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DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATIONS IN NORTH-WESTERN TUSCANY (ITALY): REMARKS ON TYPOLOGY, DISTRIBUTION AND TECTONIC CONNECTIONS

ABSTRACT: D'AMATO AVANZI G. & PUCCINELLI A., *Deep-seated gravitational slope deformations in north-western Tuscany (Italy): remarks on typology, distribution and tectonic connections.* (IT ISSN 0391-9838, 1996).

Some features make north-western Tuscany prone to Deep-seated Gravitational Slope Deformations (Dgsd), such as: high relief energy, high rainfall, intensely fractured and deformed rocks, active or recently active tectonics, strong seismicity. The territory investigated shows many examples of such phenomena, which differ owing to their geological and structural conditions, typology and activity.

The case history shows that both tectonics and lithostratigraphic structures have greatly influenced typologies and kinematic mechanisms, whilst neotectonic evolution and climatic conditions have had their influence on all phenomena studied. Among the cases where the tectonic structure is a prevailing factor, deep-seated gravitational slope deformations located on normal faults could be quoted, as those outlining the tectonic depressions of the Serchio and Magra valleys or other regional normal fault systems. These faults release and subdivide the bedrock into very large blocks, making them subject to gravitational adjustment. In addition, a preferential orientation of geomorphic features (scarps, trenches, reverse slopes, etc.) can be verified in accordance with the trends of tectonic displacements and brittle deformation systems. Some examples include the gravitational processes near Canossa, Bagnone and Chioso in Magra Valley, near San Romano in Garfagnana in the Serchio Valley and near the Abetone Pass. Block slide and rock flow are generally common types of movement, often structurally controlled by fault planes.

The lithostratigraphic structure may be frequently regarded as the main control feature in the development of deep-seated gravitational slope deformations; in particular, a structure of thick rigid rocks overlying ductile rock types is instrumental. In this case, block slides and lateral spreads are the most common kinds of movement. Some examples are found at Mt. Castri in the Serchio Valley (sandstone over shale) and in the Magra Valley near Bagnone and Chioso (marly limestone overlying shale). The underlying ductile rocks are remarkably deformed by tectonics and sometimes show deformations resulting from the load of overlying brittle rocks, such as bulges and reverse slopes.

Along the deep valleys which transversally cut the main tectonic structures, the topographic stress is sometimes considerable, owing to the Pleistocene - Holocene uplift; brittle/ductile deformations may then occur, due to gravitational slope tension rather than tectonic stress.

Finally, a considerable amount of the Dgsd here studied are believed to be dormant, because of debris filling up the trenches and no movement evidence in the past decades; in some cases, evidences of activity were recognised.

KEY WORDS: Deep-seated gravitational slope deformation, Geomorphology, Tectonics, Tuscany, Italy.

RIASSUNTO: D'AMATO AVANZI G. & PUCCINELLI A., *Le deformazioni gravitative profonde della Toscana nord-occidentale (Italia): considerazioni su tipologia, distribuzione e rapporti con la tettonica.* (IT ISSN 0391-9838, 1996).

La Toscana nord-occidentale presenta alcune caratteristiche favorevoli alla genesi delle deformazioni gravitative profonde di versante (Dgpv): elevata energia del rilievo, clima con alti valori di piovosità, rocce intensamente deformate e fratturate, tettonica attiva o recentemente attiva, alta sismicità; vi si riscontrano pertanto numerosi fenomeni di Dgpv, variabili per condizioni geologico-strutturali, tipologia e stato di attività.

I numerosi casi studiati hanno mostrato che soprattutto i lineamenti strutturali e l'assetto litostratigrafico condizionano le caratteristiche tipologiche e cinematiche delle Dgpv, mentre l'evoluzione neotettonica e le condizioni climatiche hanno sul territorio un effetto meno puntuale, influendo sostanzialmente in modo areale su tutte le Dgpv individuate.

Tra i casi in cui l'assetto tettonico può essere considerato un fattore preponderante, si citano i fenomeni di Dgpv che si impostano in corrispondenza delle faglie dirette che individuano le depressioni tettoniche della Val di Serchio e della Val di Magra o di altre faglie di importanza regionale; esse esercitano sugli ammassi rocciosi un'azione di svincolo e di frammentazione in megablocchi, permettendone l'adattamento gravitativo; si nota inoltre l'isorientazione dei caratteri morfologici fondamentali (scarpate, trincee, contropendenze, ecc.) sia con le dislocazioni tettoniche, sia con i sistemi di deformazione fragile. Questi casi comprendono: le Dgpv presso Villafranca in Lunigiana, Bagnone e Chioso in Val di Magra; i casi di S. Romano in Garfagnana e della zona del Passo dell'Abetone in Val di Serchio; i movimenti generalmente si impostano in corrispondenza dei piani di faglia e consistono in scorrimenti in blocco o in colamenti di roccia.

