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Guide for the excursion

BADLAND PROCESSES AND SIGNIFICANCE IN CHANGING ENVIRONMENTS

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1. INTRODUCTION

(G. Rodolfi)

Italian agriculture has changed considerably over the last few decades. This phenomenon, which started at the end of the second world war, was caused by the growth in industry and the consequent expansion of towns, which extended mainly in the flat areas in the bottom of the valleys. From then on, agricultural activities have been moved towards areas with a very delicate environmental equilibrium. If we consider the fact that, in Italy, about 40% of these surfaces are composed of «clays», it is easy to understand why reclaimers have focused their attention on these particular environments since the '30's. The erosive phenomena which characterize the landscapes, generically defined as «badlands», develop mainly in these environments, and in a highly intense form. They are present both on the Adriatic side (from the Langhe of Piedmont to the Apennine hilly belt of Emilia, Marche and Abruzzo, as far as Puglia and Basilicata) and the Tyrrhenian one (from Tu-

scany to Lazio, to Calabria); we find them in most of Sicily and in Sardinia too, on limited stretches (fig. 1). The Italian badland forms are generally known as *calanchi*, *biancane* and *balze*. *Calanchi* are small hydrographic basins with a well developed drainage network formed by surface processes, especially rillwash, gullying and frequent shallow landsliding on very steep slopes. *Biancane* are small clay domes up to 20 m in height, which typically are grouped in clusters. They usually have the southern side, deprived of vegetation, dominated by incised rills and micropipes, and are surrounded by miniature pediments. The last type, the *balze*, are vertical free faces (sort of crags) continuously subject to falls which cause their progressive retreat.

The first Italian studies on these topics date back to the beginning of this century, even though they referred to particular erosion forms. Other studies, connected with the beginning of the reclamation programmes, date back to the '30's. However systematic studies do not get underway until the '50's. The activity of the Istituto Sperimentale per lo Studio e la Difesa del Suolo (Issds) of Florence, which was founded in this period, was, and still is directed mainly towards the study of «clayey» environments. Other researchers in various research institutes of the Consiglio Nazionale delle Ricerche (Cnr) and the Universities, first Pisa, Florence and Siena, then Bari, Camerino and Potenza, have been dealing with the same problems since the '70's.

The main aims of this Workshop are, in substance, the following:

– to inform foreign researchers about the peculiar nature and the dynamics of the forms characterizing the Italian landscapes which can be defined as «badlands»;

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FIG. 1 - Distribution of calanchi and biancane in Italy (M. Del Sette).

- to discuss any differences or analogies with apparently similar forms in environments which are different from the Mediterranean ones;
- to formulate hypotheses on their genesis and evolution, with particular reference to the role played by the growing anthropic influence.

During the three field trips which this guide refers to, three badland environments in Tuscany will be visited:

- I. the Volterra area, where an Experimental Farm, belonging to the Istituto Sperimentale per lo Studio e la Difesa del Suolo of Florence, for the study of erosional processes is located, and where the Centro di Studio per la Geologia Strutturale e Dinamica dell'Appennino of the Cnr in Pisa, has worked for many years;
- II. the Crete Senesi area, mainly studied by the University of Siena;
- III. the Val d'Orcia area, where the Istituto per la Genesi e l'Ecologia del Suolo of the Cnr in Florence has carried out thematic surveys and set up an experimental station for the study of particular erosion forms.

The three areas are characterised by the outcropping of Pliocene marine sediments. A geo-chronological map of the central and upper Tuscany is reported in fig. 2, with the location of the study sites.

2. VOLTERRA AREA (VAL D'ERA)

2.1 THE MAIN GEOLOGICAL FEATURES OF VAL D'ERA (R. Mazzanti)

An interdisciplinary (geological, micropaleontological, sedimentological, etc.) study was carried out in the Spicchiaiola-Pignano area (eastern part of the Volterra basin, between Volterra and Castel S. Gimignano). This study examined the Neogene succession which developed in various sedimentary cycles on pre-Neogene formations. The oldest cycle follows an initial extensional event and is represented by the *Arenaria di Ponsano*; the local outcrops of this formation can be attributed to the Early Tortonian. During the late Tortonian a general extension determined some tectonic depressions of Apenninic orientation in Tuscany. The first deposition in a lacustrine environment occurred in these depressions (one of which is the Volterra depression). In the Early Messinian, the lacustrine environment was substituted by a lagoonal and brackish one, because of local communications with the Tyrrhenian Sea. The deposits of these two sedimentary episodes form a second cycle which is represented, in lithostratigraphical terms (from the oldest to the most recent unit) by the *Conglomerati di Pod. Loppiano*, the *Argille del T. Fosci*, the *Formazione della Spicchiaiola*, and the initial portion of the *Argille a Pycnodonta*. The final part of the cycle is also characterized by local and temporary evaporitic episodes.

Again in the Early Messinian, a marine transgression occurred in the Spicchiaiola-Pignano area (it has been recognized in all the basins to the west of the Middle Tuscan Ridge). This introduced a third cycle, characterized by coarse detritic deposits (*Conglomerati di Villa Mirabella*) and the reef-complex (*Calcari di Castelnuovo*) in the eastern areas (which uplifted during the previous cycle) and by pelites (*Argille a Pycnodonta*) in the western parts. The marine environments, with abnormal chemical, and also therefore biological characteristics, ended during the Messinian with a new precipitation of evaporites. The latter can be correlated to the ones which deposited after the general «salinity crisis» of the Mediterranean. The cycle ended with a prevalent clayey succession, but it is characterized by repeated gypsum levels and by travertine (*Argille del F. Era Morta*) or with coarse detritic deposits (*Conglomerati di Borro Sassicaia*). These sediments all deposited in a fresh water or slightly brackish water environment («lago-mare» facies of the Late Messinian).

In the Spicchiaiola-Pignano area, the transgression with which the fourth sedimentary cycle begins is represented by the *Conglomerati di Bosco delle Volpaie* and the *Argille azzurre*, which belong to the Early Pliocene (*Globorotalia margaritae* Zone; *Amaurolithus tricorniculatus* Zone) and lie discordantly on Messinian and pre-Neogene units. The most recent parts of the cycle, preserved in the area, also belong to the Early Pliocene (*G. puncticulata* - *G. margaritae* Zone; *A. tricorniculatus* Zone) and they do not show any sign of regression. The discordances identified between the various sedimentary cycles were related to the activities of some faults.

