ALPS 90 - Alpine Landslide Practical Seminar
Sixth International Conference and Field Workshop on Landslides

LANDSLIDE INVENTORY MAP OF THE UMBRIA REGION, CENTRAL ITALY

Fausto Guzzetti
Mauro Cardinali

Consiglio Nazionale delle Ricerche, Istituto di Protezione Idrogeologica nell'Italia Centrale, via Madonna Alta, 126 - 06100 Perugia, Italy

SUMMARY: A landslide inventory map as been completed at 1:100,000 scale for the Umbria Region (central Italy). The map covers 12,000 km^2 *and was prepared through the interpretation of aerial photographs at 1:33,000 scale. The inventory provides much new information about landsliding in Umbria and suggests some strong relations between the density and type of landslides and their lithological, structural and tectonic setting.*

1. INTRODUCTION

For the past three decades regional slope stability studies have been carried out worldwide by scientific and governmental agencies. The success of these programs depends on the correct identification and mapping of landslides (SWANSTON & SCHUSTER, 1989). Landslide inventories have therefore become a very important tool in the hands of earth-scientists and planners (KOCKELMAN, 1986).

Inventories are the simplest form of landslide mapping (HANSEN, 1984). They record the location of all landslides that have left discernible features in the area. The maps can be prepared by different methods depending on the scale, the goals, and the available resources (BOSI, 1978; CARRARA, 1982; VARNES, 1982; WIECZOREK, 1984; BRABB, 1984).

Small and very-small scale inventories can be compiled from data available in the litterature (RADBRUCH-HALL *et al.*, 1975) or by interpreting small scale aerial photographs (GUZZETTI & BRABB, 1987). Medium scale inventories are made by interpretation of aerial photographs at scales ranging from 1:60,000 to 1:20,000 with limited field checks. Generally large scale landslide inventories are prepared only for limited areas, using both the interpretation of aerial photographs, at scale greater than 1:20,000, and extensive field checks.

The possible applications of a landslide inventory depend mostly on its scale and the technique used to compile it. Small scale inventories made by interpreting aerial photographs can be used for small-scale regional planning, to identify broad areas where landslide processes are or have been concentrated, for the preparation of small-scale susceptibility maps, and for small-scale geomorphological studies. Small scale inventories compiled from the litterature can be helpful in planning additional regional projects.

Medium and large-scale landslide inventories can be used for geomorphological studies of the evolution of slopes and drainage basins. They also serve as a data-base for statistical models of landslide distribution in space (CARRARA, 1983) and time, or assessment of the degree of hazard (BERNKNOPF *et al.*, 1988). Large scale inventories are usually used to report the effects of a single catastrophic event, such as a flood or a big storm (GOVI, 1976; ELLEN & WIECZOREK, 1989), an earthquake (HARP *et al.*, 1976; GOVI & SORZANA, 1977; AGNESI *et al.*, 1983), or to map in great detail single sites affected by slope movements, mostly for planning geotechnical studies and remedial measures.

2. METHOD OF INVENTORY

The degree of landslide hazard in the Umbria Region was assessed by an inventory of the entire area. We began by plotting on a 1:100,000 scale topographic map all the landslides mapped in the reports mentioned by GUIDA *et al.*, (1979) and GUZZETTI & CARDINALI (1987). After this litterature research we added to the map all landslide deposits reported on the official geologic maps available for the area at 1:100,000 and 1:50,000 scale.

As we began checking the provisional inventory, we soon realized that the information was not distributed homogeneously over the entire area and that the types and geometric characteristics of landslides were known only in very few places. Moreover debris flows and rock falls had not been recognized in reports published previously. We became convinced that the inventory based on available data could not be easily and quickly improved and that a completely new inventory had to be prepared. The new inventory would need to be homogeneous over the entire area so that it could be used to plan more detailed research projects and to help in regional planning.

The only way to realize such an accurate product in a reasonable time frame (1 or 2 years) and with limited resources, was by a systematic analysis of aerial photographs. After a carefull review of the photo coverage available for the area, we decided to use black and white photos at 1:33,000 scale distributed by the Istituto Geografico Militare Italiano (IGMI). This set covers the entire area with a modest number of photographs (1,085) and at a scale suitable for reconnaissance mapping.

