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Typical source areas of May 1998 flow-like mass movements in the Campania region, Southern Italy

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Abstract

Flow-like mass movements in granular materials are among the most serious natural hazards, systematically producing huge amounts of damage and numerous victims, especially when involving volcanic soils. This is the case of the events in Southern Italy in May 1998, when rainfall triggered many destructive landslides along the slopes of a carbonate massif mantled by pyroclastic soils. Due to the complexity of the occurred phenomena, a shared interpretation of their triggering stage is still not available.

As a contribution to the topic, the paper initially discusses the geological and geomorphological features of the massif combining them in three hillslopes models. The models are then associated to the hydrogeological features and anthropogenic factors in order to define six typical landslides source areas that are not casually distributed on the massif. The study subsequently focuses on the most frequent type of source areas, associated to the largest unstable soil volumes and longest run-out distances. For these source areas, the triggering mechanism is discussed, with an example of geotechnical validation being proposed for a well monitored mountain basin. The geotechnical modelling at site scale confirms the geological analyses at massif scale and provides further insights into the events, thus highlighting the potential of a multidisciplinary approach for the interpretation of very complex slope instability phenomena.

Keywords: Rainfall; Landslides; Pyroclastic soils; Source areas; Triggering; Sarno–Quindici

1. Introduction

Flow-like mass movements in granular materials can be triggered by several factors (i.e. rainfall, earthquake, anthropogenic activities, weathering) and due to their characteristics (i.e. velocity of the propagating mass and absence of warning signals) are among the most destructive mass movements (Hutchinson, 2004). Examples of relevant rainfall-induced events have been recorded in Japan (Wang et al., 2002), Mexico (Capra et al., 2003), Colombia (Terlien, 1996) and New Zealand (Ekanayake and Philipps, 2002). Similar phenomena systematically occur in many parts of Italy, with analogous effects, as dramatically testified by the events in Garfagnana (Central Italy) in 1996 (D'Amato Avanzi et al., 2004) as well as in the Campania region (Southern Italy) with both regional (1910, 1924, 1954, 1997, 1998, 1999) and local events (1986, 2000, 2003, 2005) (Guadagno and Revellino, 2005).

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In this region, the events involved thin pyroclastic deposits constituted by ashy and pumice soil layers, mainly originating from the complex explosive activity of the Somma–Vesuvius volcano, and covering carbonate relieves over an area of about 1600 km^2 (Fig. 1). An historical analysis highlights that this area has been systematically threatened over the centuries by similar events that have caused huge amounts of damage and several victims (O.U. 2.38, 1998) (Fig. 2). Descriptions of both the events and consequences are available in the scientific literature, with rainfall being indicated as the main triggering factor (Chirico et al., 2000; Cascini, 2004; Fiorillo and Wilson, 2004; Guadagno et al., 2005).

However, due to the extension of the involved area, the complexity of the geological setting and the variability of the triggering mechanisms during the hydrological year, a shared interpretation for the triggering stage of these phenomena is still not available. Most of the difficulties are related to the identification and analysis of the landslide source areas. This is clearly highlighted by one of the most recent and catastrophic events that, in May 1998, caused large amounts of damage and numerous victims in the urban areas of Sarno and Quindici as well as in the neighbouring towns of Bracigliano and Siano. Referring to this event, this paper discusses the literature currently available and proposes an integrated approach aimed at recognizing the landslide source areas over the entire affected area

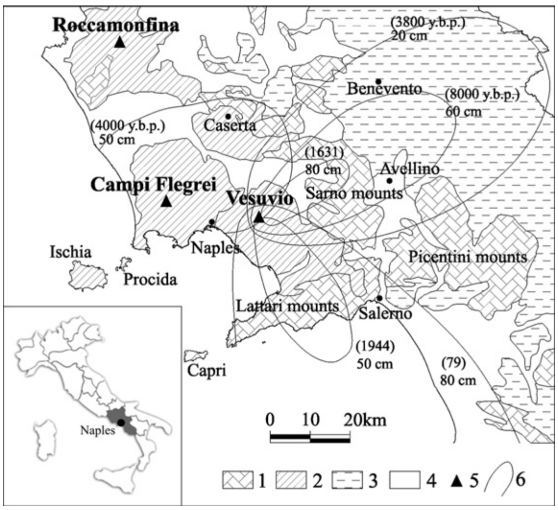

Fig. 1. Air-fall pyroclastic deposits in the Campania region: 1) carbonate bedrock; 2) tuff and lava deposits; 3) flysch and terrigenous bedrock; 4) alluvial and continental deposits; 5) volcanic complexes; 6) isopachs of the pyroclastic products from the main eruptions (in brackets eruption data) (data from O.U. 2.38, 1998).

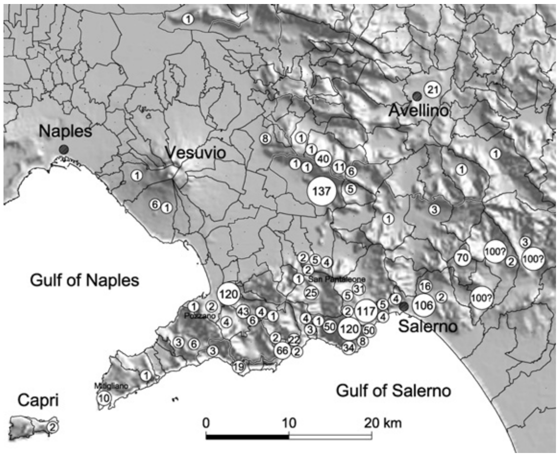

Fig. 2. Victims in the Campania region caused by flow-like mass movements in the period 1580 –1998 (O.U. 2.38, 1998).

(60 km^2). Then, the most widespread triggering mechanism is analysed at site scale.

2. The case study

2.1. The flow-like mass movements in May 1998

On 5th–6th May 1998, more than a hundred slope instability phenomena occurred along the slopes of the Pizzo d'Alvano massif, subsequently involving the towns of Bracigliano, Quindici, Sarno and Siano (Del Prete et al., 1998; Crosta and Dal Negro, 2003; Cascini, 2004; Guadagno et al., 2005; among others) (Fig. 3).

During these events, over a 48 hour period, cumulated rainfall equal to 120 mm (Fig. 4) were measured by the rain gauges located at the toe of the Pizzo d'Alvano massif (240 m a.s.l.) (Cascini et al., 2000; Cascini, 2004). The hydrological analysis of rainfall data is provided by O.U. 2.38 (1998), Chirico et al. (2000) and Fiorillo and Wilson (2004). It is worth noting that after May 1998, rain gauges were also installed at the top of the massif (1100 m a.s.l.). During the period 1999–2003, the cumulated rainfall values over time periods longer than one month were systematically similar to those recorded at the toe of the massif. On the contrary, during 1–2 day rainstorms, rainfall values in the upper part of the massif were frequently higher (1.5–2.0 times) than those recorded at the rain gauges available in May 1998. Based on these results, it can therefore be reasonably argued that, also on 4th–5th May 1998, the cumulated rainfall was higher than that measured at the toe of the relief.

During the rainstorm, over a period of about 16 hours, the slope instability phenomena occurred in the vast