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Volcanic risk perception in the Campi Flegrei area

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ABSTRACT

The Campi Flegrei which includes part of the city of Naples, is an active volcanic system; its last eruption occurred in 1538 AD. More recently two significant crises occurred between 1969 and 72 and 1982–84 and were accompanied by ground movements (bradyseism) and seismic activity, forcing people of the town of Pozzuoli to be evacuated. Since 1984 development of a volcanic emergency plan has been underway. In 2000 Civil Protection published a risk map which defined the Red Zone, an area highly at risk from pyroclastic flows, which would need to be evacuated before an eruption. The first study to evaluate the volcanic risk perceptions of the people living within the Campi Flegrei area was completed in spring 2006, resulting in the largest sample ever studied on this topic except for one on Vesuvio area residents by Barberi et al. (2008). A 46 item questionnaire was distributed to 2000 of the approximately 300,000 residents of the Campi Flegrei Red Zone, which includes three towns and four neighborhoods within the city of Naples. A total of 1161 questionnaires were returned, for an overall response rate of 58%. Surveys were distributed to junior high and high school students, as well as to adult members of the general population. Results indicated that unlike issues such as crime, traffic, trash, and unemployment, volcanic hazards are not spontaneously mentioned as a major problem facing their community. However, when asked specific questions about volcanic risks, respondents believe that an eruption is likely and could have serious consequences for themselves and their communities and they are quite worried about the threat.

Considering the events of 1969–72 and 1982–84, it was not surprising that respondents indicated earthquakes and ground deformations as more serious threats than eruptive phenomena. Of significant importance is that only 17% of the sample knows about the existence of the Emergency Plan, announced in 2001, and 65% said that they have not received enough information about the possible effects of an eruption. In addition, residents' sense of community was significantly positively correlated with both confidence in local authorities and Civil Protection as well as residents' feelings of self efficacy regarding their ability to protect themselves from a potential eruption. These results indicate that most residents of Campi Flegrei, while aware of the volcanic threat posed by Vesuvio, are not familiar with more local volcanic hazards in their area. This, coupled with little knowledge about the Emergency Plan and the very low level of information residents have about the effects of a possible eruption, suggests that authorities, in collaboration with the scientific community, should direct their efforts to better educate and inform the population about volcanic hazards and the Emergency Plan, and that such efforts could be facilitated by trying to encourage stronger community bonds.

1. Introduction

The Campi Flegrei (CF), located in the Western sector of the Neapolitan area, is well known for the occurrence of phenomena related to volcanic activity since ancient times when these events were interpreted as super-natural occurrences and the site was viewed as an entrance to the underworld. The last eruption occurred in 1538 AD at Monte Nuovo, and diffuse gas emissions, the presence of hot thermal waters, and bradyseism (ground uplift, associated with seismic swarms, and subsidence), characterize this area even today.

The repeated bradyseismic events have deeply affected the Phlegraean territory and its inhabitants. During the last most recent and significant bradyseismic crises (1969–72 and 1982–84) the partial evacuation of Pozzuoli citizens was ordered, and thousands of people were permanently relocated. The CF volcanic system and its eruptive and deformational activity have been the subject of several research studies aimed at assessing the hazards and their related risks in a densely populated area, and to develop a volcanic emergency plan. The plan is not yet completed and published, but it has already

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been presented in the form of a map defining the CF Red Zone, the area exposed to maximum expected hazard from pyroclastic flows.

On the one hand we have experienced great developments in volcanological and geophysical research and in planning for a future volcanic emergency; on the other hand we have a region where volcanic morphologies are not so evident and where the perception of any local volcanic risks is surely affected by the close proximity of one of most famous volcanoes in the world, Vesuvio.

It is within this complex framework that we have engaged in research on CF inhabitants' perceptions of risk for volcanic hazards to better understand the human dimension of the risk, by studying people's attitude toward risk as it relates to various cultural, economic, and social factors (Slovic et al., 1980; Thompson, 1980; Chester, 2005; Gaillard and Dibben, 2008). Risk perception is one of several important factors that can affect people's recognition of their vulnerability to volcanic hazards, and their possible reactions to volcanic crises (Chester, 1993; Chester et al., 1999, 2002; Dibben and Chester, 1999).

Several studies on public perceptions of volcanic hazard and risk have been conducted in the last twenty years all over the world (Kartez, 1982; Perry, 1990; Yosii, 1992; D'Ercole et al., 1995; Johnston and Houghton, 1995; Johnston et al., 1999; Paton et al., 2001; Cronin et al., 2004; Dominey-Howes and Minos-Minopolous, 2004; Gregg et al., 2004, 2008; Davis et al., 2005; Barberi et al., 2008; Carlino et al., 2008; Cashman and Cronin, 2008; Dibben, 2008; Dove, 2008; Gaillard, 2008; Haynes et al., 2008b; Lavigne et al., 2008; Leonard et al., 2008; Paton et al., 2008; Perry and Lindell, 2008; Solana et al., 2008; Wisner, 2008; Bird et al., 2009; Njome et al., 2010). Most of these studies have focused on measuring people's knowledge of volcanic hazards and their perceptions of risk, and how such perceptions are related to preparedness and responding to evacuation. Another important aspect of these studies has been to look at the role of risk communication and how messages from scientists or emergency management officials may be received by the public. In order to develop more successful education programs and emergency procedures, we must develop a better understanding of risk perception, decision making processes, and other factors that may influence the responses of an at-risk population (Mulilis and Duval, 1995; Lindell and Whitney, 2000; Paton et al., 2001; Haynes et al., 2008a). Furthermore if an emergency warning is issued, even if it ultimately proves to be false, while people's concern may increase significantly, this may not affect their awareness of, preparedness for, and compliance with future warnings (Gaillard 2008).

