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GEOMORPHOLOGICAL MAPPING AND DERIVATIVE MAPPING OF SOIL EROSION AND SOIL EROSION HAZARD IN THE BASIN OF THE DIATERNA VALICA CREEK (NORTHERN CENTRAL APENNINES, ITALY)*

With 1 figure, 2 photos, 4 tables and 1 supplement (VIII)

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Zusammenfassung: Geomorphologische Kartierung mit Ableitungskarte ,,Bodenerosion und Bodenerosionsgefährdung" im Tal der Diaterna Valica (Nördlicher Zentral-Apennin, Italien)

Die vorgestellte Karte zur Bodenerosionsgefährdung wurde zusammen mit der vorausgehenden geomorphologischen Detailkartierung 1985/86 im Rahmen und mit Unterstützung des interdisziplinären Forschungsprojekts des C.N.R. (Rom) ,,Erhöhung der Produktivität der Agrarressourcen – Unterprojekt: Agrarstrukturen in Marginalräumen" erstellt. Die Karte umfaßt das hydrologische Einzugsgebiet des Torrente Diaterna Valica im nördlichen Zentralapennin (tosko-emilianischer Apennin). Der tonige Untergrund, der die Landwirtschaft in diesem Gebiet zu tragen hat, ist stark erosions- und rutschungsgefährdet.

Die methodische Konzeption der Bodenerosions-Karte ist auf die Anwendbarkeit für die raumplanerische Praxis ausgerichtet; sie soll einerseits einen ausreichenden Informationsgehalt und andererseits eine einfache Lesbarkeit der Karte gewährleisten. Dies wird erreicht durch die flächenhafte, farblich abgestufte Unterteilung des Untersuchungsgebietes in Zonen unterschiedlicher Gefährdungsklassen, die Definierung jeder Gefährdungsklasse in der Legende nach Art und Ausmaß der aktuell stattfindenen Abtragungsprozesse, der potentiellen Gefährdung, der wesentlichen Steuerfaktoren Bodenart, Hangneigungsbereich und Bodennutzung sowie durch zusätzliche Angaben über geeignete Meliorationsmaßnahmen. Die Klassifizierung erfolgt nach den gebietsspezifischen Bedingungen durch Korrelation von erstellten Grundkarten zu den einzelnen Steuerfaktoren und den Abtragungsprozessen. Diese Grundkarten (in gleichem Maßstab von 1:10 000) werden auf Grundlage der Auswertung vorhandener Informationen erstellt. Als geeignete und sehr brauchbare Grundlage erweist sich die komplexe geomorphologische Detailkarte (nach der westdeutschen ,,GMK"-Konzeption), aus der die Angaben über Hangneigung, Bodenart und morphodynamische Prozesse entnommen werden können.

* The mapping of soil erosion and soil erosion hazard was carried out in 1985/86. It is part of the interdisciplinary project of the Italian Research Council (C.N.R.): "Increase of the Productivity of Agrarian Resources (IPRA)", subproject: "Agrarian Systems in Marginal Areas". Printing and copying of the map was generously financed by this C.N.R.-project.

1. Introduction

Slope degradation caused by landslides and water erosion has endangered the argillaceous hill and mountain landscapes of Italy in a highly increasing degree during the last decades. This is a response to economic structural changes: (a) the industrial expansion which has forced agriculture from the plains and valley bottoms onto the sloping areas and (b) the replacement of the traditional farming structure (semi-feudal, predominantly subsistence) by the modern market-oriented, highly mechanized land management, which has resulted in an increase in plot size, in machine use and monoculture. These structural changes have greatly improved the production conditions, but at the price of increased erosional activity. This is particulary true for the Northern-Central Apennines, a landscape where the balance between slope stability and land use has always been precarious. In many places, the damage makes agriculture now unprofitable or even impossible. Measures to increase or at least to maintain profitability will only succeed when accompanied by careful landscape planning, taking into account the sensitive ecological balance. Applied geomorphology can make a contribution to this planning by the analysis and evaluation of environmental conditions and geomorphodynamic processes. It is crucial that the results of such analyses should be presented to regional planning authorities in a comprehensible and usable form. These purposes, the methodical and thematical ones, are the base for the presented mapping project. The following report explains the environmental conditions of the field area as well as the cartographical method.

2. Topographical and Geographical Survey of the Field Area

The field area is the stream basin of the Diaterna Valica, a mountain torrent which runs through the Tuscan community of Firenzuola, about 50 km north of Florence. The Diaterna Valica drains into the Adriatic Sea via the Santerno River.

The Diaterna Valica basin consists of two landscape units which reflect the underlying lithology. The upper and middle parts of the valley have an undulating, smooth topography, which is associated with the highly erodible clayey bedrock („Terreni Caotici Eterogeni"). The slope angles are generally between 11° and 20° and are highly variable over short distances. Accentuated erosion by slope wash and landslides results in very rough slope surfaces with irregular, hummocky forms, transverse ridges and even counter slopes. Frequently the slope profile is completely disrupted by various kinds of landslides. In some places, the landscape has the character of a badland topography. The valley head and the slope crests are capped by various, more resistant rock masses (marly-arenaceous, calcareous-arenaceous and ophiolitic), which rise steeply above the smooth argillaceous surrounding. The maximum relief intensity is 800 m, between the 200 m wide, gravel-filled valley floor at 450 m altitude and the peak of M. Freddi at 1270 m. The relief intensity in the large middle part of the valley is between 200 m and 400 m.

The topography changes abruptly in the lower part of the valley where the stream is steeply incised into the marly-arenaceous flysch bedrock. Here, slope angles everywhere exceed 15° (often more than 20° to 30°) and the relief intensity is about 600 m.

This topography allows agrarian land-use and settlement only in the upper and central parts of the valley, i.e. in an area prone to erosion and landsliding because of its clayey substrate. The steep bedrock slopes of the lower valley are unsuited to settlement and only occasional rock terraces allow modest isolated holdings. This area is practically completely covered by woodland and used for forestry.

Apart from a few small quarries on M. Beni and in the lower valley, there is no stable industry in the whole region. Thus, the problems of a marginal agrarian economy and the ecological systems on which it is based are closely interwoven. Only the conservation and restoration of slope stability will ensure the long-term use of the area's economic base in agriculture and forestry.

3. Factors of Relief Forming

3.1. Geology

The Diaterna Valica basin contains five statigraphic-tectonic units which are important in the Northern-Central Apennines:

- Four allochthonous units in the upper and middle valley:
  (1) the "terreni caotici eterogeni" (Argille Scagliose), which cover the largest area
  (2) The "formazione di Monghidoro"
  (3) ophiolitic rocks
  (4) the "formazione dell' Alberese".

The last three of these make up the valley head and the slope crests.

- The autochthonous unit in the lower valley:
  (5) the "formazione marnoso-arenacea romagnola" (FMA).

"Terreni Caotici Eterogeni"

Clayey and clayey-marly sedimentary masses, which are characterized by chaotic structure and the lack of recognizable stratigraphic sequences, are widely distributed in the Northern Apennines. They are summarized as "Terreni Caotici Eterogeni" or "Complesso Caotico" and also known by the older authors under the term "Argille Scagliose" (in: CREMONINI & ELMI 1971). Lithologically they are grey or greenish-grey clays of chaotic and incompetent structure with numerous inclusions of solid rock lumps of varying size (some cm to some hundreds or thousands m) and varying lithology (calcarenites, sandstones, marls, ophiolites). Selective erosion exposes these inclusions as residuals, which rise from the smooth and highly degradable clays.

The tectonic subdivision of the Terreni Caotici Eterogeni and their tectonic relation to adjoining allochthonous and autochthonous units is complicated and still subject to investigations and contention (CREMONINI & ELMI 1971, GENTZ 1970, GROSCURTH 1971, REUTTER 1968). The tectonic transport mechanism is obviously to be deduced from the generally chaotic texture: Submarine sliding movements in form of slide nappes or olistolithes, which have swept away fragments of other formations, now irregularly embedded within the clayey masses. Estimates of the age range from Cretaceous to Tertiary and the tectonic movements are assumed from Oligocene to Pliocene. Deep drillings in the Diaterna valley have shown the thickness of the clays to vary up to hundreds of meters (GENTZ 1970). Gas and oil deposits occur in the area of the clays. In the field area they have been exploited since the 1930s but today they are only sufficient for local needs.

"Formazione di Monghidoro"

The Monghidoro formation occupies a triangle between Grizzana, the Futa-Pass and Loiano. With the M. Freddi and M. Oggioli, its eastern border forms the valley head of the Diaterna basin. It is constituted by a marly-arenaceous flysch, which is well exposed on the southeastern scarp face of M. Oggioli: Beds of micaceous-quartzitic sandstone layers alternating with marly and marly-silty layers. The sandstone beds are well graded, sometimes laminated, with a fairly constant thickness of about 1,5 m. The marly layers are less thick, ranging from 25-50 cm. The "Formazione di Monghidoro" is of upper Paleocene age (CREMONINI & ELMI 1971).

