Geogr. Fis. Dinam. Quat.
26 (2003), 15-27, 7 figg., 10 tabb., 1 c.

ERMANNO BUSONI & ANTONELLA COLICA *

ANALYSIS OF LINEARS, LANDFORMS AND GEOLOGY RELATIONSHIPS AND ANTHROPIC EFFECTS IN THE PERIOD 1976-1994, NORTHERN ASSO RIVER BASIN (SIENA, ITALY)

ABSTRACT: BUSONI E. & COLICA A., *Analysis of linears, landforms and geology relationships and anthropic effects in the period 1976-1994, northern Asso River basin (Siena, Italy).* (IT ISSN 0391-9838, 2003).

The knowledge of how and how much a landscape changed in a specific time period is of paramount importance to predict scenarios and trends for the future. Landscape analysis can help in understanding state factors influence on environmental changes and effects. Among the effects of the different state factors, linears, as an expression of local and regional tectonic activity, and landforms, also as consequence of anthropic actions, are to be considered. Changes of landform features (e.g type, number, etc) are to be analysed as change effects. In this view, it is important to control how anthropic pressures can lead to an increase in land degradation as a consequence of the influences of over-stressed landforms on hillslopes and watershed regime. Aim of this paper is the analysis of linears and landforms present in the landscape, their relationships and relational typologies, and the variations of the persistence of the landforms in time as a consequence of anthropic action.

In a study area, located in the northern Asso River basin (Siena, Central Italy), about 173 km^2, characterised mainly by marine pliocenic sediments, representative of the Central Italian neogenic basins, were analysed linear features (linears) and landforms, i.e. *calanco* (C), *biancana* (B), levelled *biancana* (Bl), shallow seated gravitational deformations (SSGD), levelled ones (SSGDl), *calanco* potential areas (CPA), mudflows (Fco), rockfalls (Fcr) and *balza* (Bz), their relationships, typology and temporal persistence, by aerial photo interpretation and ground control. Geology was used as first discriminant in the analysis of linears and landforms. Data were reported on a 1:10000 scale base map and analysed on 1 km^2 base grid. Several linears were found to define directional trends and affecting a large part of the study area, showing also the main regional tectonic directions: N37°, N162°, N145°, N90°, N180°; these trends are called «main trends». Main trends linears are mainly related with Pliocene clays (**pa**). Other linears show directions different from the «main trends»: the linears are called «local linears», displaying minor extension than the main trends. Different «landscapes of linears» were found as a function of the frequency of the «local linears» (n of linears/km^2), statistics of the directions of the linears and geology. Local «landscapes of linears» are related to local geology, mostly to **pa**. Relationships between landforms and linears were analysed. Variations in landform presence in the period 1976-1994 were also considered (see also the maps included). In the examined time period, all landform types, with the exception of increased CPA, were subjected to a strong decrease, either on absolute value basis, or on a relative percentage basis, referred to their presence in the initial year, 1976. Landforms levelled before 1976 (SSGDl and Bl) seem mostly subjected to continuous, yearly, slope reshaping. C, SSGD and B appear to be, at present, at major risk by new slope reshapings. These variations must be considered as effects of anthropic pressures on the landscape due to the present, mainly agricultural, land use.

KEY WORDS: Linear, Landform, Geology, Anthropic effect, Tuscany (Italy).

RIASSUNTO: BUSONI E. & COLICA A., *Analisi delle relazioni fra lineazioni, morfologie e geologia ed effetti antropici nel periodo 1976-1994, nella parte settentrionale del bacino del torrente Asso (Siena, Italia).* (IT ISSN 0391-9838, 2003).

La conoscenza di come e quanto un ambiente varia in uno specifico intervallo di tempo è importante per inquadrare scenari e tendenze future. L'analisi degli caratteristiche del paesaggio può aiutare a comprendere l'influenza dei fattori di stato sulle variazioni ed effetti ambientali. Tra i differenti effetti dei fattori di stato, devono essere considerati le lineazioni, quali espressioni dell'attività tettonica locale e regionale e le morfologie, intese anche come risultato dell'attività antropica. Le variazioni delle caratteristiche delle forme (e.g. tipo, numero, ecc.) devono essere studiate quali variazioni degli effetti. E estremamente importante controllare come le pressioni antropiche causino un incremento della degradazione, come conseguenza dell'influenza su terre super-sfruttate, su versanti e spartiacque. Scopo del lavoro è analizzare lineazioni e forme presenti nel paesaggio, loro relazioni e tipologie relazionali, e variazioni della persistenza delle forme nel tempo in seguito all'azione antropica.

In un'area campione di 173 km^2, ubicata nell'alta Val D'Asso (Siena, Italia), caratterizzata principalmente da sedimenti marini pliocenici, rappresentativa dei bacini neogenici dell'Italia centrale, è stata condotta un'indagine fotointerpretativa, utilizzando due coperture aeree dalla Regione Toscana (volo basso, scala 1:13.000) relative agli anni 1976 e 1994, ed un'indagine di campagna, ai fini di studiare le lineazioni e le morfologie presenti sul territorio, le loro interrelazioni e persistenza temporale. Le forme analizzate sono state: calanco (C), biancana (B), biancana livellata

* *CNR, Istituto per la Genesi e l'Ecologia del Suolo, Piazzale delle Cascine 15, I-50144 Firenze.*

The research was supported by CNR-GNDCI grants. Pubbl. N° 2583 GNDCI Linea 1. The map is published with funds from the CNR-GNDCI Presidency Pubbl. N° 2521 Linea 1.

The Authors are thankful to Prof. F.C. Ugolini, University of Florence, for reading and improving the original manuscript.

(Bl), deformazione gravitativa poco profonda (SSGD), deformazione gravitativa poco profonda livellata (SSGDl), «*calanco potential area*» (CPA), colamento (Fco), frana di crollo (Fcr) e balza (Bz). Il substrato geologico è stato utilizzato come primo discriminante nell'analisi delle lineazioni e delle forme. I dati raccolti sono stati riportati su mappe a scala 1:10.000 e successivamente analizzati, utilizzando griglie di indagine di 1 km^2.

Alcune lineazioni sono associabili in fasci che si estendono per vari chilometri nell'area di studio e presentano trend direzionali particolari, talora coincidenti con quelli di elementi tettonici ad andamento regionale: N37°, N162°, N145°, N90°, N180°; queste lineazioni sono state nominate trend principali. I trend principali interessano generalmente le argille plioceniche (**pa**). Altre lineazioni, non associabili alle direzioni precedenti, e di minore lunghezza sono state chiamate lineazioni locali. Differenti paesaggi di lineazioni sono stati individuati in funzione della frequenza delle lineazioni locali (n/km^2), della direzione delle lineazioni e della geologia. Anche questi paesaggi appaiono essere legati principalmente alle argille plioceniche. Vengono inoltre analizzati i rapporti esistenti fra forme e lineazioni. Sono riportate infine le variazioni di presenza delle forme nell'intervallo di tempo fra il 1976 ed il 1994 (vedere anche la carta allegata). In questo intervallo ogni forma, escluso CPA, ha subito una forte riduzione. Le forme già livellate nel 1976 (SSGDl e Bl) sembrano le più soggette ad un continuo modellamento di versante per cause antropiche. C, SSGD e B appaiono essere, al momento, le più esposte a rischio di rimodellamenti di versante. Questa variazione deve essere considerata come effetto della pressione antropica sull'ambiente dovuta principalmente all'uso agricolo.

