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# LANDFORMS AND SOIL EVOLUTION IN SOME KARSTIC AREAS OF THE LESSINI MOUNTAINS AND MONTE BALDO (Verona, Northern Italy)

ABSTRACT: MAGALDI D. & SAURO U., *Landforms and soil evolution in some karstic areas of the Lessini Mountains and Monte Baldo (Verona, Northern Italy)* (IT ISSN 0084-8948, 1982).

In different karstic areas of the southern Lessini Mountains and on Monte Baldo, slope and dolina-filling deposits may be observed, composed of mainly silty-textured materials affected by old pedogenetic phenomena. The interdisciplinary study of the different karstic landforms, slope deposits, and relative paleosols revealed the close links existing between local lithologico-structural situations, old and recent tectonic activity, and geomorphic and pedogenetic processes.

The current aspect of the karstic landscape of the Lessini Mountains and Monte Baldo is, in sum, the result of phases of intense karstic morphogenesis (accompanied by very evident pedogenesis in climatic conditions similar to those currently existing in subtropical areas) alternating with periglacial phases, during which dismantling processes of the karstic relief predominated while pedogenetic processes were greatly slowed down. During the latter phases, loess covers were also deposited, deriving from the great glacial tongues of Lake Garda and the River Adige. Neotectonics was of primary importance in the evolution of the morphostructures. Recent uplifts of a few hundred metres are easily recognizable in several places.

A diagram of the succession of the events of local chronostratigraphic significance is presented at the end of the paper.

RIASSUNTO: MAGALDI D. & SAURO U., *Geomorfologia ed evoluzione dei suoli in alcune aree carsiche dei M. Lessini e del M. Baldo (Verona, Italia Settentrionale)* (IT ISSN 0084-8948, 1982).

In diverse aree carsiche dei Lessini meridionali e del M. Baldo si osservano depositi di versante e di riempimento delle doline costituiti da materiali a tessitura prevalentemente limosa, interessati da fenomeni di pedogenesi antica. Lo studio interdisciplinare delle differenti morfologie carsiche, dei depositi di versante e dei relativi paleosuoli, ha messo in evidenza gli stretti rapporti che intercorrono tra le situazioni litologico-strutturali locali, l'attività tettonica antica e recente, i processi geomorfici e i processi pedogenetici.

L'attuale aspetto del paesaggio carsico dei Lessini e del Monte Baldo è in definitiva il risultato di fasi di intensa morfogenesi carsica (a cui si accompagnava una pedogenesi molto spinta in condizioni climatiche paragonabili a quelle esistenti attualmente nelle zone subtropicali), alternate a fasi di tipo periglaciale, durante le quali predominavano i processi di smantellamento del rilievo carsico, mentre i processi pedogenetici erano estremamente rallentati. Durante queste ultime fasi è avvenuta anche la deposizione di coltri loessiche, provenienti dalle grandi lingue glaciali del Garda e dell'Adige. La Neotettonica ha avuto un ruolo di primaria importanza nella evoluzione delle morfostrutture. Sollevamenti recenti, dell'ordine di qualche centinaio di metri, sono facilmente riconoscibili in diverse località.

A conclusione dello studio viene presentato uno schema della successione degli eventi di significato cronostratigrafico locale.

TERMINI-CHIAVE: Paleopedologia; morfogenesi di aree carsiche; loess; Pleistocene; Prealpi Venete.

## 1. INTRODUCTION

Among the most problematic aspects of the evolution of the Prealpine relief—in particular of the areas not involved in the Pleistocene glaciations—are morphodynamics and morphochronology.

In order to study these aspects from the point of view of interdisciplinary research, we aimed at a research on the relationships existing between morphogenesis and paleopedogenesis in two karstic areas of the western Venetian Prealps. The chosen areas were the high Valpantena in the Lessini Mountains and the southern sector of Monte Baldo, both near Verona (fig. 1), which were never covered by glaciers and which show peculiarities of karstic morphology, morphostructural alignments, and extent of thick covers of Pleistocene sediments influenced by ancient pedogenetic phenomena, all conditions which make them particularly suitable for research of this kind.

Moreover, as we shall see, genesis of the covers cannot be explained by considering only local situations. Instead, it depends to a great extent on the location of these areas with respect to the large glacial tongues of the Adige River and Lake Garda. The relationship between Alpine glacialism and evolution of the slopes in periglacial conditions allows us to make chronological correlations which are useful for reconstruction of the history of the relief, which was instead influenced by subtropical climatic conditions during the interglacial periods.

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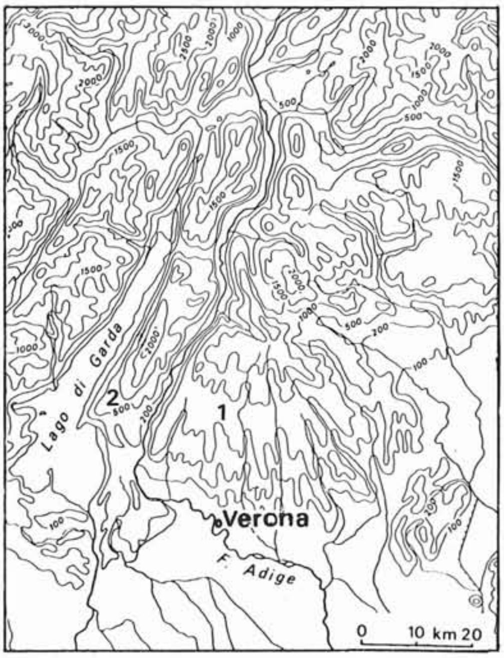

FIG. 1 - Location of the areas described in this paper: 1) large slope of Lughezzano in the Lessini Mountains; 2) southern Monte Baldo.

The high Valpantena, defined by the large ridges of the Lessini plateau, is about 10 km away from the morainic and fluvioglacial structures and the high plain.

The southern margin of the karstic plateau of Monte Baldo is only about 3 km both from the NE sector of the great morainic amphiteatre of Garda and from the most northerly hills of the morainic amphiteatre of the Adige (planimetric distances). These glacial reliefs are about 300-500 m lower than the margin of the plateau. The distance between the western sector of the plateau and the left-hand lateral moraines of the Garda glacier, lying on the western slope of Monte Baldo, is even less (1-2 km).

In the two areas considered, the relief is modelled in thick, relatively homogeneous, lower Jurassic limestone formations (Calcari Oolitici di S. Vigilio and Calcari Grigi di Noriglio).

The influence of lithology on morphogenesis is minor at this point, and does not facilitate the identification of selective forms of erosion or characteristic morphological types, as in the case of the Biancone and Rosso Ammonitico limestone formations, respectively of the lower Cretaceous and middle/upper Jurassic. The forms of the relief thus express the nature of the processes which produced them with greater clarity.

## 2. GEOMORPHOLOGICAL FRAMEWORK

### 2.1 The high Valpantena

The structural conditions and morphological features of the left slope of the high Valpantena at Lughezzano have already been reported in two preceding works (Sauro, 1978; Magaldi, Peretto & Sauro, 1981) (fig. 2).

The slope presents an irregular surface for about 450 m difference in elevation, with an average gradient of about 16°, composed of a succession of tectonic scarps (gradients of about 30°) and subhorizontal benches. The lower Jurassic limestones composing most of the slope are deeply karstified and, under the cover of Pleistocene and Holocene sediments, modelled into a complex of rounded spurs separated by grikes (*Rundkarren*).

The benches show some large dolinas, lengthened and aligned is a N-S direction. Their forms are only slightly accentuated on the surface, since they are almost completely covered with sediments, but they are still active (as shown by the presence of some ponors).

The main dolinas are:

— Ca' di Sotto, a large depression about 300 m long on the bench extending slightly under and West of Ca' di Sotto, and almost "open" towards the small gorge to the North;

— the dolinas of Ferrari, two ill-defined and smaller dolinas (∅ 60-80 m), plate-shaped, at the village of Ferrari slightly downstream from the village of Lughezzano;

— the two long dolinas situated North of Orsara, along the depression between the ridges of Monte Castelletto and Monte Ornai.

The slopes also show small valleys following the direction of the main tectonic lines (N-S). They are truncated by the cataclinal valleys running towards the main fault-angle depression; the former are profondly entrenched with steps corresponding to the scarps. The alternation of steep and undulating stretches, the presence of closed depressions, and the minutely irregular morphology of the rocky substrate caused a differentiation in the morphogenetic processes characterizing this large slope during the Quaternary.

### 2.2 Slope deposits in the high Valpantena

Thick and extensive detritic covers are to be found on the slopes and lower belts of the scarps on the left slope of the high Valpantena. Accumulations of large limestone blocks, sometimes embedded in a reddish clayey matrix and covered with a clayey silt, are often found at the base of the scarps. Below the clays or in positions where they were eroded, breccias of strongly cemented, angular, limestone fragments are sometimes found. The thickest covers of clay and silt are found in the dolinas which, as already noted, are often almost filled in.

A typical cross-section obtained from the observation of many outcrops (including a deep, recently-opened trench near Ca' di Sotto) may be described as follows (from top to bottom):

1) large limestone blocks embedded in soil sediments, replaced lateraly by breccias and/or by bluish clay;

2) mainly clayey-textured paleosols;

3) paleosols of mainly silty texture, more than 1 m

thick, disturbed by solifluxion phenomena and by colluvia;

4) loess-type silts, with recent paleosols at the top, disturbed by solifluxion;

5) silty colluvia and/or soil sediments;

6) modern soils.

### 2.3 Southern sector of Monte Baldo

In this sector the main morphological units are shown by: the surface of a large karstic plateau; a paleovalley defining it to the West and then dissecting it towards the SE, separating it from two narrow southern sectors (Monte Risare and Monte Belpo); the large scarps defining the plateau at its sides and to the South (fig. 3).

The surface of the plateau, which extends for about 6 km North to South and 3-4 km East to West, is generally tilted westwards, gradients mainly being about 20 % (although their total range is between 10 % and 30 %). The highest point is the Ex-Forte di Naole (1 675 m elev.), while the lower sectors are those of Monte Risare (876 m elev.) and Monte Belpo (880 m elev.) South of the Lumini paleovalley. Due to the marked articulation of this somewhat undulating surface, plateau features are provided by the strong contrast with the steep boundary scarps with gradients between 40 % and 60 % and the strong energy of the relief of the main chain towards the North.

The paleovalley of Prada-Lumini, composed of a series of depressions, begins at Baito Scale (1 130 m) slightly South of the Valle di Trovai on the large western slope of Monte Baldo, and extends for about 7 km to the SSW, defining the karstic plateau westwards as far as Baitei (725 m). It then bends for about 1.5 km South as far as Lumini (695 m) and finally SE in the direction of the underlying plain of Caprino (about 250 m). North of Baitei the paleovalley has been captured at several points by the narrow, steep, perpendicular valleys running towards Lake Garda.

South of Baitei the paleovalley becomes a kind of large basin (Lumini basin) which begins with an uvala about 1 km long and 200 m wide, with a subhorizontal floor. A low rim, on which Lumini di Là is situated, separates this uvala from a large dolina about 400 m across. Two other smaller dolinas are found South of the small hill of Lumini.

The delineating scarps show various aspects and features: West of the paleovalley towards Lake Garda, they correspond to a regular monoclinal stratification surface; instead, South and East, tectonic scarps are found, variously evolved by erosion. In the NE sector in particular, a step-like structure of tectonic scarps separated by narrow benches may be recognized. The benches show morphological features very similar to those of the higher overlying plateau. The largest benches are those of Malga Valfredda and Saugolo.

The most characteristic forms supplying indications on the evolution of the relief during the Quaternary are found mainly within the plateau and paleovalley, in which erosion was relatively slower than in the delineating scarps (fig. 3). The following forms are easily distinguishable: tectonic scarps of recent geodynamic evolution, karstic depressions of various sizes and aspects, small dome- or cone-shaped hills, and small valleys of cataclinal type, generally running West.

Within the ambit of the plateau, tectonic scarps, of very recent geodynamic evolution and very well preserved, are small, only exceeding a few dozen metres in a few cases. Some are small walls 1-2 m high; at the base of others, extending continuously for several km, very small bluffs may be found, like those produced by the surface faulting which takes place during particularly violent seismic events, as happened here during the Postglacial. The scarps correspond to faults following the Giudicarie system (NNE-SSW) or running N-S, and truncate some karstic forms such as large dolinas (one large truncated form is recognizable slightly North of Cima Sparavero on both sides of the Naole fault-scarp). As they face East or ESE (the opposite direction to the general tilt of the plateau surfaces), these scarps were responsible for the formation of N-S-running depressions or morphotectonic valleys, of which the main ones are the Naole and Pralungo valleys (fig. 4).

