Geogr. Fis. Dinam. Quat.
19 (1996), 335-341, 4 figg.

CLEMENTE STEFANO FOLCHI VICI D'ARCEVIA (*), BERNARDINO GENTILI (**), LUCIA LUZI (***), GILBERTO PAMBIANCHI (**) & FRANCESCO VIGLIONE (****)

DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATION IN THE CENTRAL-SOUTHERN UMBRO-MARCHEAN APENNINES: MORPHOMETRIC AND MACROSTRUCTURAL ANALYSES

ABSTRACT: FOLCHI VICI D'ARCEVIA C.S., GENTILI B., LUZI L., PAMBIANCHI G. & VIGLIONE F., *Deep-seated gravitational slope deformation in the central-southern umbro-marchean Apennines: morphometric and macrostructural analyses* (IT ISSN 0391-9838, 1996).

In the present paper the results of a statistical analysis are shown, performed on deep-seated gravitational slope deformation phenomena, mapped in the central Apennines, located in 9 1:100,000 scale map sheets (Nos 116 Gubbio, 117 Jesi, 123 Assisi, 124 Macerata, 131 Foligno, 132 Norcia, 133 Ascoli Piceno-Giulianova, 138 Terni, 139 L'Aquila), to characterize the parameters which determine their distribution or their activation. The proposed method is based on a preliminary interpretation of aerial photographs at medium scale (1:33,000) and on a subsequent detailed geological-geomorphological field survey (1:25,000, 1:10,000 scale) aimed at collecting lithostructural and tectonic data of the bedrock, to identify the different movement types. The field data are collected through a hard copy checklist and subsequently codified and inserted into a data base management system to perform the statistical analysis. The results obtained show how these phenomena are determined by particular combinations of lithological, tectonic, structural and morphological factors.

KEY WORDS: Deep-seated gravitational slope deformation, Morphometric analyses Macrostructural analyses, Central Apennines, Italy.

RIASSUNTO: FOLCHI VICI D'ARCEVIA C.S., GENTILI B., LUZI L., PAMBIANCHI G. & VIGLIONE F., *Analisi morfometrica e macrostrutturale delle deformazioni gravitative profonde di versante del tratto centro-meridionale dell'Appennino umbro-marchigiano* (IT ISSN 0391-9838, 1996).

Vengono illustrati i risultati di un'indagine statistica, relativa agli elementi geomorfologici caratteristici delle deformazioni gravitative profonde di versante, rilevate in un ampio tratto dell'Italia centrale, contraddistinto dal tipico assetto geologico dell'Appennino umbro-marchigiano. L'indagine, finalizzata all'individuazione e allo studio di detti fenomeni gravitativi, si è basata sulla preliminare interpretazione di fotografie aeree a media scala (1:33.000) e sul successivo rilevamento geologico-geomorfologico di dettaglio (scale 1:10.000 e 1:25.000).

Sono stati così individuati i fenomeni gravitativi, definendone le caratteristiche litostrutturali e tettoniche dei corpi rocciosi, i rapporti con eventuali depositi continentali ed i principali meccanismi deformativi. I dati di campagna, riportati su scheda e successivamente codificati ed elaborati statisticamente, hanno permesso di stabilire delle correlazioni, talora piuttosto strette, tra i fenomeni deformativi ed i fondamentali parametri morfometrici dei versanti, oltre che con le condizioni litostratigrafiche e tettonico-strutturali del substrato roccioso.

I 49 casi di deformazione gravitativa profonda di versante studiati, hanno permesso di evidenziare i diversi fattori di controllo di tali complessi fenomeni, all'interno delle formazioni calcaree ed arenacee dell'Appennino umbro-marchigiano.

I fenomeni di *lateral spreads* (distinti in *deep-seated block slide* e *lateral spreads* s.s.) prevalgono nettamente nelle rocce lapidee intercalate o sovrapposte a termini pelitici o caratterizzate da livelli intensamente tettonizzati o carsificati; talora risultano guidati da piani di sovrascorrimento. I fenomeni di *sackungs* sono per lo più presenti negli ammassi rocciosi fratturati, di maggior spessore, che costituiscono versanti con più elevati valori dell'energia di rilievo e dell'acclività. Tra i parametri geologico-strutturali risulta di fondamentale importanza la presenza di discontinuità tettoniche (fratture, faglie, sovrascorrimenti e retroscorrimenti), come è testimoniato sia dalla buona corrispondenza tra le direzioni di faglie e/o fratture e trincee, che dalla presenza di lineazioni tettoniche in più del 60% dei fenomeni rilevati. L'attività tettonica, in combinazione con cause climatiche, ha inoltre generato l'energia di rilievo necessaria all'innesco delle deformazioni. Importante risulta essere infine l'assetto giaciturale dei corpi rocciosi stratificati; nel 75% dei casi studiati, ricorrono infatti disposizioni degli strati a franapoggio, con inclinazione minore del pendio.

Per quanto riguarda i parametri morfometrici e morfologici del versante si evidenzia un valore minimo di 200 m dell'energia di rilievo necessario per l'innesco dei fenomeni deformativi, che può raggiungere i 900 metri, nei litotipi a più elevata competenza. La lunghezza del versante non risulta essere un fattore di controllo determinante, presentando comunque un intervallo maggiormente ricorrente tra i 900 ed i 1900 metri.