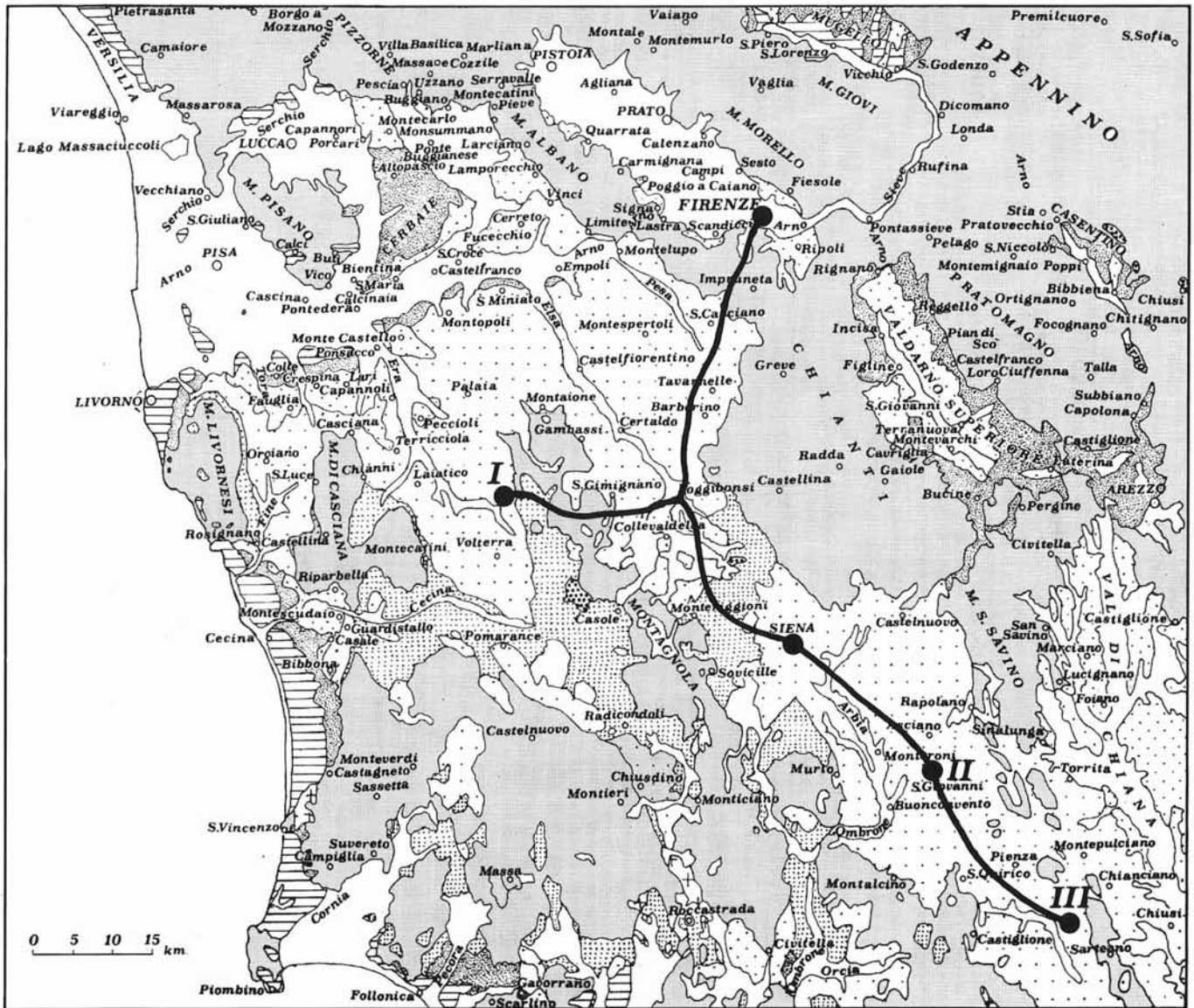


FIG. 2 - Geochronological sketch-map of Northern-Central Tuscany: 1) Holocene; 2) Upper Pleistocene; 3) Middle Pleistocene; 4) Lower Pleistocene; 5) Intrusive igneous rocks; 6) Lower and Middle Pliocene; 7) Upper Miocene; 8) Epiligurian bedrock sediments; 9) Pre-neogenic bedrock. I-II-III: Field trips.

2.2 EROSION FORMS IN THE VOLTERRA AREA
(R. Mazzanti & G. Rodolfi)

The Pliocene sedimentary cycle, in the area around Volterra, is characterized by the stratigraphic superposition of the following formations:

- *Argille azzurre marine* (Marine blue clays, Lower Pliocene), lying concordantly on an upper Miocene formation, deposited in a fresh water or hypo-haline environment (gypsum, clays, sands, conglomerates); they are of considerable thickness (about 1000 m) and can be separated into two members (lower and upper) as a result of the intercalation of a conglomerate level;

- *Argille sabbiose e sabbie delle Case Cafaggiolo* (Case Cafaggiolo sandy clays and sands), which mark the beginning of the middle Pliocene transgression;
- *Sabbie a Flabellipecten* (*Flabellipecten* sands), with intercalations of arenaceous limestones, which close the sedimentary cycle with a thickness of about 200 m.

There is a close relationship between the physical-mechanical features of the Pliocene sediments and the forms which characterize the Val d'Era landscape. The latter can all be well observed from the top of the *Balze* di Volterra (Volterra Crags). From the base of the series on up, they correspond as follows:

- Lower Blue Clays => *biancane*
- Upper Blue Clays => «B» type *calanchi*

- Sandy Clays and Sands => «A» type *calanchi* and «small *balze*»
- *Flabellipecten* Sands => *balze* di Volterra

For definitions of these forms refer to the exhaustive literature on the matter (RODOLFI & FRASCATI, 1979; MAZZANTI & RODOLFI, 1988)

2.3 SOIL-LANDSCAPE RELATIONSHIPS IN THE VOLTERRA AREA (L. Lulli)

With the exception of some residual limbs of paleosols, the soils in the area around Volterra are generally Entisols, affected to varying degrees by vertic phenomena. Inceptisols are also present. They are generally deeper and are characterized exclusively by the formation of a cambic horizon with carbonate segregation and tendentially dark brown in colour. Inside the basin we have considerable differences in the granulometric composition of the sediments, which are associated with different forms and soils (LULLI & *alii*, 1980).

Starting with the finer sediments of the Lower Blue Clays we find deposits with almost no sand which are associated with decidedly compact soils, with no deep water circulation, which are subjected to erosion, above all in the upper zone disturbed by tillage. The passage between soil and bedrock is sharp. The dominant clay is vermiculite. In these sediments, which behave like a compact mass, we have decidedly rounded erosion forms, with decortication of the surfaces and incisions located along the fractures. This gives rise to a *mammelloni* (knoll) landscape. The soils (*Lischeto* series of the Vertic Xerorthents) are always thin, massive and not very evolved. The most evident erosion forms are deep incisions with well defined edges. Actual fans of muddy material (mud flows) often form at the base of the slopes.

Again clayey materials, where montmorillonite is dominant (20%) and with a sand content of around 10% (Upper Blue Clays) develop soils, the main characteristic of which is that they produce cracks which are deep enough to affect horizon C and sometimes pass through it (*Mataione* series of the Vertic Xerorthents). Hydromorphic features are found in the deep levels. Amphitheatre-like *calanchi* (type «B», RODOLFI & FRASCATI, 1979), which evolve mainly because the soil slips over its substratum, form in these environments.

On the sandy clay and sandy deposits of Case Cafaggio the sand content increases while the montmorillonite content is reduced to about 8%, even if the tendency to cracking remains well expressed. In this case the «knife-edged» *calanchi* forms (type «A», RODOLFI & FRASCATI, 1979) appear when there is greater relief energy or greater cohesion in the sediment. In the presence of even more resistant levels *balze* form, but with escarpments which are not very high (small *balze*). The soils (*Renaglio* series of the Aquic Xerorthents) show a certain capacity to sustain trees. When the sand content reaches levels of up to 50% (*Flabellipecten* sands), the landscape changes completely in that the soils (*Renaglio* series) are able to sustain trees: well structured woods; olive groves and vineyards. The

surfaces become rounded, similar to the surfaces of clayey-silty deposits from many points of view.

2.4 THE PROBLEM OF SOIL EROSION IN THE VOLTERRA AREA (G. Chisci)

There are various kinds of clay soils in Italy. Most of them require redemption from the point of view of soil physical characteristics. In the Era R. valley these soils characterize a marginal area in the part of the watershed dominated by hilly landscapes. The agricultural system is based on two years of winter cereal small grains, followed by two or three years of pasture, utilized for sheep for milk (to make cheese) and lamb production. Over the last few years, a trend towards reducing the cultivation of winter cereals and keeping a larger area for consolidated permanent pasture has been observed, following the farmers' adoption of the EU «set-aside» policy. In this marginal area increasing pressure on land agricultural exploitation during the '50's - '80's period, consistently accelerated hydraulic and landscape disorder and erosion on slopes, thus creating serious problems in the down-stream area.

It was primarily in view of this situation that the Istituto Sperimentale per lo Studio e la Difesa del Suolo (Issds) of Florence chose this area to activate a long-term research project in the 70's. The decision was also influenced by the fact that the Issds had a research facility, the S. Elisabetta Experimental Centre, located in the vicinity of Volterra (Pisa). The aim of the specially designed multidisciplinary research was to study the ecosystem dynamics, taking into account the multiple relationships between geomorphology, soil genesis, erosion and landslide hazard, soil fertility evolution, soil hydrology and water management, optimal land use for agricultural, forestry and pasture exploitation compatible with soil and environment protection.

From the many field experiments, carried out on plots, catchments and small watersheds, it was demonstrated that various erosion forms are closely connected with soil hydrology, influenced primarily by macroporosity induced naturally into the soil by cracking, and artificially by the cloddiness produced by ploughing. Where overland flow predominates, sheet and rill erosion processes are the most intense. Otherwise, mass erosion processes prevail. Generalized soil erosion was monitored over a long period in small watersheds, representative of both smooth and rough landscape units, using two monitoring systems: a) sampling sediments in runoff from the outlet of the watershed; b) measuring long-period sediment deposition in small reservoirs. The results demonstrated that smooth morphologies, normally covered with a large extension of arable land, produce a higher amount of sediments (8.0-8.5 t ha⁻¹ y⁻¹) than rough morphologies (4.3-4.6 t ha⁻¹ y⁻¹) where a consistent part of the watershed is consolidated as pastureland, covered by grass and shrub vegetation (CHISCI, 1989, 1991; BAZZOFFI, 1984). Long-term plots and catchment trials, devoted to the experimental evaluation of different soil conservation measures, demonstrated that the control of erosion in arable land required the application of adequate mechanical measures, such as deep ploughing, contour ter-

racing and underground drainage for surface and interflow water management, slope stabilization and landslide prevention. Moreover, land degradation processes, which determine the environmental impact to a large extent, can only be kept under control by planned land use, which implies both a sufficient consolidated area and an appropriate water management system on arable slopes, in each watershed unit.