In this paper the results of our research assessing volcanic risk perception of CF Red Zone residents are presented, mainly through the evaluation of their level of knowledge of volcanic hazards and risk, their level of knowledge regarding preparedness and how to respond to warnings, their confidence in various information sources, and ways in which these factors may interact with the residents' sense of community or bond to their city or town. The investigated area includes four neighborhoods of Napoli (Bagnoli, Fuorigrotta, Pianura, and Soccavo) and the municipalities of Bacoli, Monte di Procida, and Pozzuoli.

2. Volcanic history, hazards and the Emergency Plan

2.1. Volcanic history

The CF volcanic system has been active for more than 60,000 years BP, and is presently characterized by a peculiar landscape including different volcanic landforms, plains, lakes, and coastline (Fig. 1).

The main volcanological feature is represented by a caldera structure formed during the two main events of the Campanian Ignimbrite (Barberi et al., 1978; Fisher et al., 1993; Rosi et al., 1996, 1999; Civetta et al., 1997; Fedele et al., 2003; Giaccio et al., 2008) and Neapolitan Yellow Tuff eruptions (Orsi et al., 1992, 1995; Scarpati et al., 1993; Wohletz et al., 1995) which occurred at 40 and 15 ka, respectively (De Vivo et al., 2001; Deino et al., 2003). During the last 15 ka within the caldera several volcanic edifices grew and were subsequently destroyed as a result of about 70 eruptions. Volcanism was mainly concentrated in discrete periods which alternated with quiescent periods of variable lengths (Di Vito et al., 1999; Isaia et al., 2009). Eruptions often occurred in short time intervals, varying from a few decades to centuries. After about 3400 years of rest the last eruption of Monte Nuovo occurred in 1538 AD (Fig. 2).

The volcanic activity at the CF was mainly explosive with phreatomagmatic and magmatic eruptions, while only a few effusive events were recorded in the eruptive history of the CF. During the last 15 ka (thousand years) there were only two high-magnitude eruptions including Plinian phases which occurred at 10.3 and 4.1 ka, respectively (de Vita et al., 1999; Di Vito et al., 1999), while medium and low magnitude events were predominant. The magnitude variability of the events is evidenced by the differences in the areal distribution and volume of emitted magma, which only during the high magnitude eruptions exceeded 1 km^3 (Dell'Erba, 2004; Orsi et al., 2004).

The eruptions' vent location changed over time, with the most recent one mostly concentrated in the central-eastern sector of the caldera, rather than the western sector. Contemporaneous eruptions within the two different sectors were also recorded (Isaia et al., 2009).

The eruptions were generally dominated by phreatomagmatic explosions alternating with magmatic phases and minor strombolian events, which were also recognized as the final phase of more energetic eruptions. Pyroclastic density currents were generated during the phreatomagmatic events and laid down deposits whose areal distribution was related to the eruption magnitude and vent location. Tephra fallout followed the magmatic phases and is widespread, mostly downwind toward the east, from Plinian and sub-Plinian columns, and in variable directions during the low and medium magnitude eruptions, prevailing towards the northeast.

The caldera was affected by ground deformation phenomena which led to a total uplift of about 90 m in its central part during the last 10.5 ka. Recent slow ground movement events, named bradyseisms, periodically occurred. The significant bradyseismic crises of 1970–72 and 1982–84, were accompanied by hundreds earthquakes and 3.5 m of ground uplift (Barberi et al., 1984, 1989; Berrino et al., 1984), forcing residents of Pozzuoli to be evacuated (Fig. 3, vertical ground movements at Serapis Roman market in Pozzuoli). These recent bradyseismic crises, the continuing widespread fumarolic and hydrothermal activity and the historical eruption of Monte Nuovo are the main volcanic phenomena for determining that the CF magmatic system is still active.

In an active volcanic system characterized by high frequency explosive activity alternating with long rest periods, variable vent openings and bradyseismic crises without eruptions, a volcanic hazard assessment and zoning of those areas most at risk for the expected hazards are a fundamental tool for volcanic risk mitigation strategies.

2.2. Expected hazards and emergency plan

The recent bradyseismic crises have illustrated the importance of developing civil protection actions for managing long seismic crises, as well as the preparation of a first emergency plan to deal with a possible, imminent volcanic eruption. During the 1970–72 bradyseism severe damage to buildings in the historical center of Pozzuoli led authorities to implement the evacuation of 3000 inhabitants with the support of the army. These people were then permanently re-located in the new quarter Rione Toiano, another neighborhood of Pozzuoli.

In 1983 the seismic swarms, ground deformation and the assessment of many buildings' vulnerability led to the evacuation of 30,000 people from Pozzuoli, who were eventually re–located in another new quarter of Pozzuoli, Monteruscello. Furthermore during this protracted crisis, the scientific community and Civil Protection officials decided to draw up an emergency plan to manage the evacuation of a huge number of people in the case of a volcanic eruption occurring with only a short amount of warning time.