The typology of the karstic depressions is particularly varied and interesting. Within the ambit of the plateau, the following five types (fig. 5) are readily distinguishable:

*a*) bowl-shaped dolinas;

*b*) dolinas with flat, horizontal, and very large floors, with a marked difference between minimum and maximum depths (difference between the highest and lowest points of the perimeter with respect to the floor of the depression);

*c*) dolinas with small planes in their interiors, with respect to which one or more funnel-shaped depressions are placed;

*d*) "open dolinas", with flat, horizontal floors not completely surrounded by slopes (in this case minimum depth is zero);

*e*) "opened dolinas" with no flat horizontal floor, consisting of bowl-shaped depressions with one side dissected by a small valley;

*f*) "hemi-dolinas" or cut dolinas with no flat horizontal floor, found on scarps or the sides of small valleys, interpreted as dolinas truncated along a tectonic throw surface, or due to the erosive retreat of a strongly sloping surface.

The distribution of these various types of karstic depression seems to be influenced both by altitude and by the gradient of the morphological surface on which they developed; thus, the more typical dolinas with flat horizontal floors and the "open dolinas" are found in the highest part of the plateau (figs. 6, 7, 8, 9); the opened dolinas and those aligned along small valleys are found in the lower sector, mostly in the areas with gradients of more than 20 %. Bowl-shaped dolinas with more normal features are found in the intermediate sector on less steep surfaces (e.g. Dosso dei Cavalli).

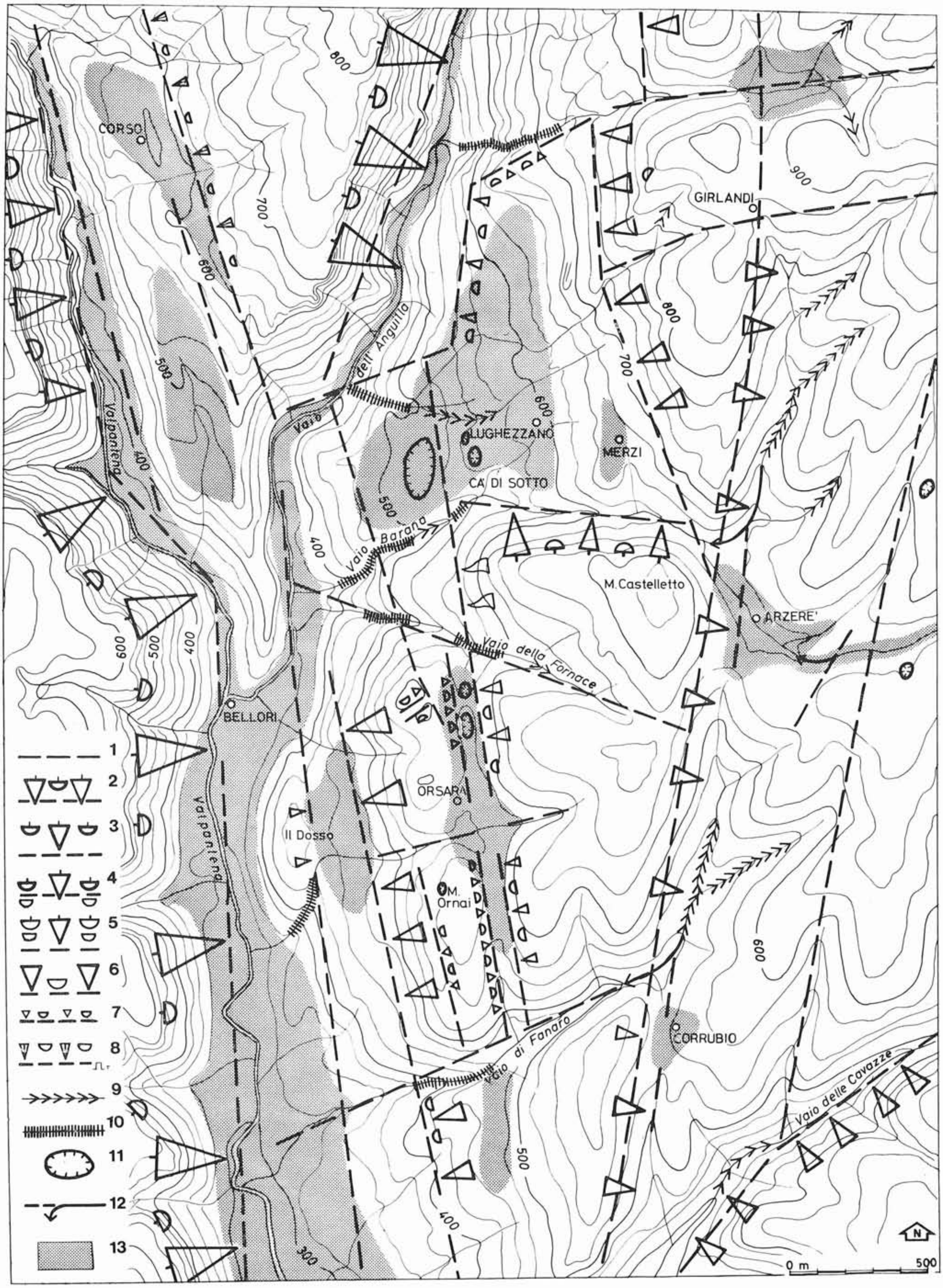


FIG. 2 - Morphostructural map of the high Valpantena in the Lessini Mts. Legend: 1) fault line; 2) scarp with top bluff and fault-line on slope; 3) scarp as in 1. but with fault line on valley floor; 4) and 5) as in 2. but with bluffs underlying the top bluff; 6) scarp with base bluff; 7) fault bluff; 8) fault bluff on monoclinal slope; 9) narrow, deep valley floors; 10) gorge with steps; 11) dolinas; 12) river capture; 13) thick detritic covers on valley floors and slopes (see also SAURO 1978 for typology and meaning of different fault scarps and fault-line scarps of the Lessini Mts.).

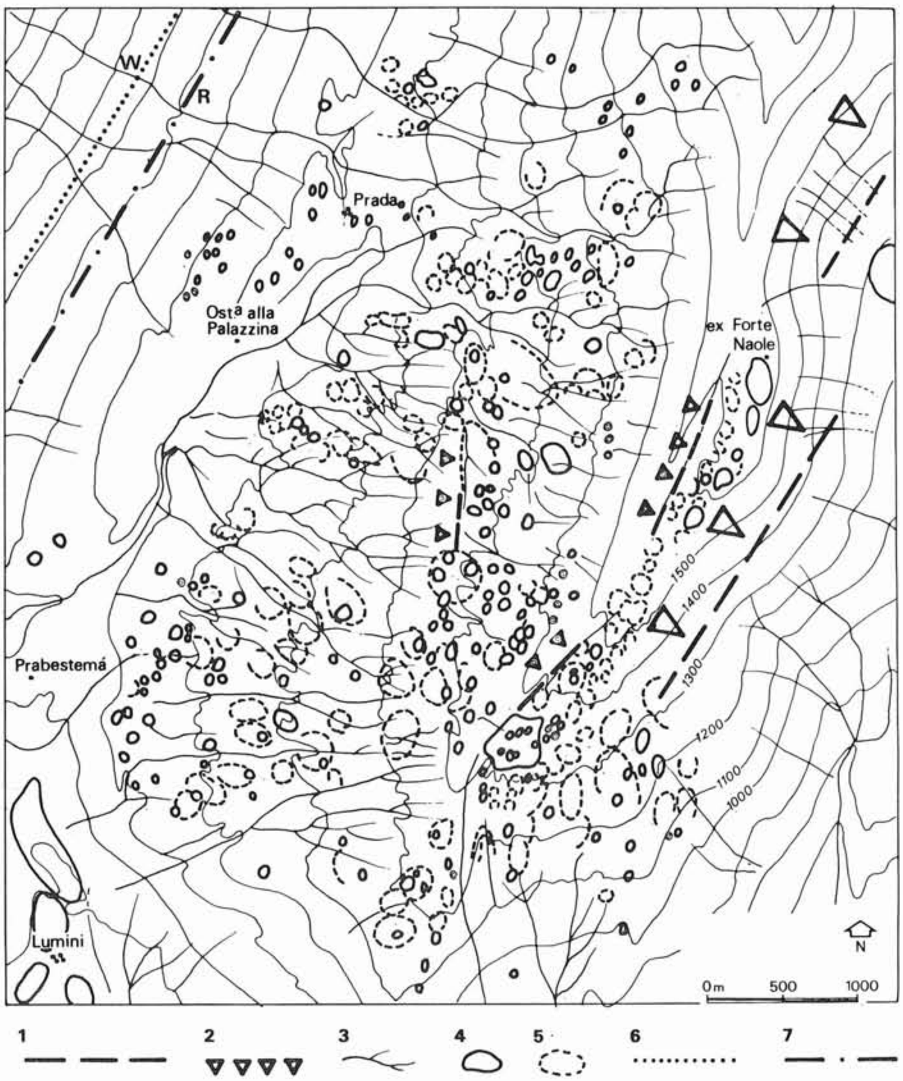


FIG. 3 - Morphological sketch of part of the southern plateau of Monte Baldo. Legend: 1) fault-line; 2) fault scarp; 3) network of small, mainly inactive, rounded-floor valleys inside plateau; 4) dolinas; 5) remains of perimeters of dolinas dismantled by erosion or completely filled by deposits; 6) approximate position of margin of glacial tongue of Lake Garda during maximum Würmiam expansion; 7) approximate position of margin of glacial tongue of Lake Garda during maximum Rissian expansion.

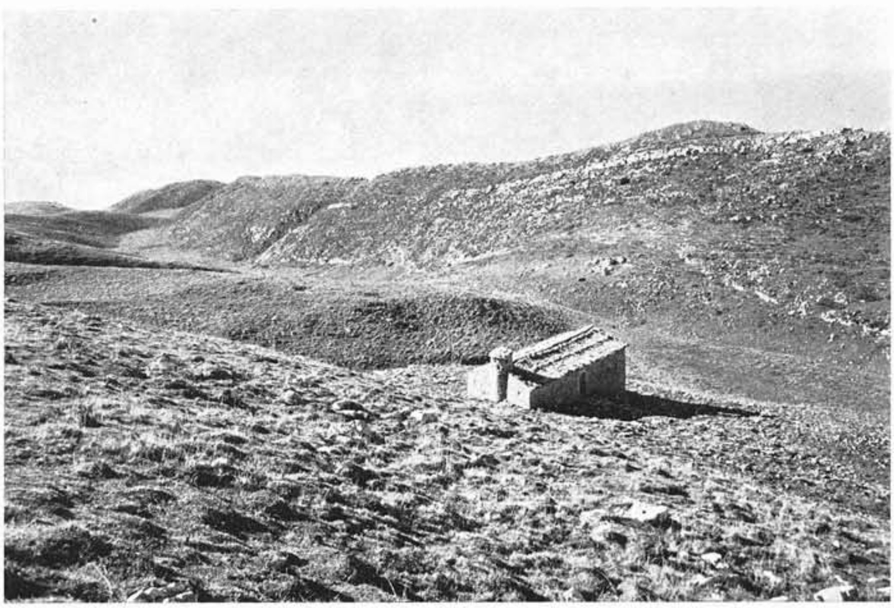

FIG. 4 - View of Naole fault scarp, with a small neotectonic wall visible at its base, formed by a very recent seismic event of presumably Holocene age.

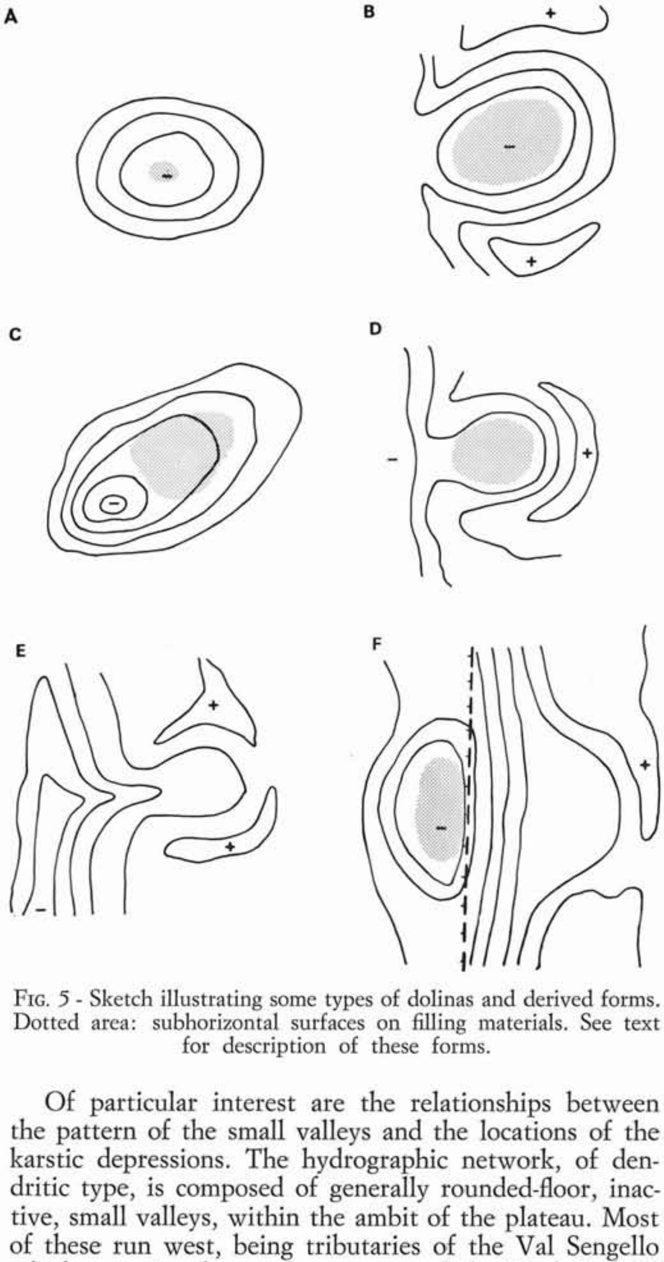


FIG. 5 - Sketch illustrating some types of dolinas and derived forms. Dotted area: subhorizontal surfaces on filling materials. See text for description of these forms.