TERMINI CHIAVE: Lineazione, Morfologia, Geologia, Effetto antropico, Toscana (Italia).

INTRODUCTION

A linear (Dainelli, 1985) is an alignment of several land features, that is, of small gullies, wet areas, streams, little depression zones, saddles and edges of fluvial banks or terraces, recognised by aero-photo interpretation. In the landscape the linears sometimes coincide with talwegs, or with part of them, in which water ways of different order are present: from gullies (or other first order branches) to stream (second or higher order).

The relationships between linears and landforms has been often studied to understand the geomorphological evolution of areas in different parts of Italy and of the world, as shown below. High speed deformations of the earth crust are required for fracturing, that is why fracture analysis is applied to a procedure which takes into consideration all the linear land features, being these, or at least the greater part of them, the direct or indirect effect of tectonic deformations. The structural deformations affecting an important thickness of rocks can also be transmitted, in time, from lower stratification structural features through the thicknesses of younger sediments up to the surface. The landforms are mostly due to the concurrence of lithologic and structural factors (Dainelli, 1985). In the Graben of Siena (Italy), which developed mainly in marine pliocenic sediments, Gelmini (1974) pointed out some linears which correspond to important tectonic lines with Apennine, Antiapennine and E-W directions, these linears affecting also the hydrographic pattern and the relief forms. Guerricchio & Melidoro (1979) use linears systems to study landslides present in Pisticci area (Basilicata, Italy), in Pleistocene-upper Pliocene marly clay and clayey marls: most of these linears are interpreted as important neotectonic discontinuities, that have also produced water channel captures and violent erosion. Systems of linears and their relationships with joints and *biancane*, that develop in Pliocene clayey sediments in the Grabens of Siena and Radicofani (Italy), were studied by Colica & Guasparri (1990): they found that *biancane* develop, preferentially, into a rhombic-like net of linears that coincide with main joints. SORIANO & alii (1992) pointed out that linears affect part of the badlands and the watercourse of de los Molinos River in Petrer (Murcia, Spain), developed in Upper Cretaceous marls. Alexander & Formichi (1993) studied the orientation, location and density of the linears, as well as the relationships with morphological phenomena, such as retrogressive slumps, drainage density and slope angle in the Montepulciano (Italy) area, which developed on Pliocene sandy and clayey sediments. To point out the possible strike-slip of faults of regional importance, Belisario & *alii* (1999) used linears to study drainage network patterns in two areas: Val Rovereto (Abruzzo), that develops mainly in Miocene deposits, and Val d'Arbia (Siena), that forms mainly in Pliocene sediments. Busoni & Colica (2001) use linears to offer an integrated landscape analysis, especially to interpret erosional and gravitational forms, such as *biancane* and shallow seated gravitational deformations (SSGD), developed in Pliocene clayey sediments in the Upper Asso River basin (Siena).

Aim of this paper is the analysis of linears and landforms present in the landscape, their relationships and relational typologies, and the variations of the persistence of the landforms in time as a consequence of anthropic action. This study has considered: linears, taking into account their directions, the substratum (geology) on which they develop, and the type of relationship with landforms, and landforms: *calanchi*, «*calanco* potential areas» (CPA; Busoni & *alii*, 1998), shallow seated gravitational deformations (SSGD; Busoni & *alii*, 1998), *biancane*, earthflows, rockfalls, and *balze*.

THE STUDY AREA

The study area, 173 km^2, is located in the northen part of the Asso River hydrographic basin. It is included in the northen part of the Siena Graben, a NW-SE depression, that developed from an extensive tectonic phase, begun in the Upper Tortoniano (Hzu & *alii*, 1978; Costantini & *alii*, 1979, 1980a, 1980b, 1982; Boccaletti & Coli, 1983). Neogenic and Quaternary rocks stratigraphy is here synthetized after Losacco (1963), Jacobacci & *alii* (1969), Boccaletti & *alii* (1987) and Berti & *alii* (1992):

pa - marine clays and sandy clays with conglomerate lenses (Early - Middle Pliocene); they constitute the largest outcrop;

ps - sand and clayey sands with molluscs, brachipods, and crustacea, with lenses or layers of conglomerate or lignite, or silty clay or clay (Middle Pliocene). Olistostromes of Mesozoic limestones and dolomitic limestones are sometimes present. These outcrops border the Middle Tuscany Ridge (Dorsale Medio Toscana) to NNE and E;

pc - polygenetic conglomerates, with varying relationships with other Pliocenic deposits. These small outcrops are also adjacent to the Middle Tuscany Ridge;

tr - travertines (Pleistocene – Holocene);

f - stream terraces, **e** - eluvial and colluvial deposits, **al** - alluvial deposits, **dt** - slope debris (Holocene).

The study area is mainly located on clayey and sandy marine pliocenic sediments. The average mineralogical composition of sediments and soils is given in tab. 1. The landscape is hilly with variable slope gradient (from 5 to over 47%); it includes limited mountain areas in the NNE and E, that are part of the Middle Tuscany Ridge (Costantini & *alii*, 1980a, 1980b) and where the Tuscan Series outcrops (ST; Jacobacci & *alii*, 1969). There are also level areas consisting of alluvial deposits of the Asso River and its tributaries (see maps: Borri Meleta, Montelifré and La Copra). Level areas are also characterised by limited travertine outcrops N of Borro La Copra and Poggio Pinci.

MATERIALS AND METHODS

Analysis of linears, landforms, and their relationships, was performed by aero-photo interpretations on 1976 and 1994 Regione Toscana aerial surveys (1:13000 scale) and ground control. The information were reported onto the following nine sections of the Tuscany Regional Technical Map (1:10000 scale): Asciano (NW vertex), Castelmuzio, Chiusure, Monte Follonico (SE vertex), San Gimignanello, Sez. 298130 (NE vertex), S. Giovanni d'Asso, Trequanda, Monterongriffoli (SW vertex). Data analysis was accomplished by circular statistics (Fisher, 1993). The 1:25000 scale final maps show most of the information obtained by graphics and the attached Note.

TABLE 1 - Pliocene sediments and soil average mineralogical compositions

	Quartz	Feldspars	Calcite	Dolomite	Kaolinite	Chlorite	Illite	Interlayer I/S	Thenardite
Rock	++(+)	(+)	++	(+)	+(+)	(+)	+	+(+)	tr
Soil	++(+)	(+)	++	tr	+(+)	(+)	+	++	tr

Linears and Landforms

Linear tectonic features were taken into account to define their influence on the evolution of the landscape and of its landforms. Rectilinear linears may be assembled in trends showing the same direction. Every linear showing an angular variation of ± 2° respect the trend directions was assigned to that trend. In the field, in corrispondence with a linear or a trend of linears, it is possible to see joints (main joints - Colica & Guasparri, 1990; fig. 1) whose directions are parallel to the linears or to the main trend. Also the directions of the joints can show angular variation of ± 2°.