The photos were flown in 1954-56, when the human activity, and in particular intensive mechanical cultivation, was much less than today. For this reason, morphological features such as landslide scarps, hummocky topography, and shallow scars are more visible on these early photos than on more recent ones. The possibility of using large-scale photographs, such as the 1:13,000 scale set flown in color by the Regione dell'Umbria in 1978, was discarded. The very large number of photographs (more than 4,000) would have quadrupled the time required for the interpretation, and the scale was too large for reconnaissance mapping on a regional basis.

We worked simultaneously on adjacent strips. Inasmuch as side-lap between the photos was at least 30%, we both saw almost the entire territory. This technique guaranteed a constant cross-checking of the interpretation.

The landslide information, originally plotted on transparent plastic sheets placed over the aerial photographs, was transferred to paper maps using a combined optical and manual technique, aided by a large-format photographic projector. During this phase, all the distortions present in the aerial photographs were corrected or eliminated. The 35 quadrangles were then photographically reduced to 1:100,000 scale for the final drafting and publication.

The 35 quadrangles, covering a total area of more than 13,000 km^2, were mapped in nine months, for an average of 25 quadrangles per man-year. This pace exceeds that reported by CAMPBELL (1985) for 1:24,000 scale quadrangles, but is slower than that needed to prepare very small-scale inventories, such as the 1:500,000 landslide map of northern New Mexico (GUZZETTI & BRABB, 1987).

3. MAP LEGEND

Design of the legend was a fundamental step in compiling the inventory map. Care was taken so that the legend would portray all the different types of slope movements present in the studied area, could be used across different morphological and geological environments, would report the degree of certainity with which the landslides were mapped, and used a widely accepted terminology (fig. 1).

The legend modified the simplified classification of landslide phenomena proposed by CARRARA *et al..*, in 1985, derived from that of VARNES (1978). Landslides names follow the usage of VARNES (1978) except for the term debris-flow used as in ELLEN & WIECKZOREK (1989).

The degree of certainity with which landslide deposits were mapped was shown by a modified traffic-lights coloring scheme. Red colors (red, light and dark violet) were used for landslides that were recognized with certainity and for which the type of movement was known. Yellow showed landslides that were recognized with certainity but for which the type of movement was unknown. Green was used for the areas were no landslides have been recognized, but where morphologic, geologic and vegetational elements suggested the possible or probable presence of landslides.

In addition to documented landslide deposits, we added to the map the locations of escarpments, sediment-source areas and badlands, and alluvial fans. These morphological features may not be related to any specific landslide, but they are related to the evolution of slopes. Therefore they represent information useful for the analysis of the landslide distribution and for the assessment of landslide hazard in the studied area.