In altri casi è l'assetto litostratigrafico che può essere considerato il carattere guida principale; in particolare, la configurazione più favorevole

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allo sviluppo di movimenti gravitativi profondi è rappresentata dalla sovrapposizione di rocce rigide su rocce duttili; in questi casi i tipi di movimento più comuni sono lo scorrimento in blocco e l'espansione laterale. Come esempi, in Val di Serchio si ricordano i fenomeni riscontrati sul M. Castri (arenarie su argilliti), in Val di Magra le Dgpv a nord-ovest di Bagnone e presso Chioso (calcari marnosi su complesso argillitico). Le rocce duttili sottostanti, intensamente deformate dalla tettonica, presentano talvolta anche deformazioni derivanti dal carico delle rocce rigide soprastanti, con rigonfiamenti e contropendenze. In alcuni casi, localizzati lungo le profonde incisioni vallive trasversali agli assi tettonici principali, lo *stress* topografico generato dai sollevamenti del Pleistocene - Olocene assume grande rilevanza; può esserci allora la comparsa di deformazioni di tipo duttile/fragile, non derivate dalle vicissitudini tettoniche, ma dalle tensioni gravitative agenti sul versante.

Infine, lo stato di attività delle Dgpv di questi territori è di valutazione difficoltosa, anche per il carattere di movimento intermittente che non di rado le caratterizza, con periodi di stasi o di movimenti impercettibili, alternati a fasi parossistiche legate a eventi sismici o a crisi climatiche. La maggior parte dei fenomeni osservati può ritenersi nel suo complesso quiescente, sulla base dei riempimenti detritici delle trincee e dell'assenza di testimonianze di movimento negli ultimi decenni; in alcuni casi sono stati riscontrati indizi di attività, prevalentemente legati alla particolare dinamica geomorfologica locale.

TERMINI CHIAVE: Deformazione gravitativa profonda di versante, Geomorfologia, Tettonica, Toscana, Italia.

INTRODUCTION

In the morphogenesis of mountain areas particular importance have large mass movements, among which Deep-seated Gravitational Slope Deformations (Dgsd) play a significant role.

Investigations carried out in the past few decades have led to a remarkable progress of knowledge on the geological and geomorphological aspects and on the mechanical, kinematic and classification aspects (PASUTO & SOLDATI, 1990, review). For further information on the Italian situation reference is made on the Proceedings of the Symposia organized by the Cnr National Group «Deep-seated Gravitational Slope Deformations» (SORRISO-VALVO, 1984, 1987, 1989; CRESCENTI & SORRISO-VALVO, 1995).

It is worth emphasizing some features that are commonly considered more typical of Dgsd (RADBRUCH-HALL & *alii,* 1976; MAHR & NEMCOK, 1977; RADBRUCH-HALL, 1978; DRAMIS, 1984; DRAMIS & SORRISO-VALVO, 1994; DRAMIS & *alii*, 1987, 1995; BISCI & *alii,* 1996), namely:
1. large extent (some square kilometres) and thickness of the rock masses involved of tens, sometimes hundreds, of metres;
2. moderate displacement with respect to the dimensions of the rock masses involved;
3. absence of a net failure surface delimiting the rock mass subject to movement;
4. very slow evolution, with long inactivity or extremely reduced activity periods, during which a sudden reactivation may take place in concomitance with earthquakes or extreme meteoric events;
5. failure mechanism due to creep;
6. kinematics often influenced by active tectonics and by the presence of residual tectonic stresses and high confinement pressure;
7. movement controlled by geological-structural attitudes rather than by local morphological configurations.

Among the morphological elements which permit to recognise the above phenomena, slope relaxation forms are common; they are localised near the summit and the foot of the slope, where the confining pressure is lower. The following surface effects are often observed:
1. the highermost portion of the deformed slope is affected by extensional stresses which produce high-angle shear planes, with which counterslope steps, graben-like trenches and double ridges are associated;
2. the lowermost portion of the slope is affected by compressional stress determining bulging and, sometimes, low-angle shear planes at the toe; shear planes may not be easily identifiable, when proper outcrops are lacking or the toe is buried by superficial deposits, such as landslide bodies, alluvial sediments or other.

The areas affected by Dgsd frequently show the following features:
1. high relief energy, with high gradient, well developed slopes, modelled in competent rock types;
2. morpho-climatic conditions favourable to a particularly active channelised erosion, with high rainfall values;
3. strong seismicity;
4. active or recently active tectonics.

North-western Tuscany is characterised by large mountain areas of the Northern Apennines, where deep-seated gravitational slope deformations are favoured by all factors listed above. Indeed, several cases of Dgsd were identified and their geological-structural and geomorphological aspects were further investigated (D'AMATO AVANZI & PUCCINELLI, 1989; DALLAN & *alii,* 1991; BUTI & *alii,* 1995; CAREDIO & *alii,* 1996; D'AMATO AVANZI & *alii,* 1995a, 1995b). These studies showed that, under the same meteoclimatic conditions, these processes are subject to a marked lithological and structural control and occur in areas affected by active tectonics, where a high relief energy is produced and residual stresses set free along deep valley cuts.

The following remarks are based on the knowledge so far acquired in the Serchio and Magra Valleys, where hundreds of large mass movements with surface of some square kilometres and thickness of several tens of metres occur. In this paper, the movements recognised as Dgsd are dealt with, disregarding large landslides.

The distinction between landslide and Dgsd, fundamentally in agreement with SORRISO-VALVO (1995), is based on the presence or not of a surface or zone of failure: in an ordinary landslide this feature is always identified or reconstructable with some continuity whereas the movements derived from a Dgsd can be explained also in absence of well-defined failure surfaces or zones. This is in agreement with HUTCHINSON (1988), who regards as «sagging of mountain slopes» those processes which «in their present state of development, do not justify classification as landslides». This discriminating principle better applies to rock flows and some types of lateral spreading, whilst most lateral spreads and block slides should better be included among landslides, which are frequently characteri-