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THE SOILS OF THE PORTOFINO PROMONTORY (NW ITALY): DISTRIBUTION, GENESIS AND PALAEOENVIRONMENTAL IMPLICATIONS

Abstract: Rellini I., Olivari S., Scopesi C. & Firpo M., *The Soils of the Portofino Promontory (NW Italy): distribution, genesis and paleoenvironmental implications. (IT ISSN 0391-9838, 2017).*

The coverage of detailed soil maps is commonly limited in Italy, and the available regional soil inventories are not adequate for local land planning strategies. The aim of this research is to map the soil units in Portofino Natural Park using a Geographical Information System (GIS) approach. Soil micromorphology is used in conjunction with routine laboratory analyses to study several representative benchmark profiles in order to determine their genesis and to assess their palaeoclimatic significance. The spatial distribution and variability of the most extensive soil types were analysed using a GIS approach and were plotted in a 1:10,000-scale soil map with a descriptive legend. We identified six Reference Soil Groups: Cambisol, Regosol, Leptosol, Luvisol, Acrisol, and Umbrisol. The GIS database was then used to produce three derived maps: soil erodibility factor, spatial distribution of soil organic carbon (SOC) and Hydrologic Soil Groups. Deep and highly weathered soils were identified on an ancient erosional surface. These soils are relict palaeosols: they were generated through long-term pedogenesis but are no longer affected by active processes. The polygenetic development of these palaeosols was highlighted by micromorphological studies showing relict features that reflect climate conditions typical of past interglacial periods, which were warmer and more humid than today. (IT ISSN 0391-9839, 2017).

Key Words: Soil mapping, Palaeosols, Palaeosurface, Micromorphology, Organic carbon, Soil erodibility.

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Riassunto: Rellini I., Olivari S., Scopesi C. & Firpo M., *I suoli del Promontorio di Portofino (NW Italia): distribuzione, genesi e implicazioni paleoambientali. (IT ISSN 0391-9838, 2017).*

In Italia, generalmente, gli studi pedologici e le relative carte di distribuzione dei suoli non raggiungono il dettaglio applicativo necessario per la pianificazione e la gestione del territorio, se non limitatamente a corredo di singoli interventi o di specifici progetti esecutivi.

L'indagine complessiva e dettagliata dei suoli presenti nei circa 1300 ettari dell'intero territorio del Parco naturale regionale di Portofino, condotta secondo il rilevamento pedologico tradizionale, supportato dai Sistemi Informativi Geografici (GIS) e dalle analisi micromorfologiche, ha consentito l'elaborazione di una carta delle unità di suolo individuate e descritte, che fornisce nuove conoscenze scientifiche e indirizzi d'uso del territorio.

La variabilità e la distribuzione spaziale dei tipi di suolo è stata rappresentata su carta tecnica regionale a scala 1:10.000, completa di legenda. Sono stati individuati 6 gruppi pedologici della World Reference Base for Soil Resources: Cambisol, Regosol, Leptosol, Luvisol, Acrisol, and Umbrisol. Il database del GIS ha consentito l'elaborazione di più carte derivate: la carta dell'erodibilità dei suoli, la carta della distribuzione del carbonio organico, la carta dei gruppi idrologici. Infine, sono stati individuati dei suoli relitti fortemente alterati, evoluti su un'antica superficie di erosione, recanti peculiari figure pedologiche. Le evidenze micromorfologiche suggeriscono un'origine poligenetica dei suoli, interessati da diversi processi sovrapposti, riconducibili a condizioni climatiche più calde ed umide delle attuali tipiche dei passati periodi interglaciali. (IT ISSN 0391-9839, 2017).

Termini Chiave: Cartografia pedologica, Paleosuoli, Paleosuperficie, Micromorfologia, Carbonio Organico, Erodibilità del suolo.

INTRODUCTION

The mapping of soils is one of the most challenging and thought-provoking aspects of the soil science discipline. The process of developing a soil map forces one to understand the fundamentals of the soils, including how they formed, how they occur across the landscape, and how they might respond to use and management (Hartemink & *alii*, 2012). Approximately two-thirds of countries around the world are mapped at a 1:1 million scale or larger, but more than two-thirds of the total land area has yet to be mapped at even the 1:1 million scale (Nachtergaele & Van Ranst, 2003). Great differences in the status of mapped area exist among countries (in both extent and scale), but the national coverage of exploratory soil maps (>1:250,000) is generally higher in developed countries. The coverage of soil maps, especially those of sufficient detail, is usually limited, and the cost of extending this coverage is high (McKenzie & *alii*, 2000).

At present, the only informative soil maps of Liguria in Northern Italy include the following: a) soil regions at a scale of 1:5,000,000, b) soil sub-regions at a scale of 1,000,000 and c) soil systems at a scale of 1:500,000. The soil information was collected and harmonized from different sources (Costantini & *alii*, 2004; Costantini & Dazzi, 2013). The scale of these maps is not adequate for local land planning strategies, but they are useful tools for soil correlation at the national level. Moreover, a large amount of soil data, mostly stored in documents and not always freely available, is scattered among public offices.

The aims of this research are to (a) map soil units using conventional soil surveys, laboratory analyses and a GIS approach in Portofino Natural Park, a typical natural coastal area characterized by a mosaic of small rural settlements and different vegetation types; (b) compare the physical and chemical soil properties to assess the suitability of the soils for most types of field crops, the effects of erosion and hydrological processes, and the spatial distributions of soil organic carbon (SOC) fractions to provide information and tools for effective decision making and land use management/planning to the natural park administration. Soil erosion is the most widespread form of soil degradation in many Italian soil regions (Costantini & Lorenzetti, 2013). SOC plays an important role in the overall C cycle, and even small changes in the SOC stock can influence the greenhouse gas concentrations in the atmosphere (Breuning-Madsen & *alii,* 2009; Brevick, 2012). For this reason, the Kyoto Protocol accounts for this important element in the management of greenhouse gas emissions (Ruiz Sinoga & *alii,* 2011). An additional goal is to c) discuss the soil processes of the different soil groups in order to explain their genesis and assess their palaeoclimatic significance in the framework of the Quaternary climatic fluctuations in the Ligurian region.

The Quaternary history of this area of Liguria is almost unknown, but the pedogenetic bodies may represent a very useful tool for reconstructing the past environments due to their sensitivity to ecosystems changes, as discussed by Rellini & *alii* (2015, 2014, 2007) for this area. Previous events affected the soil in different ways, and most of the transformation was recorded at the microscopic scale. Consequently, soil micromorphology is used in conjunction with routine laboratory analyses to study several representative palaeosols.

STUDY AREA

The Portofino Promontory lies in the Eastern Ligurian Riviera in the north-western part of Italy, between latitudes 44°20'47.897"N - 44°17'52.549"N and longitudes 9°9'18.457"E - 9°13'9.585"E. The promontory extends approximately 3 km out into the sea, interrupting the otherwise even coastline. The promontory has an area of approximately 18 km^2. The elevation of the area ranges between 0 and 600 m a.s.l. (fig. 1a), and the highest peak (610 m) is Monte di Portofino.

The bedrock is dominated by sedimentary rocks, which are known in the regional geological literature as the Cretaceous "M.te Antola flysch" and the Oligocene "Conglomerate of Portofino" (fig. 1c). The flysch is composed of marly limestone layers ranging in thickness from decimetres to metres. The marly limestones are intercalated with blackish grey layers of clayey shales with thicknesses in the centimetre-decimetre range. Alternating layers of calcarenites and sandstones are present but less common (Marini, 1981). The conglomerate consists mostly of clasts of marly limestone, sandy limestone, and sandstone, with less common clasts of ophiolitic rocks, gneisses and granites. The matrix is sandy and contains calcitic cement (Giammarino & *alii*, 1969).

The lithological characteristics and the morphology of the high-gradient slopes, which contain steep narrow rocky valleys (fig. 1b), are conducive to instability phenomena, characterized by landslides with complex kinematics and other types of mass movement (rock falls, rock slides, debris flows, etc.). Additionally, the undercutting produced by the continuous action of waves is responsible for the presence of high active cliffs along large stretches of the coastal sector (Brandolini & *alii*, 2007).

The orographic and geologic structure of the promontory is responsible for creating different vegetation zones (fig. 1d) due to the influences of exposure, slope and elevation (Girani & Olivari, 1986). This natural variability therefore results in the simultaneous presence, sometimes within a distance of a few tens of metres, of species and plants that are typical of both cold-temperate environments (mainland) and Mediterranean environments. The summit areas and most high-elevation areas are characterized by woods. In fact, mesophyllic mixed forests (*Ostrya carpinifolia, Fraxinus ornus, Quercus pubescens, Quercus ilex, Castanea sativa*, etc.) are present on the uppermost slopes or north-facing exposures and were historically exploited for timber (Battola, 2008). The maximum human pressure occurred at the end of the 1800s due to the demand for raw materials needed to meet the various requirements of an economic system based primarily on agricultural areas. This agriculture occurred along terraced bands supported by stone walls extending along the slopes of the promontory. These terraces were built up to the point where the slopes became too steep and were primarily located along the lowest and intermediate parts of the northern, eastern and western sides. Mediterranean maquis prevails on the steep slopes exposed to the south and tends to evolve naturally towards woody *Quercus ilex* communities if exposed to forest fires. Broad-leaved forests dominate the close small valleys.

The region is located within the Mediterranean humid macroclimate and features hot summers, temperate winters

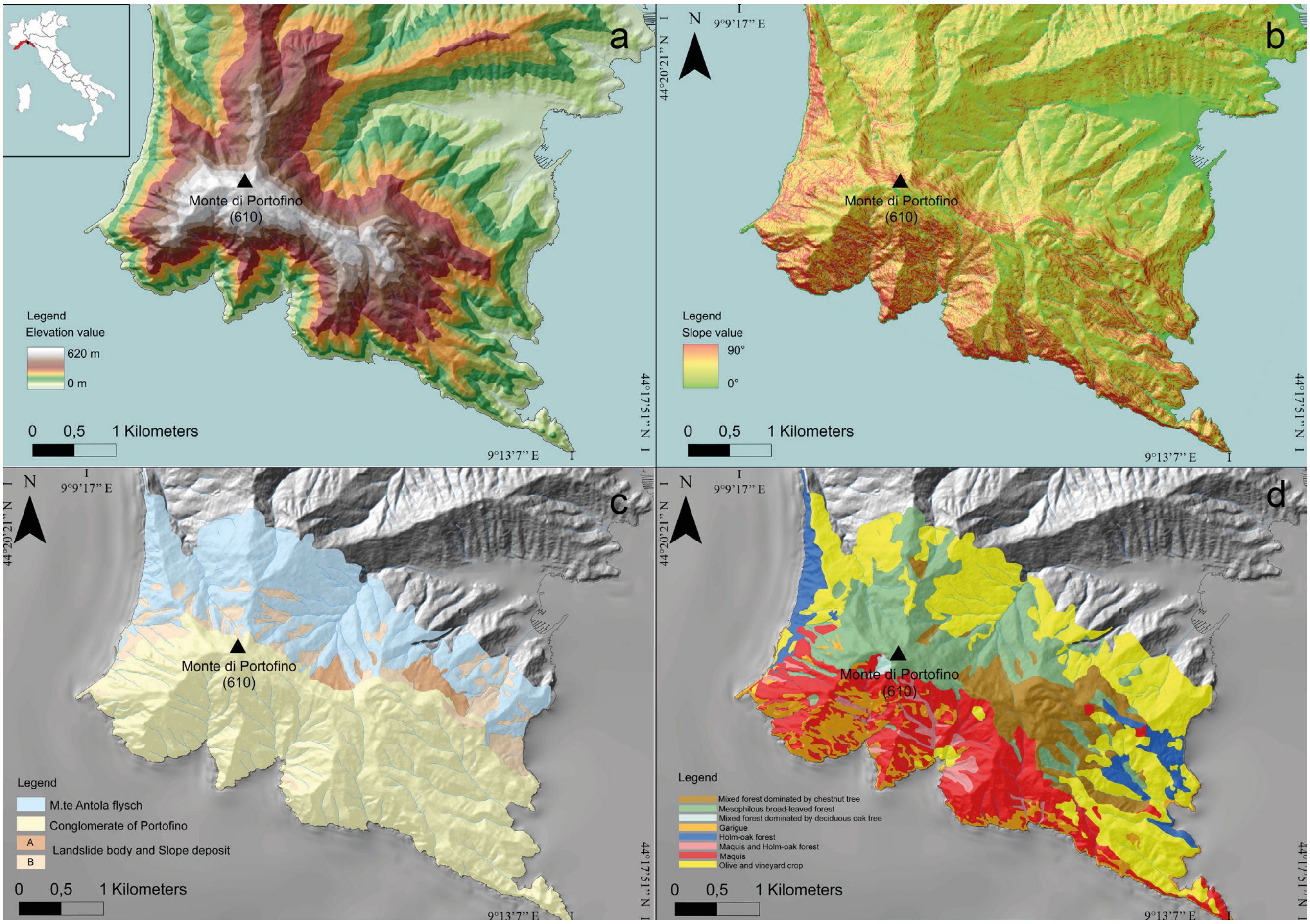

FIG. 1 - Study area: a) digital elevation model; b) slope map; c) geological map. A - landslides bodies and slope deposits constituted of pre-weathered soil material; B - landslides bodies and slope deposits; d) land use types.

and long periods of insolation, although factors such as elevation, exposure, air humidity and vegetation cover create different topoclimates (Girani & Olivari, 1986).

Rainfall is highest in autumn and lowest in summer, with mean annual rainfall ranging between 900 and 1300 mm, depending on the orographic features. The mean annual temperature is 12-13°C (Faccini & *alii*, 2005). The soil moisture regime is udic (Costantini & Dazzi, 2013), with a thermic soil temperature regime, according to Soil Taxonomy (USDA, 2006).

This costal sector in Liguria represents a region of great environmental value and has been under the protection of Portofino Natural Park since 1935 (Law 1251/1935). The seaward area became a marine reserve in 2001. The entire study area is approximately 1250 ha and lies within the limits of three municipalities: Portofino, Camogli, and Santa Margherita Ligure (see map). The purpose of the Portofino Natural Park is to protect and preserve the natural landscape.