Of particular interest are the relationships between the pattern of the small valleys and the locations of the karstic depressions. The hydrographic network, of dendritic type, is composed of generally rounded-floor, inactive, small valleys, within the ambit of the plateau. Most of these run west, being tributaries of the Val Sengello which occupies the northern sector of the Prada-Lumini paleovalley. The density of the dolinas is greatest in the areas with a modest slope, where the hydrographic network is less well developed. However, a careful study of the forms and analysis of aerial photographs (even in the deepest cut surfaces) shows the remains of the perimetral contours of many large dolinas, with diameters between 200 and 400 m, opened by erosion. Many of the more recent smaller dolinas are found grouped inside these "paleoforms". Among the more recent forms which may be correlated with the large dismantled depressions, we may quote the high dolinas of Naole and the large dolina of Colonei di Pesina, in which many other minor ones may be found. Some more or less cone- or dome-shaped hills rise a few dozen metres between the dolinas; the most characteristic are found in the sector south of Monte Sparavero.

## 2.4 SLOPE DEPOSITS AND FILLING DEPOSITS OF THE KARSTIC CAVITIES OF MONTE BALDO

Slope deposits with fine texture, almost absent on the steepest surfaces of the highest part of the plateau, are instead quite extensive in the southern area, where they are mainly composed of silts and clays.

FIG. 6 - One of the large dolinas at Naole, with flat, subhorizontal floor.

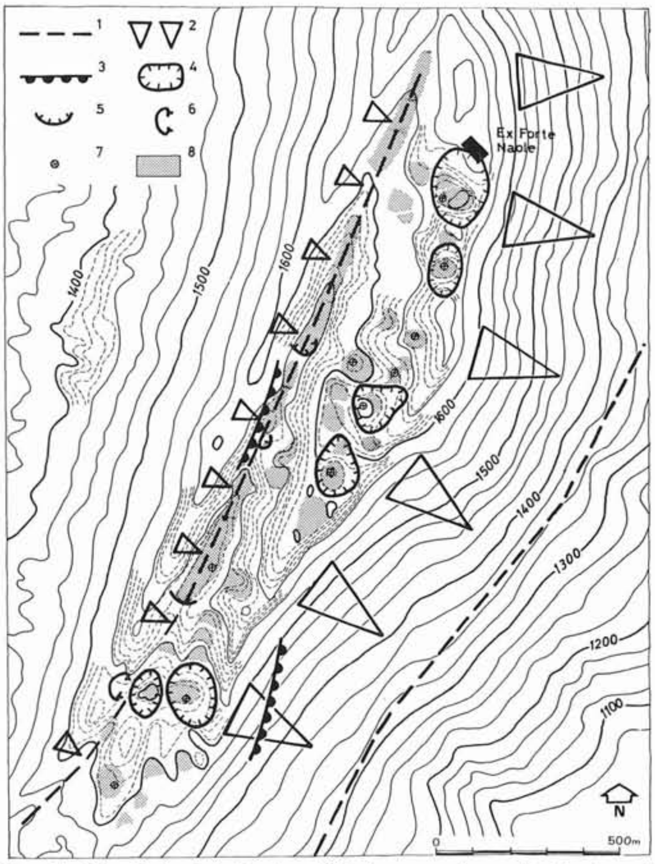


FIG. 7 - Morphological sketch of Naole area, where distribution of filling deposits of karstic cavities, characterized by flat, subhorizontal surfaces, allows recognition of relicts of many completely fossilized old dolinas. Legend: 1) fault-line; 2) fault scarp; 3) small fault step; 4) perimeters of easily identifiable dolinas; 5) countergradient in karstic valley; 6) hemi-dolina dislocated by Naole Fault; 7) ponor; 8) flat or almost flat surfaces on filling deposits of karstic depressions.

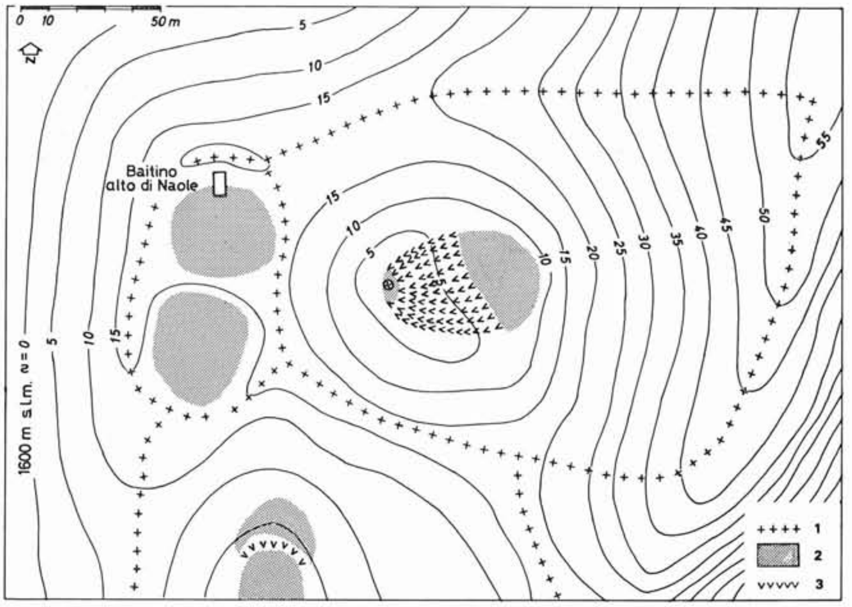


FIG. 8 - Large-scale topographic sketch of Baitino Alto di Naole area, showing clearly, left: two filled, inactive dolinas; low right: two active dolinas in which reabsorption of filling materials is taking place. Legend: 1) watershed; 2) subhorizontal surfaces on thick filling deposits; 3) scarp on deposits.

Due to te marked articulation of the karstic relief, these deposits vary in thickness from one point to another, being thickest inside the karstic depressions. Excavations and geophysical surveys have ascertained the presence inside the dolinas of the summit area (near Naole) of filling deposits sometimes more than 10 m thick, while cover thicknesses seem to become even greater in areas with lower elevation (BENVENUTI & SAURO, 1977).

These materials, which mask the rocky floor of the karstic dolinas and depressions, are responsible for the peculiar morphological features of this area. Indeed, it may be maintained that most of the dolinas have a rocky funnel-shaped floor or deep bowl shape and that the filling deposits are responsible for the different aspects of these depressions, sometimes filling them to the rim.

In the two dolinas of the Naole ridge which have been the subject of geophysical surveys, the buried slopes are much steeper than the exposed ones (BENVENUTI & SAURO, 1977). From this, it may be deduced that the ancient karstic relief had higher energy than the current one (fig. 9).

While the filling deposits of the higher area are mainly composed of rather angular limestone fragments varying in diameter from a few centimetres to some decimetres and embedded in a yellowish silt, at lower altitudes the percentage of silts and clays increases. In the vertical section of excavation in the filling deposits of some *b*) type dolinas in the Naole area (1 600 m elev.), it could be seen how many of the longer rocky fragments had been verticalized (i.e. their major axis was arranged vertically); others were aligned to produce approximately wedge-shaped forms sometimes more than 1 m high, interpreted as periglacial structures (wedges?).

On other sections in the Lumini basin deposits, impressions of other *soil wedges* are easily recognizable: in a paleosol of silty-clayey texture (Lumini Paloesol I?: see below), on a small scarp at about 700 m NNW of Lumini di Là, wedges a few cm wide and a few dm deep may be observed, filled with a practically unaltered silt. One particularly interesting section is found near foundation excavations for a house, about 500 m North of Lumini di Là. Here, a silty-textured paleosol (Fragiudalf?) is covered by an older clayey-textured soil sediment (Lumini Paleosol II?; see below) showing slickensides arranged according to the slope gradient. These structures suggest slow solifluxion in periglacial conditions in a lobe of Paleosol II which covered a more recent soil. Many large cracks in the silty paleosol are filled by the overlying clays (the largest of the wedges is max. 15 cm wide and more than 80 cm deep). When excavating near the wedges, it can be observed how these forms extend inside the deposits without undergoing significant variations in thickness. Another silty-textured paleosol with smaller wedges may be noted above the clayey paleosol, the wedges filled with practically unaltered silts (fig. 10).

The features of these sections which, together with others, will be described in detail in a later note, supply paleoenvironmental indications regarding periods of periglacial climate (1).

## 3. PALEOSOLS OF THE HIGH VALPANTENA AND MONTE BALDO

Slope deposits, giving this term only a morphological and not strictly genetic name, and filling deposits are widespread, although in the form of small strips, often affected by non-actual pedogenetic weathering phenomena.

Because of the particular location, they are often disturbed by solifluxion or overland flow.

Our pedological and sedimentological study, therefore, had to be limited to three sections only, relatively un-

(1) According to most Authors, these types of wedge are not definite proof of the existence of true permafrost, but of very similar conditions. However, WASHBURN (1973, p. 99) maintains that they may in any case represent permafrost indicators, since active wedges in areas lacking in permanently frozen soils have never been recognized.

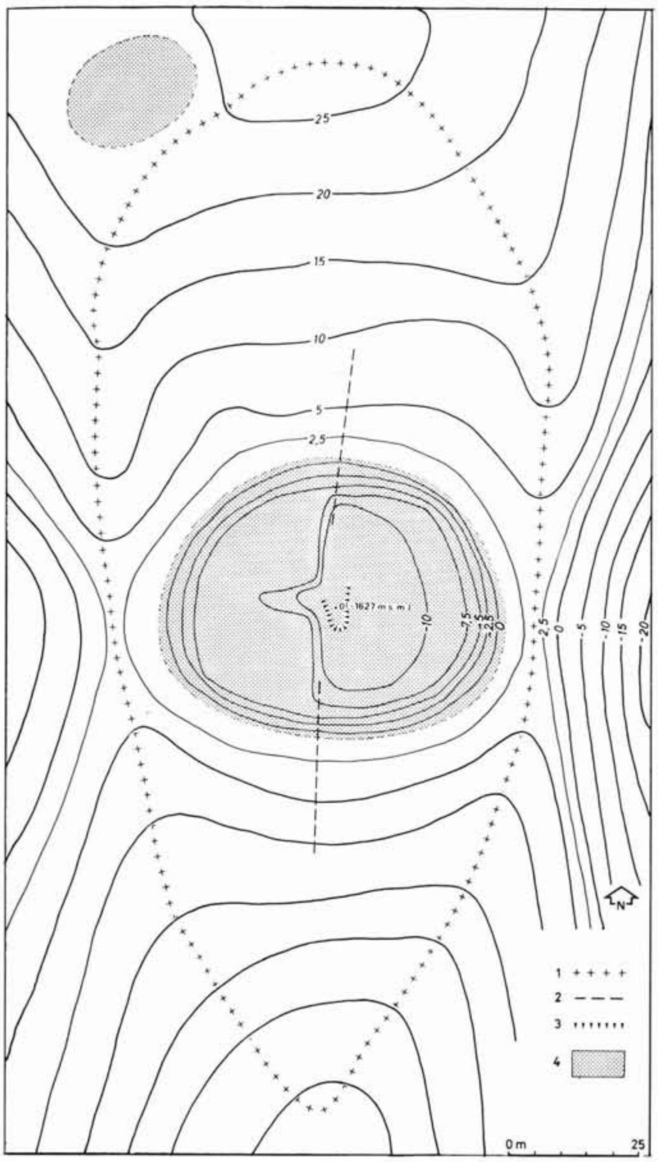

FIG. 9 - Topographic sketch of a large dolina at Naole (second south of Ex-Forte). As well as contour lines, sketch indicates contours of the rock floor, occupied by periglacial filling deposits. Legend: 1) watershed; 2) probable fault-line; 3) small scarps of depression on filling materials; 4) area occupied by filling deposits on which a subhorizontal surface extends.

disturbed, representing typical situations of old pedogenesis in the high Valpantena and on Monte Baldo.

