Giornale di Geologia Applicata 1 (2005) 53 –62, doi: 10.1474/GGA.2005-01.0-06.0006

The Ancona landslide of December 1982

Crescenti U., Calista M., Mangifesta M. & Sciarra N.

Centro Ricerche e Studi Sperimentali per le Geotecnologie – Università di Chieti – Chieti (Italy)

Abstract. In this paper the large landslide occurring in Ancona in 1982 is described and modeled. This is still a topical phenomenon that involves a lot of researchers. The works of CRESCENTI ET AL. (1977), AA.VV. (1987), COTECCHIA (1997), RAINONE ET AL. (1997), that deal with the Ancona landslide can be mentioned in this context. The main characteristics of the phenomenon are summarized and the pre-landslide stability conditions are verified utilizing a finite differences numerical code and assuming the presence of the yielding surface deduced from the numerous inclinometric surveys. This modeling gave encouraging results for a reconstruction of the kinematics of the phenomenon.

Key terms: Landslides, Marchean Region, Numerical Modeling,

Introduction

The large landslide of Ancona started in the evening of December 1982, at about 10.45 p.m., on the north-facing slope of the Montagnolo, from about 170 m a.s.l. to the sea. The slope portion affected by mass movement extends over about 3.4 km^2; along the shore it is about 1.7 km wide. The deformation phase lasted only a few hours. Many buildings were damaged beyond repair and some completely collapsed.

Lines of communications such as the Flaminia Road and the railway were interrupted (Fig. 1), lifted and moved towards the sea. The impressive landslide originated in remote ages; after its early activation the phenomenon was developed sporadically, coincident with drastic meteoric events or earthquakes.

Fig. 1. Railway (a) and Flaminia Road (b) interrupted by the landslide.

Geological framework

As regards geology, Plio-Pleistocene sediments crop out in the area. Middle Pliocene is represented by gray-blue bedded marly with sandy and silty interbedding. These rocks are unconformably overlaid by gray-bluish silt and sandy clays which, in the upper part, contain levels of sands and sandstones, and lenses of coquinic panchina; the age of these sequences is Pleistocene. Between the Middle Pliocene and Pleistocene deposits a sedimentary hiatus corresponds to the absence of the *Globorotalia inflata* biozone (Upper Pliocene). The Pleistocene sediments were uplifted by about 250 m in correspondence with the top of Montagnolo hill. They appear to be strongly lowered towards the sea, north of the Posatora-Grottine alignment, along which a normal fault was observed. Plio-Pleistocene units are intensely jointed and eluvial-colluvial deposits, at places tens of meters thick, nearly everywhere overlie them.

The main tectonic features of the area fit the framework of the northern Apennine range; folds with axes trending NW-SE, faults striking NW-SE and NE-SW (Figs 2, 3). From seismic data referring to earthquakes (CRESCENTI ET AL., 1977), it can be inferred that some epicenters are roughly aligned along faults striking NE-SW in the vicinity of the landslide area.

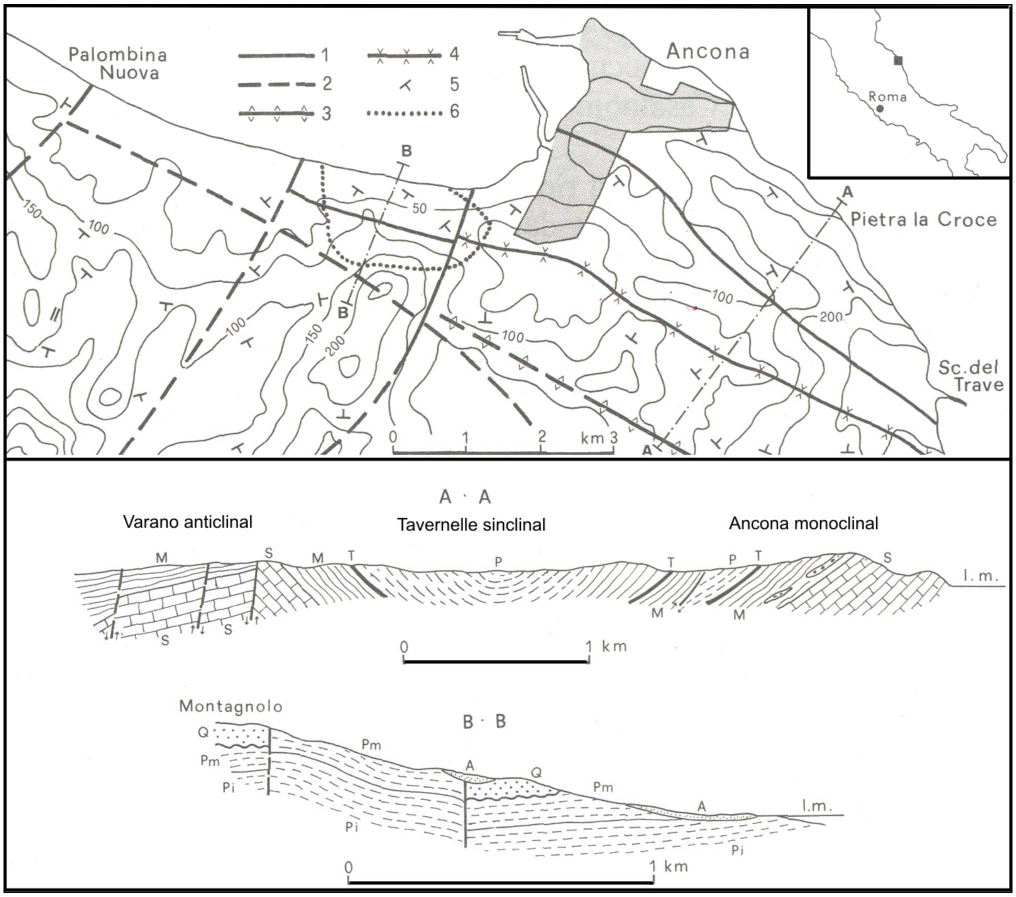

Fig. 2. Main tectonic features of the area: 1) faults; 2) probable faults; 3) anticlinal axes; 4) synclinal axes; 5) dip; 6) landslide boundary; S (Schlier formation - Middle Miocene); M, T (clays, marls, sandstones – Upper Miocene); P (marly sandy clays – Lower Pliocene Pi, Middle Pliocene Pm); Q (Pleistocene); A (cover deposits).