MATERIALS AND METHODS

Soil Mapping

The map in this study was developed following a strategy based on the concept of soil formation factors coupled with soil-landscape relationships (Hudson, 1992) and using a GIS approach. In these terms, the local patterns of topography or relief, parent material, and time, along with their relationships to vegetation and microclimate, can be used to predict the types of soils in small areas (Soil Survey Division Staff, 1993). The GIS approach provides a powerful tool for the integration of large and complex databases and models and is thought to improve the process of soil mapping. ArcGIS 9.2 Desktop (ESRI, Redmond, USA) was used to process 5-m-resolution digital elevation model (DEM) data. The DEM was based on an interpolation of contour lines from a 1:5,000 topographic map (Carta Tecnica Regionale Ligure, 2007) using a thin plate spline algorithm proposed by Hutchinson (1996). The DEM was preprocessed with low-pass filtering to extract artefacts and errors, such as local noise and terraces (Vorpahl & *alii*, 2012), using ARCGIS 9.2 (ESRI, 2004). The DEM was then hydrologically corrected to eliminate sinks using the algorithm proposed by Planchon and Darboux (2001). Then, derived attributes, such as slope gradient and wetness index, were analysed.

To create the first draft of the Map Units (MUs), we superimposed the topographic information layer derived from the DEM and all the layers related to the accessory information traditionally collected in soil surveys and now available in digital form (such as vegetation patterns, geomorphology, geology, and land use).

The used data are as follows:

- A geological and geomorphological map of the Portofino Promontory at a scale of 1:10,000, which was created in 2008 by the Regional Project (De Stefanis & *alii*, 1983). In this map, both bedrock and surficial Quaternary deposits are distinguished.
- A vegetation map at a scale of 1:5,000, which was drafted and digitalized by the authors.
- Orthophotos captured during several air surveys at different times and at different spatial resolutions (tab. 2). Each orthophoto mosaic is georeferenced according to the WGS84 (EPSG code: 32632) datum and UTM projection system.

After linking the soil information to the first draft of the MUs, the second draft of the MUs was produced. Thus, the spatial distribution and variability of the most extensive soil types were reproduced in GIS and presented in a soil map at a scale of 1:10,000, with a descriptive MU legend based on World Reference Base (WRB) classification. The modern and international classification system of the WRB (FAO, 2006) was the natural choice when drafting the map. A two-tier system was used for the qualifier level, i.e., prefix and suffix, which are the formative elements for second-level WRB classification. The WRB system is well suited to our objectives and guarantees the reproducibility and longevity of our interpretations. The MUs used in the soil map are soil consociations or associations. The consociations represent areas dominated by a soil type. In accordance with the share of its distribution in a given MU, a soil is defined as dominant when it covers more than 85% of an MU. A soil association is defined by proportions of less than 65% within an MU (USDA, 1993).

Therefore, a map unit can contain one or more soil typological units (STUs) characterized by significant differences in analytical aspects and properties important for management, such as particle size, depth, reaction and organic carbon content. STUs are named after the location where they were first identified. Finally, the soils are also grouped into Land Capability classes (LCCs, Klingebiel & Montgomery, 1961) to provide a tool to assess the potential of a soil to support a range of sustainable land uses and land management practices. The LCCs were divided into subclasses (represented by a suffix and lower-case letters) according to the major conservation problem: erosion (e), excess water (w) and root-zone limitations (s).

Soil Survey

The soil survey of the 18 km^2 study area involved digging 67 pits. Each of the 67 reference pits was described in terms of morphological features and was sampled. The accurate and reliable descriptions and analytical results enabled the full characterization of all the soil horizons to a maximum depth of 125 cm (Schoeneberger & *alii*, 2012). Complete soil analyses were carried out for each horizon in the pits (see below).

A sufficient number of samples were collected via auguring to increase the sampling density in order to define the limits between units and to meet the recommendations for a map published at a scale of 1:10,000 (Avery, 1987). The auguring locations were chosen as the compilation of the soil map progressed. Moreover, soil data (point data and map data) stored in archived records were also incorporated (Olivari, 1981). For this project, a database created by Consiglio per la Ricerca e la Sperimentazione in Agricoltura, (CNCP 3.0; Costantini, 2007) was used to compile, view and export data from soil surveys.

Laboratory soil analyses

The laboratory soil analyses were performed by the Regional Soil Analysis Laboratory in Sarzana (Spezia, Liguria) (ISO 9001 certified). For each soil sample from each horizon, the following routine laboratory procedures and analyses were performed according to the Ministero delle Politiche Agricole e Forestali (2000): the soil samples were air dried; particle size distribution analysis of the coarse fraction (>50 µm) was conducted via wet sieving; the composition of the fine fraction (<50 µm) was determined via the pipette procedure after dispersion of the sample with sodium hexametaphosphate, $(NaPO_3)_6$; the pH was measured by the potentiometric method in a 1:2.5 soil:water suspension; the total carbonate content was determined using the Dietrich Früling calcimeter; the active carbonate content was determined with ammonium oxalate; the total organic C was determined using an elemental analyser based on the Dumas methods (1831); the cation exchange capacity (CEC) and exchangeable bases were determined with $BaCl_2$-triethanolamine at a pH of 8.2; and the concentrations of extracted chemical elements were determined via flame atomic absorption spectrometry (FAAS). To interpret laboratory analytical results, the description classes of the agronomic report, obtained by CNCP 3.0 software (Costantini, 2007), were considered.

Thin sections (100x60 mm) were prepared from undisturbed samples impregnated with polystyrene diluted with acetone under vacuum after air drying (Benyarku & Stoops, 2005) and were observed using a polarizing microscope. The thin sections were described using the terms and methods of Stoops (2003). The interpretation of micromorphological features was performed according to Stoops & *alii* (2010). The redness rating (R.R.) index was calculated on the basis of the matrix colour using Munsell notation (Torrent & *alii,* 1980).

SOC Calculation

The total SOC was calculated from organic carbon (OC) concentrations using the following formula (Garlato & *alii,* 2009):

SOC tot = $\sum$ (OC*Bulk Density*depth*(1-frag)*10) horizon

The OC concentration was analysed using an elemental analyser in compliance with the proposed Italian methods (Ministero delle Politiche Agricole e Forestali, 2000). The bulk density was obtained differently for the organic and mineral horizons. For the mineral soil, we used the equations of Saxton & *alii* (1986) to calculate the bulk density from the texture, whereas for the organic horizons, we used the Hollis pedofunction (Hollis & *alii*, 1989). We calculated the OC concentration of each horizon in each profile, and the total profile SOC is the sum of the SOC in each horizon. Because the OC concentration is representative of each soil, its distribution was calculated by associating it with each cartographic unit. In other words, the SOC value of the benchmark profile was used for each MU. For soil associations, the SOC value was calculated based on the weighted average of the profiles.

K-factor calculation

The soil erodibility factor (K-factor) refers to the average long-term soil response to the erosive power of rainfall and runoff and is considered to be the rate of soil loss per unit of rainfall for a specific soil (Alexakis & *alii*, 2013). In this study, we calculated the K-factor values for the topsoils (soil erodibility is a characteristic strictly related to the surface horizons affected by water erosion) based on the soil sample analyses using the Wischmeier & Smith (1978) formula:

$$K = [2.1 * 10 - 4(12 - OM) * 1.14M + 3.25(s - 2) + 2.5 * (p - 3)] / 100 * 0.137$$

where OM is the percentage of organic matter in the surface horizon (equal to 4 in cases where the OM is greater than 4%); M is given by the textural equation:

$$M= (\% \text{ sand} + \% \text{ silt}) * (100 - \% \text{ clay});$$

and s and p are the soil structure class and soil permeability class, respectively.

The distribution of K-factor values was determined by associating a representative value (benchmark profile) with each cartographic unit. For soil associations, the K-factor value was calculated based on the weighted average of the profiles.

Hydrologic Soil Groups

The Natural Resource Conservation Service classifies soils into four Hydrologic Soil Groups based on runoff potential: A, B, C and D. Group A generally has the lowest runoff potential, whereas group D generally has the greatest runoff potential.

Based on the Soil Survey Division Staff classification (USDA, 1993), we assigned each soil MU a Hydrologic Soil Group. We took into account the soil proprieties of the reference pit of each mapped soil unit and considered the texture, compaction (bulk density), soil structure strength, clay mineralogy and organic matter content. Finally, we used standard tables to relate the saturated hydraulic conductivity (Ksat) to the Hydrologic Soil Group.

RESULTS

Soil type mapping and identification

The map showing the spatial distribution of the different soil units across the Portofino Promontory is presented in the appendix. We defined 27 MUs. The benchmark profile of each STU is briefly described in the legend, and the physical and chemical properties of the main horizons are presented in tables 1, 2 and 3. We identified six Reference Soil Groups (RSGs) among the 67 soil profiles, i.e., Cambisol, Regosol, Leptosol, Luvisol, Acrisol, and Umbrisol, with detailed descriptions based on the WRB classification (FAO, 2006).

Cambisols - Cambisols include soils with at least incipient subsurface soil formation. They are characterized by moderate weathering of the parent material, early stages of horizon differentiation and evident changes in soil structure, colour and clay content.

Cambisols are the most common soils in Italy and are the most extensive RSG in the study area (40%). Cambisols are the dominant soils on most of the slopes, both on conglomerate and limestone parent materials, but they are also found on colluvial residual deposits, typically under forest. These soils are found in 12 MUs and occur in association with Regosols or Leptosols on very steep slopes. They are often moderately deep (50-100 cm) and differ in the type of reaction (tab. 1). The Cambisols on upper slopes with steep gradients under chestnut forest (MU 9 - MU 6) and on landslide material composed of pre-weathered soil material (MU 18) are predominantly acidic and strongly desaturated. In contrast, the Cambisols on intermediate slopes under mesophyllic broad-leaved trees (MU 16) or maquis and holm oak forest (MU 2 - MU 4 - MU 7 - MU 21) are slightly acidic and eutric. They have loam and sandy loam textures and are gravelly when developed on conglomerate bedrock or colluvial deposits. In contrast, they feature a clay loam texture with scarce to common stones when developed on marly limestone bedrock. The nitrogen content is high, ranging from 0.8 to 10 g/kg. The topsoils of this group generally have moderate available P and high CEC values, whereas the subsoils feature low CEC values, except for MU 16 on marly limestone, where the CEC is always high, most likely due to a higher active clay content at depth. The Cambisols display a complete leaching of carbonate, with the exception of some soils (UC 2 - UC 11) that have traces of carbonates (values < 2%)

Regosols - Regosols are very weakly developed soils in unconsolidated material originating from different rocks types and have no diagnostic horizons. Regosols (37%) are a common soil type within the study area. They are found on the terraced slopes and in highly eroded areas in the upper parts of small catchments, often in association with the plots of charcoal burners. This soil type is found in 10 MUs. These soils are often deep and gravelly and exhibit significant textural differences (tab. 2). They feature silty loam, loam, silty clay and sandy loam textures.

TABLE 1 - The major physical and chemical features of the Cambisols profiles (Ol,Of and R horizons not considered).

Horiz.	Depth (cm)	Grain size			pH		$CaCO_3$ (%)	O.C.[d] (%)	N (g/kg)	P (mg/kg)	Cond. [e] (dS/m)	C.E.C.[f] (meq/100 g)	Exchangeable bases (meq/100 g)				B.S.[g] %
		sand	silt	clay	H_2O	KCL							Ca	Mg	K	Na	
M.U. 2 - U.T.S GHIDELLI: Leptic Cambisol Eutric Skeletic																	
A	10-20	56,3	32,9	10,8	6,8	-	1,7	6,2	3,3	99	0,8	32,5	18,9	3,2	0,5	0,5	70,8
Bw_1	20-30	47,9	35,6	16,5	7,4	-	0,9	1,4	1,4	3	0,4	17,9	7,2	1,4	0,3	0,4	51,3
Bw_2	30-50	31,9	40,3	27,8	7,6	-	1,2	0,6	1,1	-	0,4	17,5	7,5	1,2	0,1	0,4	52,6
M.U. 3 - U.T.S. ACQUA VIVA: Haplic Cambisol Eutric																	
A	0-10	46,2	43,6	10,2	5,7	-	-	6,6	4,9	1	0,9	29,8	21,2	5	0,3	0,2	89,7
BE	10-20	45,3	35,7	19	5,3	-	-	0,9	0,8	1	0,2	10,2	3,2	1,5	0,1	0,1	47,5
Bw	20-90	46,8	36,7	16,5	6,9	-	0,9	0,7	0,7	6	0,3	9,1	7,0	2,3	0,1	0,2	100
CB	90+	40,1	42,2	17,7	6,5	-	1,2	0,5	0,7	1	0,2	8,4	4,3	1,5	-	0,2	72
M.U. 4 - U.T.S. PARAGGI: Leptic Cambisol Eutric Skeletic																	
BC	2-35	42,9	43,3	13,8	6,4	4,7	-	1,1	1,1	1	-	12,5	6,9	1,5	0,1	0,2	70,4
M.U. 6 - U.T.S. MONTE CROCI: Haplic Cambisol Epidystric Skeletic																	
A	0-5	48,2	46,2	5,6	6,2	5,3	-	4,8	3,3	5	0,6	23,9	18,7	2,2	0,3	0,1	89,5
BE	5-10	45,5	38,1	16,1	5,4	3,9	-	1,2	1,1	1	0,3	13,6	3,9	0,9	0,1	0,1	37
Bw	10-60	32,5	45,2	22,3	5,5	3,9	-	0,6	0,8	1	0,3	12,5	5,1	0,8	0,1	0,1	48,6
M.U. 7 - U.T.S. MONTE BRANO: Haplic Cambisol Eutric Chromic																	
A	3-15	34,7	51,6	13,7	6,7	-	-	5,6	3,7	21	2,4	100	22,4	2,7	0,4	0,2	100
Bw_1	15-50	29,2	46,8	24	5,5	-	-	0,7	1,7	2	0,4	65,9	5,8	1,3	0,1	0,2	65,9
Bw_2	50-80	31,2	42	26,8	5,7	-	-	0,6	0,8	2	0,3	52,8	6,6	1,2	0,1	0,2	52,8
M.U. 9 - U.T.S. SEMAFORO VECCHIO: Leptic Cambisol Hyperdystric Humic																	
A	0-5	73,1	19,9	7,0	5,6	4,7	-	10,1	10,4	13,7	0,5	28,3	12,7	2,8	0,5	0,2	57,1
AB	5-10	60,5	29,7	9,8	5,5	4,2	-	2,6	2,5	4,1	0,4	12,1	1,9	0,5	0,2	0,1	22,6
Bw	10-70	57,5	32,9	9,6	5,4	4,3	-	1,7	1,4	4,1	0,3	13,1	0,8	0,2	0,2	0,1	9,9