The Ophiolites

A line of isolated ophiolitic rock masses is located east of the Monghidoro formation. One of these is M. Beni, which stands more than 200 m abruptly above its clayey surroundings. The lithological composition is complex: Predominantly diabases and serpentines, also gabbros, associated with maiolica and radiolarites. They all are of upper Jurassic and lower Cretaceous age. Mainly diabases, maiolica and radiolarites are quarried for gravel, as on the west side of M. Beni.

"Formazione dell' Alberese"

The Alberese formation is mainly defined by its lithology: An interstratification of turbiditic marly, marly-calcareous, calcareous and calcarenitic layers. In the Diaterna valley the most massive Alberese rocks are M. Canda and M. Carpinaccia at the northern valley interfluve, smaller ones are situated at the southern valley interfluve. The about 200 m steep and more than 1000 m long eastern wall of the M. Canda exposes well the interbedding of the calcarenitic and marly layers. The individual layer thickness vary from a few cm to more than 1 m. The colour is yellowish to light grey. Microfauna indicates an upper Paleocene to Eocene age (CREMONINI & ELMI 1971, GENTZ 1970).

"Formazione Marnoso-Arenacea Romagnola" (FMA)

The marly-arenaceous flysch of the FMA outcrops throughout the lower valley. The lithologic composition is similar to that one of the allochthonous Formazione di Monghidoro: Interstratification of micaceous-quartzitic sandstone layers and silty marlstone layers. Microfauna analysis indicate a Miocene age (CREMONINI & ELMI 1971, GENTZ 1970). The layer thickness ranges from some cm to about 3 m. The thicker sandstone layers are quarried for building material by a few small local firms.

Tab. 1: Average monthly temperature data for Firenzuola in °C (Period 1964–1974)
Monatliche Mitteltemperaturen in °C für Firenzuola (Periode 1964–1974)

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Firenzuola	2,5	5,1	6,5	10,2	14,0	18,7	20,4	19,7	16,1	11,8	7,7	3,0

Tectonically the FMA belongs to the autochthonous facies series "Successione Romagnola" (Cremonini & Elmi 1971) or "Umbro Marches" (Gentz 1970). The FMA submerges under the western allochthonous units, but the tectonic interlocking is complicated and still the subject of contention (Gentz 1970).

3.2. Climate

The climate of the Northern-Central Apennines is humid-moderate with precipitation maximum and temperature minimum in winter.

Precipitation data from Pietramala (845 m a.s.l.), Firenzuola (422 m a.s.l.) and Barco (741 m a.s.l.) and temperature data from Firenzuola show the climatic characteristics of the Diaterna Valica basin (Fig. 1, Tables 1 and 2). Mean monthly precipitation data show the distinct winter maximum, with peaks in September, November and February/March. The mean monthly precipitation in July and August is slightly more than 40 mm, exceeding the limit for summer aridity, but still indicating dry conditions with much reduced runoff. There is little data available on rainfall intensities but storms giving more than 20 mm precipitation per hour can occur at any time in the year. Snowfall is common in winter and the resulting snow cover may lie on the ground up to 20 days per month. However, snow depths are generally not more than 50 cm.

Mean monthly temperatures at Firenzuola vary from 2° C in January to 20° C in July. The January mean indicates that frost is common in winter (e.g. 60 days with freezing temperatures occurred at Firenzuola in 1974). These climatic conditions suggest that the natural vegetation of the catchment should be a mid-latitude deciduous forest.

Regarding the past climatic conditions for morphogenetic landform analysis, there is no evidence for Quaternary glaciation in this lower part of the Northern-Central Apennines (Suter 1950). However, Quaternary periglacial conditions are surely to be assumed: including intensive frost weathering, cryoturbation, solifluction, and other intensive processes of slope degradation.

3.3. Soils and Land Use

3.3.1. Soil Types

The following details are taken from the 1:25 000 soil map of Sanesi (1977), which is based on the Soil Classification System of the USDA.

In the Diaterna Valica, steep slopes and a high level of geomorphic activity lead to only poorly developed soils. Most of the soils in the area are Inceptisols, with Alfisols in only one small area (Serie Collina).

In the upper and middle valley, two soil series are found on the clays of the Terreni Caotici Eterogeni.

Tab. 2: Average monthly precipitation in mm and number of rain days (in brackets) (Period 1964–1974)
Mittlere Niederschläge in mm und Zahl der Regentage (in Klammern) nach Monaten (Periode 1964–1974)

	Month												Σ
	1	2	3	4	5	6	7	8	9	10	11	12	
Pietramala	136	152	154	131	88	87	53	69	152	131	215	140	1508
845 m	(10)	(12)	(10)	(9)	(9)	(8)	(5)	(6)	(7)	(9)	(12)	(10)	(107)
Barco	151	149	137	145	122	96	42	72	143	106	232	132	1548
741 m	(11)	(11)	(10)	(11)	(10)	(8)	(5)	(7)	(8)	(7)	(12)	(10)	(110)
Firenzuola	129	115	122	112	81	92	41	72	119	98	176	119	1276
422 m	(9)	(9)	(10)	(9)	(9)	(8)	(5)	(6)	(8)	(8)	(12)	(10)	(106)

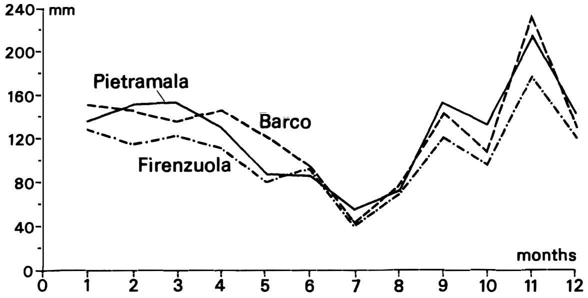

Fig. 1: Average monthly precipitation
Mittlere monatliche Niederschläge

The soils of the "Serie Peglio" show a clayey or clayey-silty texture with a medium to high water-holding capacity. During the winter they swell and may be associated with temporarily impeded drainage. In summer, shrinkage leads to large desiccation polygons. The coarse fraction of the soil (soil skeleton) increases near the Alberese rock reliefs. In contrast to these soils, the soils of the "Serie Tre Poggioli" are non-calcareous, with a low coarse fraction and show better developed profiles. They are found mainly on flatter, more stable surfaces.

Loamy soils are developed on the marly-arenaceous flysch bedrock. The "Serie M. Oggioli" and the "Serie Radicosa" have developed in the area of the valley head between M. Freddi and M. Oggioli, the less widespread "Serie Radicosa" are calcareous and found only on marly substrates. In the lower valley, the steep slopes of the FMA carry the "Serie Collina" in places with a thicker waste mantle. This is normally a deep soil with a well developed textural B-horizon and a low coarse fraction. The "Serie Castelvecchio" occurs where surface wash is most intensive and the "Serie Castellare" (with moderate profile development) on the rare flatter surfaces.

The differences between the clayey and clayey-loamy soils on the Alberese rock masses are also associated with different topographic situations. The "Serie M. Canda" is developed on the gentler slopes at the west side of the M. Canda. These soils are less or non-calcareous, with a low coarse fraction and a well developed clayey A-horizon. The "Serie Sambuco", on highly decomposed rock underground or on debris mantles, contains more carbonate and soil skeleton. The "Serie M. Carpinaccio" is found on steep rocky slopes and has a high $CaCO_3$ content and a poorly-developed profile.

The "Serie Visignano" and the "Series M. Beni 1 and 2" cover only small parts of the Diaterna Valica basin. The first of these has calcareous, clayey-loamy soils, which are developed on marls and especially prone to accelerated erosion. The latter ones are very poorly developed and restricted to the rocky scarp faces of the ophiolite masses.

3.3.2. Land Use

Agriculture in the Tuscan-Emilian Apennines has always been limited by climatic, morphologic and pedologic conditions rather than by socio-economic factors. Forestry predominates on the steeper, higher areas and cattle breeding on the flatter slopes and plains.

The upper and middle valley of the Diaterna Valica basin has to maintain the farming land, which, however, is strongly affected by slope instability (see section 2). Most of it consists of meadows and pastures and only a small part is used for cultivation of winter cereals (barley, oat and rye) for fodder. Abandoned farmland is colonized initially by spontaneous vegetation of junipers and dog-roses, which soon form dense shrub-coppice. Steeper slope parts, which are not suitable for agriculture, are cultivated by brushwood. At higher elevations conifer plantations have been used to stabilize slopes, e.g. on the lower slope of M. Carpinaccia.

The steep and rough lower valley is completely used by forest management. Brushwood cultivation is dominant, with oaks mostly at the lower elevations and beeches above the 850 m level. Economic chestnut cultivation is still common in the lower valley, but has diminished during the last 30 years. Many former chestnut woods are now overgrown by bushwood.

