PRELIMINARY EVIDENCES OF A PALEOSOL IN THE LIVING LANDSCAPE OF CIVITA DI BAGNOREGIO (ITALY)

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Abstract

A paleosol has been identified in an area of great natural interest for its geomorphologic and naturalistic aspects between the municipalities of Bagnoregio and Castiglione in Teverina (Viterbo, Italy). This investigation represents the preliminary steps of a study aimed to know the specific environmental features and dynamics prior to the eruptions of the "nenfri" of the Paleovulsini complex. The physico-chemical characteristics and some horizons morphological details such as the presence of roots fingerprint, the polyhedric angular and columnar structure suggest incipient weathering and pedogenesis. Moreover, the presence of nodules and the high salinity of deep horizons suggest the incorporation of pyroclastic material into a hydromorphic environment at the time of the eruptions, putting forward the hypothesis of a paleo-marsh under an arid paleoclimate.
Keywords: *paleosol, pyroclastic material, microbiological analysis, Civita di Bagnoregio*

Introduction

A paleosol has been identified in an area of great natural interest for its geomorphologic and naturalistic aspects between the municipalities of Bagnoregio and Castiglione in Teverina (northern Lazio, bordering Umbria). Particular attention is given to landslides and erosive events repetition that affect both the cliff on which Civita rises and the adjacent "Valle dei Calanchi" (Fig. 1). The instability of the slopes and the badlands formation are due to the movements of the marine clays underlying the volcanic deposits of the Paleovulsini Complex (Palladino et al., 2010; Mancini et al., 2003-2004) (Fig. 2). These conditions give rise to a living landscape. The paleosol is placed at the base of the volcanic sequence, a few meters above the roof of the Pliocene-Pleistocene marine deposits (massive limestone clay) in the area among Civita di Bagnoregio, the "Valle dei calanchi" and Sermugnano with the outcrop continuing towards SO-NE for about 4 km.

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Figure 1
Civita di Bagnoregio and the "Valle dei Calanchi" on the right.

Materials and methods

Soil sampling and preliminary morphological analysis of the profile (0-200 cm) were performed at Sermugnano (Fig. 2) on May 25, 2017. Before soil samples were collected, a preliminary treatment of the profile was performed by removing a thickness of approximately 5 cm of the air exposed surface so as to limit the environmental contamination phenomena.

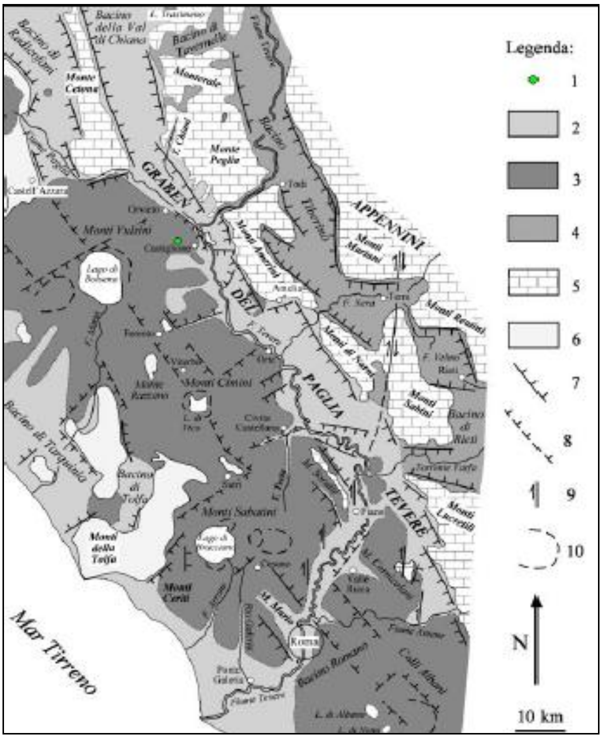

Figure 2
Tectonic scheme of the Latium region. From Mancini et al., 2003-2004 (modified).

1) location of the sampling site (Sermugnano) - 2) "neoautochthonous" sedime-tary successions, of the marine, transitional and non-marine environments (Pliocene-Quaternary) - 3) volcanic and volcano-sedimentary successions (Pliocene-Late Pleistocene) - 4) sedimentary successions of the intermontane basins (Pliocene-Quaternary) - 5) carbonate and siliciclastic successions of the Umbro-Sabina domain (Trias-Miocene) - 6) siliciclastic and carbonate successions of the Tuscan and Ligurid domains (Trias-Miocene) - 7) normal fault - 8) buried normal fault – 9) transcurrent fault - 10) caldera rim.