2.5 VEGETATION IN VAL D'ERA (S. Maccherini & V. De Dominicis)

The association *Phalarido coerulescentis-Elytrigietum athericae* which in a dynamic sense follows the relict association *Parapholido-Artemisietum cretaceae*, has been described for the Pliocene clay soils of the upper Val d'Era (LOPPI & DE DOMINICIS, 1990). It includes compact prairies dominated by *Elytrigia atherica*, widespread at the edges of cultivated land and especially on sedimentation pediments of *biancane*, in contact with pioneer vegetation with *Artemisia cretacea*. This association is subdivided into two subassociations: *inuletosum*, differentiated by *Inula viscosa*, *Pulicaria dysenterica* and *Lathyrus odoratus*, and *brachypodietosum*, differentiated by *Brachypodium rupestre*, *Oenanthe pimpinelloides*, *Pallenis spinosa*, *Hypochoeris achyrophorus* and *Anemone hortensis*. These subassociations are floristically and ecologically distinct. The first is linked mainly to soils of the *Lischeto* series, with a high clay content, and the second is more common on soils of the *Renaglio* series, with a high sand fraction. The authors compare the subassociations in terms of other environmental factors, such as altitude, aspect and slope. Statistical analysis showed that the spatial distribution of the two subassociations is determined primarily by differences in aspect, and secondarily by soil.

2.6 S. ELISABETTA EXPERIMENTAL CENTRE (ISTITUTO SPERIMENTALE PER LO STUDIO E LA DIFESA DEL SUOLO)

2.6.1 *The soils* (L. Lulli)

The sediments outcropping in the area are generally clayey-silty, with sand contents of around 10-20%. Entisols, which present vertic characteristics, have developed here. However we pass to Inceptisols when the surfaces allow the pedogenesis to last long enough. In some particular cases, actual Vertisols develop. The pedoenvironment is xeric, because of the general climatic conditions, with long dry summers, and also as a result of the natural tendency of the soils to cracking, right from the early evolution phases. Referring to the Soil Taxonomy classification system we have: Vertic Xerorthents on all the eroding surfaces; Vertic Xerochrepts on the benches and terraced surfaces; in some cases Chromic Haploxererts in small depressions along the hilly slopes. The apparent anomaly of finding vertic forms in soils which must still be considered as Entisols is due to the fact that these materials manifest

their dynamism easily, probably because of the smectitic nature of the clays already present in the sediment. Nevertheless, if we take into account the particular organization of the structures and the variation in colour, most of the silty clay soils in these areas could also be included in the Inceptisols.

As far as series are concerned, the most important and widespread is definitely the *Mattaione* series (LULLI & *alii.*, 1973). These soils (Vertic Xerorthents) are very close to Vertisols. Even though they do not present the same distinguishing features, they are characterized by cracking when dry.

2.6.2 *Experimentation currently underway in the S.E.E.C.* (P. Bazzoffi, S. Pellegrini, R. Papini, G. Brandi, A. Rocchini, O. Grasselli & M. Morandi)

This guide presents a study carried out on the hilly clayey «Cavalcanti» watershed near Volterra, in the Era Valley (Pisa). This watershed has a surface of 85 hectares and drains in the ephemeral torrent of the same name. Following PINNA (1977) the climate of the station is classified as Csa (mesothermic, humid, Mediterranean). The average temperature is 12.7 °C, ranging between extreme values of -10°C and +40°C. The average yearly rainfall is 678 mm; rainfall is concentrated in spring and autumn. ETP, following Thornthwaite, is 569 mm. Shrink-swelling phenomena dominate the hydrological behaviour of soils. In winter they present a very slow infiltration capacity, with a maximum runoff coefficient of 0.85. In summer, on the contrary, cracks determine a high infiltration capacity, and the runoff coefficient approaches zero. The aims of the experiments are: 1) to quantify the influence of different soil uses on runoff and soil erosion; 2) to gain a better knowledge of the influence of soil use on the acceleration or reduction of flood events 3) to study nutrient dynamics. These studies are carried out at different scales within the Cavalcanti watershed.

In the upper part, 62.4 ha of the watershed lead water to a reservoir with a capacity of 180000 m³, and with a dam which was built in 1954. The average slope of this part of the watershed is 23.9% and 53.8% of the surface has slope classes ranging between 20% and 50%. In this part of the catchment, studies have been carried out since 1970, and there is a lot of data available on: 1) soil characteristics, 2) hydrology 3) soil erosion, 4) sedimentation 5) radionuclide dynamics and 6) nutrient balance. Inside this part, two sub-catchments, about 5 ha in size, are monitored with a flume, electronic water level detector ISCO and automatic sampler. These two small catchments are mono crop cultivated (at present: durum wheat, on the catchment on the right and alfalfa on the other). The aim is to detect differences in hydrology and soil erosion at this scale (BAZZOFFI & *alii.*, in press). Several surveys have been performed in the body of the reservoir to measure settled sediment, Cs137 radio nuclide stratification and water quality (BAZZOFFI & PANICUCCI, 1983).

Down the dam, the watershed is studied at field scale by collecting data on two randomized blocks of 4 plots, 75

m long, up-down the slope, and 15 m wide. Each plot is equipped with an electronic Fagna-type hydrological unit (BAZZOFFI, 1993), for runoff measurement and sampling. This new device allows very accurate measurement and the analysis of runoff dynamics. In Experimental Centre an electronic meteo-station collects data on rain, radiation, humidity, temperature and wind velocity and direction every hour. Another electronic tipping bucket raingaugé collects rainfall data with a resolution of 0.2 mm. All the electronic devices in the watershed are synchronized. In the plot experiment we compared four treatments: 1) durum wheat, 2) continuous harrowed surface, 3) alfalfa and 4) grazing shrubs.

2.6.2.1 Main results

Runoff and soil erosion

A detailed analysis of rain characteristics influencing the erosive process, recorded at the Centre during the period 1964-1990, showed a dry up of climate in the short period. This trend referred to rain quantity and, in particular, to aggressiveness. In fact, the evolution of rain events showed an increase in quantity and intensity, while an increase was found in the mean lag between successive events (BAZZOFFI & PELLEGRINI, 1992). At watershed scale and on a multi-decennial average, soil erosion was 9.75 t/ha/year, as estimated by measurement of the sediments in the reservoir in the upper part of the watershed. ¹³⁷Cs-balance in soil and sediment demonstrated that only 13.9% of total radionuclide input was removed by runoff water (BAZZOFFI & PANICUCCI, 1983). Grain size distribution of sediments inside the reservoir is 10% richer in clay than that of the soils of the draining watershed. This finding demonstrates that inter-rill, rill and channel erosion processes are predominant on mass movements. The latter would have made the two grain distributions more similar (BAZZOFFI & PANICUCCI, 1984).

In mono-crop watersheds runoff volume and maximum peak flow discharge did not differ between alfalfa and wheat land use. Differences became progressively more significant when runoff volumes were considered for 10 and 30 minute periods around the peak. In fact they were reduced by 7% and 25% in alfalfa with respect to wheat. Alfalfa was also able to increase the mean duration of runoff events by about 40%. In comparison with winter wheat, grazing shrubs drastically reduced runoff by 66% and soil loss by 93%. Compared to harrowing, shrubs reduced runoff and erosion by 49% and 91% respectively, while compared with new-planted alfalfa, the reductions with grazing shrubs were 77% and 94% respectively. New alfalfa plantation was not able to protect the soil in the first year; in fact runoff volumes were 33% higher than in wheat plots, and 55% higher than in harrowed plots. Soil erosion was 24% and 38% higher respectively.

These findings are important in relation to the evolution of rills in gullies and even in *calanchi*. In fact in these clayey hilly areas, the rotation of soil use is: winter wheat, alfalfa, alfalfa, winter wheat, and soil is almost always in a vulnerable condition, especially in spring and autumn when it is

bare or scarcely covered, and aggressive rains occur. In May 1995 an intensive storm, with 78 mm of rain, and an estimated frequency of 6.5 years, occurred. This rainfall produced evident rills in the harrowed plots, and the measured soil loss was 130 t/ha. Total soil loss observed in the same plots during the entire year of 1994 was 9 t/ha. This fact demonstrates that conservation measures must be considered with respect to the risk of critical events.

