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The Ischia island flash flood of November 2009 (Italy): Phenomenon analysis and flood hazard

A. Santo [a,*], G. Di Crescenzo [a], S. Del Prete [c], L. Di Iorio [b]

[a] Department of Hydraulic, Geotechnical and Environmental Engineering (Applied Geology Division), University of Naples Federico II, via Claudio 21, 80125 Naples, Italy
[b] Professional geologist, Barano d'Ischia, Naples, Italy
[c] Campania Speleological Federation, c/o CAI sez. Naples, via Trinità degli Spagnoli 41, 80123 Naples, Italy

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ABSTRACT

The island of Ischia is particularly susceptible to landslides and flash floods due to its particular geological and geomorphological context. Urbanization in recent decades coupled with the development of tourism has increased the risk. After the November 10, 2009 event occurring in the northern sector of the island (the town of Casamicciola), a detailed geo-morphological survey was conducted to ascertain the evolution of the phenomenon. In the watersheds upstream of Casamicciola, many landslides were mapped and the volume of material involved during detachment and sliding was estimated. In the lower course area, near the town and towards the sea, flow pathways were reconstructed with the aid of extensive video footage taken during the event. Rainfall data were also analyzed and a relationship was established between the hourly rainfall rate and the flash flood. The phenomenon was found to be quite complex, with many upstream landslides stopping before reaching the urban area. In the lower course the alluvial event occurred as a flood with a very small sediment discharge, which left a very thin layer of sediment. Reconstruction of the flash flood phenomenon suggested possible action for future risk mitigation, early warning and civil protection plans.

1. Introduction

Flash floods are generally the consequence of violent storms, usually occur over limited areas, and rise and fall quite rapidly with little or no advance warning. They are one of the most significant natural hazards in the Mediterranean region, causing serious risk to life and destruction of buildings and infrastructure (Gaume et al., 2009). Indeed, flash flood vulnerability has recently increased due to increasing urbanization in flood-vulnerable areas (Huntington, 2006).

However, the main difficulty in studying and monitoring flash floods is the lack of accurate data (especially in small ephemeral mountain streams) and stems from the fact that they develop at space and time scales that conventional measurement networks of rain and river discharges are unable to sample effectively (Creutin and Borga, 2003). Moreover, the occurrence of extreme events in un-gauged watersheds generally means that there is no measured discharge information or formal records of the magnitude of the event.

The problem has attracted considerable attention in recent years, with a substantial focus on hydrological aspects (Camarasa Belmonte and Segura Beltràn, 2001; Gaume et al., 2003, 2004, 2009; Delrieu et al., 2005; Maréchal et al., 2008), in particular on peak discharge and return period estimation methods (Costa, 1987; House and Pearthree, 1995; Alcoverro et al., 1999; Rico et al., 2001), and on their geomorphic consequences (Piegay and Bravard, 1997; Gutierrez et al., 1998; Alcoverro et al., 1999; Merritt and Wohl, 2003; De Waele et al., 2010). In the last decade a focused monitoring methodology, which involves post-flood surveys, use of weather radar observation, re-analyses and hydrological modeling has been developed (Creutin and Borga, 2003; Carpenter et al., 2007; Gaume and Borga, 2008; Costa and Jarrett, 2008; Bouilloud et al., 2009; Marchi et al., 2010). In particular, post-event surveys play a critical role in gathering essential observations concerning flash floods (Borga et al., 2008).

The aim of this paper is to make a contribution to the study of flash floods in the Mediterranean climate area by describing and analyzing a meteorological event that occurred in the northern sector of Ischia (southern Italy) on November 10, 2009. Over time, Ischia has been repeatedly hit by such phenomena and it represents one of the highest risk areas in Italy for landslides and flooding. Using the survey data, we were able to reconstruct in detail what happened during the flood and to define the flood hazard at various sites in the area concerned. Such observations may be very useful and can contribute to defining risk mitigation strategies and civil protection plans.

* Corresponding author. Tel.: +39 081 7682109; fax: +39 081 7682162.
E-mail addresses: santo@unina.it (A. Santo), g.di.crescenzo@alice.it (G. Di Crescenzo), dpsossio@alice.it (S. Del Prete), drigpp@alice.it (L. Di Iorio).

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2. Geological and geomorphological setting of Ischia

The island of Ischia is a complex volcanic field in the north-western sector of the Gulf of Naples, covering an area of about 42 km^2. Due to its particular geological and geomorphological setting the island is particularly sensitive to instability events due to the presence of easily erodible volcanic soils with varying degrees of permeability. The main outcropping lithologies are represented by trachytes and latite–phonolites (Chiesa et al., 1987; Orsi et al., 1998), sedimentary deposits of marine origin and widespread accumulation of debris flow deposits whose emplacement is probably related to gravitational phenomena occurring concurrently with the resurgence of Mt. Epomeo (Rittmann and Gottini, 1980; Vezzoli, 1988; Guadagno and Mele, 1995; Mele and Del Prete, 1998).

Although the precise beginning of volcanic activity on Ischia has not yet been established, it is certainly older than about 150 ka. It is divided into two main cycles, separated by a quiescent period of about 25 ka. The distinction in two cycles has been proposed with respect to the emplacement of the formation of the Green Tuff (~55 ka) that forms the backbone of the relief of Mt. Epomeo and which is a kind of trachytic ignimbrite with a typical green color due to alteration produced by the contact with seawater (Fig. 1). In all, five major phases of volcanic activity have been recognized (Chiesa et al., 1987; Orsi et al., 1998; Vezzoli, 1988; Civetta et al., 1991) from 150 ka up to the last event, coinciding with the Arso eruption occurring in 1302.