3.4. Hydrology

The flow regime of the Diaterna Valica is torrent-like and highly seasonal. It responds to the seasonal precipitation pattern with high run-off and sediment loads in the winter and low flows in the summer.

The channel system and drainage density change with lithology. In the area of the Terreni Caotici Eterogeni, the valley system is dendritic. The two main upper courses are cut into deep, V-shaped valleys. Their river gradients are high and fluvial erosion is actively undercutting the valley walls. The two streams join at the head of the middle valley, where the valley floor widens to 150 m and has a few meters of

Photo 1: Part of the headscarp (in the background) and of the lateral scarps of a "rotational earth slump" on the southern slope of the valley. The process of landsliding is still actual, with regressive headward and lateral enlargement of the scarps. Linear erosion on the slump scarps intensifies the erosive slope destruction

Teile der oberen und seitlichen Steilhänge einer „Rotations-Hangrutschung" am südlichen Talhang

gravel fill. In winter, this is frequently flooded but, in summer, flow is restricted to the channel.

Associated to the abrupt lithologic change from the smooth clayey Terreni Caotici Eterogeni to the more resistant FMA in the lower valley, the valley floor narrows to 20/30 m. The stream has cut a narrow, steep and deep valley into the marly-arenaceous flysch. It only has first order tributaries. The flow direction follows the anti-Apennine direction SW-NE.

4. Geomorphodynamic Processes

Table 3 summarizes present denudation processes in the field area, following the classification systems of *Commissione Interministeriale* (1971) and that one by Laatsch & Grottenthaler (1972).

4.1. Mass Movement

The type of mass movement depends on the underlying lithology: Rockfalls dominate on the bedrock of the flysch formations and a variety of landslides in the clays of the Terreni Caotici Eterogeni, as well as in the unconsolidated debris mantles below bedrock exposures.

Landslides

Landslides are characterized by plastic deformation of the slide mass and by decay of its internal structure. The swelling clays of the Terreni Caotici Eterogeni are especially susceptible to landslides. Various factors other than shrink-swell potential contribute to their instability. They include fluvial slope undercutting, earthquake movements and subsidence due to the exploitation of gas and oil deposits. There also are the different inclusions, which endanger the delicate equilibrium, causing irregularities in the internal friction and stress. Exposed by denudation they are washed away. By this they leave small cavities in which water collects, further increasing the slope instability. Indicators of active landslide processes are cracks, stowage of the turf and tilted bushes and shrubs.

Soil creep

Soil creep is a gradual, continuous movement of the upper soil layers, which leaves no particular landscape forms. It is generally characterized by minor undulations, bulging surface forms and crumpling of the turf, especially at the breaks of the slopes. Where movement is deeper and faster, and if the vegetation cover remains undisturbed, larger forms such as terracettes and small hummocks may develop. Parts of the affected slopes may become so steep and rough that machine cultivation is no longer possible and the land reverts to pasture or is abandoned entirely. Soil creep occurs generally on all slopes over 11°, and often on slopes of lower gradient. It is most evident in meadows, pastures and abandoned fields because ploughing tends to remove the forms it produces.

Rotational slumps

Slumps occur as rapid failures along curved shearing surfaces, usually in more or less homogeneous soil masses. The displaced material becomes reworked after failure but as unit it is not prone to further downslope movement.

The rounded headscarps of slump failures and their convex, bulging toes are clear signs of this form of activity. In the Diaterna Valica basin, the scarps are very steep and up to 10 m high. Following failure, erosion reduces them to angles of about 8–15°. Above the scarps, tension cracks are caused by pressure release, continuing a process of regressive headward enlargement of the slump scarps.

This type of landslide is widespread on both slopes of the middle valley but especially on the V-shaped slopes of the northern branch of the Diaterna, where stream undercutting is most active.

Earth flows

Earth flows are characterized by rapid slippage of soil masses which then continue moving downslope as a slow, highly vicious flow. Generally, each earth flow has several scarps, each about 1 m high, which gives it a stair-step appearance. Fissures indicate regressive enlargement. The movement of the earth flow is normally slow enough that vegetation cover may not be disturbed. Its rough surface shows distinct convex bulges and cavities, in which impeded drainage allows ponds to form. In the study area, earth flows are less common than slumps and do seldom exeed 150 m in lenght. They often develop from the accumulation zone of slumps or in depressions.

Earth slide / Gully erosion

A combination of landsliding and gully erosion has destroyed the south-exposed slope west of the hamlet Peglio in the middle valley. This slope is more than 150 m long and 150 up to 750 m wide and the elevation difference is about 200 m. Its destruction is so far advanced that even colonizing plants find little support on it and can only maintain themselves in a few places. Farming is completely impossible. The primary failure of the slope has been through a series of rotational earth slumps at different levels, with progressive headward and lateral expansion. The slump scarps have been modified by linear erosion into gullies. The central part of the slide area is presently moving downslope as an earth flow and is drained by a meandering creek. Lateral and upslope expansion is continuing into the fields below Peglio where earth slides are already developing. Gully erosion has started to develop also on another south-exposed slope in the middle valley, as yet on a limited scale.

The intensity of landsliding and linear erosion at these sites may be explained by the coincidence of the two following factors: exploitation of gas which intensifies the slope instability and the southerly exposure which produces rapid changes in soil water content. The installation of subsurface field drains below Peglio has had some success in stabilizing the slope and preventing further extension of the gullies. Reforestation with black pine of the western high slope has been too recent to allow its effects to be evaluated yet.

Falls

A recent rockfall event, which has been of the more damaging and episodic type, is to constate only on the eastern wall of M. Beni. The smaller and less damaging debris falls are more continuous and occur at the steep walls of M. Canda and M. Oggioli. The steep slope of M. Canda is dissected by a dense network of rills and couloirs which are still active, especially during periods of high precipitation in winter.

In the upper valley between M. Beni and M. Oggioli, the surface morphology and deposits suggest earlier rockfall events. Here, permeable marly-arenaceous flysch rocks overlie the weak clays of the Terreni Caotici Eterogeni. The resulting deposits of

Photo 2: In the background: headscarps of an "earth flow" with the typical stair-step appearance.
In the foreground: one of the numerous small cavities in which water collects, further increasing the slope instability. They are caused by rock inclusions, which are denudatively exposed andwashed away

,,Erdstrom'' mit typischer Treppenstufung im Hintergrund und eine der zahlreichen kleineren Vertiefungen im Vordergrund

Tab. 3: Denudation processes in the Diaterna Valica Basin (I = Italian, G = German)
Abtragungsprozesse im Tal der Diaterna Valica

	Lithology		
Type of Movement	Terreni Caotici Eterogeni (Argille Scagliose)	Debris Material	Bedrock: Marly- or Calcareous-Arenaceous Flysch
Falls I: cadute, movimenti caduti G: Sturz- oder Fallbewegungen			*rockfall* I: frana di crollo G: Bergsturz *debris fall* I: caduta di detritio G: Steinschlag
Landslides I: movimenti franosi, frane G: Rutschungen			
low seated I: superficiale G: flachgründig	*soil creep* I: soliflusso generalizzato G: Bodenkriechen	*soil creep* I: soliflusso generalizzato G: Bodenkriechen	
deep seated I: profondo G: tiefgründig	*rotational earth slump* I: frana di scivolamento rotazionale G: Rotationshang-rutschung		
low seated with transition to flow I: superficiale G: flachgründig	*earth flow* I: frana di colamento G: Kriech- oder Erdstrom	*earth flow* I: frana di colamento G: Kriech- oder Erdstrom	
combined landslides	earth flow developed on accumulation material of rotational earth slump		
Water Erosion I: Erosione idrica G: aquatische Erosion			
areal I: areale G: flächenhaft	*sheet erosion* I: erosione superficiale G: flächenhafte Abspülung	*sheet erosion* I: erosione superficiale G: flächenhafte Abspülung	*sheet erosion* I: erosione superficiale G: flächenhafte Abspülung
linear I: lineare G: linear	*rill erosion* I: ruscellamento G: Rinnen/Rillenerosion *gully erosion* I: calanchi G: Zerrachelung	*rill erosion* I: russcellamento G: Rinnen/Rillenerosion	*rill erosion* I: ruscellamento G: Rinnen/Rillenerosion

mixed clayey-marly ground masses with many rock fragments have a rough, irregular surface topography. Similar deposits are also found at the foot of M. Canda and M. Carpinaccio. They all have been reworked by linear erosion and sheet wash and are now overgrown by grass, bushes and, in some places, trees. Hollows in the wooded upper slopes may be the sources of large rockfalls. The surface is rather uneven, rough and bulging. The material could indicate also morainic-like deposits, but there are no other indications for a Pleistocene glaciation in this region. So it must be assumed that these sediments are larger rockfall and landslide debris masses.