Landforms classification was done according to main morphogenetic processes.

Erosional processes:

Biancana (B): a dome-shaped landform, mostly present in clusters on hill slopes, usually never steeper than 25%. *Biancane* are generally lower than 20 m, with a sub-horizontal pediment (or erosion-deposition glacis - Castiglioni, 1979, Torri & *alii*, 1994). This landform mainly develops on **pa** (Guasparri, 1978; Colica & Guasparri, 1990; Guasparri, 1993; Busoni & Colica, 2001) but can also be found

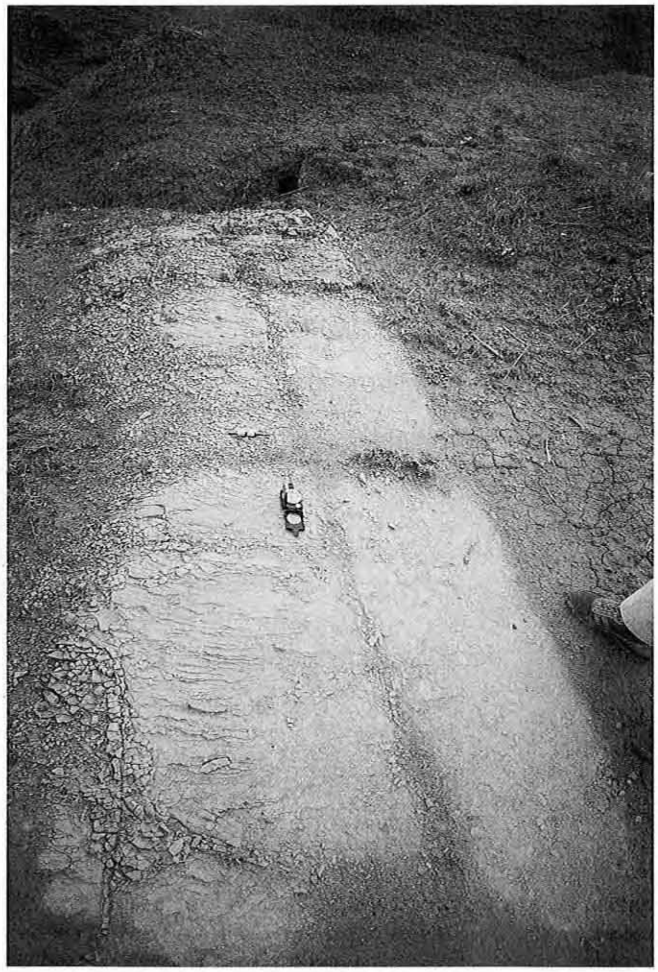

FIG. 1 - Main joint in **pa**.

on clay lenses in **ps**. The dome has asymmetrical slopes, with the southern face steeper than the northern one. The landform can be bare, half vegetated (mainly on the northern slope) or fully vegetated; in these two latter cases, soils (from Enti- to Inceptisoils) are present. On a planar view, *biancane* may develop into rhombic-like nets of joints (Colica & Guasparri, 1990; Brondi & *alii*, 1992; Benvegnu & *alii*, 1993). These vertical or quasi-vertical joints show oxidised borders and a maximum depth of 10 m. Joints are related to local and/or regional tension tectonics. The directions of the net of joints may show the same directions of the linears (Colica & Guasparri, 1990).

Erosional and gravitational processes:

Calanco (C): small drainage basin, formed by small talwegs separated by narrow, more or less sharp ridges with slope angles depending on the physical and mechanical characteristics of the sediments (Rodolfi & Frascati, 1979; Mazzanti & Rodolfi, 1988). The landform mainly develops on steep slopes (>25%), on clayey sediments, that in times may be also stratified with textures coarser than clay (Colica, 1992; 2000; Busoni & Colica, 2001). The *calanco* is generally more than 20 m deep. Joints are also present on the *calanco* slopes, but sometimes their identification is difficult because of the presence of a layer of mud «*patina*», left by mudflows, from a few mm to few dm thick (Colica, 2000).

Two *calanco* typologies are present in the study area:

1) «*calanco* asymmetrical» with respect to the main hydrographic axis or to the local stream, here the *calanco* headcut is almost linear;
2) «*calanco* symmetrical» with respect to the main hydrographic axis or to the local stream, here the *calanco* headcut is arcuated.

Calanco potential area (CPA, Busoni & *alii*, 1998): complex hill slope, generally steeper than 25%. It may represent either a transitional stage from a grazed or a cultivated area to a *calanco*; or a transition from a *calanco* area to a permanent, vegetated one (fig. 2). In the first case, features of erosional incipient calanco forming processes are evident; in the second case the *calanco* features are still recognisable (such as the old headcut and erosional and depositional forms), notwithstanding the presence of vegetation.

Gravitational processes:

Shallow seated gravitational deformation (fig. 3) (SSGD, Busoni & *alii*, 1998): they develop on hills with slope less than 20% and they may acquire elliptical, convex form. This landform develops on clay or clay with sandy lenses or layers, or on sandy clay lenses present in **ps**. The main axis of SSGD may be shorter than 60 m but longer than that of *biancane*. Generally it occurs in clusters. Rhombic-like nets of joints seem to affect the development of SSGD (Colica & Guasparri, 1990). The directions of the joint net may show the same directions of the linears. SSGDs do not seem to be linked to an evident crown.

Earthflow (Fco): landform characterised by downslope translation of soil and weathered rock over a discrete basal shear surface within well defined lateral boundaries (Soil Survey Staff, NRCS, 2001). The crown, with variable extension, may coincide with one or more joints. This convex landform usually has dimensions larger than those of the SSGD. It develops in clay sediments, with or without sand interlayers. The accumulation may be present at the foot of the scarp or along the slope, or at the foot of the slope.

Rock fall (Fcr): it develops in **ps**, **ps pc**, ST and in sand lenses present in **pa**. It is characterised by a vertical or sub-

FIG. 2 - *Calanco* Potential Area.

FIG. 3 - Shallow Seated Gravitational Deformation: in A the original and in B the cultivated landform, respectively.

vertical scarp. The scarp may coincide with one or more joints.

Balza (Bz): nearly vertical cliff, several meters high, mainly developed in **ps** and **ps pc**.

Anthropic processes:

From 1976 to 1994 agricultural use of the land caused the levelling of the landforms. In some cases the intersection between the landform basal perimeter and ground surface, the base section, is still visible. Where the human action has been more vigorous, the base section is no more visible, because large masses of soil and sediments were removed and redistributed on the levelled ground, hence hiding any trace of the base section.

Levelled biancana (fig. 4) (Bl, Busoni & *alii*, 1998): the landform has been levelled but its elliptical, or circular, base section is still visible. The destruction of this peculiar landform was carried out, not only by bulldozers but also by explosives.

Levelled shallow seated gravitational deformation (fig. 5) (SSGDl, Busoni & *alii*, 1998): the landform has been levelled but its elliptical base section is still visible.