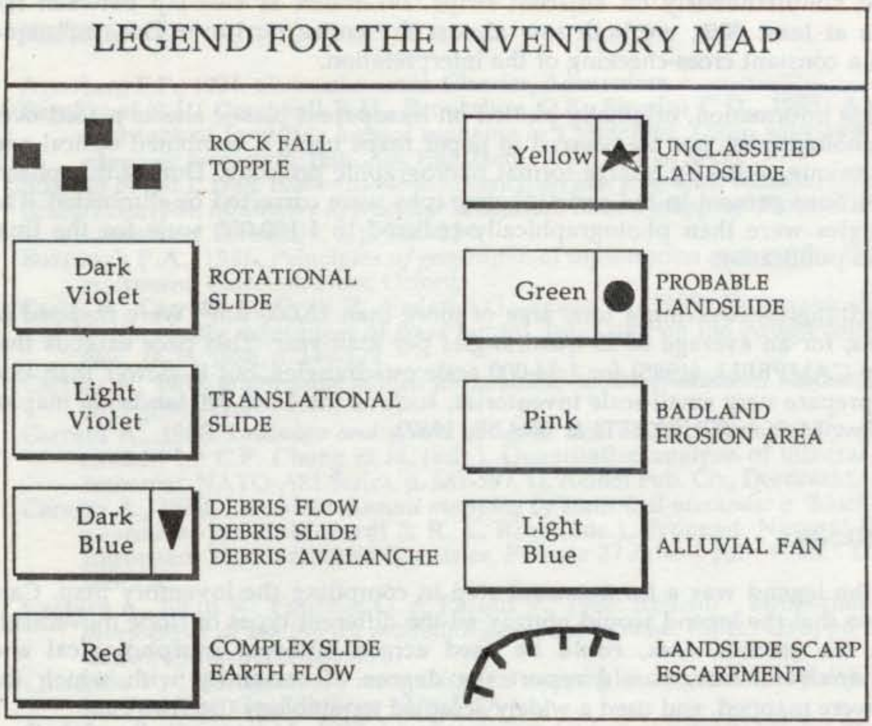

Fig. 1. Legend for the landslide inventory map. Landslide types generally follow those of VARNES (1978) except that we use the term 'Landslide' to encompass all types of slope movements. The term debris flow is used as in ELLEN & WIECKZOREK (1989); unclassified landslides are certain landslides of unknown type; probable landslides contain areas of hummocky topography.

Fig. 1. Legenda della carta inventario. I termini riguardanti i movimenti franosi sono quelli proposti da CARRARA et al., (1985) che hanno modificato la classificazione dei movimenti di versante di Varnes (1978). Il termine debris flow é stato utilizzato nella accezione proposta da ELLEN & WIECKZOREK (1989); le frane indistinte (unclassified landslides) sono frane certe per le quali non é stato possibile identificare la tipologia di movimento; le frane incerte (probable landslides) sono aree nelle quali non é stato possibile identificare con sicurezza nessuna frana, ma nelle quali sono presenti elementi morfologici, geologici e vegetazionali tali da far ritenere possibile o probabile la presenza di movimenti franosi.