In the plot experiment soil uses were also compared regarding their capability of increasing the lag time between the occurrence of the maximum rainfall peak and the maximum runoff peak. This hydrological parameter only relates to time, and does not take the intensity of the peak into consideration. The difference between the time of occurrence of the maximum rainfall peak and the maximum runoff peak was calculated for each runoff event and for each plot. The average values indicate that in the period between November and January, when soil cracks are closed, grazing shrubs increase the lag time. Alfalfa is also capable of increasing the lag time, especially in the second year after sowing, when root and canopy provide more effective soil protection. Harrowing the soil to prepare seed-bed conditions produced the shortest lag time, while ploughing increased water infiltration and the lag time of the runoff peak with respect to the rainfall peak.

Nutrient dynamics

Nitrates, ammonium and soluble phosphorus in runoff waters and total nitrogen, available, bio-available and total phosphorus in suspended sediments were determined for each runoff event. The greatest loss of nutrients occurred in alfalfa plots in the first year, followed by cereal, continuous fallow and grazing shrubs. Nitrate loss from alfalfa, cereal and harrowed plots was 12.4, 10 and 7.6 kg/ha respectively. The loss of soluble phosphorus was very low in all soil uses, and was due to fertilizer application. In the sub-catchment cultivated with cereal nitrate losses were 10.5 kg/ha, while nitrate losses from the alfalfa sub-catchment were 0.5 kg/ha. Seasonal nitrate dynamics and their distribution in the soil profile were affected by tillage and fertilization. In fact tillage increased the summer mineralization of organic nitrogen in soil and consequently caused a high NO₃-N content in soil in autumn. In winter, runoff and leaching determined significant losses in these NO₃-N quantities. The application of mineral N to cereal plots, at sowing time, did not cause an increment in NO₃-N in the soil profile in December. Furthermore, since plant uptake is very low in this period, we can conclude that mineral fertilisation can cause an increase in the loss of NO₃-N, without any significant benefit for the plants (PAPINI & *alii*, in press).

3. SIENA AREA: CRETE SENESI AND VAL D'ORCIA

3.1 THE CRETE SENESI (C. Calzolari & D. Torri)

The area of the *Crete Senesi*, or «*maligne crete*» (= bad clays) as they were called by the Italian poet G. Carducci

last century, is an area where the anthropic influence on the landscape is fairly strong, due to the fact that Siena is so near. Roughly speaking, the Crete Senesi include the basins of the Asso, Ombrone and Arbia rivers, north of Montalcino and Pienza and south of Siena. Here pliocenic marine sediments outcrop on the hills, while the valley floors are characterized by recent fluvial deposits (GUASPARRI, 1978). The alluvia can be rich in gravel along the beds of the main rivers (Arbia, Asso and Ombrone) while they have a loamy texture along the beds of the other (minor) streams. The drainage pattern reflects the nature of the lithological substratum: a typical dendritic pattern is present where the clay sediments outcrop, while a subparallel one is characteristic where sandy sediments are more frequent. All the badland forms, previously described, are present in the Crete: *biancane*, *calanchi* and *balze*. The first form, almost completely erased by the intense reclamation work which has taken place in recent years, is still widely represented in the Le Fiorentine area. On the southern border of the Crete, some of the most spectacular *calanchi* surround the abbey of Monte Oliveto Maggiore and they are threatening the small village of Chiusure. *Balze* are to be found near the town of Asciano.

3.2 MEN AND CLAY IN THE TERRITORY AROUND SIENA (B. Vecchio)

There is a marked difference between traditional land use south east of Siena (Crete Senesi and Val d'Orcia) and the predominant use to the north of the city. Even though they can both be included in the same type of land tenure, i.e. *mezzadria* (share-cropping) organized in *poderi* (sort of farm sub-units) scattered over the country-side, the kind of farming practiced is generally more intensive in the northern area and more extensive in the south east. For the latter area the definition *latifondo a mezzadria* (share-cropping latifondium) was therefore proposed. Differences also exist within the area itself: in the Crete Senesi area the valley bottoms are generally more highly populated and better cultivated than the hills. On the other hand, in Val d'Orcia it is quite the opposite. Within the general context of latifundium (understood in relation to the average conditions in the inland area of Tuscany) land was put to farming uses of varying intensity: in simpler terms, in the first half of the nineteenth century the ancient Greek-Roman biennial wheat/fallow rotation was used on the best land, on the medium quality land the rotation was wheat/several years of fallow and the most difficult land (the greater part), which includes, among other things, the *calanchi* and *biancane* areas, was used for permanent natural pasture (GIORGETTI, 1983).

With the crisis, and subsequent disappearance, of *mezzadria* (in the second half of the twentieth century) the situation was transformed completely: some estates have converted to a capitalist or farming-capitalist running system; others have regressed from a production point of view, and some have even reached the economic condition of mere gathering; other estates have been subdivided and sold in portions, each part corresponding to a *podere*; so-

me others, in the town outskirts, have in part been split up into smaller pieces, to be used for building development or small scale intensive farming.

Sheep-breeding by share-croppers no longer exists (PEDRESCHI, 1957); sheep-breeding was later introduced again by the Sardinian shepherds, who bought many of the old farms (VECCHIO, 1988). Arable land increased greatly after the '60's, to the loss of the old pasture areas. The situation has been at a standstill since the '80's and there has recently been a regression in the arable lands, linked to the changes in EU agricultural policies.

3.3 FLUVIAL DYNAMICS AND THE TUBER MAGNATUM PICO (L. Lulli)

The sites where the *Tuber magnatum* Pico (type of truffle, quite appreciated for its flavour) can be found are located along the beds of the streams which drain the badland areas. The pedo-environment where the truffle develops must have a pH > 7.6, carbonates, bulk density close to 1.1 and an interconnected porosity greater or equal to 50% of the total porosity.

These conditions are generated by a series of processes. The sediments exported from the badlands are generally silty clay. Major sedimentation episodes occur during local floods, which deposits are chaotic and made of the coarser grains (resulting texture is often loamy), with a well developed interconnected macropore net. The local topographical position and the riparian vegetation guarantee a local udic-mesic climate, which makes the sites suitable for the truffle.

3.4 NEOTECTONICS OF THE SIENA AND THE RADICOFANI BASINS (A. Colica)

An outline of the neotectonical evolution of the Siena and the Radicofani basin is presented in tab.1 (bold for general aspects, normal for the Siena basin and italics for Radicofani basin). Data are taken from the works by TREVISAN (1952), GIANNINI & TONGIORGI (1959), LAZZAROTTO & MAZZANTI (1965 a-b), JACOBACCI & *alii* (1967), GIANNINI & *alii* (1971), BARBERI & *alii* (1974), MAZZANTI & TREVISAN (1978), COSTANTINI & *alii* (1979, 1980), BOCCALETTI & *alii* (1987), BERTI & *alii* (1992), COLICA (1992), LIOTTA (1996).

The figures quoted in tab. 1 derive from COSTANTINI & *alii* (1979, 1980), modified by the author.