### 3.1 LUGHEZZANO PROFILE (VALPANTENA)

At the margins of the village of Lughezzano, exactly at the junction between a scarp downstream from the centre of the village and the bench of Tessari, a very characteristic succession of soils involving a slope deposit, composed mainly of fine materials, may be seen at several points.

The following description has already been briefly noted in a previous paper (MAGALDI, PERETTO & SAURO, 1981).

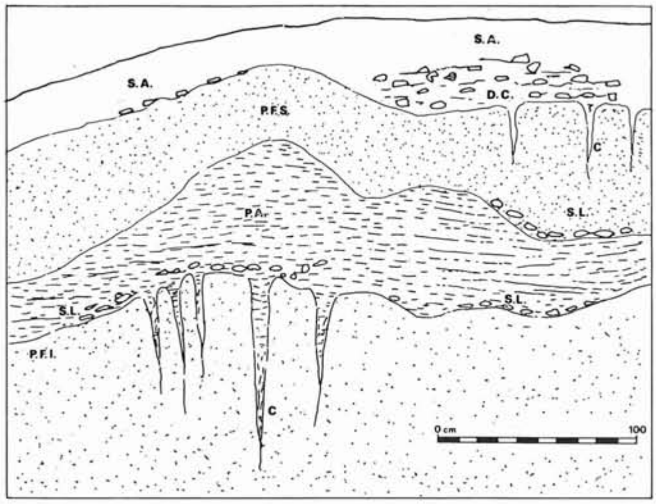

FIG. 10 - Vertical section in slope deposits, recently uncovered by excavations in Conca di Lumini (drawing based on two photographs). From bottom to top: P.F.I.: mainly silty paleosol of Fragiudalf type, with "wedges" filled with overlying material; P.A.: mainly clayey paleosol sediments of Lumini type II, subject to solifluxion; P.F.S.: paleosol similar to lower one (silty) with other impressions of small "wedges" filled with unaltered silt. At top of series, note colluvial deposits (D.C.) and modern soil (S.A.).

Undisturbed samples for thin-section analysis were taken from the various rock-layers described in the field.

Elevation: 592 m.
Land form: steep mountainous slope.
Land use: grassland.
Stoniness: no stones.
Rockiness: no rocks.

Ap — 0-90 cm. Dark yellowish-brown (10 YR 4/6) moist, light yellowish-brown (10 YR 6/5) dry silt loam; frequent fine gravel; fine subangular blocky; friable moist, slightly hard dry; common fine pores; common biological activity and medium roots; non-calcareous; clear smooth boundary.

II B21 — 90-140 cm. Reddish-yellow (7.5 YR 6/6) dry silt loam; very little fine gravel of weathered chert; weak fine prismatic; firm moist, hard dry; slightly sticky; common coarse pores; common biological activity and medium roots; common clay cutans on ped faces; few Fe/Mn cutans; few weak reddish mottles; non-calcareous; clear smooth boundary.

II B22 — 140-180 cm. Reddish-yellow (7.5 YR 4/4) dry silt loam; common reddish-brown (2.5 YR 4/4) mottles; frequent coarse gravel of fresh angular chert (stone line); medium subangular blocky; sticky; firm moist, hard dry; common fine pores; common clay cutans on ped faces; frequent Fe/Mn nodules and coatings; non-calcareous; clear smooth boundary.

III B21b — 180-220 cm. Reddish-brown (2.5 YR 4/4) dry clay; common coarse red (2.5 YR 4/7) mottles; very little fine gravel; strong medium to coarse prismatic structure; very sticky; very firm moist, very hard dry; common coarse Fe/Mn cutans; frequent slickensides and pressure faces; few clay cutans; non-calcareous; clear smooth boundary.

III B22b — 220-300 cm. Dark reddish-brown (2.5 YR 3/4) dry clay; common mottles as above; weak medium angular blocky; very sticky; very firm moist, very hard dry; very frequent Fe/Mn coatings; frequent small Fe/Mn nodules; frequent slickensides and pressure faces; non-calcareous.

Both from field observations and laboratory analyses (table 1), it is clear that the profile is composed by the overlapping of two soils separated by a stone line of angular and nearly fresh siliceous gravel.

TABLE 1

ANALYTICAL DATA OF LUGHEZZANO PROFILE.

| Depth (cm) | Horizon | Texture % Sand | % Silt | % Clay | % Organic Carbon | % Organic Matter | pH | Extractable Bases (meq) Ca | Mg | Na | K | % Ext. Acidity (meq) | C.E.C. (meq) | % Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-90 | Ap | 16.8 | 63.8 | 19.4 | 0.86 | 1.48 | 7.0 | 6.6 | 0.1 | 0.3 | 0.1 | 2.6 | 9.7 | 73 |
| 90-140 | IIB21 | 24.9 | 56.3 | 18.8 | 0.73 | 1.26 | 7.1 | 7.5 | 0.2 | 0.3 | 0.1 | 3.1 | 11.2 | 72 |
| 140-130 | IIB22 | 19.7 | 53.5 | 26.8 | 0.93 | 1.60 | 7.1 | 8.6 | 0.8 | 0.2 | 0.1 | 4.2 | 13.9 | 70 |
| 180-220 | IIIB21b | 4.7 | 18.1 | 77.2 | 0.60 | 1.04 | 6.0 | 19.3 | 6.6 | 0.3 | 0.4 | 10.0 | 36.6 | 73 |
| 220-300 | IIIB22b | 5.5 | 19.7 | 74.8 | 0.47 | 0.81 | 5.1 | 13.1 | 4.9 | 0.3 | 0.4 | 16.0 | 34.7 | 54 |

The upper paleosol (Paleosol I for short) is a typical Alfisol with some weak hydromorphic features expressed by weak reddish mottles and Fe/Mn nodules, lying on mainly silty quartzous materials.

In thin section (table 2) it may be seen how the actual A horizon formed at the expense of already pedogenized materials with argillic B features, similar to the underlying ones. B horizon shows evident clay skins and evidence of intense eluviation from higher A2 horizons which have now disappeared. The plasmatic fabric type (sepic) and presence of papules and subcutanic features indicate the frequent alternation of swelling and drying periods, also responsible for the good degree of structure of the horizon.

The effects of hydromorphic phenomena may be seen more clearly than in the field: Fe-poor areas may be found, together with Fe/Mn-enriched globules. The fact

TABLE 2

SHORT DESCRIPTION (ACCORDING TO BREWER 1964) OF MICROMORPHOLOGICAL FEATURES OF LUGHEZZANO PROFILE AND OF LUMINI STRADA SECTION. OF THE SKELETON (SKELETON GRAINS ACCORDING TO BREWER 1964), SEE FREQUENCY PERCENTAGE, TEXTURE (S = SAND, L = SILT), MINERALOGICAL COMPOSITION AND MOST FREQUENT LITHOLOGY. COLOR OF PLASMA IS EXPRESSED ACCORDING TO MUNSELL SOIL COLOR CHARTS. FOR SOME PEDOLOGICAL FEATURES, FREQUENCY INSIDE THE GROUP (P = PREDOMINANT, C = COMMON) IS ALSO GIVEN.

| | LUGHEZZANO PROFILE | | | | | LUMINI (ROAD) | |
|---|---|---|---|---|---|---|---|
| | A p | II B 21 | II B 22 | III B 21b | III B 22b | above horizon | below horizon |
| SKELETON GRAINS | 20% S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT, etc. | 10% S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT | 15% S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT | 5% S<L QUARTZ, CHERT | 5% S<L CHERT, QUARTZ | 20% S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT | 5% S<L CHERT, CHALCEDONIC NODULES, QUARTZ |
| PLASMA | 10 YR 3/3 ANISOTROPIC | 7.5 YR 5/8 ANISOTROPIC | 7.5 YR 5/8 ANISOTROPIC | 2.5 YR 4/7 ANISOTROPIC WITH SOME IRON IDROXIDES FLOCS | 2.5. YR 3/6 ANISOTROPIC WITH SOME IRON IDROXIDES FLOCS | 5 YR 4.5/6 ANISOTROPIC | 2.5 YR 4/8 ANISOTROPIC WITH SOME IRON IDROXIDES FLOCS |
| PLASMIC FABRIC | SILASEPIC | SILASEPIC TO MASEPIC | SILASEPIC TO MASEPIC | VOMASEPIC TO OMNISEPIC | VOMASEPIC TO OMNISEPIC | SILASEPIC TO MASEPIC | VOMASEPIC |
| BASIC FABRIC | AGGLOMEROPLASMIC TO PORPHYROSCHELIC | AGGLOMEROPLASMIC TO PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC |
| VOIDS | P= IRREGULAR VUGHS S= CHANNELS | P= VUGHS AND CHANNELS S= VESICLES | P= VUGHS S= CHANNELS | P= CHANNELS S= VUGHS | P= CHANNELS S= VUGHS | P= IRREGULAR VUGHS S= CHANNELS AND CHAMBERS | P= ACICULAR PLANES |
| CUTANS | — | COMMON ILLUVIATION FERRIARGILLANS | COMMON ILLUVIATION FERRIARGILLANS | P= STRESS-CUTANS S= ILLUVIATION FERRIARGILLANS | P= STRESS-CUTANS S= ILLUVIATION FERRIARGILLANS | COMMON ILLUVIATION FERRIARGILLANS | P= STRESS-CUTANS S= ILLUVIATION FERRIARGILLANS |
| GLAEBULES | P= Fe/Mn NODULES S= GLAEBULAR HALOS AND CUTANIC PAPULES | P= Fe/Mn NODULES S= PAPULES AND IRON CONCRETIONS | P= Fe/Mn NODULES AND CONCRECTIONS S= PAPULES | P= CUTANIC PAPULES S= IRON IDROXIDE GLAEBULAR HALOS | P= PAPULES S= IRON IDROXIDE GLAEBULAR HALOS | P= Fe/Mn NODULES S= PAPULES | P= Fe/Mn NODULES S= PAPULES AND CONCRECTIONS |
| PEDORELICTS | — | FRAGMENTS FROM BELOW HORIZONS | FRAGMENTS FROM BELOW HORIZONS | — | — | FRAGMENTS FROM BELOW HORIZONS | FRAGMENTS FROM ABOVE HORIZON |
| OTHER FEATURES | FECAL PELLETS | SUBCUTANIC FEATURES | — | SUBCUTANIC FEATURES | — | FECAL PELLETS AND SUBCUTANIC FEATURES | — |

that many clay cutans are covered with iron sesquioxides (sesquans) is also interesting.

Fe and Mn mobilization was probably later than that of the clays and may have been caused by the progressive stagnation of the water due to accumulation of the clay. In the deeper part of B horizon soil fragments (pedorelicts) coming from the underlying soil are found, together with fragments of greatly corroded chert impregnated with hydroxides, coarser than the materials composing the stone line.

Routine analytical data also agree with field and micromorphological observations.

In particular, Paleosol I has a neutral reaction and high saturation but low ion exchange capacity. These data are justified if we consider that the initially acid soil was later resaturated probably by waters circulating along the limestone slope and that the quantity of clay is rather low.

The second paleosol (Paleosol II of Lughezzano) has an argillic B characterized by stronger reddening, a strongly clayey texture very poor in coarse fragments, an abundance of pressure faces which tend partially to destroy the illuviation clay cutans, and different structure (prismatic to blocky).

In thin section, a plasma may be seen, composed of clay and very diffuse concentrations of iron hydroxides with common plasmatic separations near the planes (voids) and other voids. Stress cutans and papules derived from the dislocation of the illuviation clay cutans are also common, and denote the intense dynamic activity of the horizon during the swelling and drying phases.

The Fe/Mn nodules and concretions are very widespread and are due to periodic fluctuation of the water-table, which also caused the formation of some Fe-poor areas.

Illuvial cutans strongly disturbed by contraction and swelling phenomena are rather rare.

More or less rounded coarse chert fragments more than 2 mm long are also very interesting: the chalcedonic nodules are intensively corroded, decayed and impregnated with strongly oxidized iron hydroxides.

All these features suggest very advanced and probably polycyclic pedogenesis, in climatic conditions with marked differences between the dry and moist seasons.

Routine analytical data confirm the different pedogenetic evolution of the deeper horizons: the pH is lower, ion exchange is higher due to the abundance of clay, and organic matter tends to be scarcer.