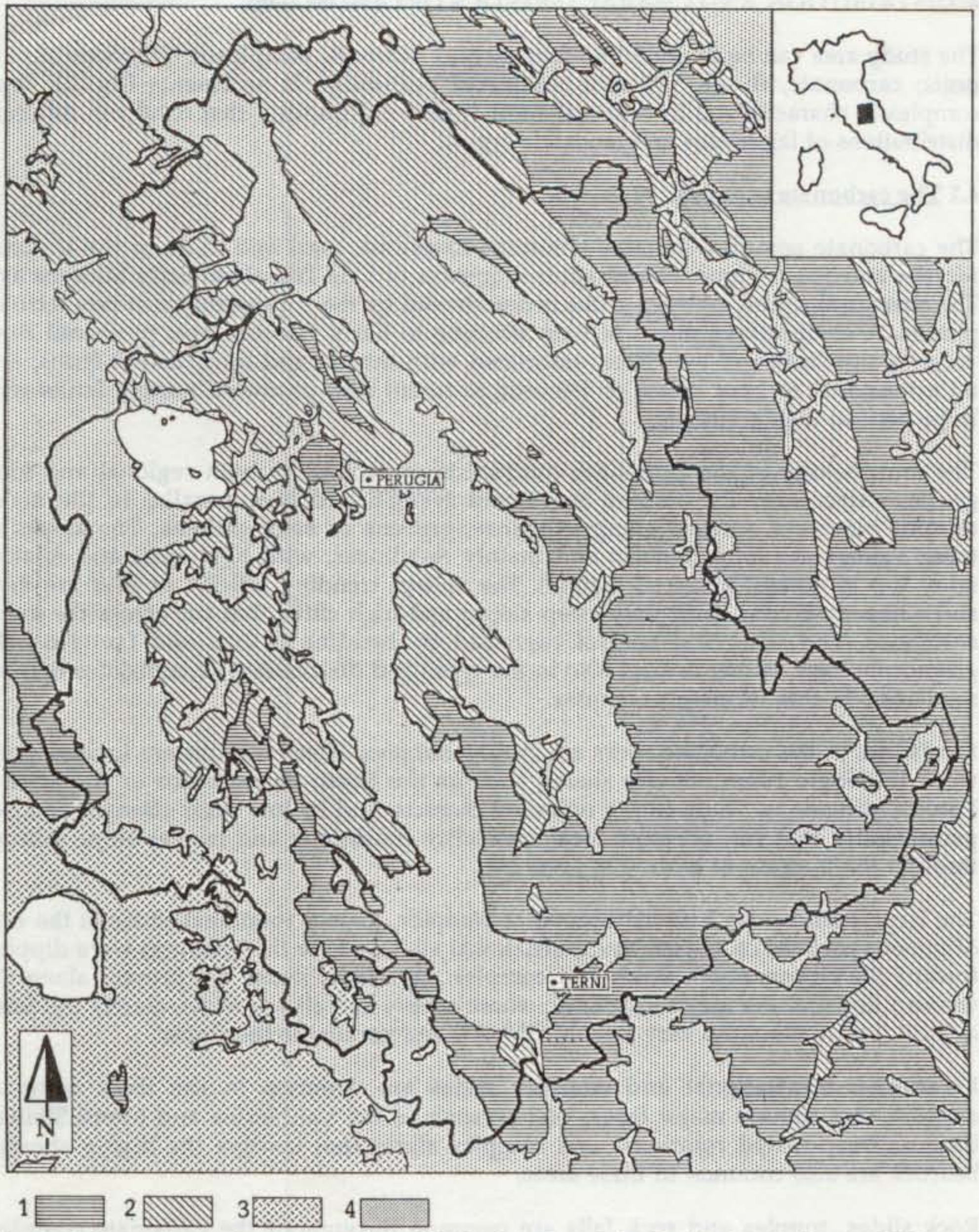

Fig. 2. Schematic geologic map (modified after Servizio Geologico Italiano, 1980; and Boccaletti & Coli, 1982). 1. Carbonate complex, 2. Flysch complex, 3. Volcanic complex, 4. Post-orogenic sediments complex.

Fig. 2. Carta geologica semplificata (modificata da Servizio Geologico Italiano, 1980 e Boccatetti & Coli, 1982). 1. Complesso carbonatico, 2. Complesso terrigeno, 3. Complesso vulcanico, 4. Complesso dei sedimenti post-orogenici.

4. DISTRIBUTION AND CHARACTERISTICS OF LANDSLIDES

The study area can be divided into four distinct lithologic complexes, or groups of rock units; carbonate, flysch, volcanic rocks and post-orogenic sediments (fig. 2). Each complex is characterized by a prevalent or typical morphology that results in different distributions of landslides and landslide types.

4.1 The carbonate complex

The carbonate complex contains dolomite, limestone, marl and shale of the Umbria-Marche and Tosco-Ligure stratigraphic sequences of Late Triassic to Early Miocene age. The structural setting of these rocks is determined by the superposition of two tectonic phases. A compressive phase of Late Miocene to Early Pliocene age, produced East-verging anticlines and synclines, associated with thrusts and transcurrent faults; and an extensional tectonic phase of Pliocene to recent age, produced normal faults with large vertical displacements.

The morphology of the carbonate complex is controlled by both regional and local geologic structure. The valleys that trend NW-SE and N-S, parallel to the major tectonic elements, formed along synclines, grabens or semi-grabens. The slopes in these valleys are long, regular and mainly rectilinear, with high total and relative relief (up to several hundred meters). The valleys trending NE-SW or E-W are deep and narrow canyons, with very steep slopes and high cliffs, that cut across the major anticlines. The structural control exercised by bedding planes and faults on the geomorphologic setting is clear also in the types and distribution of landslides that are numerous in this lithologic complex.

Landslides in the carbonate rocks are mostly complex. Shear surfaces are located along weak lithologic zones, chiefly shales, such as the Rosso Ammonitico or the Scisti a Fucoidi formations. These clayey rocks are characterized by low shear strength and low permeability that can promote local instability conditions and trigger slope failures through the increase of hydraulic pressures.

The largest landslides have developed as complex, mainly rotational slides at the core of minor synclines or as complex translational slides where the beddings were dipping toward the slopes. Earth flows and complex superficial slides are present along the western limbs of the major anticlines, where schists and clayey rocks, chiefly the Scisti a Fucoidi formation, dip very steeply (35°-45°) and parallel to the slopes.

Rotational, translational and complex slides are common in the thick colluvial deposits that conceal major thrust planes, such us the Val Nerina and Monti Sibillini thrusts. Deep-seated rotational and complex slides that involve the highly sheared bedrock are also common in these areas.

Rock slides, topples and rock falls are common throughout the carbonate complex. They are associated with faults, joint and cleavage systems in the more resistant and competent limestones (i.e. Calcare Massiccio, Corniola and Maiolica formations), along very steep slopes and in the canyons.

Peculiar to the carbonate complex are large debris-flow deposits, composed of coarse detritus in a silty and clayey matrix. Debris flows are triggered by extreme meteorological events in areas where the production of debris is abundant, such us in strongly tectonized areas, along the shear zones of major normal faults, in landslide deposits and in talus or scree slopes.

