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NATURAL RISK AND CIVIL PROTECTION

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A risk assessment methodology at Vesuvius based on the global volcanic simulation

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ABSTRACT

Vesuvius poses a great natural hazard in Europe. Its reawakening may bring an unimaginable catastrophe in the Vesuvian area and great consequences to the modern civilization. A correct risk assessment methodology at Vesuvius should involve interdisciplinary research where the volcanic hazard and risk mitigation are determined through global volcanic simulations. In this endeavor, the Commission of the European Communities should play a central role in sponsoring and organizing the required interdisciplinary research which is required for the risk quantification and mitigation in the Vesuvian area.

1 Introduction

The Somma-Vesuvius has exhibited various types of activities for the past 35,000 years (Lirer et al., 1973). Large-scale plinian eruptions Codola, Sarno, Basal, Greenish, Lagno Amendolare, Mercato, Avellino, and Pompei each erupted several cubic kilometers of material and occurred every few centuries to millennia, whereas the intermediate-scale subplinian eruptions (AD 412, 1631) occurred every few centuries each erupting about 0.1 km^3 of material (Macedonio et al., 1990). The smaller-scale strombolian and effusive events occurred every few decades, and it appears that these events normally follow the plinian and subplinian eruptions until the conduit closes (Dobran, 1993a). A common feature of the plinian eruptions is that they were intermittently interrupted due to partial column collapses producing pyroclastic surges and flows, and terminated with the interaction of magma with water from underground aquifers (Sheridan et al., 1981; Sigurdsson et al., 1985; Barberi et al., 1988, 1989).

Some insight on the future activity of Vesuvius and on its effects on the surroundings can be established from the studies of its past behavior and distribution of its products. The results from these kinds of studies are, however, poorly constrained by thermodynamics, geophysics, and thermofluid-dynamics, and a more precise assessment of the future behavior of Vesuvius could be achieved by modeling of the entire volcanic system (Dobran et al., 1990; Dobran, 1993a). The definition of the possible future behavior of Vesuvius is of major importance since

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the explosive events at this volcano have always been accompanied by severe damages and fatalities in the Vesuvian area.

In 1992, a commission formed by the Ministro della Protezione Civile of Italy produced guidelines for the evaluation of the volcanic risk associated with the Vesuvian area and established that there are about 700,000 persons exposed to the risk (GNV, 1992). Early in 1993 the National Volcanic Group of Italy (GNV) produced a call for proposals to promote a three-year plan of research on Vesuvius with the objective to obtain, through interdisciplinary approach, a quantification of the hazard of the volcano. Inspite of an urgent need to quantify the volcanic risk at Vesuvius through interdisciplinary efforts, little if any concrete steps have so far been taken by the responsible agencies both to promote and fund research to adequately assess the risk in the Vesuvian area (Dobran, 1993b).

The purpose of this paper is to summarize a risk assessment methodology which should be used for correctly assessing the volcanic risk at Vesuvius. It will be concluded that such an approach requires truly interdisciplinary research efforts and that the Commission of the European Communities may be the only viable European agency able to support and manage such efforts and avoid a future catastrophe of the most dangerous volcano in Europe.

2 Risk Assessment Methodology Based on Global Volcanic Simulation

The evaluation of a volcanic *risk*, or the possibility of a loss, such as life, property, productive capacity, *etc.*, within the area subject to the hazard(s), is based on the knowledge of hazard, vulnerability, and value (Tilling, 1989). *Hazard* is the probability of a given area being affected by potentially destructive volcanic products within a given period of time; *value* may include the number of lives, property and civil works; and *vulnerability* is a measure of the proportion of value likely to be lost in a given hazardous event. A correct risk assessment strategy must involve *risk mitigation*, which includes hazard identification and zonations, control of eruptions, and emergency management. The first two characteristics of risk mitigation can be quantified through volcanic simulations and realization of proper engineering measures to reduce or avoid the hazard. In this paper the emergency management will not be discussed, but it should be clear that this will depend on the proper realization of the first two problems associated with risk mitigation.