L'angolo di inclinazione del versante ha un valore medio pari a 22° che aumenta in assenza di faglie e/o fratture e diminuisce, al contrario, in presenza di esse e/o di sequenze litologiche costituite da calcari e calcari marnosi su marne e marne calcaree. La forma del versante in più del 70% dei casi risulta essere convessa e la profondità media stimata di tali deformazioni si attesta intorno ai 100 metri.

I fenomeni di deformazione gravitativa profonda di versante studiati, ricorrono con maggiore frequenza lungo i fronti di sovrascorrimento e/o di retroscorrimento e, soprattutto, nell'area meridionale, dove più rapido

(*) *Dipartimento di Scienze dei Materiali e della Terra, Università di Ancona.*
(**) *Dipartimento di Scienze della Terra, Università di Camerino.*
(***) *Istituto di Ricerca sul Rischio Sismico, CNR, Milano.*
(****) *Istituto di Ingegneria Ambientale, Università di Perugia.*
Work supported by Murst 40% fund.

ed intenso è stato il sollevamento neotettonico. Inoltre la presenza di tali fenomeni deformativi in aree caratterizzate da minori energie di rilievo, ma interessate da più intensa attività sismica, permette di ipotizzare un loro stretto collegamento con eventi sismici di notevole intensità.

TERMINI CHIAVE: Deformazioni gravitative profonde di versante, Analisi morfometrica, Analisi macrostrutturale, Appennino Centrale.

INTRODUCTION

The present work reports the results of a statistical analysis of deep-seated gravitational slope deformation phenomena mapped in the central Apennines (Map sheet Nos 116 Gubbio, 117 Jesi, 123 Assisi, 124 Macerata, 131 Foligno, 132 Norcia, 133 Ascoli Piceno-Giulianova, 138 Terni, 139 L'Aquila). The aim is to afford a preliminary characterization of the parameters regulating their distribution or which are determinant in triggering them. A further aim is to study the connections between gravitational movements and neotectonic activity, as reported by other Authors (CARRARO & *alii*, 1979; GUERRICCHIO & MELIDORO, 1981; SAVAGE & SWOLFS, 1986; BLUMETTI & *alii*, 1990; DRAMIS & SORRISO VALVO, 1994; DRAMIS & *alii*, 1995).

This study is part of a systematic mapping project at scales of 1:10,000 and 1:25,000 of the deep-seated gravitational slope deformation phenomena and large landslides started many years ago; so far many works have been published (COPPOLA & *alii*, 1978; DRAMIS & *alii*, 1987 and 1988; GENTILI & *alii*, 1992; FOLCHI VICI & *alii*, 1993; GENTILI & PAMBIANCHI, 1993 and 1994; FARABOLLINI & *alii*, 1995). The purpose of the project is to give an investigatory methodology for surveying and systematically classifying large-scale earth movements in the Central Apennines and to create thematic maps for studying the hazard arising from gravitational phenomena. The method proposed is based on a preliminary interpretation of medium-scale (1:33,000) aerial photographs and subsequent detailed geological-geomorphological surveys (at scales of 1:25,000 and 1:10,000). Particular care has been taken in collecting the data regarding the lithostructural and tectonic setting of the bedrock, with a view to interpreting the various types of movement. The geological-structural parameters and geomorphological characteristics of the mapped phenomena have been collected and classified on appropriate check-lists for setting up a data bank. The last phase consists in a statistical elaboration of the information collected. The present paper reports the results obtained for deep-seated gravitational slope deformation phenomena (fig. 1).

THE MAIN STRUCTURES

In the Umbro-Marchean Apennine area studied here, terrains of the Umbro-Marchean stratigraphic series crop out, formed of a sedimentary sequence with levels of differing stiffness (CENTAMORE & DEIANA, 1986). This sedimentary cover is made up of:

1) a carbonatic platform limestone unit approx. 800 m thick (Calcare Massiccio, Upper Trias-Lower Lias);

2) a well-stratified pelagic and hemipelagic succession (Middle Lias-Miocene p.p.) made up of limestone, silicious limestone, marly limestone, and marls of varying thickness in the northern and central zones between 1400 and 900 m a.s.l., related with the presence of the complete, compounded or condensed succession. In the southern portion of the area, the presence of considerable quantities of limestone deriving from the disintegration of the Latium-Abruzzi platform makes it extremely difficult to determine the thickness of the facies;

3) turbiditic silico-clastic deposits of the Umbrian, inner Marchean, outer Marchean, and «della Laga» Basins (Lower Miocene-Pleistocene).

The area of study is that part of the Apennines bordered to the west by the Umbrian Basin and to the east by the outer Marchean Basin. It is formed by the Umbro-Marchean anticline ridges to the west and the Marchean one to the east which are separated by the inner Marchean Basin syncline; to the south of the internal syncline these ridges join together, giving rise to the massif of the Sibillini Mts.