M.U. 10 - U.T.S. COSTA PINETA: Leptic Cambisol Eutric Humic																	
A	0-7	70,4	25,7	3,9	7,3	6,5	1,95	5,2	4,4	4,4	0,6	18,8	17,4	2,2	0,4	0,2	100
Bw_1	7-20	54,7	31,8	13,5	6,8	5,3	0,75	1,9	1,9	1,9	0,1	11,9	6,2	1,5	0,1	0,2	67,1
Bw_2	20-40	46,8	35,8	17,4	6,9	5,3	1,15	1,4	1,5	1,5	0,2	13,1	6,6	2,0	0,3	0,2	70
C_R	40-50	55,3	24,1	20,6	6,2	4,7	-	0,8	1	-	-	14,7	7,2	2,9	0,1	0,3	71,3
M.U. 11 - U.T.S. CERVARA: Leptic Cambisol Hypereutric Endoskeletic																	
Oh	0-5	-	-	-	6,5	6,1	3,9	14,9	9,9	18	1,6	43,9	51,4	4,8	0,9	0,3	100
Bw	5-20	32	38,3	29,7	5,9	4,2	-	1,1	0,5	4	0,4	14	16,8	1,7	0,1	0,3	100
BC	20-75	26,6	37,5	35,9	7,8	6,4	3,4	0,9	0,5	4	0,5	16,1	20,7	1,5	0,2	0,3	100
M.U. 16 - U.T.S. COSTA RAMEZZANA: Leptic Cambisol Humic Hypereutric																	
A	2-6	32	47	21	6,4	-	-	7,1	4,8	14	1,4	35,9	32,6	1,6	0,3	0,2	96,8
Bw_1	6-30	13,7	51,4	34,9	6	-	-	1,1	1,5	2	0,3	27,3	19,4	1,2	0,2	0,2	77,2
Bw_2	30-60	14	50,2	35,8	6,2	-	-	1	1,6	2	0,3	25,7	21,4	1	0,3	0,2	88,7
M.U. 18 - U.T.S. MOREGI: Haplic Cambisol Hyperdystric Escalic																	
A	2-8	38,4	51,1	10,5	4,8	-	-	8,12	5,3	12	1,8	25,1	13,4	2,1	0,3	0,2	63,5
Bw	8-60	26,8	54,8	18,4	4,7	-	-	0,6	2,3	2	0,4	9	1,1	0,3	0,1	0,2	18,6
M.U. 20 - U.T.S. TERRA ROSSA: Haplic Cambisol Eutric Skeletic																	
A	2-10	69,1	25,5	5,4	6,3	5,2	-	3,8	2,4	6	0,5	8,3	6,2	2,5	0,2	0,1	100
AB	10-20	59,2	28,3	12,5	6,2	4,6	-	1,2	0,8	4	0,3	8,4	2,1	1,5	0,1	0,1	44,6
B1	20-60	67.8	24,4	7,8	6,5	4,9	1,7	0,7	0,3	4	0,3	6,1	1,4	1,9	0,1	0,1	56,07
B2	60-100	63,2	26	10,8	6,3	4,8	-	0,5	0,4	3	0,3	7,9	1,5	3,0	0,1	0,1	59,4
M.U. 21 - U.T.S. VALLONE DEI FONTANINI: Epileptic Cambisol Eutric																	
A	2-10	47,8	39,8	12,4	6,8	-	0,9	5,7	6,7	142	0,9	37	41,2	2,9	0,4	0,2	100
Bw_1	10-35	35,6	37,9	26,5	6,4	-	-	0,6	1,1	5	0,3	18,2	14,6	2,2	0,1	0,2	93,9

[d] O.C.: organic carbon; [e] Cond.: electrical conductivity; [f] C.E.C.: cation exchange capacity; [g] B.S.: base saturation

Table 2 - The major physical and chemical features of the Regosols profiles (Ol,Of and R horizons not considered).

Horiz.	Depth (cm)	Grain size			pH		$CaCO_3$ (%)	O.C.[d] (%)	N (g/kg)	P (mg/kg)	Cond. [e] (dS/m)	C.E.C.[f] (meq/100 g)	Exchangeable bases (meq/100 g)				B.S.[g] %
		sand	silt	sand	H_2O	KCL							Ca	Mg	K	Na	
M.U. 27 - U.T.S. ACQUA FREDDA: Leptic Regosol Calcaric Humic																	
Oh	1-2	-	-	-	7	6,6	4,4	23,7	16,9	26	2,1	82,6	54,2	2,8	0,4	0,1	69,6
A	2-10	15,7	47,6	36,7	7,3	6,3	1,5	4,9	4,2	3	0,6	28,6	32,5	2,5	0,5	0,2	100
CB	10-20	15,7	48,1	36,2	7,7	6,4	3,2	2,1	2,9	2	0,6	29,3	35,5	1,4	0,3	0,2	100
C	20-100	23,4	48,1	28,5	8,2	7,2	3,5	1,2	1,8	2	0,5	26,1	31,8	0,8	0,2	0,2	100
M.U. 26 - U.T.S. SOTTO LE GAVE: Colluvic Regosol Calcaric Humic																	
Oh	8-25	-	-	-	7,2	6,9	6,1	17,4	11,1	21	1,7	62,6	78	4,2	0,8	0,4	100
C	25-100	11,7	47,9	40,4	8,1	7,3	6,7	2	1,7	6	0,7	21,9	32,7	1,8	0,4	0,4	100
M.U. 25 - U.T.S. FORNELLI: Haplic Regosol Calcaric Humic																	
A	1-10	62,7	29,7	7,6	7,7	7,1	6,1	8,4	8,7	19	0,8	30	15	1,2	0,6	0,1	56,5
AC	10-60	53,3	37,8	8,9	8,1	7,4	16,3	3,3	3,8	6	0,6	20,4	42	0,3	0,3	0,1	100
M.U. 24 - U.T.S. NOZAREGO: Endogleyic Colluvic Regosol Calcaric Skeletic																	
A	0-3	35,7	46	18,3	8	7,4	9,2	2,1	3,4	8	0,6	24,3	32,8	1,2	0,5	0,1	100
AC	3-35	29,2	46,9	23,9	8,2	7,3	11	3,1	2,1	5	0,5	19,5	29,5	0,5	0,3	0,1	100
M.U. 23 - U.T.S. GASSETTA: Leptic Regosol Orthodystric Skeletic																	
A	0-10	80	16,5	3,5	5,6	4,8	-	4,8	4	7	0,5	19,1	9	2,1	0,1	0,2	59,5
CB1	10-30	72,2	22,4	5,4	5,7	4,3	-	1	0,7	4	0,3	11,2	3	1	0,1	0,2	37,8
CB2	30-70	69,2	25,8	5	6,1	4,6	-	0,6	0,8	4	0,3	9	3,2	1,1	-	0,1	50
M.U. 19 - U.T.S. BUSSEO: Haplic Regosol Calcaric Humic																	
A	2-10	52,1	32,7	15,2	6,3	4,8	-	2,1	2,4	2	0,2	15,9	12,1	2,2	0,3	0,2	93,1
AC	10-35	31,8	32	36,2	5,6	3,8	-	0,6	0,7	1	0,2	14,3	5,1	1,2	0,1	0,2	46,1
C	35-70	40,5	40,4	19,1	5,5	3,8	-	0,5	0,8	1	0,1	11,2	2,7	0,8	-	0,1	32
M.U. 14 - U.T.S. DOLCINA: Leptic Regosol Calcaric Humic																	
A	2-10	29,8	49,9	20,3	7,2	6,6	3,2	6	4,2	17	0,8	25,6	24,5	2,2	0,6	0,2	100
AC	10-28	19	56,3	24,7	7,6	6,4	2,8	1,8	2	5	0,4	25,9	23,3	0,8	0,2	0,1	94,1
M.U. 12 - U.T.S. PORTOFINO: Colluvic Regosol Calcaric Humic																	
Ap	0-10	31,6	45,3	23,1	6,3	-	-	2,9	2,8	1	0,5	20	19,1	2,7	0,2	0,3	100
CB	10-100	25,8	40,6	33,6	6,7	-	2,1	1,7	1,7	1	0,4	19,5	15,3	2,7	0,1	0,5	95,4
M.U. 4 - U.T.S. PARAGGI 1: Colluvic Regosol Calcaric Skeletic																	
A	3-15	58,1	30,6	11,3	5,4	5,1	-	5,6	6,1	18	1,7	29,6	28,2	3,4	0,8	0,3	100
C	15-100	29,9	38,9	31,2	7,2	5,8	2,6	0,4	0,5	5	0,4	11,6	10,1	1,8	0,5	0,2	100
M.U. 1 - U.T.S. BATTERIE: Leptic Regosol Calcaric Humic																	
A	2-10	65,5	28,7	5,8	6,6	5,8	2,4	7,7	3,9	7	0,6	21,6	14,7	1,9	0,6	0,2	80,2
AB	10-60	54,4	34,2	11,4	7,3	6,2	2	2,9	1,9	4	0,4	16,9	11,8	0,9	0,4	0,2	77,5

[d] O.C.: organic carbon; [e] Cond.: electrical conductivity; [f] C.E.C.: cation exchange capacity; [g] B.S.: base saturation

Table 3 - The major physical and chemical features of the Leptosols, Luvisols and Acrisols profiles (Ol,Of and R horizons not considered).

Horiz.	Depth (cm)	Grain size			pH		$CaCO_3$ (%)	O.C.[d] (%)	N (g/kg)	P (mg/kg)	Cond. [e] (dS/m)	C.E.C.[f] (meq/100 g)	Exchangeable bases (meq/100 g)				B.S.[g] %
		sand	silt	clay	H_2O	KCL							Ca	Mg	K	Na	
M.U. 26 - U.T.S. PEGO: Haplic Leptosol Calcaric Humic																	
A	5-15	63,5	18,2	18,3	7,5	7,1	5,2	11,5	13	22	1,2	53,9	70,9	3,3	0,8	0,2	100
C	15-60	27,9	49	23,1	8,1	-	7,4	4,2	5,4	7	0,6	23,1	28,9	1,1	0,4	0,2	100
M.U. 15 - U.T.S. GAGGINI: Haplic Leptosol Calcaric																	
A	5-10	43,8	41,3	14,9	7,1	6,5	2,9	10,1	7,2	11	0,9	34,3	37	2,6	0,4	0,2	100
C	10-20	22,5	44,4	33,1	7,5	6,1	2,1	1,1	1,7	2	0,3	24,8	27,4	1,6	0,1	0,3	100
M.U. 21 - U.T.S. SAN ROCCO: Haplic Leptosol Eutric Skeletic																	
Oh	2-7	-	-	-	6,8	-	4,1	11,5	8,9	17	1,5	64,5	23	2,3	0,3	0,2	39,9
CB	7-20	23,8	39,8	36,4	6,8	-	3,1	1,3	1,6	7	0,4	28,7	22,5	2,3	0,3	0,2	88,3
M.U. 1 - U.T.S. BATTERIE 1: Hyperskeletic Leptosol Humic Calcaric																	
A	2-7	52	37,1	10,9	7,6	6,9	2,5	3,6	5,4	4	0,7	27	32,4	1,5	0,3	0,2	100
AC	7-20	48,7	41,4	9,9	7,9	7,1	4,7	3,3	4,2	4	0,7	25,4	32,9	1,4	0,3	0,1	100
M.U. 7 - U.T.S. MONTE BRANO: Haplic Leptosol Eutric Skeletic																	
A	2-7	57,5	35,9	6,6	6,2	5,9	-	13,9	8,9	6	-	39,2	31,2	3,1	1,1	0,2	90,8
CB	7-17	34,8	51,2	14	6,6	5,3	1,2	1,3	1,3	7	-	16,5	9,5	0,9	0,2	0,2	66,2
M.U. 21 U.T.S. PIANETTE: Cutanic Endogleic Acrisol Chromic																	
Oh	1-4	-	-	-	4,5	4	-	27,6	13,3	29	1,9	47,7	25,4	4,1	1,1	0,3	65
Bw	4-40	14,3	55,5	30,3	5,1	4	-	0,8	0,5	3	0,3	11,4	2	0,4	0,1	0,1	23,3
Bt	40-80	17,4	44	38,6	5	3,5	-	0,8	0,9	3	0,4	11,6	4,3	1	0,1	0,2	48,8
Cg	80-120	14,1	53	32,9	5,4	3,5	-	0,9	0,8	3	0,3	14,1	6,7	0,9	0,1	0,2	56,4
M.U. 5 - U.T.S. FOGLIACCI: Leptic Luvisol Abruptic Humic																	
A	3-20	55,8	40,8	3,4	6,7	5,9	2,5	3,6	4,5	9	0,7	27,2	23,5	2,6	0,2	0,3	97.7
E	20-30	41,2	48,8	10,4	6,5	5,1	1,1	1,2	2	2	0,1	17,1	9,1	1,3	0,1	0,2	62,4
Bt	30-50	19,7	40,5	39,8	7	-	1,5	0,6	1,4	1	-	27,1	22,6	2,4	0,1	0,4	93,8
M.U. 21 - U.T.S. FONDACO DELLE NOCCIOLE: Cambic Umbrisol Skeletic Chromic																	
A	3-25	42	46,5	11,5	4,7	-	-	8,6	4,2	9	0,4	25,3	6,1	0,8	0,2	0,2	28,4
BC	25-70+	43,1	37,5	19,4	5,3	-	-	0,7	0,8	2	0,3	10,2	2,6	0,6	0,1	0,2	34,4

[d] O.C.: organic carbon; [e] Cond.: electrical conductivity; [f] C.E.C.: cation exchange capacity; [g] B.S.: base saturation

The soils are slightly alkaline and rich in basic components and exhibit signs of secondary carbonate accumulation, as evidenced by the common presence of soft powdery lime, probably due to the dissolution of the limestone parent material or interactions with groundwater, which contains dissolved carbonates. The N content is high, whereas the available P content varies considerably among the different land uses. Very high values were observed in the holm oak forest (MU 4 - MU 26) and in some terraced soils (MU 12 - MU 14 - MU 24), which probably indicates the addition of organic residues or fertilizers. The CEC values range from medium to high. In particular, the soils on parent material consisting of base-poor colluvial deposits (UC 23), consisting mainly of pre-weathered soil material and material partially reworked by humans, show low pH values and CEC values ranging from low to medium. The available P content was found to be medium, whereas the N content is always high.