3.5 MORPHOLOGICAL AND HYDROGRAPHIC OUTLINES OF VAL D'ORCIA (A. Colica)

The upper Orcia River Valley represents a graben (Radicofani neogenic basin), filled mainly with Pliocene marine sediments, bounded in the N by the Pienza - S. Quirico d'Orcia sill, to the E by the Cetona M. ridge, to the W by the Amiata M., while in the S the sediments are buried by the Quaternary Volsini volcanic materials. At the present

TABLE 1 - Outline of geology and neotectonics of Siena and Radicofani basins

GEOLOGY, LITHOLOGY AND NEOTECTONICS OF THE NEOGENIC BASINS OF SIENA AND RADICOFANI (SI-I)				
Time Intervals	Geology	Lithology	Outcrops localization	Neotectonics
Upper Miocene	Distensive phase. A new sedimentation cycle begins. Lacustrine and brackish facies. <i>Continental facies.</i>	Clays, lignite and Breccia di Grotti <i>Breccia with liassic calcareous elements and arenaceous marly cement.</i>	Corsano, Petriccio and Grotti. <i>N of S. Casciano Bagni.</i>	The genesis of Siena and Radicofani basins originate from the distensive phase beginning during the late Tortonian. Limited basin with N-S direction. <i>Formation of the graben with NW-SE direction.</i>
Early Pliocene	Sea ingression. Sedimentation with marine facies in deep sea environment, in the central and oriental part of the basin. Fluvial and delta fan facies. <i>Sedimentation with marine facies in deep sea environment.</i>	Clays, sandy clays and conglomerates lenses. Sands and conglomerates. <i>Clays, sandy clays and sands.</i> <i>Organogenic limestone (Amphistegina and Litothamnium, dated early-middle Pliocene).</i>	From Siena to Pienza In the NW edge of the basin. <i>From the Pienza sill in the N, to Castell'Azzara in the S.</i> <i>Pienza and in the NW of Cetona Mt.</i>	Intense, rigid, distensive, mainly vertical, tectonic movements give origin to Siena and Radicofani basins (graben delimited by listric, direct faults- fig. 3 a). The Middle Tuscany ridge is probably stable. <i>The Amiata-Castell'Azzara ridge uplifts while Rapolano-Cetona-Torre Alfina ridge uplifts and tilts towards ENE.</i> <i>The Radicofani basin develops through two phases: (i) sinking between faults 1 and 2 and (ii) successive widening and sinking between faults 3 and 4. There are earth-flows. During the upper part of early Pliocene the uplifting of the Radicofani area begins (fig. 3 a).</i>
Middle Pliocene	Beginning of marine regression.	Sandy clays and sand. <i>Conglomerates with sandy layers.</i>	Midwest part of the basin. <i>W of Cetona Mt.</i>	The Cetona-Torre Alfina ridge changes from probably standstill to uplifting. The tilting (NE direction) during the uplifting determines the marine regression from the Middle Tuscany and Amiata-Castell'Azzara ridges (fig. 3 b). Uplifting of the little Murlo ridge and filling of the Siena basin. <i>Because of the uplifting, the filling of the rift occurs and the emersion of the Radicofani basin begins.</i>
Late Pliocene				Epirogenetic uplifting. The emersion of the basins continues (fig. 3 c). The Rapolano-T. Alfina, Middle Tuscany and the little Murlo ridges uplift.
Pleistocene	Continental and fluvio-lacustrine deposits. <i>Magmatic activity.</i>	<i>Red conglomerates. Clays, peats and diatomite.</i> <i>Trachybasalts, olivinic-latites and olivinic-trachytes.</i> <i>Rhyodacites.</i>	<i>Orcia Valley. Around Amiata Mt.</i> <i>Radicofani.</i> <i>Amiata Mt.</i>	Conclusion of the uplifting in the Siena basin, Middle Tuscany and Murlo ridges. <i>The epirogenetic uplifting keeps on. Intense erosion.</i> <i>Magmatic activity: Radicofani (1.3 - 0.003 Ma) and</i> <i>Amiata Mt. (0.303 - 0.287 Ma).</i> <i>Movements of the faults 5, 6, 7; along the latter, hydrothermal phenomena occur (S. Casciano dei Bagni - fig.3 d).</i> <i>The main hydrographic net follows the pre-quaternary structural patterns.</i>
Holocene	Hydrothermal activity.	Travertine deposits (Pleistocenic and Holocenic). <i>Sediment detritals</i> Alluvional terraces and deposits	Asciano and Rapolano. <i>Poggio Zoccolino, NW of Cetona Mt., around Amiata Mt. and Radicofani.</i> Along Orcia and Asso rivers	

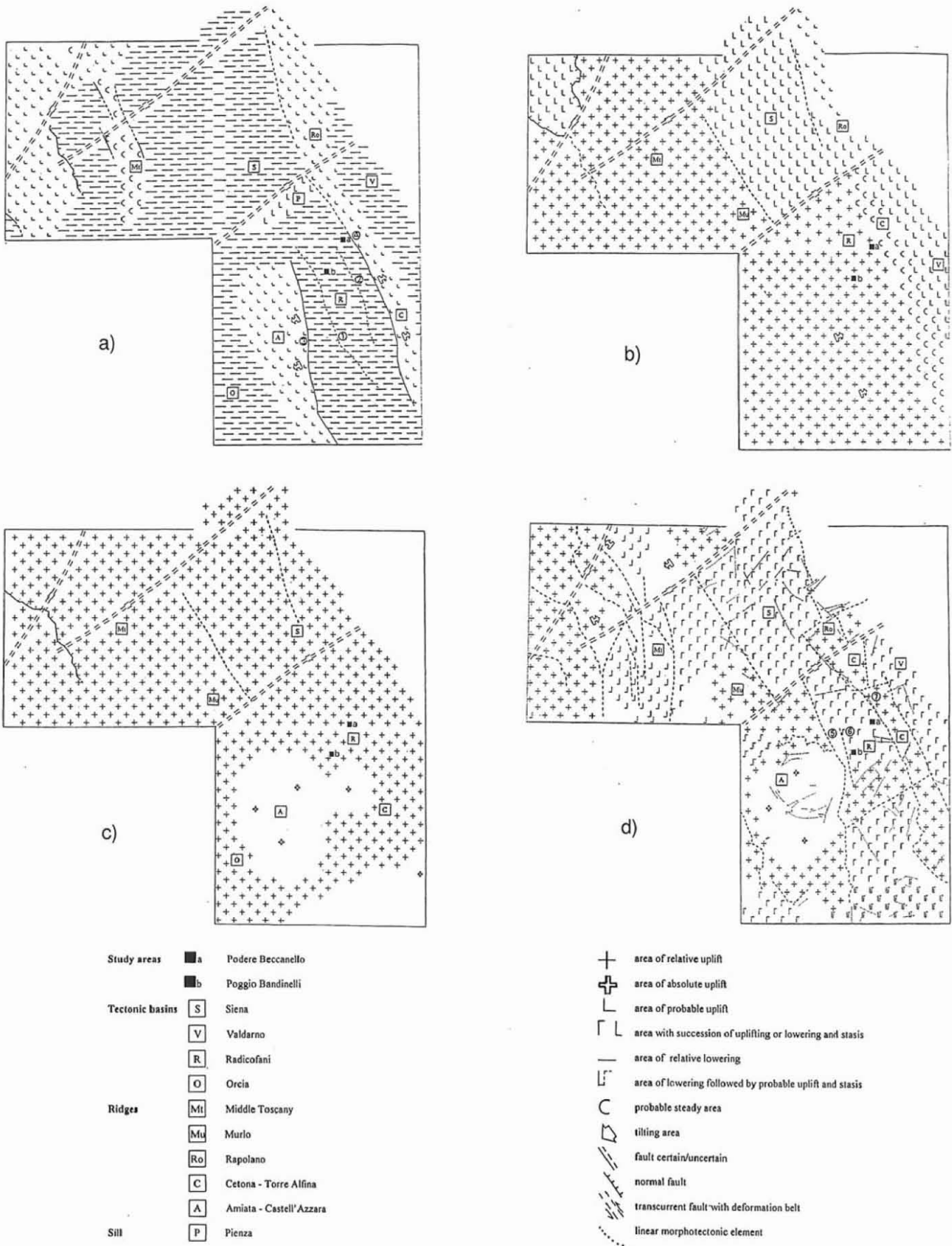


FIG. 3 - Neotectonics in Siena and Radicofani basins during: a) Early Pliocene; b) Middle Pliocene; c) Late Pliocene; d) Pleistocene.

time the sediments are uplifted to 700 m asl in some areas, such as nearby Radicofani: in this area the morphological unbalance is evident, with steep profiles presenting *calanchi* and mass movements. The rivers are driven by base dynamics and the main hydrologic net develops on NNW-SSE directions.

3.6 LANDSCAPE ANALYSIS OF VAL D'ORCIA (E. Busoni)

An integrated landscape survey was carried out on the badland area in the Upper Orcia River Valley by means aereo-photo-interpretation (scale from about 1:28,000 to 1:33,000) and field controls. The aim was to distinguish land units reflecting different erosion, mass movement trends etc., in an area that can be considered as a sample-area in relation to the evolution of Pliocene basins in Italy.