4.2. Surface Water Erosion

The intensity of linear erosion and sheet wash varies due to the subsoil, slope angle and vegetation cover. In the area of the clayey Terreni Caotici Eterogeni, the erodibility of the material and agrarian land use combine to give high denudation rates, especially in the rainy winter periods. Rills develop wherever slope angles exceed 5°, in meadows and pastures as well as in agricultural fields. In springtime, exposure of the roots of winter cereal crops is indicative of the severity of sheet erosion. In the area of the marly-arenaceous flysch bedrock the steep slopes are protected by a dense forest cover. However, local overcutting enhances accelerated linear erosion; for example, the slope between M. Beni and M. Freddi at some places is dissected by 1 m deep and 3 m wide erosion gullies.

Quantitative long-term measurement data on soil erosion in the Diaterna Valica basin is not available. However, two procedures allow first estimates of a denudation rate for the basin slopes. (1) Rodolfi and Zanchi (1983) applied the Universal Soil Loss Equation (USLE by Wischmeyer) to the area of the Terreni Caotici Eterogeni and derived rates of 30 to 80 t/hayr for agricultural fields and up to 5 t/hayr for pastures and meadows. For the steep wooded slopes of the sandstone marl flysch area, he estimated yields of 2 t/hayr by the same method. (2) In August 1985, the method of rill measurements (Schmidt 1979) was applied on six fields in the middle valley with gradients of 7° to 15°. They suggest erosion rates of between 30 and 110 t/hayr, which correspond to the estimates of Rodolfi and Zanchi (1983). Both of these results suggest a high rate of accelerated erosion on open fields, and a need for protective measures there.

5. Mapping

The presented map of the Diaterna Valica catchment is composed of four different maps: (1) a geologic sketch map, (2) a geomorphological map, (3) a map of soils and land use, and (4) the map of present soil erosion and erosion potential. The last one is based on the other three and is the final product of this study. All but the geologic map were originally compiled at the scale 1:10 000 and have been reduced to 1:15 000 and 1:20 000 for publication.

5.1. Geomorphological Map

The geomorphological map of the Diaterna Valica basin follows the concept of the German priority program: "Geomorphological Mapping of the Federal Republic of Germany", started in 1976 and financed by the Deutsche Forschungsgemeinschaft (DFG, Bonn). This concept is based on the differentiation of geomorphologic information into eight levels: (1) slope angles, (2) morphography (valleys, steps, minor forms), (3) curvatures/ridges, (4) subsurface material, subsurface rock, (5) individual geomorphologic processes, (6) areas of morphogenetic processes and structure, (7) hydrography, (8) topography. On the maps these different information levels together turn out in an useful summary of complex geomorphologic facts (Barsch & Liedtke 1980a, 1980b). These information levels can be derived singly in any combination from the map. With regard to soil erosion maps, the German procedure includes both geomorphologic processes (shown by colours) and erosional landforms (shown by symbols) as well as the process controlling factors, such as slope angle and subsurface material (Mäusbacher 1985).

The geomorphological map of the Diaterna Valica does not follow the German pattern entirely. A comprehensive mapping of subsurface materials was not carried out in this project since a soil map on the scale 1:25 000 by Sanesi (1977) already existed. For methodical and technical purposes (see 5.2) this information layer "subsurface material" is presented in a separate map together with the additional informations about land use. The German legend has been added by three special symbols to differentiate the landslide types. The process of gully erosion associated with landslides is shown by combining the symbols for linear erosion and rotational earth slump with the areal colour for gravitational and denudational processes (brown and beige stripes).

5.2. Map of Soil Erosion and Soil Erosion Hazard

The aim of the derivative map of soil erosion and soil erosion hazard is to present information for landscape planning and conservation. This requires that complex information is shown in a comprehensible, readable form if it is to be of real use. The particular methodical challenge results from this conflict between the demand for cartographic distinctiveness and the need to display much information.

5.2.1. Method

Four separate base maps at 1:10 000 have been produced from available information and form the basis of the soil erosion and soil erosion hazard map. These four base maps are of:
- slope angles
- land use
- soils
- and present geomorphic processes.

They then have been generalized and combined to define erosion zones.

Step 1: Compilation and interpretation of available information

For the Diaterna Valica catchment, the following environmental data has been available: Topographical map, geological map, soil map (Sanesi 1977), cadastral survey map, aerial photos, climate data, thematical literature. They have been augmented by the geomorphic map of the basin produced by the authors from March to November 1985. After a preliminary evaluation of these data selective checking was carried out in the field.

Step 2: Compilation of the base maps

The next step is plotting the four different base maps (slope, land use, soils and geomorphic processes). Three of them can be derived more or less directly from the geomorphologic map (Table 4).

Step 3: Compilation of the soil erosion map

A correlation of these four base maps, carried out by superimposing them, allows division into homogeneous zones with regard to slope angle, soil type, land use and predominant present soil erosion processes. This zonal division is the base for the classification of the soil erosion and the soil erosion hazard in the investigated area. Eight erosion classes are distinguished. On the map they are shown by different colours, the least eroded areas in lighter shades than the most damaged ones. A potential transition into a next higher erosion class is defined when a zone has a lower present erosion level than equivalent zones with the same environmental characteristics. This potential transition is indicated by black dots over the colour for the present erosion level. The map legend provides detailed explanation of the soil erosion classes with regard to the nature of the erosion processes and their control factors as well as to suggested protective measures.

Tab. 4: Information sources for the four base maps
Ausgangsdaten für die 4 Grundkarten

	Base maps			
Sources	slope angle	land use	soil	geomorphologic process
topographic map	○	(○)	–	–
geologic map	–	–	(○)	–
soils map	–	–	+/○	–
cadastral map	–	+	(○)	–
aerial photos	–	○	–	○
gemorphological map	+	–	+	+

(○ = can be derived from, (○) = can partly be derived from, + = can directly be taken from, – = not usable)

5.2.2. Comments to the Soil Erosion and Soil Erosion Hazard Map

The derivative map fulfills the aims defined above: It is easy to read and it provides sufficient information about type, extent and controlling factors of soil erosion for an evaluation of individual sites. Further, the classification of soil erosion degree has been developed for the local physiogeographic environment of the Tosco-Emilianic Apennines.

More than half of the map appears in the two red shades which correspond to the two highest erosion classes (7 and 8). These are areas with a slope angle between 11° and 20° and a clayey substrate. These slopes are subject to intense water erosion and landsliding and may develop a badland relief (class 8). They tend to be areas in which cultivation has been abandoned because of the severity of erosion. To prevent further expansion of these areas, protective measures for slope stabilization are required.

The 6th class of risk is similar to the 7th class in regard to the processes of denudation, but it is most associated with the side slopes of V-shaped valleys. Here landslide activity is increased by fluvial erosion at the slope base. The permanent maintenance of the existing check dams and the construction of new ones are indispensable, but at the present this is blocked by communal financial difficulties.

Areas in the 5th erosion class are normally well suited for cultivation, because their slope angle is low (7°-15°). Nevertheless, they are impaired by erosion. Strip farming, contour-ploughing and subsurface drainage could reduce these effects before further damage would be incurred.

The areas of the 4th erosion classes are in the marly-arencaceous flysch regions and at the calcareous-marly rock masses, which top the middle valley crests. Despite the steep slope angles, these bedrock slopes are only slightly affected by linear and sheet erosion due to the dense forest cover. On the steepest, bare walls rockfall and debris fall may occur. The 3rd erosion class includes areas of the debris accumulations at the foot of bedrock masses. They are affected by linear erosion and landslides only when poorly covered by vegetation. In those sites, afforestation and maintenance of the existing forest cover is the solution to erosion problems.

Areas least affected by slope erosion have gradients of less than 5°. The 2nd erosion class is characterized by the rare flat surfaces in the middle valley. There, the cultivation of cereal crops and pasture land is possible without excessive erosion hazard. The 1st class includes the limited area of alluvial plain in the middle valley where slope erosion is negligible. However, agriculture is not possible in this zone because of the gravel subsoil and winter flooding.

Thus, the map of soil erosion and soil erosion risk points out very clearly that most of the agricultural land in the Diaterna Valica basin is endangered by intense erosion and thus requires slope stabilizing measures. Any attempts to stabilize the slopes must take into account all controlling factors which include regulation of the run-off by dams, drainage of the clay soils by surface and subsurface drains, and cultivation practices to reduce erosion (e.g. contour-ploughing and strip-cropping).

6. *Conclusion*

The map of soil erosion and soil erosion hazard covers the drainage basin of the Diaterna Valica creek in the Tuscan-Emilian Apennines. It contributes to the research on environmental conditions in rural settlement areas of the Northern-Central Apennines. There, the more open and flatter valleys in less resistant clayey underground have to maintain agricultural activity and are subject to intense slope degradation. Today, these erosional processes have accelerated to such an extent that, in some places, agricultural land use is no longer economical. In the interests of protecting the economic resources of these settlement areas, a systematic and rigorous program is needed to conserve and to restore the slope stability.