The Umbro-Marchean ridge is made up of a series of periclines and of more complex anticline structures superimposed on each other with eastern vergence and thrust onto the silicoclastic sediments of the inner Marchean Basin; the Marchean ridge is mainly formed of an anticline which is superimposed on the Tertiary terrains of the outer Marchean Basin along a thrust plane which to the north of the River Chienti valley is not visible in outcrops.

The structure of the Sibillini Mts is also made up by a set of thrusts and is tectonically superimposed on the «della Laga» Basin terrains, along a complex thrust structure.

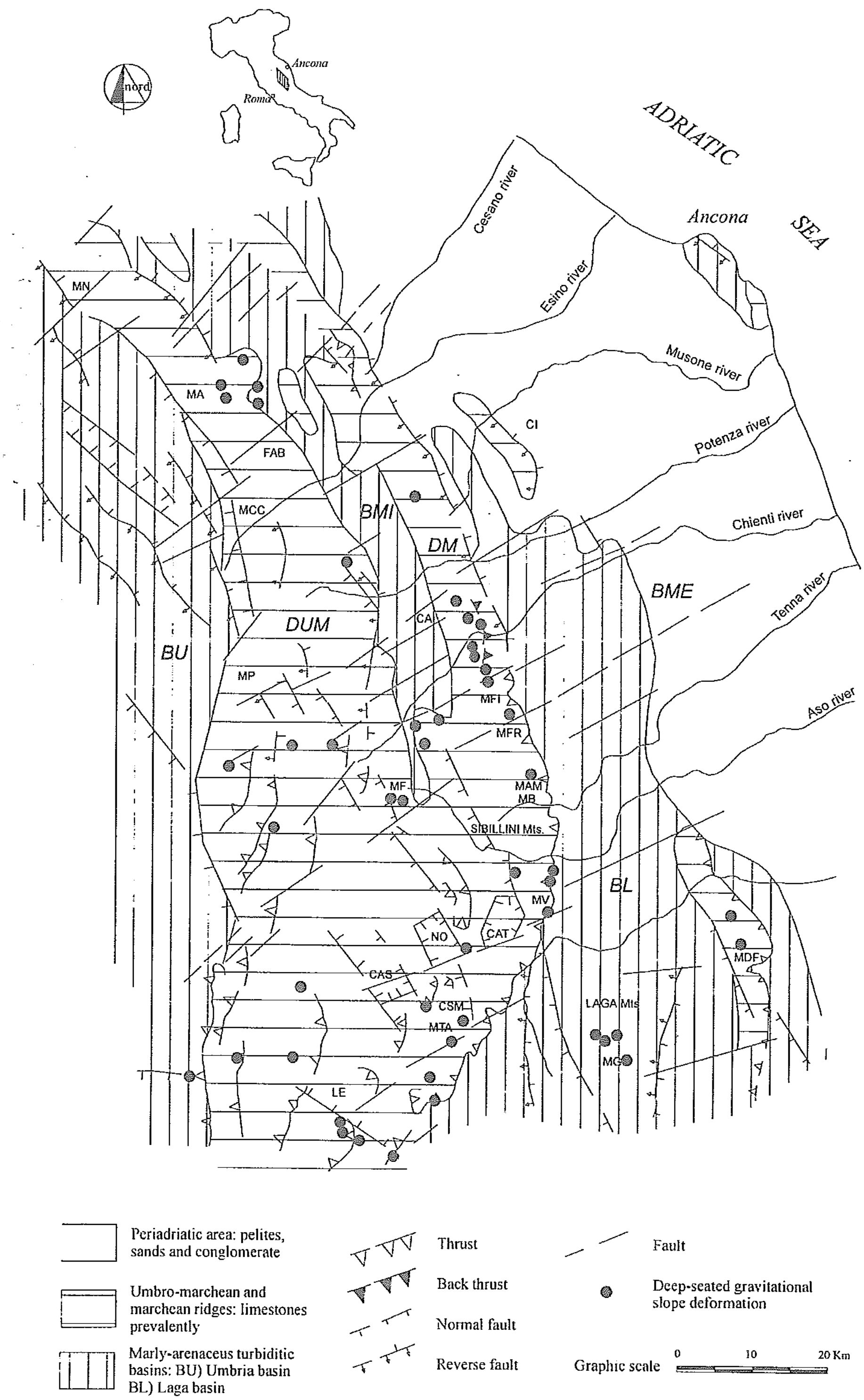
In addition, the survey area covers the eastern part of Laga Mountains, including the Montagna dei Fiori ridge structure, tectonically superimposed on the Tertiary turbiditic deposits of the «Laga» Formation (fig. 1).

The above-mentioned compressional structures, originated in Upper Miocene-Lower Middle Pliocene, were subsequently dislocated, starting in Upper Pliocene, by a series of direct faults trending prevalently between NNW-SSE and WNW-ESE; these are grouped in belts and have given rise to tectonic depressions of varying sizes (e.g., those of Montelago, Norcia, and Castelluccio) and to slopes with high relief.

ELEMENTS CONSIDERED

For the statistical survey of the observed deep-seated gravitational slope deformation phenomena, some factors considered significant were encoded and incorporated into a data bank. The lithotypes were first encoded as individual formations, and then regrouped as sequences, in particular as alternations of limestone lithotypes (C), limestone and marly limestone formations stratigraphically underlying marly formations (CM), marly formations underlying limestone ones (MC), or as alternations of arena-

FIG. 1 - Geological-structural scheme of the study area, with the location of the examined deep-seated gravitational slope deformation phenomena.