The distribution of land and degradation characteristics (morphological sequences, elementary landforms and slopes, drainage patterns, river bed, geomorphic dynamics, erosion forms, mass movements, vegetation and land use, land management systems) and their relationships in homogeneous areas (land units and land types) were analyzed (PCA and cluster analysis). The aim was to distinguish any land feature related to mass movements, erosional processes (active or not), anthropic influences, geomorphic dynamics, drainage patterns and river bed evolution, and to explain the soil response to dynamic and anthropic factors from an erosion hazard point of view (BUSONI & *alii*, 1994, 1995). One can stratify land units into five major landscape layers: (i) the basal one, including alluvial plains and terraces, alluvial and colluvial fans; (ii) gently sloping surfaces (slope <12%), with undulated morphology, subdendritic and dendritic drainage pattern, with only generic mass movements (soil slumps) and rare tilled *biancane* domes; (iii) moderately to steeply sloping areas (slope between 12 and 20%), subjected to mass movements (landslides, solifluction, creeping) and erosional forms (deep gullies [*calanchi*], *biancane* domes, deep incisions), with a subparallel drainage pattern; (iv) steeply sloping areas (slope >20%) strongly subjected to mass movements (evident, still active, landslides, solifluction and deep creeping) and erosional forms (*calanchi*, *biancane* domes, deep incisions, gullies), with a parallel drainage pattern; (v) gently sloping areas (slope <15%) waning to crests, generally around villages and small towns with high anthropic influences that have limited erosion forms (only ephemeral rill and sheet forms) and relatively small mass movement: solifluction (rare) and creep; the drainage pattern is generally subparallel, due to management practices.

3.7 LAND USE AND SOILS OF VAL D'ORCIA (C. Calzolari)

On Pliocene clays arable lands are dominant, and crops like winter wheat and winter barley are the most common. Permanent pastures are common on badlands. Irrigated crops, such as maize, are found on alluvial plains. Woodlands are present on steeper slopes, while vineyards and

olive groves, usually intercropped with arable, are found on hilly Pliocene sands and conglomerates, and on Allocthonous Complex shales (Cretaceous), present along the borders of the basin).

Soil types depend mainly on the principal lithotypes present, their management and their position on the hill-slope. As a general rule, cultivated soils are usually more eroded than natural ones, and so it is more difficult to find preserved soil profiles. Nevertheless the soil types are almost the same. On the homogeneous clays in the central part of the area, characterized by short, gently sloping hill-slopes, which are generally intensively cultivated, the typical succession of soils is represented by Inceptisols, more or less developed, on the large, rounded divides and by Entisols on the hillslope. Vertisols, associated with the previous main orders, are commonly found in the valleys. This distribution is obviously only theoretical, as erosion and mass movement processes, land reclamation works, tillage practices, and so on, strongly influence the soil pattern. Inceptisols are actually rare on cultivated areas. The same succession is present on natural landscapes, such as *biancana* badland areas. Here Vertisols are usually present on the top of larger *biancane* or small hills, as they witness, in this case, the remnants of morphological surfaces, less disturbed by the quick hillslope dynamics, typical of this area.

On the sequence of different lithologies which characterizes the same Pliocene clay formation in the southern part of the Orcia Valley, near the small town of Radicofani, where the morphology is generally steeper and *calanchi* are common, the soil types, apart from their morphological position, are also affected by the granulometric composition of the outcropping parent material. Inceptisols are commonly found, unless truncated, on conglomerates, or on sandy clays, on less sloping surfaces, Entisols on finer textures and in more sloping areas. Alfisols developed only on the Pleistocene terraced deposits along the Formone river, and on the conglomerates and sands outcropping along the borders of the ancient basin. On the clays and shales of the Allocthonous Complex, soils are very variable as they reflect the high variability of the substratum. They are usually Inceptisols, disturbed to varying degrees by erosion processes and mass movements.

3.8 NATURAL VEGETATION OF VAL D'ORCIA (S. Maccherini, A. Chiarucci, V. De Dominicis & V. Boscagli)

A detailed study on the vegetation in relation to morphology and soils was carried out in a *biancana* field located at *podere* Baccanello (see later in the text). Natural vegetation distribution is greatly influenced, both from a floristic and physionomic point of view, by the degree of anthropic disturbance, soil moisture and erosion rates (CHIARUCCI & *alii*, 1995). On basal micropediments, where the erosion/sedimentation dynamics are more active, two pioneer paucispecific vegetation types, rich in halo-tolerant, mainly therophytes species, are found. The first, belonging to the *Parapholido-Artemisietum cretaceae*, grows where the sedimentation dynamics are strong; on the other hand, a more evolved stage, characterized by the presence

of *Aster lynosyris*, *Bromus erectus*, *Dactylis hispanica*, *Phleum bertolonii* and *Plantago lanceolata*, is found in less extreme environmental conditions. On *biancana* domes and ESE facing sides, *Bromus erectus* cover increases together with other species of *Mesobromion*, *Brometalia* and *Festuco-Brometea*; the dominant species in these coenoses, besides *Bromus erectus*, are *Aster lynosyris* and *Linum strictum ssp. corymbulosum*. In wetter and cooler zones, such as impluvium lines and slope bottoms, compact grasslands dominated by *Elytrigia atherica* belonging to the *Phalarido coerulescentis-Elytrigietum athericae* are found. A vegetation type, with a floristic composition very similar to the one previously described, grows on abandoned fields and NW facing *biancana* slopes. These coenoses are unbroken pasture, without *Elytrigia atherica*, dominated by *Dactylis hispanica*, *Phleum bertolonii*, *Vicia tenuissima* and *Poa sylvicola*.

On more stable morphologies, with relatively more evolved soils and greater water availability, more evolved plant communities, with grass layer dominated by *Bromus erectus*, are found. These coenoses present a different degree of shrub cover. A paucispecific vegetation, differentiated by *Lotus corniculatus* and *Dorycnium pentaphyllum ssp. erbaceum* and by low cover of *Spartium junceum*, grows on the domes of the more stable and taller *biancana* and on steady surfaces. A vegetation type, with shrub cover ranging from 20 to 80%, dominated by *Spartium junceum* and *Pyrus amygdaliformis*, is found on slopes and on stable *biancana* domes and slopes. The more evolved shrublands, characterized by *Spartium junceum*, *Pyrus amygdaliformis*, *Crataegus monogyna*, *Prunus spinosa* and sometimes *Ulmus minor*, are found in hydrographic impluvia or foot-slopes.

Some further experiments were made at *podere* Baccanello where two plots, with their major axis perpendicular to the erosion face of a *biancana*, were chosen on micropediment. One was a control plot and the other was manipulated to prevent sedimentation. These differences gave rise to the following detectable trends:

- i) the presence of *Artemisia cretacea*, *Poa bulbosa* and *Podospermum laciniatum* was higher in the manipulated plot, whereas that of *Aegilops geniculata*, *Hordeum maritimum* and *Parapholis incurva* was higher in the control plot;
- ii) the presence of sporadic species was not very different; however on the manipulated plot species characteristic of more evolved stages, such as *Dactylis hispanica*, *Linum strictum* and *Scabiosa columbaria*, were found.

The different coenoses identified in the *calanchi* of Radicofani reflected differences in morphology and soil moisture (MACCHERINI & alii, in prep.), as found by CHIARUCCI & alii (1995) for the vegetation of the *biancane* of Val d'Orcia. The pioneer vegetation (*Parapholido-Artemisietum cretaceae*) was only found in extreme environments with severe erosion. Grasslands belonging to the *Phalarido coerulescentis-Elytrigietum athericae* and that dominated by *Dactylis hispanica*, *Hedysarum coronarium* and *Phalaris coerulescens* were associated with deposition area. Grasslands of *Bromus erectus* and those dominated by *Brachypodium rupestre* were found on different morphologies. Scrub communities at different stages of evolution were also re-

corded on different morphologies, whereas woods with *Ulmus minor* and woods dominated by *Quercus pubescens* and *Q. cerris* were recorded along impluvium lines and on original slope respectively. Pioneer coenoses linked to moist environments were found on valley floors.

Experiments were carried to study the germination ecology of species of the association *Parapholido-Artemisietum cretaceae* (MACCHERINI & alii, 1995, 1996; BOSCAGLI & alii, 1996). The factors studied were: the influence of several temperature and light regimes, of soil salinity and sowing depth on germination or emergence of *Artemisia cretacea*, grasses and legumes. We found: i) high and generally also prompt germination under the different thermo and photo periods with temperatures ranging from 2 to 20 °C; ii) high emergence capacity at all salinity levels but an emergence clearly delayed by salt; iii) a progressive decrease in final emergence percentages with increase sowing depth (ranging from 0.5 to 8 cm) and an emergence rate strongly reduced by deep planting.