For each reference year from 1976 to1994, linears were transferred on the nine sections of the Tuscany Regional

FIG. 4 - Levelled *biancana*; please, note the evidence of the recent levelling of the landform whose base sections show lighter areas on the slope.

FIG. 5 - Levelled Shallow Seated Gravitational Deformation; the lighter areas on the slope are the base sections of the landform.

Technical Map (scale 1:10000) covering the study area. Linears were studied on the basis of their directions and frequency, substratum and relationships with landforms. Landforms were analysed on the basis of their substratum and anthropic effect.

Data, as appearing in the tables, refer to actual values of the different analysed variables, obtained from the working map on 1:10000 scale, on which aero-photo-interpretation data were firstly reported. In the enclosed maps, derived from the reduction of the originals to a 1:25000 scale, some of the features were deleted to make maps more readable, however, maintaining the salient features.

Statistical analysis

Linears directions were analysed by circular statistics (Fisher, 1993), using the total population and sub-populations according to geology and related landform types. Rayleigh uniformity test was used to calculate the probability (***p***) of the null hypothesis that the data are distributed in a uniform manner (Von Mises distribution). A probability less than the chosen significance level (0.05) indicates that the data are not distributed uniformly and that they show evidence of a preferred direction. Watson F probability test was carried on the data to analyse relationships between the directions of the linears of sub-populations. The *p* value for the test is the probability associated with the null hypothesis that the two mean angles are equal. If this probability is less than the chosen significance level (0.05) then the null hypothesis can be rejected in favour of the hypothesis that the two means are different.

RESULTS AND DISCUSSION

Linear - substratum relationship. Landscapes of linears

Several linears, comprising a large part of the study area, were found to define also directional trends showing the main regional tectonic directions: N37°, N162°, N145°, N90°, N180°; these trends are here called «main trends». These main trends have mimimun and maximum length of 3,375 m and 13,375 m, respectively. Other linears show directions different from those of the «main trends»: these linears are, here, called «local linears», showing a minor extension. Relationships between main trends and substratum are given in tab. 2. As a linear may cross several formations, we have put together the crossed formations and named them «formations association».

TABLE 2 - Number of «main trends» linears relationship with geological substrata

	Main Trends				
Geology	(N37°)	(N162°)	(N145°)	(N90°)	(N180°)
pa	15	13	26	121	10
ps	5	7	3	9	
ps pc	2			1	
ps ST	9			5	
ps pa		1		1	
ST	5	4	3	21	
ST **ps**				1	
ST **ps pc**				5	
al				1	
Total	36	25	32	165	10

Tab. 2 shows that N90° main trend comprises all formations and the formations association. The N37°, N162°, N145° directions involve only some formations and associations of formations, while N180° seems to cross only **pa**. In general, the greater the number of linears is, the greater the number of crossed formations can be found. The subsequent study of local linears (having a minor extension than the main trends), has led to subdivide all the area into 1km^2 surfaces to obtain their frequencies expressed as number of local linears/km^2, and the frequency of the local linears as function of geological formations. Following this procedure we obtained fig. 6, in which peaks appear, corresponding to areas of high frequency of linears. Several «landscapes of linears» were found in function of the frequency, directions of the local linears and geology. Nine landscapes of linears were recognised, roughly coinciding with the 1:10000 sections (fig. 6 and tab. 3). We observe that in **pa** the frequency of linears is high.

Curvilinear linears were also found, affecting all the formations (Neogenic and Preneogenic). On the maps, in some cases, these linears enclose elliptical areas. In the Neogenic formation such areas are: Casella dei Poggi - Pod. S. Maria, Montepollini-Pod. La Fornace d'Arnano; the areas of Montelifrè and Piazza di Siena affect both Neogenic and Pre-neogenic formations. Some curvilinear linears are present at Petroio and NW of Castelmuzio. These zones

TABLE 3 - Number of «local linears» and their percentage as function of geology and percentage of the area covered by the geological substratum in each landscape

NW linears: 110	N linears: 220	NE linears: 74
Linears %: **pa**: 97.3; **ps**: 0.9; **tr**: 1.8 Geology %: **pa**: 65.4; **ps**: 18.6; **tr**: 3.4; **al**: 12.6	Linears %: **pa**: 63.6; **ps**: 34.1; ST: 0.9; **tr**: 0.5; **al**: 0.9 Geology %: **pa**: 51.1; **ps**: 35.2; **pc**: 1.6; **tr**: 0.8; **al**: 4.3: ST: 7.0	Linears %: **pa**: 1.4; **ps**: 98.6 Geology %: **pa**: 1.1; **ps**: 90.8; **al**: 3.6; ST: 4.5
W linears 131	Central linears: 378	E linears: 133
Linears %: **pa**: 99.2; **ps pc**: 0.8 Geology %: **pa**: 89.7; **ps**: 4.0; **pc**: 6.3	Linears %: **pa**: 80.7; **ps**: 0.3; ST: 19.0 Geology %: **pa**: 54.6; **ps**: 32.3; **pc**: 1.1; **al**: 6.1; ST: 5.9	Linears %: ST: 100.0 Geology %: **pa**: 5.4; **ps**:49.9; **al**: 0.7; ST: 43.9
SW linears: 33	S linears: 214	SE linears: 31
Linears %: **pa**: 87.9; **al**: 12.1 Geology %: **pa**: 63.6; **ps**: 30.3; **al**: 6.1	Linears %: **pa**: 92.0; **ps**: 5.0; **al**: 3.0 Geology %: **pa**: 65.0; **ps**: 24.2; **pc**: 3.9; **al**: 3.8; ST: 3.1	Linears %: **ps pc**: 100.0 Geology %: **pa**: 3.0; **ps**: 68.8; **pc**: 17.6; ST: 10.6

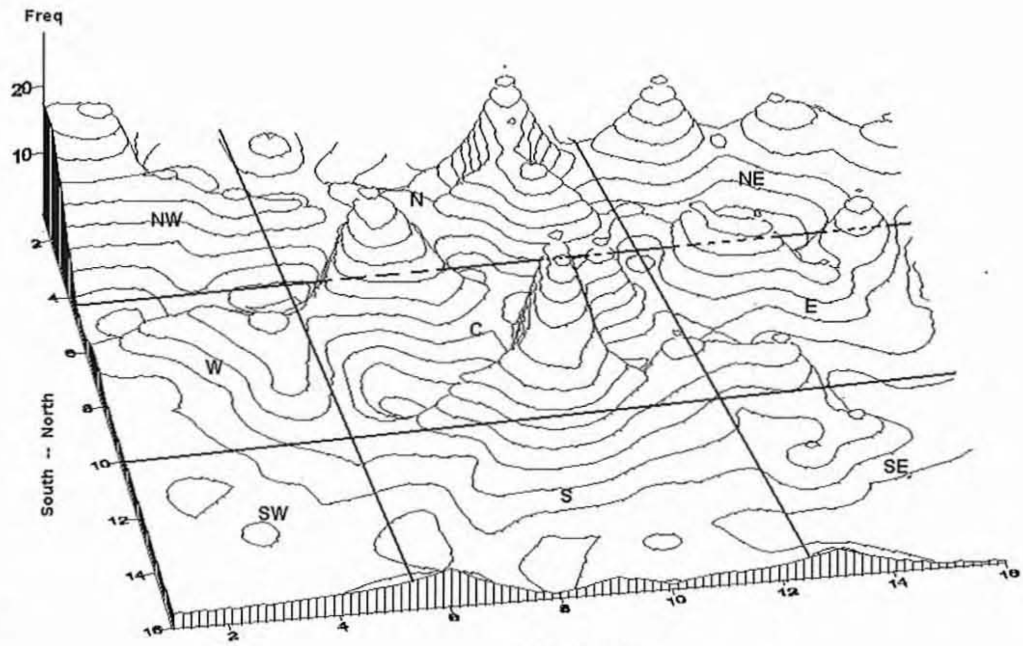

FIG. 6 - Frequencies of «local linears» (number of linears / km^2) and «landscapes of linears».