Such a program of landscape planning and conservation should be assisted by maps like the one presented. The derivative map of soil erosion and soil erosion hazard shows the area divided into zones of eight different classes of risk, represented by different colours on a topographical background. The classification is based on an analysis of environmental conditions and the correlation of four maps of present geomorphodynamic slope processes (1) and the main control factors in soil type (2), slope angle (3) and land use (4). These base maps are mainly derived from a geomorphological map, which follows the new geomorphological mapping concept ("GMK 25") developed in the Federal Republic of Germany.

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VARIATIONS OF MOUNT KENYA'S GLACIERS 1963–87

With 2 figures, 5 tables and 1 supplement (IX)

STEFAN HASTENRATH, RAOUF ROSTOM and ROBERT A. CAUKWELL

Zusammenfassung: Veränderungen der Gletscher am Mount Kenya 1963–87

In dem vorliegenden Aufsatz wird eine Karte der Gletscher am Mount Kenya vorgestellt (Maßstab 1:5000, Stand: September 1987). Diese Karte beruht auf Bodenkontrollpunkten und photogrammetrischen Kontrollpunkten, auf einer luftgestützten Triangulation dieser Punkte und der stereo-photogrammetrischen Auswertung von Bildflügen. In Verbindung mit einer Kartierung aus dem Jahr 1963 dokumentiert die Karte die Veränderung der Gletscher am Mount Kenya während der letzten 25 Jahre.

1. *Introduction*

The glaciers of Mount Kenya have been the object of an ongoing field project aimed at problems of climate and cryosphere changes in the tropics (HASTENRATH 1984). As part of this program, terminus positions were regularly measured for various glaciers. Fig. 1 and Tab. 1 offer an orientation on the ice extent in 1963 and the glaciers which disappeared earlier in this century. On the largest ice body, the Lewis Gla-

Beilage VIII zu ERDKUNDE 43,3 Beitrag Rodolfi/Zissel

CARTOGRAFIA GEORMOFOLOGICA APPLICATA ALLA CONSERVAZIONE DEL SUOLO NELLE AREE MARGINALI DELL'APPENNINO CENTRO-SETTENTRIONALE. Bacino rappresentativo del Torrente Diaterna Valica (Firenzuola, Firenze)

GEOMORPHOLOGICAL MAPPING AND SOIL CONSERVATION IN THE DISADVANTAGED AREAS OF NORTHERN-CENTRAL APENNINES. Representative watershed of the Diaterna Valica Creek (Firenzuola, Florence)

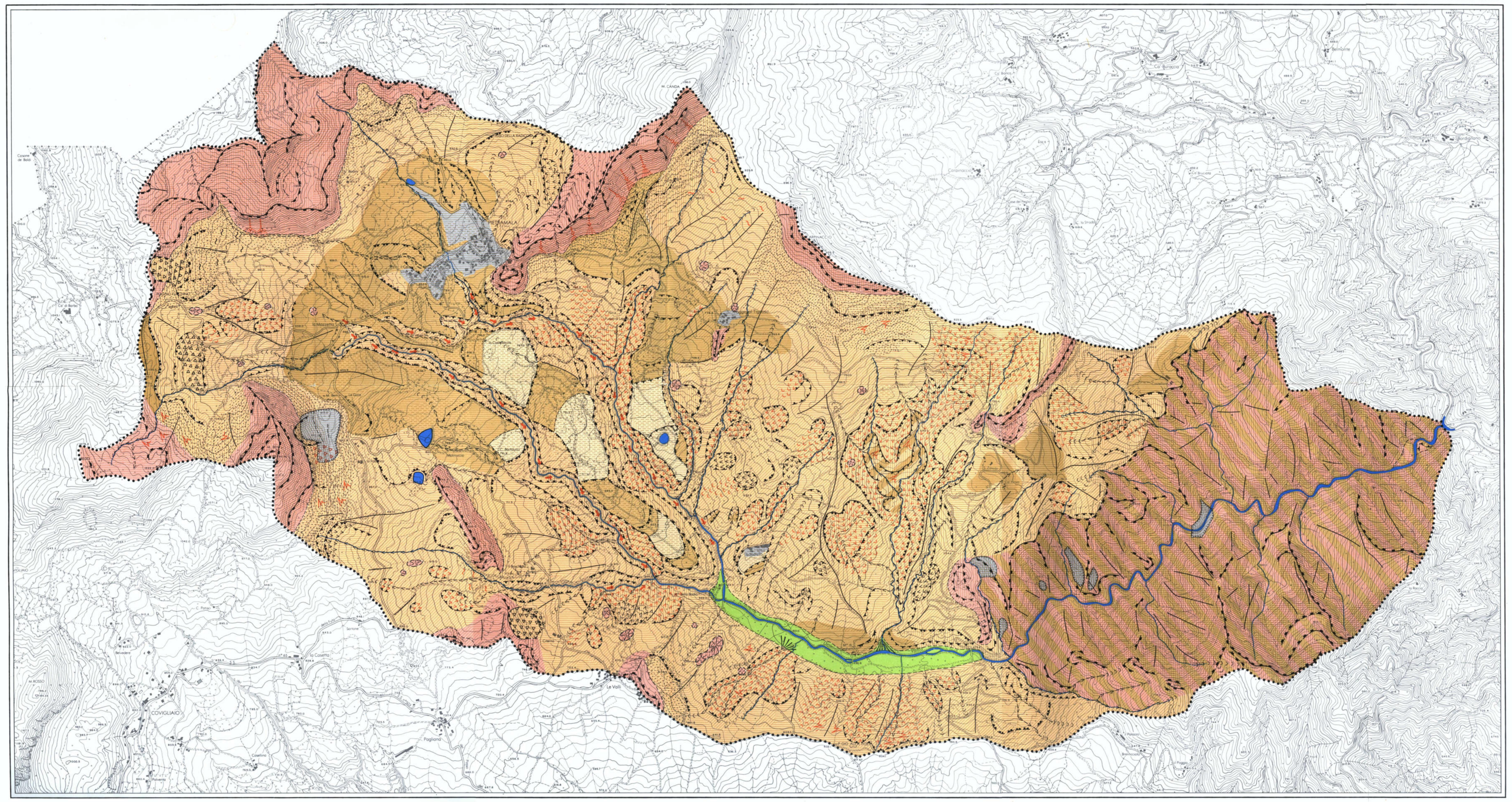
MINISTERO AGRICOLTURA E FORESTE
ISTITUTO SPERIMENTALE PER LO STUDIO E LA DIFESA DEL SUOLO
Firenze

Giuliano RODOLFI (Istituto Sperimentale per lo Studio e la Difesa del Suolo - Firenze / Research Institute on Soil Study and Conservation - Florence (Italy)) – Gabriele Annette ZISSEL (Istituto di Geografia dell'Università di Heidelberg-Germania Occidentale / Institute of Geography - University of Heidelberg (Western Germany))

CONSIGLIO NAZIONALE DELLE RICERCHE
PROGETTO FINALIZZATO I.P.R.A. "Incremento Produttività Risorse Agricole"
Area Problema 2.2: "Sistemi agricoli in aree marginali" Unità Operativa: Zanchi - Rodolfi

PROCESSI MORFOGENETICI E FORME DEL PAESAGGIO
GEOMORPHOLOGICAL PROCESSES AND LANDFORMS

scala 1:15.000 *scale*



ACCLIVITÀ DEI VERSANTI
SLOPE ANGLES

- I Classe <3°
- II Classe 3° - 7°
- III Classe 7° - 11°
- IV Classe 11° - 15°
- V Classe 15° - 20°
- VI Classe 20° - 35°
- VII Classe >35°
- frequenti cambiamenti di pendenza su brevi distanze (7°-15°) / *slope angles varying over small distances (7°-15°)*

SCARPATE E ROTTURE DI PENDIO
STEPS AND BREAKS OF SLOPE

ben conservate *well preserved*	degradate *degraded*	a) altezza (m) *a) height (m)*	l) larghezza (m) *l) width (m)*	
		1 - 5	1 - 5	Scarpate *Steps*
		1 - 5	5 - 10	
		5 - 20	1 - 5	
		5 - 20	5 - 10	
		>20		

- Orlo di scarpata calanchiva / *Edge of badlands area*
- Rottura di pendio concava / *Concave break of slope*
- Tratto di crinale o sperone a) minore, arrotondato b) principale, acuto / *Segment of ridge or spur a) minor, rounded b) main, sharp*

VALLI E VALLECOLE (larghezza <100 m)
VALLEYS AND SMALL DRAINAGEWAYS (width <100 m)