CA) Camerino, CAS) Cascia, CAT) Castelluccio, CI) Cingoli, CSM) Castel Santa Maria; FAB) Fabriano; LE) Leonessa; MA) Acuto Mt., MAM) Amandola Mt.; MB) Bove Mt.; MCC) Cucco Mt., MDF) Fiori Mt., MF) Fema Mt., MFI) Fiegni Mt.; MFR) Frascare Mt., MG) Gorzano Mt.; MLS) Siere Mt.; MN) Nerone Mt.; MP) Pennino Mt.; MTA) Alvagnano Mt., MV) Vettore Mt ; NO) Norcia; DUM) Umbro-marchean ridge, DM) Marchean ridge; BME) External marchean basin, BMI) Inner marchean basin

ceous, arenaceous-pelitic, and pelitic formations (AR). In addition, the structural data for the slopes affected by the phenomenon were reported: the bedding of the strata with respect to the slope orientation, the degree of fracturing in the lithotypes, and the presence and type of faults.

Also the slope morphology and morphometry were considered to be an element correlated with these phenomena. Included in the data bank were: the relief (in m), the average angle of inclination of the slope (in degrees), the length (in m), and the morphology of the slope (concave or convex). Of the geomorphological processes acting on the slopes, erosion due to surface waters was held to be determinant.

About 49 deep seated-gravitational slope deformation phenomena have been analysed and classified (JAHN, 1964; ZISCHINSCKY, 1969; VARNES, 1978); the most recurrent types are *lateral spreads* (subdivided in *lateral spreads* s.s. and *deep-seated block slides*), while *sackung* phenomena are rare (fig. 2a).

The formation most affected by this kind of phenomenon is the Scaglia rosata (present in 23% of the cases studied, as shown in fig. 2b), made up of limestones, marly limestones and more markedly of marly levels, and characterized by low shear resistance with the presence of notably fractured levels. Stratigraphically, this formation overlies a previously marly one (Marne a Fucoidi). Its high frequency could also be explained by the extensive outcrops in the Apennine ridges in the study area.

Also the Marne a Fucoidi is frequently affected by the deep-seated gravitational slope deformation phenomena examined. It is formed of limestones, marly limestones and marls with less pronounced mechanical characteristics than those in the considerably more calcareous formations found in the stratigraphic successions both at the top (Scaglia rosata) and at the base (Maiolica); in fact, it effectively forms a «discontinuity» inside the Umbro-Marchean limestone series. Also lithotypes with a higher limestone content and more rigid behaviour are involved in deep-seated gravitational slope deformation phenomena. Examples of these are the Maiolica, Corniola, and Calcare Massiccio which display characteristic karst levels in parallel with the stratification (FAROBOLLINI & *alii*, 1995). The silicoclastic lithotypes are affected by deep-seated gravitational slope deformation phenomena at the high reliefs, such as della Laga Mts. (fig. 1). There the phenomena can be interpreted as *lateral spreads* or *deep-seated block slides*. Massive sandstones dipping out of the slope overlying thin pelitic or arenaceous-pelitic levels, are activated in correspondence with these thin low-resistance levels; the phenomenon is favored by movement of large blocks fragmented by distensive Quaternary tectonic discontinuities. Along the main tectonic lineaments the major geomorphological evidence is observable, represented by trenches and scarps of considerable size.

A similar trend can be noticed in the frequency distribution of the phenomena related to the lithotechnical units (fig. 2c). About 26 cases comprise the first lithotechnical group (C); half of them involve rocks showing rigid behavior (limestones) overlying units with lower mechanical resistance (marls). These stratigraphical-structural conditions are in fact the most favorable for starting up these deep-seated gravitational slope deformations, as described by many authors (KAMENOV & *alii*, 1977; COPPOLA & *alii*, 1978; DRAMIS, 1984; CRESCENTI & *alii*, 1987). Very similar conditions characterize the phenomena observed in the AR lithotechnical unit (alternation of arenaceous massive and pelitic layers). In the other situations tectonic discontinuities (fractures, faults and thrust fronts) and karst levels parallel to the layering have been considered fundamental (GENTILI & *alii*, 1992; GENTILI & PAMBIANCHI, 1994; FARABOLLINI & *alii*, 1995).