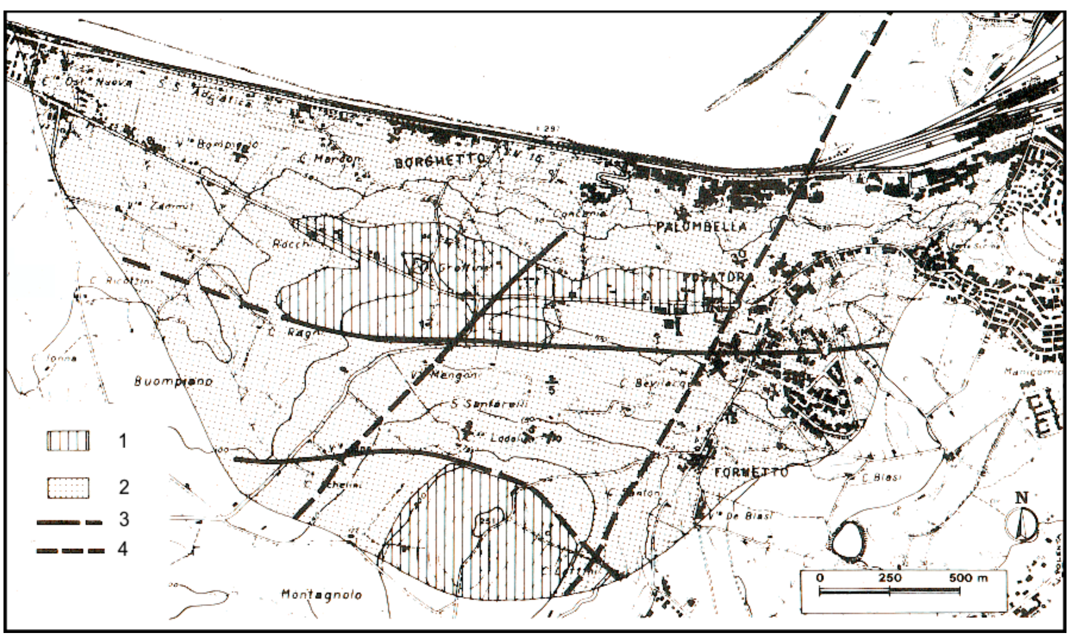

Fig. 3. Geological map: 1) sands, sandstones and bluish marly clays (Pleistocene); 2) marly clays intercalated with sands (Middle and Lower Pliocene); 3) faults; 4) faults or fractures (from CRESCENTI et alii, 1983, modified).

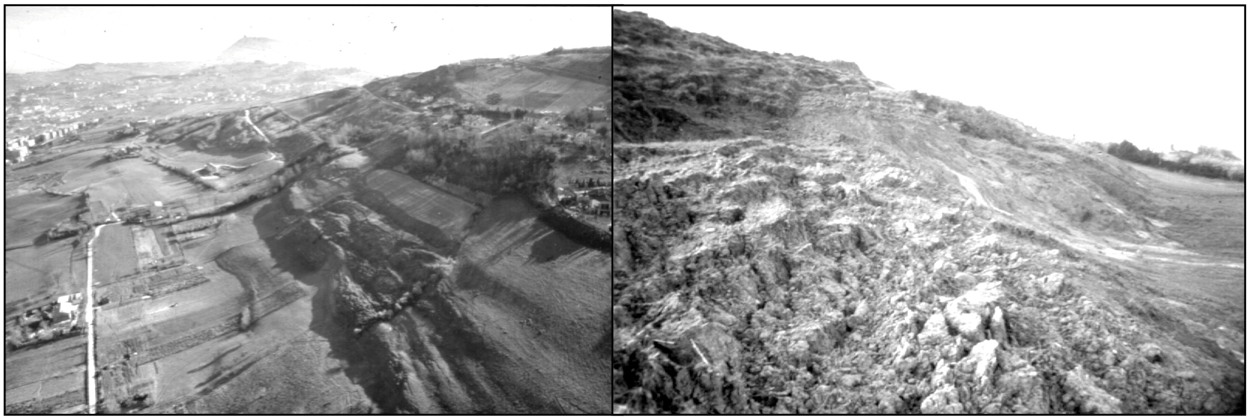

Fig. 4. Some features of the landslide: a) the upper trench (near Villa Mengoni); b) the main scarp.

From a geomorphologic point of view the Montagnolo hill shows a characteristic landslide morphology with scarps, steps, undrained depressions (trenches) and a reverse slope. Two flat-floored parallel trenches extending at elevations of about 140 m (Villa Mengoni trench - see Fig. 4) and 80 m (Posatora trench), respectively, constitute the most striking geomorphologic elements of the slope. They are graben-like features, being bounded by tensile fractures with vertical displacement. (Fig. 5). The upper trench (near Villa Mengoni) is circa 700 m long, while the lower one is 1200 m long from Posatora to Grottine.