- Valli a "V" (larghezza 25-100 m) / *"V" shaped valleys (width 25-100 m)*
- Vallecole a "V" (larghezza <25 m) / *"V" shaped small drainageways (width <25 m)*
- Vallecole a fondo concavo (larghezza <25 m) / *Saucer-shaped small drainageways (width <25 m)*
- Tratto superiore di vallecola / *Upper part of small drainageway*

FORME SINGOLE E FORME MINORI
SINGULAR AND MINOR LANDFORMS

- Piccoli rilievi isolati per erosione differenziale / *Small reliefs, isolated by differential erosion*
- Coni di deiezione / *Alluvial fans*

PROCESSI E FORME DI DEGRADAZIONE
DEGRADATIONAL PROCESSES AND LANDFORMS

attivi *active* — non attivi *inactive*

- Frana di crollo / *Rock fall*
- Frana di scivolamento rotazionale / *Earth slump*
- Frana di colamento / *Earth flow*
- Soliflusso generalizzato / *Soil creep*
- Caduta di detrito / *Debris fall*
- Ruscellamento diffuso / *Rill and sheet erosion*
- Erosione fluviale laterale / *Fluvial undercutting*
- Accumulo di detrito in coni o fasce / *Debris cones or mantles*

AREALI DI AZIONE DEI PROCESSI MORFOGENETICI
AREAS OF GEOMORPHOLOGICAL PROCESSES

- Strutturale / *Structural*
- Fluviale (piana alluvionale) / *Fluvial (alluvial plain)*
- Denudativo (lembi di antiche superfici di erosione, in smantellamento) / *Denudational (remnants of ancient erosional surfaces)*
- Denudativo (prevalenza di erosione idrica superficiale) / *Denudational (dominance of surface erosion)*
- Gravitativo (prevalenza di movimenti di massa) / *Gravitational (dominance of mass movements)*
- Denudativo - strutturale / *Denudational - structural*
- Denudativo - gravitazionale (aree calanchive) / *Denudational - gravitational (badlands)*

IDROGRAFIA
HYDROGRAPHY

- Corso d'acqua normalmente perenne / *Stream normally perennial*
- Corsi d'acqua secondari / *Minor streams*
- Stagni artificiali / *Artificial ponds*

AREE ANTROPIZZATE
MAN-MADE LANDFORMS

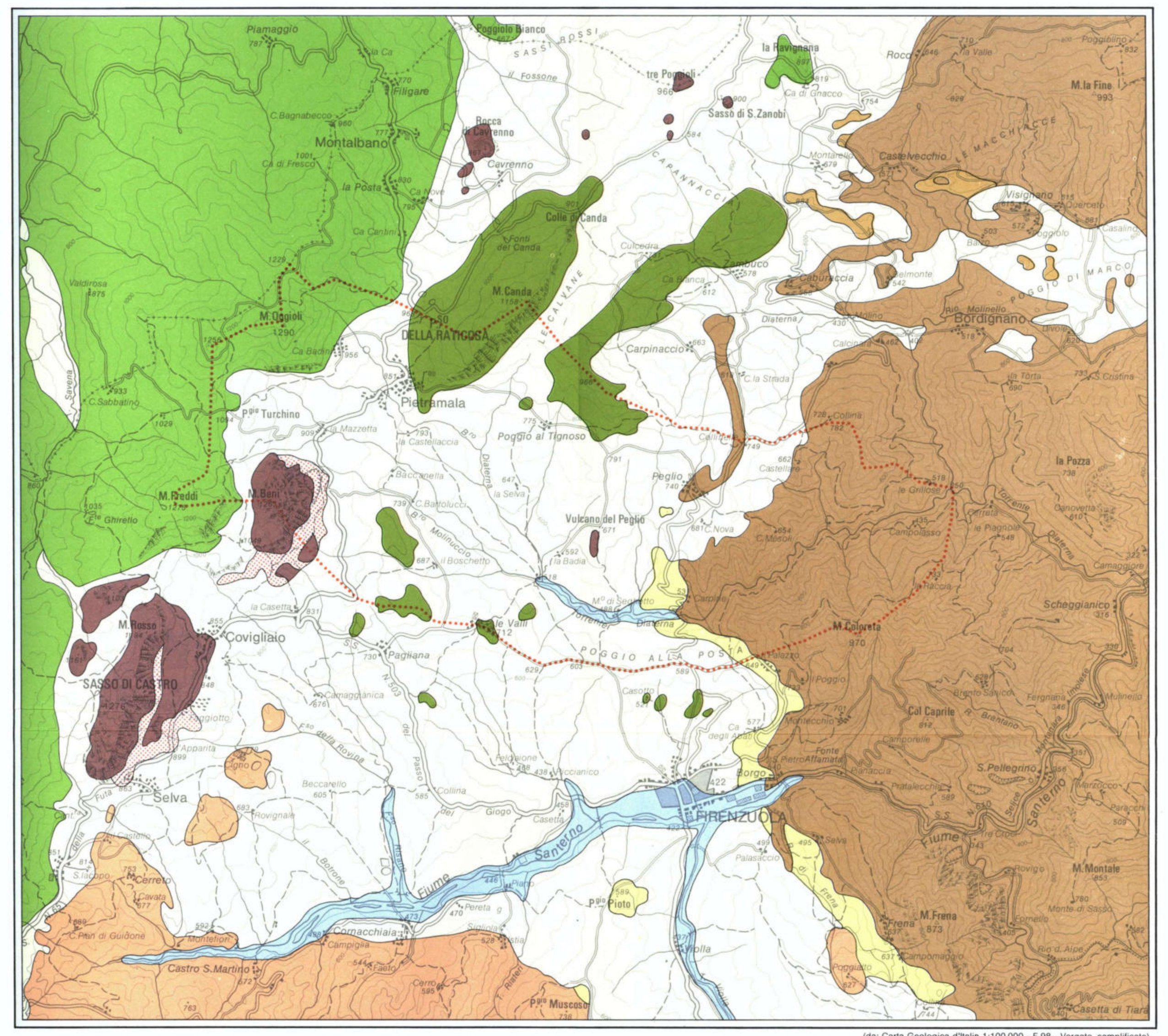
- Abitati / *Settlements*
- Cave / *Quarries*

Controllato ai sensi della
Nulla osta alla diffusione n.