LEPTOSOLS - Leptosols are very shallow soils with continuous rocks very close to the surface or soils that are extremely gravelly (e.g., on a talus slope). Leptosols are also common (8.0%) in the study area, where they are often found in areas with very steep slopes with severe erosion, which in turn results in further decreases in soil depth in common rock outcrop areas or an increase in stoniness. Some Leptosols are present on stony talus slopes. These types of soils are found in 5 MUs. The Leptosols found in the study area primarily have loam and clay loam textures. The pH varies between neutral and moderately alkaline (tab. 3). The soils are also characterized by incomplete carbonate leaching (calcaric), with a total $CaCO_3$ content that varies from 1 to 7%, and a high base saturation (equal or close to 100%). They have high N and CEC values, mostly due to the higher OC contents in the enclosures. The available P contents of these soils are low to medium, except for the surface horizon sample of the holm oak soil, which has a high P content.

Some Leptosols that were examined but not mapped developed on relicts of stratified deposits that are deeply dissected by erosion in small linear valleys at the base of escarpments (fig. 2). From a palaeoenvironmental perspective, the shape of the fragments, grain size, sedimentary structures (repetition of open-work beds), and the relationships with the different topographic locations suggest that the stratified slope deposits are éboulis *ordonnées* (Tricart & Cailleux, 1967; Francou, 1988). They often contain cementation in the matrix-supported layers and reprecipitated calcite crystals in voids.

LUVISOLS - Luvisols are soils characterized by increasing clay content with depth without marked leaching of base cations (high base saturation at some depth) and by eluviation of the topsoil. Luvisols (3%) are relatively common in 2 MUs and predominantly appear on north-facing scarps of conglomerate on the promontory (MU 5) and on limestones in the lowlands of the terraced slopes (MU 14).

The texture is silty or sandy loam at the surface, with increasing clay content with depth (tab. 3). The soils show low to medium values of $CaCO_3$ and high base saturation (equal or close to 100%). The pH values of the surficial horizons are slightly acidic, while the pH values of the deeper horizons are neutral or moderately alkaline. The CEC values of these soils are the highest within the study area. The soils in this group have medium to high available P, OC and N contents, with very high values in the cultivated soils found in MU 14.

FIG. 2 - Several outcrops of stratified slope deposits are present along the western coast of the promontory. Note the alternation of clast-supported layers and matrix-supported layers. Backpack for scale.

FIG. 3 - View of well-developed coarse angular blocky/prismatic structure in an illuvial horizon ($2Bt_2$) at the transition to the marly limestone parent rock (Cutanic Vertic Luvisol Novic, Hypereutric, MU 14). Hammer for scale.

Moreover, particular attention was paid to the soil features of these cultivated soils (MU 14) in order to obtain information about the nature of palaeoenvironmental changes. Vertic properties are observed at the transition to the marly limestone parent rock (fig. 3). The benchmark profile is located on an old terraced area at the foot of a north-facing slope.

The main morphological, physical and chemical data are reported in tables 4 and 5. The data characterize a truncated and well-structured soil ($2Bt_1$-$2Bt_2$-2C) with a vertic field appearance, including a clayey texture and a well-developed coarse angular blocky/prismatic structure (fig. 3). This soil is buried by weakly pedogenic and reworked deposits (mainly A-AC horizons), with a charcoal layer related to human activity. Notably, an abrupt textural change occurs between the two units. High P and CEC values, low base saturation values and acidic pH values are present in the AO, likely due to long-term continuous tillage and manuring. The very high CEC value in the $2Bt_2$ horizon may be related to the presence of high-activity clay (smectite). The pH is alkaline and can be related to the influence of carbonate.

The soil micromorphological observations generally support the field morphological observations and indicate that the most representative and typical micromorphological features are those of the buried B horizons. At the micromorphological level, it was possible to distinguish a dense and heterogeneous groundmass due to materials of contrasting colour and composition (fig. 4a). Dark aggregates of material from the surface horizon featuring an undifferentiated b-fabric are incorporated into the reddish groundmass with a striated b-fabric, mainly in the lower part of the profile (fig. 4b, $2Bt_2$). Angular and subangular blocky microstructures with large planar voids are observed.

In some cases, scattered yellowish zones in the groundmass and along the planar voids due to weak hydromorphic iron depletionare described. The Bt horizons correspond to the strongest clay accumulation in the soil (tab. 4), resulting from different phases of clay illuviation, with two generations of thick juxtaposed clay coatings and infillings occurring along interpedal fissures (i.e., ped surfaces, fig. 4e). The younger, yellowish-brown generation is characterized by layerless dusty clay mixed with a considerable amount of organic material, while the older reddish generation has a weak orientation, laminated internal fabric and a crescent shape. Moreover, silt/organic coatings often alternate with the laminated reddish clay coatings/infillings (layered) (fig. 4d). The older generation is often deformed or incorporated into the groundmass by shrink and swell processes related to the presence of swelling clay, which also favours the development of various striated b-fabrics and slickensides (fig. 4c). Other relevant features include iron-manganese concretions, intense bleaching and Mn-infilled inter-aggregate cracks.

ACRISOLS - Acrisols are soils that have a higher clay content in the subsoil than in the topsoil and a low base saturation at certain depths due to the humid environment and advanced degree of weathering. Acrisols (5%) are prevalent in the summit areas and are distributed in 2 MUs. They seem to be restricted to a certain combination of relief and deep weathering.

The Acrisols on the Portofino Promontory are moderately acidic (5.0<pH<5.5). They primarily have silty clay loam textures when developed on marly limestone (MU17, tab. 3) and sandy clay loam textures when developed on conglomerate. These soils have high CEC values in the surface horizon but low values at depth (5-15). The exchangeable P contents are low, while the N contents are medium to high.

The MU 8 benchmark profile, which is developed on conglomerate, consists of an AB horizon and a illuvial horizon (Bt) overlying a thick weathered zone of soft rock that retains the geologic structure (i.e., a saprolite, Crt), testifying to the fairly deep geochemical weathering. This soil exhibits abundant and thick clay coatings on the rock fragment surfaces (fig. 5), even at depth, and reddish colours due to Fe-oxide staining.

Particular attention was paid to the soil features of these soils (MU 8) to obtain information on the nature of the palaeoenvironmental changes. The results of the chemical and physical analysis (tables 4 and 5) indicate that the particle-size analysis results are consistent with the field description: the percentage of sand and stones increases with

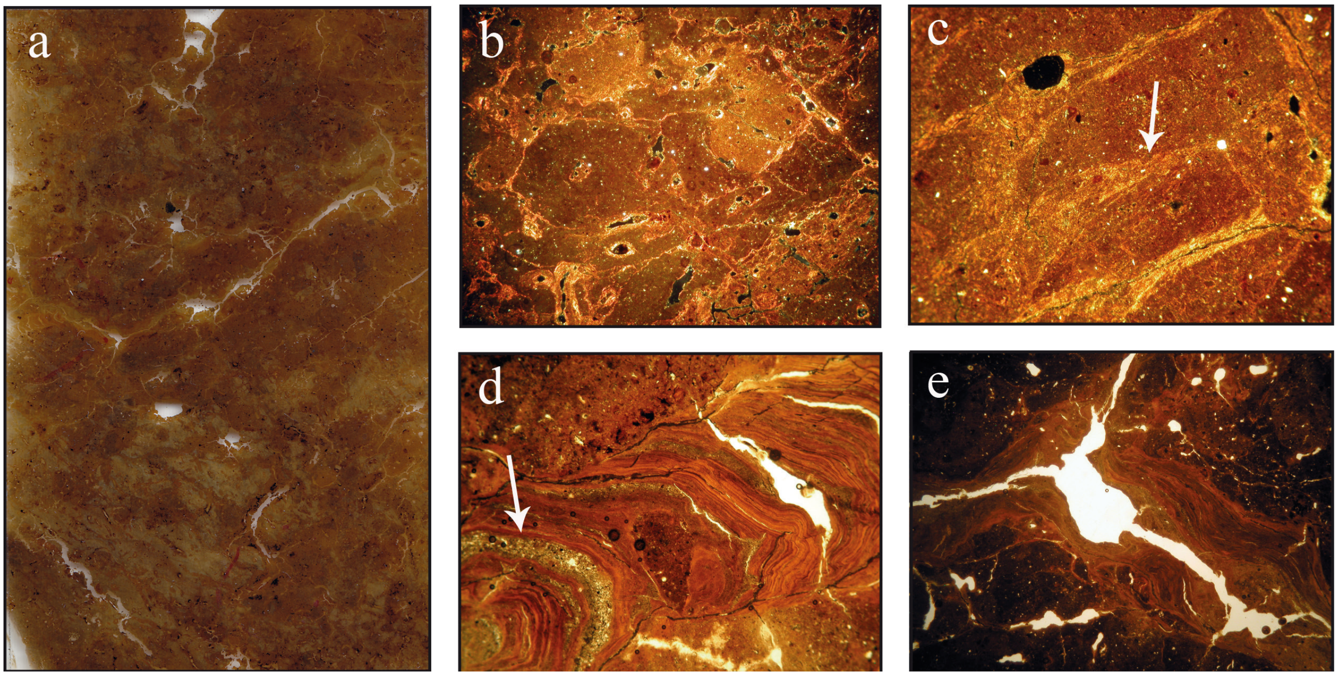

FIG. 4 - a) Flatbed scan of thin section showing the general fabric of a $2Bt_2$ horizon (Cutanic Vertic Luvisol Novic Hypereutric, UM 14) and some micrographs. Note the dense and clayey groundmass with a bleached area and heterogeneous composition. The frame length of the thin section is 5 cm. Photomicrographs: b) heterogeneous groundmass with dark aggregates of material originating from the surface horizon and a strongly developed granostriated b-fabric (the frame length is 8 mm; XPL); c) parallel-striated b-fabric due to presence of clay coatings that are deformed and incorporated into the groundmass (the frame length is 3.1 mm; XPL); d) layered infillings consisting of layers of silt/impure clay (white arrow) alternating with microlaminated pure clay (the frame length is 3.1 mm; PPL); e) juxtaposed yellowish and reddish thick clay coatings (the frame length is 8 mm; PPL).

FIG. 5 - Thick clay coatings on rock fragment surfaces in saprolite (Cutanic Acrisol Hyperdystric Abruptic, MU 8).

depth, reflecting the presence of ancient sandy conglomerate layers. The highest clay content is present in the illuvial horizon (Bt), where clay films exist on the face of peds and rock fragments. The coarse rock fragments in the horizons primarily consist of granitoids, gabbros, quartzites and marbles, which are consistent with the compositional lithofacies (fmB, see fig. 6B) of the conglomerate bedrock (Corsi & *alii*, 2014). As expected for an old soil, the pH values are acidic, and all the horizons are completely leached of carbonates (i.e., decarbonated). Organic carbon is concentrated primary in the surface horizons (O-AB), even when the underlying horizon contains a significant amount (1%). The CEC values significantly decrease from the upper horizons to the deeper horizons and appear to be directly correlated to the organic matter content. The very low values of the CEC in the B horizons support the dominant occurrence of little or no or expandable clays (kaolinite) as a whole. The adsorbing complex is always undersaturated (the base saturation percentage ranges between 14.3 and 38.7%), and the concentrations of exchangeable bases are very low, excluding those of the deep saprolite (Crt). These properties are presumably related to the acidic soil environment and indicate very intense leaching conditions in agreement with the (palaeo)climatic and topographic position.

The results of the micromorphological analysis performed on three horizons (Bt, BCrt, and Crt) allow us to observe some soil features not always recognizable at the field scale.

Among the main micromorphological features identified in the three horizons, the presence of illuvial pedofeatures is the most important. Clay coatings and infillings occur on mineral grains and in pores, and these features are particularly thick in the deep horizons (BCrt and Crt),

Table 4 - The main field features of the benchmark profiles of the soil typological units Monte Pollone (MU 8) and Allega (MU 14). See map photos.

Horiz.	Depth (cm)	Colour [a]	R.R [b]	Grain size			Structure [c]	Stones	Clay coatings
				sand	silt	clay			
UC 8	Cutanic Acrisol (Hyperdystric, Abruptic)								
O	0-3	-		-	-	-	-	(+)	-
AB	3-30	7.5YR 4/4	2.5	40.1	43.0	16.9	mSB	++	-
Bt	30-60	5YR 4/6	7.5	41.4	20.9	37.7	mAB	++	+
BCrt	60-75	2.5YR 4/6	11.25	53.4	16.2	30.4	mAB	+++	++
Crt	75-200	2.5YR 4/6	11.25	60.2	20.8	19	M	+++	+
UC 14	Cutanic Vertic Luvisol (Novic, Hypereutric)								
AO	0-3	10YR 3/2	-	58.7	30.9	10.4	mG	+	-
AC	3-40	10YR 3/3	-	26.6	51.1	22.3	cG	+++	-
2Bt1	40-65	10YR 4/3	-	10	51.1	38.9	cAB	++	+
2Bt2	65-80	10YR 4/6	-	6.7	42.9	50.4	cAB	-	++
2C	80-100	2.5Y 5/2	not sampled					+++	-

[a] Colour: recorded in the dry condition; [b] R.R. = redness rate (*sensu* Torrent et al., 1980); [c] Structure: AB = angular blocky; SB = subangular blocky, M = massive, c = coarse, m = medium; -, (+), +, ++ and +++ indicate increasing abundance of certain soil features: absent, scarce, common, frequent and abundant, respectively.

Table 5 - The main chemical features of the benchmark profiles of the soil typological units Monte Pollone (MU 8) and Allega (MU 14).