The dimensions of the involved area and the fact that deformations occurred at the same time suggested that the phenomenon was a very deep one (Fig. 6). Geognostic and geophysical surveys confirmed this hypothesis (AA.VV, 1987).

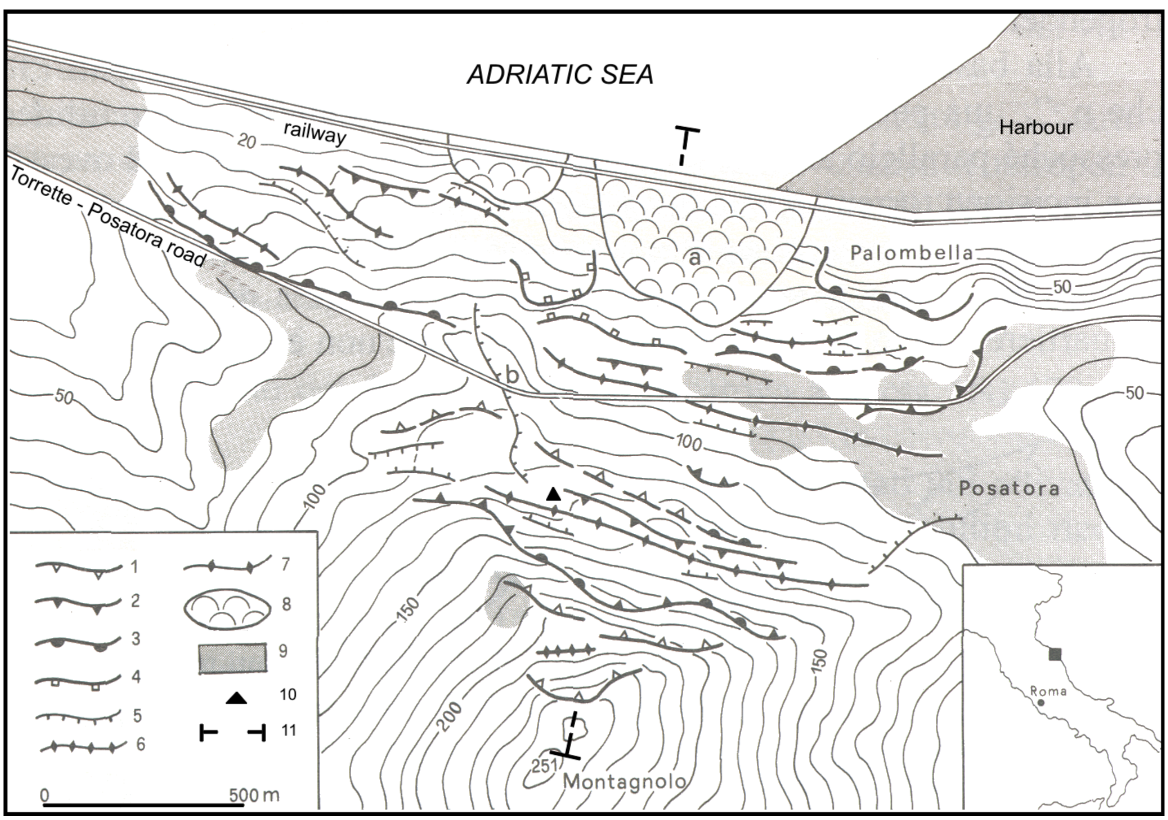

Fig. 5. Geomorphologic scheme of landslide area: 1) ancient quiescent scarp; 2) scarp activated in December 1982; 3) reactivated scarp; 4) active scarp before the landslide event; 5) secondary scarps; 6) inactive trenches; 7) reactivated trenches; 8) main superficial landslides; 9) urbanized areas (b - cemetery); 10) Villa Mengoni; 11) profile of Fig. 6 section.

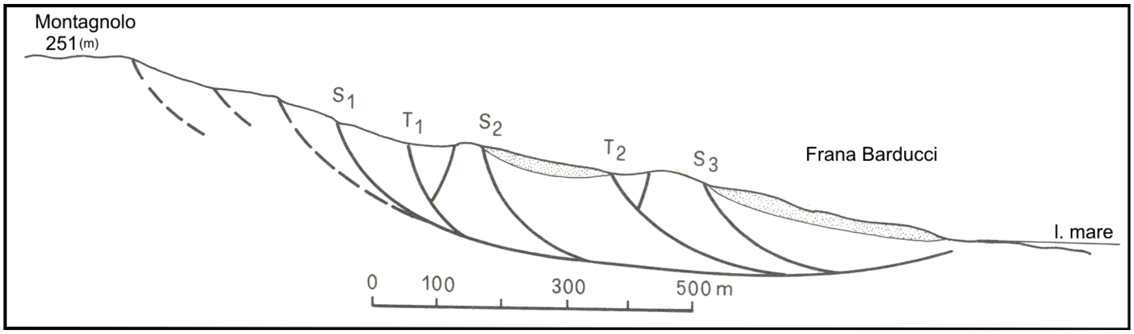

Fig. 6. Schematic section from the Montagnolo hill to the sea. We can recognize the main and secondary scarps (S1, S2 and S3) and the trenches (T1 and T2).

Therefore, also on the basis of historical data (DE BOSIS in 1859 and SEGRÈ in 1919 described the same event that occurred in November 1858), we can conclude that the large Ancona landslide of December 1982 is a very ancient, deep and complex phenomenon, (CRESCENTI ET AL., 1983): it is very ancient (more than 5000 years) in view of historical records and the hidden morphologic evidence; so it is rooted in the geologic past of the area (see also Fig. 7); it is deep in view of its extension, the regularity of the morphological elements, and the contemporaneity in which so large a landslide was mobilized; it is complex (see CARRARA ET AL., 1985) because near the deep roto-translational movement that affected the Pliocene substratum, superficial landslides are present with flow or sliding typology involving cover deposits.