Among the lithostructural control factors, one of the main ones is the type of bedding. In most of the cases examined (ca 60%, cf fig. 2d), the deformations are found at the minor strata dipping out of the slope (class A), whereas

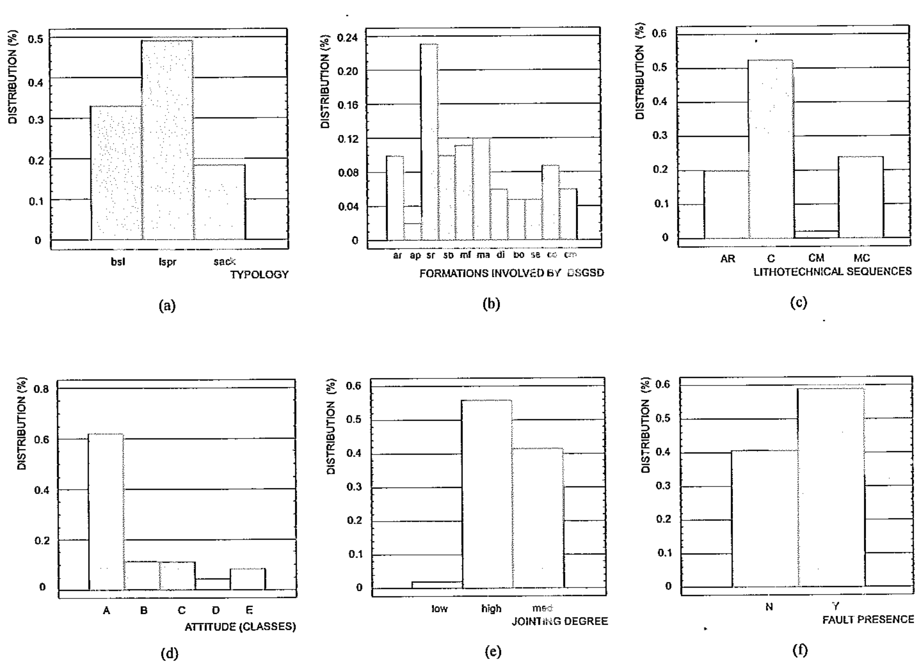


FIG. 2 - a) Frequency distribution of the phenomena (lspr=lateral spread s.s., bsl=deep-seated block slides, sack=sackung); b) percentage distribution of the d.s.g.s.d. over the lithostratigraphic units (ar=arenaceous unit; ap=arenaceous-pelitic unit; sr=Scaglia rosata; sb=Scaglia bianca; mf=Marne a fucoidi; ma=maiolica; di=calcari diasprini; bo=Bosso formation; se=Sentino limestones and marls; co=corniola; cm=calcare massiccio); c) percentage distribution of the d.s.g.s.d. over the lithotechnical units (AR=arenaceous associations intercalated with pelitic and arenaceous-pelitic levels; C=limestones and marly limestones; CM=a base of limestones and marly limestones, surmounted by marly limestones and marls; MC=a base of marly limestones and marls, surmounted by limestones and marly limestones); d) distribution of the type of bedding (A=minor dipping out of the slope; B=dipping into the slope; C=subhorizontal; D=contorted; E=major dipping out of the slope or subvertical); e) distribution of the types of fracturing (high=strong; med=medium; low=weak); f) distribution of fault occurrence (N=no; Y=yes).

the presence of strata dipping into the slope (class B) or subhorizontal (class C) is observed in fewer than 15% of the cases. Lastly, in fewer than 10% of the case, are situations found in which the strata are major ones dipping out of the slope or subvertical (classes D and E).

Subdividing the fracturing into three different classes according to the numerical frequency of the fractures, it is seen that in more than 50% of the cases the rock has a high degree of fracturing, and that only in 2% of the cases is a low degree, as shown in fig. 2e.

The distribution of the phenomena was examined from the standpoint of presence of tectonic lines. From the results obtained, shown in fig. 2f, it can be observed that more than half the cases examined occur at the important fault lines and, in particular, along the thrust and/or backthrust fronts, showing a direction subparallel to the one of the slope. To confirm this, an analysis was made of the correlation between the trends of the faults and those of the main trenches; the result was a correlation coefficient of 0.9 as shown in fig. 3a.

This emphasizes the important role played by the tectonic activity and the tectonic structure in the generation of deep-seated gravitational slope deformations.

An analysis of the morphometric data which characterize the slopes evidences the role of the relief as a predisposing factor for deep-seated creep phenomena. The slopes affected by deformation have relief values mostly between 200 and 900 m (fig. 3b); the one most frequently found (in about 16% of cases) is that of 300 m, while a secondary peak occurs at 600 m.

However, it can also be observed that low relief (200 m) is present in ca 8% of the cases examined, which proves that structural or tectonic factors are sometimes more influential than morphological ones. The relief cannot be separated from the length of slope factor, which is generally found between 900 and 1900 m, with a main peak at 1000-1400 m and a secondary one at 2600 m (fig. 3c).

The highest values, characterised by a low ratio between relief and length, correspond to *lateral spread* phenomena inside the Scaglia rosata or Calcare Massiccio formations or the arenaceous ones. Generally, the deep-seated gravitational slope deformation phenomena affect slopes of considerable size, and only 4% of the slopes have a length of less than 600 m. The regression rate between relief and length of slope affords a correlation coefficient of about 0.5 (fig. 3d), which testifies that high relief is not necessarily associated with long length of slope.

This can be due to the recent (Lower-Middle Pleistocene), intense and rapid tectonic uplifting which affected the area; it is usually connected to the strong river erosion deepening which determines, in the areas close to the river beds, the generation of steep slopes of limited size.