3.9 RECLAMATION OF THE ORCIA VALLEY (A. Colica)

In 1928 the first association for the reclamation of the Orcia Valley, Consorzio di Miglioramento Fondiario della Val d'Orcia, was established and financed by the government. A second association, Consorzio di Bonifica della Val d'Orcia, succeeded the first one in 1953 and lasted until 1980. The general reclamation plan (1953) involved a territory of 353 km², 80% of which was hills, the remaining part was mountains (20%). The area directly taken up by *calanchi*, *biancane* and mass movements is ca. 50 km². Degradation processes are particularly active in the upper valley of the Orcia river and in the catchments of several streams, with a total area of 280 km². The behaviour of the Orcia river is torrent-like, with an immediate response to rainfall. The largest discharges are distributed in November and March when precipitation peaks. Dams, gabions, walls, etc. are used for controlling water courses (including the ephemeral streams of the largest *calanchi*). An intense reforestation programme was launched to reduce shallow mass movements and erosion, including the retreat of some *calanco* heads. Drainage and fencing were used to reduce mass movements. Explosives and bulldozers were used for levelling dissected surfaces whenever possible. In the period 1965-1985, while the activity of the reclamation department was declining, old and new land-owners (often immigrants from Sardinia) were extremely active, levelling their lands with bulldozers. In practice, most of the isolated gullies and *biancana* fields were erased in this period.

3.10 PODERE BACCANELLO STUDY AREA (C. Calzolari, D. Torri, A. Colica & M. Del Sette)

The study area at *podere* Baccanello is an irregular quadrilateral, contained between the Giuncheto stream, Gonzola stream and the Vittoria provincial road (lat. 43° N, Long 11° E Grw). It extends over an area of about 20 ha, half of which is covered by *biancane*. Heights above sea le-

vel range from 330 m to 430 m. Outcropping sediments are silty clays, with monoclinical, subhorizontal attitude (N140/5NE). The sediment is diagenized and presents a concoid rupture surface. It is inorganic clays of low to medium plasticity. The textural class is silty-clayey; the granulometry of the sediment and the mineralogy of the fine fraction (< 2 mm) are given in Tab. 2. Rounded unaltered pebbles, usually calcareous (*Calcare Cavernoso*) can sporadically be found. Clays are cut by a dense net of tectonic joints which can easily be identified in field by yellowish alteration strips. The main orientation of the joint sets is N100 and N60 and they form on terrain a typical rhomboidal pattern delimiting groups of *biancana* (COLICA, 1992, COLICA & GUASPARRI, 1990). The area is the terminal part of a highly dissected, SSW facing, 20% slope. The surface drainage pattern, strongly influenced by *biancana* forms, is further complicated by a dense subsurface one. The part of the area not covered by *biancana* forms has been reshaped in several different periods, since the 20's.

The climate is transitional between subhumid and subarid, with a moderate summer hydric deficit. From the data obtained from the two nearby meteorological stations (over a 45 year period) the mean annual temperature is between 12.6°C and 14.4 °C and the average annual precipitation is between 671 and 835 mm. Soils have a xeric moisture regime, nearly ustic in less arid sites and with aquic characteristics in wetter impluvia lines. The soil temperature regime is mesic, nearly thermic. Cultivated fields, found mainly on the alluvial deposits of the Gonzola and Giuncheto streams and on reclaimed slopes, constitute up to 50% of the whole Podere Baccanello. The main crop is durum wheat (*Triticum durum*).

Pedotypes are clay soils with very homogeneous characteristics. They are mostly Typic Xerorthents, fine, mixed (calcareous), mesic, on the slopes and on the eroded surfaces and Calcixerollic (and Vertic) Xerochrepts, fine mixed (calcareous), mesic, on the more stable situations. Inclusions of Chromic Haploxererts, are seldom found in

TABLE 2 - Granulometric and mineralogical composition of sediments and soils (modified after COLICA, 1992 and CALZOLARI & *alii*, 1993). Q = Quartz; F = Feldspar; Cal = Calcite; K = Kaolinite; Cl = Clorite; I = Illite; 10i-14c = Interstratified I/Cl; 10i/14s = Interstratified I/S; S = Smectite; C = Clay; cSi = Coarse Silt; fSi = Fine Silt; S = Sand

	Q	F	Cal	K	Cl	I	(14c-14s)	(10i-14s)	S	C%	cSi%	fSi%	S%
Sediment	+++	(+)	++	+(+)	(+)	+		+(+)		46.3	44.3	7.5	1.9
Soil (AC hor.)	++(+)	(+)	+	++	++(+)	+	(+)	(+)	t	45	39	14	2

less disturbed sites. In Tab. 3 data on representative soils are given.

Different kinds of forms, characterized by different geomorphic features, are grouped together under the term *biancana*. A morphological survey allowed us to classify the forms. The results of the analysis of the spatial distribution of the different forms highlight a dimension trend from the «taller bean» forms to the terminal «souffl-like» and cone forms. Variographic analysis shows that the morphological attributes selected are significantly spatially auto-correlated over a rather short range. This suggests that the active erosive processes, responsible for the morphogenic evolution of *biancane* act mainly on a local scale. The strong geometric anisotropy detected in the 60

and 100 degree directions, parallel to the main jointing systems, also suggests a broader scale tectonic control of *biancane* evolution, probably related to an earlier stage of their formation and to the development of the jointing network across the slopes (CALZOLARI & UNGARO, in press).

Erosion processes must be subdivided into processes on the *biancana* slopes and processes between *biancane*. Gully and pipe erosion and sporadic surface mass movements belong to the latter types. The retreat rate of inter-*biancana* gullies is usually low. For example, the mean retreat rate of a gully head, measured over 5 years, was found to be 15 cm/y, with a peak of 42 cm in one week, which was triggered off by thawing snow. Pipes pass un-

TABLE 3 - Soils characteristics of stable and unstable surfaces (CALZOLARI & *alii*, 1995)

° SFSB = Strongly developed, Fine, Subangular Blocky; WMP = Weakly developed, Medium Prismatic; WMAB = Weakly developed, Medium, Angular Blocky; MMSB = Moderately developed, Medium, Subangular Blocky.

* EC in dS m⁻¹

** Total pore volume % of peds

Morphology	Profile develop.	Depth	Color	Texture	Structure°	CaCO ₃ nodules	EC* 1:5	SAR	Pore Vol. %**
Stable surface	A	20	2.5Y4/4	SiC	SFSB	-	0.26	0.48	24
	B	55	2.5Y5/4	SiCL	WMP	++	0.29	0.21	27
	BC	95	2.5Y5/3	SiCL	WMAB	+	0.35	4.6	21
	C	105	2.5Y5/2	SiC	Massive	tr	0.82	3.85	21
Unstable surface	A	40	2.5Y4/3	SiC	MMSB	-	0.26	0.34	21
	AC	95	2.5Y5/3	SiC	Massive	-	0.18		21
	C	130	5Y5/2	SiC	Massive	tr	0.7		20

der *biancane* and become clearly identifiable only when ceiling collapse reveals their presence. Pipes draw a fairly dense network, sometime coincident with the surface drainage system, other times passing under *biancana* domes. Underestimation of the pipe drainage density indicates a value greater than 5 cm/m² while the ratio «length of pipe/length of gullies» is greater than 0.5. Pediments are ephemeral: they can be removed by a storm, while their accretion rate can be greater than 8 cm/y. Channelled erosion in microrills and micropipes and diffuse erosion due to splash and regolith dissolution dominate in the bare slopes of each *biancana*. Rainfall simulation experiments (TORRI & *alii*, 1994) and laboratory tests have indicated that erosion is usually detachment limited. The upper limit to detachment is usually set by the fact that the regolith becomes erodible as soon as water has penetrated it. Before, it is almost insensitive to the normal detaching agents (splash and runoff). In practice, the presence of a very intense net of micro-fractures and pores makes diffuse surface runoff negligible. Only concentrated flow can erode. This limits the area where intense erosion takes place to 14% (from data in SORIANO & *alii*, 1992). This value is an underestimation because subsurface paths represent another 7% (from data in TORRI & BRYAN, 1997). The erosion rate, (average value on eroded SSW and SSE slopes) obtained using pins on a 30 month period, is about 4.8 cm per meter of rain (calculated from data collected by COLICA, 1992). Calculation of the middle term erosion rate (5 years) on whole slopes is presently in progress, based on terrestrial photogrammetry (CHIAVERINI & DEL SETTE, in prep.). Fractures oriented transversally to the *biancana* slope gradient can be enlarged by gravity and become sink for surface and subsurface runoff or cause a systematic diversion of flow direction (TORRI & BRYAN, 1997).