Numerical modeling

The numerical code used (FLAC_3D, 2000) is a three-dimensional finite difference method of numerical analysis for calculations of continuum mechanics. The ground is represented by elements (tetrahedrons) that are constructed by the user to describe the form of the object to be modeled. Each element behaves in accordance with a prescribed stress-deformation law, linear or otherwise, in response to the forces applied or to the constraints imposed on the contour. FLAC is based on a "*Lagrangian*" numerical scheme which is well adapted to modeling broad deformations and collapse of materials.

The general analysis carried out, as imposed by the numerical code, consists first of all in a global re-equilibrium of the system and then in the study of the break conditions. Analysis of the global re-equilibrium process is divided into three phases. In the first phase the possible presence of a filtration motion of the liquid phase inside the model is analyzed, to pinpoint, once the hydraulic equilibrium is reached, the progress of the flow vectors and the distribution of the neutral pressures independently of any mechanical effect.

Fig. 7. The old postal-house sited on the T_2 trench. The house has undergone rotation, as can be recognized from the ancient repairs.

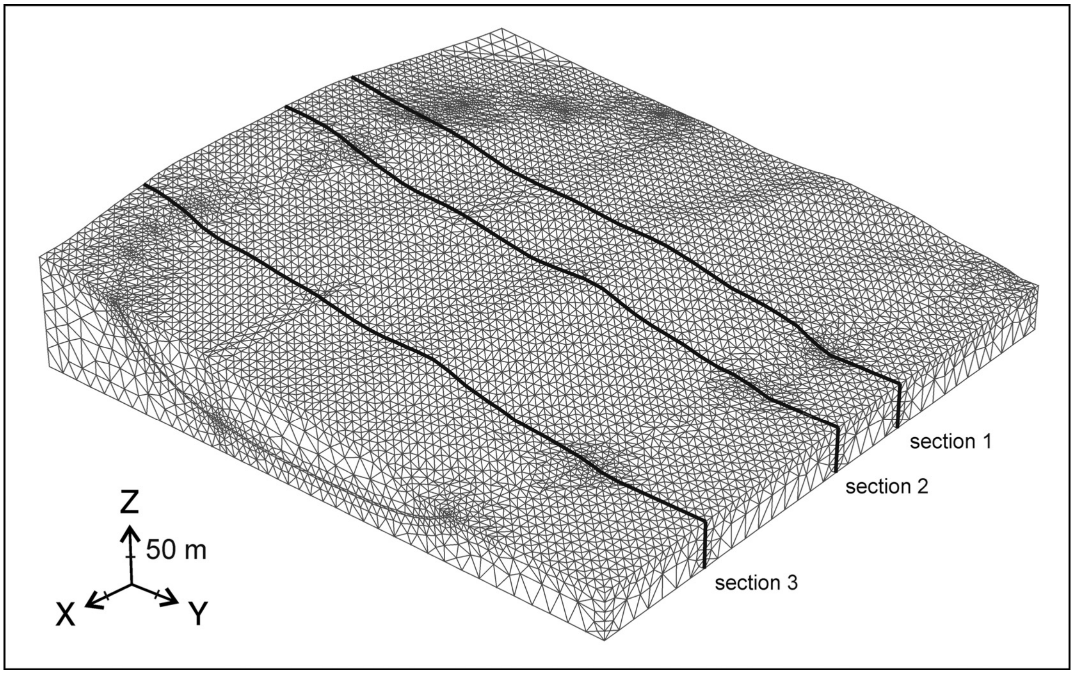

Fig. 8. Detail of the model discretized by tetrahedron elements

In the second phase, the model operates a mechanical adjustment by using the neutral pressure values drawn from the first phase and, in addition, by imposing a module of null compressibility of the water, further variations in neutral pressures are prevented. At the end of the second phase, the dislocations produced (not real) are cancelled and by inserting the characteristic parameters of mechanical behavior we move on to the third phase, in which the filtration process and the relative mechanical adjustment are analyzed simultaneously.

At the end of the analysis of the global equilibrium process, it is possible to represent the vectors of movement and the lines of isovelocity at the discretization points of the model. In this way the behavior of the system we are studying can be observed, with reference to its geometrical, physical and mechanical peculiarities.

Secondly we can introduce a perturbation in the model in the internal (physico-mechanical parameters of the land, neutral pressures, etc.) or external characteristics (application of loads, seismic events, etc.) to know the behavior of the system.

The mechanical situation used is represented by a grid constructed with tetrahedrons which define homogeneous portions of ground (Fig. 8). The tetrahedrons dimensions are chosen automatically from a numerical modeler that optimizes the model to reduce both the effects of scale due to the dimensions of the model (1.5 x 1.0 km) and the calculation times which were necessarily heavy for the specific case.

The values for the physical-mechanical parameters relating to the three lithotypes of the geological model are fixed in the barycenter of the tetrahedrons. Different physico-mechanical characteristics were attributed, but for all of them Druker-Prager's constitutive law was used (CHEN & HAN, 1988), which simulates very well elasto-plastic behaviors in complex situations of broad deformations. Table 1 shows the values of the parameters used in the numerical calculations. These have been taken from bibliographical data and from numerous studies and laboratory tests on the Ancona clays.

Tab.1 – Values of physical-mechanical properties used in the calculation.

