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Examples of mudslides hazard in the Southern Apennines (Italy)

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Abstract
Large landslides are very common in the areas of the Apennine Chain constituted by highly fissured clayey and flysch formations.
These mass movements have intermittent phases of reactivation linked to heavy rainfall or seismic shocks. The quiescence periods can last on average over 20 years. These long periods of quiescence cause obliterations of mudslides bodies and subsequently create high hazards in land use.
The cases of Senerchia and Buoninventre in the upper valley of Sele river are illustrated as examples.

1. Introduction

Mudslides are some of the most frequent mass movements in the mountainous areas of the Southern Apennines and cause major problems from the engineering and geological point of view. Especially old mudslides, because of their size and periodic reactivations, very often affect farming areas, buildings, roads, pipelines and residenzial zones. Despite the considerable damage caused each year, these large landslides bodies have not been given sufficient attention. It is therefore important that the problem be faced through the study of areal photography, field mapping and other site and laboratory investigations.

The area of upper valleys of the Sele, Ofanto and Calore rivers hit by the earthquake of 23rd November 1980 offers case histories of hazard connected with the reactivation of large mudslides.

2. Physical setting of the area of the upper valleys of the Sele, Ofanto and Calore rivers

The upper valleys of the Sele, Ofanto and Calore rivers are situated in the southern Apennine Chain. These areas are geologically constituted by overthrusts connected with Alpine tectonics. The tectonic elements of the Chain were subsequently fractioned in a system of horst and graben determined by direct faults of the Quaternary epoch.

The upper parts of the horst are constituted by jurassic and cretaceous limestones while in the valleys clayey and flysch formations prevail (fig. 1).

The limestones are important aquifers and numerous springs can be found along the valley slopes running along the tectonic contact between limestones and clayey and flysch units.

The area is one of the most active in the world because of the frequency and intensity of the earthquake, the scale of erosion phenomena and the diffusion of landslides.

The repetition of various erosive and sliding phases has determined complex morphological conditions because of the superimposition of old and new features. Where the area is constituted by highly tectonized clayey and flysch formations we find a predominance of mudslides. The most common clayey formation is constituted by varicoloured clays of the Cretaceous and Eocene epochs. This formation, of deep sea deposit, is