TABLE 4 - Directional analysis of local linears in the nine «landscapes». Rayleigh uniformity test calculates the probability **p** of the null hypothesis that the data are distributed in a uniform manner. A probability less than the chosen significance level (0.05) indicates that data are not distributed uniformly and that they show evidence of a preferred direction

«landscapes»	NW	N	NE	W	Central	E	SW	S	SE
Observations	110	220	74	131	378	133	33	214	31
Mean vector (μ)	65.42°	59.36°	141.79°	49.79°	63.34°	48.80°	83.72°	69.47°	55.70°
Length of mean vector (r)	0.22	0.41	0.08	0.34	0.36	0.1	0.23	0.26	0.24
Concentration	0.45	0.9	0.17	0.72	0.77	0.19	0.47	0.55	0.5
Circular variance	0.78	0.59	0.92	0.66	0.64	0.9	0.77	0.74	0.76
Circular standard deviation	99.84°	76.47°	127.86°	84.38°	82.08°	124.13°	98.51°	93.65°	96.58°
Standard error of mean	17.41°	6.36°	56.71°	10.16°	5.62°	36.63°	30.51°	10.35°	29.67°
Rayleigh test of uniformity (**p**)	0.01	0	0.6	0	0	0.3	0.18	0	0.16

seem to interrupt the rectilinear main trend, making the latter more irregular. Bends of the Asso River may be caused by the presence of two elliptical zones: Casella dei Poggi - Pod. S. Maria; Montepollini- Pod. La Fornace d'Arnano (see maps).

Rayleigh uniformity test was applied to the directions of local linear in the above mentioned nine landscapes (tab. 4).

In NW, N, W, Central and S landscapes, linears show preferred orientations. In all the other landscapes they show random orientations. Comparing these data with those of tab. 3, one may observe that landscapes, in which preferred orientations of the linears appear, generally coincide with high frequency of linears on **pa**, except the SW landscape which shows a random distribution of the orientations of linears (tab. 4).

Watson probability test has been applied to the directions of linears of the nine landscapes, as shown in tab. 5. If p is less than 0,05 the mean directions of the local linears belong to different populations.

TABLE 5 - Watson probability test (p) on the directions of the linears of «landscapes». Italics values indicate that the two means differ at the chosen significance level (0.05)

	NW	N	NE	W	Cen	E	S	SW	SE
NW		0.3	*0*	*0*	0.7	0.1	0.5	0.11	0.4
N			*0*	0.1	0.3	0.2	*0*	*0.02*	0.7
NE				*0*	*0*	*0*	*0*	*0*	*0*
W					*0*	0.9	*0*	*0*	0.6
C						0.1	0.2	*0.04*	0.4
E							*0*	*0*	0.6
S								0.17	0.2
SW									0.1
SE									

As shown in tab. 5, the mean directions of local linears of the nine landscapes are different. Thus NW differs from NE and W; in turns N differs from NE, S and SW. Also NE differs from all the others sectors. West differs from Central, S, SW, NW, and NE. Central differs from SW, NE and W; E differs from S, SW and NE; S differs from N, NE, W and E; SW differs from N, NE, W, Central and E and SE differs from NE. The comparison between tab. 5 and tab. 3 shows the presence of a population of linears in the NE landscape, where 98.6% local linears develop on **ps**, which is different from all the other populations. NorthWest, N, W and Central populations, where linears primarily develop on **pa**, differ from the populations of the other landscapes, primarily on **pa**. East population, where 100% local linears develop on ST, differs from S (on **pa**: 92%) and SW (on **pa**: 87.9%) ones. South population (on **pa**: 92%) differs from N (on **pa**: 63.6%), NE, W (on **pa**: 99.2%) and E (100% on ST) ones. SouthWest population (on **pa**: 87.9%) differs from N (on **pa**: 63.6%), NE, W (on **pa**: 99.2%), Central (on **pa**: 80.7%) and E (100% on ST) populations. SouthEast population (on **ps pc**: 100%) differs from NE population.

Landform - substratum relationships

Landforms mostly develop according to geology (tab. 6). On Pliocenic clays one finds: *biancane*, levelled *biancane*, *calanchi*, CPA, SSGD, levelled SSDG and earthflows; instead, on Pliocenic sandy-clays are present: SSGD, levelled SSGD, *calanchi*, CPA and earthflows. On coarser textured Pliocenic sediments one observes rockfalls and *balze*; finally, on preneogenic rocks, one encounters mainly rockfalls (tab. 6).

Linears - landform relationships

Firstly, it should be noted: that not all linears are related to a landform; also, that different landforms may be related to a single linear and that a single landform may be related to more linears. Linears cannot be masked by anthropic activities: their number remains constant in time. The anthropic activities may destroy the landforms with the con-

TABLE 6 - Relationships among landform types with geology

	Geology			
	pa	ps	ps pc	ST
Landform type				
C	*			
CPA	*			
B - Bl	*			
SSGD - SSGDl	*			
Fco	*			
Fcr		*	*	*
Bz		*		

sequence that the relationships between linears and landforms are lost. Relationships between main trends and landforms are shown in tab. 7 on the basis of the 1976 situation. The N90° main trend is related to each landform; the other main trends are related to only some of the landforms.

From 1976 to 1994, the relation between the local linears and the percentage of the landforms related to linears is shown in fig. 7 in which each landform is related in more than 50% of the cases to the local linears, except levelled *biancana* in 1976 and SSGD in 1994. *Calanchi* are related to linears for 74.8% and 75.1% of the cases in 1976 and 1994 respectively. For CPA, relationship cases vary from 74.1% in 1976 to 63.2% in 1994. For *biancane* the variation is from 70.4% to 60%, while for levelled *biancane* it ranges from 45.6% to 100%. For SSGD relationship varies from 100% to 46%, while for levelled SSGD goes from 54.5% to 66.2%. The relationship among earthflows, rockfalls, *balze* and linears has been studied by analysing the relationship between the crown and linears. This relationship in 1976 and in 1994 is, respectively, of 70.4% and 100% for earthflows; of 63.2% and 80% for rockfalls; instead it remains at 66.6 % for *balze*.