Parameters	cover deposits	clays	remolded clays
γ (unit volume weight) - (kNm^{-3})	19.5	21.0	20.5
c' (cohesion) - (Pa)	1. E3	30. E3	-
φ' (friction angle) - (°)	23	25	18
Poisson's ratio	0.3	0.25	0.33
bulk modulus - (Pa)	3. E6	6. E6	6. E5
shear modulus - (Pa)	2. E6	4. E6	4. E5

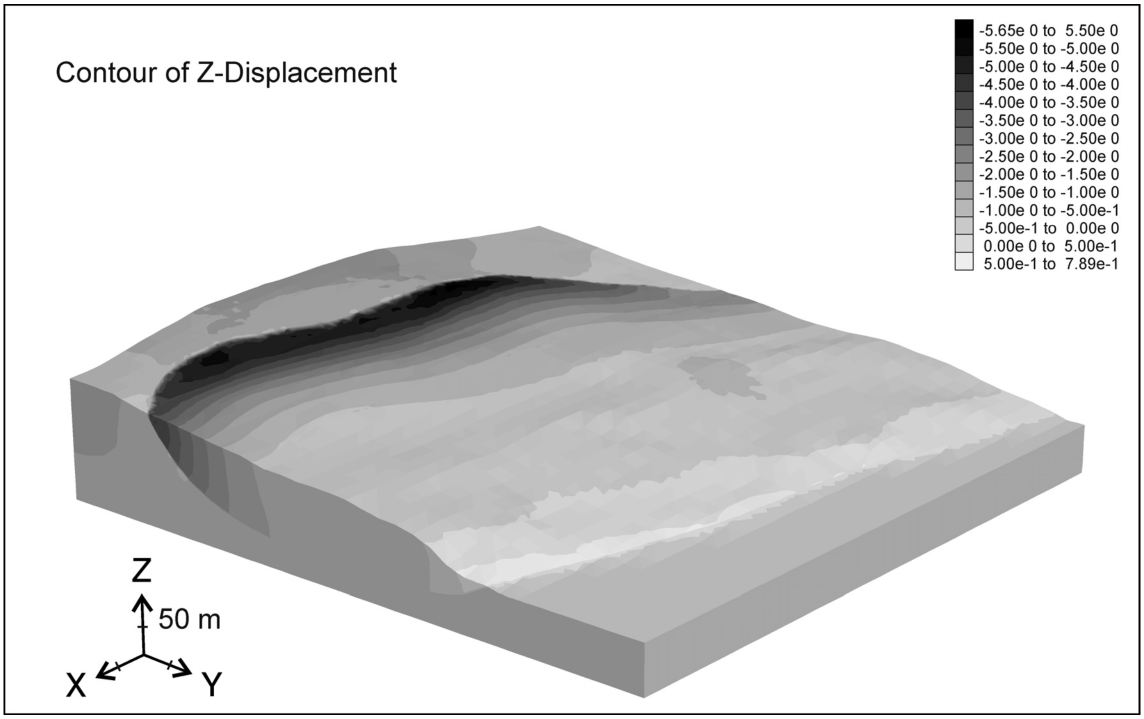

Fig. 9. Vertical displacements occurring in the slope as deduced from the modeling.

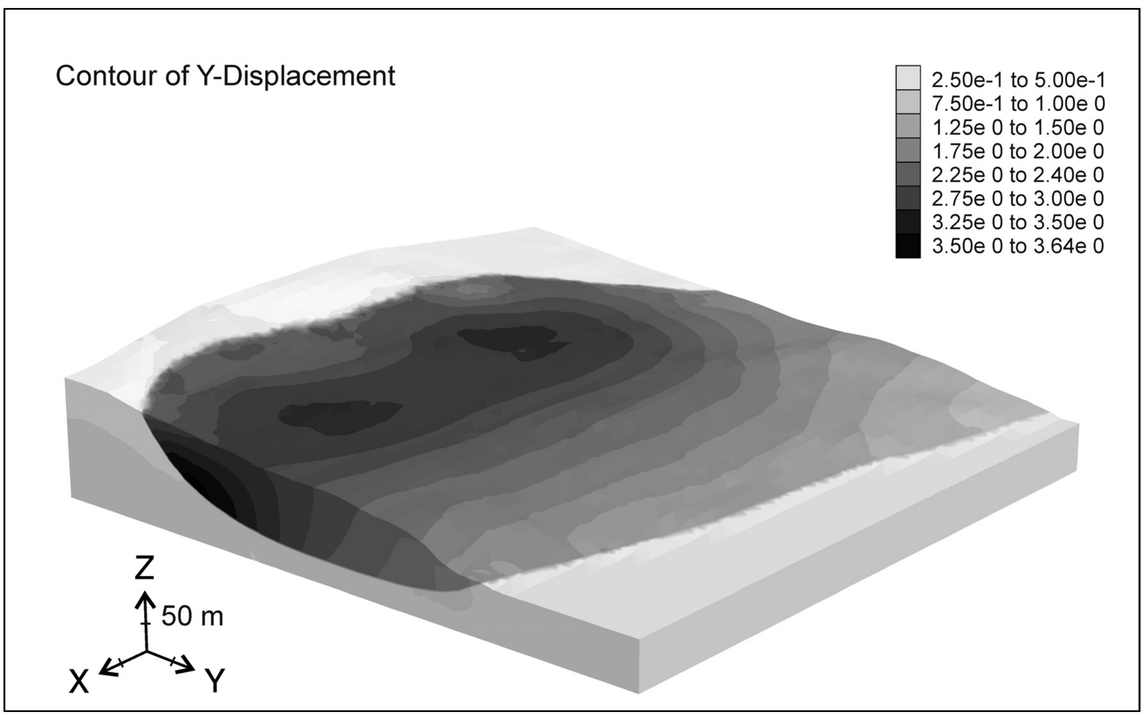

Fig. 10. Displacements along the y direction occurring in the slope and deduced from the modeling.