### 3.2 Lumini profile (Monte Baldo)

In the depression of Lumini, a sequence substantially similar to that found at Lughezzano may be recognized. Here the pedogenized sediments, studied on a vertical section of about 6 m exposed after excavations in the village, are much thicker and more widespread, both due to their particular geomorphological situation and to probable soil creep phenomena which mobilized and variously distributed part of the materials.

Elevation: 695 m.
Land form: slope of a large dolina.
Land use: grassland.
Stoniness: no stones.
Rockiness: no rocks.

0-30 cm. Recently constipated material from excavations for building on top of soil.

Ap — 30-70 cm. Brownish-yellow (10 YR 6/6) dry silt loam; no coarse fragments; weak fine subangular blocky; friable moist, slightly hard dry; common roots; few fine pores; non-calcareous; abrupt irregular boundary.

II B21 — 70-120 cm. Strong brown (7.5 YT 5/6) dry clay loam; very little fine gravel; fine subangular blocky; firm moist, hard dry; frequent weak reddish mottles; common small Fe/Mn cutans and clay cutans; non-calcareous; gradual smooth boundary.

II B22 — 120-200 cm. Strong brown (7.5 YT 5/6) dry clay loam; very little fine gravel; coarse prismatic; frequent weak reddish mottles; very frequent Fe/Mn and clay cutans on the ped faces; firm moist, hard dry; noncalcareous; diffuse smooth boundary.

II B23 — 200-230 cm. Strong brown (7.5 YR 5/6) dry loam; no coarse fragments; moderate medium to coarse prismatic structure; frequent Fe/Mn cutans; frequent clay cutans and small Fe/Mn nodules; firm moist, hard dry; common red (2.5 YR 4/6) mottles; few weak yellowish mottles; non-calcareous; gradual smooth boundary.

II B24 — 230-280 cm. Strong brown (7.5 YR 5/6) dry loam; no coarse fragments; medium prismatic; common red (2.5 YR 4/6) mottles; very frequent Fe/Mn cutans; frequent Fe/Mn nodules and clay cutans; consistency as above; non-calcareous; diffuse smooth boundary.

II B25 — 280-330 cm. Reddish-yellow (7.5 YR 6/6) dry silty clay loam; no coarse fragments; structureless, massive; common red (2.5 YR 4/6) mottles; few clay cutans and nodules; frequent Fe/Mn coatings and nodules; common fragments of the above horizon; consistency as above; non-calcareous; abrupt smooth boundary.

III B2b — 330-500 cm. Dark red (2.5 YR 3/6) dry clay; little fine gravel of strongly weathered angular chert; coarse subangular blocky tending to prismatic structure; common slickensides and pressure faces; frequent Fe/Mn cutans and nodules; firm moist, very hard dry; very few clay skins on ped faces; non-calcareous.

The overlying paleosol (Lumini Paleosol I) is very similar to its correspondent at Lughezzano (table 3).

Texture varies from medium to moderately fine (according to Soil Taxonomy) and color, with the exception of the plow horizon, falls into the 7.5 YR page of Munsell Soil Color Charts. Here too, in a more definite way, features of slight hydromorphy may be seen, such as reddish mottles and Fe/Mn cutans.

B horizon, unlike Lughezzano, is very thick and clearly of the argillic type with sometimes very large clay cutans, visible even to the naked eye.

TABLE 3

Analytical data of Lumini profile.

| Depth (cm) | Horizon | Texture % Sand | % Silt | % Clay | % Organic Carbon | % Organic Matter | pH | Extractable Bases (meq) Ca | Mg | Na | K | % Ext. Acidity (meq) | C.E.C. (meq) | % Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30-70 | Ap | 15.2 | 61,3 | 23.5 | 1.07 | 1.85 | 5.0 | 4.1 | 0.2 | 0.2 | 0.3 | 6.5 | 11.3 | 42 |
| 70-120 | IIB21 | 31.9 | 38.9 | 29.2 | 0.53 | 0.91 | 5.5 | 6.6 | 0.6 | 0.3 | 0.1 | 7.4 | 15.0 | 51 |
| 120-200 | IIB22 | 32.9 | 34.8 | 32.3 | 0.60 | 1.04 | 4.6 | 3.5 | 0.8 | 0.2 | 0.1 | 8.3 | 13.4 | 34 |
| 200-230 | IIB23 | 30.7 | 43.9 | 25.4 | 0.53 | 0.91 | 4.6 | 2.1 | 1.6 | 0.3 | 0.1 | 9.7 | 13.8 | 30 |
| 230-280 | IIB24 | 46.3 | 37.1 | 16.6 | 0.47 | 0.81 | 5.0 | 4.5 | 2.1 | 0.3 | 0.1 | 8.5 | 15.5 | 45 |
| 280-330 | IIB25 | 19.8 | 50.4 | 29.8 | 0.60 | 1.04 | 5.0 | 3.6 | 0.2 | 0.2 | 0.1 | 6.6 | 10.7 | 38 |
| 330-350 | IIIB2b | 29.1 | 16.3 | 54.6 | 0.20 | 0.35 | 4.8 | 6.5 | 2.5 | 0.2 | 0.2 | 12.1 | 21.5 | 44 |

TABLE 4

SHORT DESCRIPTION (ACCORDING TO BREWER 1964) OF MICROMORPHOLOGICAL FEATURES OF LUMINI PROFILE (SEE ALSO CAPTION OF TABLE 2).

| | LUMINI PROFILE | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ap | II B 21 | II B 22 | II B 23 | II B 24 | II B 25 | III B 2b |
| SKELETON GRAINS | 50% . S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT, etc. | 7% . S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT, etc. | 15% . S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT, etc. | 20% . S<L QUARTZ, FELDSPARS MUSCOVITE, etc. | 20% . S<L QUARTZ, FELDSPARS CHALCEDONIC NODULES etc. | 7.5% . S<L QUARTZ, FELDSPARS MUSCOVITE, CHERT, etc. | 5% . S<L MAINLY CHERT, SCARCE QUARTZ |
| PLASMA | 10 YR 5/8 ANISOTROPIC | 5 YR 5/8 ANISOTROPIC | 7.5 YR 5/6 ANISOTROPIC | 5 YR 5/8 ANISOTROPIC | 5 YR 5/8 ANISOTROPIC | 5 YR 5/8 ANISOTROPIC | 2.5 YR 4/6 ANISOTROPIC WITH SOME IRON IDROXIDES FLOCS |
| PLASMIC FABRIC | SILASEPIC | SILASEPIC TO INSEPIC | SILASEPIC | SILASEPIC TO MASEPIC | SILASEPIC TO MASEPIC | SILASEPIC TO MASEPIC | VOMASEPIC AND OMNISEPIC |
| BASIC FABRIC | AGGLOMEROPLASMIC | AGGLOMEROPLASMIC TO PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC | PORPHYROSCHELIC |
| VOIDS | P= IRREGULAR VOIDS S= CHAMBERS | P= EQUANT TO PROLATE VUGHS S= SMOOTHED CHAMBERS AND PLANES | P=EQUANT TO PROLATE VUGHS S= SMOOTHED CHAMBERS | P= SMOOTHED VUGHS S= CHANNELS AND CHAMBERS | P= IRREGULAR CHANNELS S= CHAMBERS, VUGHS, PLANES | P= SMOOTHED VUGHS S= CHANNELS AND CHAMBERS | P= IRREGULAR CHANNELS S= SMOOTHED CHAMBERS AND VUGHS |
| CUTANS | ——— | COMMON ILLUVIATION FERRIARGILLANS SCARCE SESQUANS | COMMON ILLUVIATION FERRIARGILLANS SCARCE SESQUANS | COMMON ILLUVIATION FERRIARGILLANS | COMMON FERRIARGILLANS SCARCE SESQUANS | COMMON FERRIARGILLANS SCARCE SESQUANS | COMMON STRESS AND ILLUVIATION CUTANS |
| GLAEBULES | P= Fe/Mn NODULES S= CUTANIC PAPULES | P= Fe/Mn NODULES S= GLAEBULAR HALOS AND PAPULES | P= Fe/Mn NODULES S= GLAEBULAR HALOS AND PAPULES | P= Fe/Mn NODULES S= PAPULES AND IRON CONCRETIONS | P= Fe/Mn NODULES S= IRON CONCRETIONS AND PAPULES | P= Fe/Mn NODULES S= PAPULES | P= Fe/Mn NODULES S= PAPULES AND Fe/Mn CONCRECTIONS |
| PEDORELICTS | ——— | ——— | ——— | ——— | ——— | RED PEDORELICTS FROM BELOW HORIZON | ——— |
| OTHER FEATURES | FECAL PELLETS | ORTHO - SESQUIOXIDIC - STRIOTUBULES | ——— | ——— | NEOCUTANS AND QUASICUTANS | ——— | NEOCUTANS AND QUASICUTANS |

In thin section (table 4) signs of reworking may be seen in A horizon and abundant ferriargillans in B horizon; Fe and Mn hydroxide cutans are rarer.

The morphology and frequency of the cavities shows marked biological activity along the whole profile. The type of plasmatic fabric and frequency of papules show processes similar to those for Lughezzano Paleosol I. Overall, both the field and micromorphological features indicate pedogenesis similar to that of Lughezzano Paleosol I, but more advanced as regards alteration and evolution.

The chemical analyses are unlike those of Lughezzano, with decidedly more acid pH and a low base saturation, therefore confirming the greater alteration of the profile.

The paleosol excavated only for a small thickness under the soil now described (Lumini Paleosol II) differs from the overlying one due to its redder color (2.5 YR), strongly clayey texture, abundance of Fe/Mn cutans, and presence of pressure faces and slickensides. The micromorphological features are identical to those of Lughezzano Paleosol II, so they will not be described again here.

However, the chemical analyses show some differences with respect to the corresponding soil at Lughezzano: pH, ion exchange and degree of saturation are all slightly lower.

The stone line separating the two paleosols at Lughezzano is missing in the Lumini section. Instead, a transitional horizon appears, with features more similar to those of the overlying horizons but with abundant pedo-relicts coming from the underlying horizon, easily recognizable in thin section.

A similar but much smaller section is recognized along the road going through the village. The thin-section observations appear briefly in table 2 under the title "Lumini Road" and indicate that the samples come from soil horizons which were strongly disturbed by solifluxion phenomena connected with freezing and thawing.

A separate description must be given of the higher

Lumini horizon (0-70 cm). Because of the disturbance caused by excavations and plowing, a pedogenetic sequence which is definitely different from the underlying ones cannot be recognized. However, in the light of observations on other sections, it is probable that these horizons represent the remains of a more recent soil with the same mineralogical characteristics as the parent material of the underlying soil.

### 3.3 Naole profile (Monte Baldo)

The third profile examined is that of Naole, near one summit of the southern Monte Baldo.

Elevation: 1 610 m.

Land form: bottom of a dolina, almost flat surface.

Land use: alpine grassland.

Stoniness: fairly stony.

Rockiness: very few rocks.

02 — 0-35 cm. Very dark brown (10 YR 2/3) moist, dark brown (10 YR 3/3) dry silt; no coarse fragments; weak fine crumb structure; very friable moist, soft dry; common fine pores; common worm casts; abundant fine roots; non-calcareous; clear broken boundary.

B — 0-40 cm. Yellowish-brown (10 YR 5/4) dry silt loam; no coarse fragments; weak fine granular structure; very friable moist, soft dry; common biological activity; common fine roots and fine pores; non-calcareous; abrupt irregular boundary.

C — 40-140 cm. Light yellowish-brown (10 YR 6/4) dry silt loam; very frequent coarse gravel of weathered limestone; structureless, non-coherent; very friable moist, loose dry; non-calcareous; clear irregular boundary.

II R — < 140 cm. Fragments of S. Vigilio limestone with loess-like silt mixed.

This is an only slightly evolved soil (table 5) occupying the flat floor of a dolina-shaped cavity a few dozen metres in diameter. Pedogenesis began with a silty material lying on rocks of the Calcari di S. Vigilio Formation.

The profile contains an organic horizon and a cambic B horizon which may also be interpreted as an umbric epipedon. Pedogenesis seems substantially conditioned by acidification caused by slow decomposition of organic matter coming from the surface horizon.

