THE SOMMA-VESUVIUS MEDIEVAL ERUPTIVE ACTIVITY: A STUDY OF ITS IMPACT ON THE HEAVILY INHABITED SOUTH-WESTERN SECTOR OF THE VOLCANO

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ABSTRACT

The focus of this PhD thesis is the assessment of the hazards related to the presence of pyroclastic deposits in the densely populated Vesuvian area, evaluating, in particular, the hydrogeological and the volcanic hazard. Particular attention was paid to the town of Torre del Greco, because its territory is the most affected by these two typologies of hazard, due to its natural morphology originated by the historical eruptive Vesuvian activity and to the anthropological alterations of its area.

This work improved the understanding of Vesuvius eruptive behaviour and contributed significant data for the generation of more reliable models for the evaluation of the volcanic hazard for the population that lives on the flanks and in the surroundings of this volcano. The work was divided in three parts: *i*) a detailed mapping of the South-Western sector of Vesuvius, integrating stratigraphic and petrologic data with archaeological and historical information; *ii*) a study of the medieval eruptive activity of the Somma-Vesuvius volcano, an important period of the activity of Vesuvius, which has been definitely under-researched; *iii*) the assessment of the hazard connected to the volcaniclastic flows.

INTRODUCTION

Our planet undergoes continuous transformations due to the influence of natural phenomena and of the inconsiderate man-made alterations of the territory. The concept of total risk was born due to the interactions among man and the environment. It is based on the combination of natural and socio-economic factors, and it is quantified using the following relation (Allen *et al.*, 1980):

RISK = f (hazard, vulnerability, value of exposed).

To each hypothetical natural event will be attributed a value of risk, and consequently an expected damage, defined as "*the probability of economic loss for the occurrence of a natural event*". The fundamental assumption is that "*future events will occur in an area with the same mode (style and size) and with the same average frequency with which they occurred in the past*". Hence, the paramount importance of investigating and reconstructing in detail the behaviour of the natural phenomenon that occurred in a given area.

The Italian territory is affected by a multiplicity of natural phenomena, each one with an associated degree of risk. We can define two types of risk: *i*) tectonic and volcanic; *ii*) hydrogeological (which can be further subdivided in hydraulic and geomorphological).

In volcanic areas, in addition to the risk of eruptive events, it is very common the occurrence of volcanic-related mud flows (Pareschi *et al.*, 2000), which can be sin-eruptive and inter-eruptive (Capra *et al.*, 2004), the latter occurring when intense and/or persistent rains remobilize loose pyroclastic deposits (Zanchetta *et al.*, 2004).

Under the implicit assumption that past activity is the key for understanding the future, a detailed reconstruction of the eruptive history is of the utmost importance in order to produce a realistic model of an active volcano. Furthermore, the results stemming from an historical analysis of the eruptive history must be integrated and connected with data regarding the current geodynamic situation of the area.

The whole dataset consents then to generate an updated cartography by means of GIS, which allows to render the hazard readily visible through thematic maps. A zonation map, which can be used to construct a possible hazard map, can be constructed combining the morphological characteristics of the area with the concavity and the form factor of the basin, the distribution of gradients, derived using an accurate Digital Elevation Model (DEM), the study of its hydrology, and the thickness of the pyroclastic deposits (from fall, surge, and flow; Bisson *et al.*, 2010).

The huge demographic and urban growth of the towns located on the slopes of Vesuvius, the high risk associated with the probability of the event, and the expected eruptive scenery, are the main reasons why this volcano has become one of the most studied and monitored in the world.

Vesuvius is located in the graben structure of the Campanian Plain, which formed during the opening of the Tyrrhenian Basin in the Plio-Pleistocene, and that was followed by volcanic activity in its late stage. Somma-Vesuvius is a composite stratovolcano, made up of the ancient Somma caldera and of a recent central cone, Vesuvius. Its history is filled with events displaying different types of eruptive styles and, of course, the volcano is widely known for its paroxysmal Plinian eruptions, of which the best known is the Pompeii Eruption of AD 79, described by the letters of Pliny the Younger to Tacitus.

