane or of clay minerals. These Andisols (Allic Fulvidands) are akin to Spodosols (Haplohumods ?) although there is no clear evidence of Al-chelates translocation through the soil profile. We could propose for this soil the neologism « Alu-andosol très humifère ».

Indeed, this climosequence shows a complete transformation of weathering processes in the soils. However, the effects of the climate variation are reinforced by other two local factors. On the upper part of the soil climosequence a very porous, freely drained, and more recent pyroclastic material favours the genesis of Andisols. Whereas, downward to the middle and lower part of the soil climosequence, where the pyroclastic parent materials become more and more cemented, indurated and older, the formation of clay minerals and then their translocation are favoured.

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