On the northern slope of one *biancana* the soil is under stress, due to creeping and shallow mass movements. The abundant soil fissures become the main way of water percolation down to the massive deep horizon. This facilitates the further sliding of soil mass, and the general instability. Other erosion forms only exist here when vegetation is scarce. Soil confining with the eroded slopes is undercut by the slope retreat and removed by slides and mass flow. Bare, eroded north slopes are usually moister than south slopes, due to the effects of aspect and slope angle. The higher moisture content on the north slope increases the chances of pioneering plant species establishing a permanent cover. If the findings on the germination and emergence dynamics of pioneering, reported in a previous paragraph, are considered, then a feedback mechanism, that facilitates plant colonization, can be envisaged. It includes a reduced erosion rate on the wetter N-slope, and a consequent increased rate of soil formation. Hence, salt leaching is anticipated in comparison to the S-slopes increasing the chances for pioneering species to established a permanent soil cover.

According to the results of soil and vegetation surveys (CALZOLARI & *alii*, 1993a; CALZOLARI & *alii*, 1993b; CHIARUCCI & *alii*, 1995), and to the main erosion processes active in the area (TORRI & *alii*, 1994; TORRI & MONACI, 1991;

TORRI & BRYAN, 1997), a residual surface, on which the most evolved soils and the most structured vegetation under xeric conditions are found, has been identified (CALZOLARI & *alii*, 1993b). This surface, with a NNE-SSW orientation and an average slope of about 5%, is strongly dissected by 1st order streams. A soil catena on this surface has been studied. Seven soil profiles, at different evolution stages, have been described and analyzed, porosimetric measurements have been performed and thin sections prepared and described. The main pedogenetic processes are salt leaching, organic matter and calcium carbonate dynamics, structure evolution and vertisolisation. The zones where preserved soils are located are dispersed around and into the *biancana* field. Their spatial distribution indicates a predominance of digitated linear erosion over other erosion forms (e.g. rill/interrill erosion and mass movement). Other observations indicate that the *biancana* field is not the result of a «single» event but that several critical events have contributed to the present landscape. This is in agreement with information derived from other sources: 1) a *cabreo* (painting depicting a farm, its *podere* and the land use) made in 1837 shows arable lands and 2 huts where *biancane* now dominate; 2) the podere Baccanello was a convent (already ruined in 1820). This second finding indirectly supports the idea that the *biancane* which are presently undermining the place where the convent stood, were not there when the convent was founded (presumably in this millennium). Hence the combination of events that trigger off the genesis of the *biancana* forms have a return period of less than 5 centuries.

3.11 POGGIO BANDINELLI STUDY AREA (A. Colica, I. Chiaverini, M. Del Sette & D. Torri)

A study site was selected in an area where *calanchi* dominate. Both at the head and at the foot of the *calanchi* area, two *biancana* fields extend over horizontal or slightly sloping morphological surfaces. The area is located between Poggio Bandinelli and Podere Paiccia (6 km NW of Radicofani - Siena), within the basin of the Scalonca stream (tributary of the Orcia river) that spans over a 4 km² area, with 290 m total relief difference. The entire basin is characterized by marine pliocenic sediments arranged in anticline with axial direction N155. Clay, sandstone and some conglomerates are the sedimentary rocks that outcrop in the area. The analyses of a vertical section, running through 63 layers in 290 m, with thickness varying from levels (4 cm) to banks (10 m), show that texture (USDA classification) varies from clay through sandy loam. Other parameters measured were total porosity, bulk density, Atterberg limits, mineralogy, pH, CEC, SAR and ESP (tab. 4 and 5). In the *calanchi* area (62% of the total surface) and in the *biancana* fields (16%) subvertical fracture systems (sets of joints) are present with typical yellow alteration stripes. The sets of joints have different directions: N70 which coincides with the direction of the Scalonca stream, N155 which coincides with the strike of local anticlinal axes and N20, N60 (of the same age) with N120.

TABLE 4 - Mean values of porosity, bulk density, Atterberg limits, pH (saturated paste 1:1), C.E.C., S.A.R. and E.S.P. (Colica, 1992)

Porosity %	Bulk density g/cm ³	L.L.	P.L.	pH	C.E.C. meq/100g	S.A.R.	E.S.P. %
18,6	2,1	37,8	19,7	7,5	9,9	20,3	22,6

TABLE 5 - Mineralogy of the samples (mean values). The most frequent interstratified is characterized by Illite/Smectite (the ratio of 2:1). Traces of thenardite are sometime present (Colica, 1992)

Quarz	feldspar	calcite	dolomite	kaolinite	clorite	illite	interstratified
++(+)	(+)	++(+)	(+)	+(+)	(+)	+	+(+)

The climate of the basin is Mediterranean subtropical (after Thornthwaite, C2, Im 0-20, B1', PE 570-712, S2, Ia>33,3, Ih>20, a'<48%) with average annual rainfall of about 670 mm (COLICA, 1992) and with a mean temperature of about 12 °C (FALCIAI & alii, 1979).

The *calanchi* area develops along the slopes of the Scalonca basin with a NW and SE exposure. Erosional phenomena such as gullies, rills, mudflows and rockfalls occur along the *calanchi* slopes. Mudflows are more frequent along the wetter slopes (NW aspect), while rockfalls occur exclusively along the SE slopes. The *calanchi* area shows a gentler dip (average value 24°), as well as a greater natural water content (mean value 17.5%) in the NW face, than in the SE aspect (50°, 14.4%). The NW facing slope is usually covered, either by a layer of poorly developed soil, or by a relatively deep layer of weathered material (which is the result of local weathering and the accumulation of material removed from upslope). The SE exposed slope evolves through gullies, rills and mudflows, as well as active rockfalls. Part (22%) of the basin was levelled and devoted to agricultural uses or reafforested. In 1975, the zone located near Poggio Bandinelli, which surrounds the main *calanco* heads, was reforested (about 0.1 km², mainly conifers - *Cupressus arizonica*, *Cupressus sempervirens* and *Pinus nigra* - and some broad-leaf trees - *Fraxinus ornus*) and is presently undercut by the slope dynamics of the *calanco* headcuts. Measures were taken to reduce erosion within the *calanco* slopes. In 1989 the NW slopes of the Scalonca stream, close to the main *calanco* heads, were levelled and many wooden fences were placed transversally along the slope, while five earth dams were built in the stream to control solid discharge, favour sedimentation and stabilize the slope foot.

Two areas were selected, one on the NW slope and one on the SE slope, for studying their short-middle term evolution in detail. The observed section of the NW exposed slope can be subdivided into four small basins, separated by sharp crests. Their evolution was examined in a semi-quantitative way comparing photos taken in temporal sequence from a fixed location in front of the slope (from 1989 up to now). Erosion by rills, gullies, and mudflows is directed, either toward the lateral crests or upslope, the

latter being dominant. Movements take place either during, or immediately after, periods of prolonged rainfalls. Collapse of soil and regolith occurs along the slope. These materials are transported either few meters downslope or directly into the thalweg as mudflow. In the former case, successive slides transport the accumulated material slowly downslope. The section on the SE slope, characterized by two little *calanco* basins, was examined in a quantitative way, with the aid of an analytical plotter (Stereobit) which allows the comparison of terrestrial photogrammetric spots made in temporal sequence (from 1991 to 1993) from one fixed location in front of the slope (COLICA & MASI, 1994; in press). Gullies and rockfalls have been taken into account in the analysis (Tab. 6).

TABLE 6 - Linear development of gullies and scarps and areal development of landslide bodies over 1000 m²

Period	gully m	scarp m	landslide body m ²
December 1991	306	234	553,4
July 1992	337	220	530,4

In a later phase, detailed research was carried out on a single, large rockfall, the aim being to establish a method for the evaluation of the volumetric variations of landslides (COLICA & MASI, 1995). The flow of material deriving from the rockfall, and passing through a controlled plane is about 1.40 m³m⁻²y⁻¹. Still on the same experimental area, the temporal series of photos has been updated and the construction of a digital terrain model is presently in progress using a more advanced instrumentation (Galileo-Digicart) which will allow a better description of the slope dynamics. The evaluation of the erosion rate, due to the retreat of the *calanco* headcuts, and of the volumetric variations of some small *calanco* basins, due to erosional and depositional phenomena, is presently in progress (CHIAVERINI, COLICA & DEL SETTE, in prep.). The evaluation will be based on the comparison of aerial photos (dating to 1954, 1976, 1994). The work is mainly aimed at defining the critical area of the basin at which headcut retreat stops.

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