4.2 The flysch complex

The flysch complex includes thick sequences of thinly bedded, graded deposits composed chiefly of marl, sandy shale and mud rhythmically interbedded with a variable percentage of coarse sandstone, of the Umbria-Marche, Toscana and Liguria sequences of Late Paleocene to Early Miocene age.

The morphologic setting of this lithologic complex is strongly controlled by the geologic structure and, in particular, by the attitude of bedding planes. Slopes are long and regular, and have a low gradient where bedding dips toward them, and are short, irregular and locally very steep where bedding dips into them. The total relief is low, but the relative relief may be very high. Cuestas and badlands are common.

Slope movements of all kinds are very common. They are one of the most important factors that shape the morphology of the terrain. The mechanical and hydrogeological variability that characterizes all levels of this complex promotes the formation of shear surfaces along the weakest beds of the stratigraphic sequence.

Large, complex slides are more abundant where bedding dips nearly parallel to the slope or dips less steeply than the slope. Landslides start as translational movements in the depletion area and turn, more or less gradually, into flows in the toe or accumulation area. The rate of movement of these landslides is usually slow and reactivations are common. Rockslides and rock falls can form where bedding dips into the slopes. Shear surfaces are complex and tend to develop along fault planes, joints and cleavage systems.

Earth flows, solifluction and, more rarely, rotational and shallow translational slides are common in the superficial colluvial cover, mostly inside larger landslide deposits. These landslides leave very faint features that can be easily removed by erosion or human action, making the identification of these movements very difficult.

Badlands are common in the flysch complex, particularly in the north-western and south-western sections of the studied area. They develop where sandstones are virtually absent in the stratigraphic sequence, and where bedding planes are horizontal or dip into the slope. These areas do not have slope stability problems, but they are areas of high surface erosion and may constitute important sources of sediment.

4.3 The volcanic complex

The volcanic complex is limited to the south-western corner of the studied area. It contains lava flows, ignimbrites and pyroclastic deposits belonging to the Monti Vulsini volcanic complex (1.0-0.1 million years b.p.).

Terrain in the area has a tabular morphology controlled by the thick cap of volcanic rocks that overlies marine deposits, chiefly clay, sand and conglomerate of Plio-Pleistocene age. Slope movements are extensive but limited to the edges of the volcanic cap. They are rotational slides, with a distinct retrogressive character that tend to turn into flow slides toward the toe area. Slope movements occur in both the competent volcanic rocks and the underlying incompetent sediments. Small shallow slides and flows can also develop in the colluvial cover of large landslide deposits.

Detailed geological and geotechnical investigation, carried out to solve the stability problems of the town of Orvieto (MANFREDINI *et al.*, 1980; DIAMANTI & SOCCODATO, 1981; LEMBO-FAZIO *et al.*, 1984; CECERE & LEMBO-FAZIO, 1986). have shown that failure of limited sections of the volcanic cap are strictly related to movement in the underlying Plio-Pleistocene deposits. Failure of the volcanic cap has two main causes: reduction of the retaining stresses at the base of the cliffs, due to landsliding in the Plio-Pleistocene deposits, and increase of tensile stresses in the volcanic rocks due to the different deformability of these rocks in contrast to the more plastic marine sediments.

Conditions of instability are further increased by superficial water, and by the leaking of water from aqueducts, drainage and sewer systems, especially in urbanized areas. The water, if not channelled or controlled, can cause the build-up of hydraulic pressures in the tensile fractures present in the volcanic cap, triggering rock falls, topples, slab failures and even rockslides.

4.4 The post-orogenic sediments complex

This complex is characterized by great lithological variability. It contains continental, lacustrine and marine deposits, composed chiefly of over-consolidated clay and silty-clay, sand and conglomerate of Pliocene and Pleistocene age, detritus of different origin and recent alluvial deposits. Numerous investigations carried out to study the slope movements of the Perugia hills (RIGHI *et al.*, 1986), the Todi hill (TONNETTI, 1978) and the Montone area have shown the geometric, geological, hydrological and geotechnical complexity of these sediments. This makes the identification of simple or typical landslide models very difficult.