Along the profile, 8 horizons were identified (Fig. 3) and for each one a soil sample was collected. The soil samples were air-dried, milled and hand screened to 2 mm prior to analysis. Physical and chemical analyses were carried out according to the Italian official methods (MiPAF, 2000). The pH was determined potentiometrically in a 1:2.5 (w/v) soil-deionised water suspension for mineral or organic horizons (Van Reeuwijk 2002). The total organic C (TOC) and total N (TN) contents were measured by dry combustion (EA-1110 Thermo Scientific Lab). The exchangeable cations were determined by inductively coupled plasma optical emission spectrometry (ICP-OES; Ametek, Arcos Spectro) after exchange with 1 M NH_4^+ acetate at pH 7 (Summer and Miller 1996). Amorphous iron oxide (FeO) and aluminium oxide (AlO) forms were estimated by extraction with acid ammonium oxalate (Schwertmann 1964), and Fe and Al in the extracts were measured by ICP-OES. Microbial biomass content was determined using fumigation-extraction method (Vance et al., 1987). The organic C from fumigated and unfumigated samples extracted with 0.5 M K_2SO_4 was measured using a TOC analyser (TOC-VCPN, Shimadzu). The enzymatic activities (cellulase, α- and β-glucosidase, xylosidase, acid phosphatase, chitinase, arylsulfatase and butyrate esterase) were determined according to the method described by Marx et al. (2001) and Vepsäläinen et al. (2001) using fluorogenic methylumbelliferyl (MUF) substrates..

The elements considered for the attribution of the term "Paleosol" are the presence of morphological figures related to plant roots, the presence of profile horizons and evidences of soil structures (Retallack, 1988).

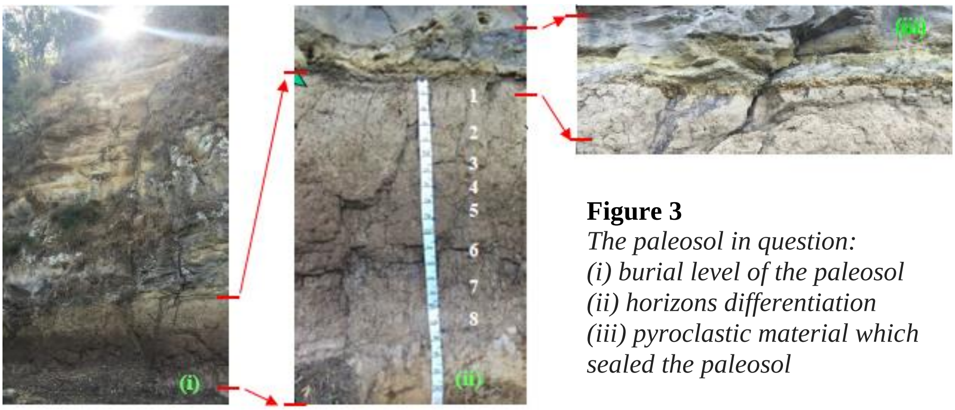

Figure 3
The paleosol in question:
(i) burial level of the paleosol
(ii) horizons differentiation
(iii) pyroclastic material which sealed the paleosol

Results and discussion

The deposits of the volcanic complex Paleovulsini are characterized by several trachytic-phonolithic pyroclastic flow units dated to the area under examination (at Civitella d'Agliano, 5 km to SSE of Sermugnano) with K / Ar 505.2 ± 5.7 (Nappi et al., 1995) and known as formation of Civitella d'Agliano (Aurisicchio et al., 1992)

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or “nenfri” (Cioni et al., 1987; Nappi et al., 1995). Several flow units have been recognized above the paleosol, but although they have similar characteristics (though with small thicknesses), it has not yet been possible to reliably correlate them to the "nenfri". From the morphological description of the profile the following evidences emerged: deep and surface diffused fine roots (1 mm) , sometimes designating a diffuse carbonic veil (Fig. 4a); sporadic roots 1.0-1.5 cm wide, in the deep layers with shape similar to rhizome (Fig. 4b); a polyhedric angular and columnar structure (Fig 4 c), the presence of nodules whose dimensions range from 1 to 10 mm suggesting the incorporation of pyroclastic material into a hydromorphic environment at the time of the eruptions (Fig. 4 d).
The sedimentation areas identified in the Sermugnano area are swamp, tin or ripening environment. The physico-chemical characteristics of the paleosol analyzed (Tables 1-3) suggest pedogenic alteration of rock substrates as incipient weathering and a paleo-marsh environment with arid paleoclimate due to the high saline concentration, especially in the deep horizons (5 and 6).