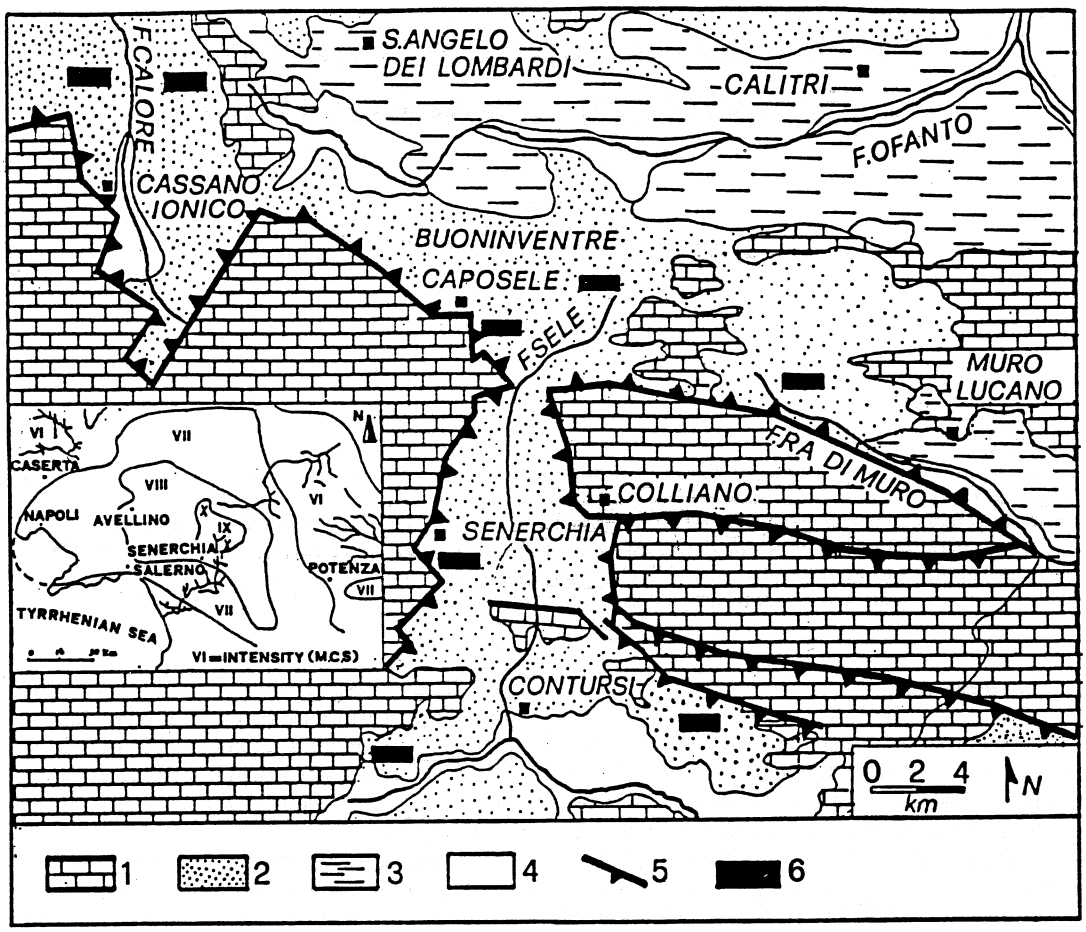

Fig. 1. Map showing the location of Senerchia and Buoninventre mudslides and their relationship to the geology of the Irpinian Apennine area and to the earthquake of 23rd November 1980 (after Postpischl *et al.*, 1982, mod). 1) Limestones and Dolomitic limestones (Cretaceus-Jurassic). 2) Varicoloured clays and Irpinian Flysch (Eocene-Oligocene). 3) Blue clays, sands and conglomerates (Pliocene-Calabrian). 4) Fluvial deposits. 5) Faults. 6) Location of main mudslides and mudflows reactivated by 1980 earthquake.

composed of green, grey and red argillites with interbedded rocky layers of calcirudites, marly limestones, calcilutites and fine quartz sandstones.

The formation is constituted by prevailing mass of clays characterized by typical scaled and laminated fabric. The scales are heterometric shear platelets of clayey material that was originally strongly overconsolidated and are often mixed with lithorelicts of various sizes and natures. This particular scaly fabric is thought to have been formed in a fairly uniform kinematic condition as a consequence of tectonic thrusting (Del Prete *et al.*, 1979). The formation often has a thick cover of periglacially weathered high plastic material which often feeds the mudslide and mudflow bodies.

In time the behaviour of the landslide bodies is characterized by intermittent reactivations linked to recurrences of heavy rainfall and, above all, seismic shocks. During the quiescent period, which may last for more than twenty years on

average, the morphological features become less apparent and the existence of mudslides may be disguised. This increases the hazard of land use.

3. The case of Senerchia

The village of Senerchia is situated in the south of Apennines, about 70 km E. of Naples, on the right bank of the Sele river. The village is built on a thick plaque of cemented detritus of the middle-lower Quaternary. The detrital plaque is located between the steep limestone upslope and the gentler downslope composed of varicoloured clays. Along the tectonic contact between limestones and clays we find numerous springs.