TABLE 5

Analytical data of Naole profile.

| Depth (cm) | Horizon | Texture % Sand | % Silt | % Clay | % Organic Carbon | % Organic Matter | pH | Extractable Bases (meq) Ca | Mg | Na | K | % Ext. Acidity (meq) | C.E.C. (meq) | % Base Saturation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-35 | 02 | 9.6 | 82.8 | 7.6 | 15.41 | 26.50 | 5.5 | 7.1 | 0.5 | 0.3 | 0.1 | 33.0 | 40.9 | 20 |
| 0-40 | B | 19.6 | 67.9 | 12.5 | 5.52 | 9.15 | 5.5 | 7.1 | 0.4 | 0.3 | 0.1 | 11.7 | 19.6 | 40 |
| 40-140 | C | 16.3 | 76.4 | 7.3 | 2.36 | 4.03 | 6.0 | 23.4 | 0.3 | 0.2 | 0.1 | 3.3 | 27.3 | 89 |

In thin section slight incorporation of the organic matter into the mineral fraction may be seen, together with common biological activity—shown by voids, organic pellets and pedo-tubules, some pedo-relicts, and some nodules of Fe hydroxides. The plasmatic fabric is silasepic with agglomeroplasmic structure. Overall, the impression is of an only slightly evolved soil which has, however, undergone a certain amount of disturbance due to freezing and thawing phenomena. The presence of vesicles is significant here, since they may be related to air bubbles trapped in the soil.

### 3.4 Mineralogical and textural composition

The light minerals found in the three profiles are substantially the same in all the samples examined, and do not show any noteworthy features. Quartz, acid felspars and muscovite are found, mainly of the same size as the silt. They are sporadically accompanied by chert fragments and chalcedonic nodules, sometimes sand-sized or even larger.

TABLE 6

Mineralogical composition (in %) of heavy fraction (between 62 and 250 micron) in three profiles studied.

| Minerals (%) / Depth (cm) | LUGHEZZANO 0-90 | 90-140 | 140-180 | 180-220 | LUMINI 30-70 | 70-120 | 120-200 | 200-280 | 230-330 | 330-350 | NAOLE 0-35 | 35-70 | 70-150 | 150-180 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RUTILE | 1 | 6 | 3 | 2 | 2 | 2 | 6 | 1 | 2 | 9 | 3 | | 2 | 1 |
| ANATASE | | | 3 | | | | | | | | | | | |
| BROOKITE | | 1 | | | 2 | 1 | 1 | 2 | 1 | | | | | |
| ZIRCON | 3 | 6 | 4 | | 1 | 3 | 5 | 10 | 5 | 13 | 1 | 1 | 2 | 2 |
| TOURMALINE | 13 | 16 | 18 | | 9 | 19 | 18 | 17 | 33 | 18 | 7 | 1 | 2 | 3 |
| GARNET | 2 | 3 | 5 | 13 | 2 | 2 | 7 | 4 | 5 | 13 | 6 | 12 | 15 | 15 |
| SPINEL | | 1 | | | | | | | 1 | | | | | |
| STAUROLITE | 10 | 9 | 10 | 3 | 6 | 12 | 6 | 28 | 19 | 7 | 3 | 1 | 2 | 3 |
| CHLORITOID | 1 | 1 | 1 | | | 2 | | 1 | | | | 1 | | |
| TITANITE | | 3 | 3 | 3 | 1 | 1 | 1 | | | | 3 | | 2 | 4 |
| ANDALUSITE | 1 | 2 | 4 | 6 | 10 | 31 | 17 | 10 | 5 | 9 | 1 | 2 | 1 | 2 |
| KYANITE | 2 | 5 | 5 | | 4 | 2 | 4 | 5 | 3 | 2 | 1 | 1 | 2 | |
| SILLIMANITE | | | | | 3 | 1 | 2 | | 1 | | | | | |
| EPIDOTE | 55 | 41 | 36 | 40 | 37 | 15 | 27 | 17 | 19 | 22 | 22 | 24 | 21 | 25 |
| GLAUCOPHANE | | | | | 1 | | | | | | | | | |
| ACTINOLITE/ HORNBLENDE | 11 | 6 | 5 | 33 | 21 | 9 | 6 | 5 | 6 | 7 | 52 | 50 | 47 | 42 |
| DIOPSIDE | 1 | | 3 | | 1 | | | | | | | 4 | 2 | 2 |
| APATITE | | | | | | | | | | | 1 | 3 | 2 | 1 |

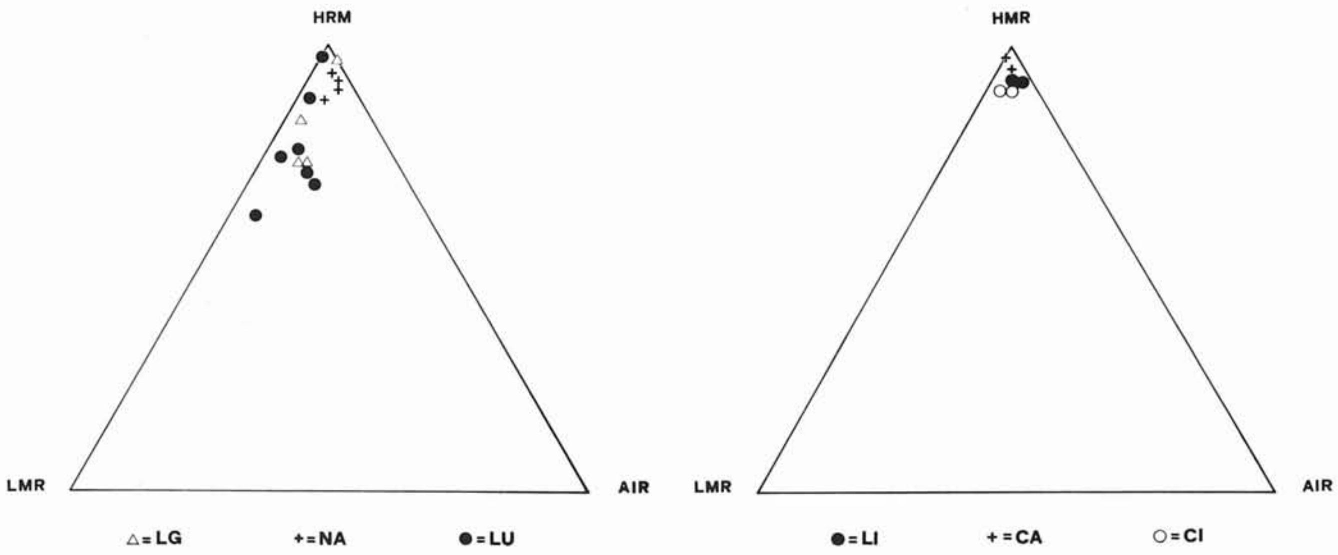


FIG. 11 - Diagrams showing provenance of heavy materials ranging between 62 and 250 micron. HRM = minerals from high grade metamorphic rocks; LMR = minerals from low-grade metamorphic rocks; AIR = minerals from acidic igneous rocks. List of minerals is detailed in text. *a*) diagram of the Lughezzano, Lumini and Naole profiles; *b*) diagram of profiles of western and front amphitheatre of Lake Garda, prepared on mineralogical analyses of D. MAGALDI, published by F. MANCINI (1969). Sampling Sites: LG = Lughezzano; NA = Naole; LU = Lumini; LI = Limone; CA = Calvagese; CI = Ciliverghe.

The few heavy minerals (p.s. $> 2.9$), also of the same size as the silt (table 6) are more interesting and were therefore examined with greater accuracy. Unlike most of the light minerals, the heavy minerals are in fact usually distinctive of specific lithological types. Their study furnishes very important information on the provenance of clastic sediments.

In this case too, the minerals observed were the same in all three profiles, although their quantities differed. Using the table published by PETTIJOHN (1975), the following groups of minerals, in relation to provenance, were recognized:

1) Minerals from high-grade metamorphic rocks: garnet, hornblende-actinolite, kyanite, sillimanite, andalusite, staurolite, epidote, anatase, brookite, rutile;

2) Minerals from low-grade metamorphic rocks: brown tourmaline, chloritoid, glaucophane;

3) Minerals from acidic igneous rocks and pegmatites: apatite, titanite, zircon, pink tourmaline.

Plotting the representative dots of the various samples in a ternary diagram with vertexes respectively being the percentage of minerals coming from high-grade metamorphic, low-grade metamorphic, and magmatic rocks, it may be seen (fig. 11) that all the samples are composed of an equal mineralogical association mainly coming from high-grade metamorphic rocks. It is interesting to note that the same association was found by one of the authors in some paleosols which developed in the loess and fluvioglacial deposits of the Garda morainic amphitheatre (MAGALDI in MANCINI, 1969) (fig. 11).

In any case, it seems justifiable to state that the main primary source of the minerals found in the three stations is in the large Southern Alpine metamorphic region of Lake Garda and the Adige River basins.

Inside each profile the distribution of each heavy mineral does not show noteworthy features, due to the original mineralogical variability of the sediments and the very small quantities of the mineral themselves (due to the selective deflational action of the wind).

The $Z+T/A+P$ ratio too ($Z$ = % zircon, $T$ = % tourmaline, $A$ = % amphibole, $P$ = % pyroxene), sometimes used to estimate the degree of weathering of different pedological horizons, is influenced by the various lithological discontinuities and is of small applicative significance in soils of this type. Instead, it seems more valid to compare the three profiles according to the frequency of all the heavy minerals.

For this, the minerals were divided into four classes according to their different degree of weathering and thus of persistence.

The classes (1-4) were made bearing in mind the many papers in this specific sector (BREWER, 1964) and experience acquired in the study of the persistence of various minerals in a pedogenetic environment. Ordered according to decreasing stability, the classes include the following minerals:

— class 1 (very stable): rutile, anatase, brookite, zircon, tourmaline;

— class 2 (stable): titanite, garnet, staurolite, spinel, chloritoid;

— class 3 (unstable): andalusite, kyanite, sillimanite, epidote, glaucophane;

— class 4 (very unstable): actinolite, diopside, apatite.

Showing the cumulative trend of the four classes for each profile in diagram form, the marked difference of weathering between the Lumini and Lughezzano profiles and that between these profiles with respect to Naole is clear (fig. 12).

These results agree with the above pedological and micromorphological observations.

The use of cumulative diagrams for the above four stability classes thus seems definitely useful when dealing with soils poor in heavy minerals coming from parent materials with unhomogeneous distributions by their very nature. The diagram does display very well the progressive disappearance of the most alterable species, passing from only slightly evolved soils to more evolved ones.

With the aim of obtaining information on the origin of the parent material of the three pedological profiles, detailed granulometric analyses were carried out using a Sartorius Sedimentation Balance, according to the methodology already used in previous researches (FERRARI & *alii*, 1970).

Since routine pedological analyses showed the predominance of the silty fraction, the cumulative granulometric curves were compared with the loess distribution diagram proposed by one of the authors during study of the "Rilievo isolato di Trino Vercellese" (GRUPPO DI STUDIO DEL QUATERNARIO PADANO, 1976).

Almost all the representative curves of the various samples from the three profiles (fig. 13) plot inside the loess distribution area: only a few, coming from the deeper horizons of Lumini and Lughezzano and thus referable to Paleosol II, are partially outside it. Also in the light of results coming from the other sectors of this study, it may thus be maintained that materials giving rise to Lumini and Lughezzano Paleosols I and the Naole soil are eolic in origin (see table 7).

The scarce content of heavy minerals is again a typical carachter of loess sediments.

The origin of the parent material of Paleosols II will be discussed later.

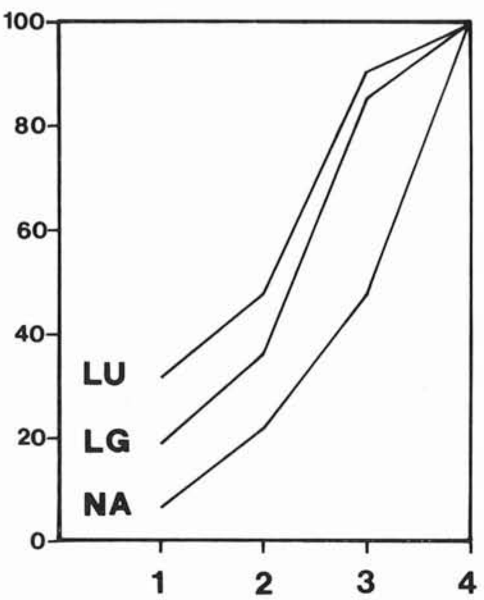


FIG. 12 - Different degree of weathering on the three profiles, visualized with diagram constructed with minerals of the heavy fraction, grouped by different stability classes. In ordinate: cumulative percentages of each class; in abscissa: classes listed in order of decreasing stability. The value of each class is the result of the sum of the percentages of heavy minerals showing same resistance to pedogenetic weathering. See text for list of mineral weathering.

### 3.5 CLASSIFICATION AND PALEOCLIMATIC SIGNIFICANCE

Classification was carried out according to the criteria suggested by the 1975 Soil Taxonomy (USDA) which is the most complete and precise system currently available for soil classification, although it is not very suitable for paleosols.

The Lughezzano and Lumini profiles clearly represent a sequence of two paleosols which should preferably be classified separately. Instead, the Naole profile is composed of one undoubtedly younger soil, in any case less evolved than the preceding one.