Cartografia: S.E.L.C.A. Via R. Giuliani 153 - Firenze - 1987

SCHEMA GEOLOGICO GENERALE
GEOLOGICAL SKETCH MAP

scala 1:50.000 *scale*

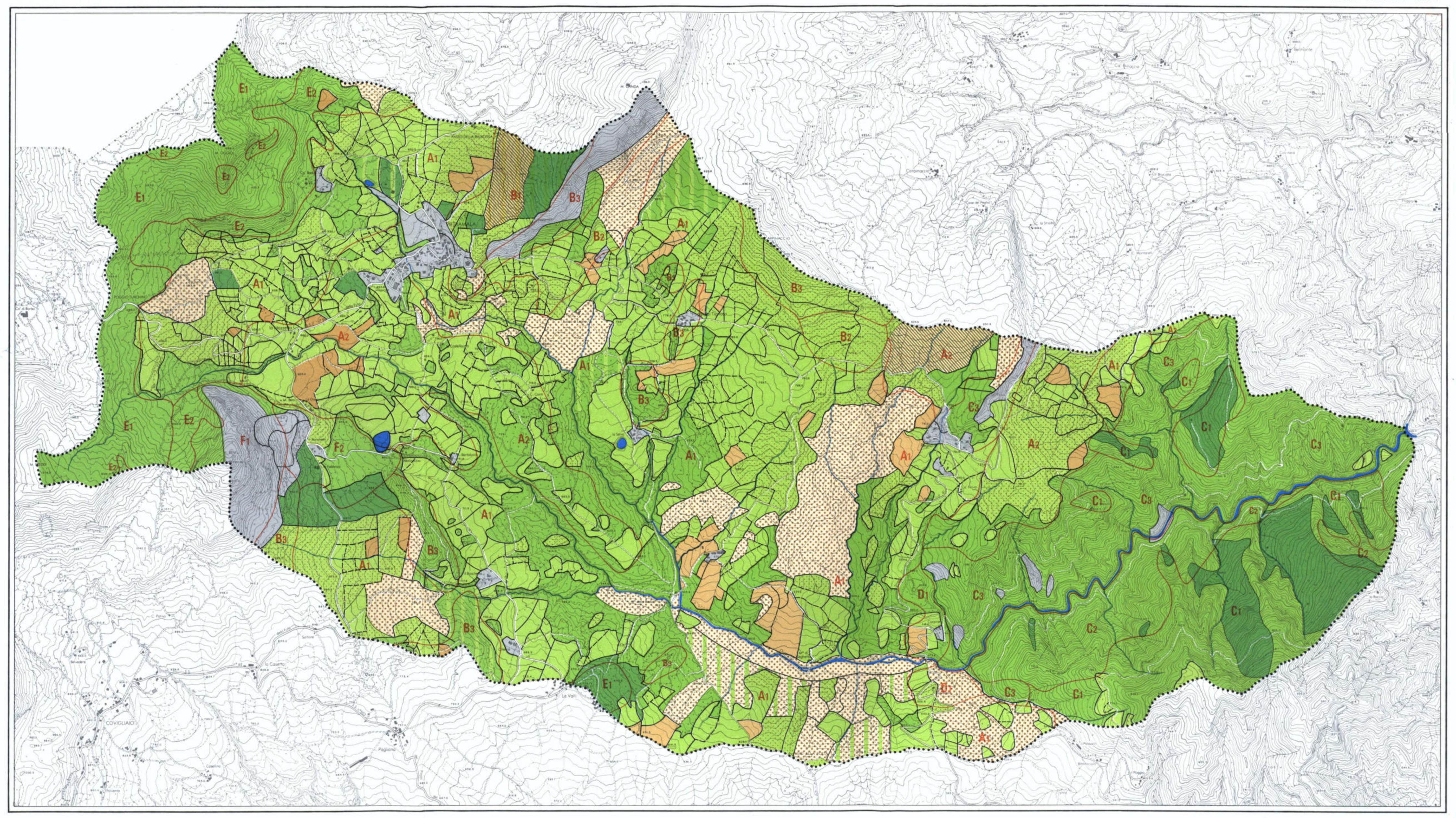


(da: Carta Geologica d'Italia 1:100.000 - F.98 - Vergato, semplificato)

- Depositi alluvionali recenti ed attuali, prevalentemente grossolani, incoerenti **(Olocene)** / Loose, prevalently coarse alluvial deposits ***(Holocene)***
- Depositi di versante recenti ed attuali, prevalentemente grossolani, incoerenti **(Olocene)** / Loose, prevalently coarse slope deposits ***(Holocene)***
- Marne stratificate o laminate, grigio-brune, con intercalazioni arenacee e siltitiche **(Tortoniano)** / Grey-brown marls with interbedded graywackes and siltstones ***(Tortonian)***
- Arenarie e siltiti quarzoso-feldspatiche, micacee e dolomitiche, alternate a marne siltose **(Serravalliano-Langhiano)** / Micaceous and dolomitic graywackes, alternating with silty marlstones ***(Serravallian-Langhian)***
- Marne e marne siltose, grigie e giallastre, a stratificazione indistinta **(Langhiano-Oligocene)** / Marlstones and silty marlstones, grey and yellowish ***(Langhian-Oligocene)***
- Arenarie quarzoso-feldspatiche, micacee e calcitiche, alternate a marne siltose e siltiti **(Langhiano-Oligocene)** / Micaceous and calcitic graywackes, alternating with silty marlstones and siltstones ***(Langhian-Oligocene)***
- Calcari marnosi con calcareniti, marne e marne argillose **(Eocene inf.-Paleocene sup.)** / Marly limestones with calcarenites, marlstones and clayey marlstones ***(lower Eocene-upper Paleocene)***
- Arenarie quarzoso-feldspatiche, micacee, con calcareniti, alternate a marne siltose e calcari marnosi **(Paleocene-Cretaceo sup.)** / Micaceous graywackes, with calcarenites, alternating with silty marlstones and marly limestones ***(Paleocene-upper Cretaceous)***
- Serpentine, gabbri, diabasi ("ofioliti"), associate a diaspri, calcilutiti e calcari silicei con argilliti **(Cretaceo-Giura)** / Serpentines, gabbroes, diabases ("ophiolites") associated with red chert, calcilutites and cherty limestones with mudstones ***(Cretaceous-Giura)***
- Argille e argille marnose inglobanti calcari, marne, ofioliti e frammenti di altre formazioni - "Terreni Caotici Eterogenei" / Clayey and marly clayey matrix with limestones, radiolarites, ophiolites and fragments of other formations - "Tectonic Melange"
- **Bacino idrografico del Torrente Diaterna Valica** / ***Drainage basin of the Diaterna Valica Creek***

SUOLI E LORO UTILIZZAZIONE ATTUALE
SOILS AND ACTUAL LAND USE

scala 1:20.000 *scale*



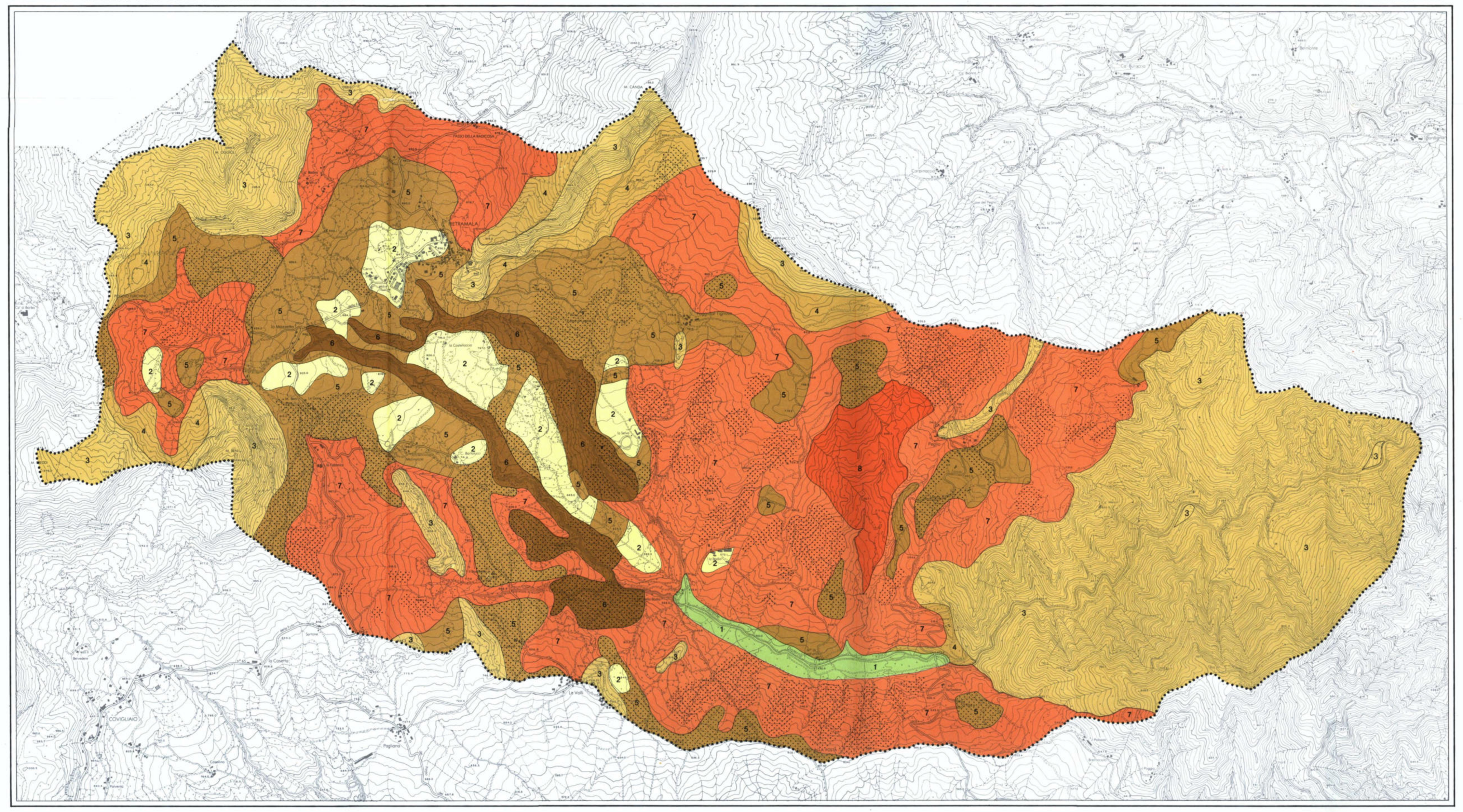
- Bosco ceduo / *Coppice*
- Bosco d'alto fusto (castagneti, abetine, pinete) / *High forest (chestnut groves, fir and pine woods)*
- Rimboschimento / *Forestation*
- Cespugliato e/o incolto / *Bushy and/or uncultivated areas*
- Seminativo / *Arable land*
- Prato-pascolo / *Pasture land*
- Prato-pascolo in abbandono / *Abandoned pasture land*
- Roccia affiorante, cave, centri abitati / *Rock outcrops, quarries, urban settlements*
- Siepi di confine / *Boundary hedges*
- Limiti degli appezzamenti coltivati (piste campestri, scoline, ecc.) / *Boundaries of cultivated fields (country paths, ditches, etc.)*
- Corsi d'acqua, stagni / *Streams, man-made ponds*
- Vie di comunicazione o di servizio / *Main and minor roads*
- a b — Recenti cambiamenti di utilizzazione (**a** = utilizzazione attuale; **b** = utilizzazione precedente) / *Recent changes on land use (**a** = actual; **b** = former)*