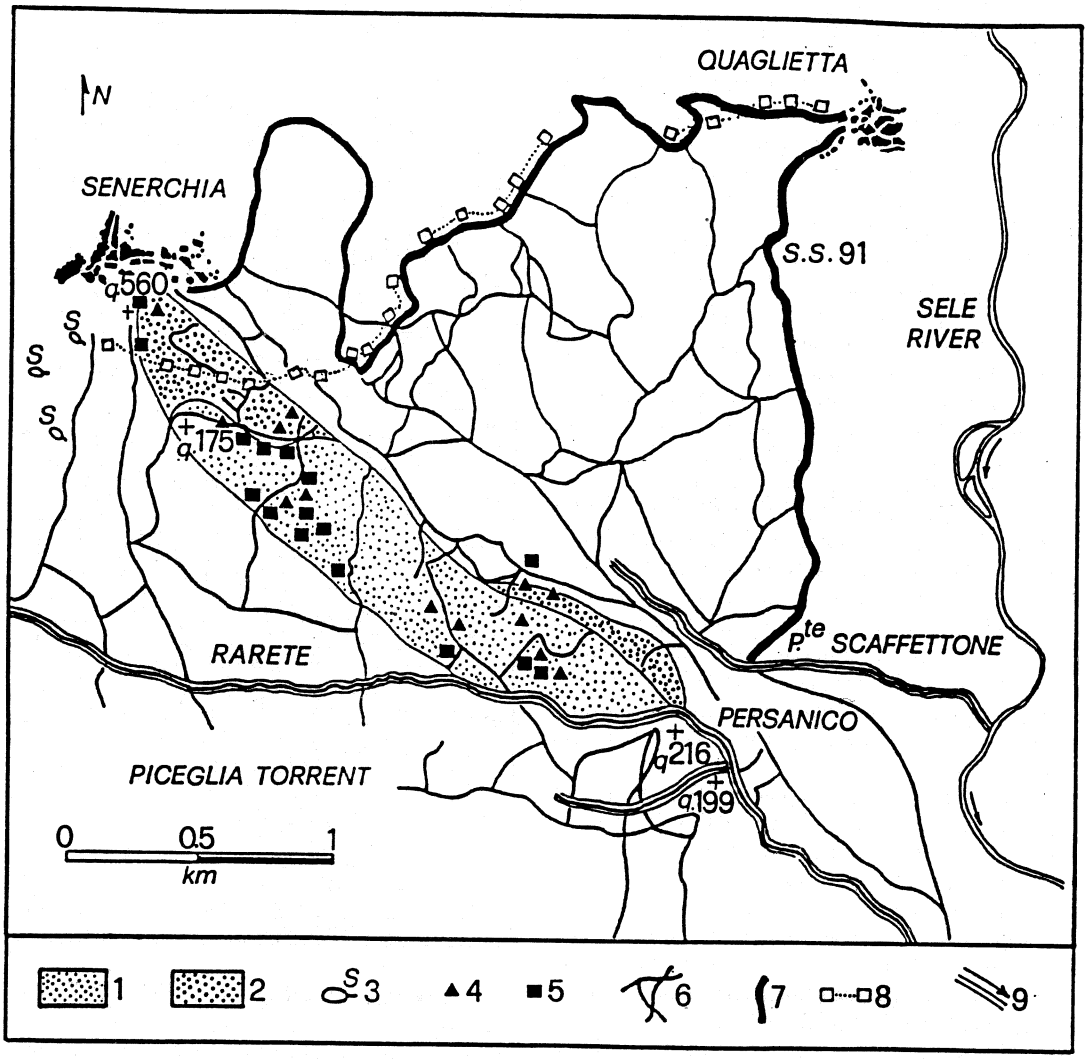

Fig. 2. Plan showing the extent of Senerchia Mudslide before and after the earthquake of 23rd November 1980. 1) Old pre-existing mudslide body from areal photographs of 1955. 2) Mudslide expansion after the earthquake of 23rd November 1980. 3) Spring. 4) Houses built before 1955. 5) Houses built after 1955. 6) Secondary roads. 7) Main roads. 8) Pipelines. 9) River.

The Senerchia mudslide, reactivated by 1980 earthquake, has its rear scarp located a few meters S. of Senerchia village itself, near the tectonic contact between limestones and clays, where a spring group pours a conspicuous amount of water into the downslope landslide area.

The reactivated mudslide has a length of 2.7 km and its toe is located a few hundred metres from the Sele river (fig.2).

The body of landslide is predominantly constituted by varicoloured clays, included some slabs of detrital cemented breccias, deriving from the demolition of the major detrital plaque on which the village of Senerchia is located.