The determination of volcanic risk at Vesuvius should be based on an interdisciplinary scientific model which must be tested with past eruptions (Dobran, 1993a). Such a *Global Volcanic Simulator* could be used to establish probabilistic hazard maps and an assessment of vulnerability of the population and property in the Vesuvian area. The volcanic hazard-zonation maps should delimit the zones of hazard related to *each type of event*, such as due to tephra fallout, lava flows, pyroclastic flows, debris avalanches and lahars, volcanic gases, *etc.* These requirements are the "how' and "when" objectives of volcanology as advocated by Dobran et al. (1990). From simulations, the volcanic events can be established as probabilities because the system modeling constraints cannot be ascertained with certainty. The production of hazard-zonation maps for the Vesuvian area should be based on the past eruption events as well as on the forecasted events produced by a Global Volcanic Simulator. As an example of current modeling capabilities, Figure 1 illustrates the time-wise distribution of pyroclastic flows at Vesuvius which were produced by simulating magma ascent along the conduit and volcanic columns (Dobran et al., 1993) for a medium-scale eruption typical of the 1631 eruption which

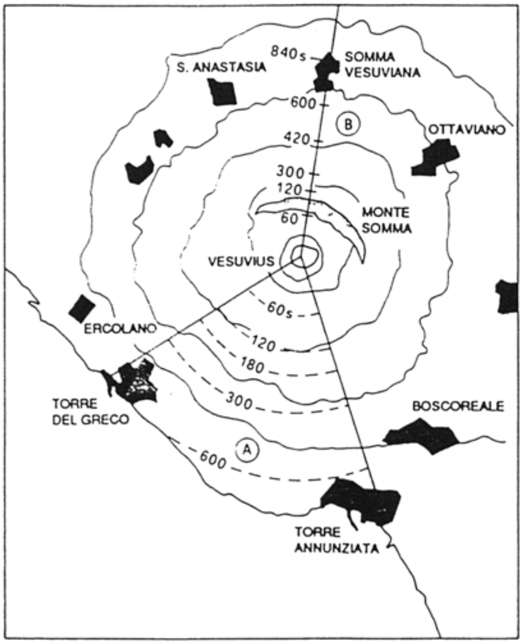
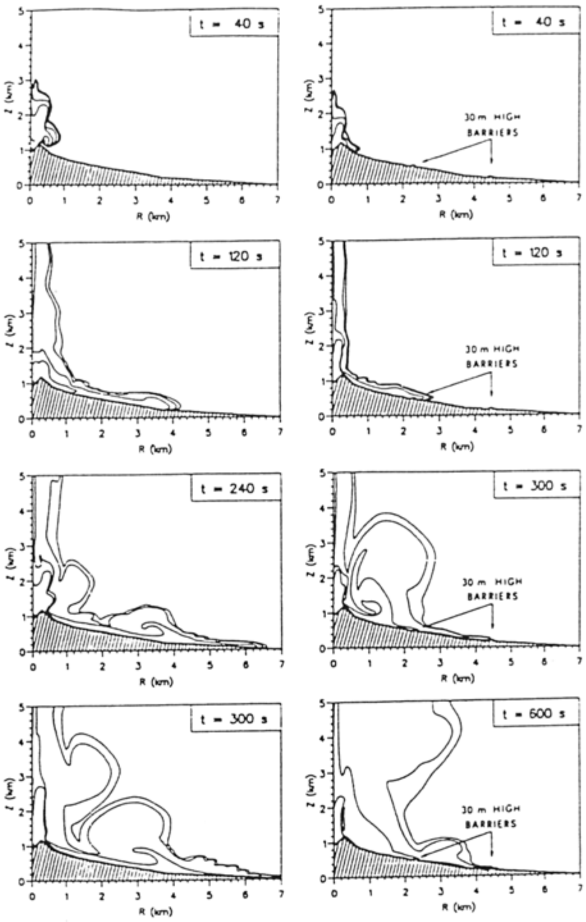


Figure 1. Pyroclastic flow hazard at Vesuvius due to a medium- scale eruption (Dobran et al., 1993). The topographies A and B are in the directions of Tyrrhenian Sea and Somma Vesuviana, respectively, where the times denote the arrival of pyroclastic flows at different distances from the vent. Note that the pyroclastic flows reach the Tyrrhenian Sea and are not arrested by Monte Somma.

killed several thousand people (Rosi et al., 1993). As seen from this figure, the pyroclastic flows reach the Tyrrhenian sea in less than 10 minutes and are not even stopped by the Monte Somma relief. Such simulations are very effective to investigate strategies for hazard and vulnerability reductions of pyroclastic flows as shown in Figure 2. This figure shows pyroclastic flows moving along the slopes of Vesuvius with and without artificial barriers constructed on the slopes. A 30 m high barrier constructed at about 4.5 km from the vent demonstrates dramatically how through the appropriate engineering measures an energetic pyroclastic flow may be stopped and its hazard reduced considerably. This implies that it may indeed not be necessary to depopulate the Vesuvian area population, but only relocate the populations in those areas where the engineering measures cannot be realized effectively. The realization of such measures depends on the *quantification* of future volcanic events at Vesuvius which can be adequately realized only by developing global volcanic simulation capabilities.