At least four of the major Plinian events occurred over the past 18,000 years, and were separated by periods of quiescence of variable length or by minor activities ("inter-Plinian" stage). A detailed knowledge of the behaviour of the volcano in these stages is of primary importance for the prediction of its possible future eruptions (Andronico & Cioni, 2002).

METHODS

The morphology of the municipality of Torre del Greco is the result of a combination of constructive and destructive events, and while it is still possible to identify the location and the characteristics of many outcrops, the intense urbanization has obliterated several important ones, making the reconstruction much more challenging.

This territory is also affected by frequent events such as landslides (*i.e.*, debris-flows), floods, and erosion, which contribute to increase the hazard conditions. These events are associated to the presence of loose volcanic deposits and are triggered by heavy rainfalls that tend to remobilize them. These are historically recurring events, as shown by the attempt of the Borbone to control water flow in the Vesuvian area by the way of building the Regi Lagni. The highly chaotic urbanization of the Vesuvian area turned many riverbeds, which represented originally natural outflow paths for rainwater, in streets (riverbeds-roads), totally altering the function of the original drainage network. This morphological analysis highlighted the present hydrogeological condition and defined the likely paths of lava flows and above all of mud flows, both of great importance for the definition of the hazard.

The collection of historical documents such as chronicles, iconographies, and paints, combined with the reconstruction of the historical toponomastic and the usage of maps to connect all the available data, proved to be an invaluable multidisciplinary tool to determine the evolution of the town of Torre del Greco and to develop a reliable assessment of the volcanic hazard in the study area.

RESULTS

Through the field surveys, it was possible to produce a new and detailed volcanological map of the South-Western sector of Vesuvius, at the 1:10,000 scale (Fig. 1).

Oldest volcanic deposits outcropping in the mapped area are the pyroclastic covers of the great Plinian eruption of Avellino (4,000 BP), so it has been considered the last 4,000 years of eruptive activity of Vesuvius. The mapping work was done integrating stratigraphic and petrologic data with archaeological and historical information, showing interaction between volcanological, morphological, and human aspects of this very densely populated sector of the volcano.

Here all the historical lava paths and tephra deposits were accurately and correctly identified, reported, and mapped using the subdivision of stratigraphic/cartographic elements in Synthetic Units, which greatly helped the description of the volcanic behaviour.