The landslide is already been investigated by Del Prete *et al.*, 1981, Cotecchia and Del Prete, 1984, Cotecchia *et al.*, 1986.

In order to have a more complete evaluation of the phenomenon, a parallel study was carried out on the past and recent morphological evolution of the old landslide body. The study was carried out through a comparison of areal photography and topographical maps of 1955, 1973, 1981 and 1984, and was completed by means of a study of the documents belonging to the archives of the town all of Senerchia.

From the areal photographs of 1955 we can observe the preexistence of the mudslide body. This body is located between 475 m and 216 m above sea level and has a length of 2025 m with a maximum width of 450 m. On this landslide body one can see abundant arboreal vegetation and eight farmhouses, concentrated above all in the degradation and accumulation zone. Moreover, a pipeline is visible just uphill of the old rear scarp (fig. 2).

In the areal photographs of 1973 it may be observed that the size of the landslide body is the same as in 1955 while the number of farmhouses and connected roads has grown.

One may easily presume that the investment involved was made because of the fertility of the landslide material on the one hand and because of the duration of the quiescent period giving an illusion of stability on the other.

The effect of the reactivation of the mudslide following the earthquake of 1980 has consequently assumed catastrophics proportions. In fact, 29 farmhouses and the entire network of roads and pipelines were destroyed, in spite of the good geological and geomorphological predictability.

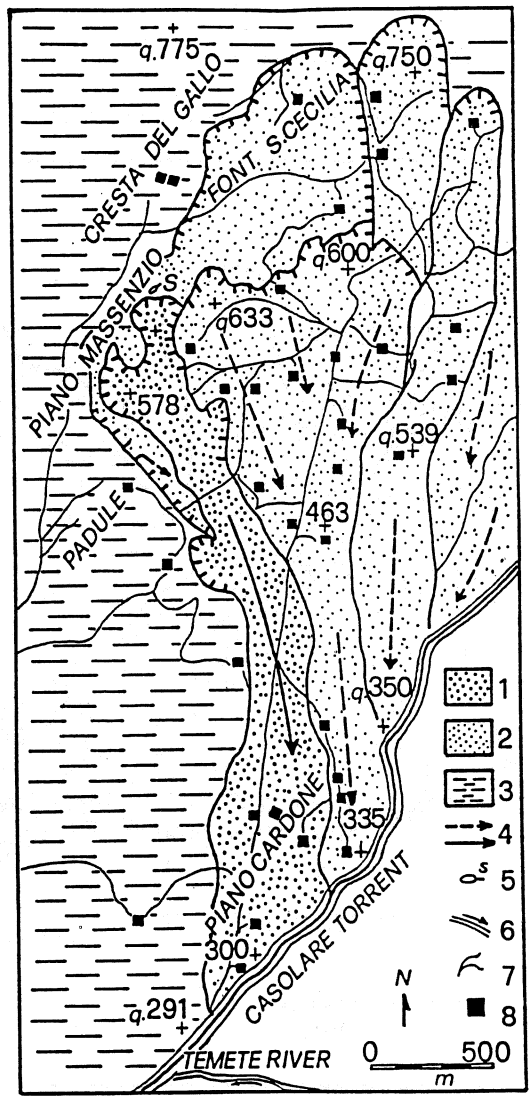

Fig. 3. Map showing the present setting of the Buoninventre area. 1) Mudslide reactivated by the earthquake of 23rd November 1980. 2) Old mudslide bodies not reactivated by the earthquake of 23rd November 1980. 3) Varicoloured clays of Sicilide complex. 4) Main directions of mudslides. 5) Spring. 6) Torrents and rivers. 7) Roads. 8) Houses.

4. The case of Buoninventre

The Buoninventre area lies in the Sele valley, about 7 km N.E. of Senerchia. After the earthquake of 1980 a mudslide of huge proportions took place with a volume estimated at 25×10^6 m^3, a length of 2950 m and a width of 500 m.

Also for this area areal photographs are compared for the years 1955, 1973, 1981 and 1983.