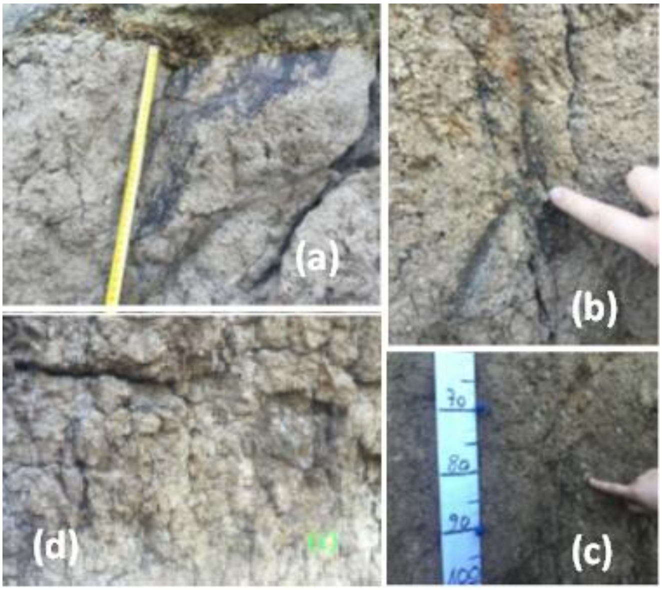

Figure 4
Morphological details:
(a) surface diffused fine roots (1 mm);
(b) sporadic roots (1.0-1.5 cm wide) in deep horizons, with shape like rhizome;
(c) presence of nodules from 1 to 10 mm;
(d) polyhedric angular and columnar structure

Table 1. *Physico-chemical properties of paleosol*

Hori-zons	Depth	TOC	TN	pH		CSC	$CaCO_3$	EC	ESP	Sand	Silt	Clay
	cm	g kg^{-1}		H_2O	KCl	$Cmol_{(+)}kg^{-1}$	%	dS/m	%		%	
1	0-30	1.0	0.3	7.5	7.0	32	5	1.6	12	28.5	40.2	31.3
2	30-60	1.0	0.3	7.2	6.8	30	2	6.0	12	17.6	66.5	15.9
3	60-70	0.7	0.3	7.1	6.6	28	2	6.6	8	33.9	55.1	11.0
4	70-90	0.8	0.3	7.2	6.6	24	2	7.5	11	35.1	51.4	13.5
5	90-110	1.1	0.3	7.1	6.9	25	4	11.0	18	38.4	49.3	12.3
6	110-150	1.7	0.4	7.1	7.0	26	1	16.7	23	15.8	66.6	17.6
7	150-170	1.7	0.3	7.5	7.1	27	tr.	2.4	6	17.6	60.3	22.1
8	170-200	0.1	0.1	7.2	7.0	22	tr.	1.1	4	37.1	49.4	13.5

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Table 2. *Total elements content in paleosol.*

Hori -zons	Depth cm	Si	Al	Fe	Mn	K	Mg	Na	Ca	S
		g kg^{-1}								
1	0-30	0.106	52.5	41.5	---	8.8	3.1	2.3	11.2	0.7
2	30-60	0.069	78.9	55.3	0.3	11.3	3.7	3.1	14.1	1.6
3	60-70	0.043	60.7	44.6	0.4	8.3	3.2	2.1	10.8	1.5
4	70-90	0.075	59.0	43.1	0.2	7.7	3.5	0.6	7.6	1.4
5	90-110	0.344	63.6	50.4	0.3	8.7	3.7	0.8	7.4	1.4
6	110-150	0.042	85.3	52.4	0.3	8.6	3.9	1.2	8.0	0.8
7	150-170	0.060	103.6	38.3	0.1	7.0	2.2	1.1	6.1	1.6
8	170-200	0,099	98.2	37.4	0.1	6.7	1.6	0.4	6.4	0.5

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Table 3. *Content of elements extracted in ammonium oxalate acid* (o), *sodium pyrophosphate* (p) *and solubles* (s).