Deep-seated landslide movements are very common. They are mostly slides where the stratification is parallel or dips toward the slope, and slumps where the strata dip into the slope. In both cases they tend to turn into flows or complex slides. The shear surfaces are located mostly along silty and clayey layers, along the boundary between clay and sand, or along other lithologic discontinuities.

Where a conglomeratic cap overlies over-consolidated clay and sandy deposits, failure of the lower beds can trigger slope movements in the conglomerate cap itself. Rock falls, topples, slab failures, and debris falls are common in these areas.

Flows, shallow slumps and slides in the superficial deposits on the cultivated hillsides are common. In these areas the recurrence of small, shallow slides and flows results in the formation of a characteristic hummocky topography, especially inside large, deep-seated landslide deposits.

Complex landslide movements can also develop in the thick talus deposits that are so abundant in the Umbria-Marche region. In some places the entire detrital cover slides, more or less uniformly, on the underlying bedrock (CANUTI *et al.*., 1986). Small debris flows and debris slides are also common on talus and scree slopes.

5. RELIABILITY AND APPLICATION

The of degree of accuracy of the inventory map was determined by detailed examination of about 2% of the area, and a reconnaissance examination of approximately 10% of the total area. The detailed field checks were carried out in the Tescio basin and the Monte Coscerno and Monte Bove areas at 1:10,000 scale, and in the Gualdo Tadino area at 1:25,000 scale. The reconnaissance checks were made mainly along roads in the Todi, Terni, Valnerina, Gubbio and Perugia areas. The reliability of the inventory was further strenghtened by comparison with other morphologic and geologic maps, at similar and larger scales, that reported landslides or related slope processes. Our landslide inventory provides from 40% to 100% new information with respect to maps at similar scales. The comparison with very detailed morphological and geological maps (CATTUTO, 1973; DRAMIS, 1976; CONVERSINI *et al.*, 1977; DECANDIA, 1982; CENTAMORE, 1983; COSTANTINI *et al.*, 1988) was also very satisfactory.

The inventory map seems particularly helpful in identifying deep-seated slides of any kind, it provides new information on the type of landslides, and it addresses for the first time the problem of debris flows and of rock falls. The photo-interpretation technique overlooked or missed a few very small and shallow landslides, some very old landslides, landslides that occurred after 1954-56, and probably landslides in urbanized or agricultural areas where human activity has destroyed the recognition features. Because of these deficienses, the map should not be used to determine the landslide hazard at any specific site.

The map supports small-scale morphologic studies as well as regional planning. It can be used to statistical analyze the spatial distribution of landslides (CARRARA, 1983), to determine the degree of landslide susceptibility on a regional scale, and, if integrated with socio-economical data, to evaluate the landslide risk (BRABB, 1984; BERNKNOPF *et al.*, 1988).

However the inventory was produced primarely through the interpretation of aerial photographs, with only limited field checkings. Landslides that occured after the 1954-56 period, that were too small to be visible at the scale of the photos or that were too shallow to leave discernable or lasting signs, may have not been mapped. It must be stressed that even if the abundance of landslides in any area can be used to indicate problems in using the land, the map should never be used to determine the landslide hazard at any site.

ACKNOWLEDGMENTS

Alberto Carrara and Earl E. Brabb provided useful comments and recommendations during various steps of this work. Review by Richard J. Pike greatly improved the manuscript.

REFERENCES

Agnesi V., A. Carrara, T. Macaluso, S. Monteleone, G. Pipitone & M. Sorriso-Valvo (1983) - Elementi tipologici e morfologici dei fenomeni di instabilità dei versanti indotti dal sisma del 1980 (Alta valle del Sele). Geol. Applic. e Idrogeol., Vol. 18, n. 1, p. 309-341.

Bernknopf R.L., R.H. Campbell, D.S. Brookshire & C.D. Shapiro (1988) - A probabilistic approach to landslide mapping in Cincinnati, Ohio, with applications for economic evaluation. Bull. Assoc. Engin. Geol., Vol. 25, n. 1, p. 39-56.

Boccaletti M. & M. Coli (1982) - Carta Strutturale dell'Appennino settentrionale. C.N.R., Progetto Finalizzato Geodinamica. Public. n. 429.

Bosi C. (1978) - Considerazioni e proposte metodologiche sulla elaborazione di Carte di Stabilità. Geol. Applic. ed Idrogeol., Vol. 13, p. 245-281.