In the Lughezzano profile, Paleosol I may be classified as a Typic Hapludalf, considering the actual udic soil moisture regime.

According to Soil Taxonomy, soils of this type formed mainly on late Pleistocene deposits or on surfaces of the same age, now covered with deciduous forest. They suggest climatic conditions slightly warmer and moister than current ones, with relatively well differentiated dry and wet seasons. For a similar soil studied in the Mugello Valley (Florence), SANESI (1965) speaks of a moist Mediterranean climate.

The underlying paleosol is completely different. The few recognizable horizons make precise classification according to Soil Taxonomy difficult if not impossible.

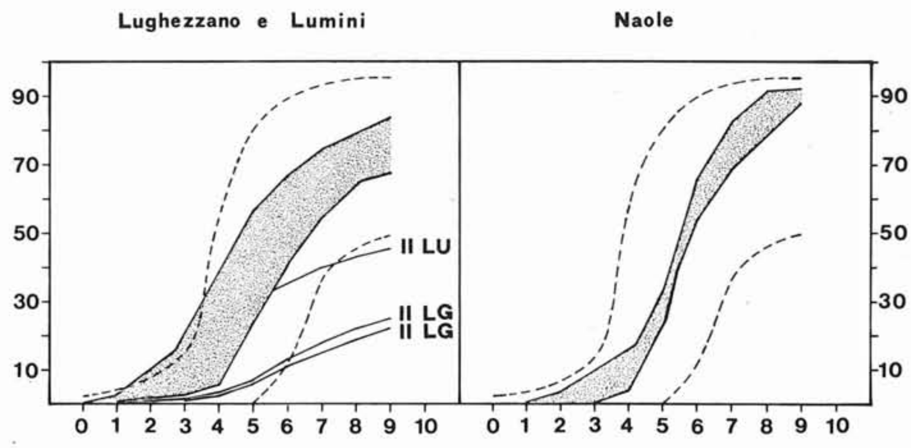


FIG. 13 - Comparison between patterns (shaded zone) of cumulative granulometric curves of Lughezzano and Lumini (left), Naole (right), and distribution diagram of fresh and weathered loess (dotted lines). II LU and II LG represent cumulative curves of Paleosols II respectively from Lumini and Lughezzano. In abscissa: dimensions expressed in phi scale; in ordinate: percentages.

TABLE 7

CUMULATIVE SIZE CLASSES OF VARIOUS HORIZONS OF THE THREE PROFILES. IN ABSCISSA: DEPTH OF HORIZON IN CM; IN ORDINATE: CLASS INTERVAL IN MICRON.

| | LUGHEZZANO | | | | | LUMINI | | | | | | | NAOLE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Size class (micron) \ Depth (cm) | 0-90 | 90-140 | 140-180 | 180-220 | 220-300 | 30-70 | 70-120 | 120-200 | 200-230 | 230-280 | 280-330 | 330-350 | 0-35 | 35-70 | 70-150 | 150-180 |
| 2000-1000 | 0.6 | 2.1 | 2.1 | 0.3 | 0.5 | 1.0 | 0.8 | 0.9 | 0.9 | 0.7 | 1.3 | 0.6 | - | 0.2 | 0.1 | 0.4 |
| 1000-500 | 1.6 | 3.3 | 3.5 | 0.4 | 0.7 | 1.7 | 1.6 | 2.0 | 1.5 | 2.7 | 3.0 | 0.9 | - | 1.1 | 0.5 | 0.7 |
| 500-250 | 3.1 | 5.1 | 5.5 | 0.5 | 0.8 | 2.3 | 3.0 | 10.0 | 2.3 | 3.5 | 5.2 | 1.1 | 0.1 | 4.1 | 1.4 | 1.3 |
| 250-125 | 6.9 | 11.7 | 11.7 | 1.6 | 2.1 | 3.3 | 14.4 | 18.6 | 10.4 | 21.7 | 9.3 | 1.6 | 0.4 | 10.7 | 4.6 | 2.1 |
| 125-62 | 12.0 | 18.2 | 21.1 | 3.4 | 4.3 | 6.5 | 28.4 | 29.7 | 25.2 | 39.8 | 18.4 | 23.6 | 4.7 | 16.6 | 13.9 | 9.0 |
| 62-31 | 24.3 | 35.4 | 35.3 | 6.8 | 7.3 | 28.9 | 37.4 | 38.1 | 39.4 | 56.7 | 23.8 | 30.4 | 23.8 | 28.3 | 33.7 | 27.2 |
| 31-16 | 49.8 | 57.5 | 52.6 | 12.1 | 13.5 | 52.7 | 52.7 | 51.1 | 55.9 | 66.9 | 41.4 | 35.5 | 64.8 | 54.1 | 65.6 | 66.4 |
| 16-8 | 66.5 | 68.1 | 62.1 | 16.0 | 18.5 | 65.3 | 63.5 | 60.2 | 64.1 | 74.6 | 54.6 | 39.9 | 82.9 | 69.1 | 75.1 | 80.1 |
| 8-4 | 77.1 | 76.3 | 68.4 | 18.9 | 22.6 | 71.8 | 68.4 | 65.5 | 70.5 | 77.9 | 64.6 | 43.2 | 91.5 | 78.3 | 82.0 | 86.9 |
| 4-2 | 80.6 | 81.2 | 73.2 | 22.8 | 25.2 | 76.5 | 70.8 | 67.7 | 74.6 | 83.4 | 70.2 | 45.4 | 92.4 | 87.5 | 93.2 | 92.3 |
| 2-0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

However, considering the strong degree of alteration, abundance of clay, and intense red colour with hue = 2.5 YR, these horizons may tentatively be ascribed to a Rhodic Vertic Paleudalf. These soils are currently found on relatively stable surfaces and, according to Soil Taxonomy, go back to the last interglacial period or to older periods, representing tropical or at least sub-tropical conditions, with marked differences between moist and dry seasons. A quite similar sequence may also be recognized in the Lumini profile. However, Paleosol I shows more advanced weathering, making it a Typic Hapludult. The Udults are soils currently found in humid climates in mid or low latitudes with well-distributed rainfall.

Instead, Paleosol II (at least as regards what may be recognized in the remaining horizons) is perfectly similar to that of Lughezzano, in both macro- and micro-morphological aspects.

However, the Lughezzano profile shows evidence of having been resaturated in bases, following the circulation of ground waters coming from the limestones. This conditions did not occur at Lumini, which is situated in a very wide, deep depression, and formed on a very thick deposit.

The Naole profile represents a soil situated in environmental conditions which did not favour pedogenesis. It may be classified as a Hystic Cryumbrept, since it differs from the Typics due to the presence of an organic layer. The Cryumbrepts are soils commonly found in high mountain areas and in high latitudes, generally holding grass and forest (conifer) vegetations.

## 4. CONCLUSIVE CONSIDERATIONS

The local lithologico-structural situations (passive role of the "structure"), tectonic activity, geomorphic processes (erosive and depositional processes with particular reference to karstic and periglacial ones), and pedogenetic processes are closely linked. An initial framework of these phenomena in the Lessini Mountains has been given in a preceding paper (MAGALDI, PERETTO & SAURO, 1981), while this paper now allows reconstruction in more detail.

In the two areas described, the relief has assumed clearly distinct features due to difference in morphologico-structural type. In effect, the slope of Lughezzano has a larger average gradient and fragmentation into smaller tectonic blocks than the plateau of southern Monte Baldo. On the Monte Baldo plateau "a periglacial karst with dolinas and small valleys" prevails, surrounded by large tectonic forms; instead, the Lughezzano slope holds a "tecto-karst" with very few evident karstic depressions, but with fundamentally karstic hydrogeologic behaviour. Referring to the features of the Pleistocene cover sediments too, it may be said that, in the case of Monte Baldo, the morphological processes were typical of a plateau zone, while in the case of Lughezzano, slope processes prevailed.

The current karstic forms are masked by deposits which have filled the original dolinas sometimes to the rim. On the other hand, the presence of deposits showing traces of ancient pedogenetic phases is evidence of the age of the karstic forms which trapped the sediments later involved in pedogenesis. It may thus be hypothetized that the main phase of karstic mophogenesis preceded events favourable to dolina-filling and to the dismantling of the karstic forms.

The distribution, features and stratigraphy of the covers provide useful elements for the reconstruction of the history of these regions. As we have seen, the deposits are particularly thick inside the karstic hollows and at the foot of the tectonic scarps. On the basis of observations on the sections of the village of Lughezzano, Lughezzano-Ca' di Sotto, Lumini, Naole and the others of southern Monte Baldo, the following sequence may be hypothetized (from bottom to top):

1) slope deposits and coarse limestone materials, with breccias, which pass laterally to bluish and greenish laminated clays;

2) fine clastic sediments giving rise to Paleosols II (Paleudalfs);

3) silty clastic sediments giving rise to Paleosols I (Hapludults and Hapludalfs);

4) silt layers sometimes containing coarse materials of cryoclastic origin, and remains of paleosol with argillic

or fragipan horizons (Fragiudalfs?) observed near Ca' di Sotto;

5) soil sediments;

6) actual soils.

The slope deposits with limestone blocks and breccias have already been correlated to large-scale late Pliocene and Pleistocene tectonic phases (PASA, 1954; CARRARO & *alii*, 1969). The features of the clasts (whose sizes vary greatly) and the distribution of these deposits at the bases of the main tectonic scarps favour this hypothesis.

Greater problems arise when coming to the interpretation of the bluish and greenish clays which, in some cases, could be referred to marshy environments characterized by glacial barriers or tectonics. These sediments are still being studied.

Referring to the fine clastic sediments on which almost all the paleosols developed, analyses clearly show that they are loess deposits of various ages which formed at the expense of mainly silty materials coming from the large glacial structures of Lake Garda and the Adige River. The geographical distribution of these loesses is doubtless wider than that shown on summary examination. In agreement with the opinion of CHARDON (1977) on the "red earth" of the Serle Plateau, we believe that Lughezzano and Lumini Paleosols II also formed at the expense of a loess-type deposit, partly modified by synsedimentary colluvia. The later strong clay production partially obliterated the original silty texture of the deposits.

The angular limestone fragments embedded in the silt producing the Fragipan soil (particularly abundant in the higher areas) are signs of the intense dismantling of the karstic relief by cryoclastic processes during cold phases. The solifluxion structures in the sediment of Paleosol II (which flowed on to the silts) are significant here, together with the soil wedges and wedge-shaped structures composed of iso-oriented limestone fragments which are indicators of permafrost or of very similar conditions.

As regards the paleosols which are useful both for studies on relative chronology and as paleo-environmental indicators (MAGALDI, 1979), the type II Paleosols show features allowing them to be attributed to the *monosiallitization facies* (2). This includes strongly altered soils rich in iron hydroxides which probably evolved in subtropical climatic conditions during a long interglacial period. Instead, the type I Paleosols are part of the later *old bisiallitization facies* (2), characterized by lesser reddening and weathering of the profile. They are characteristic of a following interglacial period. Lastly, although in a preliminary way, it may be maintained that the clayey Paleosol of Ca' di Sotto, the soil of Naole, and others recently discovered in southern Monte Baldo fall into the facies of *recent bisiallitization*, characterized by moderate pedogenetic evolution which presumably took place during the Würmian interstadials, in climatic conditions only slightly different from present-day ones, although rainfall was greater.

Fragipan, the hardened horizon appearing in the upper Paleosol, is still of obscure significance in pedology, but some Authors believe that its formation may be the result not only of pedogenesis, but also of the constipation exercised following soil freezing (permafrost): the discovery of soil wedges and solifluxion structures favours this interpretation.

Among the most significant morphological elements, we quote here:

*a*) *morphotectonic context*: although on one hand this supplies indications on the old age of the erosion surfaces on which karst morphogenesis took place, on the other it evidently expresses the results of several important neotectonic phases (relationships between the old erosion surface in Jurassic limestone and the polyphasic tectonic scarps of different size which have broken it);

*b*) *dolinas*, whose typology includes remains of large dolinas mostly dismantled by erosion, large still active dolinas, medium and small dolinas, and dolinas completely filled with sediments. The buried slopes of the latter are more tilted than those without covers. "Faulted" dolinas emphasize the chronological relationships between neotectonic and karstic forms;

*c*) *"cone-shaped" or dome-shaped ridges*, which may also be interpreted as relict forms of a more energetic karstic relief than the present one;

*d*) *small rounded valleys*, whose network overlies that of many "dismantled dolinas", the result of morphogenesis under periglacial conditions.