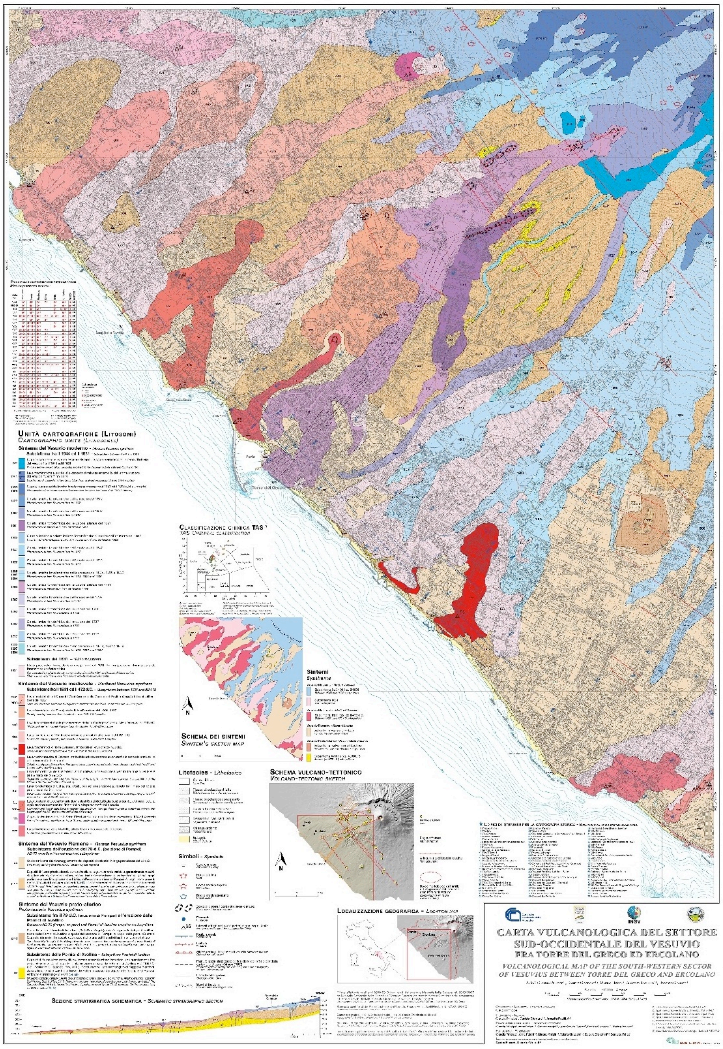

Fig. 1 - Volcanological map of the SW sector of Vesuvius between Torre del Greco and Ercolano (Principe *et al*., 2013).

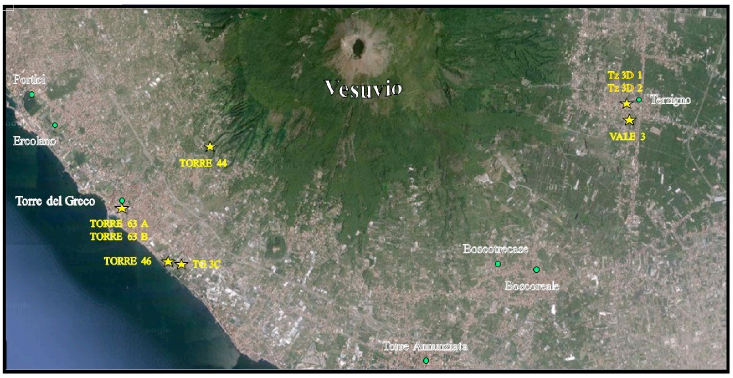

Fig. 2 - Location map of the outcrops of the AD 1139 eruption.

Archaeological and historical data were used in support of the cartography of the lava flows emitted during the last 2,000 yrs. During medieval time only few tens of lava flows were emplaced in this area. They were mainly outpoured from lateral vents recognized and mapped, instead than directly from the central Vesuvius crater. These eccentric vents are positioned very near to the present coastline.

During field investigations, in particular in quarries, it was possible to recognize pyroclastic deposits linked to the medieval activity of Vesuvius (Fig. 2).

This period was investigated on the basis of historical chronicles, tephrostratigraphic sequences and chemical analyses. In particular, the glasses of tephra fallout products of the AD 1139 eruption of Vesuvius were analysed. The result evidenced a phono-tephritic chemical composition, which represents a less evolved magma compared to the two small-scale Plinian eruptions of AD 472 and AD 1631, considered as stratigraphic markers (Fig. 3).

The fieldwork allowed to collect useful data for the assessment of the hazard connected to the volcaniclastic flow events, also documented by historical chronicles. Therefore, from the combination of historical information, precipitation data, morphological parameters and volcanological features, using a GIS-based methodological approach, it was possible to obtain, as a final result, the precise identification of the source areas of the volcaniclastic flows and of the physical parameters that control their onset (Fig. 4).

In fact, the historical analysis of the spatial and temporal distribution of the volcaniclastic flows recorded in the Vesuvian area during the 20th - 21st centuries (1906-2010) indicated that the area mostly affected by such phenomena was the South-Western sector of Somma-Vesuvius and, in particular, the Torre del Greco municipality. This study integrates and combines, on GIS platform, information deriving from different sources, such as: *i*) historical chronicles and local reports (20th century), *ii*) scientific literature about the recent activity of Somma-Vesuvius (AD 1631-1944), *iii*) rainfall data (20th century), and *iv*) morphological and morphometric analyses obtained by the DEM.