Horiz	pH		$CaCO_3$ (%)	O.C.[d] (%)	N (g/kg)	P (mg/kg)	Cond.[e] (dS/m)	C.E.C.[f] meq/100 g)	Exchangeable bases (meq/100 g)				B.S.[g] %
	H_2O	KCL							Ca	Mg	K	Na	
UC 8	Cutanic Acrisol (Hyperdystric, Abruptic)												
O	5.4	4.1	-	26.7	5.6	5	0.4	35.8	11.1	2.1	0.4	0.3	38.7
AB	5.0	3.8	-	6.2	2.2	4	0.35	22.5	2.4	0.5	0.1	0.2	14.3
Bt	5.2	4.0	-	1.0	0.7	3	0.35	15.6	1.4	0.8	0.02	0.2	15.6
BCrt	5.1	4.0	-	0.7	0.4	3	0.35	7.5	1.2	0.7	0.03	0.3	29.6
Crt	5.3	4.1	-	0.2	0.2	5	0.32	7.5	6.4	0.6	0.03	0.2	96.9
UC 14	Cutanic Vertic Luvisol (Novic, Hypereutric)												
AO	6.6	6.0	5.4	12.9	10.6	64.1	1.06	46.8	11.3	2.4	0.1	0.1	29.8
AC	7.8	6.4	1.1	1.5	2.2	4.3	2.2	23.6	18.9	0.7	0.1	0.3	84.7
2Bt1	8.1	6.4	6.3	0.5	0.7	4.3	0.7	13	18.8	7.0	1.5	0.8	100
2Bt2	8.0	6.3	6.8	0.5	0.7	4.3	0.7	31.7	17.3	3.9	0.8	0.8	71.7
2C	not sampled												

[d] O.C.: organic carbon; [e] Cond.: electrical conductivity; [f] C.E.C.: cation exchange capacity; [g] B.S.: base saturation.

where two distinct generations can be clearly observed. The coatings show marked differences in colour, texture, and extinction pattern. In particular, the older fine clay coatings appear laminated and crescentic. They usually show sharp extinction bands between crossed polars (XPL) and are often observed in the pores that cross the rock fragments or on their surfaces (fig. 7b-7c). In contrast, the later clay coatings are not easily recognizable because they are broken and assimilated into the soil matrix. These coatings show a diffuse band of extinction in XPL. More-

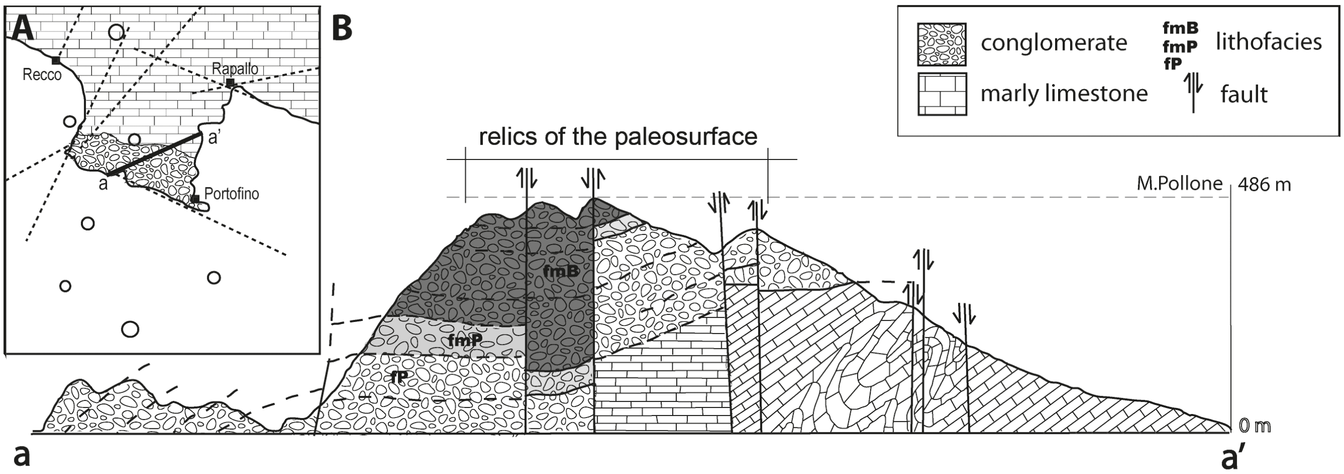

FIG. 6 - A) Geological sketch map of the Portofino Promontory and surrounding areas showing the main tectonic lineation (dashed line), the trace of the geological section and the seismicity map. Some earthquake epicentre positions (circles) are aligned and located either on land or on the continental shelf. B) Geological section passing through the highest elevations of the paleosurface and highlighting the normal faults that dismembered the paleosurface into several parts and the main conglomerate lithofacies. The Paraggi Lithofacies (fP) is characterized by the dominance of carbonate clasts and less common volcanic and metamorphic clasts. The Monte Pallone Lithofacies (fmP) is characterized by less abundant carbonate and more abundant quartz, metabasic, metamorphic and crystalline clasts. The Monte Bocche Lithofacies (fmB) is characterized by the absence of carbonate clasts, the dominance of marble/dolomite and non-carbonate sedimentary clasts, and the subordinate presence of intrusive igneous clasts (Corsi & *alii*, 2008, redrawn).

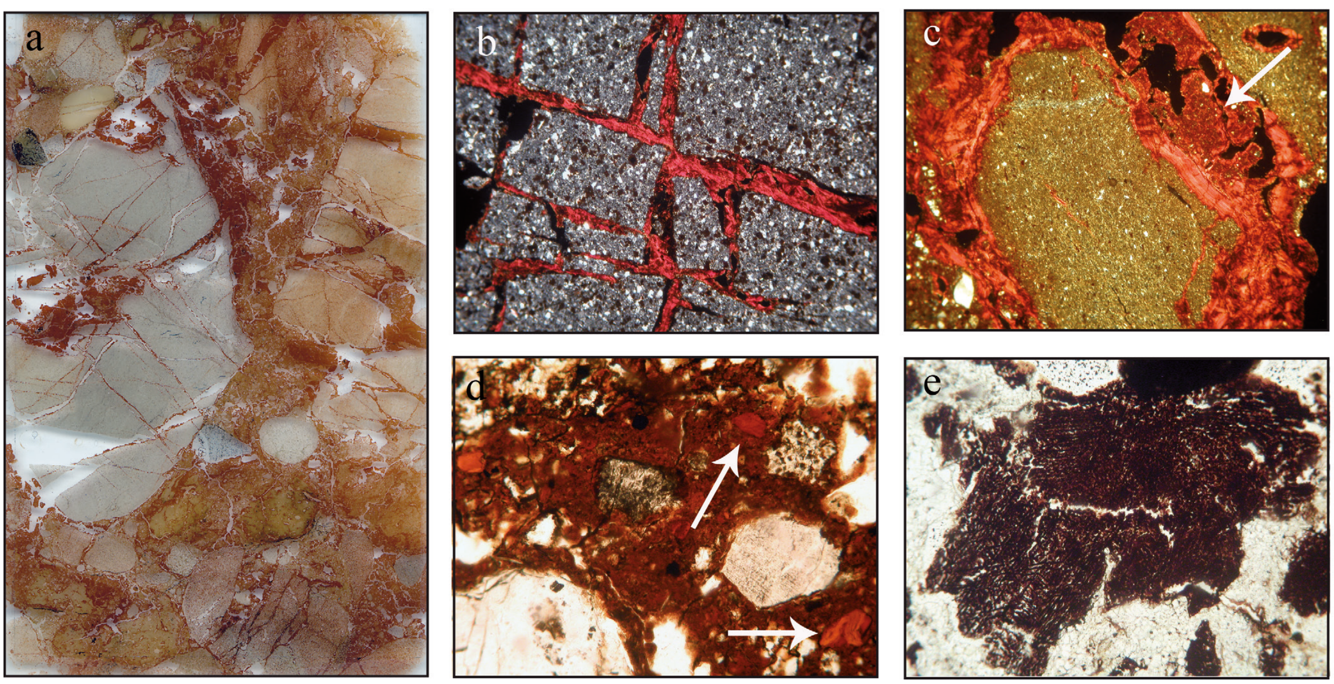

FIG. 7 - a) Flatbed scan of a thin section showing the general fabric of a Crt horizon (Cutanic Acrisol Hyperdystric Abruptic, MU 8) and some photomicrographs. The fabric of the saprolite is related to the original lithic fabric of the conglomerate, and the weathering of primary minerals caused voids to develop and the break-up of the lithic fabric. The frame length of thin section is 5 cm. Photomicrographs: b) abundant illuvial clay infillings in fracture planes (the frame length is 3.1 mm; XPL); c) infillings of pedoplasmated material derived from a higher layer covering clay coatings are observed in voids (the frame length is 3.1 mm; XPL); d) fragments of clay coatings incorporated into silty clay groundmass in a Bt horizon (the frame length is 1250 µm; PPL); d) example of a mineral grain replaced by an Fe-rich secondary product (the frame length is 1250 µm; PPL).

over, the abundant silt or pedoplasmated material derived from the higher horizons is often mixed with the clay coatings (fig. 7c). In the Bt horizon, subangular fragments of clay coatings (papules, *sensu* Brewer, 1976) are randomly distributed in the groundmass and feature sharp to diffuse extinction bands (fig. 7d). In addition, other relevant features observed in the thin sections include passage features and loose continuous infilling of channels with mineral-or-

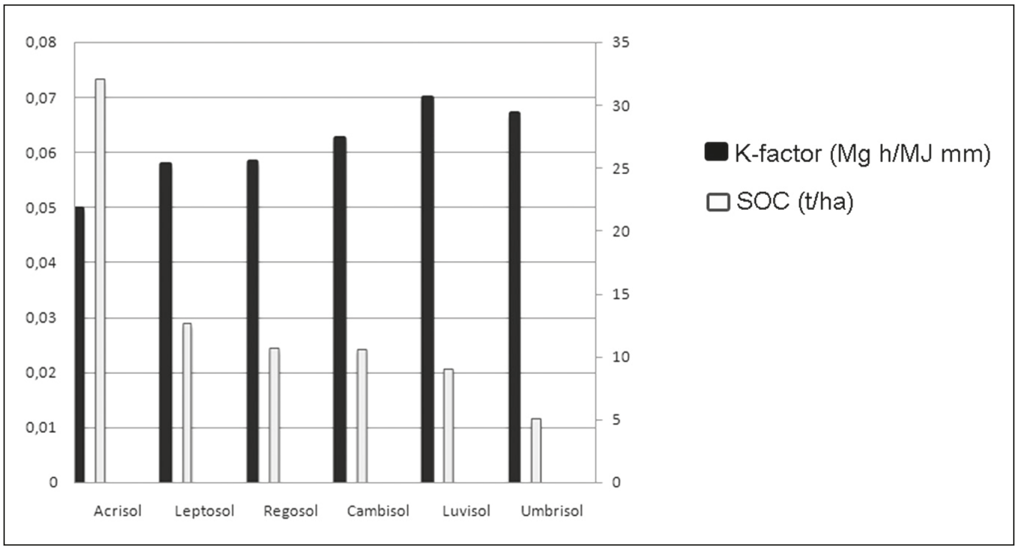

FIG. 8 - Graph showing correlation between the mean values of SOC and K-factor for the identified Soil Groups.

FIG. 9 - Deep weathering in fissures and cracks at the base of an terraced soil. Note the abrupt contact between the residual soil material and the reworked terraced infill. Trowel for scale.

ganic excrement, indicating a high degree of biological activity in these horizons. In the saprolite horizons (fig. 7a), the weathering degree of the primary minerals is higher: grains exhibit severely etched surfaces and are characterized by abundant clay neogenesis and iron staining (fig. 7e). Coatings/infillings of limpid authigenic clay occur in some voids in the lower saprolite. Furthermore, the quartz grains are fractured, and mica flakes appear to be intensely weathered, often to kaolinite, and split apart along cleavage planes.

UMBRISOLS - The soils in this group are found in areas with undisturbed organic matter accumulation within the mineral surface horizon under low base saturation conditions. These soils are a less common soil group, covering only 0.5% of the whole area, and they are located in a single map unit (MU 22).

These soils occur in a small valley filled with unconsolidated material at higher elevations on an upper south-facing slope under deciduous oak trees (*Quercus rubra*), where precipitation is relatively high. In particular, the environmental conditions created by this land use type and microclimate appear to be favourable for the development of Umbrisols. The texture of these soils is dominantly loamy. The analysis results (tab. 3) confirm that the soils in this group have deep and acidic organic horizons with high CEC values and medium to high N and available P contents. These values naturally decrease with depth, and the CEC values in particular become low.

Soil-based thematic maps

Three thematic maps were derived from the produced soil map and contain basic soil data that are important for soil management. We produced SOC (t/ha), soil K-factor (Mg h/MJ mm) and Hydrologic Soil Group distribution maps of the area (see, appendix).

In the study area, the values of SOC range from 3 to 34%, with an average of 12.2%. Approximately 25% of the soils are classified as the lowest SOC class (from 3 to 6% SOC in the soil profile), whereas less than 20% of the soils are classified as the high SOC class.

The soil erodibility is quite high. The annual value of soil loss ranges from 0.031 to 0.083 Mg h/MJ mm, with

FIG. 10 - Fossil travertine deposits at Cala dell'Oro (see map). The age of the travertines is uncertain. The possibility that the deposit is associated with flowing spring water during cooler, more humid Quaternary stages cannot be excluded.

an average of 0.06 Mg h/MJ mm. Approximately 20% of the soils fall in the most erodible soil class, whereas more than 50% of them fall in the medium-low erodibility class. Moreover, we correlated the mean SOC and K-factor values for each soil group (fig. 8). In the studied area, the SOC decreases from Acrisols to Umbrisols, whereas the K-factor decreases from Luvisols to Acrisols. The graph clearly confirms that an increase in SOC content is correlated with a decrease in soil loss, likely because SOC has a significant effect on the physical characteristics of the soil (such as the structure and bulk density). Therefore, the SOC content can be used as an indicator of the state of preservation or degradation of a soil (Conforti & *alii*, 2013)

DISCUSSION

The general patterns of soil formation

In the map and in the previous chapter, the soil characteristics were extensively described. This section focuses on some general aspects, such as the major soil forming processes and the influence of the various soil forming factors. A soil is a result of the combined action of different soil forming factors (Jenny, 1941). The parent material is recognized as a key component of most soil formation models, and many studies confirm the strong influence of lithology on soil distribution (Gray & *alii*, 2016). In fact, the soil features and general trend of soil genesis on the Portofino Promontory were also found to be strongly related to the nature of the parent material. Thus, the soil map legend is primarily based on the soil parent material.