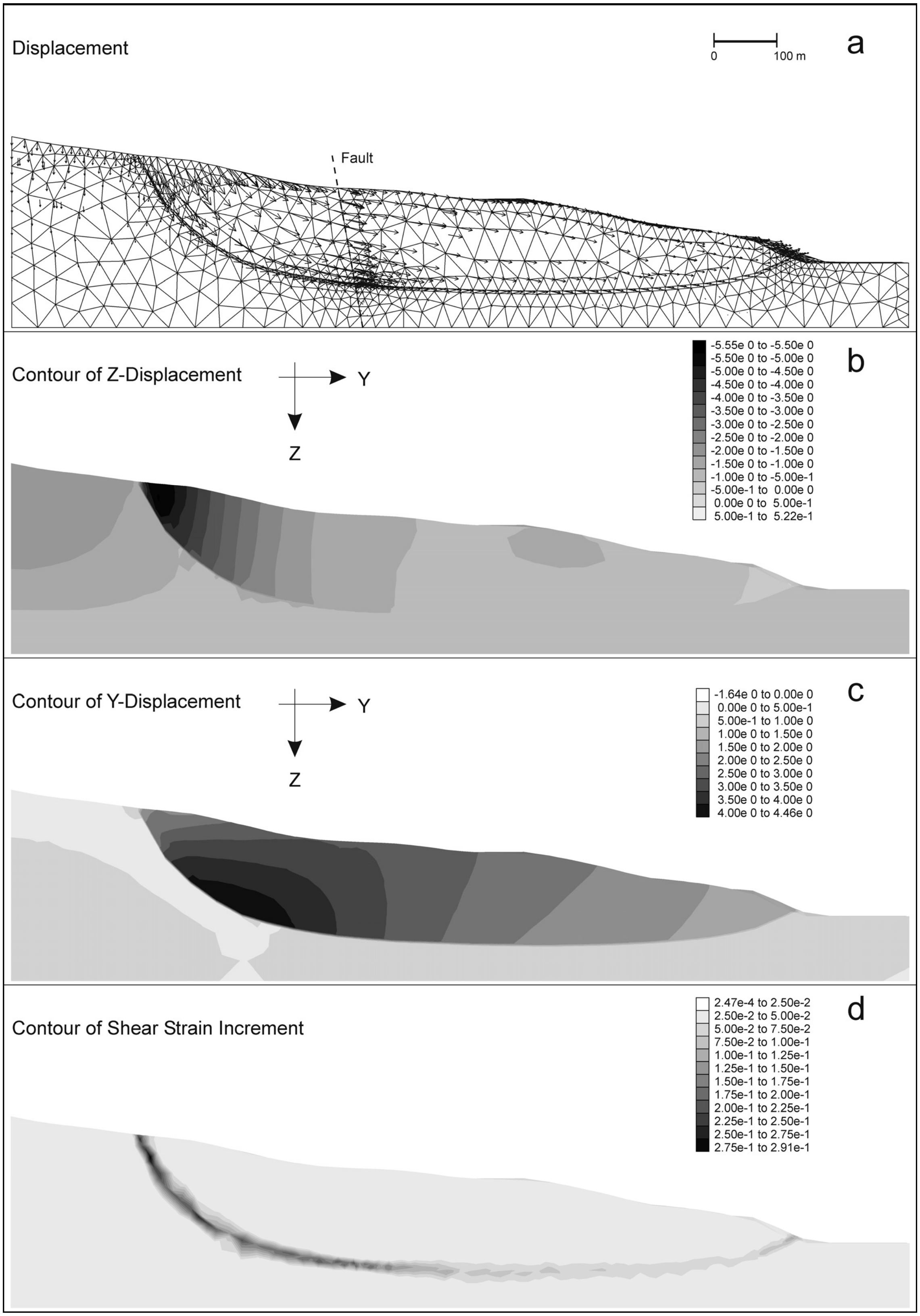

Fig. 11. Results of the numerical modeling in Section 1: a) distribution of displacement vectors, b) contour of vertical displacements, c) contour of displacements along the y direction, d) max shear strains distribution.