This approach allowed the recognition of the source area of the volcaniclastic flows that affected the Torre del Greco municipality during the last 110 years, individuating also the key parameters (slope, curvature, and precipitation) necessary to trigger the potential volcaniclastic flows. Moreover, possible relationships between the fallout deposits of the main recent eruptions of Somma-Vesuvius and the historical volcaniclastic flows of Torre del Greco were considered. The results indicate that a funnel-shaped area located immediately SW of the Somma-Vesuvius caldera boundary could be the source zone for the volcaniclastic flows that invaded the Torre del Greco municipality, probably remobilizing pyroclastic materials mainly derived, from the 1822 eruption.

The methodology here proposed can be used not only in sin-eruptive conditions, but also during a period of volcanic quiescence when heavy and/or persistent rains might be able to remobilize loose pyroclastic deposits. Despite this approach represents only a starting point for studies aimed at the assessment and mitigation of

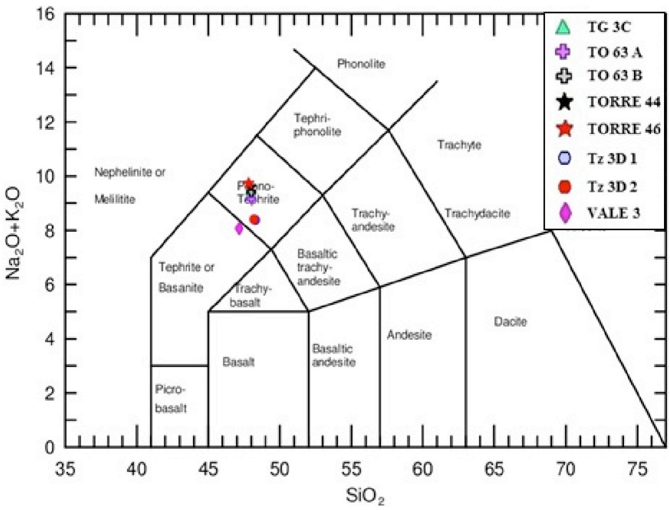

Fig. 3 - Silica/Total alkali plot (TAS) of the samples of the AD 1139 eruption.

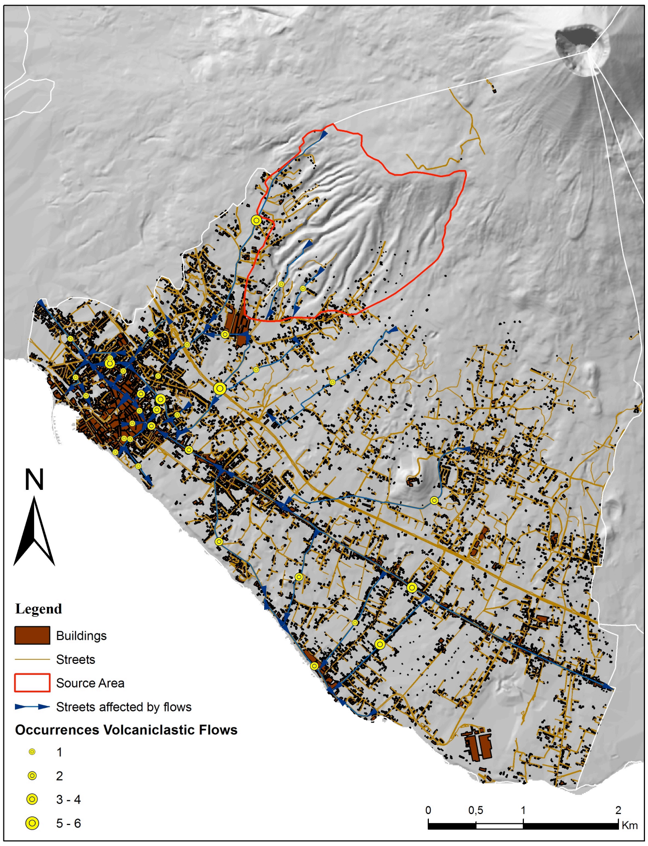

Fig. 4 - Urban elements drape on shaded relief image in Torre del Greco municipality. Red line indicates the source area; the paths of the flows are drawn by blue thin lines with directional arrows; the size of the yellow circles indicates the number of events recorded in the streets (DEM from Tarquini *et al.*, 2007).