In soils on consolidated pre-Quaternary clastic rocks (conglomerates and sandstones), clay translocation and rubefaction are important processes, as evidenced by the presence of Luvisols, Acrisols and Cambisols. In the study area, rubefaction is distinctly associated with good drainage (both external and internal) and is a prominent process in soils with coarse textured material (tab. 2). The occurrence and intensity of rubefaction also depend strongly on the age of the soil (see Relict features).

In these soils, the clay contents are initially low, and the soils are highly permeable (see the discussion of the hydrologic groups). Cambic horizons, with evidence of carbonate removal, are more common (MU 9). Upon weathering, clay is commonly formed and is rapidly translocated, usually either from an overlying horizon (vertical illuviation; Acrisols, MU 8) or from a horizon upslope (lateral illuviation; Luvisols, MU 5). Consequently, permeability decreases, even if there is a general absence of pseudogleying and stagnation features. The soils, with increasing age, have better developed and redder argillic horizons. In these older and highly evolved soils (Acrisols, MU 8), illuviation coatings are thick and common, and a deep saprolite is present in the lower part of the solum.

The soils on marly limestone first form non-vertic cambic horizons. The internal drainage may initially be rather good, but upon further release of expandable 2:1 clays, the permeability rapidly decreases and vertic processes become active (MU 14). Generally, because of their instability and topographic position, these soils do not reach the Vertisol stage (MU 16). The residual soils in the summit and footslope positions are mostly considerably older than the soils on the slopes. These are relict soils marked by distinct clay translocation and subsoil clay contents but not by high rubefaction (R.R. = 0). These soils, occurring in areas with low mean slope gradients, are associated with stagnation in the lower horizons (MU 14 and MU 17). The low mean slope gradient decreases the lateral drainage of the soil, resulting in a shallow water table, which, in turn, increases the soil redoximorphic features. In particular, the footslope context also affects the soil clay mineralogy by concentrating water, cations and sediments, which influences the hydrolysis processes and the development of vertic features (MU 14). In fact, the abundance of released and leached cations in the seepage or runoff water induces both chemical saturation and the cessation of hydrolysis. This process favours smectite formation and the shrinking and swelling of the subsoil. Therefore, after an early stage as a Cambisol (or Vertisol), clay translocation becomes an increasingly influential process.

The Quaternary slope deposits (colluvia and landslides) mainly consist of transported soil aggregates and are therefore characterized by the colour and other characteristics of the soils from which they are derived. For instance, the base-poor, acidic and reddish soils on marly limestone bedrock at the bases of north-facing slopes (MU 19 - MU 20) consist mainly of pre-weathered soil material related to the destruction of an older surface (MU 8, see above) located at a higher topographic position on conglomerate. Clay illuviation in these soils is absent or too weak to meet the requirement of an argic horizon. Therefore, this soil can be classified as a Cambisol due to the presence of soil structure and evidence of the removal of carbonates. The soils found in recent colluvia derived from limestone soils (MU 24-27) are weakly developed and show less pronounced decalcification phenomena, as evidenced by the common presence of soft powdery lime, the high total carbonate content and the alkaline pH values (calcaric Regosol). The same characteristics were shown by few soils developed on extremely gravelly deposits, probably due to thermoclastic or cryoclastic phenomena on conglomerate slopes (see Leptosols, éboulis ordonnées) that lack a pedogenic matrix.

Human activities have also been an important driving factor in the evolution of the soil on the Portofino Promontory. In this context, the human impact interfered with soil formation processes through vegetation changes caused by fire and reforestation, relief modification and soil redistribution. In some cases, the soil redistribution and movement of earth related to terracing (introduced to minimize erosion and expand the cultivated area) on both conglomerate and limestone slopes contributed to soil rejuvenation (Regosol, MU 12) by forming soils with a higher percentage of coarse elements and lower organic matter contents. The abandonment of the terraces affected their stability, increasing the risk of mass movement events. Terracing is certainly an important anthropogenic factor affecting the Portofino soils, but the intense activity of the charcoal burners (Olivari, 2007) also contributed to soil redistribution and rejuvenation, primarily due to the preparation and management of plots before, during and after the production phase.

The indispensable contribution of vegetation, often the result of profound man-made changes over the centuries and directly linked to the microclimate, must be considered. In fact, some pedogenic processes are influenced by vegetation and the resulting humus. For instance, the thicker O and A horizons (umbric, see map, MU 22) in the deciduous *Quercus rubra* oak forest reflect both greater organic carbon inputs associated with a more mature and better established vegetation community and a presence of easily mineralized humus, which improves the melanization processes and accumulation of organo-mineral colloids. Apart from this exception, the soils of the Portofino Promontory mostly have poorly developed A horizons (<20 cm) overlain by a thin litter (O horizon, 2-3 cm), composed of leaves and twigs. Generally, the C/N ratios of these soils are near 10, indicating a Mull humus form, characterized by well-humified organic matter rich in stable mineral-organic complexes. In some cases (*Chestnut* soils), the acidic pH of the organic horizons induces a decrease in litter decomposition rates and is reinforced by slow humification (C/N ratios of approximately 20) with formation of the Moder humus form. Thus, decomposition and humification are active processes, but many of the soils have lost a significant thickness of the surface horizon due to erosion, likely induced by forest fires or cutting and harvesting of the vegetation in areas traditionally used as coppices. Recently, the development of outdoor and recreational activities (trekking and mountain biking) and the presence of wild boar have led to an increase in vegetation removal and soil erosion processes (due to concentrated runoff), thereby increasing the loss of SOC.

Organic carbon

SOC is sensitive to a range of factors, including climate, topography, soil and vegetation management, among other anthropogenic factors (Tan & *alii*, 2004). Several studies have estimated differences in SOC in relation to vegetation and topography, land use, and climate.

In the study area, in accordance with the findings of Paustian & *alii* (1997), the SOC content decreases with increasing soil disturbance, as evidenced in soils developed on slope deposits rearranged for agricultural purposes (terraces, MU 12). Higher SOC concentrations are present in areas with little soil disturbance and in forested environments (holm oak) or maquis.

Moreover, the SOC storage is influenced by temperature and moisture regime, in accordance with Fantappiè & *alii* (2010). The SOC sequestration decreased from the field sites with humid conditions to the field sites with semiarid conditions, and the highest SOC values were observed in small valleys with N-facing aspects (MU 27 and MU 17). These soils are characterized by colluvial parent material, and the high SOC stock could also be due to the deposition of soil eroded from higher topographic positions (Fernández-Romero & *alii*, 2014).

The SOC stock is also related to soil age, as our study confirms. The SOC stock is high in older soils (palaeosols) under forest (Acrisol, MU 8).

In summary, a protected environment with a thick and mature forest that encourages soil preservation and litter development is the best environment for SOC preservation and formation. Forest fires represent an extremely serious environmental issue in the Mediterranean region. Adequate landscape-level planning policies that integrate the assessment of forest fire risk should be considered because the burning of the surface biomass could lead to the loss of the SOC stock (litter and humus) and promote soil erosion.

Soil erodibility

One key parameter for the evaluation of soil erosion is the soil erodibility, expressed as the K-factor in the widely used Universal Soil Loss Equation (USLE, Wischmeier &

alii, 1978) and in the Revised USLE (RUSLE, Renard & *alii,* 1997). The K-factor, which expresses the susceptibility of a soil to erosion, is only related to soil properties, such as organic matter content, soil texture, soil structure and permeability. The K-factor, expressed in Mg h/MJ mm, represents an integrated annual value of the soil profile reaction to soil detachment and transport by raindrops and surface flow (Renard & *alii,* 1997).

Due to the relationship between the K-factor and the soil texture, soil erodibility is therefore strictly related to the geologic substrate. In the study area, the direct relationship between the geologic substrate and the K-factor distribution is clear (see map). For instance, high K-factor values correspond to soil horizons on the conglomerate, which are more sandy and much more permeable, whereas low values correspond to soil horizons on the marly limestone.

Soil erodibility, together with the other USLE factors, such as management practices (P-factor), vegetation cover (C-factor) and morphological conditions (LS-factor), can also be influenced by agricultural practices and human intervention in land management. The MU with the highest K-factor value (MU 10) has favourable morphological conditions for soil conservation but lacks adequate vegetation cover protection (olive grove). Consequently, this MU is one of the most at risk for soil erosion. In contrast, the other MUs with high K-factor values have excellent vegetation cover protection, such as the *Quercus ilex* forests in MU 4 and MU 7 or the mixed forests in MU 5 and MU 23, but they feature unfavourable morphological conditions, such as very steep slopes. These observations are important for the present land cover preservation strategies. Possible cutting of the forest would cause serious consequences in terms of soil erosion. Therefore, the K-factor dataset can serve as a guide for the application of better conservation practices (e.g., increasing or preserving SOC in areas prone to high levels of soil erosion or adapting soil management methods in areas of high risk).

Soil hydrology

The geologic substrate plays a important role in determining the hydrologic soil type. A direct relationship between the geologic substrate and Ksat is observed (see appendix). The effect of the geologic substrate can be explained by the hydrodynamic properties of the bedrock and its weathering products. For instance, weathering of marly limestone produces silty clay, leading to clay soil horizons (tab. 1, 2 and 3) with restricted drainage and redoximorphic features. In contrast, the soil horizons developed on conglomerate are more sandy and much more permeable and do not exhibit lower redoximorphic features.

Therefore, the characteristics of the conglomerate-derived soils favour the infiltration of overland flow, limiting its evaporation rate. The water flowing through the thick soils at higher elevations (MU 8) can reach the cracked conglomerate, forming deep groundwater and a long-term 'reservoir' in the natural water cycle (Olivari,1981).

Groundwater percolation through cracks in the conglomerate leads to morphologically karst-like phenomena known as "pseudokarst" (Eberhard & Sharples, 2013). The percolation of water loosens the bonds between mineral grains, causing carbonate enrichment in the flowing water. When this water flows out at the surface, carbonate deposits (travertine) precipitate (fig. 10).

Moreover, this process permits preferential pathways to develop, which gradually become enlarged and can form small caves, although the most significant caves are the wave-excavated sea caves that develop along joint fractures close to the coast (Faccini *& alii*, 2008).

The groundwater formation process supplies the numerous perennial springs that occur both at high altitudes along the conglomerate-limestone contact and under the sea (Olivari, 1981). These springs feed the aqueducts of the municipalities of Camogli, Santa Margherita Ligure and Portofino.

Therefore, the presence of a thick and broad pedologic cover plays a key role in the capture and supply of clean water, makes water available for uptake by vegetation and mitigates hydro-geologic risks.

Relict features

Some features of the Acrisols (MU 8) and Luvisols (MU 14) identified in thin sections were been interpreted as relict features. These features allow us to regard these soils as polygenic palaeosols, i.e., they are related to pedogenetic processes active during the Pleistocene under different palaeoclimates and are not in equilibrium with present-day climatic conditions. Polygenetic soils occur when climate changes are large enough to produce new soil properties without obliterating the existing properties (Chadwick & *alii*, 1995). These soils formed in a earlier landscape and were subsequently truncated to varying degrees and influenced by later soil forming processes.

For instance, clay illuviation is the main soil-forming process in Mediterranean soils, although clay cutans are generally rare or appear only as thin coatings on mineral surfaces or peds (Fedoroff, 1997). Usually, thin and undisturbed textural features that coat or infill apparently active voids are considered as signature of recent particle translocation. Therefore, these features can be tentatively ascribed to the lower-middle Holocene (Rellini & *alii*, 2014; Khün, 2003; Van Vliet-Lanoë, 1990). Thus, the presence of polycyclic clay illuviation with thick juxtaposed clay-silt coatings is incompatible with the present-day climate and may be indicative of older phases of clay illuviation and complex pedologic processes in a single soil (Fedoroff & *alii*, 2010).

The argillic horizons of MU 8 and MU 14 probably record the imprint of a palaeoclimate characterized by wet conditions (required for water percolation and clay illuviation) but also by a marked seasonal contrast, possibly with higher temperatures that allowed capillary water evaporation and deposition of suspended clays that adhered to ped and pore surfaces (Scarciglia & *alii,* 2006; Fedoroff, 1997). Such conditions are typical of past interglacial periods (Rellini & *alii*, 2015; Catt, 1989), which were warmer and more humid than today. Additionally, the development of large planar voids and slickensides, such as those described in the lower Luvisol horizons (MU 14), is favoured by warm, humid, seasonally contrasting conditions that enhance wetting-drying cycles and the resulting shrink-swell (vertic) dynamics (Coulombe & *alii*, 1996). The vertisolisation in the vertic Luvisols (MU 14) on marly limestone has been a partially functional process that has not been able to overshadow the most important long-term and recent clay illuviation process. Analogous considerations, in terms age and palaeoclimate, may explain the intense rubefication (high R.R., Torrent & *alii*, 1980) recorded in the soil horizons of UC 8 because the reddening of a soil matrix requires similar environmental conditions (Schwertmann & Taylor, 1989). Additionally, the specific presence of kaolinite in these soils, accounting for the low CEC values and micromorphological features, may indicate soil-forming conditions that were particularly humid (but well drained), prone to hydrolysis and leaching phenomena, possibly warmer than today, and/or experienced a longer duration of pedogenesis (Dixon, 1989).

Rellini & *alii* (2015) described certain pedofeatures (i.e., juxtaposed compound coatings) that were very similar to the features of the Acrisols (MU 8) and Luvisols (MU 14) in other palaeosols along the Ligurian coast, indicating changes in the local or environmental conditions during the Pleistocene. Moreover, thick juxtaposed coatings were found in an early Pleistocene palaeosol characterized by a deep argillic horizon covering an intensely weathered saprolite with illuviated clay in fissures and voids on the Manie Plateau, located approximately 100 km west of the site along the Ligurian coast (Rellini & *alii*, 2007; Trombino, 1996).