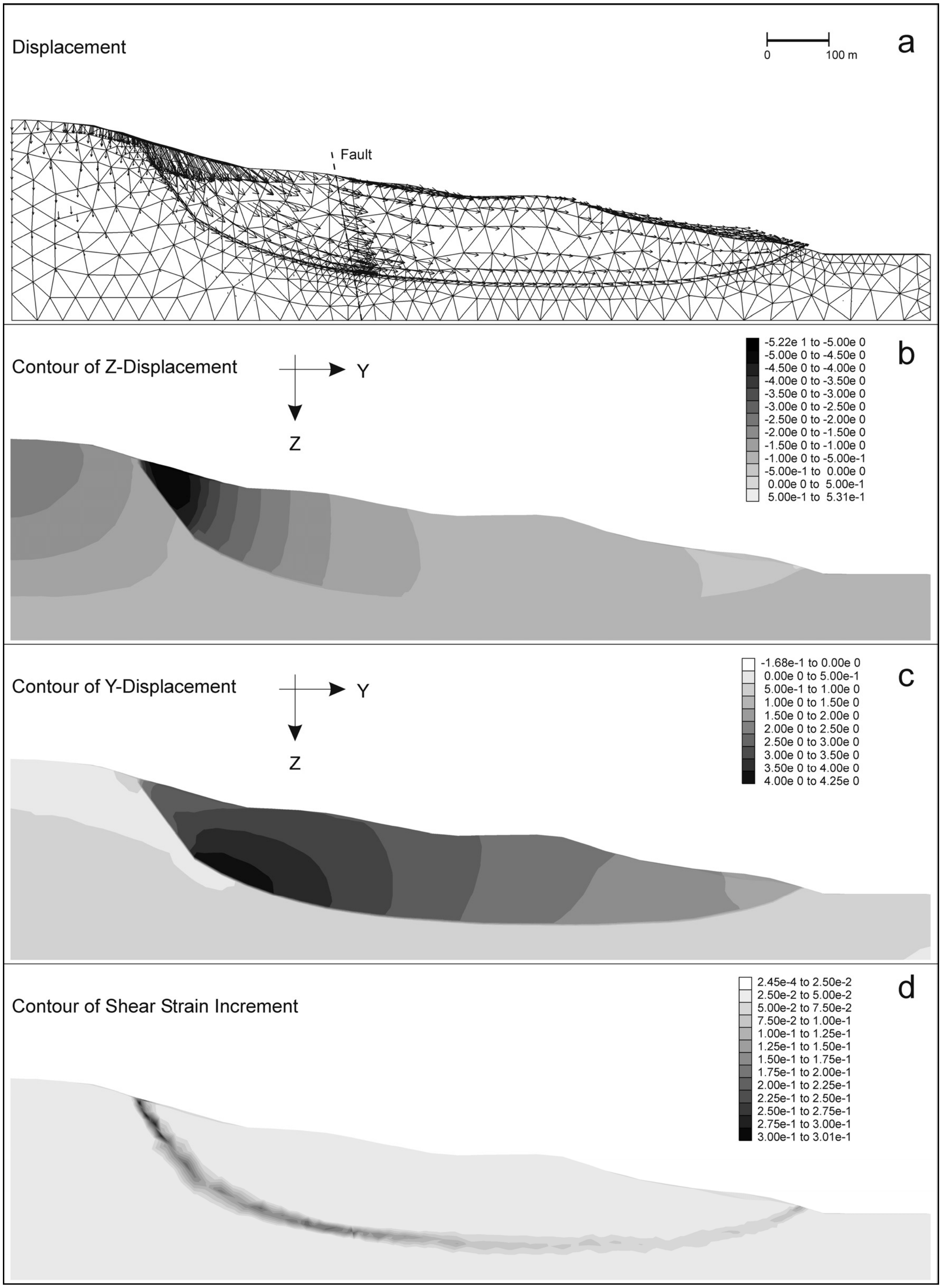

Fig. 12. Results of the numerical modeling in Section 2: a) distribution of displacement vectors, b) contour of vertical displacements, c) contour of displacements along the y direction, d) max shear strains distribution.