The mean angle of slope values range from 15° to 30° with an average of about 22° and a peak between 20° and 21° (fig. 3e), which is in agreement with literature data (MAHR, 1977; MORTARA & SORZANA, 1987). Relatively low values could testify that the lithostructural and tectonic characteristics are more determinant than the morphological and morphometric parameters. To confirm this hypothesis, the mean angles of slope both in absence and in presence of faults were compared (fig. 3f). In the first case an angle of more than 20° can determine the triggering of deformation, whereas in the second case an averagely lower angle is enough, since in 50% of the cases deformation occurs with angles of less than 20° down to a minimum of 15°.

The representation was performed by «Box and Whiskers» type graphics, where the width of the «Box» is pro-

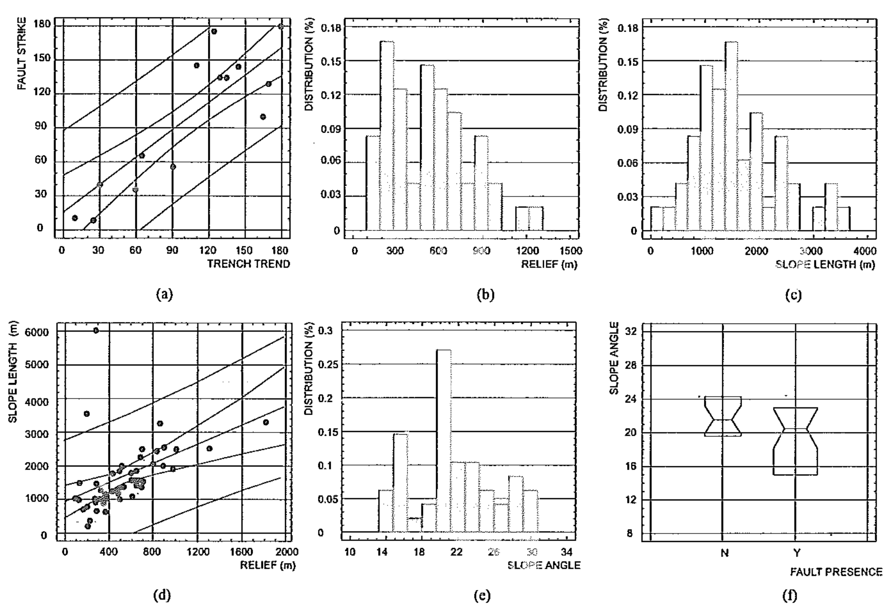


FIG. 3 - a) Regression rate between the trend of the faults and that of the trenches; b) distribution of the relief; c) distribution of length of slope; d) regression rate between length of slope and relief (the length of the slope, in m, is reported in the ordinate axis); e) distribution of the slope angle; f) relationship between the angle of slope and the presence of faults (the value of the angle of slope is given on the axis of the ordinates).

portional to the square root of the number of observations, while its length covers 50% of them (interquartile range). The central line indicates the median and its size is proportional to that of the step calculated. When the lines marking the median of the two groups separate, there is a statistically significant difference between the medians, and thus between the groups.

The geomorphological investigations also dealt with the shape of the slopes affected by the deep-seated creep classifying it as concave, convex or rectilinear (fig. 4a).

In addition to the slopes, also those zones were measured which are affected by deformation with an almost normally distributed angle of slope, and with values ranging from 14-15° to 28°, with a mean of ca 22° (fig. 4b). The most frequently occurring value (in more than 20% of cases) was 16°. The relation between the angle of the deformed zones and the lithological sequences is represented in fig. 4c. In this graph, no substantial differences are observed because the median of the value in the AR sequence is ca 23°, while that for the limestone sequences (C) is 20°, and in MC-type sequences it is ca 22°. The only feature observed is the presence of a certain dispersion in lower values (up to 14°) for the MC lithological sequence compared to the others. That could be explained by the presence of underlying marly levels that induce the triggering of these phenomena even at lower angles. Lastly, the deformation thicknesses, as hypothesized by kinematic interpretation of the movement deduced from geological and geomorphological surface data, ranged between 100 and 200 m with an evident peak between 100 and 120 m (in 37% of cases, cf fig. 4d).

It can also be noticed that the slopes which were triggered by the deformations in absence of faults are affected by river erosion deepening in nearly all cases (ca 75%), as shown in fig. 4e, f. In the opposite case, that is in presence of faults, only 31% of the slopes are affected by river erosion deepening. This can be due to the fact that the relief necessary to start a deep-seated deformation is a direct consequence of the tectonic activity (e.g., fault scarps, thrust/backthrust fronts). On the contrary, where no tectonic dislocations occur, it is always uplifting combined with river erosion which can give rise to such deep-seated deformations.

CONCLUSIONS

Deep-seated gravitational slope deformation phenomena are complex and derive from a combination of different factors. In the present study, the data deduced from a sample of these phenomena have evidenced the different control factors inside the limestone and arenaceous formations of the Umbro-Marchean Apennines.

The most frequent typologies are block slide and lateral spread, mostly present in rocks either intercalated with or overlying marls or pelites, or characterized by intensely tectonized or karstified levels and occasionally controlled by thrusts. The gravitational phenomena attributable to sackung are usually present in fractured rocks and their relief and slope angle values are higher that those of the former type. Of the geological-structural parameters, the presence of preexistent fracturing, and even more so that of intense recent extensional tectonics, is fundamental.