	UNITÀ PEDOLOGICHE Soil units	PROFILO Profile	TESSITURA Texture	SCHELETRO Coarse fragments	PROFONDITÀ Depth	STRUTTURA Structure	DRENAGGIO Drainage	CLASS. USDA USDA class.
A_1	Serie Peglio	A B C	argillosa clayey	variabile variable	moderata moderate	poliedrica grossolana coarse blocky	imperfetto imperfectly drained	Typic & Aquic Eutrochrepts
A_2	Serie Tre Poggioli	A B C	argillosa clayey	modesto low	moderata moderate	poliedrica grossolana e fine fine-coarse blocky	imperfetto imperfectly drained	Typic & Aquic Eutrochrepts
B_1	Serie M.Canda	A B C	argillosa clayey	modesto low	moderata moderate	poliedrica media medium blocky	ben drenati well drained	Typic Eutrochrepts
B_2	Serie Sambuco	A B C	franco-argillosa loamy-clay	elevato very high	moderato-profondo moderate-deep	poliedrica media e grossolana medium-coarse blocky	ben drenati well drained	Typic & Rendollic Eutrochrepts
B_3	Serie M.Carpinaccio	A B C	franco-limosa loamy-silty	moderato moderate	moderata moderate	poliedrica fine e media fine-medium blocky	eccessivamente ben drenati excessively well drained	Rendollic & Typic Eutrochrepts
C_1	Serie Collina	A B_t C	franco-sabbiosa loamy-sandy	scarso very low	profondo deep	poliedrica media e grossolana medium-coarse blocky	moderatamente ben drenati moderately well drained	Typic & Ultic Hapludalfs
C_2	Serie Castellare	A B C	franca loamy	scarso very low	moderata moderate	poliedrica media e grossolana medium-coarse blocky	moderatamente drenati moderately drained	Dystric Eutrochrepts
C_3	Serie Castelvecchio	A B C A C	franca loamy	frequente high	sottile/roccioso shallow/rocky	grumosa, fine fine crumb	eccessivamente drenati excessively drained	Typic Eutrochrepts
D_1	Serie Visignano	A B C A C	franco-limosa loamy-silty	scarso very low	profondo deep	poliedrica fine e media fine-medium blocky	ben drenati well drained	Typic Eutrochrepts
E_1	Serie M.Oggioli	A B C	franca loamy	scarso very low	profondo deep	poliedrica fine e media fine-medium blocky	moderatamente ben drenati moderately well drained	Dystric Eutrochrepts
E_2	Serie Raticosa	A B C	franco-argillosa loamy-clay	scarso/moderato very low/moderate	moderatamente profondo moderately deep	poliedrica fine e media fine-medium blocky	ben drenati well drained	Typic Eutrochrepts
F_1	Serie M.Beni I	A C	sabbioso-franca sandy-loamy	elevato very high	sottile/roccioso shallow/rocky	grumosa fine fine crumb	eccessivamente drenati excessively drained	Umbrepts
F_2	Serie M.Beni II	A B C	franco-sabbiosa loamy-sandy	elevato very high	moderata-profondo moderate-deep	poliedrica fine fine blocky	eccessivamente drenati excessively drained	Dystric Eutrochrepts

da Sanesi, 1977 *from Sanesi, 1977*

LIVELLI DI RISCHIO E CRITERI DI CONSERVAZIONE DEL SUOLO
LEVELS OF HAZARD AND SOIL CONSERVATION CRITERIA

scala 1:20.000 *scale*



1	Area pianeggiante, costituita da depositi alluvionali prevalentemente grossolani, con vegetazione arbustiva. Occasionalmente soggetta ad inondazione, non è utilizzabile per l'agricoltura a causa della eccessiva pietrosità. *Alluvial plain with shrub vegetation on coarse deposits, occasionally subject to flooding. It cannot be utilized for agriculture because of its high stoniness.*
2	Aree a debole acclività (3°-7°) con colture erbacee o prati-pascoli, su suoli prevalentemente argillosi. Processi denudativi (ruscellamento superficiale) di normale intensità. Dal punto di vista del controllo dell'erosione, sono possibili tutte le colture, con vincoli relativi al tipo di lavorazione. *Gently sloping areas (3°-7°) with herbaceous crops or grazing meadows on prevalently clayey soils. Denudational processes (rill and sheet erosion) of normal intensity. Concerning erosion control measures every crop is possible, restricted however by the ploughing system.*
3	Aree a forte acclività (>20°) con affioramenti di roccia coerente, o protette da una densa copertura vegetale (bosco ceduo, castagneto da frutto). Ruscellamento superficiale di normale intensità. Cadute di detrito in corrispondenza delle scarpate più acclivi. Da mantenere a bosco. *Steeply sloping areas (>20°) with outcrops of coherent rock, or protected by a dense vegetation cover (coppice, fruit chestnut groves, etc.). Rill and sheet erosion of normal intensity; debris falls from the steepest slopes. To be retained wooded.*
4	Aree ad acclività compresa fra 15° e 20°, con accumulo di detriti provenienti dalla unità precedente, per lo più incolte. Il ruscellamento superficiale è maggiormente evidente, e si manifestano localizzati e superficiali movimenti di massa. A causa della elevata pietrosità e della pendenza, le aree non coperte da bosco dovrebbero essere rimboschite. *Moderately to steeply sloping areas (15°-20°) prevalently uncultivated, with accumulation of debris coming from the preceding unit. Rill erosion becomes more evident, and superficial mass movements can occur. Because of its high stoniness and steep slopes, the unwooded areas should be forested.*
5	Aree ad acclività compresa fra 7° e 11°, con bosco ceduo, colture erbacee o prati-pascoli, su suoli prevalentemente argillosi. Il ruscellamento superficiale è marcato; le ondulazioni dei versanti testimoniano il verificarsi di lenti movimenti di massa. Sono possibili le colture non a righe, con vincoli di alternanza con colture prative. *Moderately sloping areas (7°-11°) with coppice, herbaceous crops or grazing meadows on prevalently clayey soils. Rill erosion is accentuated; the undulations of the slopes show the occurrence of slow mass movements. Crops are possible, however only when not in rows and alternating with grass pasture lands.*
6	Aree ad acclività compresa fra 11° e 20°, con bosco ceduo, cespugliato o prati-pascoli, su suoli prevalentemente argillosi. Soggette a marcato ruscellamento e a movimenti di massa (scivolamenti rotazionali) per erosione al piede da parte dei corsi d'acqua. La loro utilizzazione, ravvisabile unicamente nel prato o nel prato-pascolo, deve essere vincolata alla sistemazione idraulica dei corsi d'acqua. *Moderately to steeply sloping areas (11°-20°) with coppice, bush or grazing meadows on prevelently clayey soils. Subject to strong rill erosion and to mass movements (earth slumps) because of slope undercutting by streams. Their utilization, only possible as permanent or grazing meadows, must be coupled to the rivers control.*
7	Aree ad acclività compresa fra 11° e 20°, con bosco ceduo, rimboschimenti, prati-pascoli e frequenti coltivi abbandonati, su suoli prevalentemente argillosi. Soggette a severa erosione e ad estesi e profondi movimenti di massa (scivolamenti rotazionali e colate). Unica utilizzazione nei tratti meno dissestati è il pascolo permanente, che può essere esteso con cautela alle zone in frana, vincolato a leggeri rimodellamenti e ad una capillare sistemazione delle acque superficiali. *Moderately to steeply sloping areas (11°-20°) with coppice, reforestations, permanent and grazing meadows, and many abandoned fields, on prevalently clayey soils. Subject to both severe erosion and wide and deep mass movements (earth slumps and flows). In the less unstable patches the only utilisation is permanent meadow, which can be cautionsly extented to the sliding areas by slight slope smoothing and a careful surface water control.*
8	Aree a morfologia molto accidentata, con roccia affiorante o vegetazione arbustiva, su suoli prevalentemente argillosi. Soggette ad estesi e profondi movimenti di massa, a colate di fango e terra e a severa erosione incanalata, in rapida evoluzione. Nessuna possibile utilizzazione agro-silvo-pastorale. Gli interventi sistematori devono essere condotti nel solo intento di ritardare l'estendersi del fenomeno alle aree circostanti, mediante la disciplina delle acque superficiali. *Very dissected sloping areas, with rock outcrops or shrub and bush vegetation on prevalently clayey soils. Subject to wide and deep mass movements (earth slumps and flows) and severe (rill to gully) erosion, quickly evolving. Any kind of land use is prevented. The only purpose of reclamation works can be to prevent the spreading of this phenomenon to the surrounding areas, by means of stabilizing the local base level.*

Aree con potenziale tendenza ad assumere le caratteristiche del livello di rischio immediatamente superiore.
Areas potentially susceptible of taking on the upper level of hazard.