The development of a Global Volcanic Simulator for Vesuvius requires volcanological, geological and geophysical data, and parametrization of magmas to define the volcanic system, verify the computer simulations, and forecast future volcanic events at Vesuvius. These data pertain to the definition of initial and boundary conditions of the volcanic complex and the



(a) (b)

Figure 2. Computer simulations of volcanic plumes and pyroclastic flows moving along the southern slopes of Vesuvius (Dobran, 1993). (a) Column collapse from an eruption typical of the AD 79 gray eruption phase of Vesuvius. At 300 s from the beginning of column collapse a phoenix cloud is seen at about 3.5 km from the vent and the flow reaches the Tyrrhenian Sea 7 km away from the vent. (b) Column collapse from a medium-scale eruption of Vesuvius and the effects of 30 m high barriers placed at about 2.5 and 4.5 km from the vent. At 600 s shown in the figure, the pyroclastic flow is arrested by the lower barrier. Contour levels shown in the figures represent pyroclasts volumetric fractions and, starting from the outer flow region, correspond to 10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}, and 10^{-1}.

identification of the 1631 eruption parameters (Dobran, 1993a). The identification of initial and boundary conditions requires the establishment of substructural conditions of the volcano, such as magma supply, magma differentiation, and volcanic edifice conditions. In particular, the establishment of a geological model of Vesuvius is necessary for a detailed specification of the volcanic edifice. The identification of the 1631 eruption parameters required for simulator verification calls for a topographic reconstruction of the Vesuvius prior to the eruption in 1631, detailed studies of stratigraphic layers and their spatial and temporal correlations to establish the composition and granulometry of the erupted material and association of these data with the conditions at the vent during the course of the eruption, provenance and characterization of lithics, identification of the location and thermal states of aquifers, and reconstruction of the time-wise behavior of mass flow-rates during the plinian and pyroclastic flow phases of the eruption. Geophysical studies at Vesuvius are urgently needed and should involve the realization of high-resolution and three-dimensional seismic tomography. The thermodynamic parametrization studies of magmas should have the objective of parametrizing the Vesuvian magmas in terms of composition, pressure, and temperature where the time-scale of molecular relaxation processes may be important.

The forecast of volcanic events at Vesuvius requires global modeling of the volcanic system (Dobran, 1993a). This modeling should adequately resolve the thermofluid-dynamic processes of magma mixing, differentiation, and crystallization in the magma chamber, changes in the magma chamber geometry with time due to the inflow and outflow of magma and changing stresses of surrounding rocks, magma ascent along the conduit(s) and interaction with conduit's walls, structural response of the volcanic edifice to magma chamber and conduit processes, and distribution of erupted products in the atmosphere and along the slopes of the volcano. The global model should therefore simulate all relevant physical processes below and above the surface of the Earth well and efficiently. A volcanic system such as Vesuvius may be conveniently divided into different parts or domains characterized by unique properties or characteristic physical phenomena. These parts may consist of magma chamber, conduit, soil or country rock, and pyroclasts domains. Modeling of elastic, plastic, and nonhomogeneous media, and multicomponent and multiphase flow phenomena in magma chamber, conduit(s), and atmosphere requires the development of appropriate physical models and associated constitutive equations. The global simulation of Vesuvius will thus depend on the effectiveness of combining different domain models into an overall computational scheme involving a multiprocessor computer environment whereby to each processor of a multiprocessor computer, or to each computer in a distributed computer environment, is assigned a single domain or part of this domain. The appropriate division of computational tasks among processors in a parallel computational environment will require careful optimization studies involving physical models, numerical algorithms, and computer architectures.

3 Vesuvius as a High Priority Research on Natural Hazards

The responsible scientists cannot underestimate the destructive potential of Vesuvius, and the responsible politicians cannot dismiss the issue just because Vesuvius is not active at present. This volcano produced violent explosive eruptions in the past, and if the history is any lesson it will erupt again in the foreseeable future and may produce consequences unimaginable in human toll and property loss. Today we have the resources to start working toward this appointment with Vesuvius in the future and should not allow the problem to slip because of our human weaknesses. The Vesuvius problem transcends the Italian boundaries, both in terms of sponsoring as well as carrying out an interdisciplinary research required for the quantification of volcanic risk. The agencies responsible for assessing the volcanic risk at Vesuvius, among which GNV and the Commission of the European Communities which sponsor research on natural hazards. cannot afford to wait for a disaster to strike the Vesuvian area.

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