Brabb E.E. (1984) - Innovative approaches to landslide hazard and risk mapping. IV Intern. Symposium on Landslides, Toronto, September 1984, Vol. 1, p. 307-323.

Campbell R.H. (1985) - Methods and costs for delineation of susceptibility to mud flows and other landslides. In R.H. Campbell ed., Feasibility of a nationwide program for the identification and delineation of hazards from mud flows and other landslides: U.S. Geological Survey Open File Report 85-276, p. C1-C4.

Canuti P., E. Marcucci, S. Trastulli, P. Ventura & G. Vincenti (1986) - Studi per la stabilizzazione della frana di Assisi. Atti XVI Conv. Naz. Geotecnica, Bologna, 14-16 Maggio 1986, Vol. 1, p. 165-174.

Carrara A. (1982) - Cartografia tematica, stoccaggio ed elaborazione dati. C.N.R. Progetto Finalizzato Conservazione del suolo. Atti del convegno conclusivo, Roma 9-10 Giugno 1982, p. 265-281.

Carrara A. (1983) - Multivariate models for landslide hazard evaluation. Mathematical Geology, Vol. 15, n. 3, p. 403-426.

Carrara A., B. D'Elia & E. Semenza (1985) - Classificazione e nomenclatura dei fenomeni franosi. Geol. Applic. e Idrogeol., Vol. 20, p. 223-243.

Cattuto C. (1973) - Carte e lineamenti geomorfologici del territorio di confluenza fra il F. Chiascio ed i torrenti Rasina e Saonda. Geologica Romana, Vol. 12, p. 105-124.

Cecere V. & A. Lembo-Fazio (1986) - Condizioni di sollecitazione indotte dalla presenza di una placca lapidea su un substrato deformabile. Atti del XVI Congresso Naz. di Geotecnica. Bologna 14-16 Maggio 1986. Vol. 1, p. 191-202.

Centamore E., F. Dramis, B. Gentili & S. Leoperdi (1983) - Aspetti geomorfologici e morfogenesi in atto nell'area circostante Pietralunga (Perugia). Studi Geologici Camerti, Vol. 8, p. 43-66.

Conversini P., S. Lupi, E. Martini, P. Pialli & P. Sabatini (1977) - Rupe d'Orvieto - Indagini Geologico-Tecniche. Quaderni della regione dell'Umbria.

Costantini A., C. Ghezzo & A. Lazzarotto (1988) - Carta geologica dell'area geotermica di Torre Alfina. Scala 1:25.000. In Buonasorte et al. Ricerca ed esplorazione nell'area geotermica di Torre Alfina. Boll. Soc. Geol. It., Vol. 107, p. 265-337.

Decandia F.A. (1982) - Geologia dei monti di Spoleto (prov. di Perugia). Carta geologica a scala 1:25.000.

Diamanti L. & C. Soccodato (1981) - Consolidation of the historical cities of San Leo and Orvieto. Proceed. X Internat. Conf. Soil Mechanics and Foundation Engineering - Stockholm, 15-19 June 1981, p. 75-82.

Dramis F., B. Gentilini & U. Pieruccini (1976) - La degradazione dei versanti nel bacino del Sentino (Appennino umbro-marchigiano). Studi Geologici Camerti, Vol. 11, p. 45-72.

Ellen S.D. & G.F. Wieczorek (1989) - Landslides, Floods and Marine effects of the storm of January 3-5, 1982, in the San Francisco Bay Region, California. U.S. Geological Survey Professional Paper 1434, p. 63-112.

Govi M. (1976) - L'evento alluvionale del 7-8 ottobre 1970 in Liguria, i dissesti sui versanti a nord di Voltri (Genova). C.N.R. IRPI, Torino.

Govi M. & Sorzana P.F. (1977) - Effetti del terremoto: le frane. Rivista Italiana di Paleontologia e Stratigrafia, Vol. 83, n.2, p. 329-368.

Guida M., Iaccarino G., Metcalf G. & Vallario A. (1979) - Bibliografia delle Frane dal 1900 al 1978. CNR IT ISSN 00 85-2309. Vol. 40, Roma, pp. 362.

Guzzetti F. & E.E. Brabb (1987) - Map showing landslide deposits in Northwestern New Mexico. U.S. Geological Survey Open File Report 87-70.