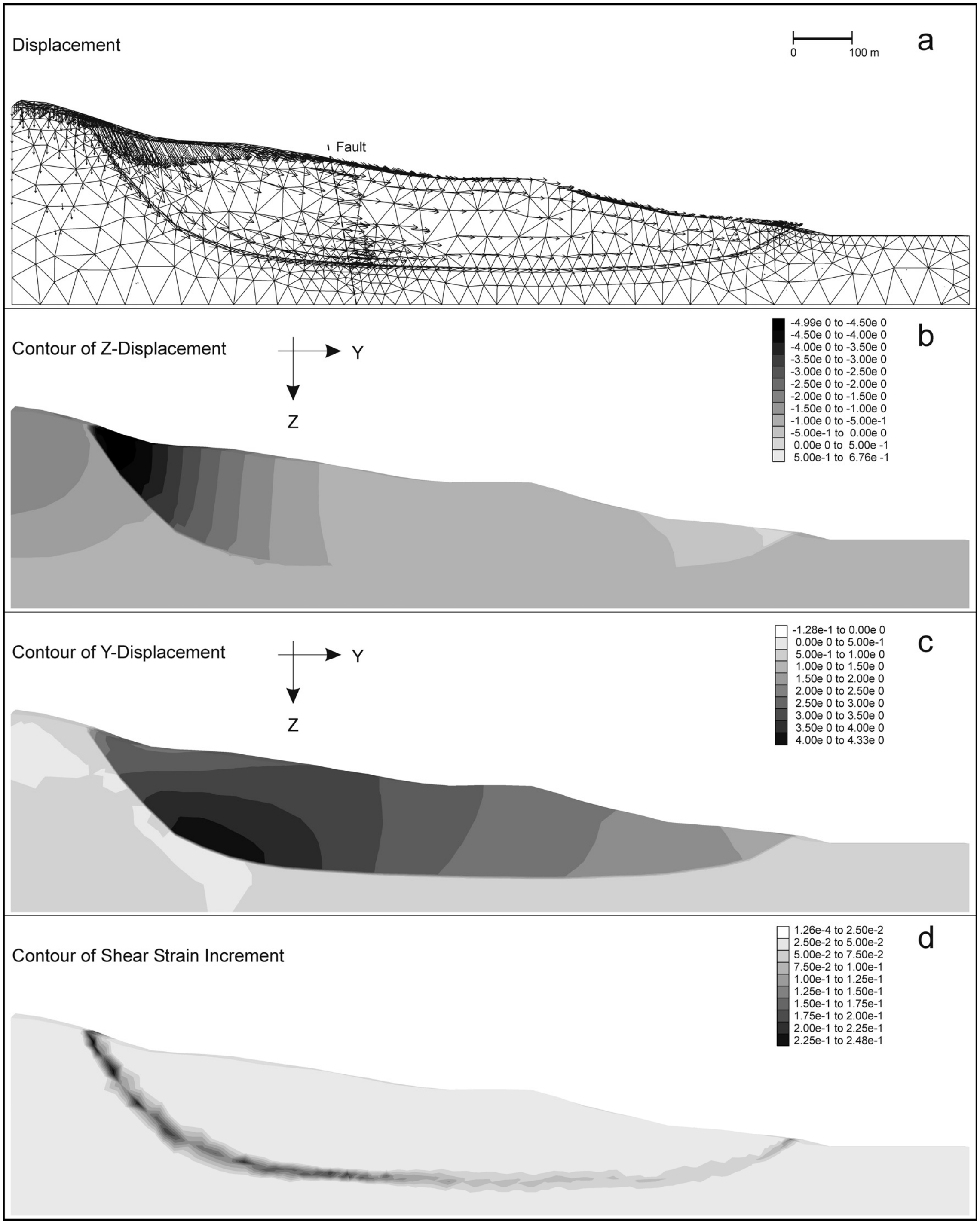

Fig. 13. Results of the numerical modeling in Section 3: a) distribution of displacement vectors, b) contour of vertical displacements, c) contour of displacements along the y direction, d) max shear strains distribution.

In the modeling, the piezometric level was considered in stationary conditions avoiding the effects of the pollution that in soils with very low permeability are negligible.

The presence of an important tectonic discontinuity that certainly played a fundamental role in the evolution of the slope was considered, so as to include the effects of the possible dislocations of the fault plane. The obtained results show a clear behavior of the slope.

Figures 9 and 10 show the contour of mesh deformations with the representation of the vertical and along y direction displacements. The modeling has well represented and simulated the actual behavior of the investigated geological system. To have a better reading of the phenomenon, three sections have been extrapolated (see Fig. 8 for their location). For each section some diagrams have been represented (Figs 11, 12 and 13), in particular the distribution of displacement vectors, the contour of vertical displacements, the contour of displacements along y direction (maximum dip of the slope) and the max shear strains distribution. It can be deduced that the movement is mainly conditioned by the presence of the fault. Upstream of the fault the slope evolves in a rotational cinematic with an important settlement (more than 5 m) in the area of the main scarp. Downstream of the fault the movement is mainly translational with a swelling phenomenon at the bottom of the slope.

Conclusions

This work has illustrated briefly the geological and geomorphologic peculiarities of the vast Ancona landslide that represented one of the most important collapse to have occurred in Italy in the last decades. Moreover some results obtained from a 3D-modeling have been discussed; these aimed at reproducing the large-scale gravity-driven collapse. For the modeling, a finite-difference numerical code was used assuming a system disturbed by an important tectonic discontinuity.

When this landslide occurred many debates were held to evaluate whether the phenomenon could have been expected. The geological evidence was that a dormant landslide was present in the area. The modern recently built infrastructures (railway, roads) were intact and did not present fractures or signs of movements. In the case of the old postal-house sited on the T_2 trench, that in the past had been subjected to rotation and subsequently repaired, its conditions had become stable.

To recognize the hazard of the landslide in any satisfactory way, only a numerical analysis could be used to draw the conclusion that the large mass movements, such as that under examination, are also classified as intermittent, that is, repeated in time after phases of apparent inactivity. Their reactivation is mainly caused by the decline in mechanical resistances along the break surfaces, due also to the anomalous increase in interstitial pressures.

References

AA.VV. (1987) - La Grande Frana di Ancona del 13 dicembre 1982. Numero Speciale, Studi Geologici Camerti, Università di Camerino, Italy.

CARRARA F., D'ELIA B. & SEMENZA E. (1985) – Classificazione e nomenclatura dei fenomeni franosi. Geol.Appl. e Idrog., **XX** (2), 223-244, Bari.

DE BOSIS F. (1859) - Il Montagnolo: studi ed osservazioni. Enciclopedia Contemporanea. Gabrielli, Fano (Italy).

CRESCENTI U., NANNI T., RAMPOLDI R. & STUCCHI M. (1977) - Ancona: considerazioni sismo-tettoniche. Boll. Geof. Teorica Appl., **73-74**, 33-48.

CRESCENTI U., CIANCETTI G., NANNI T., RAINONE M.L., TAZIOLI G.S., VIVALDA P., COLTORTI M., DRAMIS F., GENTILI B., PAMBIANCHI G., MELIDORO G., SEMENZA E. & SORRISO-VALVO M. (1977) - La Grande Frana di Ancona del 1982. Atti del XI Cong. Naz. di Geotecnica, A.G.I., 31-46, Spoleto.

CRESCENTI U. (1992) – Eventi catastrofici recenti del territorio italiano. In "Frane e territorio: le frane nella morfogenesi dei versanti e nell'uso del territorio" a cura di A. Vallario, 321-334, Liguori Editore, Napoli.

COTECCHIA V. (1997) - La Grande Frana di Ancona. Atti dei Convegni Lincei n. 134, "La stabilità del suolo in Italia: zonazione sismica–frane", Roma 30-31 maggio 1996, 187-259, Roma.

FLAC_3D, *Fast Lagrangian Analysis of Continua*. Version 4.0, Itasca Consulting Group, Minneapolis, Minnesota USA, 2000.

RAINONE M.L., SCIARRA N. & SIGNANINI P. (1997) - La grande frana di Ancona del 1982: i problemi irrisolti. Atti dei Convegni Lincei n. 134, "La stabilità del suolo in Italia: zonazione sismica–frane", Roma 30-31 maggio 1996, 269-273, Roma.

SEGRÈ C. (1919) - Criteri geognostici per il consolidamento della falda franosa del Montagnolo . Boll. Soc. Geol. It., **38**, 99-131.