The variations of the relationships between linears and landforms in the 1976-1994 period are:

- percentage of *calanchi* related to linears does not change in spite of the anthropic impact;
- percentage of CPA related to linears decreases in spite of an increase of 5.5% of the landform type (tab. 10);
- relationships between linears and landforms decrease for *biancane* and SSGD;

TABLE 7 - Relationships among linears of the «main trends» with landform types, in 1976

Year 1976 - Landforms

MAIN TRENDS	n LINEARS	SSGD		SSGDl		C		CPA		B		Bl		in main trends		
		n	*rel %*	n	*rel %*	n	*rel %*	n	*rel %*	n	*rel %*	n	*rel %*	Tot. n	*%*	n lin/Tot. n
N37	36	3	*13.04*											3	*4.23*	12.00
N162	25	2	*8.70*			1	*4.35*	1	*16.67*					4	*5.63*	6.25
N145	32	9	*39.13*			3	*13.04*							12	*16.90*	2.67
N90	165	6	*26.09*	4	*100.00*	19	*82.61*	4	*66.67*	12	*100.00*	3	*100.00*	48	*67.61*	3.44
N180	10	3	*13.04*					1	*16.67*					4	*5.63*	2.50
Tot	*268*	*23*		*4*		*23*		*6*		*12*		*3*		*71*		3.77
Total %			*32.39*		*5.63*		*32.39*		*8.45*		*16.90*		*4.24*		*100.00*	

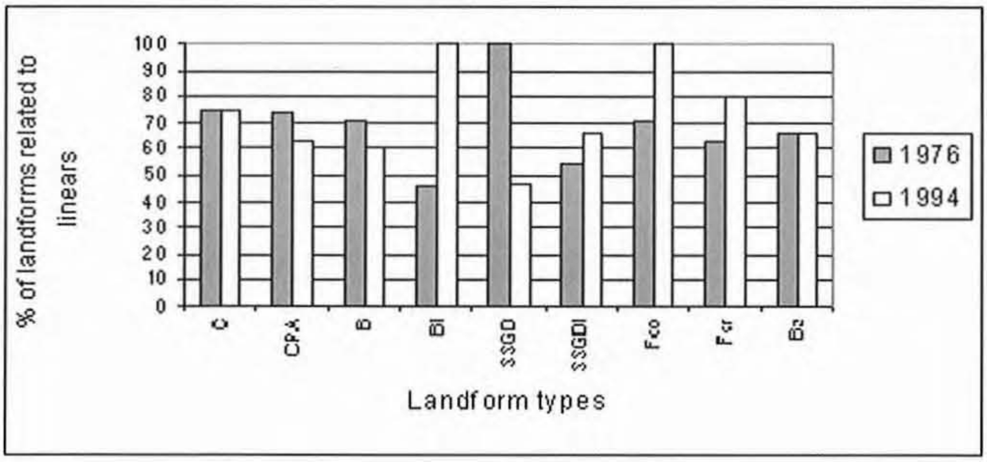

FIG. 7 - Percentage variations of presence of the landform types in the considered time period.

– levelled *biancane* and levelled SSDG increase their relationships with linears, notwithstanding a decrease of the landforms of 68.5% and 54.5%, respectively (tab. 10);
– earthflows and rockfalls increase their relationships with linears;
– the relationship remains constant for *balze*.

In the recently levelled forms, the relationships between base sections and linears are generally more evident. However, in rockfalls and earthfalls, the relationships with linears are more defined. For the other landforms it is possible to observe a general decrease of their relationships with linears.

Some landforms do not seem directly related to linears. However, observations made in the immediately nearby areas showed the presence of joints with the same directions of the local linears or of the main trends.

Typology of the relationships between linears and landforms

Typology of the relationships between linears and landforms was studied from the 1976 air-photos. Linears can relate to landforms in several ways. Tables 8 and 9 show the typology percentage of the relationships between linears and landforms. The following typologies were defined:

l (limit): linears limit the landform; it is tangent to the crown of C, CPA and Fcr;

ai (indirect effect): linears coincide in C with the main hydrographic axis representing the base level for tributaries that control the evolution of the landforms;

l-head (limit the headcut): linears coincide with the landforms headcut in C and CPA;

TABLE 8 - Typological percentages of the relationships between linears and landform types in **pa**

Typology	l	ai	l-head	ad	t	d
Landform type						
C	24.3	15.8	4.5	10.2	45.2	—
CPA	8.8	—	8.8	52.9	29.5	
B-Bl	—	—	—	—	—	100
SSGD-SSGDl	—	—	—	—	—	100
Fco	—	—	—	—	100	—

TABLE 9 - Typological percentages of relationships between linears and landform types in **ps, pc,** ST

Typology	l	ad	t	p	inter	al
Landform type						
Fcr	14.3	28.6	14.3	28.6	7.1	7.1
Bz	—	—	50	—	25	25

TABLE 10 - Anthropic effect. Variations of landform types in the period 1976-1994. Most of the differences are the effects of anthropic pressure on the landscape

	1976 n. of landforms	1994 n. of landforms	Differences between totals Abs. value	%
C	309	201	–108	*–34.9*
CPA	54	57	+3	*+5.5*
B	54	40	–14	*–25.9*
Bl	57	18	–39	*–68.4*
SSGD	30	15	–15	*–50*
SSGDl	156	71	–85	*–54.5*
Fco	27	19	–8	*–29.6*
Fcr	87	65	–22	*–25.3*
Bz	6	6	0	*0*
Totals	780	492	–288	*–36.9*

ad (direct effect): linears coincide in C, CPA with the main hydrographic axis that has a direct control on the landforms; for Fcr the linears coincide with the base level driving the rock slides;

t (cut): linears cut the landforms: C, CPA, Fco, Fcr and Bz; it does not coincide with the hydrographic axis or the base level;

d (net): linears are part of the net in which the landforms develop (mainly B, Bl and SSGD, SSGDl);

p (parallel): linears are parallel to the crown of Fcr;

inter (interrupt): the landforms (Fcr and Bz) interrupt the linear;

al (aligned): linears are aligned with the landforms (Fcr and Bz).

Anthropic effects on landscape

The present article and the maps highlight the changes of the landforms occurred in the period from 1976 to 1994. Tab. 10 shows the loss of each landforms as absolute and percentage values in the considered time interval. It must be remarked that in absolute value there is a decrease in landforms, except CPA and *balze*. The last column shows that almost all the landforms underwent a decrease; this trend can be considered as a consequence of their destruction by agricultural land-use on slopes less steep than 25%.

Landforms which underwent the highest percentage destruction were those previously levelled in 1976 (Bl and SSGDl). This fact is a consequence of the yearly agricultural practices that redistribute the upper soil layer and tend to maintain a levelled slope surface. Consequently each base section of the landform is masked. SSGD, *calanchi*, earthflows, *biancane* and small rockfalls show a minor percentage loss. Because of their vertical walls *balze* have not been modified. *Calanchi* partly changed into vegetated CPA.

SUMMARY AND CONCLUSIONS

We present the analysis of relationships among linears, landforms and geology and anthropic effects in the period from 1976 to 1994, in an area of the northern part of Asso River basin (Siena - Italy). Linears show directions either according to the regional tectonic trends (main trends), or different directions that can be considered as locally generated (local linears). The local linears are shorter than main trends.