Guzzetti F. & M. Cardinali (1987) - Archivio dei dissesti della Regione dell'Umbria. CNR-IRPI, Perugia, Rapporto Interno n. 93.

Hansen, A. (1984) - Landslide hazard analysis, In D. Brunsden & D.B. Prior eds., Slope Stability. John Wiley & Sons, New York, p. 523-602.

Harp E.L., R.C. Wilson & G.F. Wieczorek (1981) - Landslides from the February 4, 1976, Guatemala Earthquake. U.S. Geological Survey Prof. Paper 1204-A., pp. 35

Kockelman W.J. (1986) - Some techniques for reducing landslide hazards. Bull. Assoc. Eng. Geol., Vol. 23, n. 1, p. 29-52.

Lembo-Fazio A., G. Manfredini, R. Ribacchi & M. Sciotti (1984) - Slope failure and cliff instability in the Orvieto tuff. IV Int. Symp. on Landslides - Toronto. Vol. 2, p. 115-120.

Manfredini G., S. Martinetti, R. Ribacchi & M. Sciotti (1980) - Problemi di stabilità della rupe di Orvieto. Atti XIV Conv. Naz. Geotecnica. Firenze Vol. 1, p. 231-246.

Radbruch-Hall D.H., R.B. Colton, W.E. Davis, B.A. Skipp, I. Lucchitta & D.J. Varnes (1976) - Preliminary landslide overview map of the conterminous United States. U.S. Geological Survey M.F.S. Map 771.

Righi P.V., G. Marchi & G. Dondi (1986) - Stabilizzazione mediante pozzi drenanti di un movimento franoso nella città di Perugia. Atti XVI Conv. Naz. Geotecnica, Bologna, 14-16 Maggio 1986, Vol. 2, p. 167-179

Servizio Geologico d'Italia (1980) - Carta Geologica dell'Umbria. Scala 1:250.000.

Swanston D.N. & Schuster R.L. (1989) - Long-term landslide hazard mitigation programs: Structure and experience from other countries. Bull. Assoc. Engin. Geol., Vol. 26, n. 1, p. 109-133.

Tonnetti G. (1978) - Osservazioni geomorfologiche sulla frana del Fosso delle Lucrezie presso Todi (PG). Mem. Soc. Geol. It., Vol. 19, p. 205-213.

Varnes D.J. (1978) - Slope movement, types and processes. In R.L. Schuster. & R.J. Krizek, eds. Landslides analisys and control. Transportation Research Board, National Academy of Sciences, Washington, D.C., Special Report 176, p. 11-33.
Varnes D.J. & IAEG Commission on Landslides (1982) - The principles and practice of landslides hazard zonation. UNESCO press.
Wieczorek G.F. (1984) - Preparing a detailed landslide-inventory map for hazard evaluation and reduction. Bull. Assoc. Eng. Geol., Vol. 21, n. 3, p. 337-342.

RIASSUNTO

La 'Carta inventario dei movimenti franosi della Regione Umbria ed aree limitrofe' è stata realizzata a scala 1:100.000, attraverso l'interpretazione di 1085 fotografie aeree in bianco e nero, a scala 1:33.000 (volo GAI del 1954-56). Essa riporta più di 5.000 movimenti franosi, classificandoli in base al grado di certezza con il quale sono stati riconosciuti sulle fotografie aeree o sul terreno, ed alla tipologia del movimento (Fig. 1). Oltre alle frane nella carta sono riportate le aree in forte erosione, i calanchi, i coni alluvionali recenti e le scarpate morfologiche maggiori. Questi elementi, pur non essendo riferibili a nessun movimento franoso specifico, sono tuttavia indice di instabilità e quindi sono utili per una corretta valutazione della suscettibilità a franare. Dall'analisi della carta risulta evidente come la distribuzione, l'abbondanza e la tipologia dei movimenti franosi siano in stretta correlazione con la struttura geologica regionale, ed in particolare con le caratteristiche litologiche (Fig. 2), e l'assetto giaciturale. La carta da un quadro nuovo della franosità nella Regione dell'Umbria e può essere utilizzata per ricerche geomorfologiche sulla stabilità dei versanti, per la valutazione del rischio di frana, nonche per pianificazioni territoriali a scala regionale.