Frost activity probably also intensely affected these soils. Fragments of microlaminated clay coatings (*papulae*) are commonly present in the Bt horizons of the Acrisol (MU 8, fig. 7d). These features can be regarded as markers of environmental changes from interglacial periods to glacial periods (Simon & *alii*, 2000). Moreover, we cannot exclude the possibility that silty-clay and dusty coatings alternating with pure clay coatings in these palaeosols reflect the rapid particle translocation due to freeze-thaw cycles during glacial periods (Van Vliet-Lanoë, 2010; Scarciglia & *alii*, 2006). The presence of thick stratified slope deposits that lack a pedogenic matrix (see Leptosols, fig. 2), produced by frequent freeze-thaw cycles or thermal changes, suggests that cold and dry periglacial conditions also occurred in this coastal sector of northern Italy at the beginning of the Late Pleniglacial, as already observed by Rellini & *alii* (2013).

Palaeosurface and deep weathering

The Portofino Promontory is a zone of tectonic uplift (seismic activity) that has led to the development complex relief. The tectonic activity is evidenced by recent seismicity (Regional Seismic Network of Northwestern Italy, Ferretti & *alii*, 2008), which affects the Ligurian continental margin and is characterized by earthquakes (fig. 6A) with a Richter magnitude of generally less than 4 (Castello & *alii*, 2004). A portion of the top of the promontory is quite wide and gently slopes to the eastern sectors (Monte Pollone, see map). This area forms a sort of high, disarticulated erosional plain formed on the Oligocene conglomerate bedrock. The palaeosurface is dismembered into several parts with different sizes and elevational positions (fig. 6B). These surfaces are the remnants of an older, more extensive subaerial erosional surface that was probably already exposed during the early Pliocene transgression and is recognizable in many other sectors of the Ligurian coast (Carobene & Cevasco, 2011; Biancotti & Motta, 1998). During the early Pliocene, the Ligurian Basin continued to subside, and the inner part of the continental shelf began to experience uplift (Fanucci & *alii*, 1984; Fanucci & Nicolich, 1986). The relic paleosurface is now reduced to several residual relics located on top of the local relief due to early-middle Pleistocene block faulting (normal fault activity, see fig. 6B). During the Quaternary, this sector of the Ligurian coast continued to experience uplift (Fanucci & *alii*, 1980). This notably transformed the previously planated landscape, creating the main morphological features present in the range today. This successive stepping of tectonic pulses likely also led to the development of a new surface at a lower position (MU 10, see map).

The relics of the ancient land surface are covered by a thick saprolite and characterized by a palaeosol (Acrisol, MU 8). Moreover, relicts of deep weathering are found in fissures and cracks in the conglomerate at lower elevation (fig. 9). Here, the erosion has been severe, and the residual soils can be considered erosional remnants. These remnants are also relatively common in the littoral zone.

Due to the presence of the saprolite, the large-scale morphogenesis of the top surface of the Promontory must have taken place before the Quaternary during a hotter and wetter period than the present one. In fact, a long period of ground surface stability (geomorphological and possibly climatic) under biostatic conditions was likely necessary to generate the observed deep weathering (saprolite) and intense pedogenesis (Scarciglia & *alii*, 2005; Thomas & *alii*, 1999). The environmental conditions during the Quaternary, with its climatic cooling and repeated glaciations, was not optimal for the weathering layering (Migon & Lidmar-Bergström, 2002), although deep weathering (and rubefaction) was likely favoured by the characteristics of the conglomerate bedrock, which contains abundant clasts (basalt, metabasite, and gabbro) with easily weatherable and Fe-rich minerals (facies fmB, Corsi & *alii*, 2014, fig. 6B).

The hypothesised age of the soils presented here is quite uncertain but is consistent with and in no way contrasting with the existing understanding of the genesis of similar pedofeatures and soils in Italy (Bartolini & *alii*, 1984; Carnicelli & Costantini, 2013) and with the evolution of palaeosurface. Moreover, more intensely weathered palaeosols from the early Pleistocene suggest a climate with more humid phases and geomorphodynamic stability in the Mediterranean region (Wagner & *alii*, 2014; Günster & Skowronek, 2001; Cremaschi & Ginesu, 1990), thereby favouring deep weathering.

In particular, the Acrisol shows relict features that are very similar to those observed in a relict paleosol on the Manie Plateau (see Relict features). A quantitative geomorphologic study (Biancotti & Motta, 1998) found that most of large-scale morphogenesis of the top surface of the Manie Plateau, which is responsible for development of the largest karst sags, occurred during the interglacial Alpine period in the early Pleistocene. The archaeological finding of an archaic Acheulean bifacially worked tool (Lower Palaeolithic) discovered in this relict paleosol (Vicino, 1982) confirms this hypothesis. Thus, the good relationship between the two paleosols suggests an early Pleistocene age for the Portofino Promontory paleosols. The early Pleistocene period appears to have been wetter and hotter, resulting in more extensive leaching and weathering of the palaeosols on the conglomerate and more significant development of vertic features on the marly limestones.

Analogous geomorphological and climatic considerations (i.e., warm and humid interglacial conditions) may explain the intense, polycyclic clay illuviation in the palaeosol subsoil (Catt, 1989; Fedoroff, 1997, Scarciglia & *alii*, 2005). In fact, the Quaternary climatic change caused polypedogenesis in the soils that formed on the stable surface (Rellini & *alii*, 2015). Exogenic processes (together with the tectonic generation of relief) then modified the promontory landforms during the Quaternary. For instance, the fluvial network dissected the erosional surfaces and overall led to intense denudation processes with mass movement events, erosion of the palaeosols and subsequent accumulation of thick sequences of sediments.

CONCLUSIONS

Detailed soil mapping of the Portofino Promontory required intensive field investigation and sampling due to the complex environmental setting. The landscape approach to soil surveying is well developed. The completion of the detailed survey of the Portofino Promontory took approximately three years, making this one of most valuable planning datasets in existence for the Liguria region. The spatial distribution and variability of the most extensive soil types were reproduced in GIS and presented in a soil map at a scale of 1:10,000 with a descriptive legend. We identified six RSGs: Cambisol, Regosol, Leptosol, Luvisol, Acrisol, and Umbrisol. The GIS dataset was used to produce three derived maps (soil erodibility factor, spatial distribution of SOC and soil hydrological groups) for decision making in a region that is threatened by soil degradation. Moreover, our dataset will also contribute to the existing tools associated with national soil mapping and soil OC/OM datasets and will support the European Soil Bureau (ESB), based at the Joint Research Centre (Ispra), by validating new records associated with the soil and OC maps of Europe.

Due to its complex geologic and climatic history, the time, landscape stability (preservation of the palaeosurface) and parent material factors are major contributors to the extent of pedodiversity on the Portofino Promontory. Since the Last Glacial Maximum, the soils have experienced incipient soil formation, with at least the beginning of horizon differentiation, humus accumulation and carbonate removal (Regosol and Cambisol), while the clay illuviation horizons likely formed only in special morphological conditions. Soil development is distinctly more advanced after polycyclic weathering. Polygenic and strongly weathered soils exist in the study area and have not yet been affected by erosion (Acrisols and Luvisols). These soils are relict palaeosols (Ruellan, 1971): they were generated through long-term pedogenesis but are no longer affected by active processes. In particular, the formation of the Acrisols is directly related to the development and preservation of an extensive ancient erosional surface (palaeosurface) that enabled rates of weathering to exceed those of erosion and favoured saprolite development. The palaeosol features suggest the existence of a warmer and wetter climate in northern Italy during the Early Pleistocene. The soil development episodes during the Quaternary were not continuous and were instead governed by pulses of tectonic uplift and climatic change, giving rise to soil erosion.

Land use planning to preserve the cultural and natural heritage of the landscape (geosites) should take into account the presence of the described palaeosols, which are currently included in the currently existing Portofino Natural Park, because these palaeosols preserve a large amount of information about the environments of the past and because they are important SOC pools and a long-term 'reservoir' of natural water.

REFERENCES

Alexakis, D.D., Gryllakis, M.G., Koutroulis, A.G., Agapiou, A., Themistocleus, K., Tsanis, I.K., Michaelides, S., Pashiardis, S., Demetriou, C., Aristeidou, K., Retalis, A., Tymvios, F. & Hadjimitsis, D.G. (2013) - *GIS and remote sensing techniques for the assessment of land use changes impact on flood hydrology: the case study of Yialias Basin in Cyprus*. Natural Hazards and Earth System Sciences (discussion paper), 1, 4833-4869.

Avery B.W. (1987) - *Soil survey methods: a review*. Technical Monograph No. 18, Silsoe: Soil Survey & Land Resource Centre. 86 pp.

Bartolini C., Bidin, D., Ferrari G.A. & Magaldi D. (1984) - *Pedostratigrafia e Morfostratigrafia nello Studio delle Superfici Sommitali Situate fra Serchio e Ombrone Pistoiese*. Geografia Fisica e Dinamica Quaternaria, 7, 3-9.

Battola A. (2008) - *The management of forests and natural sites in the Park of Portofino*. In: Vegatation management in periurban natural spaces. Fédération Européenne des Espaces Naturels et Ruraux Métropolitains et Pèriurban, Proceedings of technical meeting held in Milano (Italy), 5-6 june, 47-51.

Benyarku C.A. & Stoops G. (2005) - *Guidelines for preparation of rock and soil thin section and polished sections*. Quaderns DMACS 33, Paperkite Editorial, Departament de Medi Ambient I Ciències del Sòl, Universitat de Lleida.

Biancotti A. & Motta M. (1998) - *Morfotettonica dell'Altopiano delle Manie e Zone Circostanti (Liguria Occidentale)*. Geografia Fisica e Dinamica Quaternaria, Suppl. I, 45-68.

Brandolini P., Faccini F., Robbiano A. & Terranova R. (2007) - *Geomorphological hazard and monitoring activity along the western rocky coast of the Portofino Promontory (Italy)*. Quaternary International, 171/172, 131-142.

Breuning-Madsen H., Elberling B., Balstroem T., Holst M. & Freudenberg M. (2009). *A comparison of soil organic carbon stock in ancient and modern land use systems in Denmark*. European Journal of Soil Science 60, 55-63.

Brewer R. (1976) - *Fabric and Mineral Analysis of Soils*. Robert E. Krieger Publishing Company, Huntington, 482 pp.

Brevik E.C. (2012) - *Soils and climate change: gas fluxes and soil processes*. Soil Horizons, 53 (4), 12-23.

Carnicelli S. & Costantini E.A.C (2013) - *Time as a Soli Forming Factor and Age of Italian Soils*. In : Costantini E.A.C. & Dazzi C. (Eds.). The Soils of Italy. World Soils Book Series. Springer Netherlands, 93-104.

CAROBENE L. & CEVASCO A. (2011) - *A large scale lateral spreading, its genesis and Quaternary evolution in the coastal sector between Cogoleto and Varazze (Liguria-Italy).* Geomorphology, 129, 398-411.

CASTELLO B., MORO M., CHIARABBA C., DI BONA M., DOUMAZ F., SELVAGGI G. & AMATO A. (2004) - *Seismicity Map of Italy.* I.N.G.V, Roma.

CATT J.A. (1989) - *Relict properties in soils of the central and northwest European temperate region*. Catena Supplement,16, 41-58.

CEVASCO A., FACCINI F., NOSENGO S., OLIVARI F. & ROBBIANO A. (2004) - *Valutazioni sull'uso delle classificazioni geomeccaniche nell'analisi della stabilit*à *dei versanti rocciosi: il caso del Promontorio di Portofino (Provincia di Genova).* GEAM, 111, 31-38.

CHADWICK O.A., NETTLETON W.D. & STAIDL G.J. (1995) - *Soil polygenesis as a function of quaternary climate change, Northern Great Basin, U.S.A.* Geoderma, 68, 1-26.

CONFORTI M., BUTTAFUOCO G., LEONE A.P., AUCELLI P.P.C., ROBUSTELLI G. & SCARCIGLIA F. (2013) - *Studying the relationship between water-induced soil erosion and soil organic matter using Vis-NIR spectroscopy and geomorphological analysis: A case study in southern Italy.* Catena, 110, 44-58.

CORSI B. (2008) - *Le vie del conglomerato. Due itinerari geologici nel parco di Portofino. Guida alle escursioni.* Regione Liguria, Il Parco di Portofino Edizioni, 115 pp.

CORSI B., ELTER F.M., GIAMMARINO S. & PIAZZA M. (2014) - *The Portofino Conglomerate (Eastern Liguria): lithostratigraphic notes.* Volume Convegno in memoria di Piero Elter "I rapporti tra l'Appennino settentrionale e le Alpi occidentali: stato dell'arte a 50 anni dalla "ruga del Bracco", Pisa, 26-27 giugno 2014, Dipartimento di Scienze della Terra - Università di Pisa.

COSTANTINI E.A. (2007) - *Linee guida dei metodi di rilevamento e informatizzazione dei dati pedologici*. CRA, Ministero delle politiche agricole alimentari e forestali, Firenze, Italia, 280 pp.

COSTANTINI E.A.C., L'ABATE G. & URBANO F. (2004) - *Soil Systems of Italy.* (Online) http://soilmaps.entecra.it/ita/cartadeisuoli5.html

COSTANTINI E.A.C. & LORENZETTI R. (2013) - *Soil degradation processes in the Italian agricultural and forest ecosystems.* Italian Journal of Agronomy, 8 (4), 233-243.

COSTANTINI E.A.C. & DAZZI C. (Eds.) (2013) - *The Soils of Italy.* World Soils Book Series, Springer Netherlands, 354 pp.

COULOMBE C.E., WILDIN, L.P. & DIXON J.B. (1996) - *Overview of vertisols: characteristics and impacts on society.* In: SPARKS D.L. (Ed.) Advances in Agronomy, vol. 57, Academic.

CREMASCHI M. & GINESU S. (1990) - *Morfogenesi e Pedogenesi Tardo Terziaria e Pleistocenica Antica nella Nurra Occidentale (Sardegna).* Nota Preliminare. Geografia Fisica e Dinamica Quaternaria, 13, 81-82.

DE STEFANIS A., MARINI M. & TERRANOVA R. (1983) - *Geomorfologia di Aree Campione della Liguria (con cartografia geologica di base).* REGIONE LIGURIA - C.N.R. Progetto finalizzato "Conservazione del suolo", Sottoprogetto "Fenomeni Franosi", Pubblicazione n. 249 - SELCA Firenze. Press, New York, 289-375.