Tectonics is a primary control factor that is proved both by the high level of correspondence between the trend of the fault and that of the trench and by the presence of tectonic lines in more than 60% of the phenomena surveyed. The tectonics has acted in combination with cau-

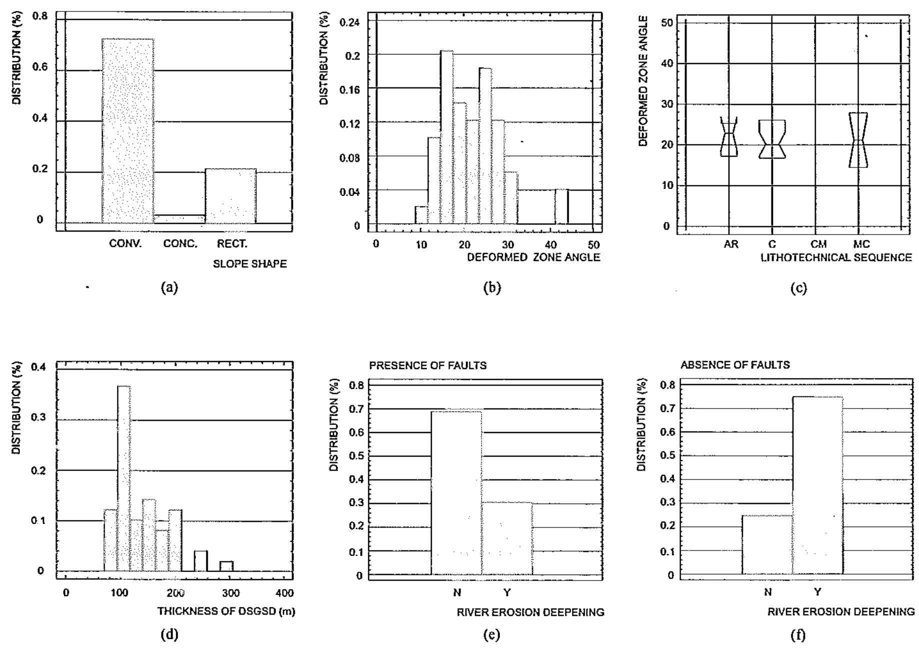


FIG. 4 - a) Distribution of slope morphology (conv=convex; conc=concave; rect=rectilinear); b) distribution of the deformation zone angle of slope; c) relationship between the lithotechnical sequence and the deformation zone angle (the value of the deformation zone angle is given on the axis of the ordinates), AR=arenaceous associations intercalated with pelitic and arenaceous-pelitic levels; C=limestones and marly limestones; CM=a base of limestones and marly limestones, surmounted by marly limestones and marls; MC=a base of marly limestones and marls, surmounted by limestones and marly limestones; d) distribution of deformation zone thickness; e, f) presence of strong river erosion deepening at the base of the slope in presence (e) or absence (f) of faults (Y=yes; N=no).

ses of climatic origin creating the relief needed to trigger the deformations (intense tectonic uplifting and the consequent deep cutting of the hydrographic net, AMBROSETTI & *alii*, 1982).

The bedding of the strata is also important; in 75% of cases it is of the minor dipping out of the slope type determining block slide and lateral spread phenomena. With regard to the morphometric and morphological slope parameters, the minimal value for the relief needed to trigger the phenomena is 200 m, and in the cases examined it can reach 900 m, above all in the lithotypes with greater stiffness. Slope length does not prove to be a determining control factor, and mostly ranges from 900 to 1900 m. The mean value for the angle of slope is 22°, which can increase in absence of faults and, conversely, decrease in the presence of faults and of lithological sequences formed of limestone and marly limestone over marls and calcareous marls. In more than 70% of cases the slope morphology was convex and the average estimated depth of these deformations lies at around 100 m.

Observation of the distribution of deep-seated gravitational slope deformation phenomena in the studied area (fig. 1) reveals a particular frequency of these phenomena along the thrust and/or backthrust fronts and above all in the southern area, where a more rapid and intense uplifting has occurred. The presence of such phenomena in areas characterized by minor relief but affected by intense seismic and neotectonic activity leads to the hypothesis of a connection with the seismic events of considerable intensity that have occurred in the area.

REFERENCES

AMBROSETTI P., CARRARO F., DEIANA G. & DRAMIS F. (1982) - *Il sollevamento dell'Italia Centrale tra il Pleistocene inferiore ed il Pleistocene medio.* C.N.R. - P.F. «Geodinamica» - Contributi conclusivi per la realizzazione della Carta Neotettonica d'Italia, pubbl. n. 513, 219-223.

BLUMETTI A.M., DRAMIS F., GENTILI B. & PAMBIANCHI G. (1990) - *La struttura di Monte Alvagnano - Castel S. Maria nell'area nursina: aspetti geomorfologici e sismicità storica.* Rend. Soc. Geol. It., 13, 71-76.

CARRARO F., DRAMIS F. & PIERUCCINI U. (1979) - *Large-scale landslides connected with neotectonic activity in the Alpine and Apennine ranges.* Proc. XV Meeting «Geomorphological Survey & Mapping», Modena, 213-230.