As far as, the relationship between linears and geology, it appears that the N90° main trend affects all geological substrata; the N37°, N162° and N145° affect only some of them, while N180° seems to cross only **pa**. Areas with the higher frequency of linears are mostly on **pa**.

Linears appear both straight or curvilinear. The curvilinear linears surround elliptical areas interrupting the straight main trends.

The analysis, on one square kilometer basis, of frequency and directions of the local linears shows the presence of different landscapes of linears, that is, of areas in which linears show statistically significative differences among the populations of their directions.

The Rayleigh test of uniformity (***p***) applied to the directions of the local linears shows that these have preferred orientations in the NW, N, W, Central, and S landscapes. The other landscapes show uniformely distributed orientations of the linears. On **pa,** one finds the landscapes with preferred orientations of the linears, with the exception of the SW landscape.

The Watson test, applied to the populations of the directions of the linears of each landscape, shows that, the NE landscape (98.6% of local linears are on **ps**) is different from all the other populations.

In general, landscapes of linears can be recognised on the basis of geological distribution (tab. 3), frequencies of local linears (fig. 6) and of the two statistical tests.

As far as the relations between forms and geological substrata, our results show that forms are mostly developed according to the geology. On Pliocenic clays are present: *biancane*, levelled *biancane*, *calanchi*, CPA, SSGD, levelled SSGD and earthflows. On Pliocenic sandy-clays are present: SSGD, levelled SSGD, *calanchi*, CPA and earthflows. On coarser textured Pliocenic sediments, rockfalls and *balze* are found; and, finally, on pre-neogenic rocks, mainly rockfalls.

As far as the relations between linears and forms our results show that the N90° main trend affects all the landforms; the remaining main trends interest only some landform types.

Landforms are related for more than 50% of the cases with linears, with the exception of Bl in 1976 (45.6%) and of SSGD in 1994 (46.6%). Each time that landforms do not seem to be in direct relation with linears, ground controls show that in most cases joints (main joint - Colica & Guasparri, 1990), with the same direction of the local linears or of the main trends, are present in the landform areas, or in the nearby areas.

Between 1976 and 1994, landforms related to linears changed as follows:

- the percentages of *calanchi* related to linears do not change in time in spite of the anthropic action;
- the percentages of CPA in relation with linears decrease from 74.1% to 63.2%, in spite of a 5.5% increase of the landforms;
- the *biancane* and SSGD decrease their relationships with linears from 70.4% to 60.0% and 100.0 to 46.6%, respectively; this fact can be attributed to the anthropic activities on the landscape;
- the levelled *biancane* increase the relationship with linears, from 45.6% to 100.0%, notwithstanding a 68,5% decrease of the landform type;
- the levelled SSGD increases from 54.5% to 66.2%, in spite of the decrease of 54.5% of the landform type;
- the earthflows and rockfalls increase their relationships with linears from 70.4% to 100.0% and from 63.2% to 80.0%, respectively; this fact can be attributed to the last meteo-climate phenomena occurred before the air-photo flight;
- the relationships between linears and landforms remain constant for *balze*.

The analysis of the typology of the relationships between linears and landforms shows that most of *calanchi, balze* and all of earthflows are intercepted (typology t) by linears. In CPA linears coinciding with main hydrographic axis prevail (typology ad). B, Bl, SSGD and SSGDl are delimited by linears (d). Rockfalls are mainly affected by two typological relationships: first: linears coincide with the main hydrographic axes (ad); and second: linears are parallel to the crown of the landforms (p).

In the period from 1976 to 1994, the landforms undergoing the greatest variations are those already levelled before 1976 (Bl and SSGDl). Remarkable variations are found for SSGD, that generally develop on less steep slopes than *calanchi* but underwent anthropic activities for agricultural use. Minor variations are showed by *calanchi*, earthflows, *biancane* and small rockfalls. Because of their vertical walls, the presence of *balze* remains constant. *Calanchi* were partly transformed into vegetated CPA.

In conclusion this work shows a close relationship between geology, landforms and linears. This relationship is evident in the area of study. The anthropic impact on the landscape affects the existing landforms and creates others. We achieved these conclusions by employing linears and statistical analysis of circular data. This approach can used in other neogenic basins.

REFERENCES

ALEXANDER D. & FORMICHI R. (1993) - *Tectonic Causes of Landslides.* Earth Surf. Process. and Landform, 18, 311-338.

BELISARIO F., DEL MONTE M., FREDI P., FUNICIELLO R., LUPIA PALMIERI E. & SALVINI F. (1999) - *Azimuthal Analysis of Stream Orientations to Define Regional Tectonic Lines.* Zeit. Geomorph. N.E. Suppl, 118, 41-63.

BENVEGNU F., BRONDI A., COLICA A., CONTI P., GUASPARRI G., POLIZZANO C., SABATINI G. & TASSONI E. (1993) - *Studies of migration factors in clay in real situations. Study of fractures in clays of the neogenic basin of Siena.* Nuclear Science and Technology Series, European Communities Commission, Luxembourg (Office for Official Publications of European Communities), 53 pp.

BERTI A., CALABRESI G., CALITERNA L., FORLANI CONTI M., FARSI F., GUIDI F., LAZZAROTTO A., MANTOVANI E., MICHELUCCINI M. & NIZZI GRIFI L. (1992) - *Il Duomo di Pienza - 1549 - 1984. Studi e Ricerche.* Ministero per i Beni Culturali ed Ambientali, Soprintendenza per i Beni Ambientali ed Architettonici di Siena. Ed. Cantini, Firenze, 167 pp.

BOCCALETTI M. & COLI M. (1983) - *La tettonica della Toscana: assetto ed evoluzione.* Mem. Soc. Geol. It., 25, 51-62.

BOCCALETTI M., DECANDIA F.A., GASPERI G., GELMINI R., LAZZAROTTO A. & ZANZUCCHI G. (1987) - *Note illustrative. Carta strutturale dell'Appennino settentrionale.* CNR - P.F. Geodinamica, Sottoprog. 5 Modello strutturale, Gruppo appenninico settentrionale. Tip. Senese, 203 pp.

BRONDI A., COLICA A., CONTI P., GUASPARRI G., POLIZZANO C. & SABATINI G. (1992) - *Joints in clay of neogenic basin of Siena.* Mineral. Petrogr. Acta, 35, 51-65.

BUSONI E. & COLICA A. (2001) - *Le lineazioni nell'analisi integrata del paesaggio: loro relazioni con forme di degradazione del suolo.* Atti del Convegno Nazionale S.I.S.S., Venezia 12-16 giugno 2000. Boll. Soc. It. Sc. del Suolo, 50, 251-260.

BUSONI E., COLICA A. & SALVADOR SANCHIS P. (1998) - *Integrated analysis of the Asso river basin (Siena Italy).* Map: scale 1:30000. C.N.R. Istituto per la Genesi e l'Ecologia del Suolo, Florence, 1998.

CASTIGLIONI G.B. (1979) - *Geomorfologia.* UTET, Torino, 436 pp.