DIXON J.B. (1989) - *Kaolin and Serpentine Group Minerals.* In: DIXON G.B. & WEED S.B. (Eds.), Minerals in Soil Environments, 2nd Edition. Soil Science Society of America, Book Series No. 1. Madison, WI, 467-525.

DUMAS J.B.A. (1831) - *Procédés de l'analysc organique.* Annales de chimie et de physique, 247, 198-213.

EBERHARD R. & SHARPLES C. (2013) - *Appropriate terminology for karst-like phenomena: the problem with 'pseudokarst'*. International Journal of Speleology, 42(2), 109-113.

FAO, FOOD AND AGRICULTURAL ORGANIZATION OF THE UNITED NATIONS (2006) - *World Reference Base for Soil Resources 2006.* 2nd edition. Rome, Italy.

FACCINI F., BONINO E., BRANDOLINI P., PICCAZZO M., OLIVARI F. & ROBBIANO A. (2005) - *Phenomenes de condensation et sources perennes dans le Promontoire de Portofino (Italie).* In: Actes du colloque Climat Urbain, Ville et Architecture, Genes 7-11 September 2005, 205-208.

FACCINI F., PICCAZZO M., ROBBIANO A. & ROCCATI A. (2008) - *Applied Geomorphological Map of the Portofino municipal territory (Italy).* Journal of Maps, 451-462.

FANTAPPIÈ, M., L'ABATE, G. & COSTANTINI, E.A.C. (2010) - *Factors Influencing Soil Organic Carbon Variations in Italy During the Last Three Decades.* In: ZDRULI P., PAGLIAI S., KAPUR M. & P. FAZ CANO (Eds.), Land Degradation and Desertification: Assessment, Mitigation and Remediation. Springer Science + Business Media B.V., 435-465.

FANUCCI F., PINTUS S., TEDESCHI D. & VIGNOLO A. (1980) - *Dati preliminari sulla neotettonica dei Fogli 83-94 Rapallo, Chiavari.* Contributi preliminari alla realizzazione della Carta Neotettonica d'Italia, Pubbl. n. 356 del Progetto Finalizzato Geodinamica, 1305-1327.

FANUCCI F. & NICOLICH R. (1986) - *Il Mar Ligure: nuove acquisizioni sulla natura, genesi ed evoluzione di un "bacino marginale".* Memorie della Società Geologica Italiana, 27, 97-110.

FANUCCI F., FIRPO M., PICCAZZO M. & MIRABILE L. (1984) - *Le Plio-Quaternaire de la Mer Ligure: epaisseurs et conditions d'accumulation*. Marine Geology, 55, 291-303.

FEDOROFF N. (1997) - *Clay illuviation in Red Mediterranean soils*. Catena, 28, 171-189.

FEDOROFF N., COURTY M.A. & GUO Z (2010) - *Palaeosoils and relict soils.* In: STOOPS G., MARCELLINO V., FLORIAS M. (Eds), Interpretation of micromorphological features of soils and regoliths. Elsevier, Amsterdam, 623-662.

FERNÁNDEZ-ROMERO M.L., LOZANO-GARCÍA B. & PARRAS-ALCÁNTARA L. (2014) - *Topography and land use change effects on the soil organic carbon stock of forest soils in Mediterranean natural areas.* Agriculture Ecosystems and Environment, 195, 1-9.

FERRETTI G., MORASCA P., SCAFIDI D., SPALLAROSSA D., TURINO C. & EVA C. (2008) - *Near real time and automatic capabilities of the renewed Regional Seismic Network of North-Western Italy (RSNI).* 31st Assembly of the European Seismological Commission - ESC08, Hersonissos, Greece, 2008, Program and Abstracts Book, 99.

FRANCOU B. (1988) - *Eboulis stratifiés dans les Hautes Andes Centrales de Pérou*. Zeitschrift für Geomorphologie 32 (1), 47-76.

GARLATO A., OBBER S., VINCI I., SARTORI G. & MANNI G. (2009) - *Stock attuale di carbonio organico nei suoli di montagna del Veneto.* Museo Tridentino di Scienze Naturali, Studi Trentini di Scienze Naturali, 85, 69-81.

GIAMMARINO S., NOSENGO S. & VANNUCCI G. (1969) - *Risultanze geologico paleontologiche sul Conglomerato di Portofino (Liguria orientale).* Atti Istituto di Geologia Università di Genova, 7, 305.

GIRANI A. & OLIVARI S. (1986) - *Guida al Monte di Portofino.* Sagep Ed., Recco, 160 pp.

GRAY J.M., BISHOP T.F.A. & WILFORD J.R. (2006) - *Lithology and soil relationships fo rsoil modelling and mapping.* Catena, 147, 429-440.

GÜNSTER N. & SKOWRONEK A. (2001) - *Sediment-soil sequences in the Granada Basin as evidence for long- and short-term climatic changes during the Pliocene and Quaternary in the Western Mediterranean*. Quaternary International, 78 (1), 17-32.

HARTEMINK A.E., LOWERY B. & WACKER C. (2012) - *Soil maps of Wisconsin*. Geoderma, 189-190, 451-461.

HOLLIS J.M. & WOODS S.M. (1989) - *The measurement and estimation of saturated soil hydraulic conductivity.* SSLRC Research Report, Silsoe, Beds.

HUTCHINSON M.F. (1996) - *A locally adaptive approach to the interpolation of digital elevation models*. In: Proceedings, Third International Conference/ Workshop on Integrating GIS and Environmental Modeling, Santa Fe, New Mexico, USA, January 21-25.

HUDSON B.D. (1992) - *The soil survey as a paradigm-based science*. Soil Science Society of America Journal, 56, 836-841.

KÜHN P. (2003) - *Micromorphology and Late Glacial/Holocene genesis of Luvisols in Mecklenburg-Vorpommern (NE-Germany).* Catena, 54, 537-555.

JENNY H. (1941) - *Factors of Soil Formation. A System of Quantitative Pedology*. McGraw Hill Book Company, New York.

MARINI M. (1981) - *Analisi geologico-strutturale ed interpretazione paleogeografica e tettogenetica dei calcari del M.Antola (Appennino ligure).* Ofioliti, 6 (1), 119-150.

MCKENZIE N.J., GESSLER P.E., RYAN P.J. & O'CONNELL D.A. (2000) - *The role of terrain analysis in soil mapping*. In: WILSON J.P. & GALLANT J.C. (Eds.), Terrain analysis: Principles and applications. Wiley, New York,

MIGOŃ P. & LIDMAR-BERGSTRÖM K. (2002) - *Deep weathering through time in central and northwestern Europe: problems of dating and interpretation of geological record*. Catena, 49, 25-40.

MINISTERO DELLE POLITICHE AGRICOLE E FORESTALI (2000) - *Metodi di analisi chimica del suolo.* ANGELI F. (Ed.), *Osservatorio nazionale pedologico e per la qualità del suolo*. International Society of Soil Science, Società Italiana della Scienza del Suolo, Milano.

NACHTERGAELE F.O. & VAN RANST, E. (2003) - *Qualitative and quantitative aspects of soil databases in tropical countries*. In: STOOPS G. (Ed.), *Evolution of tropical soil science: past and future*. Koninklijke Academie voor Overzeese Wetenschappen, Brussel, 107-126.

OLIVARI S. (1981) - *Lineamenti idrogeologici del Conglomerato di Portofino*. Unpublished Thesis, University of Genova.

OLIVARI S. (2007) - *Quando sul Monte si cuoceva il carbone*. Le memorie del Parco, Le Mani Editore, Recco, 79 pp.

PAUSTIAN K., LEVINE E., POST W.M. & RYZHOVE I.M. (1997) - *The use of models to integrate information and understanding of soil C at the regional scale*. Geoderma 79, 227-260.

PLANCHON O. & DARBOUX F. (2001) - *A fast, simple and versatile algorithm to fill the depressions of digital elevation models*. Catena, 46, 159-176.

RELLINI I., TROMBINO L., FIRPO M. & PICCAZZO M. (2007) - *Geomorphological context of "plinthitic paleosols" in the mediterranean region: examples from the coast of western Liguria (Northern Italy).* Revista Cuaternario Y Geomorfologia, 21 (1-2), 27-40.

RELLINI I., FIRPO M., MARTINO G., RIEL-SALVATORE J. & MAGGI R. (2013) - *Climate and environmental changes recognized by micromorphology in Paleolithic deposits at Arene Candide (Liguria, Italy).* Quaternary International, 315, 42-55.

RELLINI I., TROMBINO L., ROSSI P.M. & FIRPO M. (2014) - *Frost activity and ice segregation in a paleosol of the Ligurian Alps (Beigua Massif, Italy). Evidences of past permafrost?* Geografia Fisica e Dinamica Quaternaria , 37 (1), 29-42.

RELLINI I., TROMBINO L., CARBONE C. & FIRPO M. (2015) - *Petroplinthite formation in a pedosedimentary sequence along a northern Mediterranean coast: from micromorphology to landscape evolution*. Journal of Soils and Sediments, 15 (6), 1311-1328.

RENARD K.G., FOSTER G.R., WEESIES G.A., MCCOOL D.K., & YODER D.C. (1997) - *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation*. U.S. Department of Agriculture, Agriculture Handbook 703, 384 pp.

RUELLAN A. (1971) - *L'Histoire des sols, quelques Problèmes de Définition et d'Interprétation*. Cahier ORSTOM, Pédologie 9 (3), 335-344.

RUIZ SINOGA J.D., PARIENTE S., ROMERO DIAZ A. & MARTINEZ MURILLO J.F. (2011) - *Variability of relationships between soil organic carbon and some soil properties in Mediterranean rangelands under different climatic conditions (South of Spain)*. Catena, 94, 17-25.

SAXTON K.E., RAWLS W.J., ROMBERGER J.S. & PAPENDICK R.I. (1986) - *Estimating generalized soil-water characteristics from texture.* Soil Science Society of America Journal, 50(4), 1031-1036.

SCARCIGLIA F., LE PERA E., VECCHIO G. & CRITELLIA S. (2005) - *The interplay of geomorphic processes and soil development in an upland environment, Calabria, South Italy*. Geomorphology, 69, 169-190.

SCARCIGLIA F., PULICE I., ROBUSTELLI G. & VECCHIO G. (2006) - *Soil chronosequences on Quaternary marine terraces along the northwestern coast of Calabria (Southern Italy).* Quaternary International, Vol. 156-157, 133-155.

SCHOENEBERGER, P.J., WYSOCKI, D.A., BENHAM, E.C. & SOIL SURVEY STAFF (2012) - *Field Book for Describing and Sampling Soils, Version 3.0*. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE, 300 pp.

SIMON M., SANCHEZ S. & GARCIA I. (2000) - *Soil-landscape evolution on a Mediterranean high mountain*. Catena, 39, 211-231.

SOIL SURVEY DIVISION STAFF (1993) - *Soil Survey Manual*. In: USDA-NRCS Agricultural Handbook No. 18. U.S. Gov. Print. Office, Washington, DC.

STOOPS G. (2003) - *Guidelines for Analysis and Description of Soil and Regolith Thin Section*. Soil Science Society of America, Inc., Madison, WI, USA, 184 pp.

STOOPS G., MARCELLINO V. & FLORIAS M. (2010) - *Interpretation of micromorphological features of soils and regoliths*. Elsevier, Amsterdam, 720 pp.

TAN Z., LAL R.,. SMECK N.E, CALHOUN F.G., SLATER B.K., PARKINSON B. & GEHRING R.M. (2004) - *Taxonomic and geographic distribution of soil organic carbon pools in Ohio*. Soil Soil Science Society of America Journal, 68, 1896-1904.

THOMAS, M.F., THORP, M. & MCALISTER, J. (1999) - *Equatorial weathering, landform development and the formation of white sands in north western Kalimantan, Indonesia*. Catena, 36, 205-232.

TORRENT J., SCHWERTMANN U. & SCHULZE D.J. (1980) - *Iron oxide mineralogy of some soils of two river terrace sequences in Spain*. Geoderma, 23, 191-208.

TRICART, J. & CAILLEUX, A. (1967) - *Traité de Géomorphologie* 2, Sedes, Paris, 512 pp.

TROMBINO L. (1996) - *Lateriti nelle Regioni Mediterranee: Studio Micromorfologico del Paleosuolo dell'Altopiano delle Mànie (Finale Ligure).* Atti Ticinensi di Scienze della Terra, Serie Speciale, 4, 65-76.

USDA, UNITED STATES DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE (1993) - *Soil Survey Manual*. Handbook 18, United States Department of Agriculture, Natural Resources Conservation Service, Washington, D.C., 438 pp.

USDA, UNITED STATES DEPARTMENT OF AGRICULTURE NATURAL RESOURCES CONSERVATION SERVICE (2006) - *Keys to Soil Taxonomy, Tenth Edition*. United States Department of Agriculture, Natural Resources Conservation Service, Washington, D.C., 438 pp.

VAN VLIET-LANOË B. (2010) - *Frost Action*. In: STOOPS G., MARCELLINO V. & FLORIAS M. (Eds.), *Interpretation of micromorphological features of soils and regoliths*. Elsevier, Amsterdam, 81-108.

VAN VLIET-LANOË B. (1990) - *The genesis and age of the argillic horizon in Weichselian loess of northwestern Europe*. Quaternary International, 5, 49-56.

VICINO G. (1982) - *Il Paleolitico inferiore in Liguria*. Atti XXIII Riunione Scientifica Istituto Italiano Preistoria e Protostoria, Firenze.

VORPAHL P., ELSENBEER H., MÄRKER M., & SCHRÖDER B. (2012) - *How can statistical models help to determine driving factors of landslides?* Ecological Modelling, 239, 27-39.

KLINGEBIEL A.A. & MONTGOMERY P.H. (1961) - *Land capability classification*. USDA Agricultural Handbook 210, Washington, DC, 21 pp.

WISCHMEIER W.H. & SMITH, D.D. (1978) - *Predicting rainfall erosion losses - a guide to conservation planning*. In: US Department of Agriculture Science and Education Administration Agriculture, Handbook No. 537, Washington, DC.

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