CENTAMORE E. & DEIANA G. (1986) - *La geologia delle Marche.* Studi Geol. Camerti Vol. Spec., 145 pp.

COPPOLA L., DRAMIS F., GENTILI B. & PIERUCCINI U. (1978) - *Paleofrane nelle formazioni mesozoiche dell'Appennino umbro-marchigiano.* Mem. Soc. Geol. It., 19, 99-109.

CRESCENTI U., DRAMIS F., GENTILI B. & PAMBIANCHI G. (1987) - *Deformazioni gravitative profonde di versante e grandi frane nell'area a sud di Monte Porrara (Appennino centrale, Abruzzo).* Mem. Soc. Geol. It., 39, 477-486.

DRAMIS F. (1984) - *Aspetti geomorfologici e fattori genetici delle deformazioni gravitative profonde.* Boll. Soc. Geol. It., 103 (4), 681-687.

DRAMIS F., FARABOLLINI P., GENTILI B. & PAMBIANCHI G. (1995) - *Neotectonics and large-scale gravitational phenomena in the Umbria-Marche Apennines, Italy.* Steepland Geomorphology, (O. Slaymaker Ed.), John Wiley & Sons Ltd. 199-217.

DRAMIS F., GENTILI B. & PAMBIANCHI G. (1987) - *Deformazioni gravitative profonde nell'area di Monte Gorzano (Monti della Laga, Appennino centrale).* Boll. Soc. Geol. It., 106 (2), 265-271.

DRAMIS F., GENTILI B. & PAMBIANCHI G. (1988) - *Deformazioni gravitative profonde e grandi frane in un tratto di valle trasversale dell'Appennino Marchigiano (F. Chienti).* Boll. Mus. St. Nat. Lunigiana, 6-7, 29-33.

DRAMIS F., GENTILI B. & PAMBIANCHI G. (1994) - *Deep-seated slope deformations and connected large-scale landslides in the Umbria and Marche regions.* Spec. vol. for VII Intern. Iaeg Congr., Lisbona, 36-41.

DRAMIS F. & SORRISO-VALVO M. (1994) - *Deep-seated gravitational slope deformations, related landslides, and tectonics.* Eng. Geology, 38, 231-243.

FARABOLLINI P., FOLCHI-VICI D'ARCEVIA C., GENTILI B., LUZI L., PAMBIANCHI G. & VIGLIONE F. (1995) - *La morfogenesi gravitativa nelle formazioni litoidi dell'Appennino centrale.* IV Semin. Gruppo Dgpv, Chiusi della Verna (AR), 24-28 Maggio 1993. Mem. Soc. Geol. It., 50, 123-136.

FOLCHI-VICI D'ARCEVIA C., LUZI L. & VIGLIONE F. (1993) - *La frana di Monte Rotondo (M. Sibillini - Marche Sud-occidentali): indagini geomorfologiche, geologico-strutturali ed analisi di stabilità.* Atti del 3° Convegno dei Giovani Ricercatori di Geologia Applicata.

GENTILI B. & PAMBIANCHI G. (a cura di, 1993) - *Carta delle deformazioni gravitative profonde di versante e grandi frane nell'Appennino Centrale (Foglio 124 Macerata).* Interlinea, Teramo.

GENTILI B. & PAMBIANCHI G. (1994) - *Gravitational morphogenesis of the Apennine chain in Central Italy.* Proceed. 7th Int. Iaeg Congr., Lisbon 5-9 September 1994.

GENTILI B., PAMBIANCHI G. & ARINGOLI D. (1992) - *Rimodellamenti gravitativi del tratto di anticlinorio marchigiano compreso tra i fiumi Chienti e Fiastrone.* Studi Geol. Camerti, 12, 163-169.

GUERRICCHIO A. & MELIDORO G. (1981) - *Movimenti di massa pseudo-tettonici nell'Appennino dell'Italia meridionale.* Geol. Appl. Idrogeol., 14 (1), 13-22.

KAMENOV B., ILIEV IL. & AVRAMOVA-TACHEVA E. (1977) - *Conditions for the origin, mechanism and dynamics of block landslides in Bulgaria.* Bull. Iaeg, 16, 98-101.

JAHN A. (1964) - *Slope morphological features resulting from gravitation.* Zeit. Geomorph., S.B. 5, 59-72.

MAHR T. (1977) - *Deep-reaching gravitational deformations of high mountain slopes.* Bull. Iaeg, 16, 121-127.

MORTARA G. & SORZANA P.F. (1987) - *Fenomeni di deformazione gravitativa profonda nell'arco alpino occidentale italiano.* Boll. Soc. Geol. It., 106, 303-314.

SAVAGE W.Z. & SWOLFS H.S. (1986) - *Tectonic and gravitational stress in long symmetric ridges and valleys.* Journ. Geophys. Res., 91 (B3), 3677-3685.

VARNES D.J. (1978) - *Slope movement. Types and processes.* In: SCHUSTER R.L. & KRIZEK R.J. (eds.), *Landslides. Analysis and control.* Nat. Acad. Sciences, Spec. Rep. 176, Washington D.C., 11-35.

ZISCHINSKY U. (1969) - *Über sackungen.* Rock Mech., 1 (1), 30-52.