COLICA A. (1992) - *Processi erosivi in calanchi e biancane e loro implicazioni per le opere di conservazione nell'alta Val d'Orcia (SI).* Tesi di Dottorato di ricerca, Università degli Studi di Firenze, 163 pp. (Unpublished).

COLICA A. (2000) - *Analysis of the genesis and evolution of calanco morphology in an experimental area of Paiccia (Radicofani, Siena, Italy).* Geogr. Fis. Dinam. Quat., 23, 21-32.

COLICA A. & GUASPARRI G. (1990) - *Sistemi di fratturazione nelle argille plioceniche del territorio senese. Implicazioni geomorfologiche.* Atti Accad. Fisiocritici Siena. Ser. XV, 9, 29-36.

COSTANTINI A., GANDIN A., LAZZAROTTO A. & SANDRELLI F. (1979) - *Neotettonica del foglio 129 S. Fiora. Nuovi contributi alla realizzazione della carta neotettonica d'Italia.* Pubbl. n. 251 del Progetto Finalizzato Geodinamica, C.N.R., 1-674.

COSTANTINI A., GANDIN G., GUASPARRI G., MAZZANTI R., LAZZAROTTO A. & SANDRELLI F. (1980A) - *Neotettonica dei fogli 111 Livorno, 112 Volterra, 113 Castelfiorentino, 119 Massa Marittima, 120 Siena, 121 Montepulciano, 126 Isola d'Elba, 127 Piombino, 128 Grosseto, 129 S. Fiora.* In: Contributi preliminari alla realizzazione della Carta Neotettonica d'Italia, pubbl. n. 356 del Progetto Finalizzato Geodinamica, C.N.R., 1-487.

COSTANTINI A., GANDIN A., GUASPARRI G., MAZZANTI R., LAZZAROTTO A. & SANDRELLI F. (1980B) - *Neotettonica dei fogli: 111 Livorno, 112 Volterra, 113 Castelfiorentino, 119 Massa Marittima, 120 Siena, 121 Montepulciano, 126 Isola d'Elba, 127 Piombino, 128 Grosseto, 129 S. Fiora.* In: Contributi alla realizzazione della carta neotettonica d'Italia: Parte III. Pubblicazione n. 356 del Progetto Finalizzato Geodinamica, C.N.R., 989-1453.

COSTANTINI A., LAZZAROTTO A. & SANDRELLI F. (1982) - *Il Graben di Siena.* Progetto Fin. - Sottoprog. Energia Geotermica - C.N.R., 11-32.

DAINELLI P. (1985) - *Summary of Remote Sensing Techniques and Geological Applications.* Geomap, Florence, Italy, 1-44.

FISHER N.I. (1993) - *Statistical analysis of circular data.* Cambridge University Press, Cambridge, New York, Melbourne, 277 pp.

GUASPARRI G. (1978) - *Calanchi e biancane nel territorio senese: studio geomorfologico.* L'Universo, 48, 97-140.

GUASPARRI G. (1993) - *I lineamenti geomorfologici dei terreni argillosi pliocenici.* In: La storia naturale della Toscana meridionale. M.P.S., 89-106.

GELMINI R. (1974) - *Studio fotogeologico del bacino neogenico senese (Toscana Meridionale).* Boll. Soc. Geol. It., 93, 837-860.

GUERRICCHIO A. & MELIDORO G. (1979) - *Fenomeni franosi e neotettonici nelle argille grigio-azzurre calabriane di Pisticci (Lucania) con saggio di cartografia.* Geol. Appl. Idrogeol., 14(1), 105-138.

HZU K.J., MONTADERT L., BERNAULLI D., CITA M.B. & EKINSON A. (1978) - *History of Mediterranean Salinity Crisis.* In: Hzu K.J. & *alii*, Init. Report D.S.D.P., Washington, 42, 1053-1078.

JACOBACCI A. & MALATESTA A. (1968) - *Carta Geologica d'Italia alla Scala 1:100.000, foglio 121 - Montepulciano.* Libreria dello Stato, Roma.

JACOBACCI A., MALATESTA A. & MARTELLI G. (1969) - *Note Illustrative della Carta Geologica, foglio 121 - Montepulciano.* Servizio Geologico d'Italia, 73 pp.

LOSACCO U. (1963) - *Osservazioni geologiche e geomorfologiche nei dintorni di Pienza e nella media Val d'Orcia.* L'Universo, 48, 4, 659-688.

MAZZANTI R. & RODOLFI G. (1988) - *Evoluzione del rilievo nei sedimenti argillosi e sabbiosi dei cicli neogenici e quaternari italiani.* In: Canuti P. & Pranzini E. (ed.), La gestione delle aree franose, Ed. delle Autonomie, 13-60.

RODOLFI G. & FRASCATI F. (1979) - *Cartografia di base per la programmazione degli interventi in aree marginali.* Ann. Ist. Sper. Studio e Difesa del Suolo, 10, 38-80.

SOIL SURVEY STAFF, NRCS, (2001) - *National Soil Survey Handbook.* Title 430 - VI, 629 pp.

SORIANO D., COLICA A. & TORRI D. (1992) - *Estudio preliminar de la estructura y propiedades de los materiales en la evolución de badlands.* In: Lopez Bermudez F., Conesa Garcia C. & Romero Diaz M.A: (ed.), *Estudios de Geomorfologia en España* (Actas II Reunión Nacional de Geomorfologia), Tomo I, Murcia (España), 183-191.

TORRI D., COLICA A. & ROCKWELL D. (1994) - *Preliminary study of erosion mechanics in a biancana badland (Tuscany - Italy).* Catena, 281-294.

(Ms. received 15 December 2002; accepted 30 April 2003)

ERRATA CORRIGE TO THE ENCLOSED MAP

GEOLOGY:

9th line instead of «Polygenetic conglomerates, with several relationships with the other Pliocene deposits» read «Pliocene polygenetic conglomerates»

LANDFORMS

Erosional processes:
7th line: instead of «...with...» read «...to...»
19th line: instead of «if...» read «where...»

Erosional and gravitational processes:
4th line: instead of «...clayey sediments stratified...» read «...stratified clayey sediments...»
6th line: instead of «if...» read «where...»
10th line: instead of «if...» read «where...»
12th line: instead of «...linking the its lowest...» read «...linking its lowest...»
14th line: instead of «...to a calanco; either...» read «...to a calanco, or...»

Gravitational processes:
5th line: instead of «Net joints directions...» read «Directions of the net of joints...»
14th line: instead of «...descrete...» read «...discrete...»

NOTE

2nd line: instead of «...can be terrific and give...» read «...can be catastrophic and gives...»
4th line: instead of «...can go very high;...» read «...can rise very high,...»
9th line: instead of «...central Italy...» read «...Central Italy...»
13th line: instead of «...these trends are called...» read «...these are called...»

Captions:
Fig. 1
1st line: instead of «Frequencies...» read «Frequency...»
Table 3
4th line: instead of «(red italics bold values)» read «(red values)»
Table 6
3rd line: instead of «...neither...» read «...either...»
4th line: instead of «...nor...» read «...or...»
Table 8
2nd line: instead of «...analized...» read «...analysed...».