The features of the deposits and form thus allows us to distinguish the following three types of morphogenetic phase (fig. 14):

I) one or more old phases of karstic morphogenesis on limestone surfaces lacking a cover of periglacial sediments;

II) several phases in which dismantling processes of the karstic relief predominated, with the accumulation of thick sedimentary covers in the depressions;

III) several phases alternating with the preceding ones, with relative stability of the morphological surfaces and formation of thick soils, more greatly developed on the filling deposits, characterized by prevailing karstic dissolution.

(2) The terms monosiallitization and bisiallitization were introduced into pedological literature by PEDRO (1968) to indicate on a world scale some general pedogenetic trends. The terms have the following meanings: *monosiallitization* = pedogenetic process giving rise to strong removal of silica and consequent neoformation of 1:1 clays; *bisiallitization* = pedogenetic process with weaker removal and later neoformation of 2:1 clays.

Subsequently, these terms were used by one of the Authors to define three phases of different pedogentic evolution from a qualitative point of view (monosiallitization, old bisiallitization, recent bisiallitization) which are found in many soils formed on old and recent Quaternary clastic sediments.

The identification of each phase may be independent of knowledge on the neoformed clay type and is usually based on the degree of evolution of the profile, the hydration conditions of the iron sesquioxides in B horizon, and the weathering degree of primary minerals in several horizons.

It is very interesting to observe that most argillic B horizons ascribed to monosiallitic and old bisiallitic phases show the requirements of the Paleo-argillic B horizon as defined in the new Soil Classification for England and Wales after AVERY (1980).

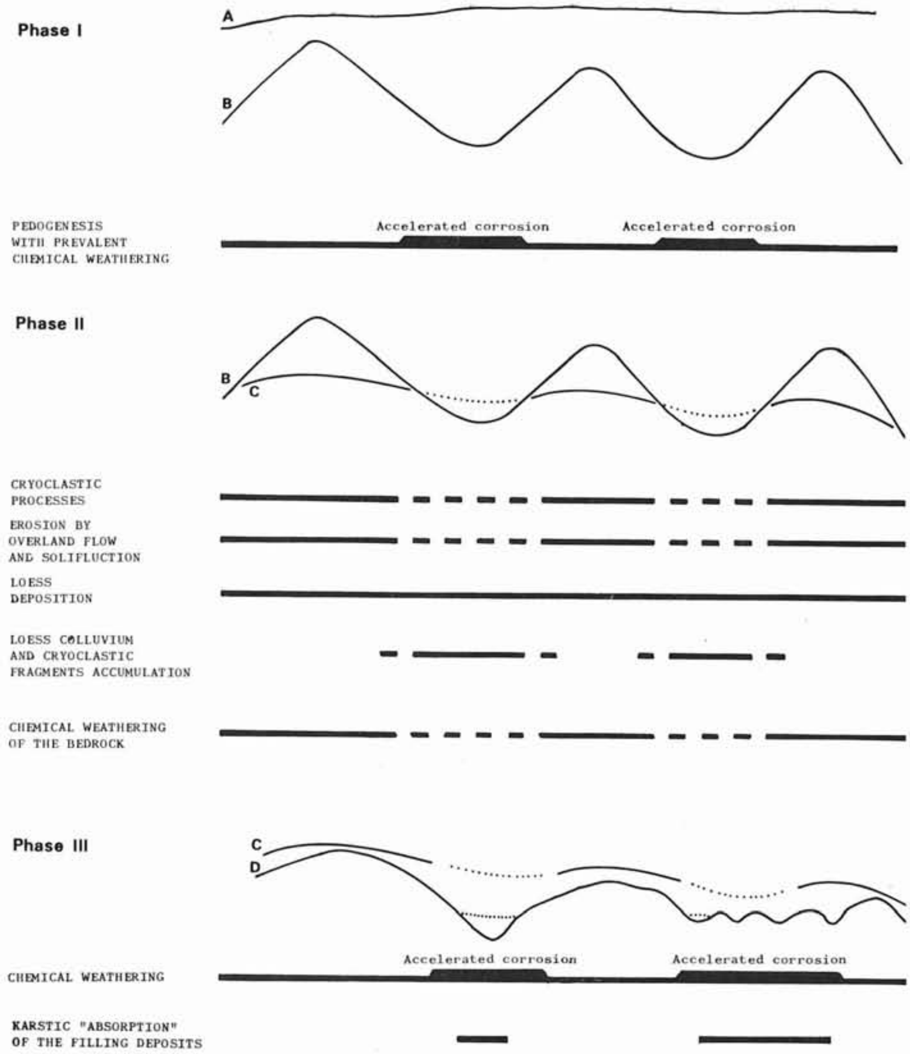


FIG. 14 - Diagram illustrating types of evolutional phase of relief and role of different erosional and depositional processes. After an initial phase of karstic morphogenesis on limestone without detritic cover, alternate phases occurred, with dismantling of karstic relief in periglacial conditions (type II) and karstic erosion on an originally complex relief, in subtropical climatic conditions. The letters A, B, C, D, make reference to the morphological profiles (profiles of the rocky surfaces = continuous lines; profiles on deposits = dotted lines).

During the I phases, the identifiable karstic relief was composed of more or less cone- or dome-shaped hills with large, deep dolinas (mostly dismantled and generally hard to distinguish).

The II phases of relief dismantling and filling of the karstic depressions may be correlated with periods during which wind deposited on the slopes loess coming from the proglacial areas of the large glacial tongues of the Adige and Lake Garda. During the same phases, cryoclastic phases also operated, dismantling the ridges between the dolinas and producing large quantities of angular fragments which, together with eolic silt, contributed to the filling of the hollows. These loess covers on the slopes made cryoclastic action easier, since they with-held snow melt and also facilitated solifluxion by loose materials. The disactivation of the karstic depressions, caused by their almost total filling with sometimes fine sediments and by the probable existence of permafrost which sealed the karstic fissures, facilitated erosion by channelled waters in periglacial conditions. This explains the development of an embryonic water network provided by more or less rounded-floor valleys, overlying the dolina pattern. On the topographic map of southern Monte Baldo, this embryonic network may also be seen from the extremely tortuous trend of the contours, mainly on the surfaces of average slope between 20-25 % and 35-40 % (fig. 3).

The alternate pedogenetic phases accompanied by intense karstic morphogenesis (type III) may instead be referred to interglacial periods in which, in subtropical climatic conditions with alternating moist and dry seasons, the morphological surfaces were covered with forest. As regards certain aspects, environmental conditions may have corresponded to phase I, with the difference that the morphological surface no longer showed homogeneous features and lithology, being composed of alternating surfaces of naked rock (ridges and steeper slopes) or rock covered only by a thin layer of sediments (intermediate-gradient slopes) and of surfaces with thick sedimentary covers of very different composition (in the karstic depressions and on the less steep slopes). This influenced modelling features, limiting karstic morphogenesis in the filled and partially impermeabilized dolinas, i.e. in those very areas where an accelerated type of corrosion had previously taken place. In these phases,

TABLE 8

Succession of morphogenetic and pedogenetic events during Quaternary in Lessini Mts. and Monte Baldo area.

| CHRONOLOGY | | TECTONIC EPISODES | EROSIONAL AND/OR DEPOSITIONAL PROCESSES | PEDOGENETIC PROCESSES |
|---|---|---|---|---|
| PALEOMAGNETIC | RELATIVE | | | |
| BRUNHES | HOLOCENE | RECENT EPISODE OF ORSARA AND NAOLE | Erosion started by man by deforestation and agricolture (deposition of colluvia at the base of the slopes and in the depressions) | Modern<br>Pedogenesis in a forest environment during the climatic "optimum" |
| | MIDDLE AND UPPER PLEISTOCENE | | Erosional processes on the slopes and deposition of loess and colluvia in the depressions | Moderate |
| | | | Moderate processes | Pedogenesis of the paleosol of Naole and Ca' di Sotto |
| | | | Periglacial erosion and deposition of loess covers | Moderate |
| | | EPISODE OF VAJO DELL'ANGUILLA, NAOLE AND VALFREDDA | Moderate physical processes (prevalent chemical weathering) | Pedogenesis of the paleosol I of Lughezzano and Lumini |
| | | | Erosional processes on the slopes and deposition of loess and colluvia in the depressions | Moderate (stone line development) |
| | | | Moderate physical processes (prevalent chemical weathering) | Pedogenesis of the paleosol II of Lughezzano and Lumini |
| | | | Periglacial erosion and deposition of loess covers | Moderate |

a reduction in volume of the filling deposits in the depressions took place, following their alteration and sometimes reabsorption thanks to the reactivation of the absorbing systems of certain dolinas and to chemical erosion at the point of contact between filling and buried slopes. At the same time, next to other dolinas completely fossilized by their deposits or near the perimeter of old dolinas dismantled in a preceding phase, new systems may be identified, caused by the development of alternative absorbing systems which, from the functional viewpoint, substitute those of old, now inactive dolinas.

These actions, linked to the succession of different climatic and environmental conditions, were accompanied by others caused by the recent tectonic evolution of the limestone morphostructures. Various indications lead us to believe that, during the first and more important karstification phase, both the plateau of southern Monte Baldo and the large Lughezzano slope were generally less tilted than they are now. Later, due to the activation of many faults, the main morphotectonic units broke up, accompanied by tilting of the blocks and formation of tectonic scarps among them (Sauro, 1978; 1979). Morphological steps and fault-angle depressions were thus formed, while relief energy increased and the tilt of the old karstified surfaces was accentuated (figs. 2 and 3). If we presume that the original karstic plateau of southern Monte Baldo was connected with the Malga Valfredda bench, which shows exactly the same morphology, the relative uplift of the Naole block may have been as much as 200-300 m after the first important karstic morphogenetic phase.

As we have already said, the presence of "faulted" dolinas at the sides of some of the well-preserved fault scarps may sometimes be recognized (fig. 7).

Tectonic movements of the type illustrated were active in very recent times, since the most recent fault scarps, with throws sometimes greater than 2 m, are post-glacial (SAURO, 1978; 1979; 1981). These movements favour the progressive demolition of the karstic relief which only remains preserved in the less steep areas where, however, it is partially fossilized by slope deposits.

Lastly, the modifications caused by man's activity on slope processes is worthy of note. It seems that in these karstic mountain areas erosion started by man in protohistorical times by deforestation (felling and burning) (a forest of large beeches grew during the Atlantic period, corresponding to the Neolithic, in the mountain area), grazing and agriculture, has been relatively intense and "accelerated" with respect to other preceding erosive phases caused by variations of climate and vegetal environments (SAURO, 1977) ([3]).

On the whole, the extensive thick sedimentary covers of anthropogenous soils, deriving partly from the erosion of paleosol flakes which survived the environmental crises of the upper Pleistocene, are signs of the strong disturbances caused by human activity on natural processes.

Definitively then, and partly on the basis of knowledge on other Prealpine and Alpine areas (CHARDON, 1975; 1977; NICOD, 1981; SAURO, 1981), the evolution of the southern Monte Baldo karstic relief may be summarized as follows:

1) identification of a structural plateau and erosional exhumation of the thick, lower Jurassic, limestone formations;

2) strong dissolution phase with development of a high-energy karstic relief supplied by large deep dolinas, sometimes with polygonal contours, separated by partly cone-shaped ridges;

3) morphogenetic phases of periglacial type with partial dismantling of the karstic relief and filling of many cavities with eolic and cryoclastic sediments;

4) pedogenetic phases in the moist subtropical conditions typical of the interglacial periods, with renewed karstic morphogenesis in unhomogeneous rocks (periglacial covers and limestone).

([3]) We would like to quote here some observations which, although restricted in scope, seem significant in this context:

— in a dolina at Lughezzano, a proto-historical paleosurface rich in flint instruments was found buried under more than 2 m of anthropogenous colluvium (MAGALDI, PERETTO & SAURO, 1981);

— near Fittanze del Monte Risare (southern Monte Baldo), within the ambit of the Rosso Ammonitico, a strong contrast may be observed between the areas used until recently for grazing sheep and cultivated areas: the grazing areas are very rocky with many large spurs and slabs sometimes more than 1 m high, carved by the rounded karren typical of the « covered karst » (i.e. formed under a soil). The cultivated areas are far less rocky and only so along the steeper belts, which are arranged by the contribution of materials into terraces.

In phases 2, 3 and 4 neotectonic events dislocated the plateau and broke it up, increasing its gradients. In a similar fashion, it may be presumed that, during the first karstification phase, the Lughezzano slope was less steep and that it was later dislocated into a step-type motif on which only the largest dolinas, with better drainage corresponding to the fault lines, were preserved. However, some dolinas are almost completely filled.

The chronology of these events and phenomena is very difficult, partly because the whole classic chronostratigraphy of the continental Quaternary has been greatly revised during the last few years. An attempt at fitting it into a more elastic framework, less dependent upon old and by now superseded models, is proposed in table 8, which takes into account the subdivision and correlations recently presented by BOWEN (1981).

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