volcaniclastic flows hazard, the methodology here adopted can be applied in other volcanic zones with similar characteristics to the Somma-Vesuvius area, providing a useful contribution for the prevention of volcaniclastic flows.

SUMMARY AND CONCLUSIONS

The field work carried out in the territory, was instrumental to reconstruct the paths of some medieval lava flows and to determine the location of possible eruptive centre which were buried either partially or completely, or obliterated by building constructions. Principe *et al.* (2004) identified a few medieval eruptions with eccentric vents close to the coastline. Here, it has been possible to recognize other eccentric medieval vents very close to the coastline.

Using the detailed cartography it was possible to observe that the medieval tephra fallout, in particular that of the AD 1139 eruption, was found to occur in the SW sector of Vesuvius, in addition to the finding of Rolandi *et al*. (1998), which studied twenty sections from outcrops around the eastern sector of the volcano, from Sant'Anastasia to Torre del Greco. The present level of medieval tephra of the AD 1139 eruption in both Eastern and South-Western sectors of Vesuvius, allowed to identify a different dispersion pattern and consequently a new horizon that is relevant in terms of fallout hazard.

From the study and analysis of the sampled medieval tephra fallout, it was found that modern tephra are characterized by a predominant distribution to East (Arrighi *et al.*, 2001). However, in the SW area the tephra were found in the higher slopes (Piano delle Ginestre and Cappella Bianchini) where they caused remobilization and development of lahars.

The AD 472 eruption deposits do not outcrop in the SW sector, but they can be observed in other sectors of the volcano and in Pollena. Along the coast they can be traced only in Torre Annunziata. In the South-Western sector the only major medieval level that can be located is the AD 1139 tephra eruption.

The field work carried out on the territory allowed to identify and map the historically known deposits of lahars which caused a large number of victims and considerable damages to the territory. One of these outcrops is near the vents of the 1794 eruption.

GIS processing of historical and field data of epiclastic deposits in the SW sector of Vesuvius showed that the modern lahars were the result of remobilization of modern tephra which outcrop only in the Piano delle Ginestre, were triggered by rainfalls and then funnelled along the waterways of Cappella Bianchini.

Using the DEM it was possible to determine the morphometric parameters (slope, curvature) and delimit the hydrographic basins, with their respective areas of confluence (source area) and accumulation (expansion area), and the possible channels of water-flow, currently modified by human interventions (riverbeds-road).

Hydrologic Annals were important to study the amount, intensity, and duration of daily rainfalls in relation to years, months and, consequently, seasons.

For the AD 79 eruption of Pompeii, the lahars deposits are impressive and more important than modern ones, because they affected the entire coast producing a flat morphology.

In conclusion, the work done in the South-Western sector of the Somma-Vesuvius volcano allowed to: *i*) to significantly improve the mapping of medieval eruptions; *ii*) improve the awareness of risk connected to the opening of eccentric effusive vents; *iii*) increase the knowledge of the AD 1139 medieval explosive eruption; *iv*) confirm the mechanisms and the distribution of epiclastic deposits.

Based on data available in the literature, the prevailing direction of the Vesuvian tephra is eastward. The data obtained in this work identified an eruption classified like a violent Strombolian, the AD 1139 eruption, which has southward direction. The other eruptions are the AD 79 Plinian eruption, with a very high column, and 1822 Sub-Plinian eruption.

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