The town of Casamicciola lies at the foot of the northern slope of Mt. Epomeo, which can be defined as a structural slope (fault scarp) with very high gradients and relief energy. Along this slope a parallel-type drainage network has developed, forming deep gorges, known locally as *cave*, with sub-vertical and unstable walls. In general, these mountain stream basins show an ephemeral drainage. The headwater areas of the Casamicciola basins have a limited extension (<1 km^2) and are homogeneous as regards land use since the vegetation cover is coppiced woodland.

Landslides and alluvial events have repeatedly affected the slopes of Ischia (Fig. 2 and Table 1), as well as the steep walls of the main gullies and the cliffs along its coastal perimeter (Del Prete and Mele, 1999, 2006). In all, up to the time of writing 240 landslides (*sensu* Cruden and Varnes, 1996) are known to have occurred on the island in previous centuries (Debris slide, 55%, and rock fall, 23%, represent the most common type; Fig. 3a and b). The first occurred both along artificial and natural slopes (especially slopes of ravines and streams, 53%), involving incoherent pyroclastic depos-

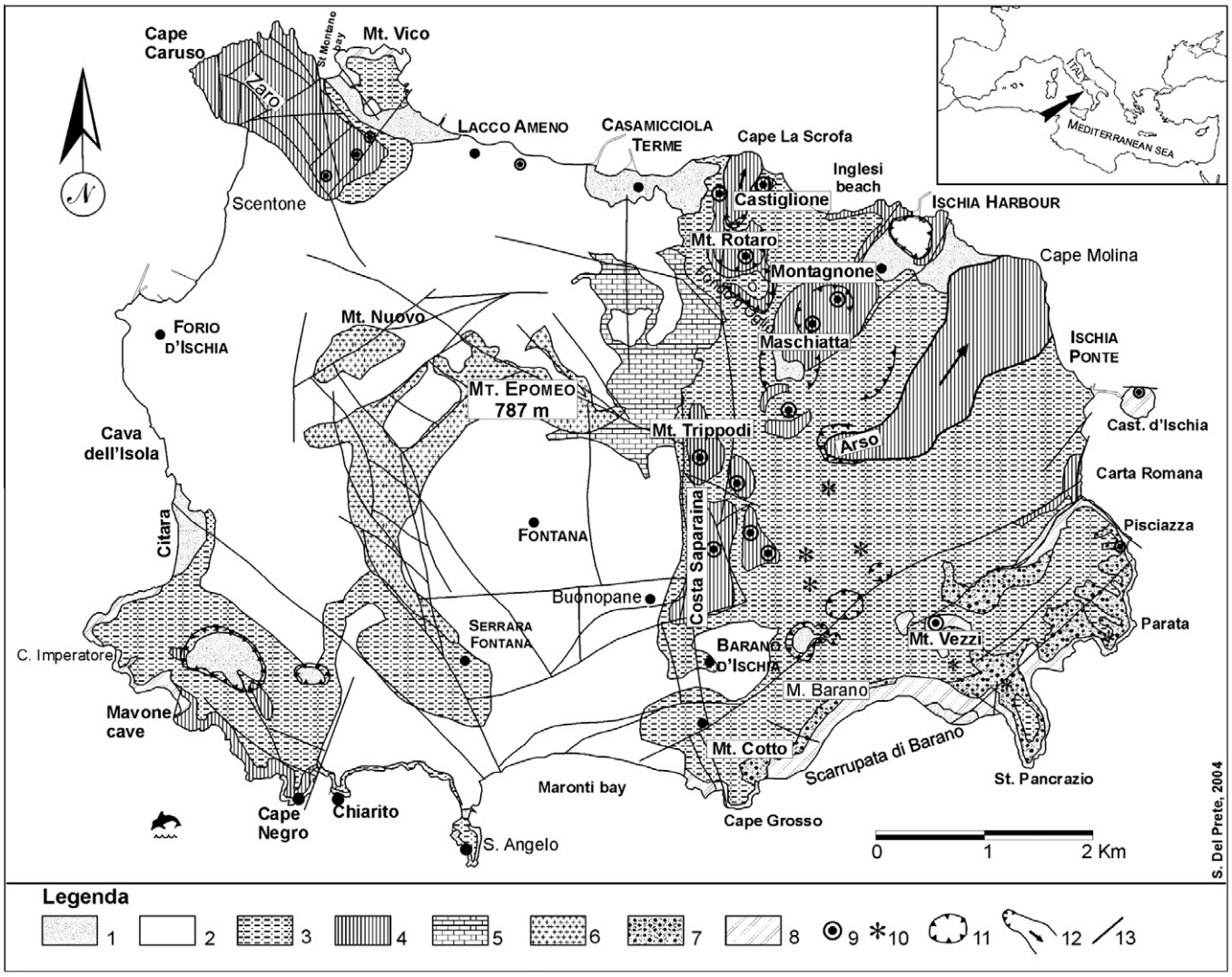

Fig. 1. Geological sketch map of Ischia (after Del Prete and Mele, 2006). Legend: (1) recent beach deposits, recent slope talus; (2) Mt. Epomeo debris flow deposits; (3) pyroclastic deposits of the younger cycle (<55,000 ybp); (4) lava flows of the younger cycle (<55,000 ybp); (5) sandstone, marl and siltstone of the Colle Jetto formation; (6) Mt. Epomeo Green Tuff (55,000 ybp); (7) pyroclastic deposits of the older cycle (>55,000 ybp); (8) lava flows of the older cycle (>55,000 ybp); (9) lava dome; (10) eruptive center; (11) crater rim; (12) lava flow; (13) fault.