From the areal photographs of 1955 we may observe that hydrographic network of the basin in question is composed of several small torrential gulleys, surrounding the mudslide bodies belonging to different sliding periods. Moreover, an absence of vegetation, farmhouses and roads may be noted.

From the areal photographs and maps of 1973, on the other hand, we may observe considerable investment made in the area with building farmhouses, roads, pipelines and tree coltivations. The disastrous effects of the reactivation of the landslide body on this area are visible in fig. 3.

After the reactivation of the landslide no measures were taken to investigate the surrounding mudslide areas since the real situation was not apparent to non-specialists geologists or engineers.

The actual situation is given in fig. 3 which shows the mudslide bodies that were not reactivated by the earthquake but which exhibit morphological conditions that are very close to the reactivated mudslide.

The results of stability analysis with infinite slope are reported in fig. 4. In this figure we may also see the slope fields of all the mudslide bodies surveyed in Buoninventre basin, the residual shear strength values obtained by laboratory tests and critical *ru* values.

5. Conclusions

The illustrated area of Senerchia and Buoninventre can be considered as sample areas for

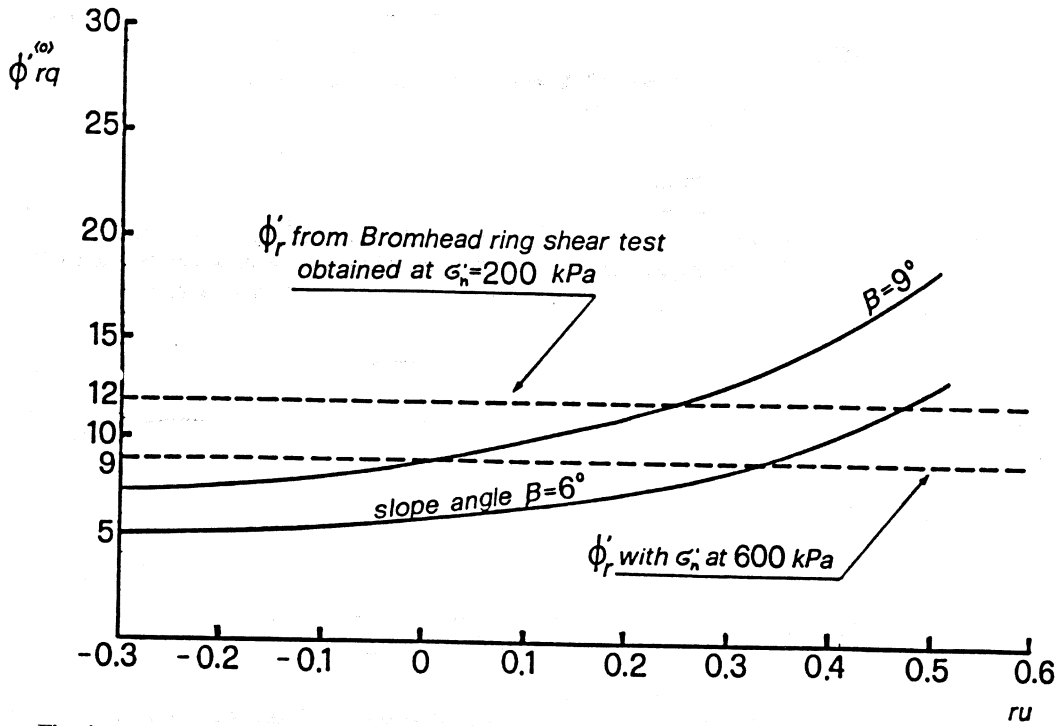

Fig. 4. Results of bidimensional infinite slope analysis of the mudslides of Buoninventre area.

mudslide hazard in the Apennine Chain and they allow for the following conclusions:

a) the mudslides and mudflows are very common in the highly fissured clayey and flysch formations of the Apennine Chain covered by thick periglacially weathered material;

b) this type of landslide is prone to periodic reactivation, especially as a consequence of seismic shocks;

c) the larger and older landslides, with long quiescent periods, exhibit obliterated surface features and are often not recognized but are utilized because of their fertility for agricultural purposes, thus greatly increasing landslide hazard.

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