Hori -zons	Depth cm	Si (o)	Al (o)	Fe (o)	Mn (o)	Si (p)	Al (p)	Fe (p)	Mn (p)	F (s)	Cl (s)	NO_3 (s)	SO_4 (s)
		mg kg^{-1}											
1	0-30	70	159	78	14	25	31	25	4	80	761	487	5033
2	30-60	34	86	35	10	77	100	81	7	26	2411	393	481
3	60-70	14	133	73	23	18	75	40	6	13	2982	333	613
4	70-90	25	125	93	14	60	38	36	4	12	1894	241	914
5	90-110	147	107	164	24	56	33	31	2	12	4835	347	487
6	110-150	36	141	140	3	7	103	90	2	15	9115	396	103
7	150-170	47	159	96	6	8	121	14	1	23	1257	100	37
8	170-200	14	95	57	6	76	32	7	1	35	207	---	0

The significant decrease in organic carbon and of the biochemical properties in surface horizons compared to the deep ones suggested the "baking" effect of the pyroclastic particles on the surface of the paleosol (horizons 1-4) which generated a loss of organic matter and of biologically active forms (Fig. 5). In addition, despite the low content of organic matter, a detectable biomass microbial content was observed in both horizons (Fig. 6). In this context, it would be interesting to deepen the study from the microbiological point of view to gain information on the structure of the microbial community.

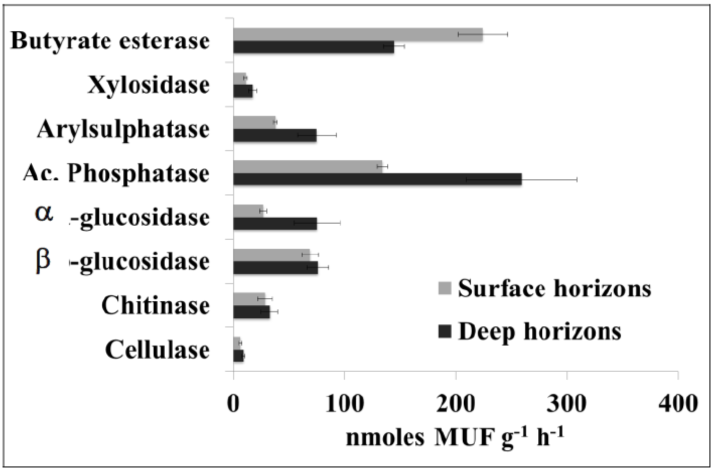

Figure 5
Enzymatic activities in the surface and deep horizons of the paleosol. Butyrate esterase values are expressed in 10^{-1}.

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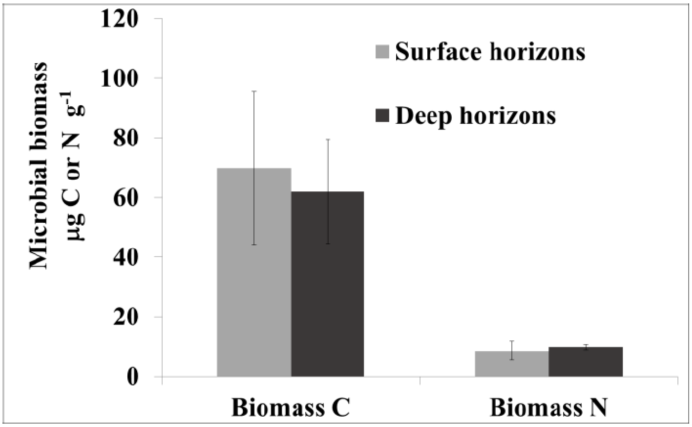

Figure 6
Microbial biomass carbon and nitrogen content in the surface and deep horizons of the paleosol..

Conclusions

The identification and preliminary study of the paleosol, in the particular landscape that characterizes the area of Civita di Bagnoregio, lay the basis for knowing the characteristics and dynamics of the environment in the period prior to the eruptions of the "nenfri" of the Paleovulsini complex. The study will therefore continue through chemical and mineralogical, as well as microbiological analyzes, to be carried out also in other profiles in the same area with the same morphological characteristics.

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